Radiology
Team 438

Radiology of hematopoietic diseases

Lecture 25

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Objectives

- Recognize the applications and limitations of radiology for various hematologic disorders.
- Understand the appearance of common forms of anemias and possible differentiation.
- Identify the common locations and appearance of lymphoma.
- Explain the appearance of multiple myeloma.

Color Index: Important | Doctor's Notes | Extra | Female slides | male slides

Team Leaders


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Introduction

Blood contents:

1. Cells: RBCs, WBCs, Platelets.
2. Plasma.

Blood disorders		
RBCs	**WBCs**	**Platelets**

• **Polycythemia**
• **Anemia**
  ○ Sickle cell
  ○ Thalassemias
  ○ Others - nutritional (Iron deficiency), hemolysis (G6PD deficiency).
	• **Lymphoma**
	• **Multiple myeloma**
	• **Leukemia** (usually radio has no role).
		Bleeding/coagulation disorders

Anemia features on imaging:

Reactive increase in red bone marrow

- First response: your body will increase the RBCs production in bone marrow, which is called **intramedullary hematopoiesis**.
- Expanded bone marrow in bones including long bones, more obvious in hands, feet, limbs, skull (seen on x-ray & CT) when the anemia has been there for sufficiently long time and severe.
- Decreased T1 MRI signal in vertebral body bone marrow than adjacent discs.
- Visible on X-ray.

New marrow areas in potential organs

- If the previous mechanism wasn't enough and the patient is still anemic, or if the previous mechanism isn't working (aplastic anemia/myelofibrosis), some other sites will try to synthesize RBCs (**extramedullary hematopoiesis**), but in normal adult these sites don't do hematopoiesis.
- Such as: Liver, Spleen, Lymph nodes, Thymus, Paraspinal areas with possible extension into spinal canal outside the dura, Kidneys, Meninges, Skin.
- It's rare nowadays to see extramedullary hematopoiesis in unusual sites like kidney, meninges, etc. because patients are diagnosed and treated early before they reach this severity.

Transfusions iron overload (Hemochromatosis)

- Exogenous; in chronic anemia, due to transfusion.
- because our bodies can't get rid of the iron, so it will be deposited somewhere, usually in liver and spleen brain (basal ganglia), pancreas ,etc.
- **Increased CT density (brightness).**
- Changes in MRI signal of liver & spleen.

Sickle Cell Disease

Sickle Cell Anemia prone to:

Infracts

- Anywhere in the body:
  - Spleen (splenic sequestration)
  - Kidneys (Kidney infarction is expected in sickle cell anemia)
  - Brain
  - Bones.

Infections

- Common in sickle cell anemia more than other types of anemia.
- Pneumonias, Osteomye

- You can't specify which type of anemia the patient has depending on the radiologic features above (these above + previous slide), just say chronic/severe anemia, but if it's associated with infection/infarcts then the probability of SCA is high.
- If we correct the anemia, the extramedullary hematopoiesis will disappear.

Sickle Cell Disease:

❖ May be manifested as:

1

Anemia cause:

- Growth failure.
- Hyperkinetic heart failure.
- Expanded intramedullary hematopoiesis.
- Presence of extramedullary hematopoiesis.

2

Vaso-occlusive due to sickling which will cause microinfarction then it will leads to:

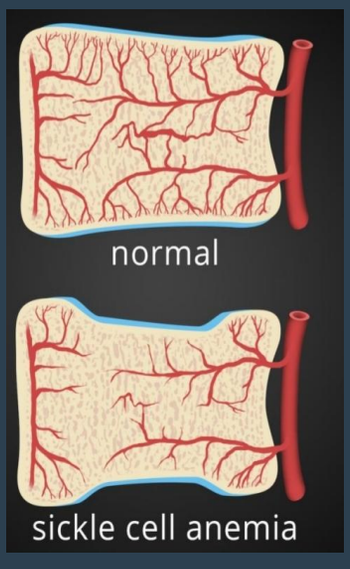
- Infarcts in spleen, bone marrow, kidney, bowel, brain, muscles etc.

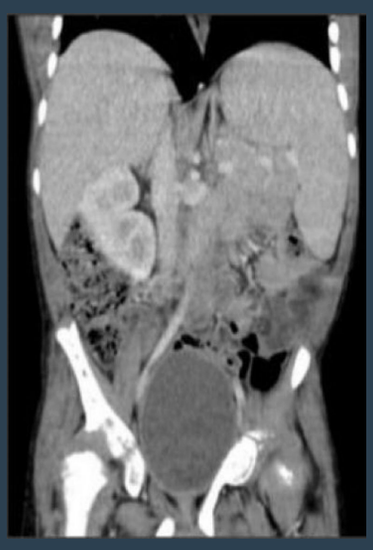
3

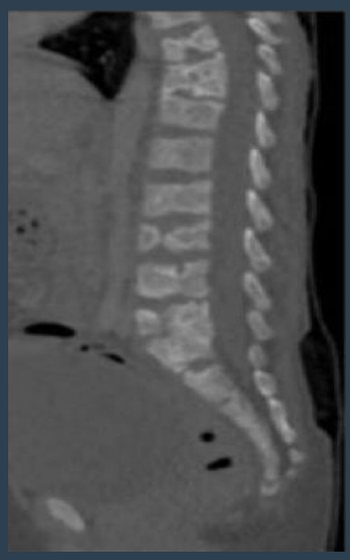
Superimposed infection due to splenic malfunction:

