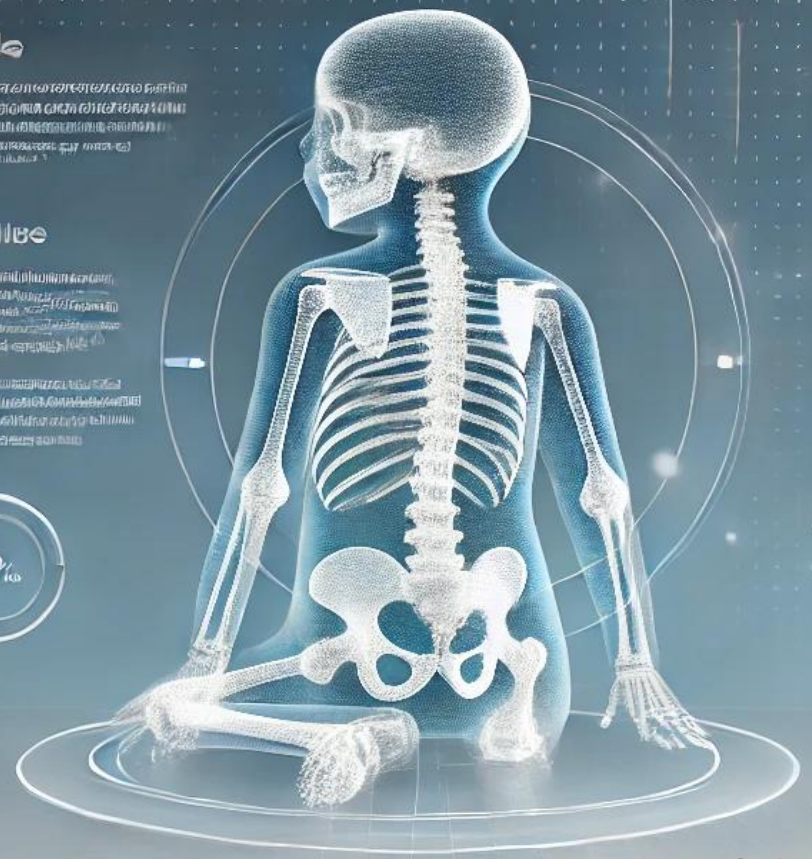

بسم الله الرحمن الرحیم

Bone Densitometry in Children

Principles and Applications



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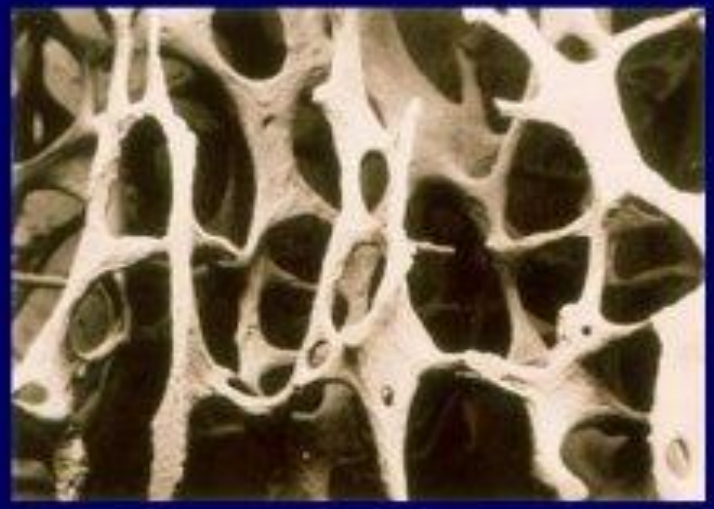
What is Osteoporosis in children?

What is/are indication(s) for densitometry?

Definition of Osteoporosis

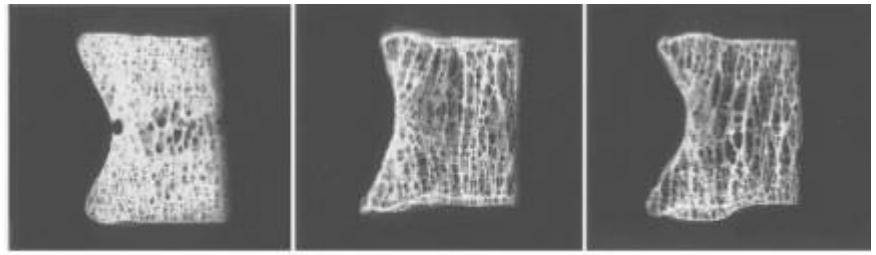
Osteoporosis is defined as a skeletal disorder characterized by compromised bone strength predisposing a person to an increased risk of fracture.

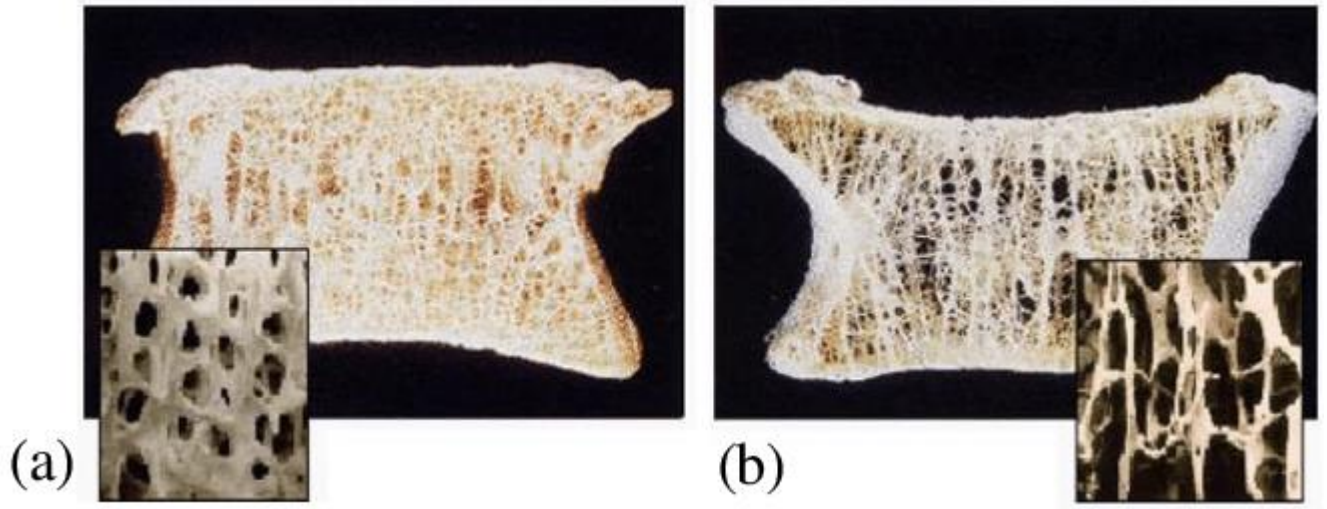
Normal bone



Osteoporosis

NIH Consensus Development Panel on Osteoporosis *JAMA* 285:785-95; 2001


(a)
(b)
(c)


(a)
(b)

BONE STRENGTH

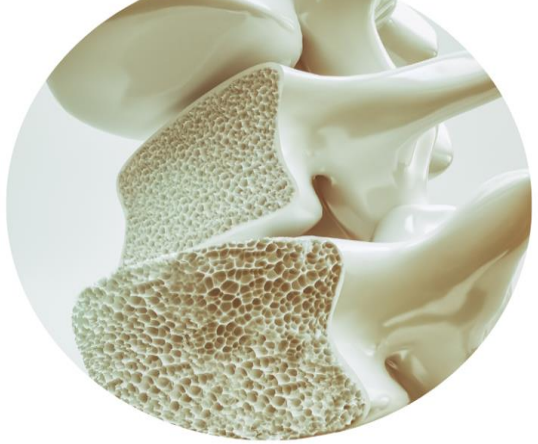
BONE MINERAL DENSITY

Gram of mineral per area

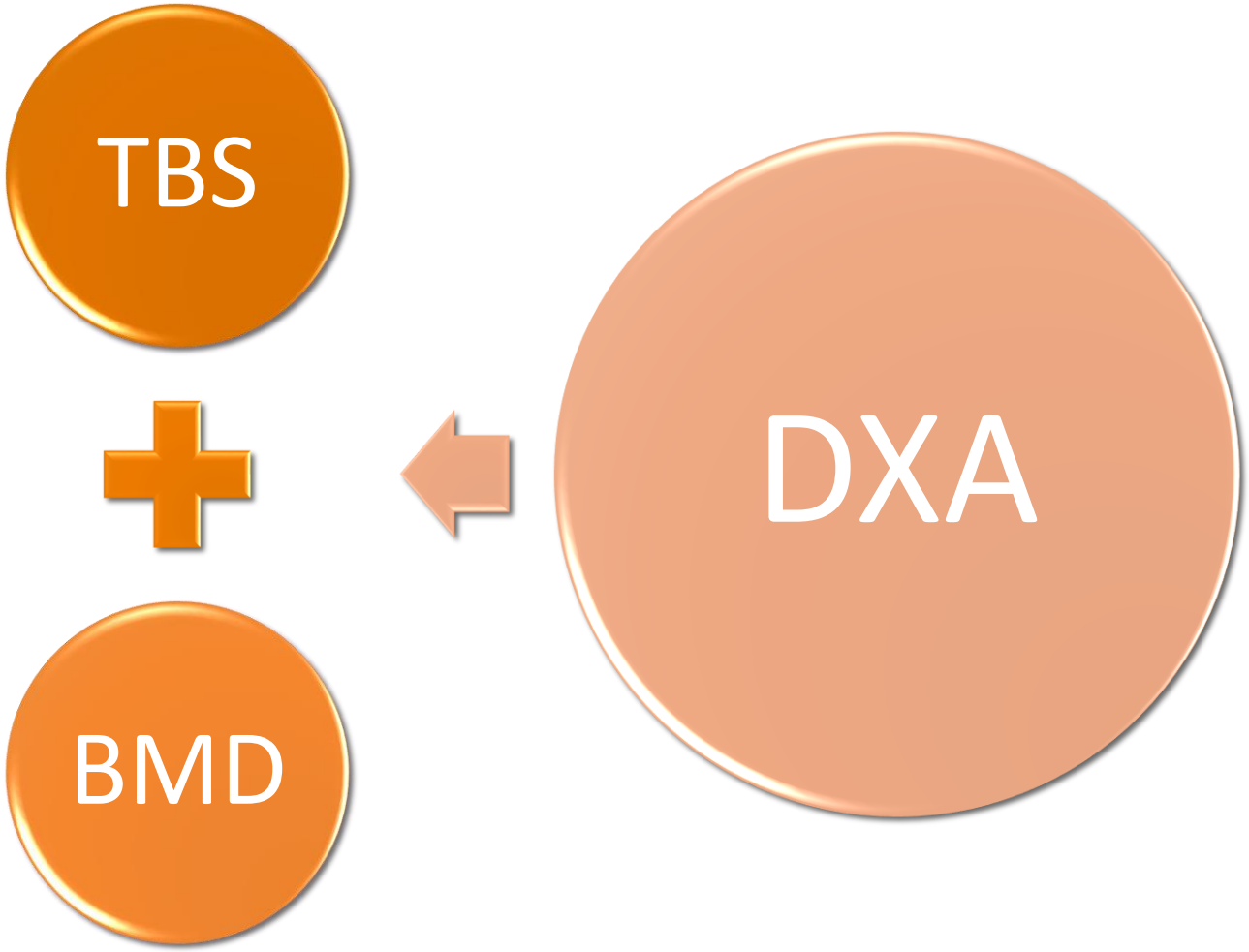
+

BONE QUALITY

- Bone architechture
- Bone turnover
- Bone size & geometry



Mineral Content	Bone Quality
Bone Mineral Density/Content	Trabecular Bone Score
BMD/ BMC	TBS


TBS
BMD
DXA

DXA or DEXA

Dual-Energy X-ray Absorptiometry

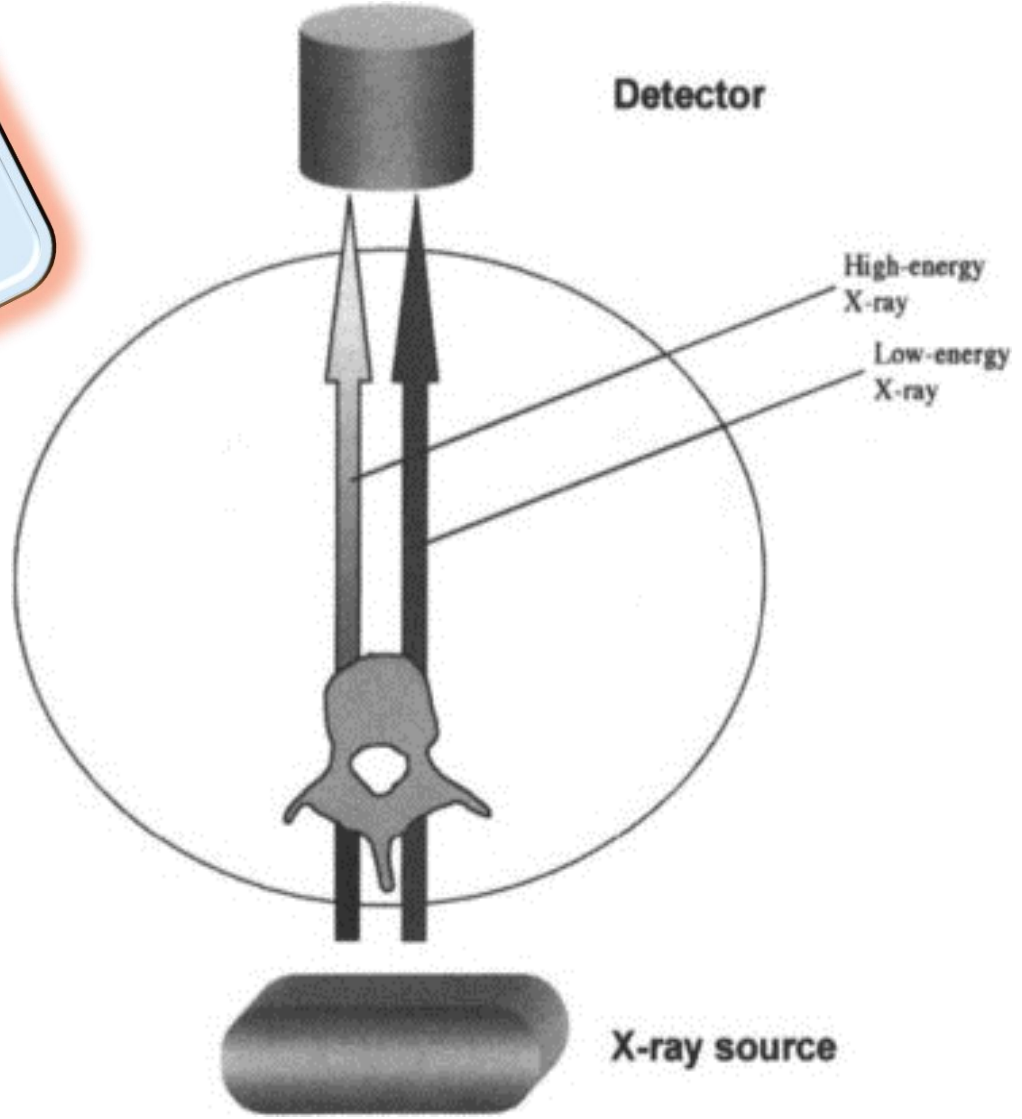
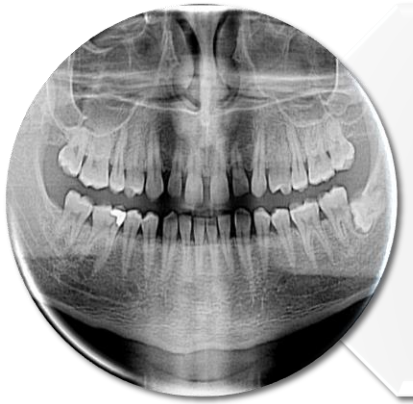


TABLE 2. Comparison of Radiation Exposure from Different Imaging Modalities

Imaging Modality Type	Model	Patient Exposure, μSv
Body CT scan		5,000–15,000
Head CT scan		2,000–4,000
Lumbar spine x-ray		600–1,700
Lateral spine x-ray		820
Dental bitewing		60
Chest x-ray		50



0.005mSv

The radiation dose of current DEXA systems is small, as low as ***0.001 mSv***
much less than a standard chest or dental x-ray

ORDERING DXA FOR CHILDREN AND ADOLESCENTS

Indication for densitometry in children

Definition of osteoporosis in children and adolescents

To diagnose osteoporosis two main criteria need to be met*:

1) Low bone mineral content (BMC) or low bone mineral density (BMD)
2) A clinically significant fracture history

**In the absence of vertebral compression fractures*

Bone mass criteria (1)

Low BMC or BMD is defined as a BMC or areal BMD Z-score that is less than or equal to –2.0, adjusted for age, gender, and body size, as appropriate.

