Osteoporosis-Diagnosis and Treatment Considerations 2025

Allegheny Health Network

"I ONLY HAVE OSTEOPENIA, NOT OSTEOPOROSIS"

OSTEOPENIA

- Describes bone that appears less dense on radiographs
- T-scores on DXA between -1.0 and -2.5
- >60% of white women age 65 and older are osteopenic
- Fracture risk is lower in osteopenic individuals than in those with osteoporosis, but the greater numbers entail that most fractures occur in osteopenic individuals

OSTEOPENIA

- Siris, et al Proportion of fractures (>50%) including hip fractures greater in group with osteopenia

- Rotterdam 50+% of both vertebral and non-vertebral fractures occurred in those women with osteopenia 60+% in men with osteopenia

- McClung 2024 Interventions targeting only those with osteoporotic BMD will have little effect on total fracture numbers,as the majority of those who fracture will remain untreated

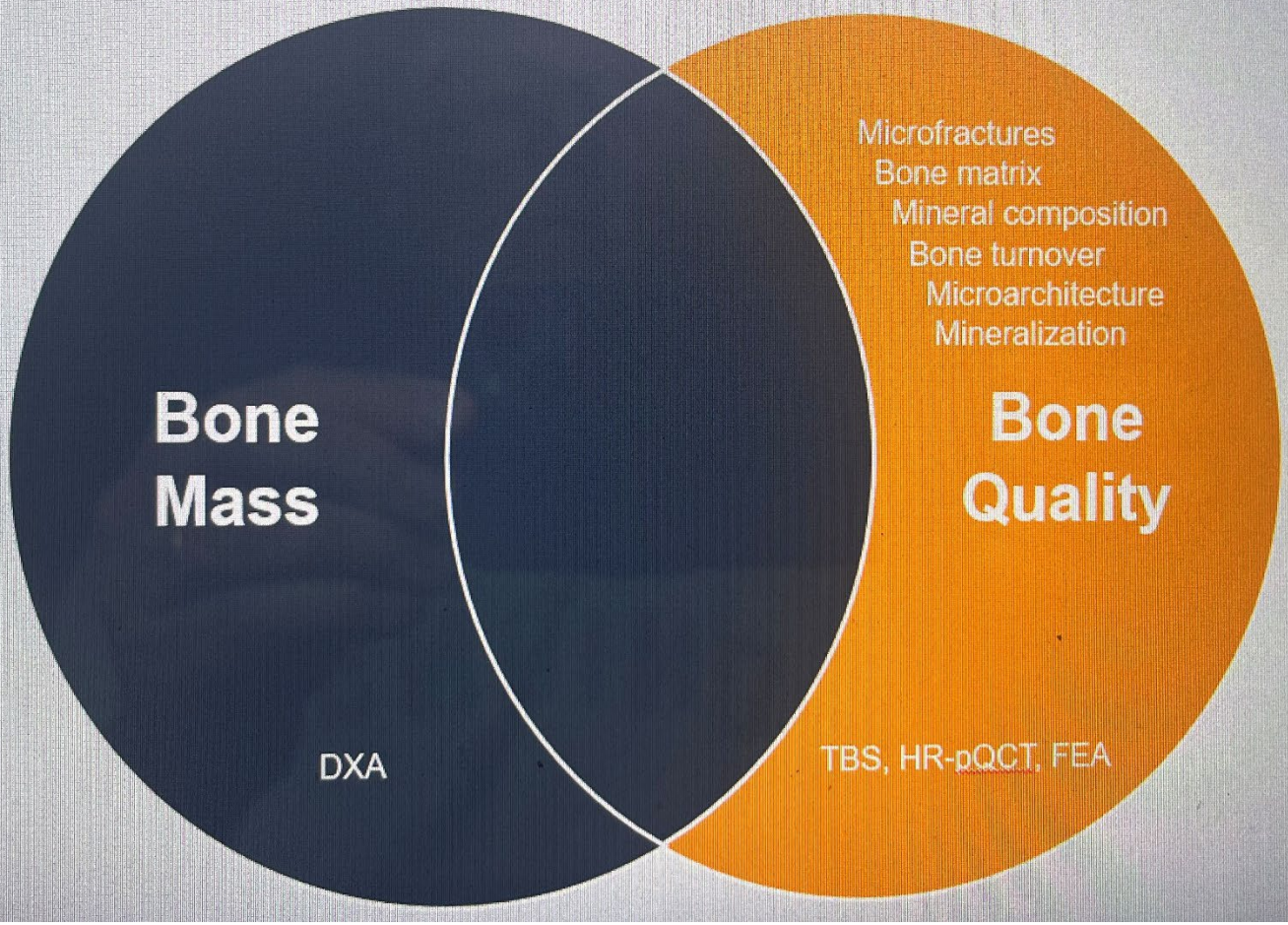
  "The use of BMD alone in determining intervention thresholds is demonstrably problematic"

OSTEOPENIA

Osteopenia is not a meaningful diagnosis and a formal calculation of fracture risk should be the key element in making therapeutic decisions

Allegheny Health Network

Factors beyond BMD alone determine bone strength[1,2]



Allegheny Health Network

DEXA

- Dual Energy Xray Absorptiometry

-High precision xray that measures bone mineral density (BMD) and bone loss

-noninvasive

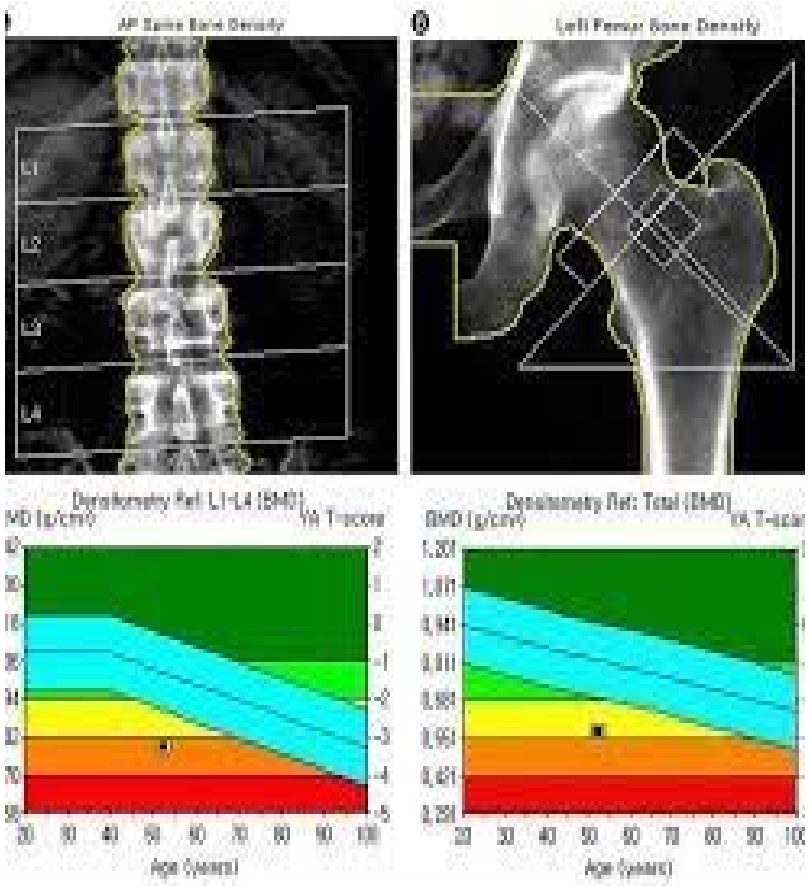
-fast

-low level of radiation (5 uSv)

-Best technique for assessing BMD in post menopausal women (WHO)

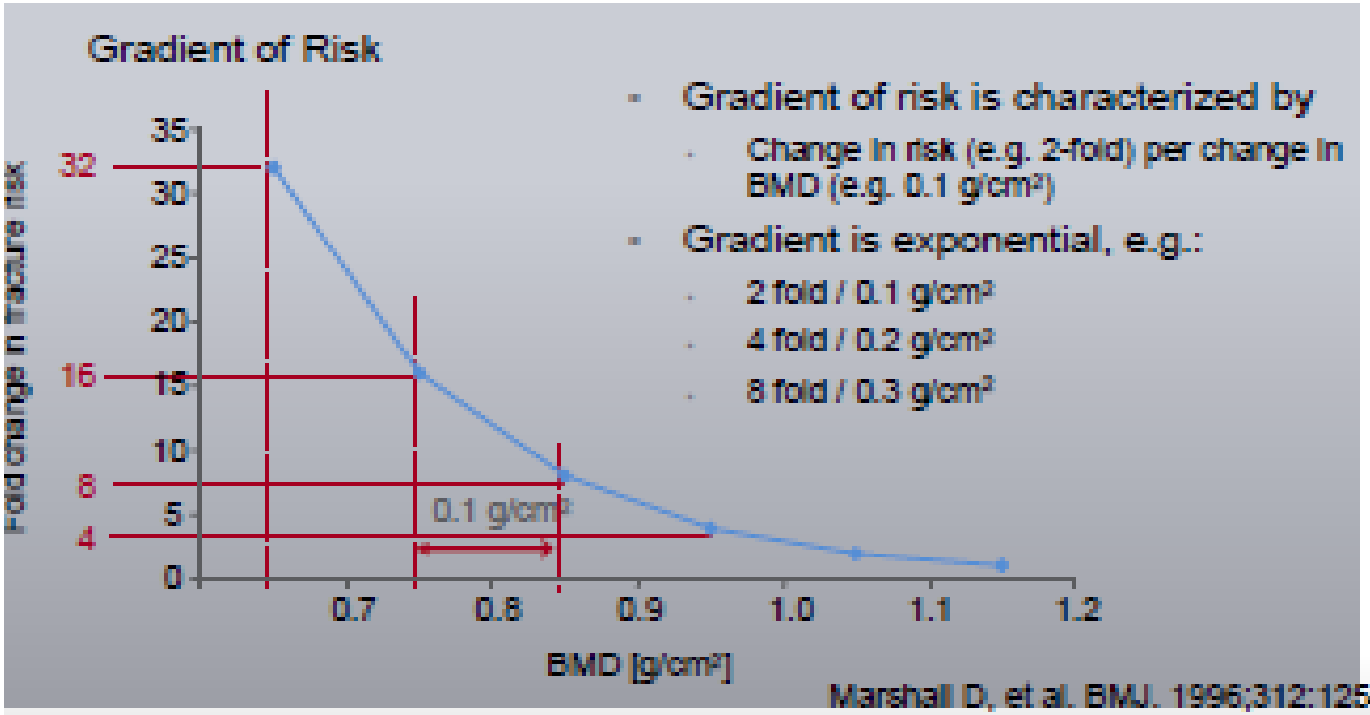
-Measures and monitors BMD in gm/cm squared (areal)

DEXA Scan Errors



- Patient Positioning
- Edges
- Artifacts (contrast, pannus, hardware, fracture, arthritis)
- Region of interest

Fracture Risk Increases Exponentially with Declining BMD



Allegheny Health Network

What is Trabecular Bone Score (TBS)?

Trabecular Bone Score, or TBS, is a computer software application that is installed on DXA machines. The program takes the DXA image of the lumbar spine (low back) and creates a greyscale pixel image of the vertebral trabecular bone microstructure. The resulting image provides an indirect measure of the trabecular microarchitecture. A dense structure, with lots of well-connected trabeculae, has a large number of pixels with small amplitude changes. They are variations of very light and light grey. Think of it like a dense sponge with very small holes.

A porous structure has fewer pixels with much greater amplitude in their color variations. They are light where bone is present to very dark or black where the structure has broken down and appears more porous or full of holes. This is like a sponge with large holes or spaces.

