Expanded Clinical Use of DXA And Opportunistic CT

NOF ISO 19: May 17, 2019

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Disclosures

- **Research support**
  - Radius
  - GE Healthcare

- **Consultant**
  - Amgen

Some of this is my opinion Noted as such by orange font
Before Expanding DXA
Use We Need to Stop Trying to Destroy It

“Rather than waging war on a now underutilized but remarkably useful clinical test, we recommend that DXA be embraced and appropriately encouraged by healthcare professionals, stakeholder societies, payers, and the media.”
US DXA Testing, Diagnosis and Hip Fracture Trends

- 14,391 additional hip fractures
- $576 million additional expenses
- 2,878 additional deaths

DXA Medicare Payments
- $139

Osteoporosis Diagnosis
- 17.9%

DXA Testing
- $82

Fractures per 100,000 Women Age 65+ Age-adjusted to the 2014 Age Distribution

Slide courtesy of E. Michael Lewiecki, MD
Fracture Risk Assessment Includes DXA
It is an Excellent Clinical Tool

But DXA is Often Poorly Performed
“Errors and discrepancies in radiology practice are uncomfortably common, with an estimated day-to-day rate of 3-5% of studies reported… The inevitability of imperfection is explained, while the importance of striving to minimise such imperfection is emphasized.”

Brady, AP, Insights Imaging (2017) 8:171-182
Major Errors in DXA Reports Are Common

42% in a recent study

Major error definition: “Provision of inaccurate information that could potentially lead to incorrect patient care decisions.”

- Low reimbursement?
- Perception that this is a lab test requiring no overview?
- Ageism??
- Other??

A Couple of Examples…..

These are real clinical DXA interpretations
The DXA Data Reported Must Make Physiologic Sense

76 yo female; multiple prior fractures, DXA obtained to monitor teriparatide therapy

“In comparison with the prior, there has been a significant increase in the L1-L4 BMD (13%), in the dual femur neck mean (40%) and the dual femur total mean (69%).
Artifacts Must be Excluded From the Reported DXA Data

“The L1-4 BMD is 1.089 g/cm² consistent with osteopenia.”
Evidence of Ongoing Competence in DXA is Needed for ANY Reimbursement

“reasonable that third party payers reimburse only those DXA practices where evidence of initial training and ongoing competence exists.”

Krueger, et. al, J Clin Densitom, 2019, 22:115-124
Bad DXA Reports Will Cause You to Make Bad Patient Care Decisions

You need to personally review the DXA image prior to making treatment decisions

Personal opinion
Take a Standardized Approach to Evaluating DXA Images (PEAR)

◆ Positioning
  • Is the patient correctly positioned?
  • Is hip internal rotation appropriate?

◆ Edges
  • Do the bone edges/bone map correctly include only bone?

◆ Artifacts
  • Are any present? Might they affect the BMD result?

◆ Regions of interest
  • Check intervertebral markers, vertebral numbering, femoral neck region placement
We Need to Monitor With DXA

- “…. treat with pharmacologic therapy for 5 years.”
- “ACP recommends against bone density monitoring during the 5-year pharmacologic treatment period.”
  - “When prescribing bisphosphonates, clinicians should discuss the importance of adherence.”


This does not pass the common sense test and is not based on good data

Personal opinion
Common Sense Says We Need to Monitor Something

“I want you to stay on this drug that you’ve heard a lot of bad things about, because I say it’s the right thing to do.”

“In summary, we find monitoring BMD to be an essential component of osteoporosis care, directly analogous to monitoring blood pressure or lipid status in patients being treated for hypertension or hyperlipidemia respectively.”

ISCD Likely to Recommend Monitoring

Monitoring BMD (in combination with other factors) can:

- Be used to determine whether treatment should be started
- Detect bone loss, indicating need for assessing adherence and secondary causes of bone loss
  - Leads to re-evaluation of treatment options
- Be used to monitor individuals following cessation of osteoporosis pharmacologic therapy

Preliminary ISCD Positions: ISCD Annual Meeting 2019
Expanding DXA: Trabecular Bone Score (TBS)

- TBS is a DXA software program that estimates bone texture information from a regular PA spine DXA scan
  - Is a derived unitless index, not a direct physical measure
- TBS is associated with bone microarchitecture and fracture risk
- TBS provides fracture risk information that is additive to BMD and clinical risk factors

Silva et al. J Bone Miner Res. 2014 29:518–530
TBS is Not a Direct Measure of Microarchitecture, But is a Surrogate
Principle of TBS