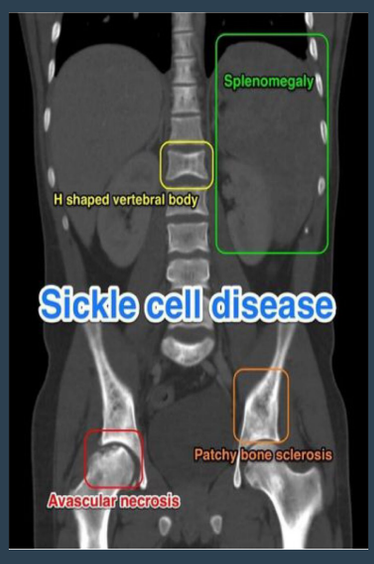
- Pneumonia (Pneumococcus, H. influenzae, Staph. aureus, Chlamydia, and Salmonella).
- Osteomyelitis (Salmonella) imp to differentiate between OM & bone infarction.
- Resistance against malaria.

SCA pictures:





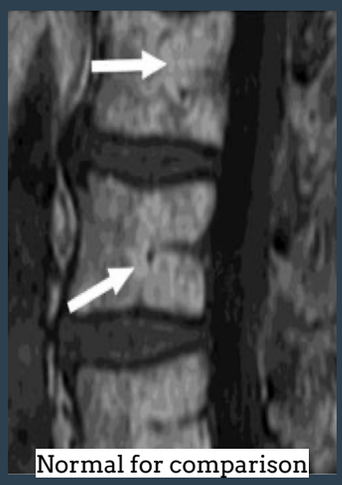




Sickle Cell Disease

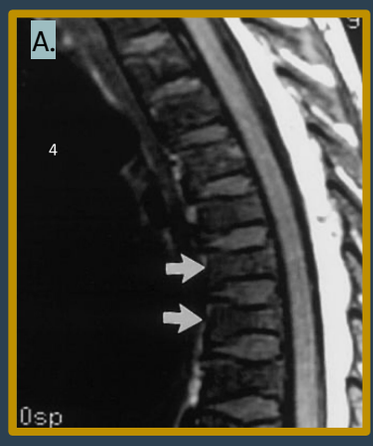
SCA cases:

01 **Red marrow in vertebral bodies in a 7-year-old girl with Sickle Cell Anemia.**


Normal for comparison

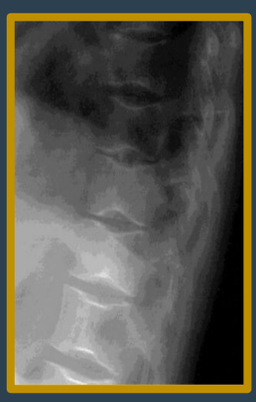
Sagittal T1-weighted MRI of spine shows:

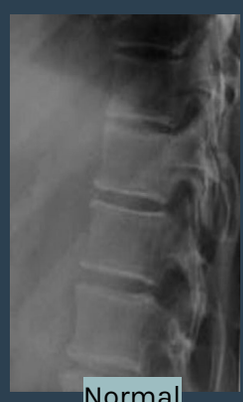
- Low signal intensity in vertebral bodies compared to discs, Can be seen in any kind of anemia not just sickle cell.
- H-shaped vertebrae (arrows A) due to osteonecrosis of vertebral endplates.
- **H shaped** vertebrae is characteristic of sickle cell due to central depression of end plate.
- "Honda sign".
  - Depressed center due to avascular necrosis (microinfarction).
  - if you see infarction with signs of anemia then it's highly suggestive of SCD.



02 **Lateral radiograph of spine shows: H-shaped vertebrae in a 15-year-old patient with SCA.**

- Classic boxlike endplate depressions in middle portion (*see the lowest vertebra shown*) due to osteonecrosis of the vertebral endplates.

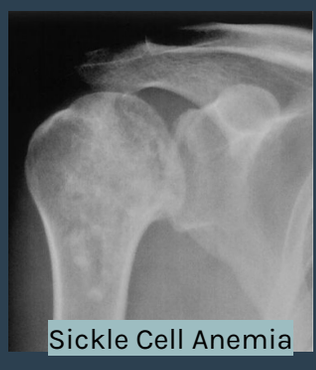


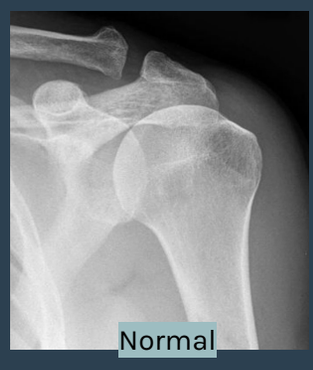

Normal

- Bone infarcts typically occur in the medullary cavities and epiphyses.
- Epiphyseal infarcts are frequently seen in the femoral and humeral heads and more often bilateral than avascular necrosis due to other diseases.

03 **Frontal radiograph of right shoulder in a 22-year-old patient:**

- Medullary bone infarcts in SCA.
- Area of patchy sclerosis and radiolucency.
- Signs avascular necrosis (infarction) of the bone in SCA:
  - Flattening of the humeral head.
  - Irregularity of the articular surface.
  - Heterogeneous density of the bone.