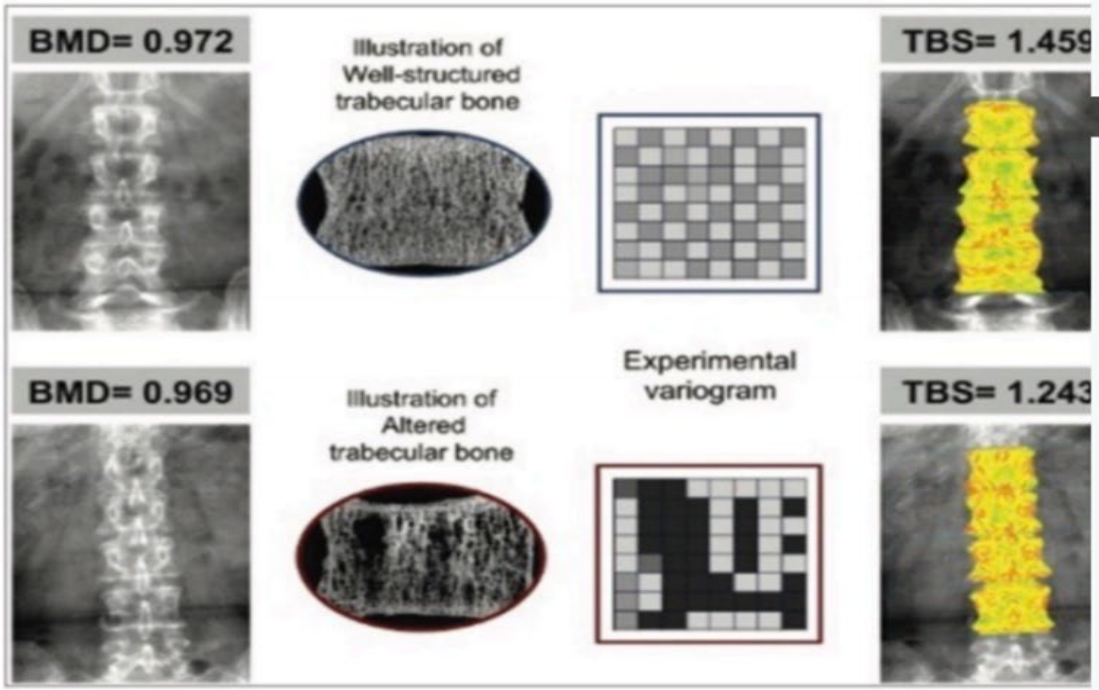


Figure 1: An illustration of the basic TBS principle and relationship to BMD. The upper panel shows BMD and TBS of a 73-year-old woman with BMI of 24.2 kg/m2 and the lower panel shows BMD an TBS of a 74-year-old woman with BMI of 24.3 kg/m2. The images of the bone architecture and the experimental variogram demonstrate TBS principles: the bone with a greater number of trabeculae

Screening for Osteoporosis

- Opportunistic screening: CT images obtained for other indications but can be used to assess bone status

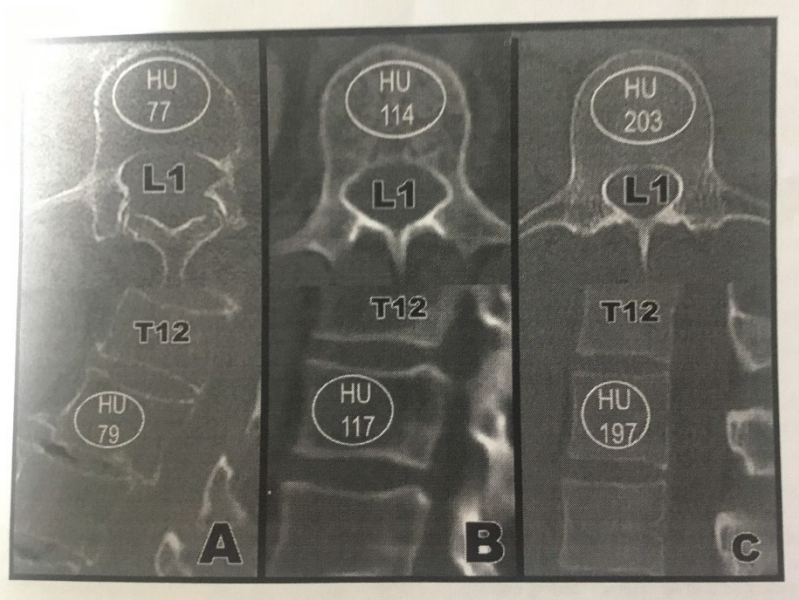
- Performed using standard PACS software tool
  L1 vertebral body preferred

- Variability in diagnostic numerical values

  >150 normal bone
  <100 suggests osteoporosis (Current Concepts Review 2018 <135 indicates risk for osteoporosis)
  <50 hardware failure even with cement augmentation

Allegheny Health Network

Screening for Osteoporosis



- Hounsfield Unit (HU)
- Xray attenuation is proportional to the atomic mass and atom density of the tissue subject to radiation
- For bone, HU proportional to the mineral density

Allegheny Health Network

Biomechanical Computed Tomography Analysis

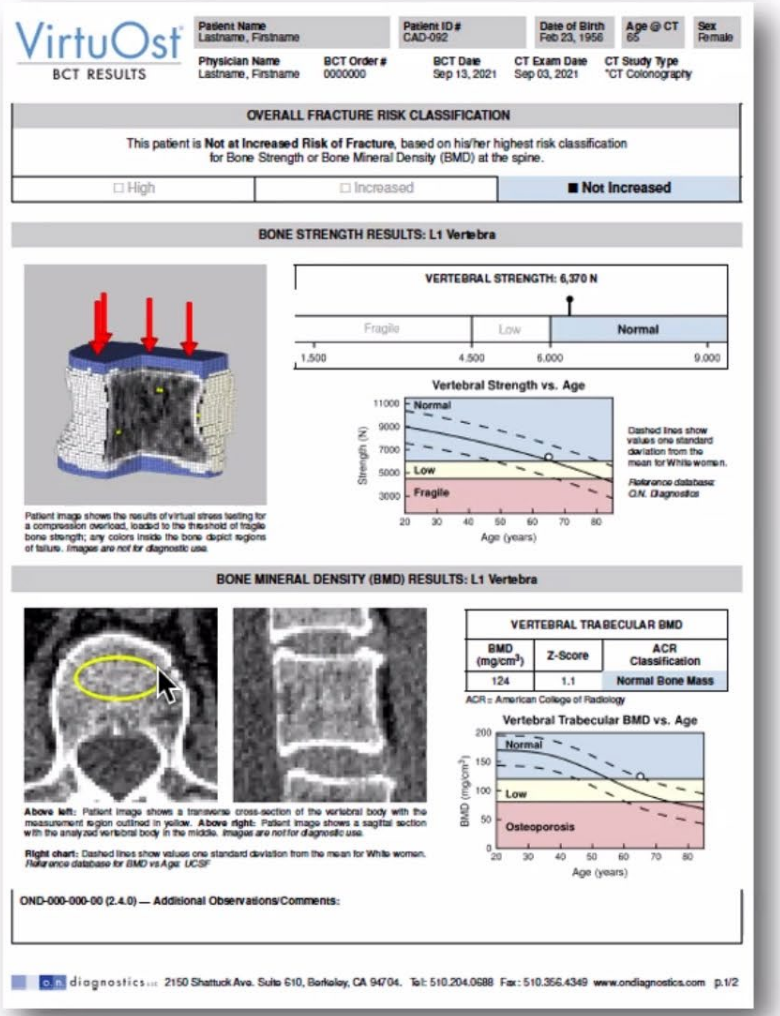
- CT based diagnostic test for osteoporosis that measures both bone mineral density and bone strength

- FDA cleared in US as diagnostic test for osteoporosis
  Does not require confirmation by DXA

- VirtuOst software tool combines advanced medical image processing, principles of bone biomechanics, and non-linear finite element analysis to simulate a typical fracturing event

Allegheny Health Network

Spine BCT



VirtuOst® BCT RESULTS

Patient Name	Patient ID #	Date of Birth	Age @ CT	Sex
Lastname, Firstname	CAD-092	Feb 23, 1956	65	Female

Physician Name	BCT Order #	BCT Date	CT Exam Date	CT Study Type
Lastname, Firstname	0000000	Sep 13, 2021	Sep 03, 2021	*CT Colonography

OVERALL FRACTURE RISK CLASSIFICATION

This patient is **Not at Increased Risk of Fracture**, based on his/her highest risk classification for Bone Strength or Bone Mineral Density (BMD) at the spine.

☐ High | ☐ Increased | ■ Not Increased

BONE STRENGTH RESULTS: L1 Vertebra

Patient image shows the results of virtual stress testing for a compression overload, loaded to the threshold of fragile bone strength; any colors inside the bone depict regions of failure. *Images are not for diagnostic use.*

VERTEBRAL STRENGTH: 6,370 N

Fragile | Low | Normal

1,500 | 4,500 | 6,000 | 9,000

Vertebral Strength vs. Age

Strength (N): 11000, 9000, 7000, 5000, 3000

Normal / Low / Fragile

Age (years): 20, 30, 40, 50, 60, 70, 80

Dashed lines show values one standard deviation from the mean for White women.

Reference database: O.N. Diagnostics

BONE MINERAL DENSITY (BMD) RESULTS: L1 Vertebra

Above left: Patient image shows a transverse cross-section of the vertebral body with the measurement region outlined in yellow. **Above right:** Patient image shows a sagittal section with the analyzed vertebral body in the middle. *Images are not for diagnostic use.*

Right chart: Dashed lines show values one standard deviation from the mean for White women. *Reference database for BMD vs Age: UCSF*

VERTEBRAL TRABECULAR BMD		
BMD (mg/cm³)	Z-Score	ACR Classification
124	1.1	Normal Bone Mass

ACR = American College of Radiology

Vertebral Trabecular BMD vs. Age

BMD (mg/cm³): 200, 150, 100, 50, 0

Normal / Low / Osteoporosis

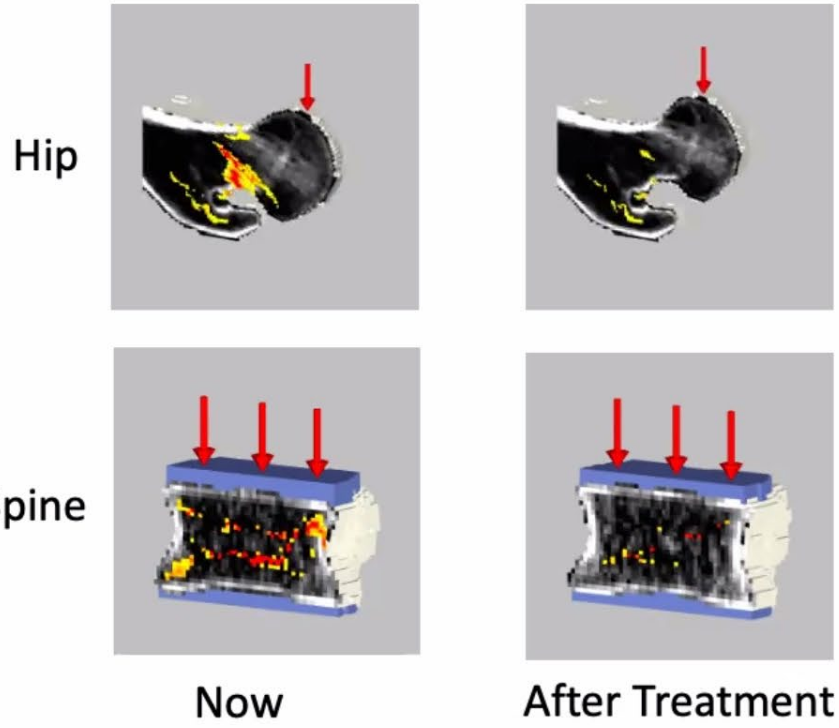
Age (years): 20, 30, 40, 50, 60, 70, 80

OND-000-000-00 (2.4.0) — Additional Observations/Comments:

O.N. diagnostics LLC 2150 Shattuck Ave. Suite 610, Berkeley, CA 94704. Tel: 510.204.0688 Fax: 510.356.4349 www.ondiagnostics.com p.1/2

Images courtesy of O.N. Diagnostics; copyright O.N. Diagnostics

Biomechanical Computed Tomography analysis* (BCT)