High TBS

Low TBS

Slide courtesy of Didier Hans, Ph.D.
Can Have Same BMD but Different TBS

Two patients with Same L1-L4 BMD

Normal trabecular Bone architecture

Degraded trabecular bone architecture

Homogeneous: High TBS

Heterogeneous: Low TBS

Adapted from Silva et al. J Bone Miner Res. 2014, 29:518–530
TBS Results Are Used to Adjust FRAX
Lower (bad) TBS increases fracture risk, higher (good) TBS reduces it

Two patients (age 50 and 80) with same 10-year risk (21%)
Two patients (age 50 and 80) with same 10-year risk (4.6%)

McCloskey EV, et. al, Calcif Tissue Int, 2015: 96; 500-509
Lumbar Spine TBS: 1.481
Attention: TBS values are accurate only for patients (women and men) with a BMI in the range [15 – 37 kg/m²]

The 10 year probability of fracture (%)
Adjusted for TBS
Major Osteoporotic Fracture: 12
Hip Fracture: 0.6

Lumbar Spine TBS: 1.012
Attention: TBS values are accurate only for patients (women and men) with a BMI in the range [15 – 37 kg/m²]

The 10 year probability of fracture (%)
Adjusted for TBS
Major Osteoporotic Fracture: 26
Hip Fracture: 4.1

Height (cm)
165.1

BMI: 26.6
The ten year probability of fracture (%) with BMD
Major osteoporotic fracture: 16
Hip Fracture: 1.5

If you have a TBS value, click here: Adjust with TBS
In Addition to Altering FRAX, I Find the Painting Scaffold Analogy Helpful When Discussing TBS and Treatment Benefit/Risk With Patients

![Painting Scaffold Analogy](image)

<table>
<thead>
<tr>
<th>BMD</th>
<th>TBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal T-score ≥ -1</td>
<td>Normal T-score ≥ -1.31</td>
</tr>
<tr>
<td>Osteopenia -1 &lt; T-score &lt; -2.5</td>
<td>Partially degraded 1.23 &lt; TBS &lt; 1.31</td>
</tr>
<tr>
<td>Osteoporosis T-score ≤ -2.5</td>
<td>Degraded TBS ≤ 1.23</td>
</tr>
</tbody>
</table>

Personal opinion
Degenerative Spine Disease is Common: Report TBS From the Vertebrae Used for BMD Reporting

- 182 pts; vertebrae excluded on clinical interpretation (NB)
- 80 excluded
  - BMI, hardware, all vertebrae affected, no hips
- Mean age 71; lowest T-score -2.8

“…..it seems prudent to utilize the vertebrae least affected by degenerative changes for both BMD and TBS determination.”

White R, et. al, Arch Osteoporos, 2018: 13; 87
Expanding DXA: VFA Should Be Part of DXA For Appropriate Patients

**Vertebral Imaging Should be Performed**

- In all women age 70 and older and all men age 80 and older if BMD T-score is < -1.0 at the spine, total hip or femoral neck.
- In women age 65 to 69 and men age 70 to 79 if BMD T-score is < -1.5 at the spine, total hip or femoral neck.
- In postmenopausal women and men age 50 and older with
  - Low trauma fracture during adulthood (age 50+)
  - Historical height loss of 1.5 inches or more (4 cm)
  - Prospective height loss of 0.8 inches or more (2 cm)
  - Recent or ongoing long term glucocorticoid treatment

NOF Clinicians Guide
VFA Radiation Dose ~1/200\textsuperscript{th} That of Lateral Spine Radiographs and VFA Can be Part of the DXA Order in EMR
Moderate and Severe Fractures (Grade 2 or 3) are Often Easy to Identify
Mild (Grade 1) Fractures are NOT Easy
Don’t Call “Mild” Fractures on VFA
This is Not Unique to VFA
Even Experts Using Radiographs Have Difficulty Identifying Fractures

![Graph showing number of vertebral fractures identified by different radiologists and consensus.]

203 women Radiographs reviewed twice by expert Radiologists
Consensus defined as agreement of any of two of three readers

Fuerst, et. al, Osteoporos Int, 20:1199-1205, 2009
Any Fractures?
Any Fractures?
Morphometry is Not an Easy Solution to Vertebral Fracture Diagnosis

- Seems “objective” but subjectivity remains
- May over-diagnose non fracture abnormalities (short height due to degenerative changes)
- Need visual assessment to confirm fracture; VSQ

“...quantitative morphometry should not be performed in isolation, without visual assessment to confirm the detected vertebral deformities as fractures.”