Clinically significant fracture history (2)

Defined as one or more of the following:

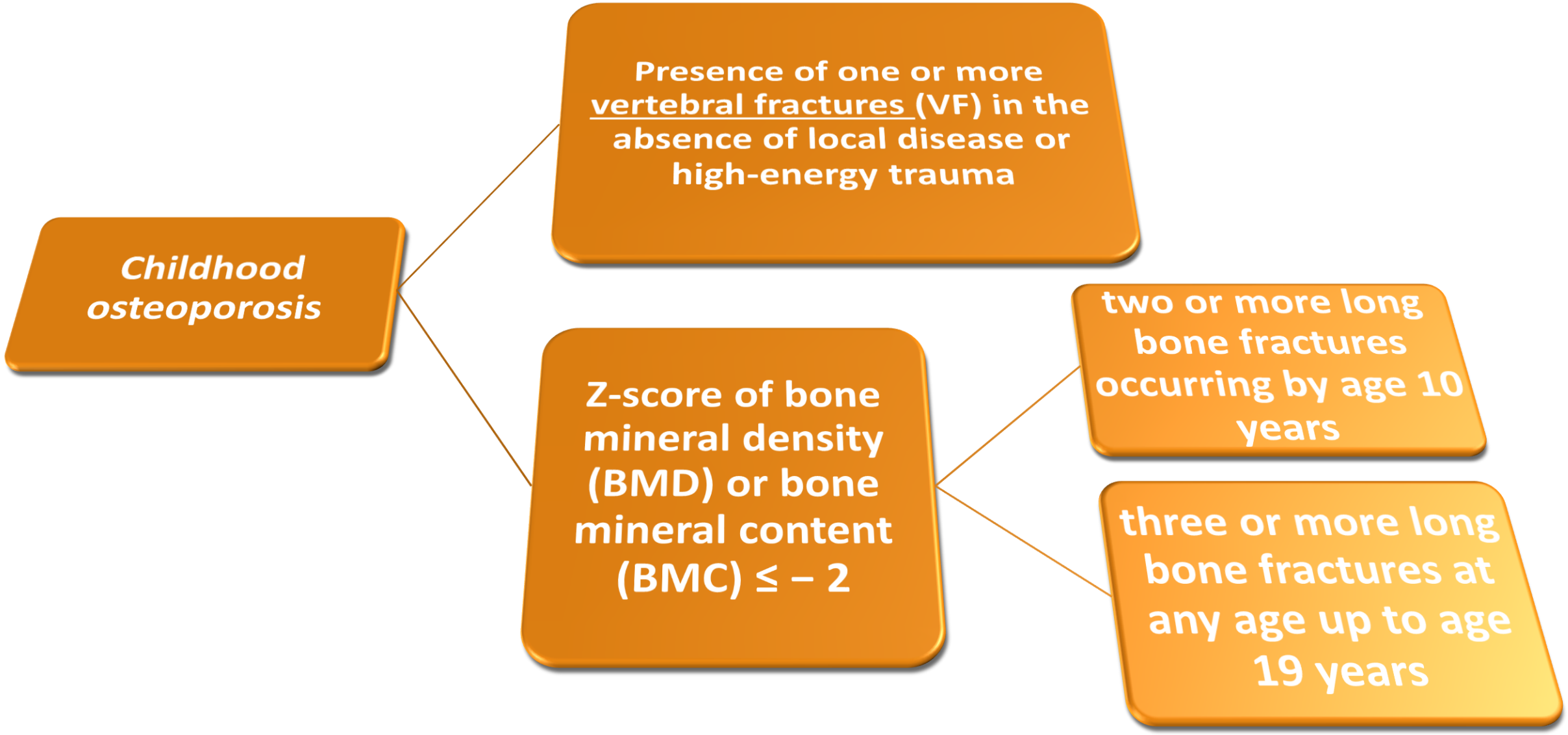
- Two or more long-bone fractures by the age of 10 years
- Three or more long-bone fractures by the age of 19 years

Vertebral compression fractures - an exception

- One or more vertebral compression fractures is indicative of osteoporosis and the diagnosis can be made without fulfillment of the two main criteria.

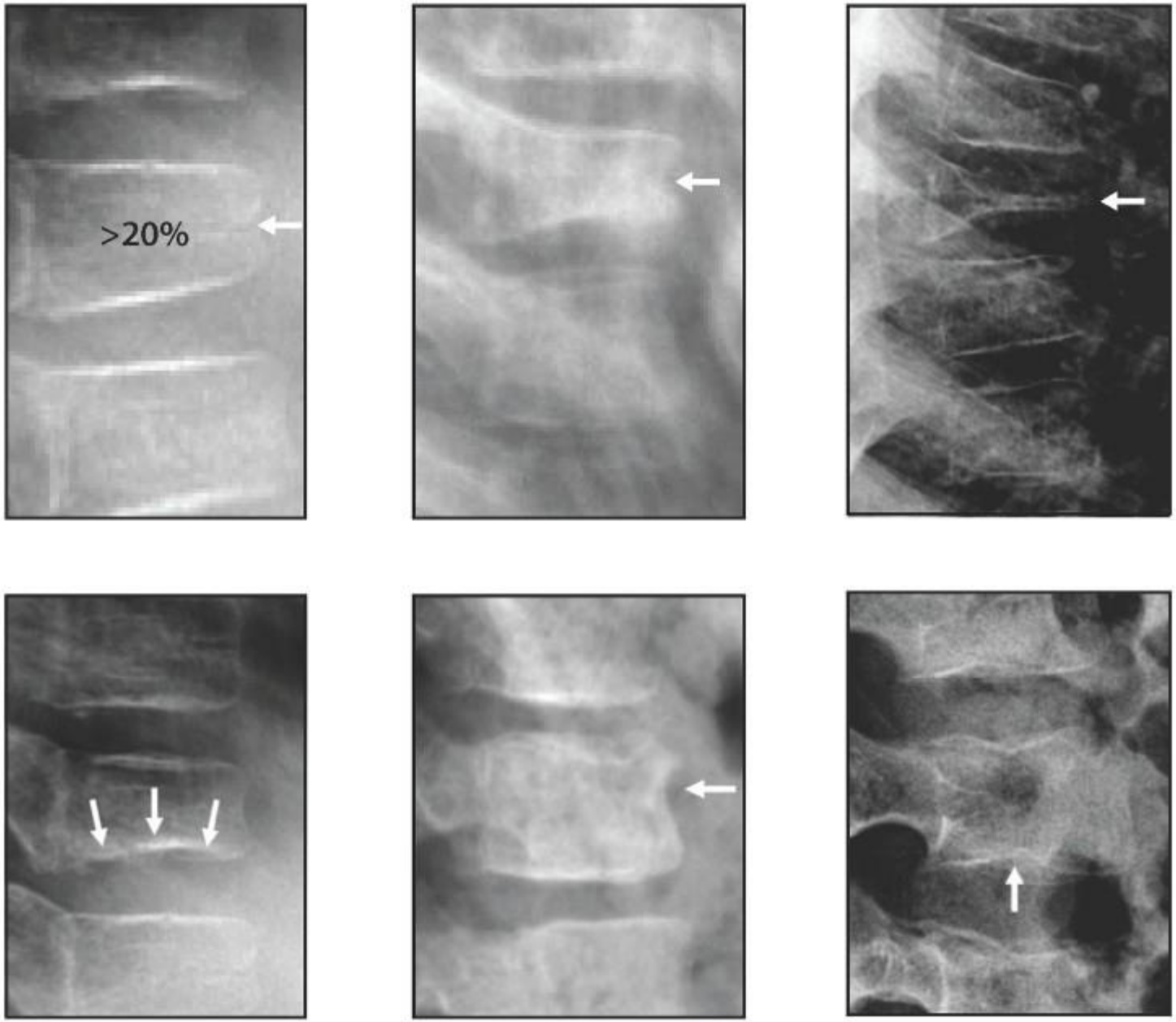
(Vertebral compression fracture = loss of vertebral height at any point of >20%)

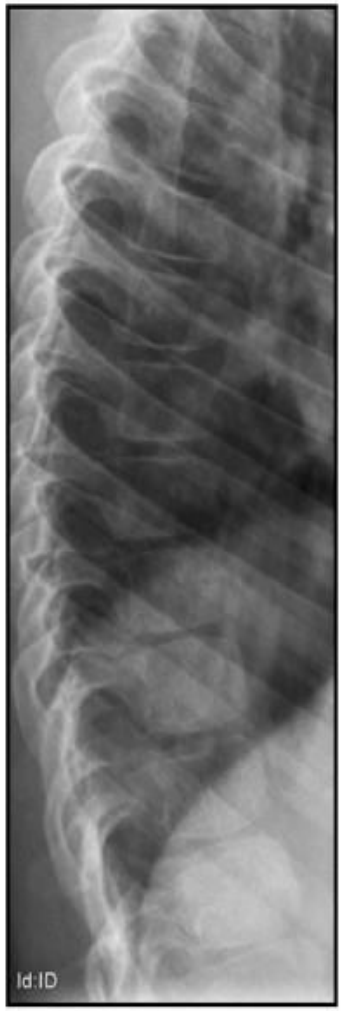
Only fractures resulting from traumas with mild to moderate energy are considered significant. Fractures of the nose, skull, fingers or toes are not considered clinically significant.


Childhood osteoporosis
Presence of one or more vertebral fractures (VF) in the absence of local disease or high-energy trauma
Z-score of bone mineral density (BMD) or bone mineral content (BMC) ≤ – 2
two or more long bone fractures occurring by age 10 years
three or more long bone fractures at any age up to age 19 years

Consider a DXA scan in those with a significant fracture history

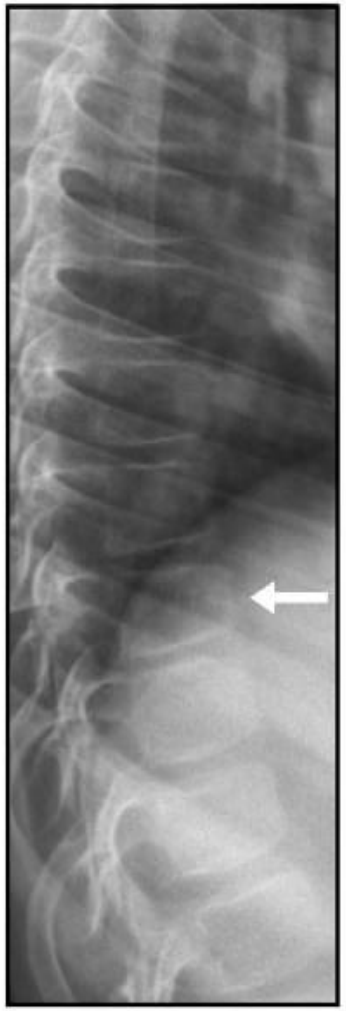
- ≥ 1 vertebral compression fractures
- ≥ 2 long bone fractures by 10 years old*
- ≥ 3 long bone fractures by 19 years old