*** Facility sends CT scan to OND; OND performs the BCT test (+ optional VFA) and returns results ± interpretation**

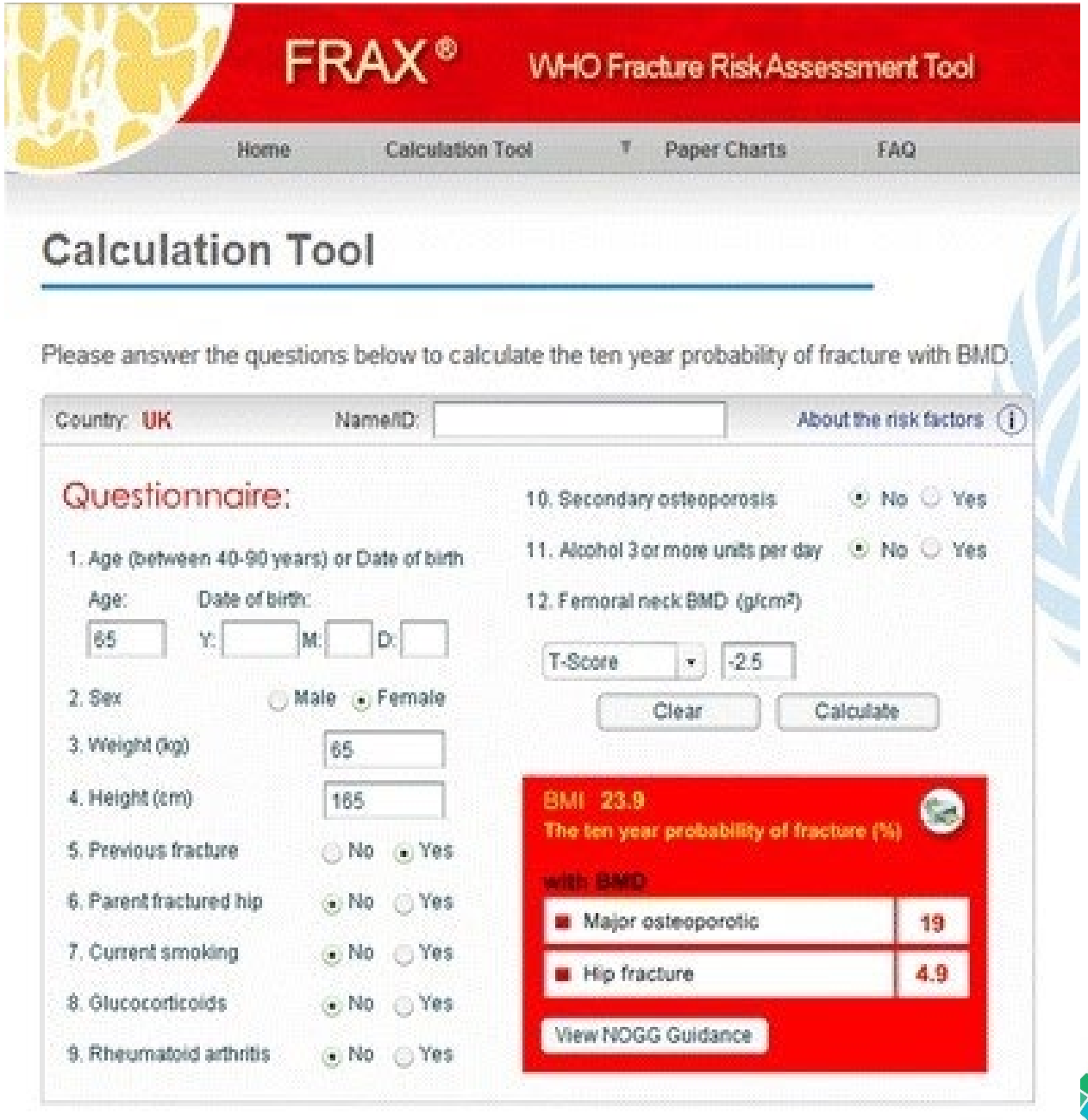
Functional virtual stress testing

- Bone strength (from finite element analysis)
- Bone mineral density
  - Same measurement as CT density (77078)
  - Same measurement as DXA hip (77080)
- Fracture risk assessment
- Validated clinically in over 7,000 patients **
- Optional VFA as add-on
- VirtuOst®, FDA cleared (K113725; K171435)

Convenient, safe, cost-effective

- Repurposes recent CT (hip and/or spine)
- No extra procedure or radiation exposure
- Fully remote, no patient visit

** Keaveny et al, *Osteoporos Int* 31:1025–48, 2020



Allegheny Health Network

Adachi *et al. BMC Musculoskeletal Disorders* (2021) 22:224
https://doi.org/10.1186/s12891-021-04051-9

BMC Musculoskeletal Disorders

RESEARCH ARTICLE Open Access

Fragility fracture identifies patients at imminent risk for subsequent fracture: real-world retrospective database study in Ontario, Canada

Jonathan D. Adachi[1], Jacques P. Brown[2], Emil Schemitsch[3], Jean-Eric Tarride[4,5,6], Vivien Brown[7], Alan D. Bell[7], Maureen Reiner[8], Millicent Packalen[9], Ponda Motsepe-Ditshego[9], Natasha Burke[9] and Lubomira Slatkovska[9*]

Abstract

Background: The secondary fracture prevention gap in the osteoporosis field has been previously described as a 'crisis'. Closing this gap is increasingly important in the context of accumulating evidence showing that an incident fragility fracture is associated with an increased risk of subsequent fracture within 1–2 years, known as imminent fracture risk. The objective of this study was to use health services data to characterize the time between index fragility fractures occurring at different osteoporotic sites and subsequent fractures.

Methods: This retrospective observational study used de-identified health services data from the publicly funded healthcare system in Ontario, the largest province of Canada. Patients aged > 65 with an index fragility fracture occurring between 2011 and 2015 were identified from the ICES Data Repository using International Classification of Diseases (ICD)-10 codes. We examined median time to subsequent fragility fractures for osteoporotic fracture sites until the end of follow-up (2017). BMD assessment and use of osteoporosis therapies following index fracture were also characterized.

Results: Among 115,776 patients with an index fragility fracture, 17.8% incurred a second fragility fracture. Median time between index and second fracture occurring at any site was 555 days (interquartile range: 236–955). For each index fracture site examined, median time from index to second fracture was < 2 years. The proportion of patients with BMD assessment was 10.3% ≤1 year prior to and 16.4% ≤1 year post index fracture. The proportion of patients receiving osteoporosis therapy was 29.8% ≤1 year prior, 34.6% ≤1 year post, and 25.9% > 3 years post index fracture.

Conclusions: This cohort of Canadian patients aged > 65 years who experienced a fragility fracture at any site are at imminent risk of experiencing subsequent fracture within the next 2 years and should be proactively assessed and treated.

Keywords: Osteoporosis, Fragility fracture, Subsequent fracture, Real-world data, Imminent fracture risk, Post fracture care, Secondary fracture prevention

Risk of subsequent hip and vertebral fractures Lorentzon 2024

- Higher in younger patients
- Higher in men than women
- Higher in those patients with a recent fracture (<2yrs)
- Risk of subsequent hip/vertebral fractures >wrist fractures

Table 2 Risk of incident hip fracture per site of recent fracture

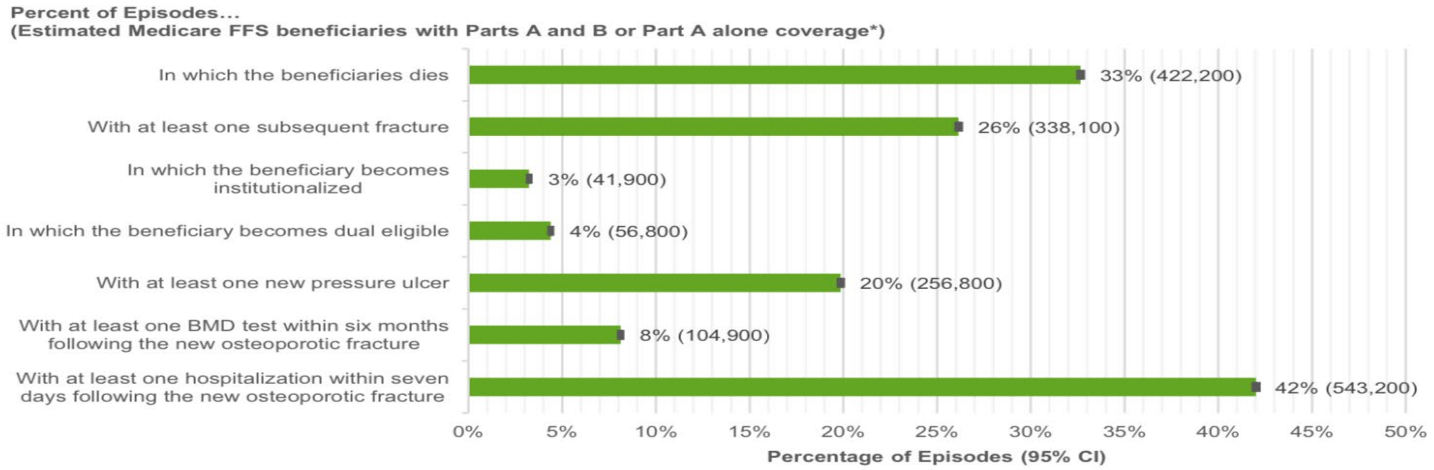
Fracture site	At risk *N*	Events *n* (%)	Incidence rate per 1000 py	Hazard ratio (95% CI)	
				Model 1	Model 2
No previous fracture	2,984,489	99,671 (3.3%)	4.17 (4.14–4.19)	1 [REF]	1 [REF]
Skull and facial bones	5358	358 (6.7%)	9.78 (8.79–10.8)	1.69 (1.52–1.88)	1.58 (1.43–1.76)
Cervical vertebra	1112	79 (7.1%)	11.5 (9.14–14.4)	1.53 (1.22–1.90)	1.45 (1.16–1.81)
Thoracic vertebra	1693	181 (11%)	18.0 (15.5–20.8)	2.18 (1.88–2.52)	2.05 (1.77–2.37)
Lumbar vertebra	2663	285 (11%)	17.9 (15.9–20.1)	2.05 (1.82–2.30)	1.92 (1.71–2.15)
Collapsed vertebra, unspec	6815	977 (14%)	33.8 (31.7–36.0)	2.15 (2.02–2.29)	1.98 (1.86–2.11)
Rib	8482	668 (7.9%)	12.1 (11.2–13.1)	1.95 (1.81–2.10)	1.82 (1.69–1.96)
Pelvis	6184	908 (15%)	32.4 (30.4–34.6)	2.06 (1.93–2.20)	1.94 (1.82–2.08)
Clavicle	2914	203 (7.0%)	10.3 (8.97–11.9)	1.91 (1.66–2.19)	1.83 (1.59–2.09)
Scapula	946	51 (5.4%)	7.30 (5.44–9.60)	1.44 (1.09–1.89)	1.40 (1.06–1.84)
Upper end of the humerus	11,994	1471 (12%)	19.4 (18.4–20.4)	2.19 (2.08–2.31)	2.11 (2.01–2.23)
Shaft of the humerus	1227	126 (10%)	16.2 (13.5–19.3)	2.07 (1.73–2.46)	1.93 (1.62–2.30)
Lower end of the humerus	1238	127 (10%)	16.8 (14.0–19.9)	1.91 (1.61–2.27)	1.80 (1.51–2.14)
Upper end of the ulna	1638	160 (9.8%)	14.6 (12.4–17.1)	2.04 (1.74–2.38)	1.96 (1.67–2.28)
Upper end of the radius	2204	80 (3.6%)	4.46 (3.53–5.55)	1.39 (1.11–1.73)	1.35 (1.09–1.69)
Forearm shaft	1146	81 (7.1%)	9.83 (7.80–12.2)	1.54 (1.24–1.92)	1.49 (1.20–1.85)
Lower end of the radius	22,313	1811 (8.1%)	11.1 (10.6–11.6)	1.63 (1.56–1.71)	1.60 (1.53–1.68)
Lower end of the ulna and radius	2051	222 (11%)	15.5 (13.5–17.7)	1.82 (1.59–2.07)	1.78 (1.56–2.03)
Carpus	1957	68 (3.5%)	4.32 (3.36–5.48)	1.15 (0.91–1.46)*	1.12 (0.88–1.42)*
Metacarpus	3590	229 (6.4%)	8.52 (7.45–9.70)	1.76 (1.54–2.00)	1.69 (1.48–1.92)
Finger	6237	304 (4.9%)	6.24 (5.56–6.98)	1.64 (1.47–1.84)	1.58 (1.41–1.77)
Neck of the femur	12,412	1406 (11%)	25.5 (24.2–26.9)	1.58 (1.50–1.67)	1.49 (1.42–1.58)
Pertrochanteric fracture	8464	905 (11%)	26.8 (25.1–28.6)	1.36 (1.28–1.46)	1.28 (1.20–1.37)
Subtrochanteric fracture	1861	178 (9.6%)	21.1 (18.1–24.4)	1.18 (1.02–1.36)	1.11 (0.96–1.28)*
Shaft of the femur	1110	86 (7.7%)	14.8 (11.8–18.3)	1.10 (0.89–1.36)*	1.05 (0.85–1.29)*
Lower end of the femur	1058	76 (7.2%)	14.3 (11.2–17.8)	1.16 (0.93–1.45)*	1.09 (0.87–1.37)*
Patella	1803	179 (9.9%)	14.1 (12.1–16.3)	1.87 (1.62–2.17)	1.80 (1.56–2.09)
Upper end of the tibia	2730	201 (7.4%)	10.4 (9.05–12.0)	1.80 (1.57–2.07)	1.74 (1.52–2.00)
Shaft of the tibia	1010	49 (4.9%)	6.70 (4.96–8.86)	1.75 (1.32–2.31)	1.64 (1.24–2.17)
Lower end of the tibia	986	49 (5.0%)	6.89 (5.09–9.10)	1.58 (1.20–2.09)	1.52 (1.15–2.01)
Fibula alone	1274	65 (5.1%)	7.01 (5.41–8.94)	1.36 (1.07–1.74)	1.31 (1.03–1.67)
Ankle	7303	293 (4.0%)	5.13 (4.56–5.75)	1.17 (1.05–1.32)	1.14 (1.02–1.28)
Other parts of the lower leg	4340	249 (5.7%)	7.58 (6.67–8.58)	1.58 (1.40–1.79)	1.51 (1.33–1.71)
Tarsus	1183	61 (5.2%)	6.60 (5.05–8.48)	2.10 (1.63–2.70)	2.00 (1.56–2.57)
Metatarsus	3689	180 (4.9%)	6.29 (5.40–7.28)	1.44 (1.25–1.67)	1.38 (1.20–1.60)
Toe	2408	79 (3.3%)	4.09 (3.24–5.09)	1.32 (1.06–1.64)	1.27 (1.02–1.59)
Other recent fracture	2397	247 (10%)	16.7 (14.6–18.9)	2.23 (1.97–2.53)	2.08 (1.83–2.35)
Any old (> 2 yrs) fracture	293,051	20,516 (7.0%)	10.1 (9.99–10.3)	1.51 (1.49–1.53)	1.50 (1.48–1.52)

Risk of incident hip fracture per site of recent fracture. Event rates were calculated as the number of events per 1000 person-years and are presented with exact Poisson 95% confidence intervals. The multivariable Cox model was adjusted in two steps: model 1 for age and sex; model 2 with added adjustment for inclusion year, osteoporosis medication, multiple recent fractures, and Charlson comorbidity index

*p value > 0.05

patients with a recent fracture had a substantially increased risk of vertebral fracture in a Cox model adjusted for age and sex (model 1), regardless of fracture group investigated (Table 3). These hazard ratios were only slightly affected by multivariable adjustment (Table 3 and Fig. 3). Any recent vertebral fracture was associated with the greatest elevation of subsequent vertebral fracture risk (HR 8.33, 95% CI 7.45–9.31), while a recent distal radius fracture conferred the lowest risk increase (HR 1.64, 95% CI 1.46–1.85).