Genant & Jergas, Osteoporos Int, 2003
A MAJOR Future Direction in “Osteoporosis” Care is Closer Collaboration With Orthopedics

Need to Expand DXA to Orthopedics

Orthopedic Surgeons Are Increasingly Becoming Interested in Bone Health Optimization Both Pre- and Post-operatively

Why Is This The Case?

Personal opinion
Unassailable Facts

- Bone health is poor in > 50% of elective orthopedic surgical patients
- BMD decreases by 10-20% after arthroplasty surgery
- Bone quality affects outcomes
  - Revisions
  - Subsidence
  - Loosening
- There is an epidemic of periprosthetic fractures
- Treatment of bone disease mitigates negative effects
- Bone health largely ignored at the present time

Slide Courtesy of Paul Anderson, M.D.
Periprosthetic Fractures Are Common and Are Osteoporosis-related

- Total knee arthroplasty (TKA) is common
  - ~15% of Americans age 70+ have had a TKA
- Occurs in up to ~5.5% of TKA patients
  - Are “low trauma,” generally due to falls
  - Challenging to repair and have devastating consequences
- 60-80% of patients undergoing TKA have low BMD
- TKA leads to distal femur bone loss (~15%)
  - Multiple potential mechanisms
- Low BMD + loss increase periprosthetic fracture risk

Periprosthetic Fractures are Bad
Periprosthetic Femur Fracture = Hip Fracture

- Retrospective chart review of patients with distal femur periprosthetic fracture
- 87 lateral locking plate
- 53 distal femur replacement

20+% 1 year mortality; only ~half regain prior mobility

Hoellwarth, et. al., Injury 2018; 49: 392-397
Fracture Data Do Not Yet Exist, But Likely That We Can Reduce Post-op Complication Risk

- Bone loss after TKA can be mitigated by pharmacologic treatment (bisphosphonates or teriparatide)
- Osteoporosis associated with subsidence around arthroplasty implants
- A meta-analysis finds bisphosphonate treatment following THA and TKA reduces revision surgery by over 50%

  Shi, et. al., Osteoporos Int, 2018;29(7):1525-1537

- Prospective studies needed
Pre-op Health Optimization is Common For Multiple Conditions (Why NOT Bone?)

Pre-operative Bone Health Optimization

- Diagnosis osteoporosis, osteomalacia, hyperpara, etc
- Correct calcium and vitamin D deficiency
- Provide nutritional support (notably protein)
- Falls risk reduction
- Bone active medications (anabolics/bisphosphonates)
Suboptimal Bone Status is Endemic in Patients Referred for Bone Health Optimization: UW 2019

- Retrospective EMR review of 42 patients referred by orthopedic surgeons to UW BHO program
  - 36 spine surgery, 4 THA, 2 TKA
- 36 female/6 male; mean age 66.9 years
- Mean 94 days between BHO and surgery
- Osteoporosis risk factors present in 57%
  - DM, glucocorticoid use, RA, vitamin D deficiency, early menopause, hyperparathyroidism, hyperthyroidism, male hypogonadism
- Prior fragility fracture in 13 (31%)

Karaman, et. al; submitted for presentation at ASBMR 2019
Suboptimal Bone Status is Endemic in Patients Referred for Bone Health Optimization: UW 2019

DXA BMD Dx Classification
- Osteoporosis
- Osteopenia
- Normal

TBS Microarchitecture Status
- Degraded microarchitecture
- Partially degraded
- Normal
- Not available

Opportunistic CT w/in 2 yrs
N = 15
- Osteoporosis (HU ≤ 100)
- Osteopenia (HU 101-149)
- Normal (HU ≥ 150)

Karaman, et. al; submitted for presentation at ASBMR 2019
68 yo Female Fell 6 Months After TKA
No prior evaluation; subsequent DXA T-score -3.5
Will DXA Expand in Orthopedics?

The Importance of Bone Mineral Density in Hip Arthroplasty: Results of a Survey Asking Orthopaedic Surgeons about Their Opinions and Attitudes Concerning Osteoporosis and Hip Arthroplasty
Gerrit Steffen Maier, Kristina Kolbow, Djordje Lazovic, and Uwe Maus

433 14-question surveys
Orthopedic surgeons in Europe and New Zealand

In the situation of known osteoporosis, 100% would use cemented hip prosthesis
Currently most are not cemented...