>20%



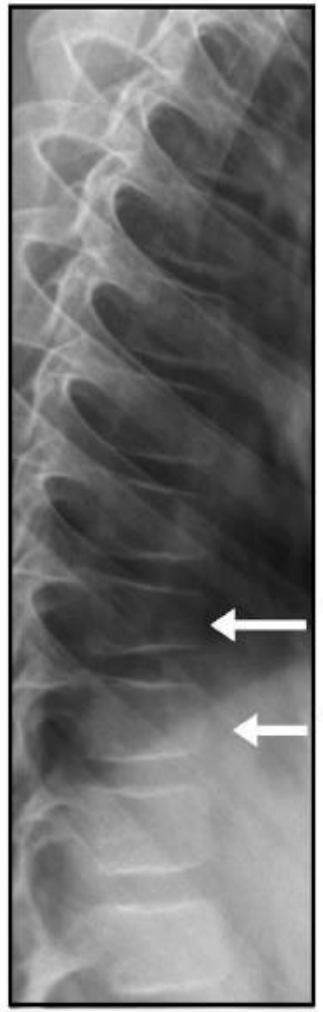
8 yrs

Normal



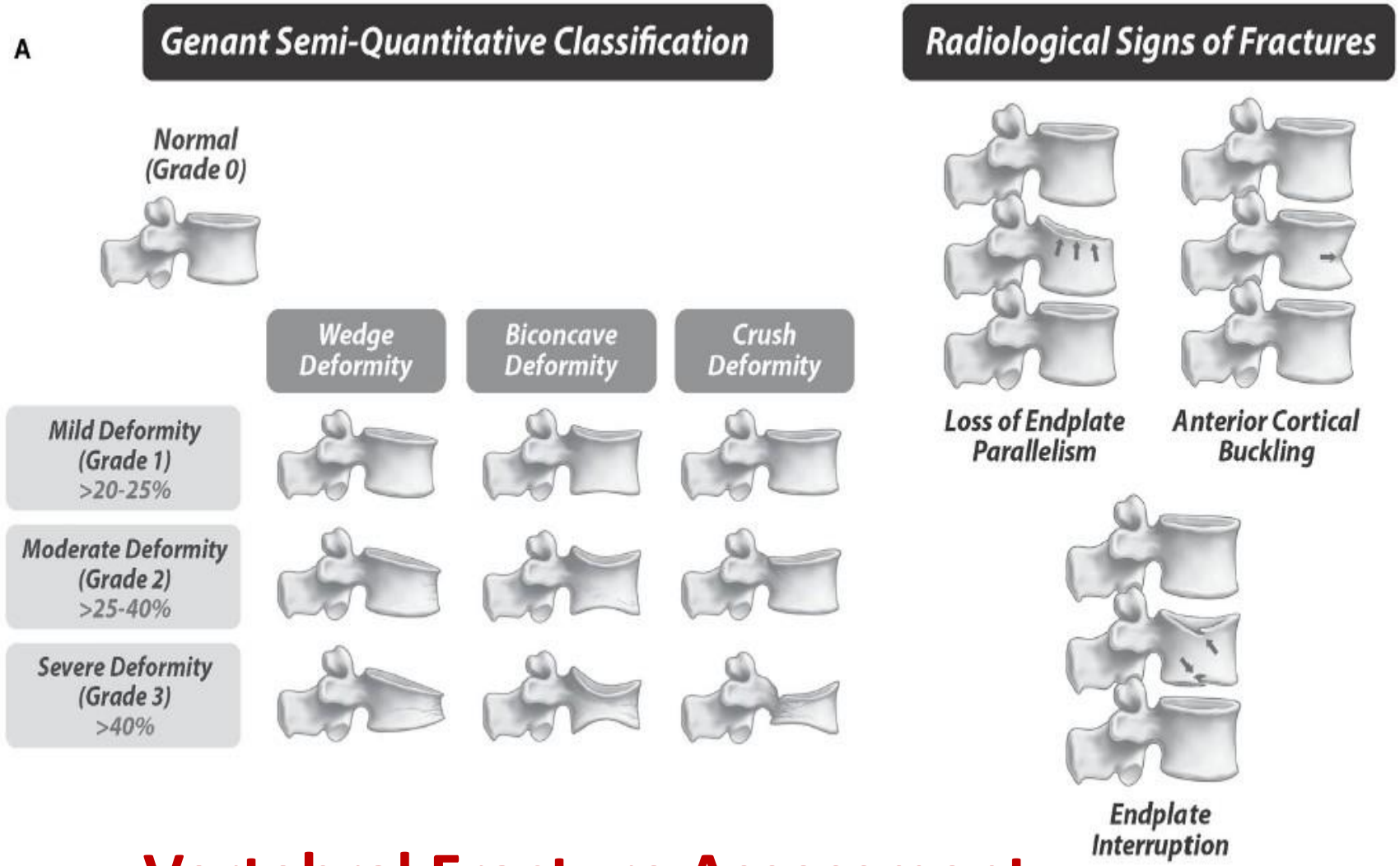
9 yrs

Grade 1 vertebral fracture

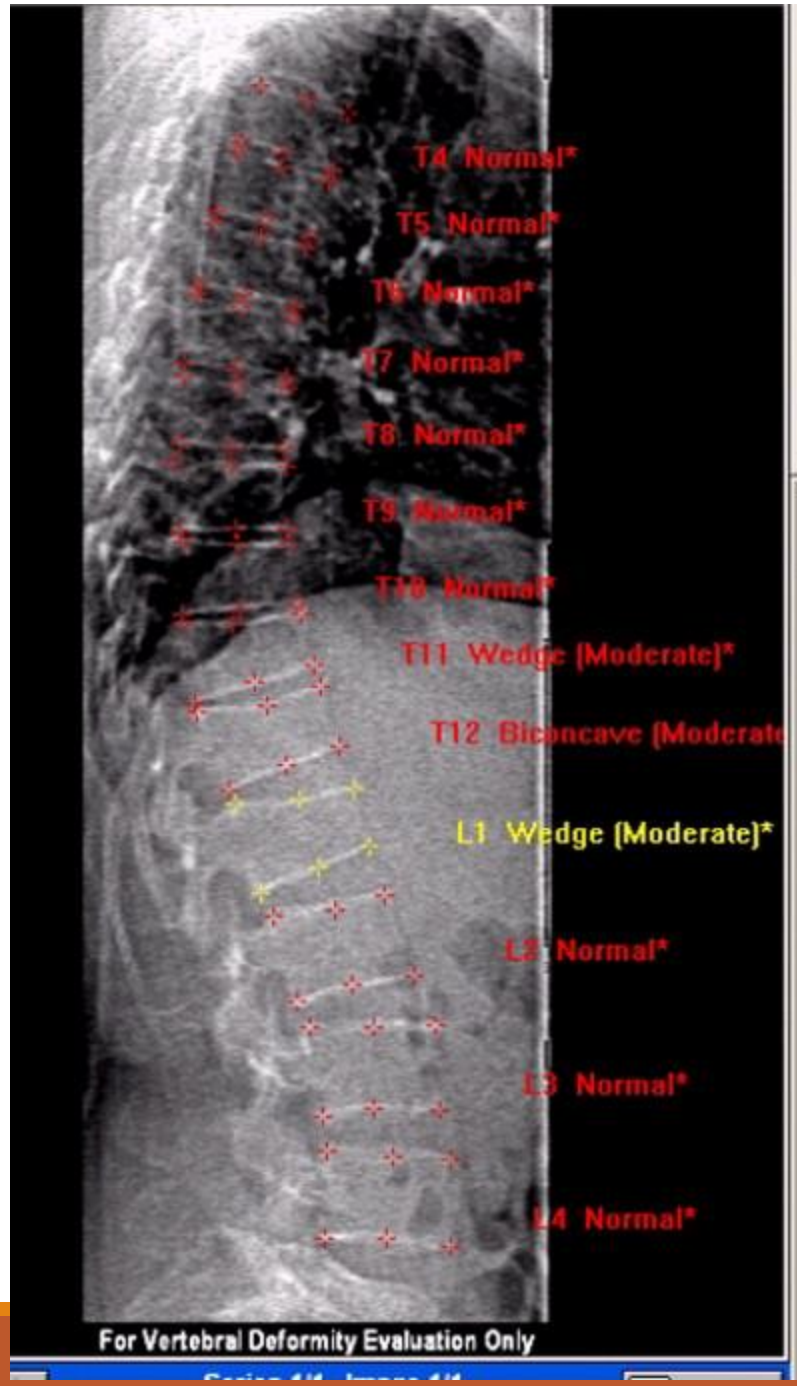


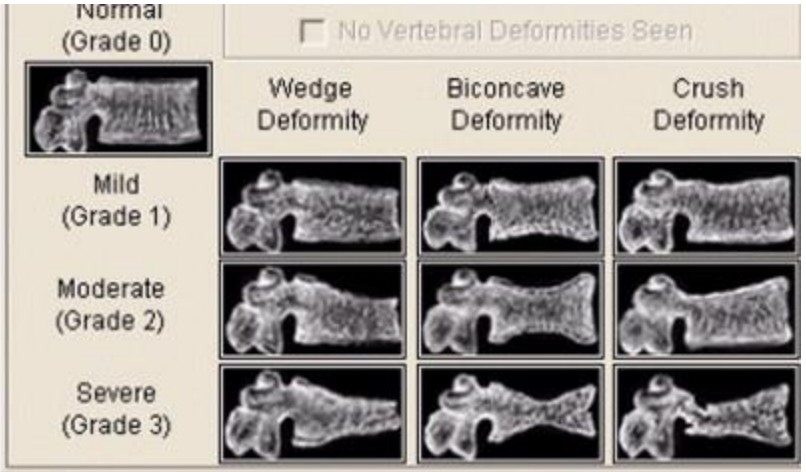
11 yrs

Progression of the T9 vertebral fracture
New Grade 1 vertebral fracture at T10



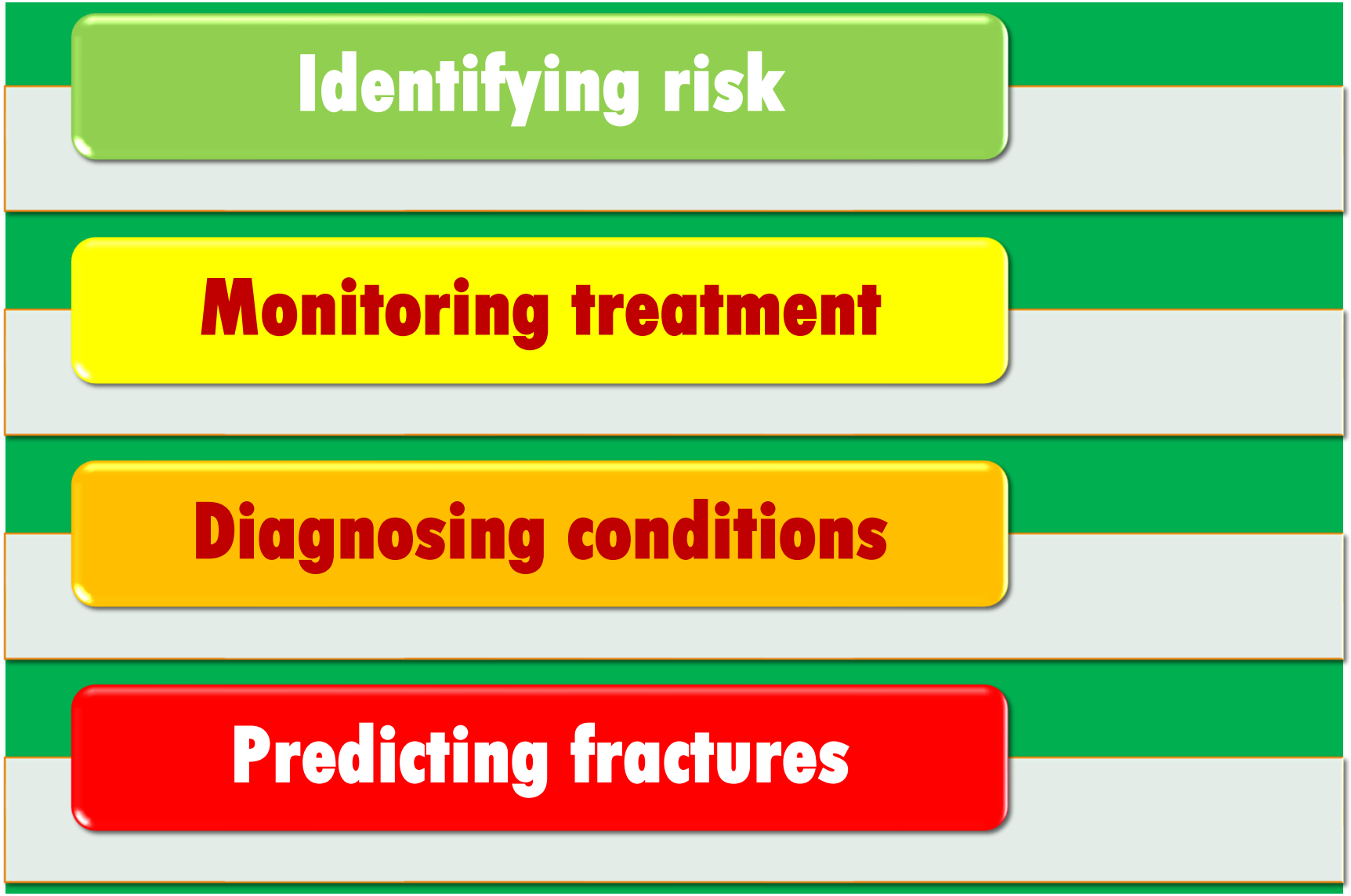
Vertebral Fracture Assessment (VFA)



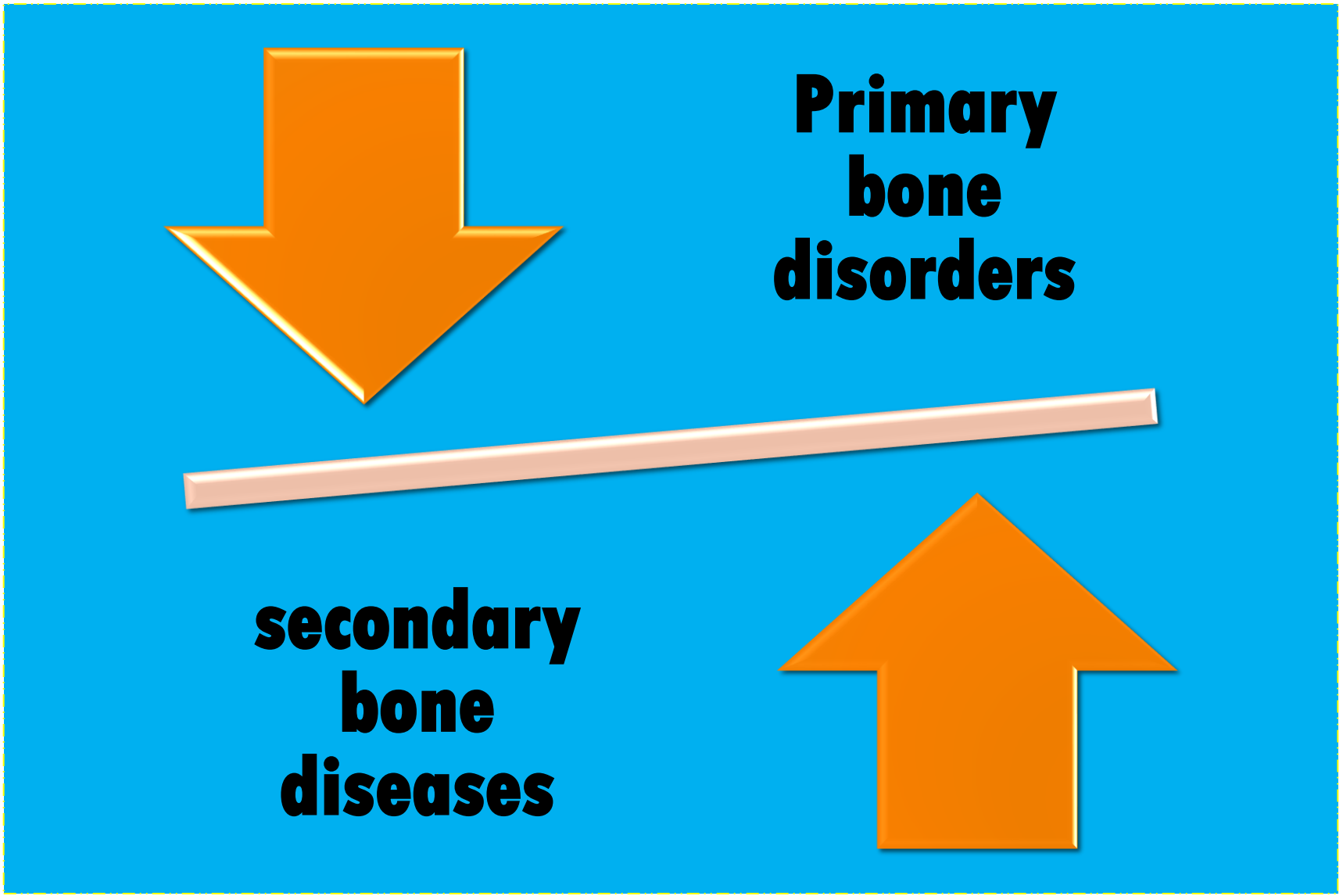


Vertebral Assessment

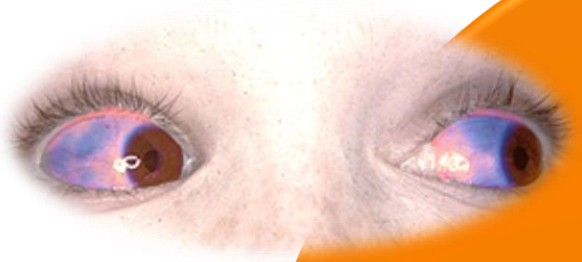
	Height (mm)			Percent Deformation		
Label	Post	Mid	Ant	Wedge	Biconcave	Crush
	Deformity (Grade)					
T4	17.8	18.3	18.2	0.0%	-3.1%	2.5%
	Normal					
T5	19.9	17.9	18.5	6.8%	9.9%	0.0%
	Normal					
T6	19.4	18.1	19.2	1.1%	6.7%	0.0%
	Normal					
T7	21.1	19.6	18.5	12.3%	6.8%	0.0%
	Normal					
T8	20.9	19.4	18.7	10.5%	7.0%	0.0%
	Normal					
T9	21.1	20.2	19.5	7.3%	4.3%	0.0%
	Normal					
T10	22.4	20.2	18.3	18.5%	9.9%	0.0%
	Normal					
T11	24.3	18.8	16.1	33.7%	22.5%	0.0%
	Wedge (Moderate)					
T12	26.3	19.4	19.4	26.2%	26.5%	0.0%
	Biconcave (Moderate)					
L1	28.9	22.5	18.1	37.6%	22.4%	0.0%
	Wedge (Moderate)					
L2	27.0	23.7	27.1	0.0%	12.2%	0.5%
	Normal					
L3	27.8	25.4	26.4	5.2%	8.8%	0.0%
	Normal					
L4	27.3	25.1	26.7	2.2%	8.3%	0.0%
	Normal					
Std Dev	1.0	1.0	1.0	5.0%	5.0%	5.0%

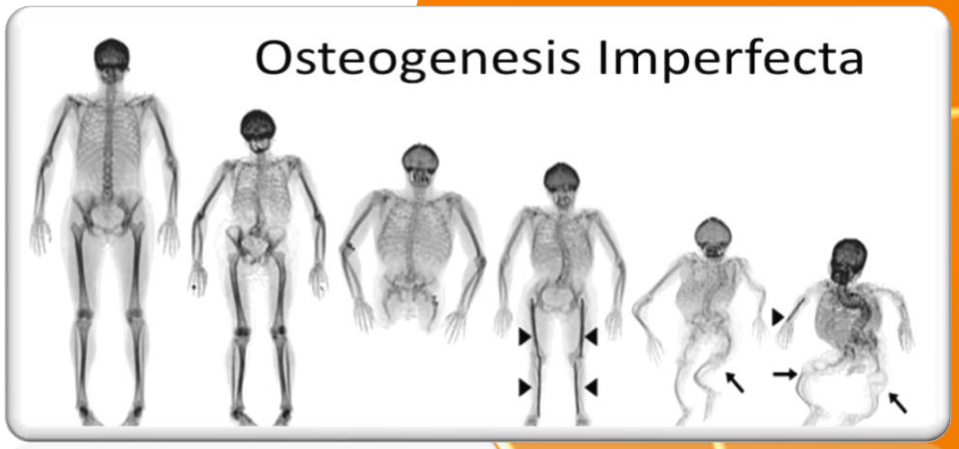

Identifying risk
Monitoring treatment
Diagnosing conditions
Predicting fractures

Consider in all children and adolescents with **primary bone disease** or at risk of **secondary bone** disease if the DXA result (BMD) is likely to influence/change management


Primary bone disorders
secondary bone diseases

Congenital and genetic conditions



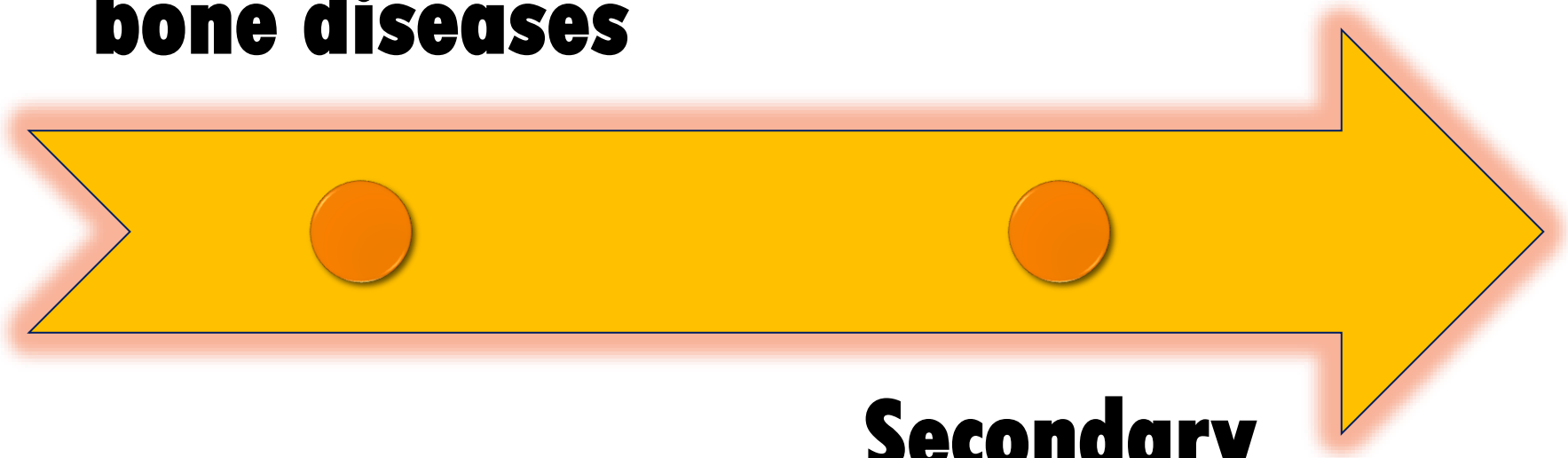


Structural collagen or connective tissue defects

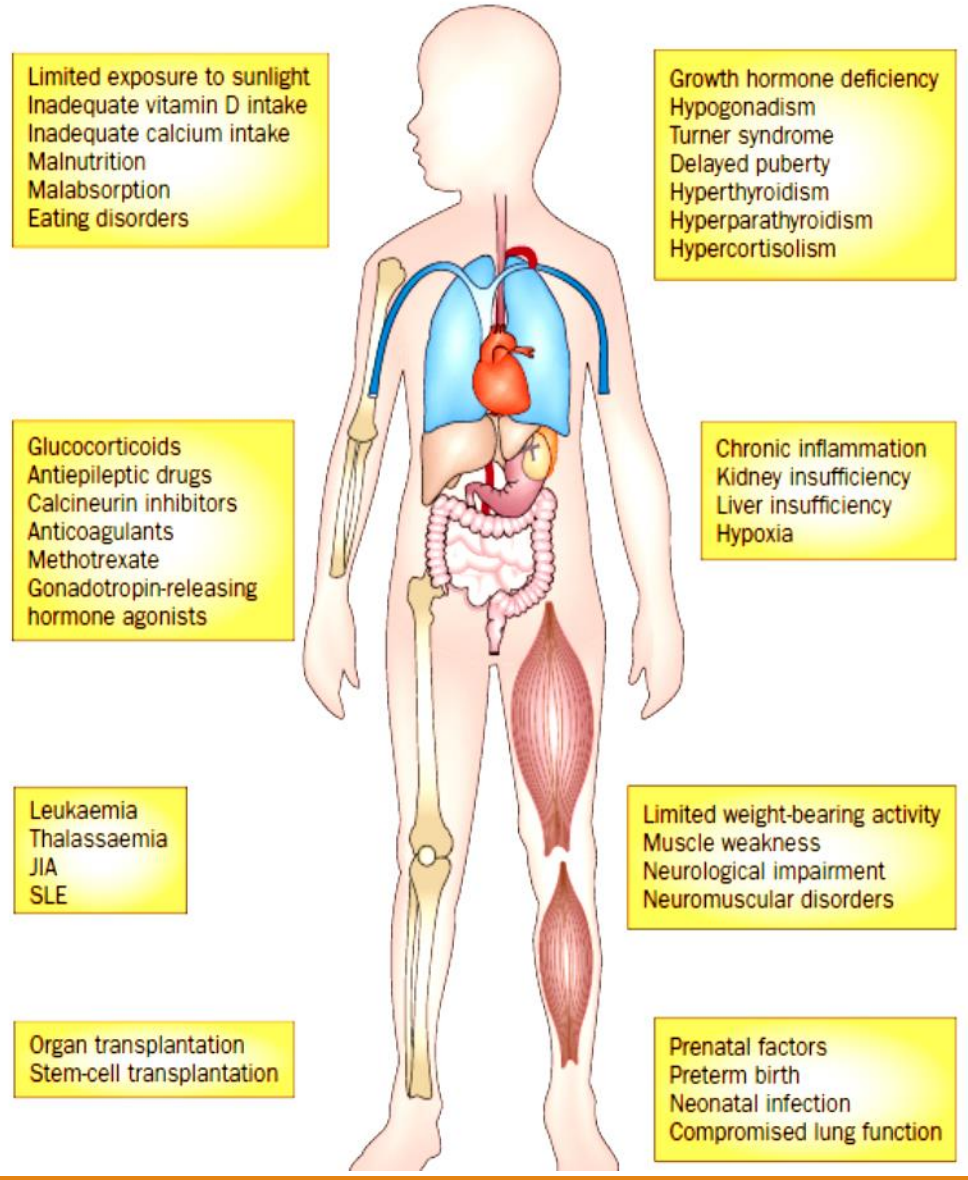
- **Osteogenesis imperfecta**
- **Ehlers–Danlos syndrome**
  Marfan syndrome
  Pseudoxanthoma elasticum