FIGURE 5: PROPORTION OF MEDICARE FFS BENEFICIARIES WITH A NEW OSTEOPOROTIC FRACTURE IN 2016 WHO HAD KEY POST-FRACTURE EVENTS DURING THEIR OSTEOPOROTIC FRACTURE EPISODES (N=949,727)



* Estimated by extrapolating our calculated fracture rate for Medicare FFS beneficiaries with both Parts A and B coverage to those covered with Part A alone. Note: Metrics were not adjusted for key events to exclude beneficiaries who died during the osteoporotic fracture episode from the denominator of the proportions (i.e., beneficiaries were not required to survive for the length of the osteoporotic fracture episode). Confidence intervals for the proportion of beneficiaries who had key post-fracture events during their osteoporotic fracture episodes were calculated based on the mean and standard deviation of the sampling distribution of each proportion.

The following subsections describe these findings in more detail.

Hospitalizations

Nearly half (45%) of beneficiaries experienced at least one acute inpatient stay within 30 days of their new osteoporotic fractures; many of these hospitalizations occurred within a week of the fracture event and were likely associated with the fracture. Over half (57%) had at least one hospitalization eight days or more after the anchor event (Figure 5).

Vertebral Fractures

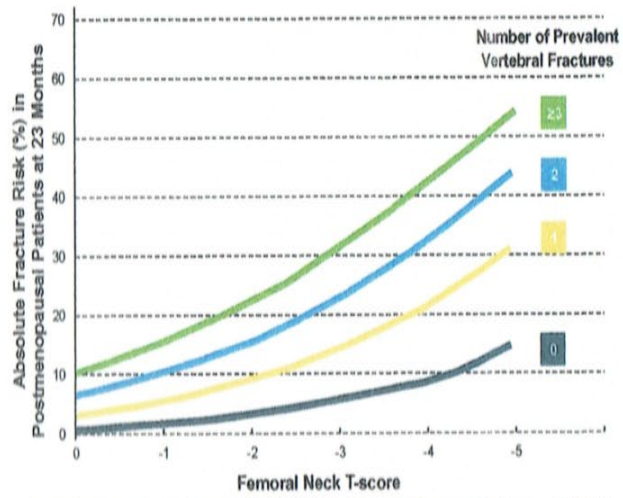
- Most common fractures
- Insidious
- Progressive
- Often unrecognized
- Associated with

  deformity, height loss, back pain

Predict future vertebral and non-vertebral fractures (especially multiple compression fractures)

Vertebral Fractures

FRACTURE RISK INCREASES WITH NUMBER OF PREVALENT VERTEBRAL FRACTURES DUE TO OSTEOPOROSIS[1]



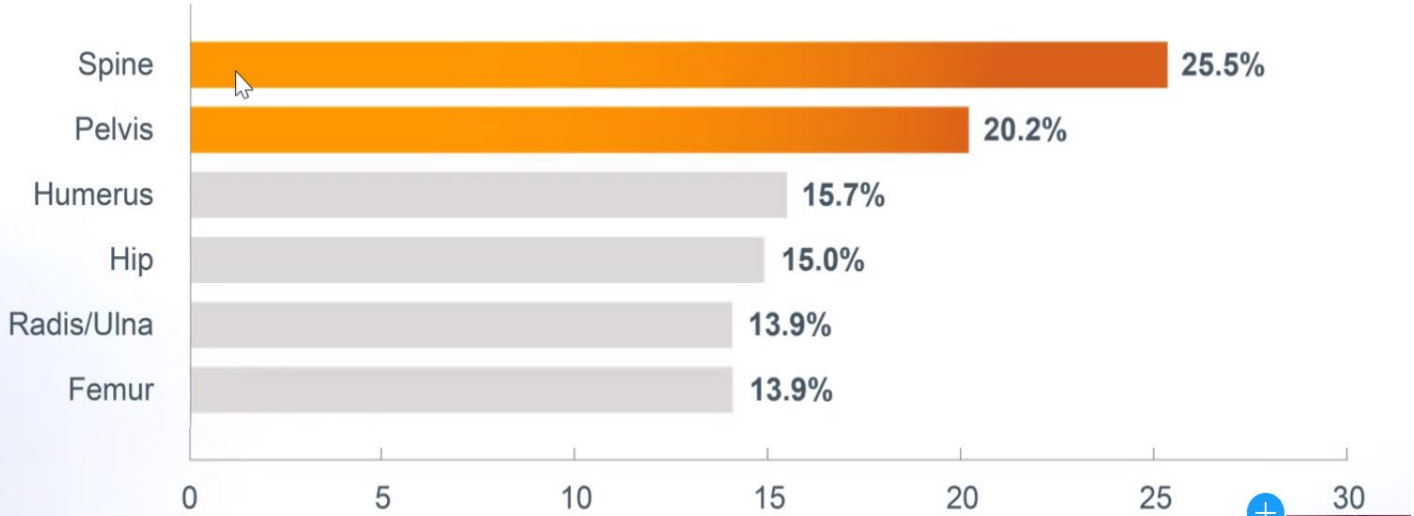
Data are from the pooled placebo groups of 2 clinical trials of postmenopausal women with osteoporosis (N=2,651)

1. Siris ES, et al. *Osteoporos Int.* 2007;18(6):761-770.

Please see Important Safety Information, including Boxed Warning regarding osteosarcoma, on slides 4-8 and accompanying full Prescribing Information and Medication Guide. See full User Manual that accompanies the delivery device.

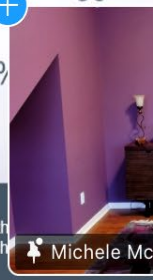
Lilly

While subsequent fracture risk is high across sites, it is highest after vertebral fractures



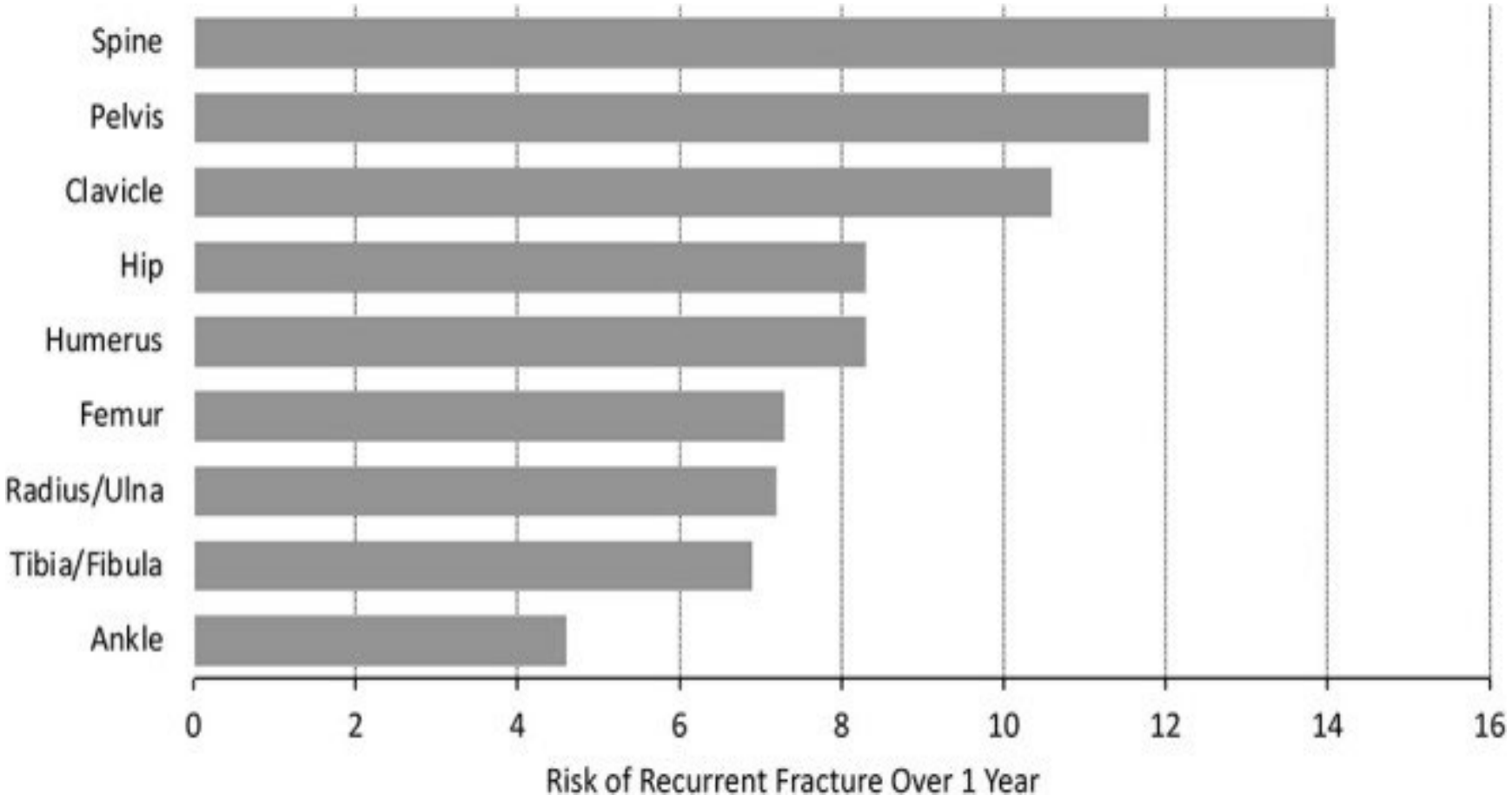
*Analysis included women aged ≥ 65 years (N = 377,561) with incident clinical fractures at any skeletal site except skull, face, fingers, toes, patella, sternum, scapula, and ribs. Of th
assessment of 2-year risks. Some sites were excluded as they may have been due to trauma and may be challenging to accurately ascertain from claims data. Not all study sites sh
(12.1%), and ankle (9.5%).

Reference: Balasubramanian A, et al. *Osteoporos Int*. 2019;30:79-92.



Allegheny Health Network

JBMR 2024



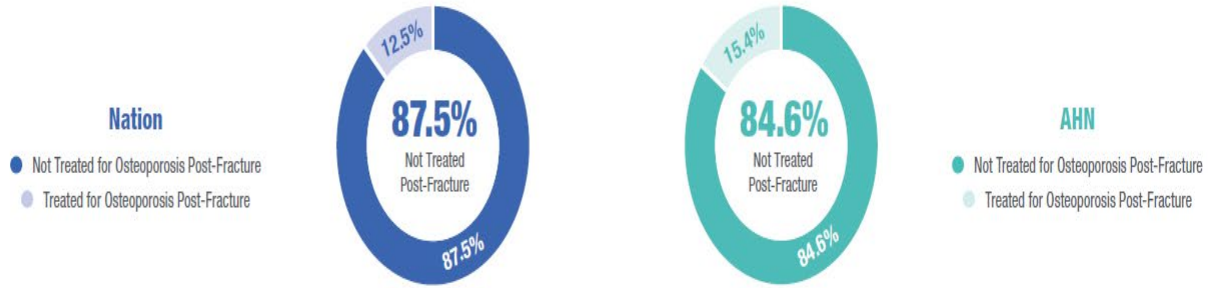
One-year risk of recurrent fracture in women > 65 years of age, based on site of initial fracture, from Medicare database of 377,561 women with first fracture.

Allegheny Health Network

Most women do not receive any osteoporosis treatment post-fracture.

Over 87% of women nationally do not receive any osteoporosis treatment within 12 months of a fracture.