Sickle Cell Anemia

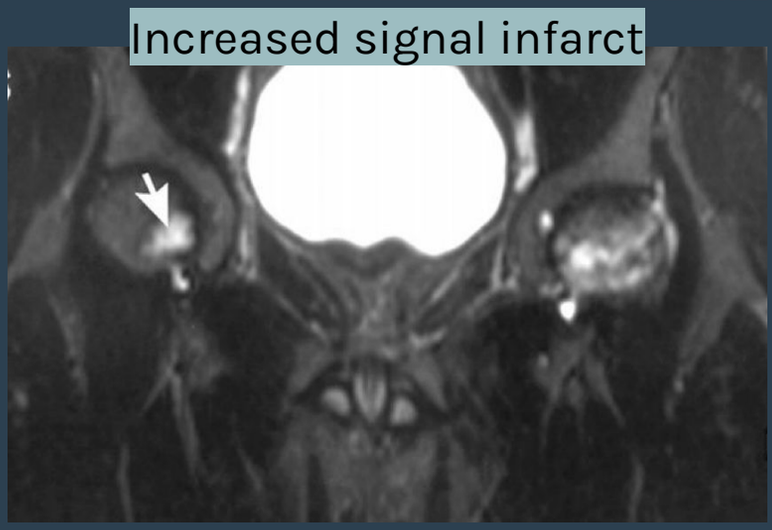

Normal

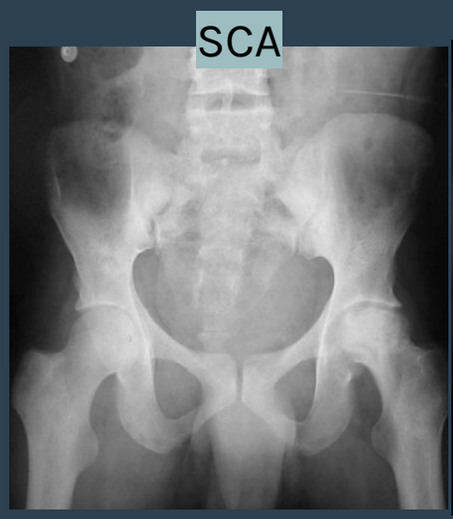
04 AP radiograph in a 44-year-old man shows:

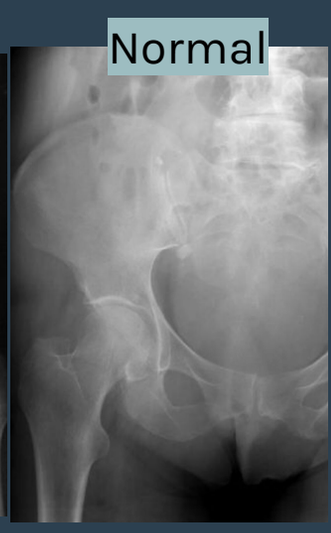
- Left hip → Advanced avascular necrosis.
  - more sclerosis and intermittent area of lucency.
- Signs avascular necrosis (infarction) of the bone in SCA:
  - Flattening of the Femoral head.
  - Irregularity of the articular surface.
  - Heterogeneous density of the bone.
- Right hip → Normal.
- He also has secondary osteoarthritis.

Coronal STIR MRI image in the same patient:

- Right hip → Stage 1 avascular necrosis
  - there is bone marrow edema in the medial part only
- Left femoral head → Advanced changes of avascular necrosis
  - there is bone marrow edema
- Bone marrow edema (white arrow) appears as an increased signal due to early bone infarction. Increased signal infarct.



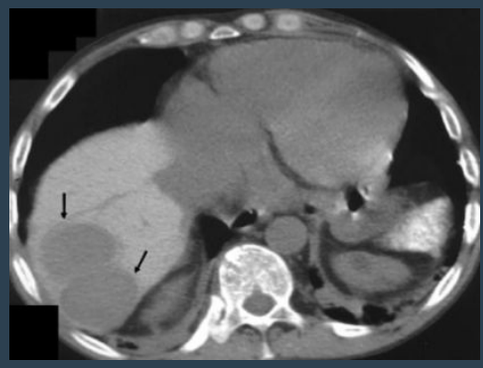




It's important to keep in mind that X-ray modality is not sensitive to early stages of bone necrosis!! In this 44-year old case, x-ray only was able to detect the necrosis in its late stages, while MRI detected it even the early changes in the right hip!

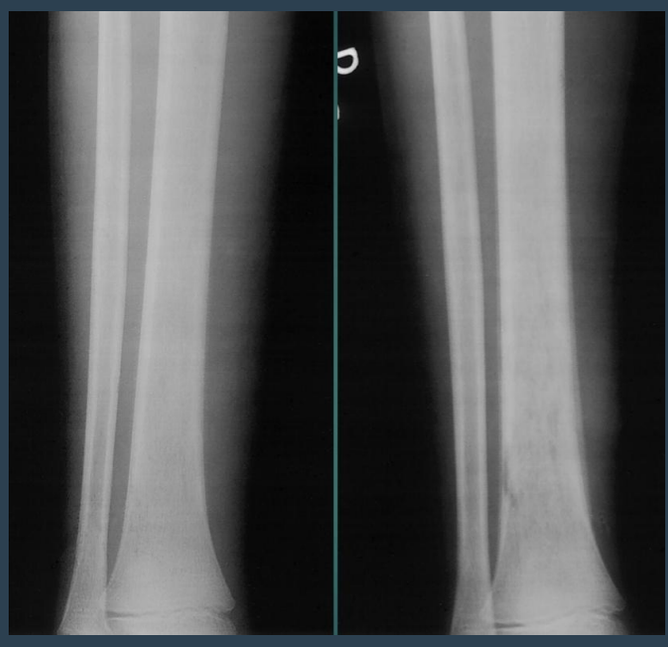
05 A 40-year-old man with sickle cell disease.