Idiopathic Juvenile Osteoporosis

Secondary bone diseases

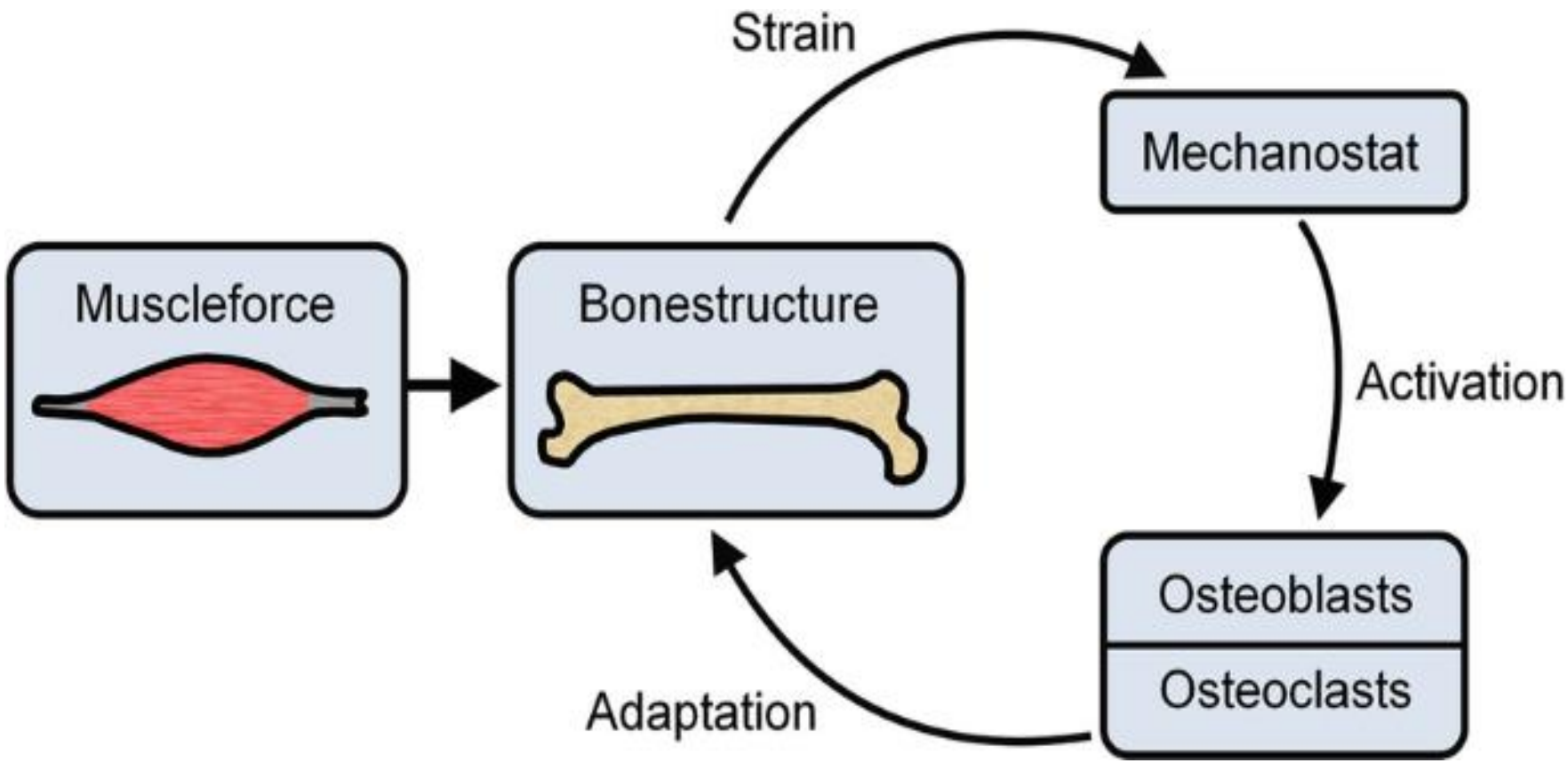


Secondary Osteoporosis

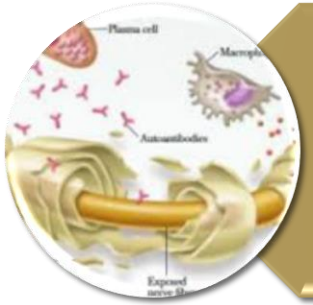

Limited exposure to sunlight
Inadequate vitamin D intake
Inadequate calcium intake
Malnutrition
Malabsorption
Eating disorders
Growth hormone deficiency
Hypogonadism
Turner syndrome
Delayed puberty
Hyperthyroidism
Hyperparathyroidism
Hypercortisolism
Glucocorticoids
Antiepileptic drugs
Calcineurin inhibitors
Anticoagulants
Methotrexate
Gonadotropin-releasing hormone agonists
Chronic inflammation
Kidney insufficiency
Liver insufficiency
Hypoxia
Leukaemia
Thalassaemia
JIA
SLE
Limited weight-bearing activity
Muscle weakness
Neurological impairment
Neuromuscular disorders
Organ transplantation
Stem-cell transplantation
Prenatal factors
Preterm birth
Neonatal infection
Compromised lung function

Neurological Disorders and Osteoporosis

Mechanostat model of bone Strength



Bone Loss and Inactivity



Chronic Inflammatory Neuropathy

Increased Fall Risk

Medication-Induced Bone Loss

Medication-Induced Bone Loss

Antiepileptic Drugs

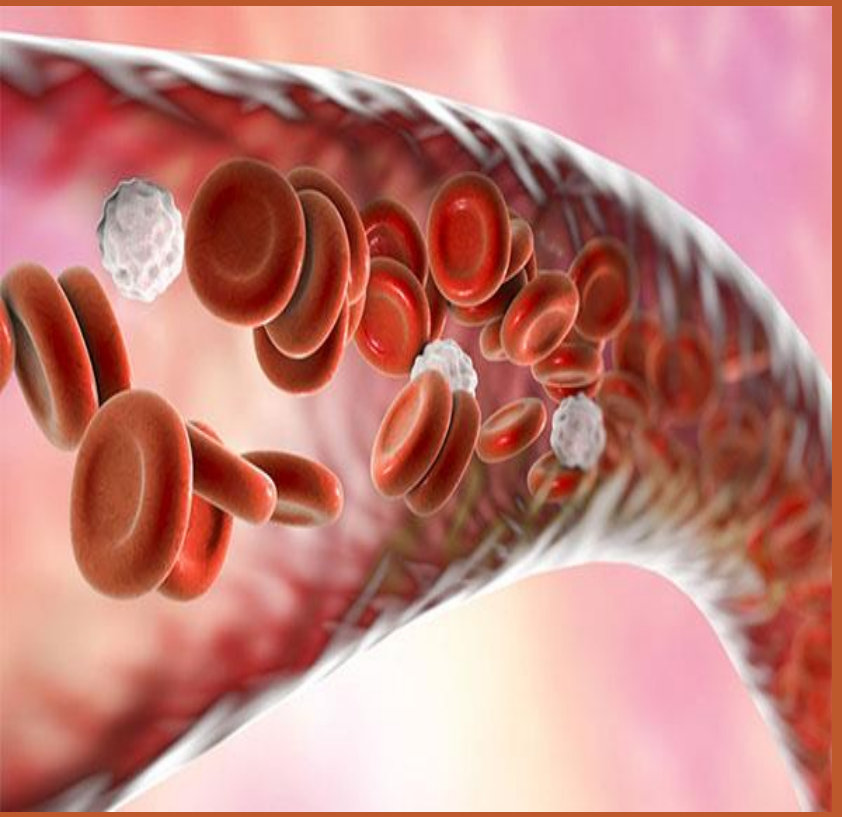
Some seizure medications can interfere with vitamin D metabolism, affecting bone health.

Glucocorticoids

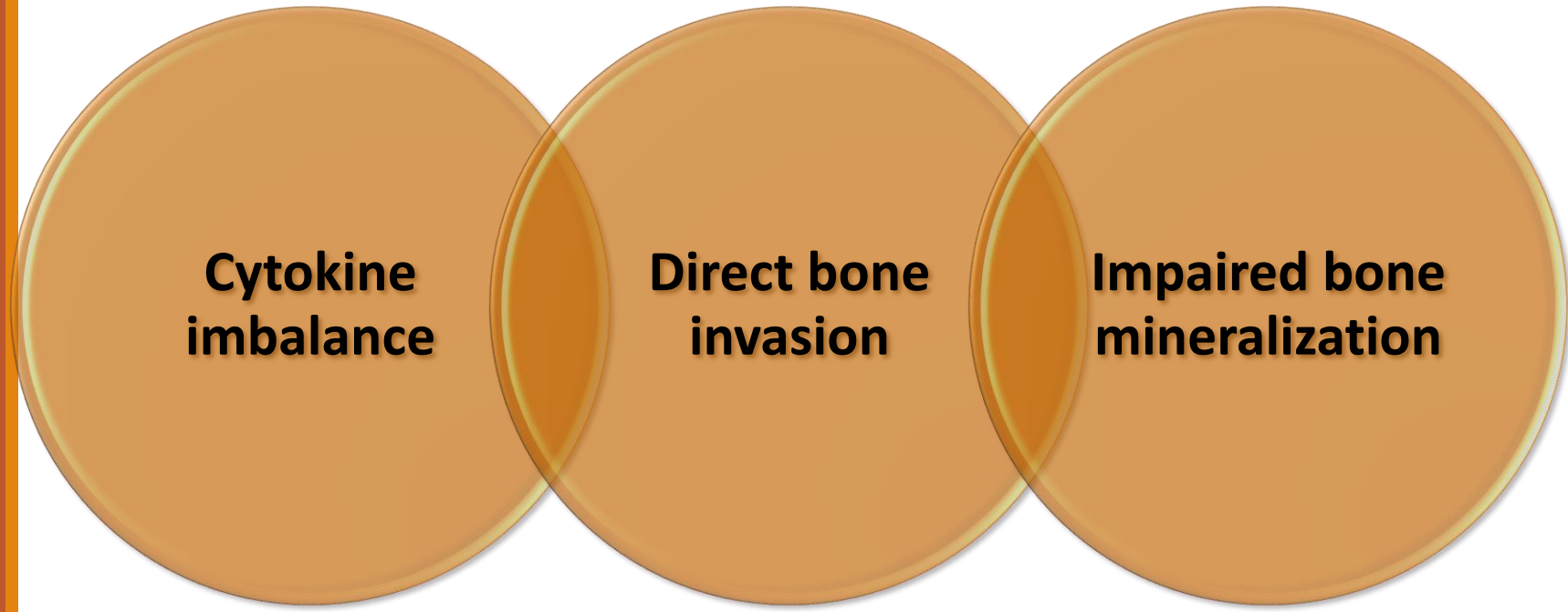
These steroids, often used in neurological treatments, can rapidly decrease bone density.

Ketogenic Diet

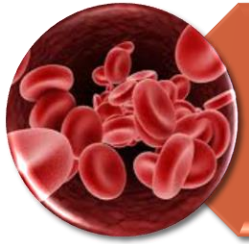
This high-fat, low-carb diet used for epilepsy may impact bone metabolism.



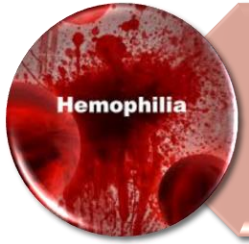
Hemato-Oncological Disorders and Osteoporosis



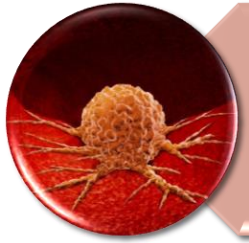
Sickle cell anemia



Thalassemia

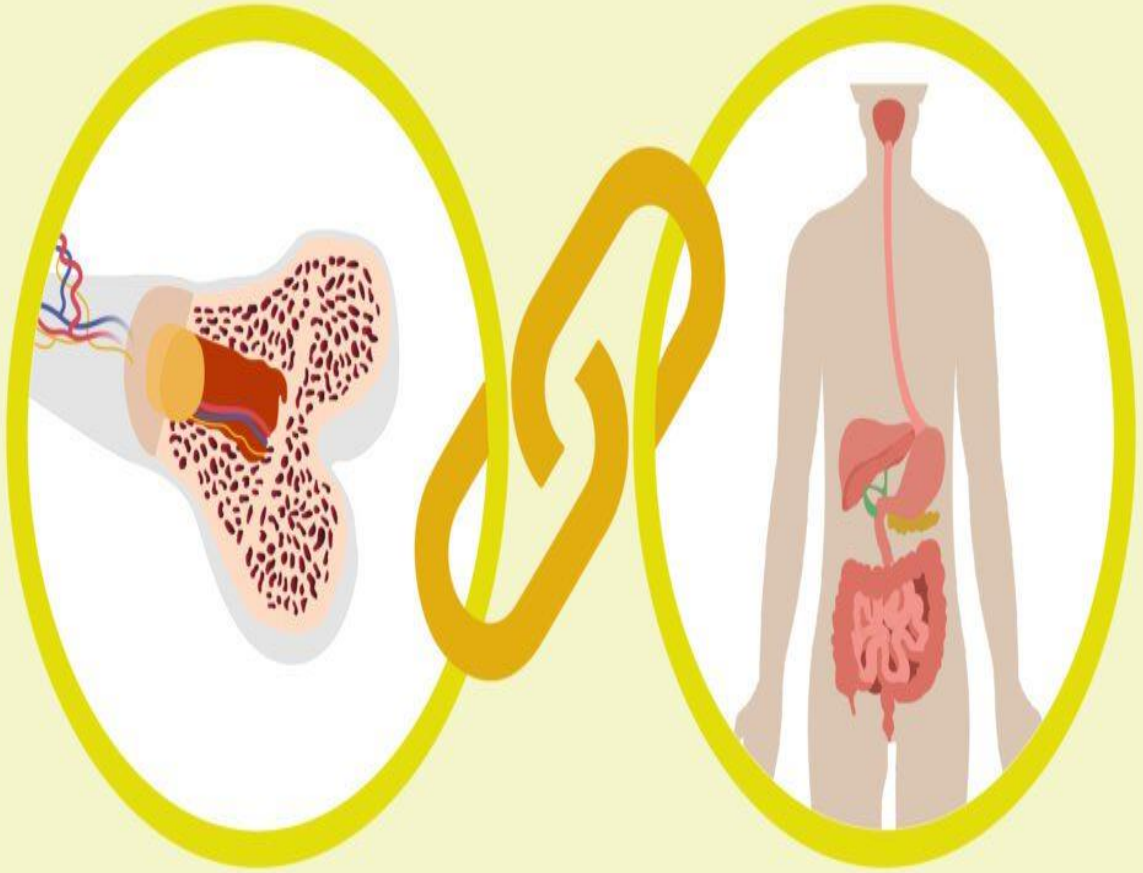


Hemophilia

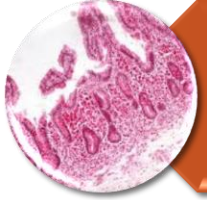


Neoplasms

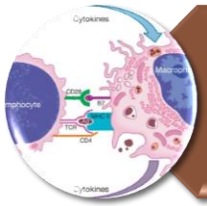
Chemotherapy, Radiation therapy
Transplantation