Percentage of Women without Osteoporosis Treatment within 12 Months Post-Fracture, January 2019–December 2023[1,*]



Note: Percentages include patients with a fracture January 2019–December 2022. The patient's activity was then monitored for 12 months following the most recent fracture, and the number of patients with a subsequent treatment for osteoporosis during that 12-month follow-up period is reported. Data were calculated as the number of women who had a fracture with a prescription or procedure code for an osteoporosis treatment within 12 months post-fracture, divided by the number of women with at least one fracture January 2019–December 2022.

A very small percentage of patients receive anabolic or antiresorptive osteoporosis therapy within three, six, or 12 months of a fracture.

Percentage of Women with Osteoporosis Treatment within 12 Months Post-Fracture, by Timing and Treatment Type, January 2019–December 2023[1,*]

Population	Anabolic Therapy			Antiresorptive Therapy		
	0–3 Months	0–6 Months	0–12 Months	0–3 Months	0–6 Months	0–12 Months
Nation	0.4%	0.6%	0.8%	7.1%	9.6%	11.9%
AHN	0.3%	0.5%	0.7%	9.1%	12.2%	14.8%

Note: Percentages include patients with a fracture January 2019–December 2022. The patient's activity was then monitored for 12 months following the fracture, and the number of patients with a subsequent treatment for osteoporosis during the 3-, 6-, and 12-month follow-up periods are reported. Data were calculated as the number of women who had a fracture with a prescription or procedure code for the specified therapy class during the post-fracture time frames reported (0–3 months, 0–6 months, 0–12 months), divided by the number of women with at least one fracture January 2019–December 2022.

Timely recommended osteoporosis treatment is not prioritized following fractures.

Allegheny Health Network

Diagnoses of Osteoporosis

- BMD measurement (T score < or = -2.5)
- Hip fracture, with or without BMD test
- Clinical vertebral, proximal humerus or pelvis fracture in patient with osteopenia
- Incidental finding of a vertebral fracture on radiographs
- FRAX hip fracture risk 3% of greater or major osteoporotic risk 20% or greater at 10 years

Osteoporosis Int 2014 (BHOF, ISCD)

Allegheny Health Network

Very High Risk Definition (AACE Guideline Update 2020)

T score < or = -2.5 and fragility fracture

T score < 3.0 or fracture within 12 months

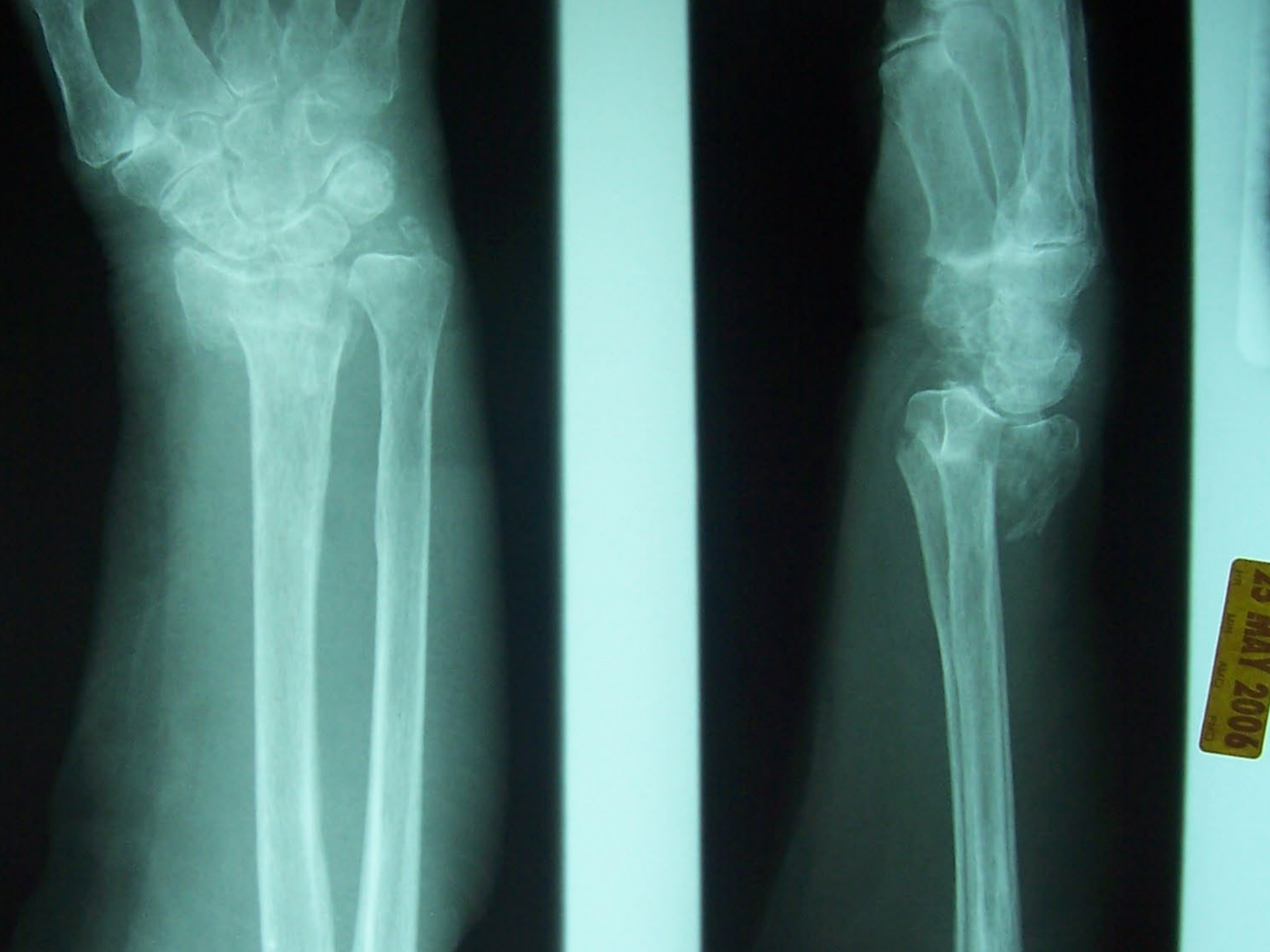
Fracture while on other approved therapy

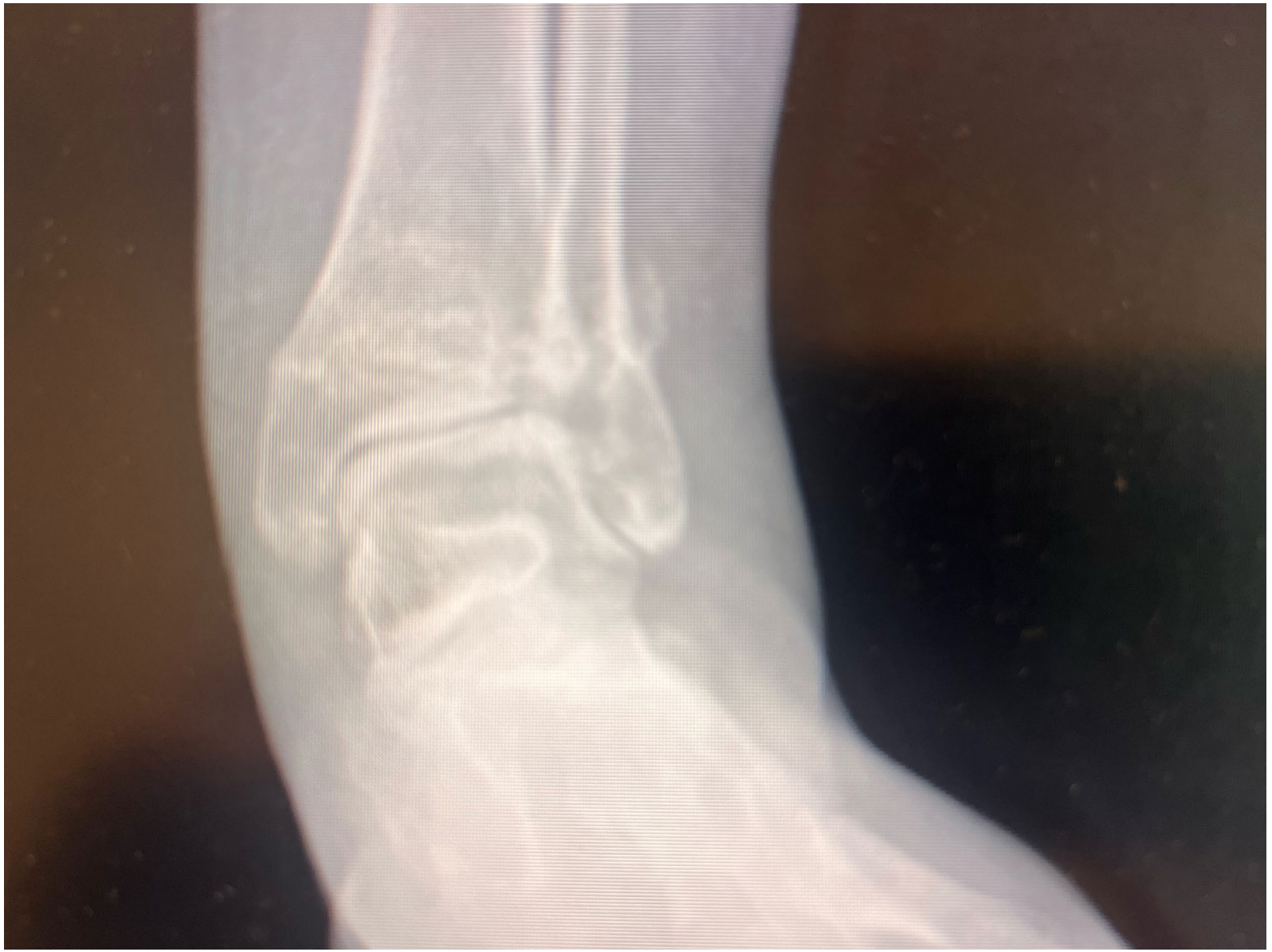
Multiple vertebral fractures

Severe vertebral fracture (>40% loss of vertebral height)