Maier, et. al; Advances Orthopedics; 2016; Article ID 8079354, 5 pages  http://dx.doi.org/10.1155/2016/8079354
We Are Moving Toward Routine DXA Prior to Elective Orthopedic Surgery

Probable Forthcoming ISCD Recommendations for pre-op DXA

- Women > 65
- Men > 70
- Inflammatory arthritis
- Glucocorticoid use (≥ 5mg prednisone/day for 3 mo)
- Diabetic
- H/O Fracture after age 50
- FRAX major osteoporotic fracture risk > 8.4%
Additional ISCD Orthopedic Positions

- Bone health assessment should be considered in patients prior to elective orthopaedic and spine surgery.
- When poor bone quality is identified during surgery, bone health assessment including DXA testing is indicated.
We Can (and need to) Perform Distal Femur DXA

Greater bone loss identified at distal

Need region of interest standardization and automation

We Can (and need to) Measure BMD Around Prostheses

51 yo female with R hip pain that is limiting her activity

X-ray read As negative; ortho note indicates “Remodeling along the lateral cortex.”

Gruen zone BMD (g/cm^2)

1: 0.330
2: 1.443
3: 1.942
4: 1.724
5: 2.046
6: 1.412
7: 0.898
We Can, and In Some Clinical Situations Need to, Perform Lateral Distal Femur DXA May be Particularly Relevant for SCI

Need region of interest standardization and automation
Expanding DXA: Measure BMD in Those With Spinal Cord Injury
Pending ISCD Recommendations

- All adults with spinal cord injury resulting in permanent motor or sensory dysfunction should have a DXA scan of the proximal tibia, distal and proximal femur, as soon as medically stable

- Serial DXA assessment of treatment effectiveness should include evaluation at the total hip, distal femur, and proximal tibia
Expanding DXA: Seek Impending AFF Prior to Fracture
DXA Can Detect Lateral Cortical Thickening
These Were Seen With the Benefit of 20/20 Hindsight

Images courtesy of Fergus McKiernan; presented at RSNA 2013
DXA Full Femur Imaging Works
282 consecutive patients on antiresorptive Rx

- Lateral beaking in 12 (4.3%)
- Confirmed by x-ray in 9
- Positive predictive value of beaking; 83%

“...extended femur scanning by DXA appears to be able to detect incomplete AFF in patients on antiresorptive treatment with negligible radiation exposure and without additional costs when DXA is performed for follow-up evaluation.”

Images from: Van de Laarschot, et. al, J Bone Miner Res, 2017; 32;1632-1639
Pending ISCD Recommendations Regarding Full Femur Imaging

- Full-length femur images (FFI) should be used
- Consider bilateral FFI if receiving bisphosphonate or denosumab therapy for ≥ 3 years (or discontinued within the last year) especially if receiving glucocorticoids
Expanding Clinical Opportunistic CT Use
We Can Be Using Opportunistic CT Clinically Now

“Opportunistic screening denotes the use of diagnostic CT scans to screen for patients at high (and potentially also for low) fracture risk.”

LOTS of CT Scans Are Being Done

~ 400 non-head CT scans annually per 1000 Medicare beneficiaries

This is not 40% of ALL people, but CT data is often easily available in EMR

Growth in # of CT scans per 1,000 Medicare beneficiaries

MEDPAC: Health care spending and the Medicare Program, June 2016
Opportunistic CT is Virtually Free, Requires NO Additional Testing and NO Additional Radiation Exposure

If it works, why not use it??

What data support using opportunistic CT?
Analysis of >2,000 CT-DXA pairs

• Spine HU correlated w/ central DXA (performed w/in 6 months)
• T12-L5 ROI’s obtained but focus on L1

Results using L1 trabecular HU:
- 110 HU threshold >90% specific for osteoporosis
  - Sensitivity = 52%
- 100 HU threshold PPV = 68%
- 200 HU threshold NPV = 99%

119 pts with a moderate or severe compression fx
- 52% (62 pts) had a DXA FN (T-score > -2.5)
- 97% had an L1 attenuation <145 HU

Examples of L1 ROI Placement and HU Results

Practically; <100 HU ~osteoporosis, <150 HU ~low BMD

Average: 19.74(HU)  Average: 92.98 (HU)

Average: 147.85 (HU)  Average: 209.69(HU)