Gastroenterological Disorders and Osteoporosis

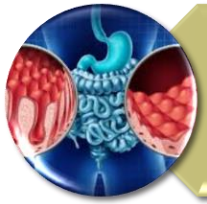


Malabsorption of nutrients

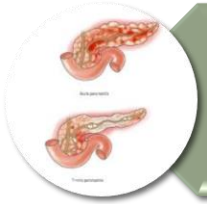


Chronic inflammation

Nutritional deficiencies

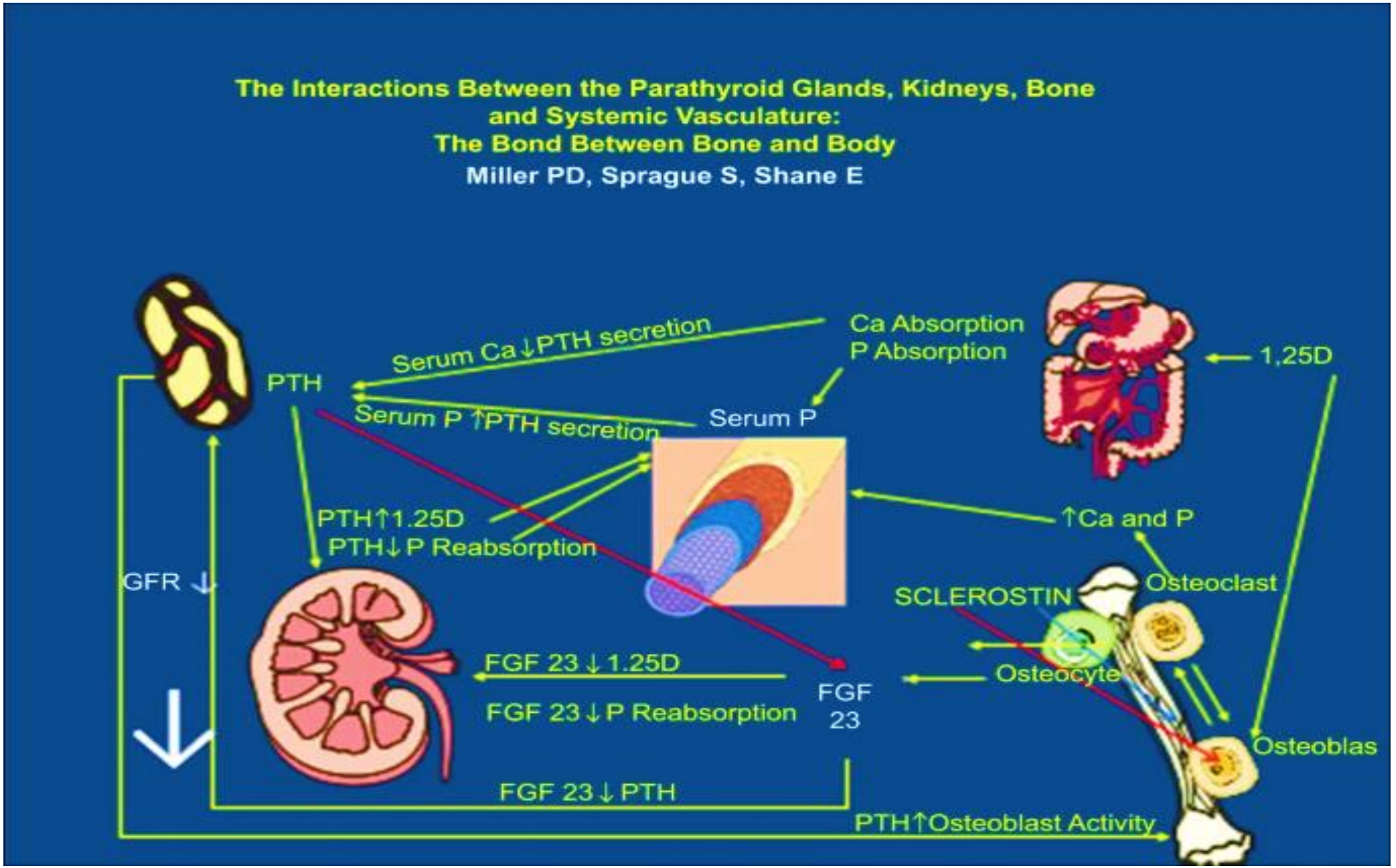


Celiac disease



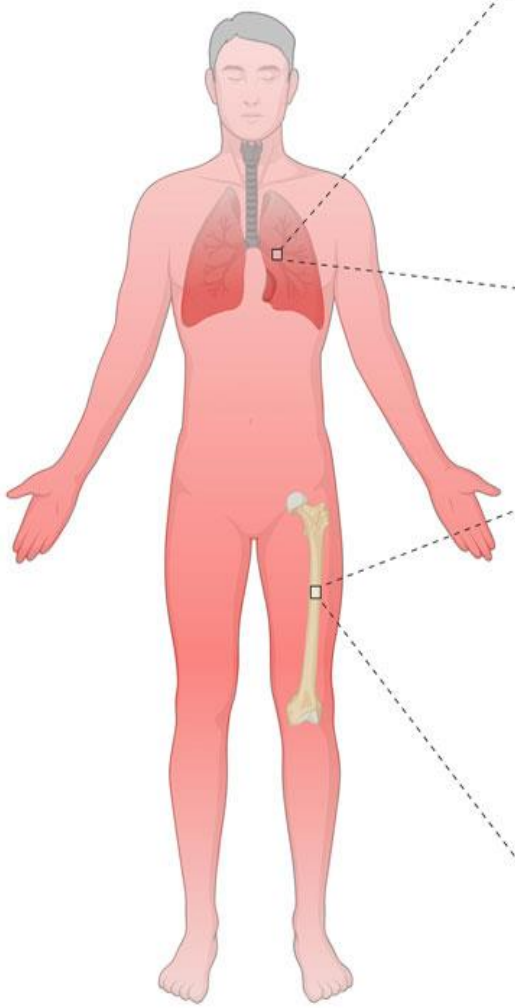
Chronic pancreatitis,
Liver Insufficiency

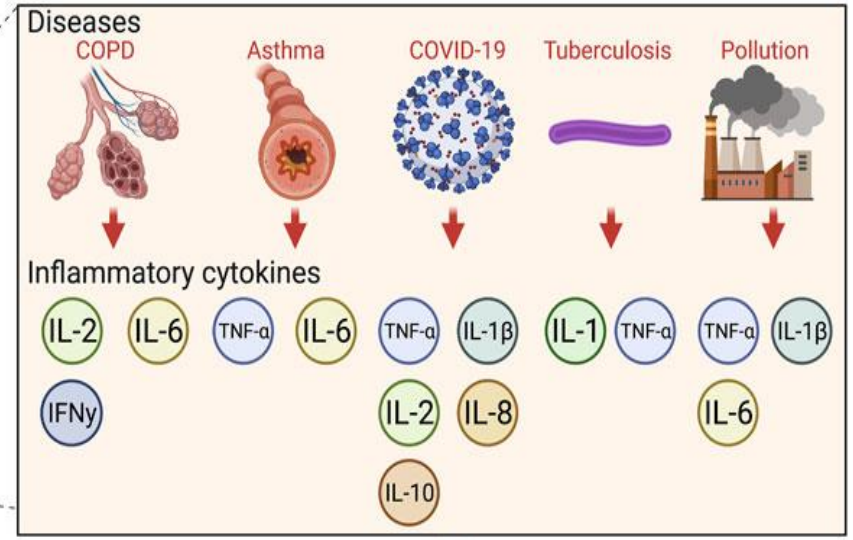
Inflammatory bowel disease (IBD)

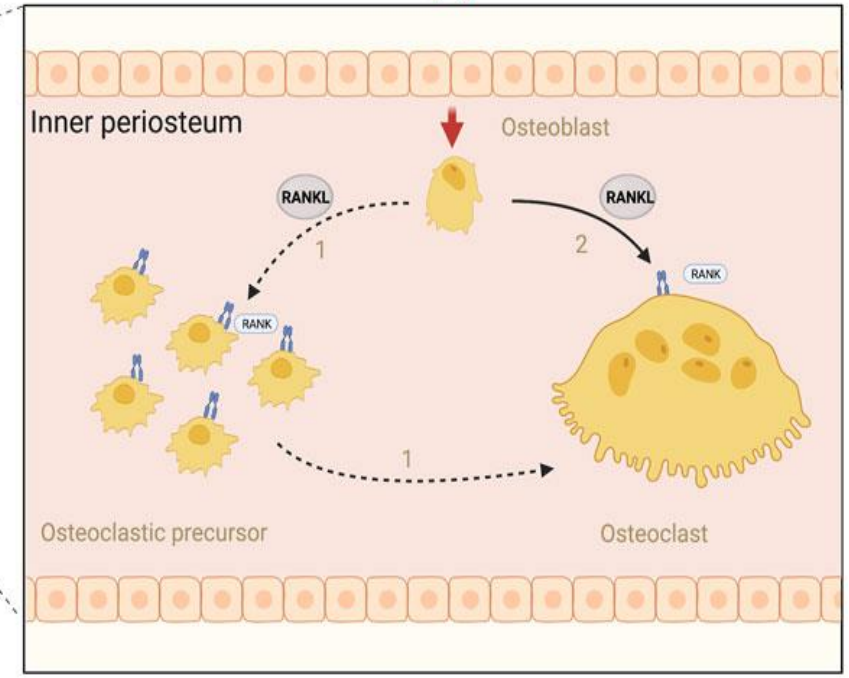

The Interactions Between the Parathyroid Glands, Kidneys, Bone and Systemic Vasculature:
The Bond Between Bone and Body
Miller PD, Sprague S, Shane E
PTH
Serum Ca↓PTH secretion
Ca Absorption
P Absorption
1,25D
Serum P ↑PTH secretion
Serum P
PTH↑1.25D
PTH↓P Reabsorption
↑Ca and P
GFR ↓
SCLEROSTIN
Osteoclast
FGF 23 ↓ 1.25D
Osteocyte
FGF 23 ↓ P Reabsorption
FGF 23
Osteoblas
FGF 23 ↓ PTH
PTH↑Osteoblast Activity

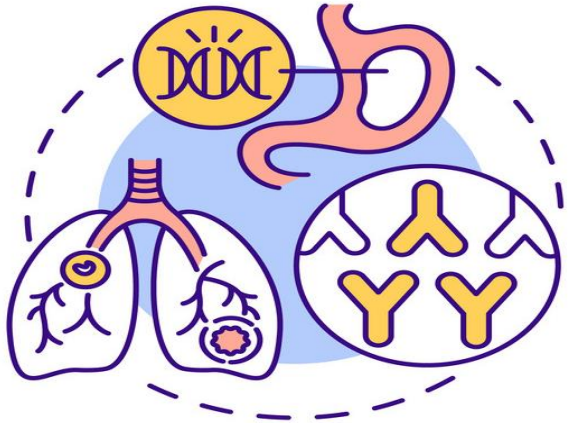
Respiratory diseases

Osteoclast differentiation and maturation

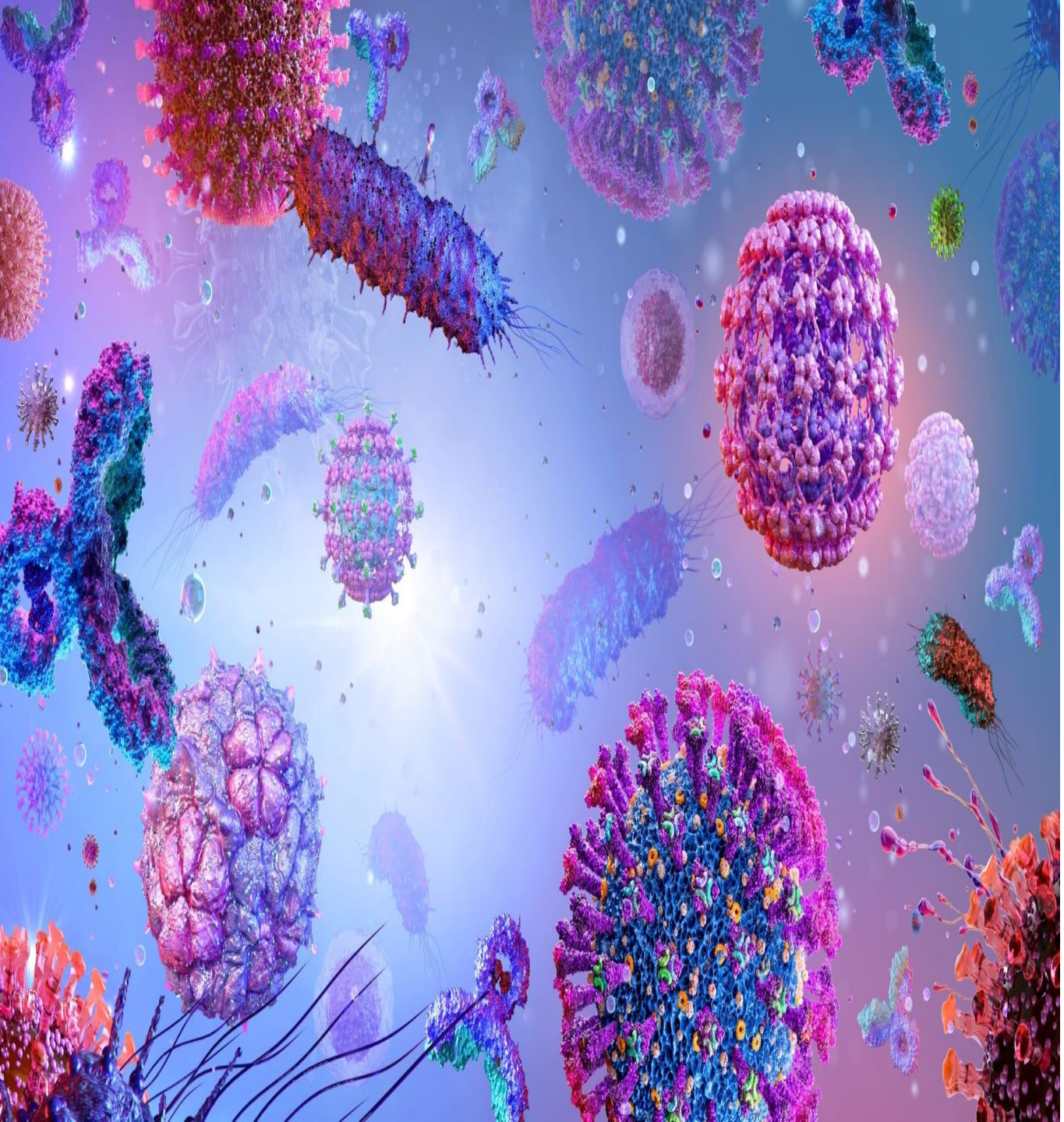








Cystic Fibrosis



Infectious causes of osteoporosis

B and C viruses
Human immunodeficiency virus
Borrelia burgdorferi
Mycobacterium tuberculosis
Staphylococcus aureus
Toxoplasma gondii

Endocrine conditions

Primary hypogonadal states

- Turner syndrome
- Klinefelter syndrome

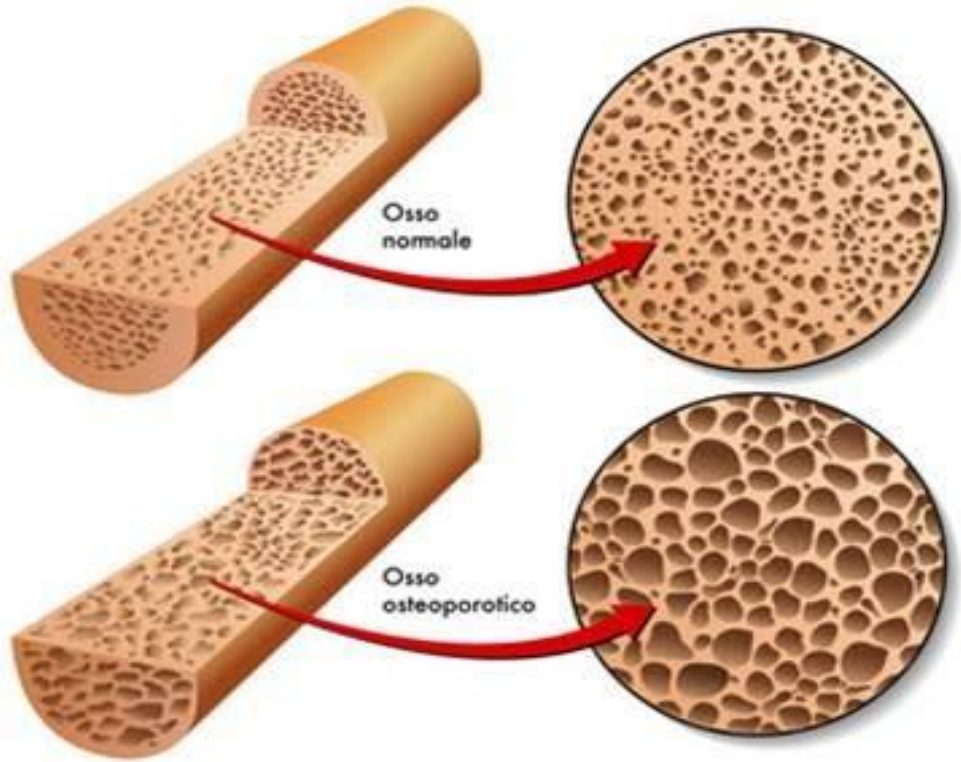
Secondary hypogonadal states

- Anorexia nervosa
- Bulimia nervosa

Other

- Acromegaly, adrenal insufficiency; Cushing syndrome
- Diabetes mellitus (types I and II)
- Growth hormone deficiency
- Hyperparathyroidism and hyperthyroidism

Osteoporosis



Chronic inflammation is also associated with osteoporosis.

Glucocorticoid-induced osteoporosis (GIOP) for patients with rheumatic or nonrheumatic conditions receiving >3 months treatment with glucocorticoids (GCs) ≥2.5 mg daily.

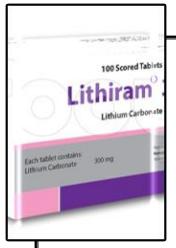
Acid suppression therapies: proton pump inhibitors

Anticoagulants: warfarin, heparin

Anticonvulsants: sodium valproate; phenytoin; carbamazepine

Antidepressants: selective serotonin reuptake inhibitors

Anti-hormonal therapies: aromatase inhibitors

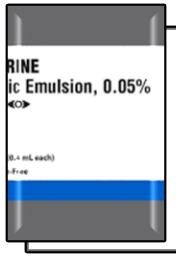


Anti-manic therapies: lithium

Anti-psychotic therapies

Anti-retroviral drugs: tenofovir

Contraceptives: progesterone



Cytotoxic drugs (chemotherapy): ciclosporins and tacrolimus

Diuretics: furosemide

Glucocorticoids and corticotrophins: prednisolone; dexamethasone,Neoticasone

Gonadotrophin-releasing hormone analogues: buserelin; goserelin; cyproterone acetate

Lipase inhibitors: orlistat

Therapeutic agents associated with childhood osteoporosis. Modified from Munns and Cowell[3].

Therapeutic agent	Proposed mechanism for osteoporosis
Methotrexate	Uncertain. Impaired osteoblastic protein synthesis, abnormal vitamin C metabolism.
Cyclosporine	Uncertain. Possible dysregulation of the osteoprotegerin (OPG)-OPG ligand system with a resultant high turnover state[36].
Heparin	Uncertain. a) Decreased 1-α-hydroxylase activity with reduced vitamin D and elevated PTH. b) direct effect on cancellous bone with an increase in bone resorption and decrease in bone formation.
Radiotherapy	Growth hormone deficiency, hypogonadism, AVN, muscle atrophy.
Depot medroxyprogesterone acetate	Central hypogonadism.
Gonadotropin releasing hormone (GnRH) analogues	Central hypogonadism.
L-thyroxine suppressive therapy	Increased bone resorption secondary to osteoblast mediated T3 osteoclast activation.
Anti-convulsants	Altered liver metabolism of 25-OH vitamin D[25]. Low BMD is also induced by the direct effects of anti-convulsant drugs on bone cells, resistance to PTH, inhibition of calcitonin secretion, and impaired calcium absorption[37].