- **Axial unenhanced CT scan at thoracoabdominal level:**
  - Arrows → two uniformly low-attenuation (compared with liver parenchyma), well circumscribed lesions.
  - Bilobed hypodense liver due to iron overload because of multiple blood transfusions.
- Percutaneous biopsy showed **extramedullary hematopoiesis**.



06 Salmonella osteomyelitis in a 10-year-old boy with SCA.

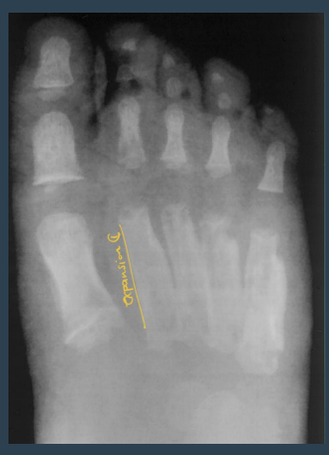
- Left → Initial film at onset of lower shin pain and fever (normal).
- Right → Film 7 days later shows mottled lower tibial shaft and diffuse periostitis of the lower diaphysis.
- Heterogeneous density of the bone is a sign of bone infection (OM).
- Moth-eaten appearance. (it's a pattern of bone involvement by multiple lytic lesions that is described as permeative bone destruction (permeative process in bone).



- Bone infarcts and osteomyelitis are difficult to differentiate on history (pain + anemia), clinical examination and plain x-ray images but they are very important to avoid complications of osteomyelitis.
- The treatment will be different in both, so we need an accurate Diagnose, how? By additional imaging (best by MRI, CT can be used, also can be done by US) because in X-ray they are similar, If you see fluid/abscess collection → Infection , NO → Infarction.
- **MRI findings that highly suggest infection:** (All of the 3 = infection)
  - Cortical defects in bone.
  - Adjacent fluid collections (abscess) in soft tissue.
  - Bone marrow enhancement.
- Ultrasound guided aspiration of fluid collection around the involved bone can be confirmatory.
- **MRI is gold standard in differentiating between bone infarcts and osteomyelitis.**
- Management:
  - Infarction → Conservative and observation.
  - Infection → Antibiotic.

07 Hand-foot syndrome (Dactylitis), in SCA:

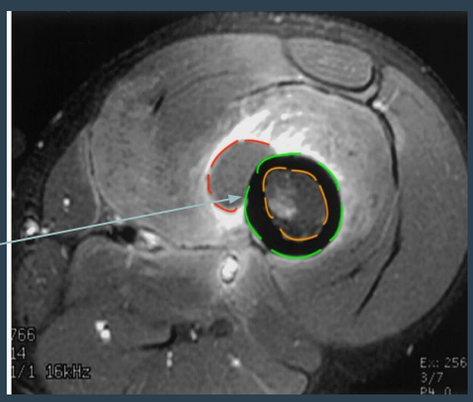
- **Frontal radiograph of right foot in a 3-year-old girl**.
- Thick periostitis and subperiosteal new bone along the metatarsal shafts. And metacarpal phalanges. Inflammation of the bone.
- 1- Expensio, 2- Supposed to be concave, 3- New bone formation.

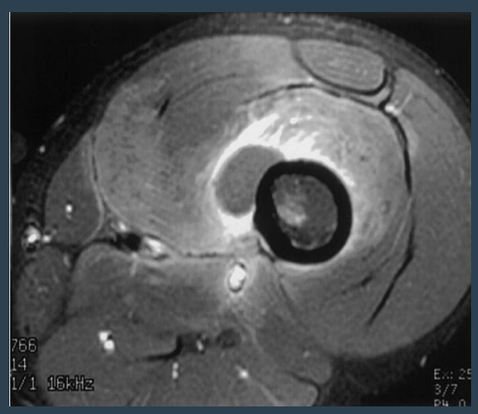


08 Osteomyelitis of femur in a 24-year-old patient with SCA.

- **Axial T1-weighted MRI after contrast shows:**
  - Heterogeneous enhancement of marrow cavity.
  - Rounded low-signal-intensity area adjacent to the shaft that is non-enhancing (fluid collection=Abscess).
  - Enhancement of the soft tissues around the shaft and of the adjacent musculature.
  - Areas of enhancement are likely infected.

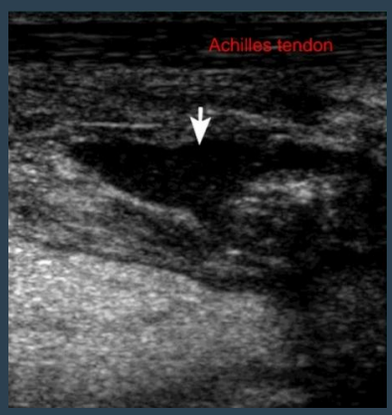
- Red:Abscess.
- Orange: Bone marrow.
- Green:Cortex.
- Enhanced bone marrow