FRAX >30% MOF or >4.5% hip fracture

High fall risk


25 MAY 2006

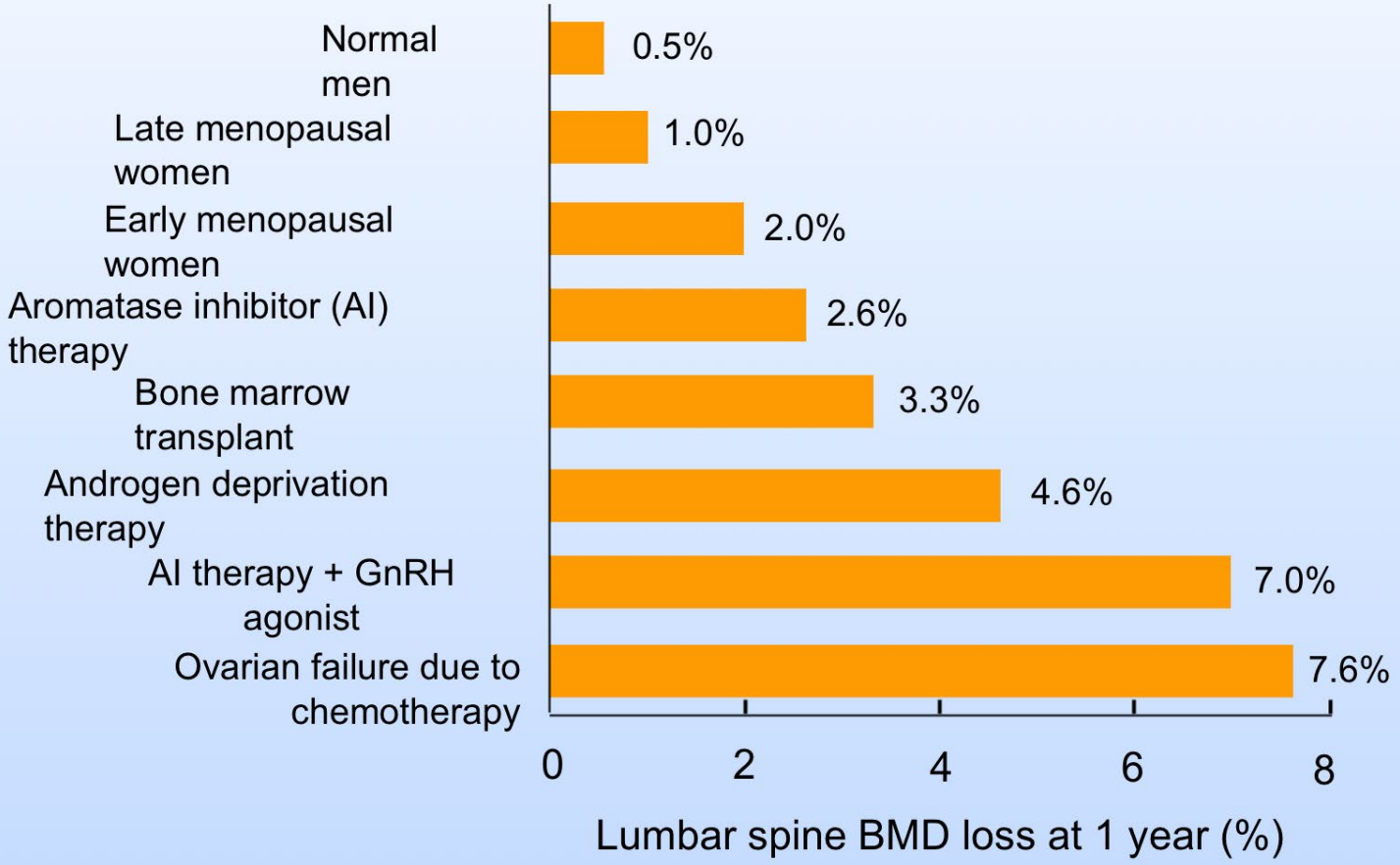


Allegheny Health Network

OSTEOPOROSIS/FRACTURES - SECONDARY CAUSES/CONTRIBUTING FACTORS

- Endocrine Disorders
  - Cushing's syndrome
  - Hypogonadism
  - Primary hyperparathyroidism
  - Hyperthyroidism
  - Idiopathic hypercalciuria/kidney stones
  - DM 1&2
  - Chronic hyponatremia
  - Primary hyperaldosteronism
- GI Disorders
  - Malabsorption (celiac)
  - Gastric surgery
  - IBD
  - Bariatric surgery
  - Liver disease
  - Pancreatic insuff
- Hematologic
  - Multiple myeloma, MGUS
  - Mastocytosis
  - Thalassemia/hemochromatosis
- Lung Disease
  - COPD
  - Asthma
  - Cystic fibrosis
- Others
  - OI/genetic bone diseases
  - RA
  - CKD
  - Alcohol
  - Osteomalacia
  - Immobilization/SCI/CVA/spaceflight
  - HIV/treatment
  - Eating disorders
  - Medications

BMD Loss with Cancer Therapies

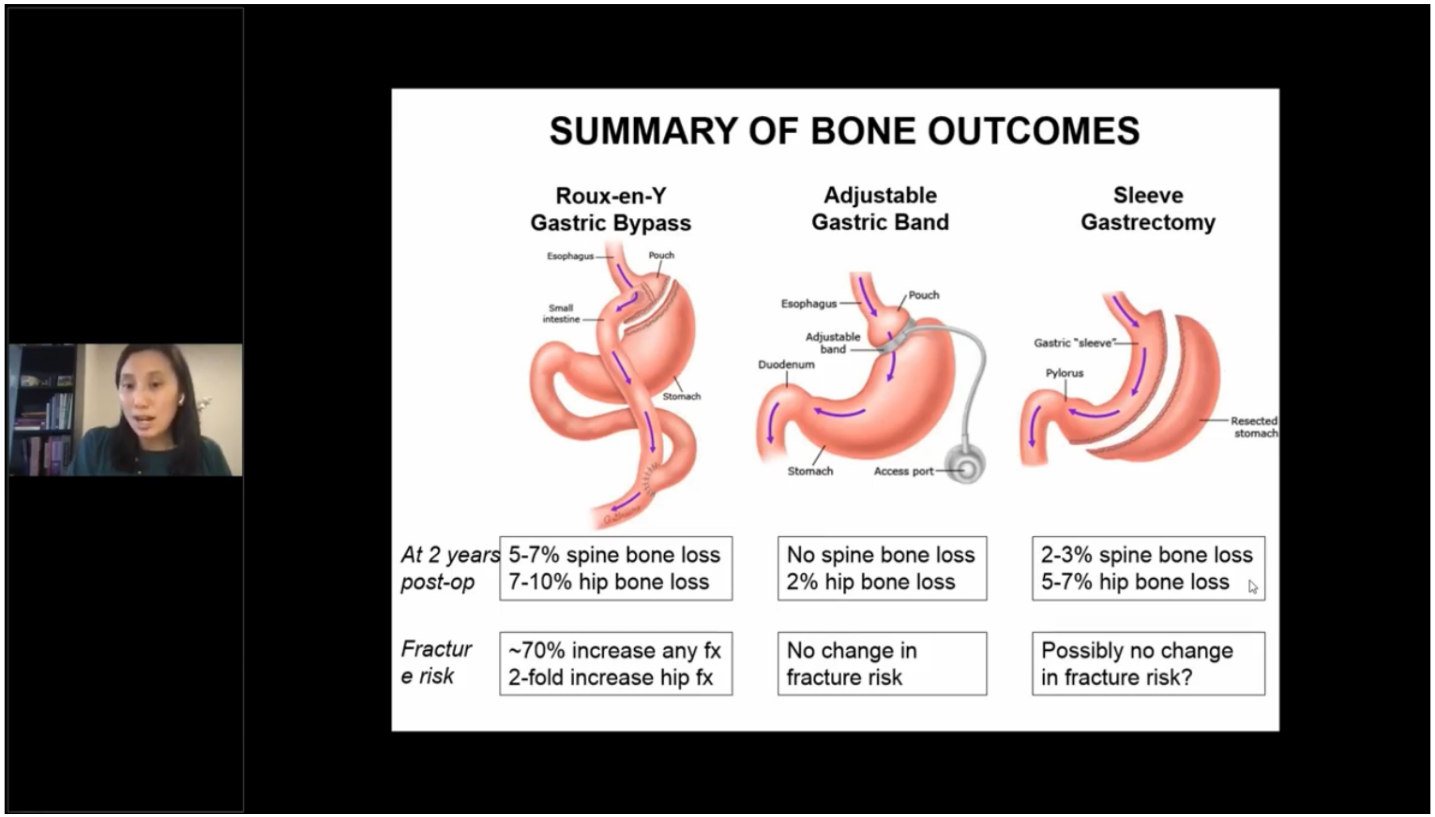


Uluckan et al. (2009) Primer Metab. Bone Disease Disord. Miner. Metab. 386.

Allegheny Health Network

Virtual Own the Bone Symposium: Part II

0 Likes



SUMMARY OF BONE OUTCOMES

	Roux-en-Y Gastric Bypass	Adjustable Gastric Band	Sleeve Gastrectomy
At 2 years post-op	5-7% spine bone loss 7-10% hip bone loss	No spine bone loss 2% hip bone loss	2-3% spine bone loss 5-7% hip bone loss
Fracture risk	~70% increase any fx 2-fold increase hip fx	No change in fracture risk	Possibly no change in fracture risk?

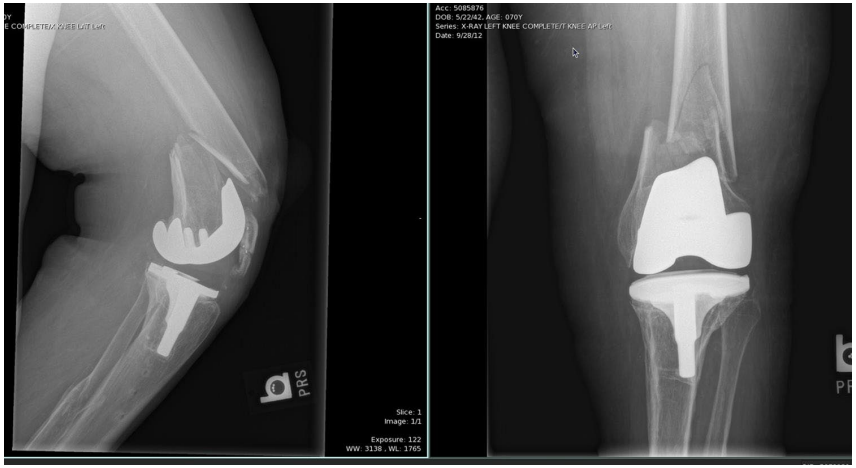
Allegheny Health Network

The following medicines may cause bone loss:

- Aluminum-containing antacids
- Antiseizure medicines (only some) such as Dilantin® or Phenobarbital
- Aromatase inhibitors such as Arimidex®, Aromasin® and Femara®
- Cancer chemotherapeutic drugs
- Cyclosporine A and FK506 (Tacrolimus)
- Gonadotropin releasing hormone (GnRH) such as Lupron® and Zoladex®
- Heparin
- Lithium
- Medroxyprogesterone acetate for contraception (Depo-Provera®)
- Methotrexate
- Proton pump inhibitors (PPIs) such as Nexium®, Prevacid® and Prilosec®
- Selective serotonin reuptake inhibitors (SSRIs) such as Lexapro®, Prozac® and Zoloft®
- Steroids (glucocorticoids) such as cortisone and prednisone
- Tamoxifen® (premenopausal use)
- Thiazolidinediones such as Actos® and Avandia®
- Thyroid hormones in excess

Note: This list may not include all medicines that may cause bone loss.

Preoperative Patients



Osteoporosis is Common and Undertreated prior to Total Joint Arthroplasty (JBJS 2019)

Up to 25-33% of patients undergoing elective TJR surgery meet the NOF criteria to receive pharmacologic osteoporosis treatment (2022-2023)

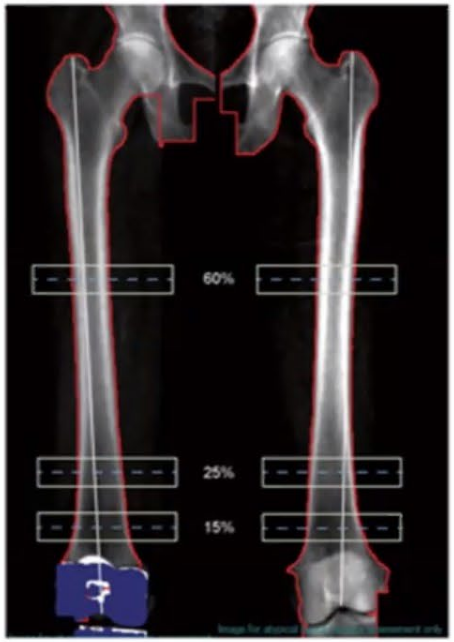
10-20% of patients undergoing elective spine surgery meet the World Health Organization (WHO) bone mineral density criteria for osteoporosis (2022)

Preoperative Patient Optimization

- 64% of candidates for TKR or THR had osteoporosis/osteopenia (Archives of osteoporosis 2022 Korea)
- Osteoporosis can increase the risk of periprosthetic fracture and revision surgery in total knee arthroplasty (J Arthroplasty 2024)
- Patients with osteoporosis are at higher risk for periprosthetic femoral fractures and aseptic loosening following total hip arthroplasty (Orthopedic clinics of NA 2024)
- Preoperative screening is recommended for high-risk osteoporotic patients to minimize risk of complications in total hip arthroplasty- aseptic loosening, subsidence, periprosthetic fractures (Hip Pelvis 2024 Scandinavia)

Effect of Orthopedic Surgery on Bone Structure?