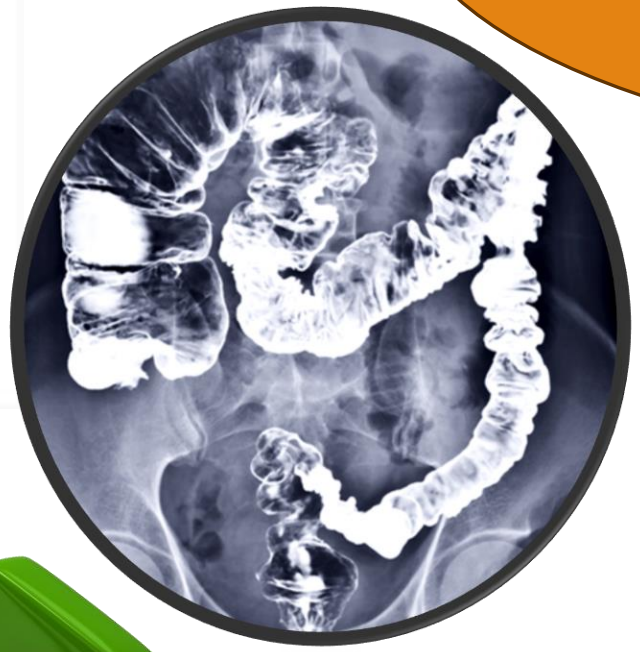
Table 3 Assessment of BMD for certain diseases or chronic treatments involved in childhood secondary osteoporosis

Disease / Treatment	BMD assessment
Celiac disease	DXA if: -no adequate dietary adherence -irregular menstruation -anemia -other risk factors for fractures [74]
Cerebral palsy	Difficult lumbar spine X-ray interpretation in cases of severe scoliosis. Total-body or distal femur DXA (area with higher fracture risk), only if there are fragility fractures [8].
Duchenne muscular dystrophy	Baseline DXA and annual monitoring. Lateral spine x-ray: Baseline - On GCs treatment: Repeat every 1–2 years. - Not on GCs treatment: Repeat every 2–3 years. - If back pain or ≥ 0, 5 SD decline in spine BMD Z score on serial measurements over 12-month period: Repeat. Refer to osteoporosis specialist following the first fracture [11].
Rett syndrome	Baseline DXA, and serial controls according to individual risk [15].
Epilepsy	Consider DXA for epileptic patients receiving anti-epileptic drugs for a prolonged period [13]
Thalassemia	DXA every 2 years from adolescence [12]
Inflammatory/ systemic disease	Consider DXA for patients receiving high doses of GCs [74].
Juvenile idiopathic arthritis (JIA)	< 6 years: DXA in the presence of fragility fractures. > 6 years: DXA if not presenting rapid remission of JIA or in need of high doses of GCs [18].
Neoplasms	Baseline DXA two years after completing chemotherapy with osteotoxic drugs; e.g., MTX, GCs or hematopoietic cells transplantation; or secondary effects that favor osteoporosis development (growth hormone deficiency, hypogonadism, etc.) DXA follow-up based on the results of baseline DXA and persistent risk factors [17]

Cystic fibrosis	DXA in children ≥ age 8 if: - weight < 90% ideal weight - FEV_1 < 50% - Delayed puberty - High dosis of GCs > 90 days per year At 18, all of them [101].
Diabetes mellitus	DXA if: - low BMD specific risk factors - increased daily insulin dosis - impaired renal function - fracture history [74]
Anorexia nervosa	DXA in patients with amenorrhea for more than 6 months [13].
Systemic lupus erythematosus	DXA evaluation in patients with prolonged systemic GCs exposure exceeding ≥0.15 mg/kg daily for ≥ 3 months. Repeat on an annual basis if Z-score ≤ − 2 [102].

DXA dual-energy x-ray absorptiometry, *BMD* bone mineral density, *GCs* glucocorticoids, *MTX* methotrexate, *FR* risk factors

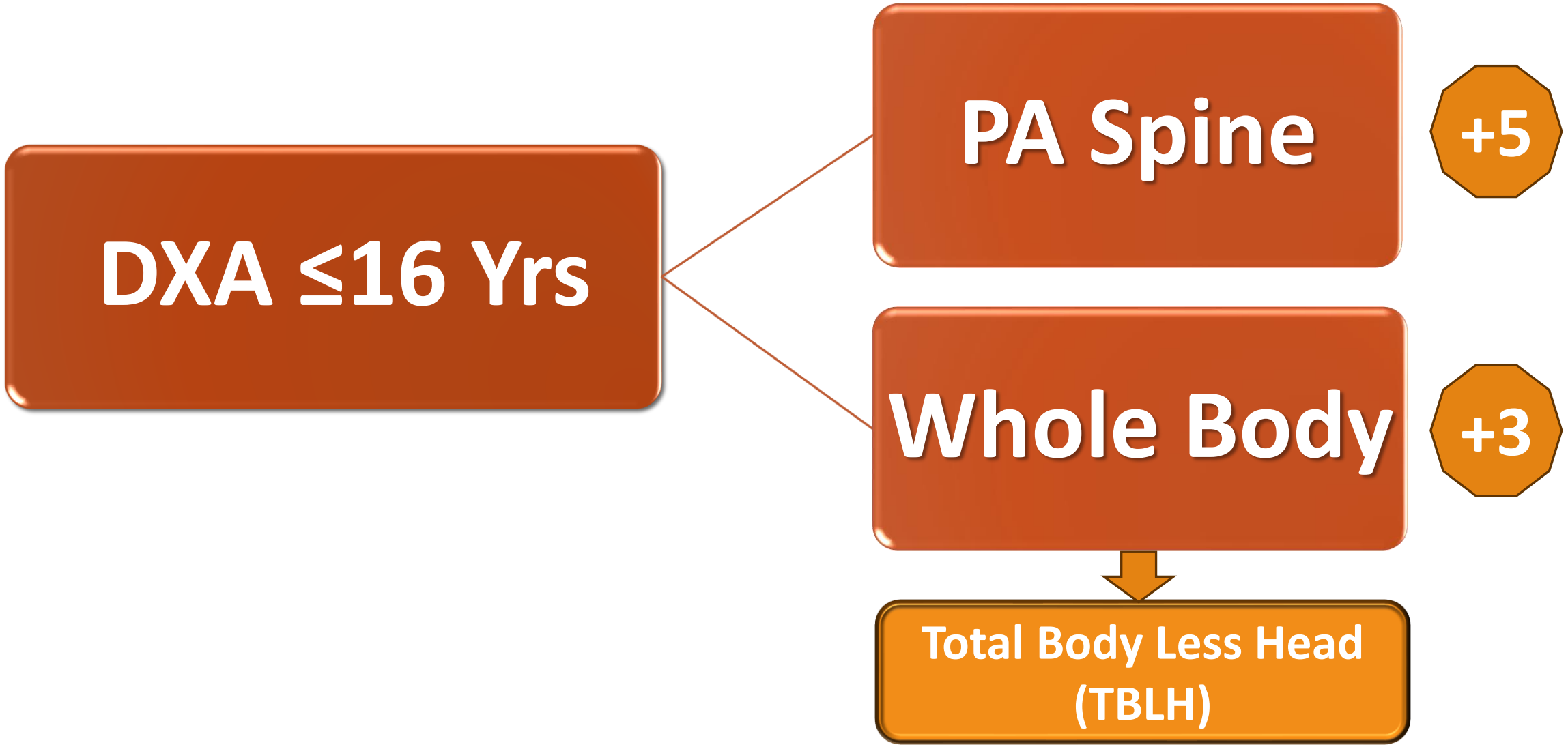
Contraindication



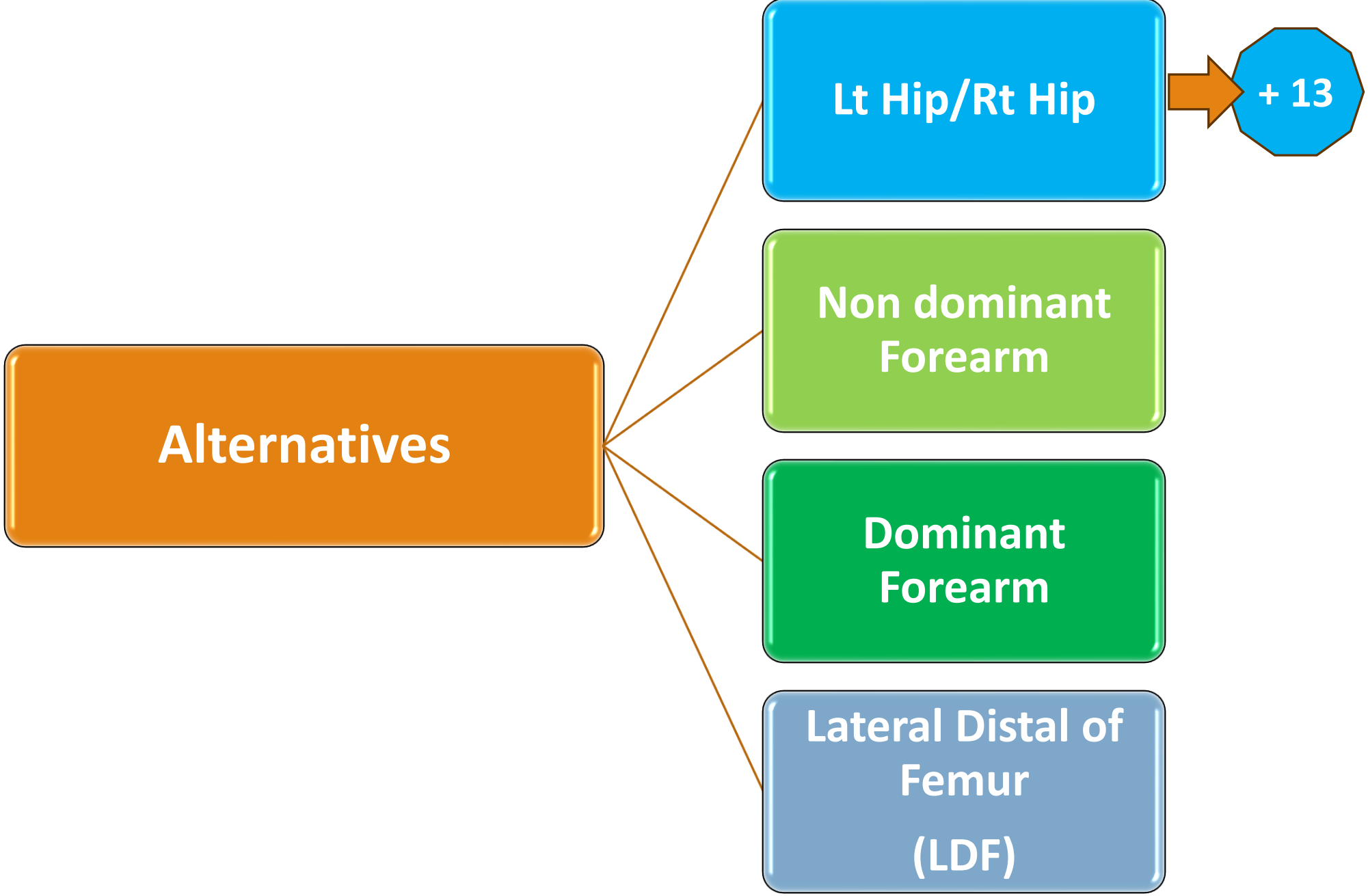
No absolute contraindication

Body weight exceeding limit for DEXA scanners(>120-130kgs)

Which Sites Should be Scanned?


DXA ≤16 Yrs
PA Spine
+5
Whole Body
+3
Total Body Less Head (TBLH)

- **Total body and spine** for children ages **4–15**
- **Hip and spine** for children ages **16** and older


Alternatives
Lt Hip/Rt Hip
+ 13
Non dominant Forearm
Dominant Forearm
Lateral Distal of Femur
(LDF)

تصویربرداری

فیزیوتراپی

خدمات پزشکی

سایر خدمات پاراکلینیکی

خدمات ارجاعی


اطلاعات نسخه پاراکلینیک
نوع خدمت *
نام خدمت *
حداقل یک حرف از عبارت مورد نظر را وارد کنید...
تاریخ موثر انجام
___/__/__
گفتار درمانی
پزشکی هسته ای
رادیوتراپی
ادیومتری
آنژیوگرافی
سنجش تراکم استخوان
دیالیز
ویرایش
حذف
ثبت قلم پراستفاده
حذف تمام اقلام نسخه

اطلاعات نسخه پاراکلینیک

نوع خدمت *

سنجش تراکم استخوان

نام خدمت *

مقدار فیلد الزامی می باشد

ت

نام خدمت

۶-۴۶۳۸۳-سنجش تراکم استخوان

۹-۳۸۲۶۸-سنجش تراکم استخوان تمام سیستم اسکلتی

سنجش تراکم اااستخوان(SNGLE PHOTON)

BONE SURVEY-۴۳۵۱۸-۰ تا سن (۱۰) سالگی

سنجش تراکم اااستخوان(DUAL PHOTON)

صفحه ۱ از ۱

تعداد *

۱

+ افزودن به لیست

ردیف	نام خدمت	تعداد	تاریخ موثر

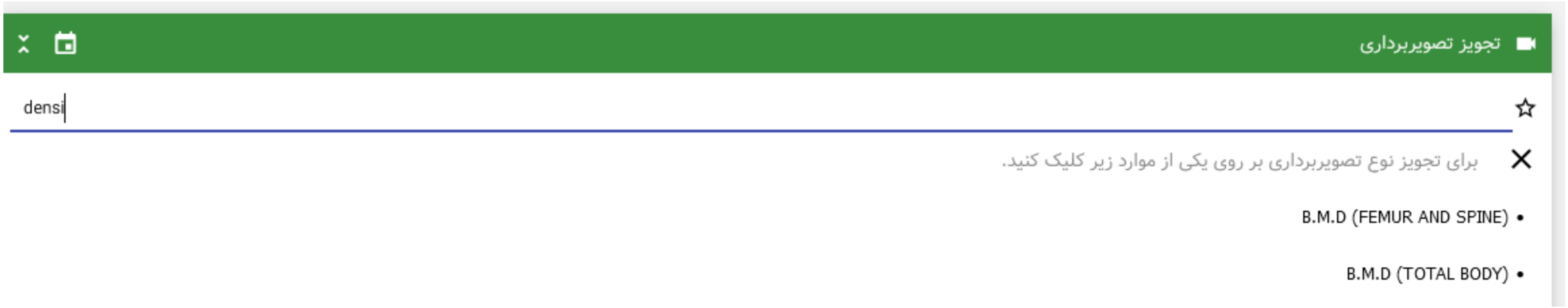
+ اطلاعات تکمیلی نسخه

ثبت نسخه پاراکلینیک

پاک کردن فرم

ذخیره نسخه پراستفاده

چاپ

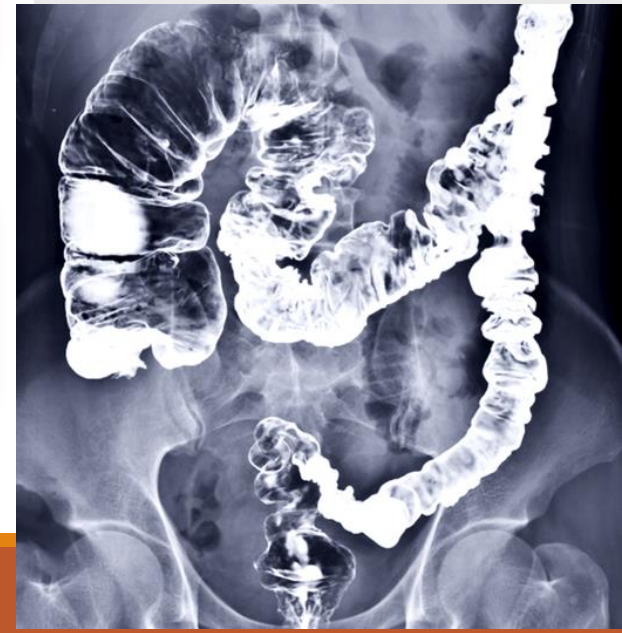

تجویز تصویربرداری
densi
برای تجویز نوع تصویربرداری بر روی یکی از موارد زیر کلیک کنید.
B.M.D (FEMUR AND SPINE)
B.M.D (TOTAL BODY)

Preparation

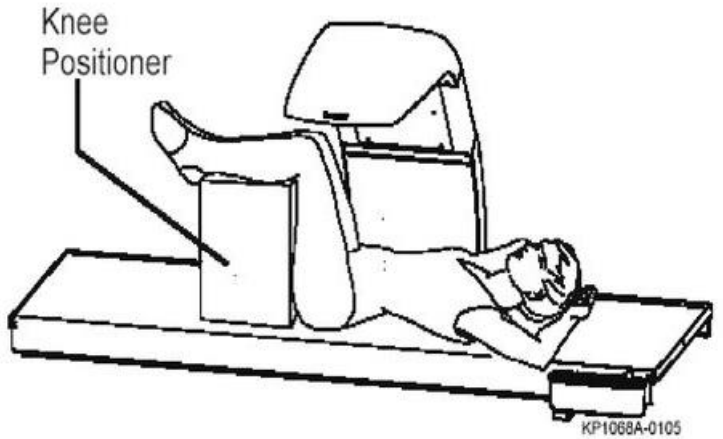
Avoid use of calcium tablet on exam day (better from 24 hrs before Dexa)