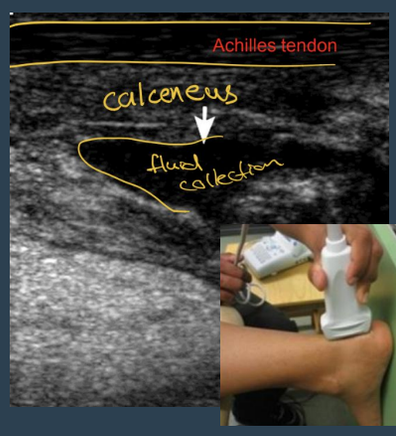




09 Soft-tissue infection in a 52-year-old man with homozygous sickle cell disease:

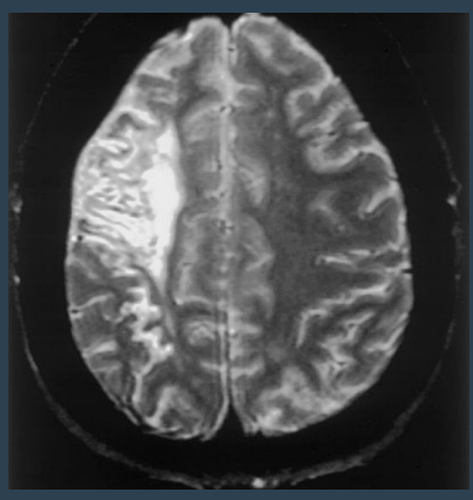
- **Longitudinal high-resolution ultrasound image of Left ankle shows:**
  - Arrow → hypoechoic (dark) fluid collection deep to Achilles Tendon.
- Thick pus was aspirated from this area under ultrasound guidance.



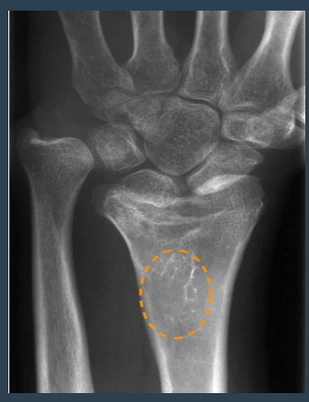


10 Chronic infarct in a 19-year-old patient with SCA and longstanding mild left sided weakness (signs of stroke):

- **Axial T2-weighted MRI shows:**
  - Area of high signal intensity and enlargement of overlying CSF spaces, compatible with chronic infarction and atrophy.
  - Multiple Infarction in right cerebral hemisphere, unusual in normal person, but expected in SCA patient.



11 Growth disturbance in distal radius in a 12-year-old girl:

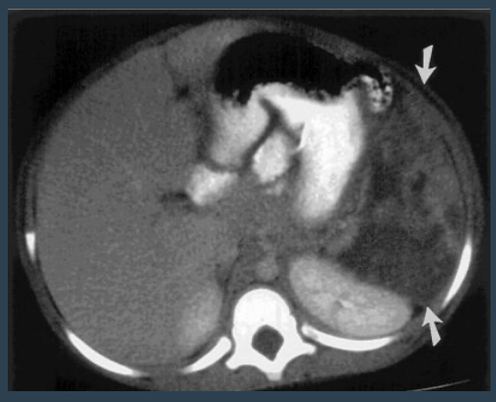


- **Anteroposterior (AP) radiograph of left wrist shows**
  - Epiphyseal shortening and a cup deformity of adjacent metaphysis.
  - Also changes of old bone infarct in distal radius.
  - Early closure of growth plate due to radius infarction.

12 Sequestration (infarction) syndrome with splenic infarction in SCA:

- **Axial CT after contrast shows:**
  - A. Enlarged spleen that enhances heterogeneously and minimally with large non-enhancing areas (arrows). Areas of infarction
  - B. Photograph of spleen in a different patient shows areas of congestion and central necrosis.

A.



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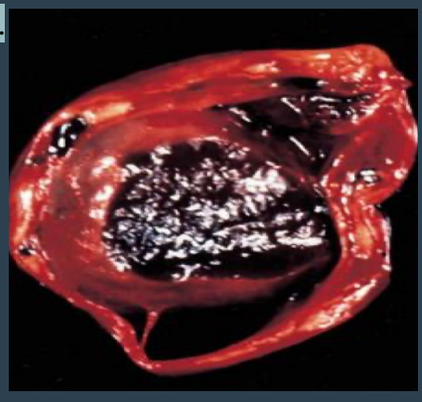
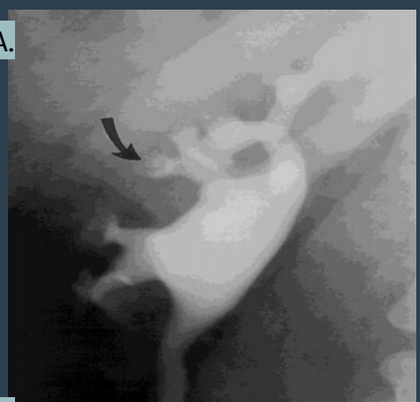


13 32-year-old man with SCA:

- **Frontal view of kidney during excretory urography in a 32-year-old man with SCA shows:**
  - B. small, round collection of contrast material in a missing papillary tip (arrow).contrast is leaking out
- Papillary necrosis has a lot of causes, like pain killers (commonest), alcohol and SCA.
- A. Photograph of a kidney from a different patient shows loss of papillary tips in some upper pole pyramids (arrows). Papillary necrosis and retrograde reflux of contrast. (typical sign).

A.