- Create inflammatory state
- Cytokine production
- Osteoclast activation
- Regional bone loss
- Fracture risk

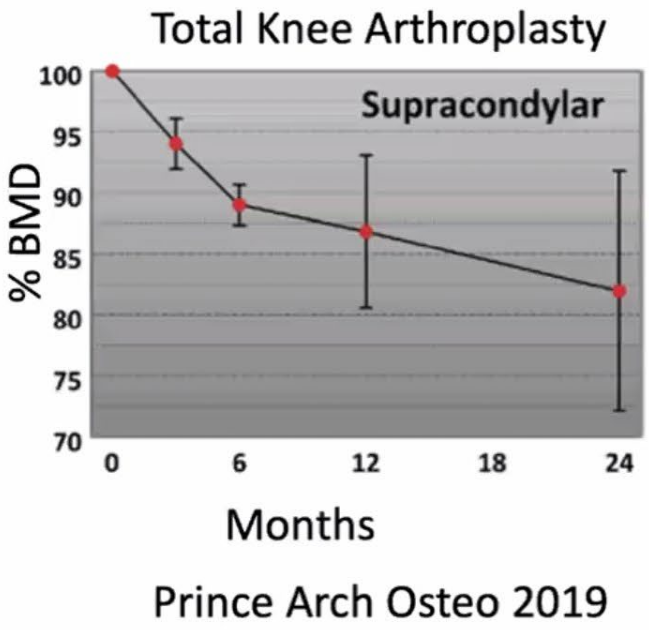


Archives of Osteoporosis (2019) 14:23
https://doi.org/10.1007/s11657-019-0572-7

REVIEW ARTICLE

Changes in femoral bone mineral density after total knee arthroplasty: a systematic review and meta-analysis

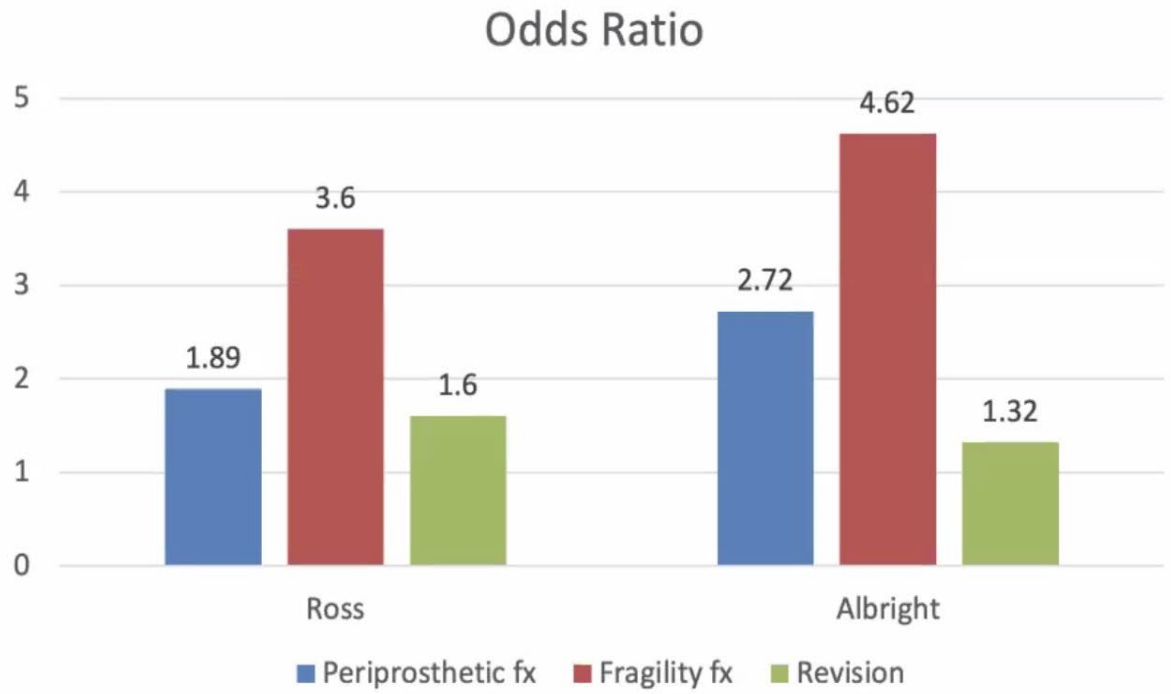
Joel M. Prince[1] · James T. Bernatz[1] · Neil Binkley[2] · Matthew P. Abdel[3] · Paul A. Anderson[1]



Prince Arch Osteo 2019

Impact Prior Fragility Fracture on Periprosthetic Fracture Risk

- Propensity matched studies
- Odds ratio
- Fragility fx within 3 yrs



Albright J Arthropl 2022
Ross Arthr Today 2021

Revisiting Cemented Femoral Fixation in Hip Arthroplasty

JBJS Current Concepts Review 2022

- Higher early revision rates for cementless compared to cemented femoral stems are related to a greater risk of periprosthetic femoral fracture and early implant loosening Seen in elderly patients, most notably women (both arthroplasty and hemiarthroplasty)

- Recommend considering cement fixation in patients :
  >age 70(particularly women)
  Patients with osteoporosis including those with prior fragility fractures

- When intraoperative broach stability cannot be obtained

Allegheny Health Network

Periprosthetic femoral fractures

Well-fixed cemented stems fracture most commonly around the area near the tip of the prostheses

Uncemented stems have a lower load to fracture, which can also be associated with a lower bone mineral density

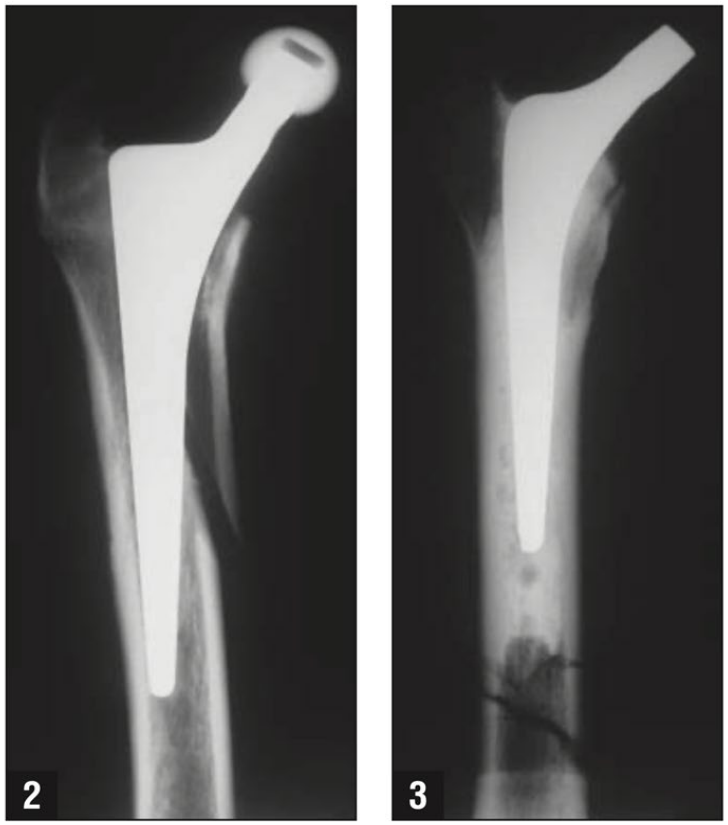
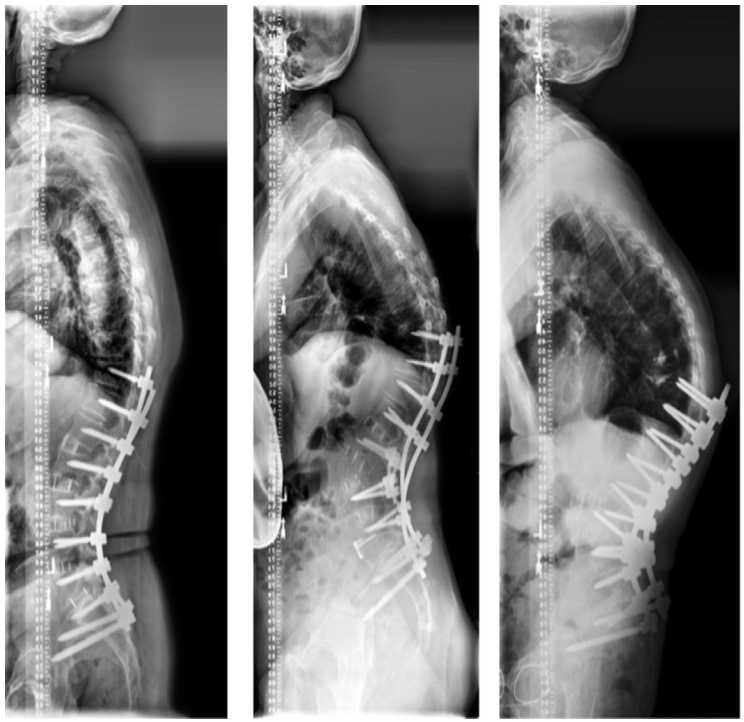


Figure 2: Radiograph showing a typical type A Vancouver periprosthetic fracture after loading. **Figure 3:** Radiograph showing a typical type C Vancouver periprosthetic fracture after loading.

Osteoporosis Complications in Lumbar Surgery



- Pseudarthrosis
- Failure of Instrumentation
- Proximal Junctional Kyphosis (PJK)
- Compression Fracture
- Revision Surgery

Recent retrospective studies demonstrate 2-3X complication rates in those patients with T scores below -1.0 !

Allegheny Health Network

Kaiser Study Validating BCT for Spinal Fusion Outcomes

Observational cohort study

N=469 first-time fusion patients

BCT on CT before surgery

Follow for up to 5 years

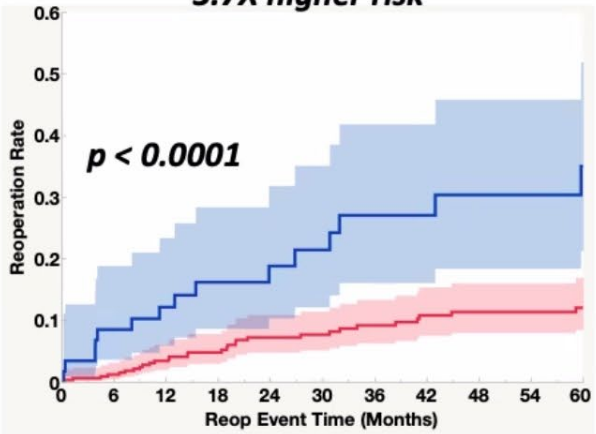
Measure BCT at the UIV level

BCT blinded to outcomes

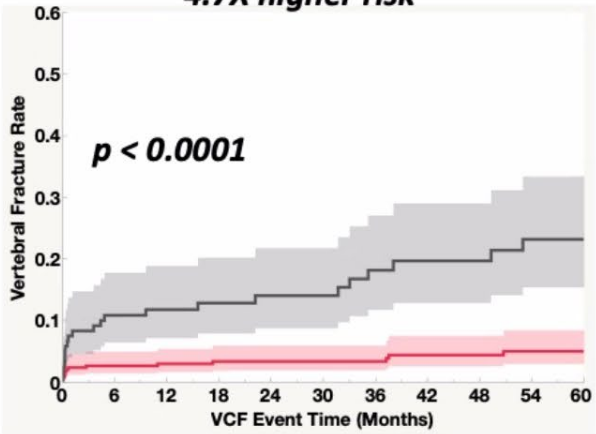
Clinical outcomes:

- **Reoperation (any reason)**
- **Vertebral Fracture**

Reoperation (any cause)
3.7X higher risk



Vertebral Fracture
4.7X higher risk



FBS and/or BDO positive (one or both)
FBS and BDO positive (both)
No osteoporosis (negative for FBS and for BDO)

BDO = BMD-defined osteoporosis
Vertebral trabecular BMD ≤ 80 mg/cm^3

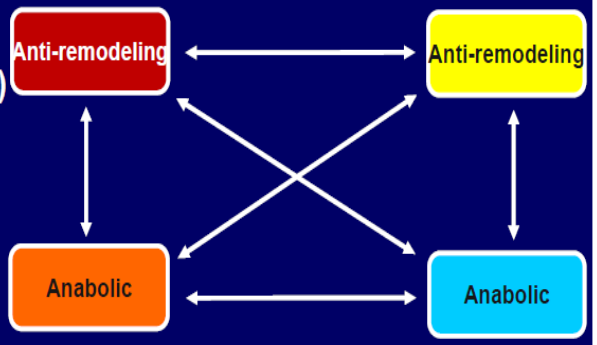
FBS = Fragile bone strength
Vertebral strength ≤ 4,500 N women; 6,000 N men

Conclude: Spinal-fusion patients who pre-operatively tested positive for osteoporosis by BCT were at high risks of vertebral fracture and reoperation

Keaveny, *Spine Journal* 2023

OSTEOPOROSIS TREATMENT OPTIONS

- Anti-remodeling agents *(inhibit bone turnover)*
  - Estrogen (approved for prevention only)
  - Estrogen agonists/antagonist (raloxifene)
  - Bisphosphonates (oral and IV)
  - RANK ligand inhibitor (denosumab)



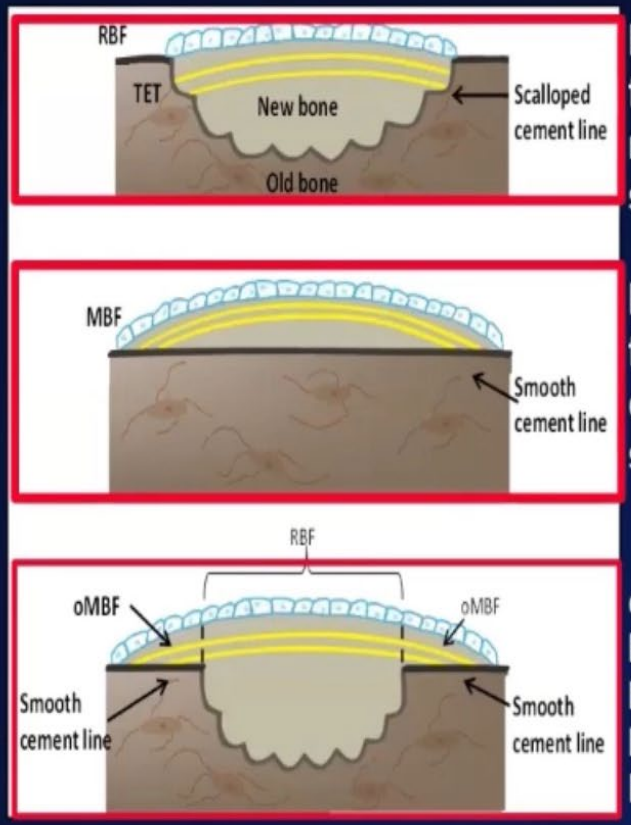
- Osteoanabolic agents *(activate bone formation)*
  - Remodeling stimulators (*increase formation and resorption*)
    - Parathyroid hormone receptor activators
      - teriparatide and abaloparatide
  - Modeling stimulator *(increase formation, decrease resorption)*
    - Sclerostin inhibitor
      - romosozumab