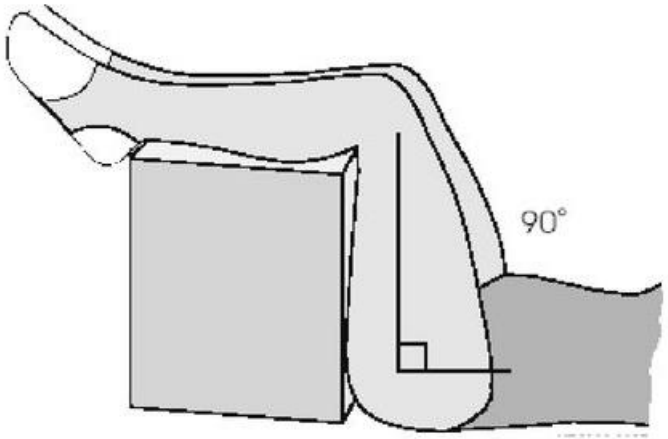
Wear of loose & comfortable clothing without zippers, belt or button made on metals

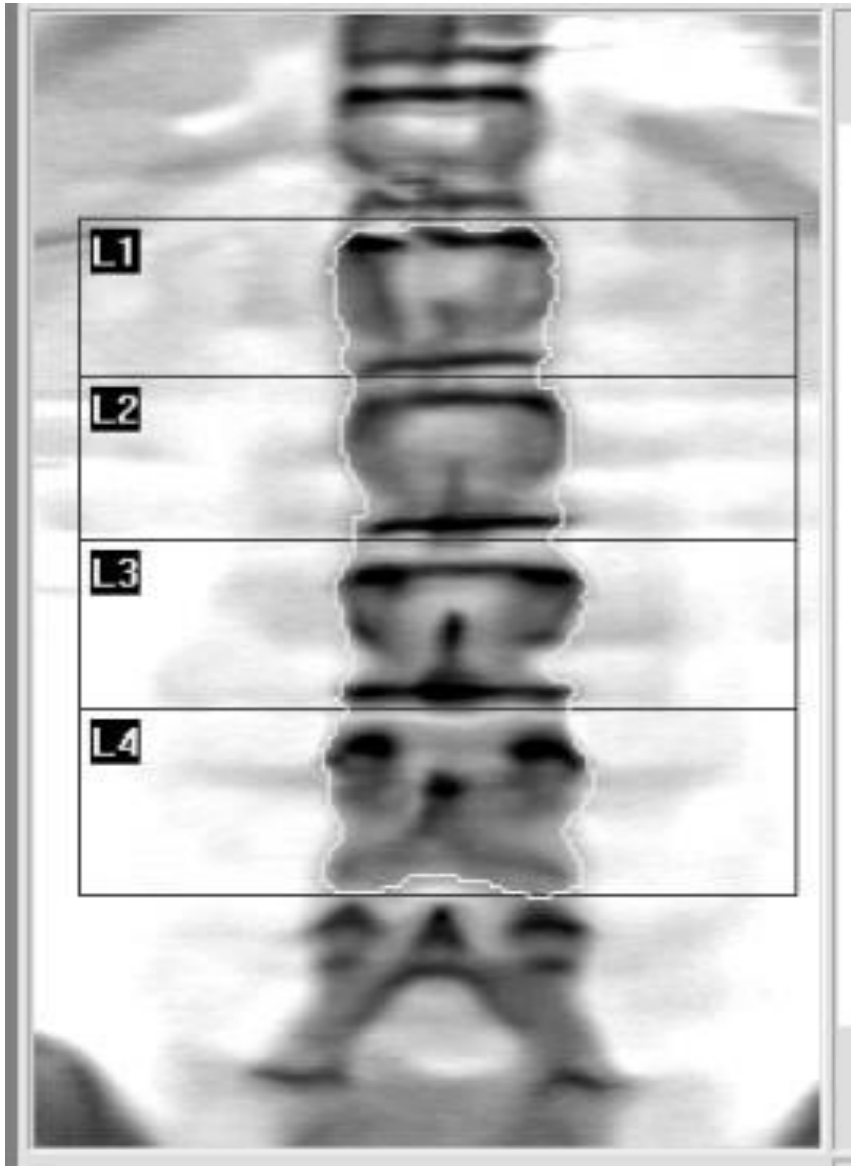
Avoid of performing in patients has had barium enema or radioisotope or CT scan (delay until 14-10days after mentioned Dexa)