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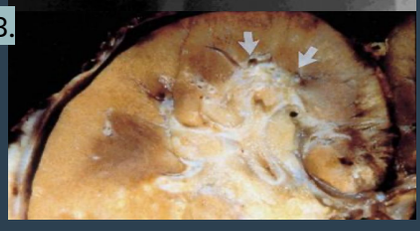
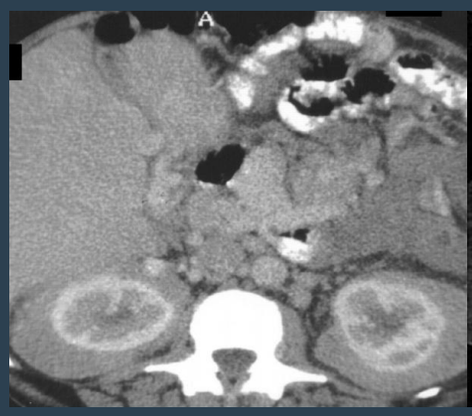
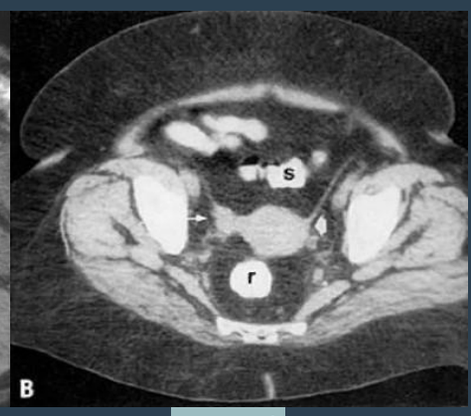


Myelofibrosis

Myelofibrosis Cases:

- Extramedullary hematopoiesis
  - new area of hematopoiesis OUTSIDE of bone marrow. Myelofibrosis
  - Red marrow replaced by fibrous scar tissue. Which is why the body starts looking for new areas to make RBC.

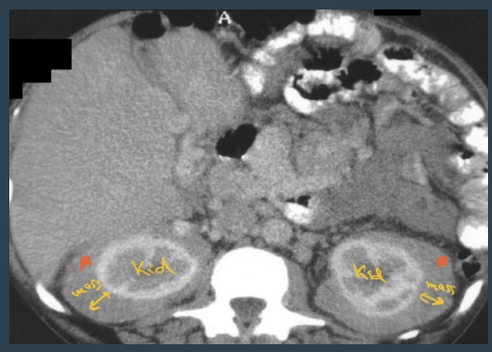




Normal:

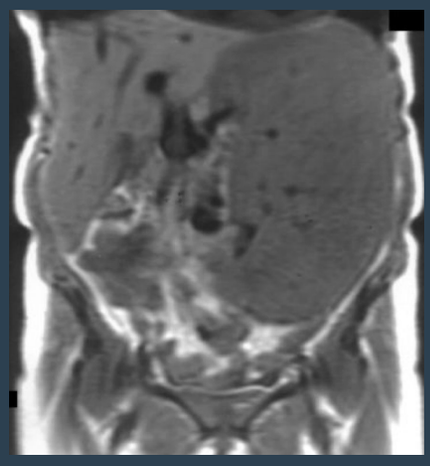
1 56-year-old man with myelofibrosis:

- **Axial contrast-enhanced CT scan through kidneys:**
  - Bilaterally symmetric enhancing perinephric masses.
  - Biopsy showed **extramedullary hematopoiesis.**
  - **Severe chronic anemia with extramedullary hematopoiesis.**
  - If we don't have a history and we won't be sure; it will be doubtful and may be mistaken by tumor and further investigation is needed.



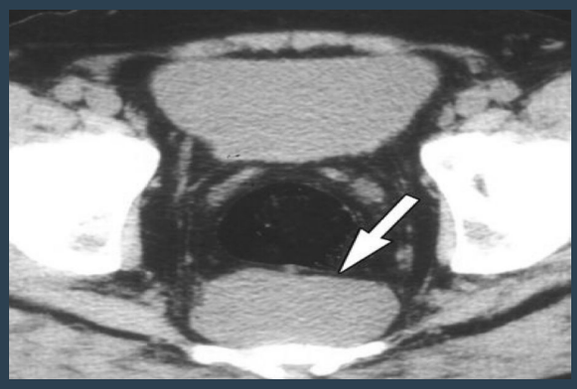
2 51-year-old woman with myelofibrosis:

- **Coronal T1-weighted MR image shows:**
  - Massively enlarged spleen 10 times bigger with a darker signal due to iron overload production.
- Splenic biopsy was followed by splenectomy.
- Pathologic examination revealed **extramedullary hematopoiesis in the spleen.**
- also common in non-functional bone marrow.



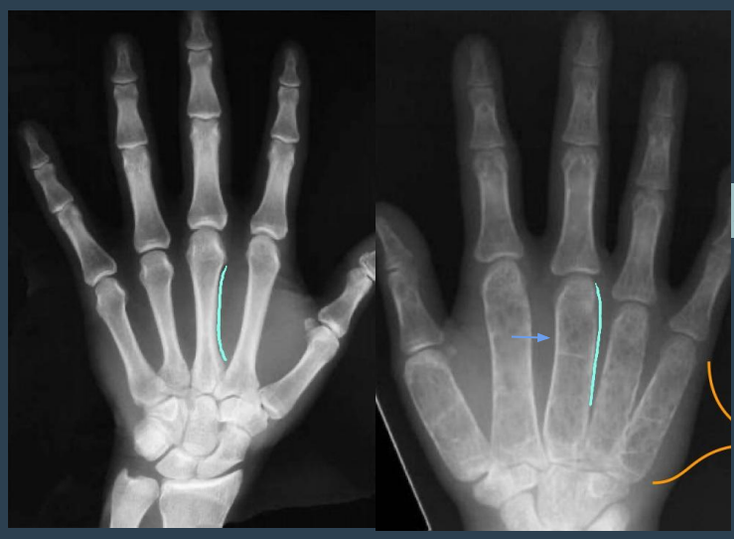
3 48-year-old man with hemolytic anemia and myelofibrosis:

- **Axial CT scan through pelvis shows:**
  - Arrow → well-marginated presacral soft-tissue mass (typical sign).
  - Any soft tissue mass below the rectum and sacrum (presacral space) is abnormal.
  - No bony erosion = sign of benign mass.
- Biopsy (not often needed) showed:
  - **extramedullary hematopoiesis**.