Allegheny Health Network

RBF = Remodeling-based formation

MBF = Modeling-based formation

oMBF = Overflow Modeling-based Formation (also referred to as oRBF=overflow Remodeling-based bone Formation)



RBF: bone formation over remodeled surfaces

MBF: bone formation over quiescent surfaces

oMBF or oRBF : bone formation beyond the boundaries of the BRU

Dempster DW et al Longitudinal Effects of Teriparatide or Zoledronic Acid on Bone Modeling- and Remodeling-Based Formation in the SHOTZ Study. J Bone Miner Res. 2017 Nov 30. 10.1002/jbmr.3350. [Epub ahead of print]

Switching Osteoporosis Therapies:
Anti-remodeling Drug to an Osteoanabolic Agent

- In treatment-naïve patients, BMD and fracture protection are better with an anabolic drug vs a bisphosphonate
- The BMD response to anabolic agents is smaller in patients previously treated with an anti-resorptive drug
- There are very limited fracture data with the sequence of an anti-remodeling drug followed by an anabolic agent

Reasons to switch from an anti-remodeling drug to an osteoanabolic agent:

- inadequate response to an anti-remodeling agent
- marked increase in patient's fracture risk

Anabolic first approach in high risk

Normal: FRAX without BMD of < 10% or no fracture after age 50 then no DXA and no BHO referral. For others; normal BMD, MOF < 20%, no prior fracture, normal TBS and HU when available

Osteopenia/intermediate risk: Lowest T-score -2.4 or better, no prior fracture, MOF risk <20%

Osteoporosis/high risk: Lowest T-score -2.5 to -3.4 and MOF risk < 30%

Severe osteoporosis/ very high risk: Lowest T-score ≤ -3.5 OR MOF risk > 30% OR recent fracture OR multiple prior fractures

Aging Clinical and Experimental Research (2022) 34:695–714
https://doi.org/10.1007/s40520-022-02100-4

REVIEW

Management of patients at very high risk of osteoporotic fractures through sequential treatments

Elizabeth M. Curtis[1] · Jean-Yves Reginster[2,3] · Nasser Al-Daghri[4] · Emmanuel Biver[5] · Maria Luisa Brandi[6] · Etienne Cavalier[7] · Peyman Hadji[8,9] · Philippe Halbout[10] · Nicholas C. Harvey[1,11] · Mickaël Hiligsmann[12] · M. Kassim Javaid[13] · John A. Kanis[14,15] · Jean-Marc Kaufman[16] · Olivier Lamy[17] · Radmila Matijevic[18,19] · Adolfo Diez Perez[20] · Régis Pierre Radermecker[21] · Mário Miguel Rosa[22] · Thierry Thomas[23,24] · Friederike Thomasius[8] · Mila Vlaskovska[25] · René Rizzoli[5] · Cyrus Cooper[1,11,26]

Received: 11 February 2022 / Accepted: 18 February 2022 / Published online: 24 March 2022

Abstract
Osteoporosis care has evolved markedly over the last 50 years, such that there are now an established clinical definition, validated methods of fracture risk assessment and a range of effective pharmacological agents. Currently, bone-forming (anabolic) agents, in many countries, are used in those patients who have continued to lose bone mineral density (BMD), patients with multiple subsequent fractures or those who have fractured despite treatment with antiresorptive agents. However, head-to-head data suggest that anabolic agents have greater rapidity and efficacy for fracture risk reduction than do antiresorptive therapies. The European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (ESCEO) convened an expert working group to discuss the tools available to identify patients at high risk of fracture, review the evidence for the use of anabolic agents as the initial intervention in patients at highest risk of fracture and consider the sequence of therapy following their use. This position paper sets out the findings of the group and the consequent recommendations. The key conclusion is that the current evidence base supports an "anabolic first" approach in patients found to be at very high risk of fracture, followed by maintenance therapy using an antiresorptive agent, and with the subsequent need for antiosteoporosis therapy addressed over a lifetime horizon.

Keywords Osteoporosis · Epidemiology · Imminent · Fracture · Anabolic · Antiresorptive

Bone Volume Enhancement

Denosumab	+3.5%
Teriparatide	+8-10%
Abaloparatide	+9-10%
Romosozumab	+ 15%
Bisphosphonates	+ 0%

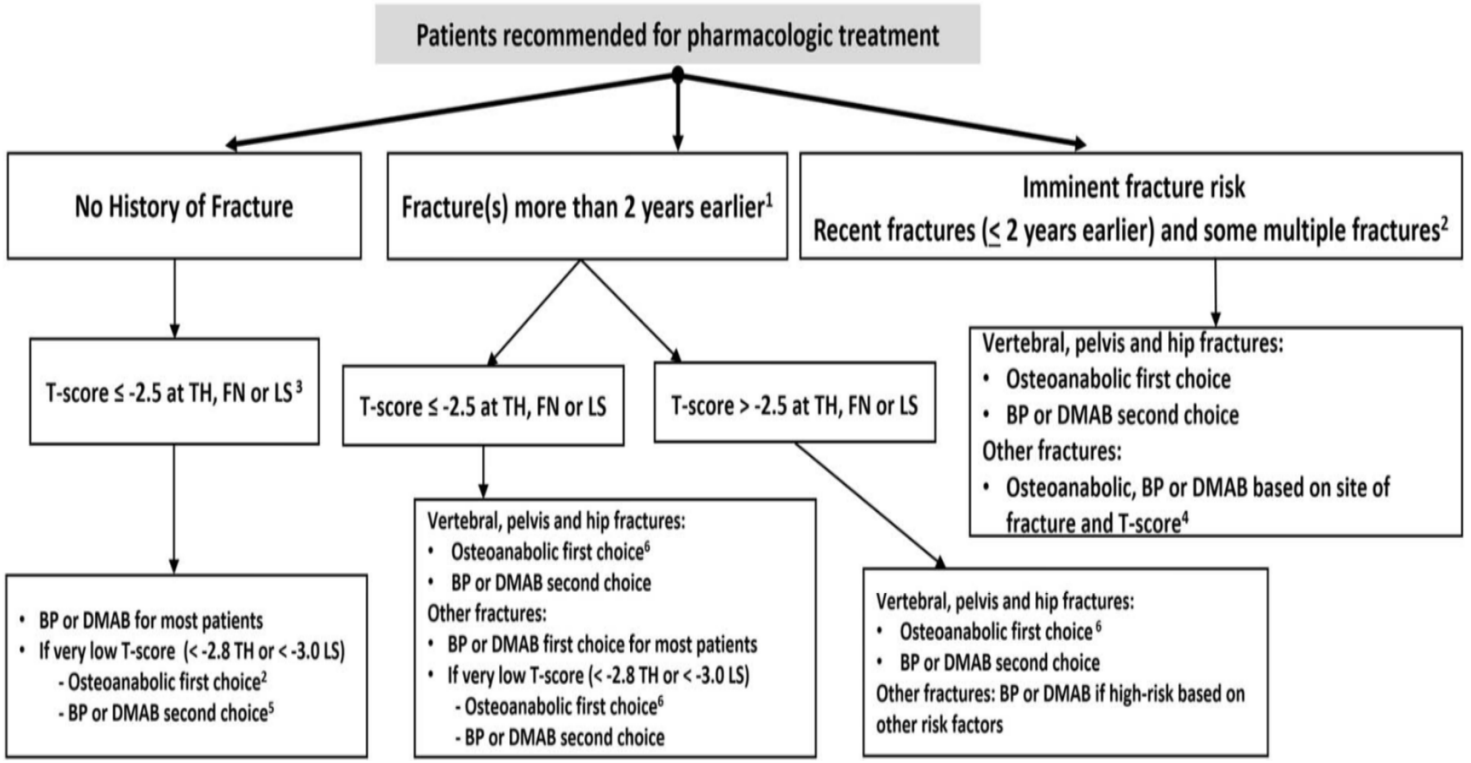
Allegheny Health Network

Post Operative Bone Volume

- Fracture PTH > Zoledronic Acid
- Arthoplasty (Stable Fixation) Zolendronic Acid
- Poor Implant Fit PTH
- Spine Fusion with Instrumentation PTH

Treatment Targets:

- For imminent risk patients, maximal rapid reduction in fracture risk
- For patients with T-score ≤ -2.5, minimal target is to increase T-score to > -2.5, higher for patients with fracture history, or other major risk factors
- For patients with T-score > -2.5, increase TH T-score by 0.2 (3%) and LS by 0.5 (6%)



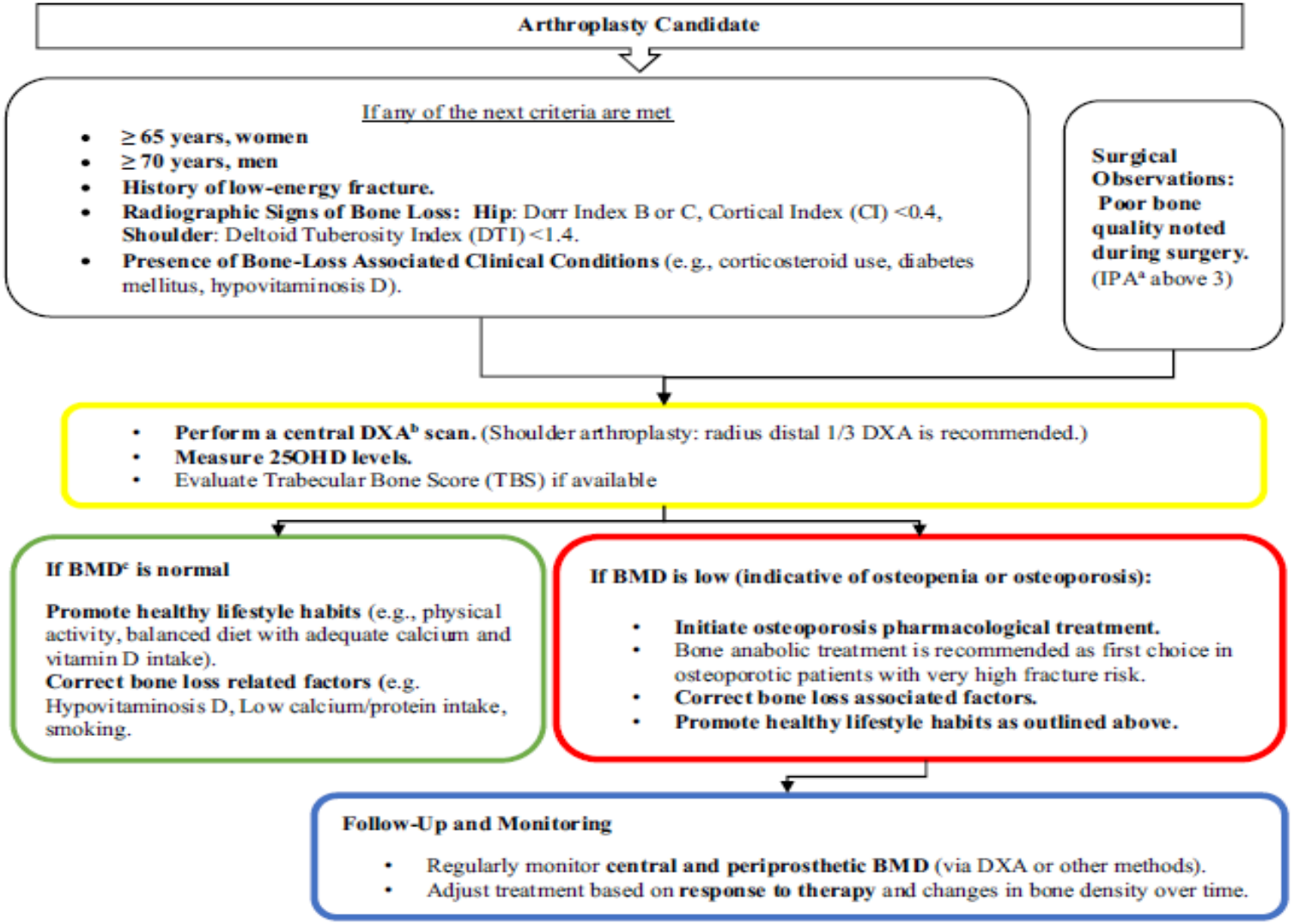


Fig. 7 Arthroplasty bone optimization algorithm. [a]IPA, intraoperative physician assessment; [b]DXA, bone density scan. [c] BMD, bone mineral density. *The treatment selection should be directed by objectives and individualized for each patient

Allegheny
Health Network

THANK YOU