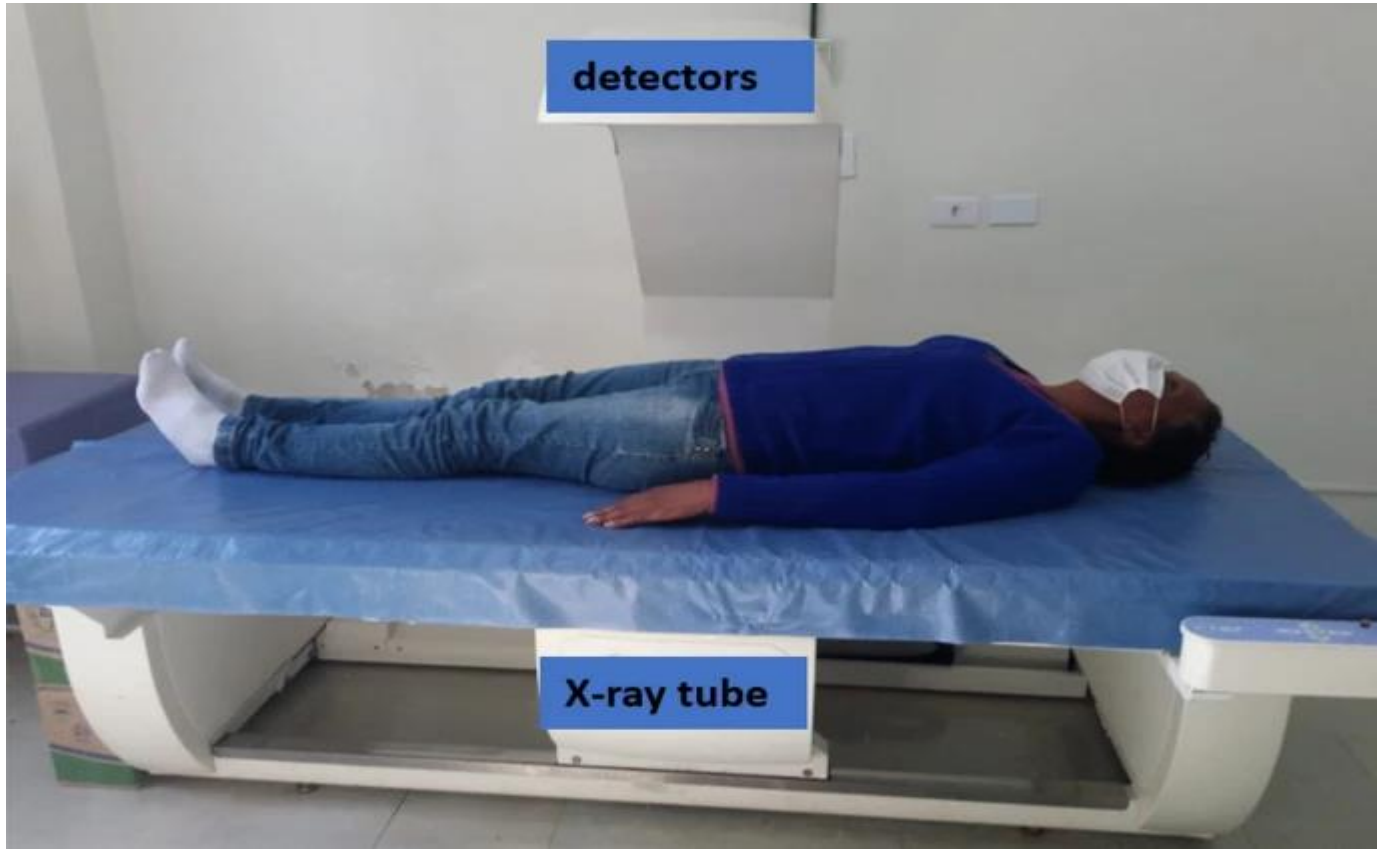
AP Lumbar Spine

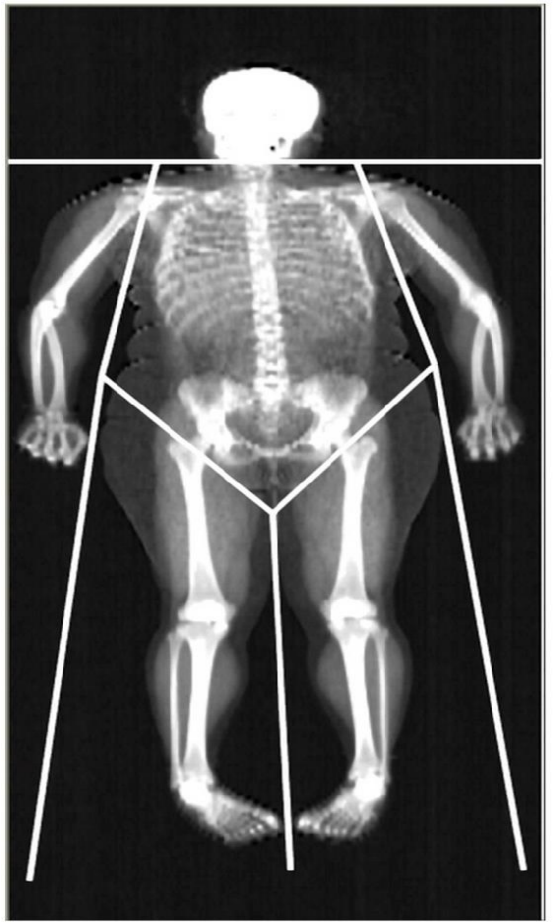




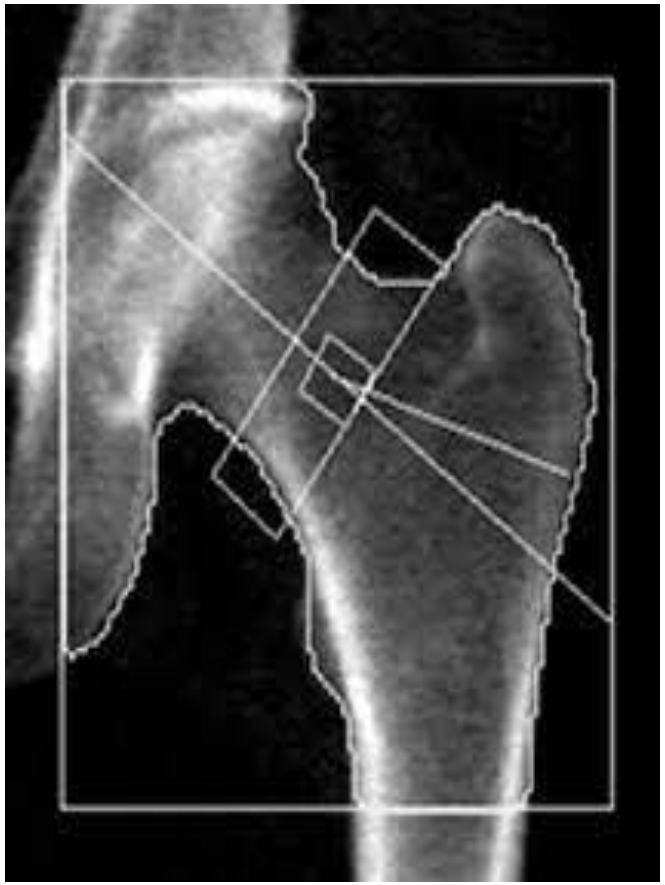

L1
L2
L3
L4

Whole Body Position

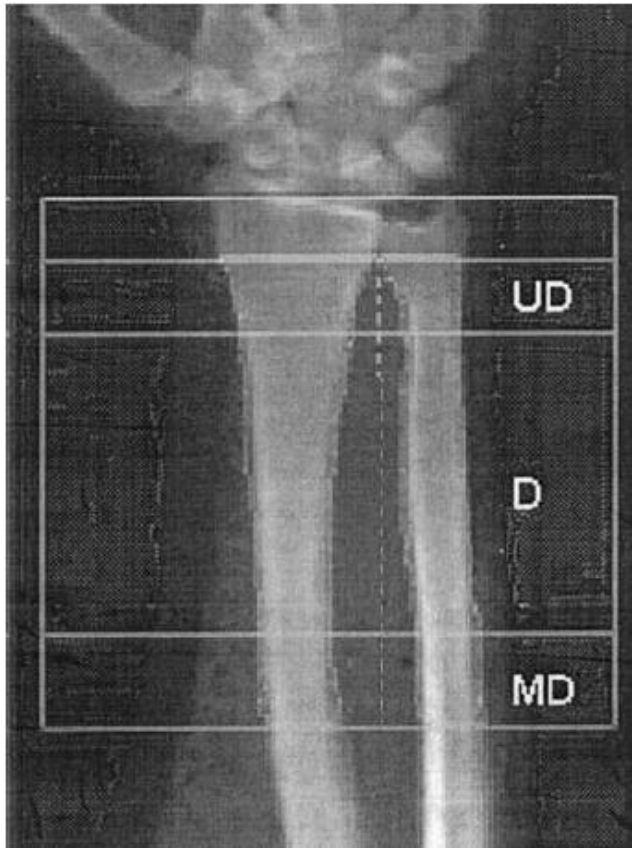




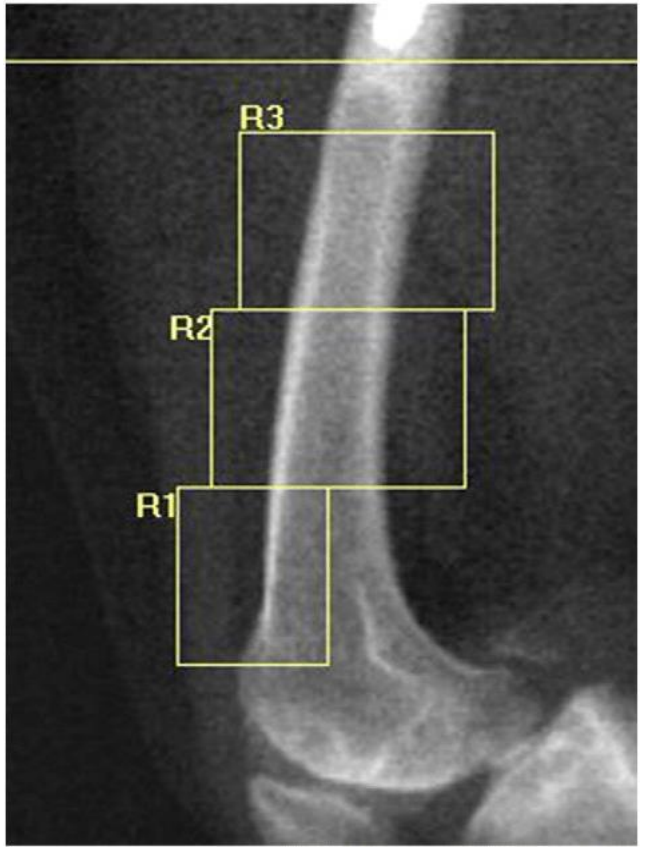
Proximal femur DXA measurements



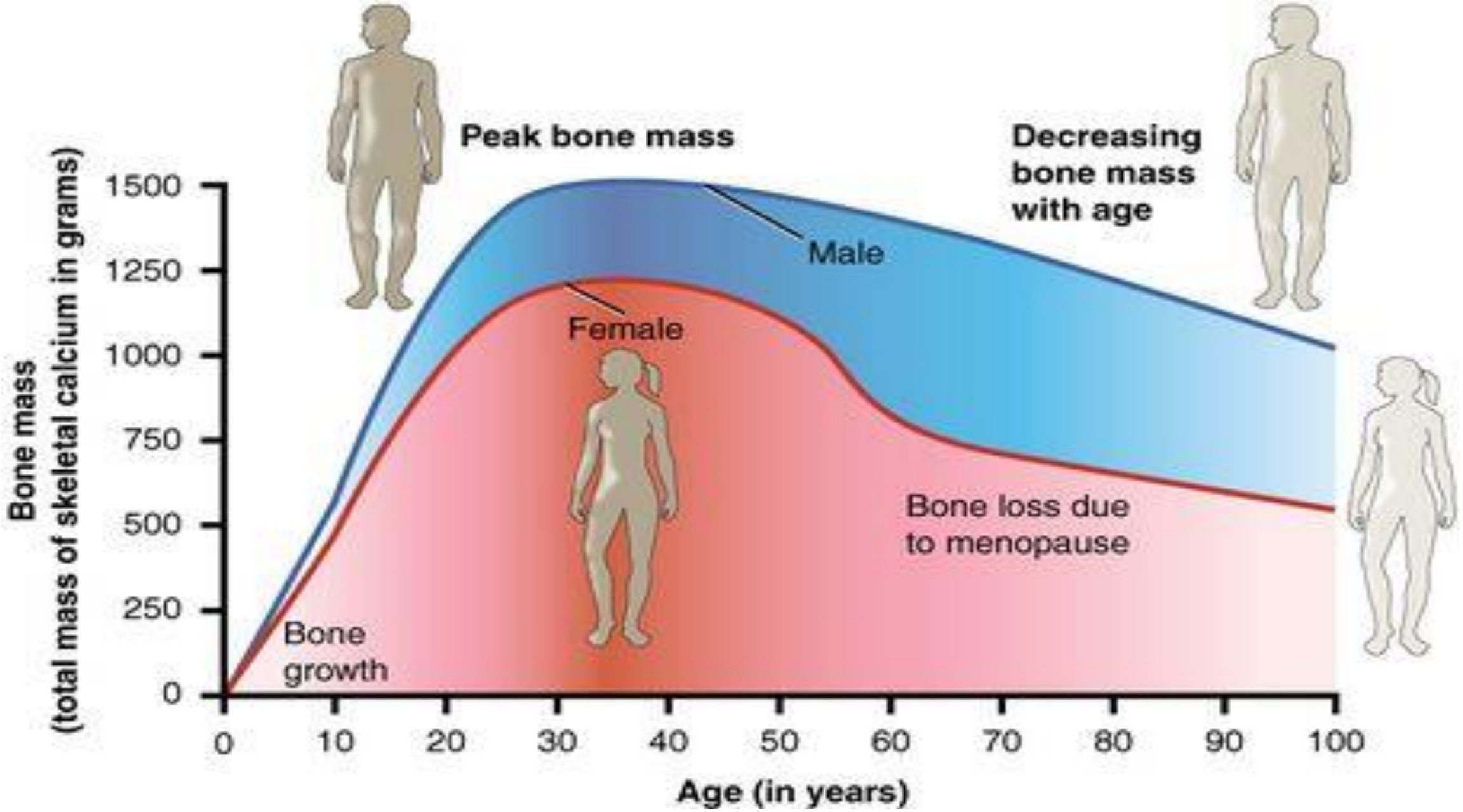
Forearm DXA



Lateral Distal Femur (LDF) DXA



Differences between adult and pediatric densitometry

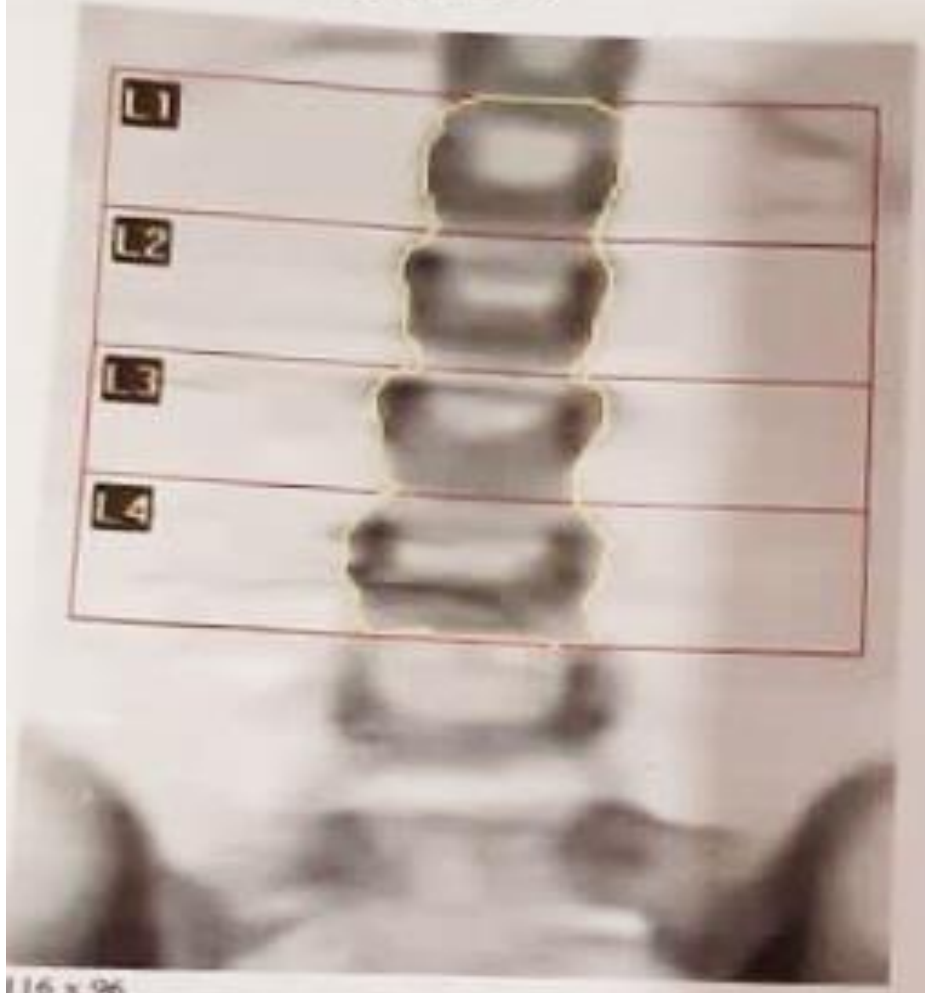

Peak bone mass
Decreasing bone mass with age
Male
Female
Bone loss due to menopause
Bone growth
Bone mass (total mass of skeletal calcium in grams)
1500
1250
1000
750
500
250
0
0
10
20
30
40
50
60
70
80
90
100
Age (in years)

Name: [redacted]
Patient ID:
DOB: 24 April 2016

Sex: Female
Ethnicity: Pediatric

Height: 126.0 cm
Weight: 27.0 kg
Age: 8

Referring Physician: Dr:ASLANI



116 x 96

Scan Information:

Scan Date: 23 September 2024 ID: A09232407
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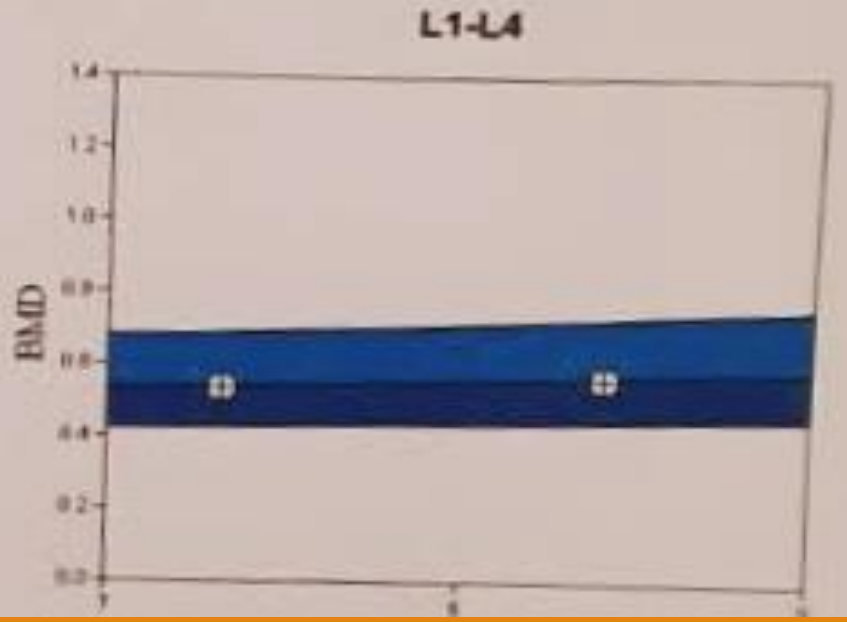
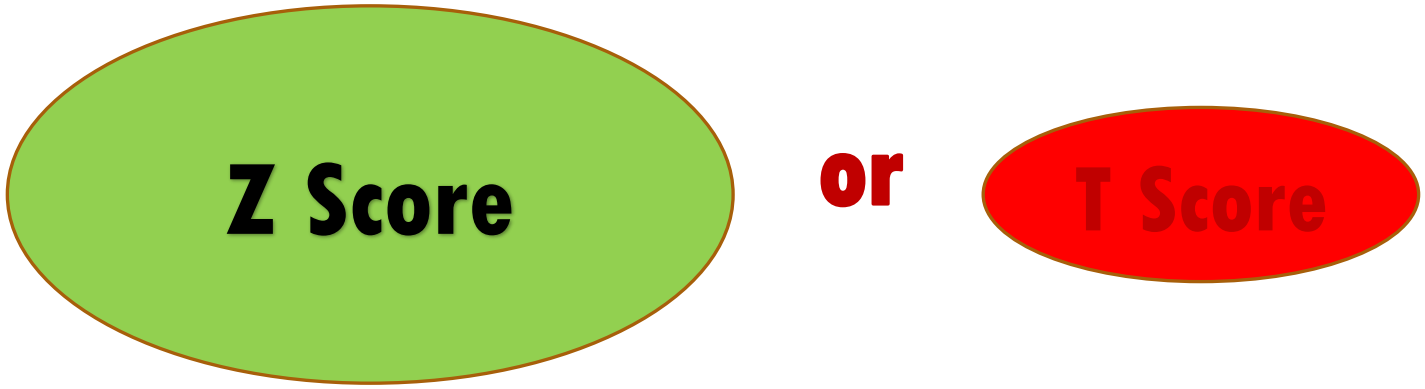
Analysis: 23 September 2024 08:42 Version 13.6.1.3
Lumbar Spine
Operator: Saf
Model: Horizon Wi (S/N 306432M)
Comment:



Interpretation



$$\text{T-score} = \frac{\text{Patient's Measured BMD - Mean BMD of Young Normal Population}}{\text{SD of BMD of Young Normal Population}}$$

$$\text{Z-score} = \frac{\text{Patient's Measured BMD - Mean BMD of Age Matched Group}}{\text{SD of BMD of Age Matched Group}}$$

T-scores should not appear in pediatric DXA reports

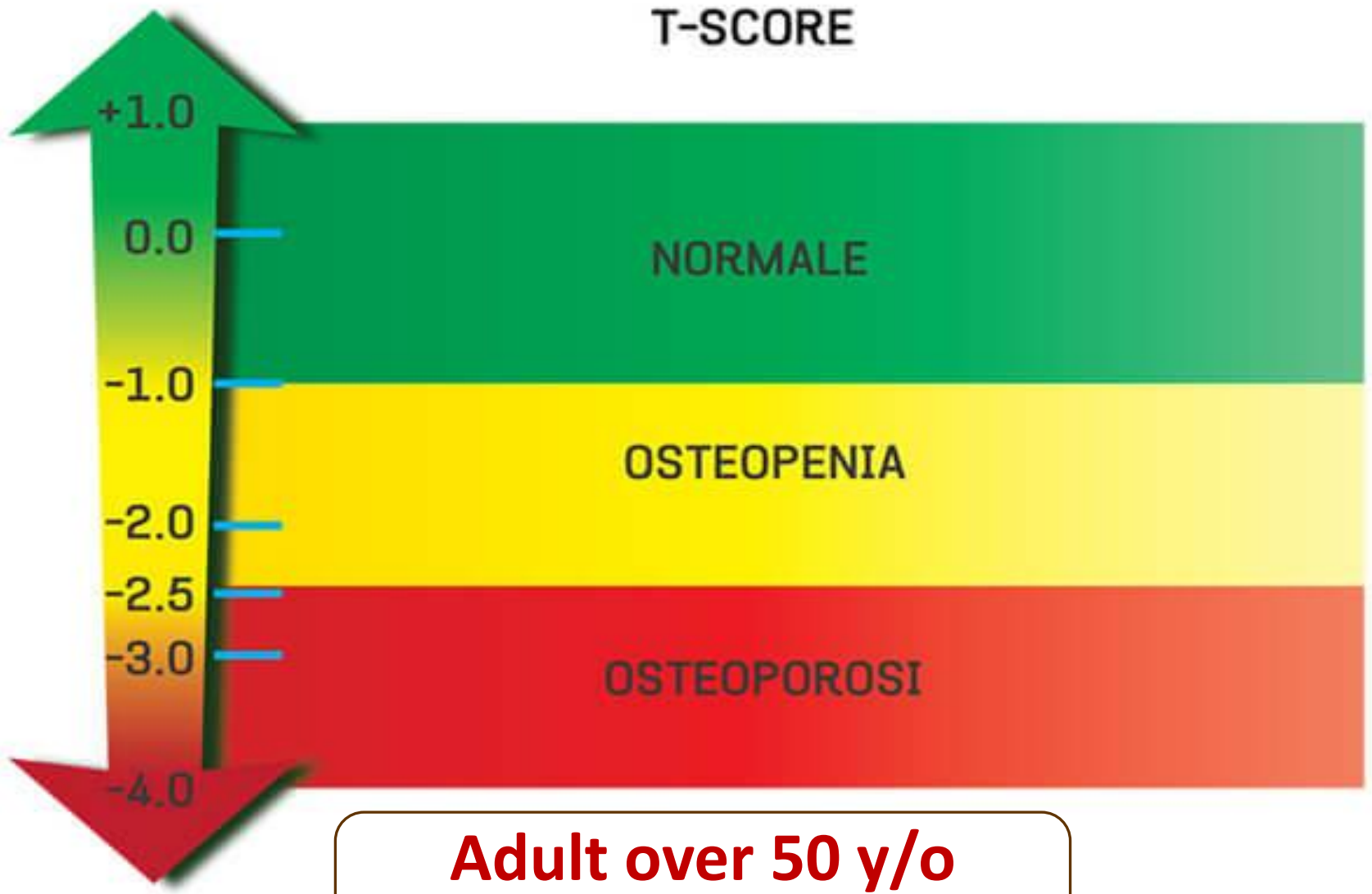
The term “osteopenia” should not appear in pediatric DXA reports.

The term “osteoporosis” should not appear in pediatric DXA reports without a clinically significant fracture history.

“Low bone mineral mass or bone mineral density ” is the preferred term for pediatric DXA reports when BMC or areal BMD Z-scores are less than or equal to -2.0 SD.

Children and adults under 50

Z-score of -2.0 or lower	below the expected range for age
Z-score above -2.0	within the expected range for age



Adult over 50 y/o
Osteoporosis

BMC

- Bone Mineral Content(gr)

BMD

- Bone Mineral Density(g/cm2)

Overdiagnosis of Osteoporosis in Children

- Use of T-score to diagnose osteoporosis (62%)
- Use of a reference database that does not consider gender or ethnic differences (21%)
- Incorrect bone map (21%)
- Inattention to short stature (15%)
- Other measurement or statistical error (12%)

J Pediatr. 2004 Feb;144(2):253-7

Table 6 Basic Diagnostic Studies

Laboratory test	Variables to analyze
Blood count	
Blood chemistry	Calcium, ionized calcium, phosphorus, magnesium, total proteins, creatinine, urea, glucose, 25-hydroxyvitamin D_3, PTH, TSH, free T4
24-hour urine chemistry	Calcium, phosphorus, creatinine, tubular phosphorus reabsorption, sodium
Urine screening	Ca/Creatinine[a]
Bone turnover makers	Total alkaline phosphatase

[a]Sample from a single urination, preferably first one in the morning

Table 5 Daily calcium and vitamin D requirements according to age

Age	Calcium (mg)	Vitamin D (IU)
0–6 months	200	400
6–12 months	260	400
1–3 years	700	600
4–8 years	1000	600
9-18 years	1300	600

Prevention

27	Oral calcium supplementation could improve BMD in healthy children with a low-calcium diet. Nevertheless, increasing calcium intake by means of calcium-rich foods is preferable to supplementation [36–38, 76].	5	D	90%
28	With respect to children with chronic diseases, adequate treatment of the disease is the most important step to be taken regarding osteoporosis prevention and treatment [23, 77–79].	2b	B	

Treatment

29	Vitamin D supplementation must be prescribed for all those patients with chronic pathologies presenting levels lower than 20 ng/mL and for those with levels between 20-30 ng/mL who present Z-score ≤ − 2 or any data showing bone fragility [51, 80, 81].	4	D	90%
30	For children and adolescents with a low BMD or osteoporosis, calcium supplementation is recommended, particularly for those patients with a low-calcium diet, as well as supplementation of the proper amount of vitamin D_3 in order to keep plasmatic levels of 25-hydroxyvitamin D_3 higher than 30 ng/dL [82, 83].	2b	B-C	
31	The required amount of calcium and vitamin D supply needed in children with pathologies that can jeopardize intestinal absorption or modify their body's use of these nutrients is unknown. For this reason, in the event that such patients present osteoporosis or low BMD according to chronological age, it is advisable to initially prescribe the dose required to ensure a recommended daily intake of healthy children. Treatment can be modified according to plasmatic 25-hydroxyvitamin D_3, iPTH and calciuria levels, which must be monitored every six to twelve months [49–51, 82, 83].	5	D	90%
32	Treatment with BP should be administered to those pediatric patients with osteoporosis (Z-score ≤ − 2 + pathological fracture or VF regardless of Z-score) [9, 84–88].	1b	A	
33	Treatment with BP can be considered for patients without osteoporosis, but a low BMD in early puberty (Tanner 2): - When active risk factors are present: patients with Z ≤ − 2. 5 SD (with a declining trajectory confirmed at least on two separate occasions with one year apart). - When patients no longer present active risk factors: patients with Z ≤ -3DS (with a declining trajectory confirmed on at	5	D	78%

Treatment with BP

32	Treatment with BP should be administered to those pediatric patients with osteoporosis (Z-score ≤ – 2 + pathological fracture or VF regardless of Z-score) [9, 84–88].	1b	A	
33	Treatment with BP can be considered for patients without osteoporosis, but a low BMD in early puberty (Tanner 2): - When active risk factors are present: patients with Z ≤ – 2. 5 SD (with a declining trajectory confirmed at least on two separate occasions with one year apart). - When patients no longer present active risk factors: patients with Z ≤ -3DS (with a declining trajectory confirmed on at least on two separate occasions with one year apart) [9, 84–87].	5	D	78%
34	Intravenous BPs should be used whenever there are VF, if there is some contraindication to the use of oral BPs, or according to the patient's preferences [88–91].	3a	B-C	
35	Oral BPs can be used in the absence of contraindications and VF, or during the de-escalation phase [9, 84–87].	5	D	70%
36	The BP dosage should be discontinued or progressively reduced in those patients not presenting fractures during the preceding year and having reached a Z-score higher than -2 [9, 84–87].	5	D	90%

Follow-up

37 A follow-up is recommended for patients at risk for osteoporosis while other risk factors persist and during treatment with calcium and/or vitamin D_3, BPs or other osteoporosis treatments [49, 51, 74].

38 Calcium and phosphorus metabolism (serum levels of calcium, phosphorus, alkaline phosphatase, iPTH and 25-hydroxyvitamin D_3) should be evaluated on an annual basis [49, 51].

39 During treatment with vitamin D, it is recommended to monitor serum levels of 25-hydroxyvitamin D_3 every 6 to 12 months, unless the dosage is changed. In such cases, patients should be monitored at 3–6 months [49, 51].

40 During supplementation with calcium and/or vitamin D_3, calcium/creatinine levels in urine should be monitored at least once a year. Renal ultrasounds should be conducted to rule out nephrocalcinosis in the event of calciuria increase, or when it is not possible to determine calciuria due to the patient's age or pathology [49–51, 82, 83].