Images courtesy of P Pickhardt, MD
Those With Vertebral Fracture on CT Likely to Have Low HU (not necessarily low DXA BMD)

Example of Patient with Vertebral Fracture and Low HU and Osteopenic DXA

- Prior to standard sagittal reconstruction fractures missed on (axial) CT in 84% (81 patients)
- 48% (39 of 81 pts) of unreported fx’s had a non-osteoporotic T-score (better than -2.5)
- Sagittal evaluation of the spine on CT is important

Carberry, et. al., Radiology 2013 Jul;268(1):120-6
Image courtesy of P Pickhardt, MD
IV Contrast Increases Lumbar HU

- CT w/o & w/ IV contrast in 157 adults
  - Mean difference post-contrast was +11 HU
  - Overall ROC AUC performance was similar

Pickhardt, et. al., Osteoporos Int, 2016 Jan;27(1):147-52
Opportunistic CT Can Derive “DXA-Equivalent” T-scores and Entered into FRAX
Femoral neck BMD evaluation on routine CT

“…opportunistic use of CTXA T-scores could enhance osteoporosis screening.”

Pickhardt, et. al., J Clin Densitom. 2015 Jan-Mar;18(1):5-12
Can/Should Other Skeletal Sites Be Evaluated with Opportunistic CT?

86 year old male with low back pain

- Presents to ER with non-specific low back pain
- No imaging done
- Hx of two falls in past two months
- No personal or FH of osteoporosis
- Non-smoker, non-drinker
- No bone active meds
- Discharged on pain meds
- Returned 3 days later; MRI reveals sacral fracture
Prior CT Available: Obtained Due to Abdominal Pain
L1 HU = 100
Clinical Example Using CT Data Now

63 yo white male; s/p lung transplant on prednisone 5 mg daily. T-spine fracture on follow up CXR and started on weekly alendronate 3 months ago.

DXA data:
FN T-score -2.8
L1-4 T-score -2.2

While you could argue that his BMD isn’t terrible and that he should receive anti-resorptive Rx; given his “awful” HU, I elected anabolic Rx.
Conclusions RE: Opportunistic CT

- Clinically important bone data available on body CT examinations is currently largely ignored

- Opportunistic CT can
  - Increase screening
  - Detect unsuspected low bone mass and fractures
  - Use it clinically now! I see no reason NOT to use data that is readily available
  - Potentially reduce need for DXA screening if normal

- Implementation will ultimately require engagement of body/general Radiologists
Opportunistic CT Likely to be Endorsed by ISCD

- Opportunistic CT-based attenuation using Hounsfield Units (HU) can be used to estimate the likelihood of osteoporosis (L1 HU < 100) and normal (L1 HU > 150) bone to guide decisions regarding bone health assessment.
Finite Element Analysis
Biomechanical Computed Tomography analysis (BCT)

- Analytical technique that relies on imaging data
- Assumes material properties of the bone tissue
- Assigns pixels of an image set as bone or non-bone, and assigns material properties of the tissue to that element
- Creates a “mesh” of the bone pixels
- Imposes modeled loading on the mesh
- Calculates the expected properties of the entire structure from the size and shape of the mesh
Proprietary Approach is Available That Estimates Whole Bone Strength (Newtons) of Spine or Hip Using Existing CT Scans

“We conclude that biomechanical CT analysis of previously acquired routine abdominal or pelvic CT scans is at least as effective as DXA for identifying patients at high risk of hip fracture.”

Adams, et. al., J Bone Miner Res, 2018; 33: 1291-1301
Osteoporosis Clinical Imaging; May 2019

- More DXA scanning is needed; not less
- “We” need to demand quality
- DXA should be done to monitor osteoporosis treatment
- TBS is a valuable addition to DXA
- VFA is an essential component of osteoporosis care
- Expect increased use pre- and post-operatively in orthopedic and spine surgery
- Full length femur scans can be used to seek AFF
- Opportunistic CT is often available and provides additional insight for free

Personal opinion
Thank You
HU of ~90-100 Likely Osteoporosis

Graffy, et. al., AJR 2017 September, Vol. 209, No. 3 : pp. 491-496
Clinical Example Using CT Data Now

69 yo white female; known low BMD on bisphosphonate holiday
New vertebral fx on CT performed for abdominal pain
Should she receive anabolic Rx?

DXA data:
FN T-score -2.4
L1-4 T-score -1.3

While you could argue that everyone with vertebral Fx should receive anabolic Rx; given her “good” HU, I elected anti-resorptive Rx.