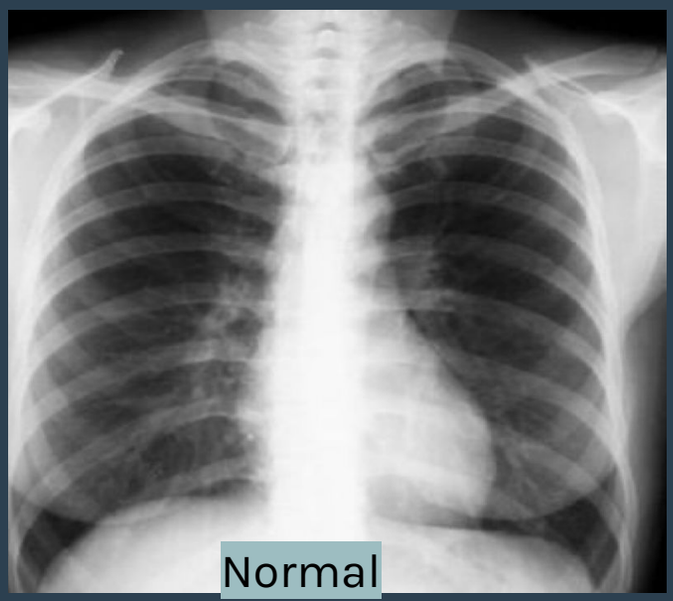
Thalassemia Features & Cases:

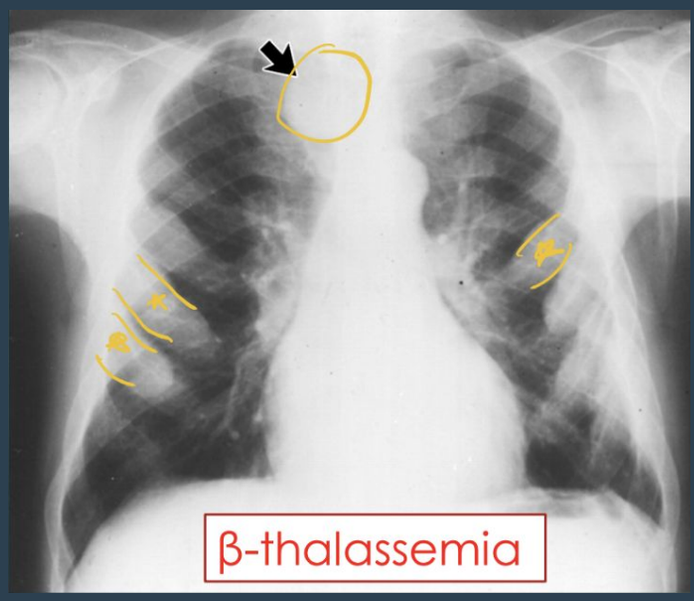
- Decreased bone density with coarse trabeculae, due to expansion of bone marrow & thinning of the cortex.
- Wide medullary cavity with thin cortex.
- Loss of concavity of metacarpal bones (expansion, bulle shaped, stubby bone, widening of the bones).
- Changes here can be seen in **severe anaemia with intramedullary hematopoiesis** but it is classic for thalassemia.
- Spongy bone, Remember that x-ray doesn't give you the diagnosis of thalassemia.



01 25-year-old man with β-thalassemia:

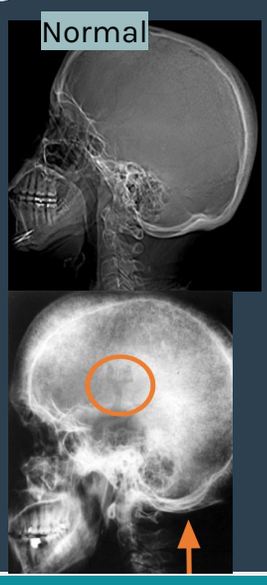
- **PA radiograph of chest shows:**
  - Arrow → right upper paraspinal (paravertebral) thoracic mass compatible **with extramedullary hematopoiesis**.
  - Diffuse expansion of ribs, (ribs are made of bone marrow so expanding = hyperactivated red marrow).
  - Increased brightness due to increased density of soft tissue.



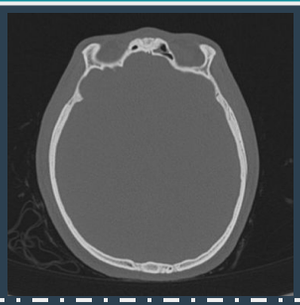
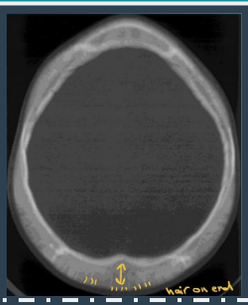


Thalassemia

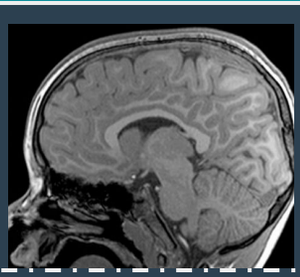
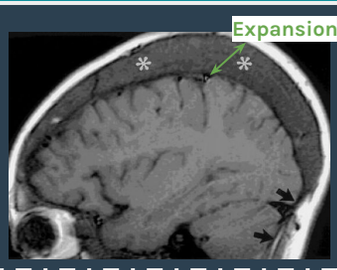
02 25-year-old man with β-thalassemia:



- **Lateral skull radiograph shows:**
  - Outward expansion of diploic space (bone marrow) with **hair-on-end appearance.**
  - Widened groove for middle meningeal artery **(circle)**
  - Spared occipital bone (has no bone marrow) **(arrow)**
- **Anything seen in thalassemia can also be seen in severe anemia with intramedullary hematopoiesis**

Normal	Axial CT image of upper skull
	

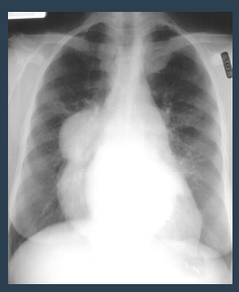
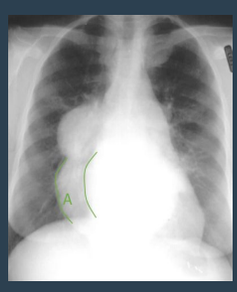
- Diploic space widening with hair on end appearance.
- Trabecular prominence.

Normal	Sagittal MRI of brain
	

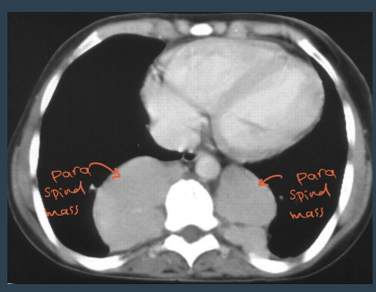
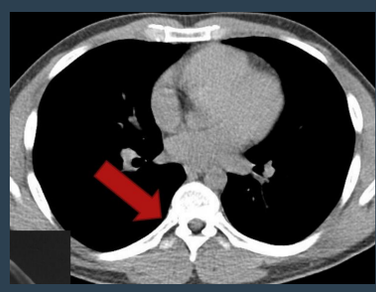
- Diploic space widening representing hyperactive red marrow (*).
- Arrows → Spared occipital bone which has no marrow elements.

03 23-year-old woman with history of thalassemia and known extramedullary hematopoiesis:

PA chest film	Axial contrast-enhanced CT

- Double density sign of posterior mediastinal mass.
- Well-marginated, bilateral, paraspinal masses compatible with **extramedullary hematopoietic tissue**.

- Uniformly enhancing bilateral paraspinal hemopoietic masses with NO bony erosion
  - (it's not an aggressive (bening) mass).
- This is why it's not a sarcoma. (A) Double density sign confirms mass in mediastinum. seen in Lymphoma, infection, TB, but if in thalassemia patient it means extramedullary hematopoiesis.

Lymphoma

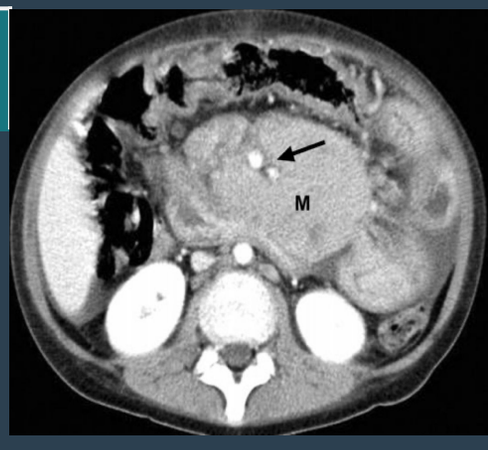
Lymphoma:

- It's neoplastic proliferation of the lymphocytes.
- Again, radiology has no role in diagnosing the subtypes of lymphoma, but we can identify the disease extent because sometimes it's hard to do physical examination of these masses especially if it is in a deep location ex: near the aorta.
- Most of the time we do CT ,,, MRI takes long time.
- Imaging has two role: Staging and guiding the biopsy if no other accessible lymph node is available.
- Lymphoma can present as mass anywhere in the body

Hodgkin's Disease (Classical)	Non Hodgkin's Lymphoma
→ Lymphocytic predominance. → Mixed cellularity. → Lymphocytic depletion. → Nodular sclerosis - the most common. → Most common in cervical and mediastinal.	→ **Large B-cell lymphomas** (abdomen and nodes) most common, → Burkitt lymphoma (jaw and abdomen) due to viruses like EBV virus. → Burkitt-like lymphoma (abdomen and nodes). → Lymphoblastic lymphoma (Mediastinum, nodes, bone marrow). → Anaplastic large cell lymphoma (Nodes, skin, soft tissue, bone). → Other peripheral T-cell lymphomas. → MALT lymphoma.

Cases:

1- Non Hodgkin's Lymphoma (NHL) in an 11-year-old boy.

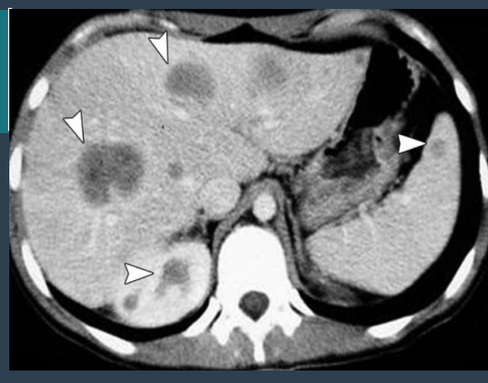


Axial CT scan with **contrast** shows:

- Large lymphomatous mass (M)* encasing the mesenteric vessels (arrow).
- Lymphoma mass does not compress (displace) or invade (not aggressive), it encases it respects other surrounding structures.

*fluffy mass & it's not compressing on the vessels but encasing them instead

2- NHL in a 16-year-old girl.

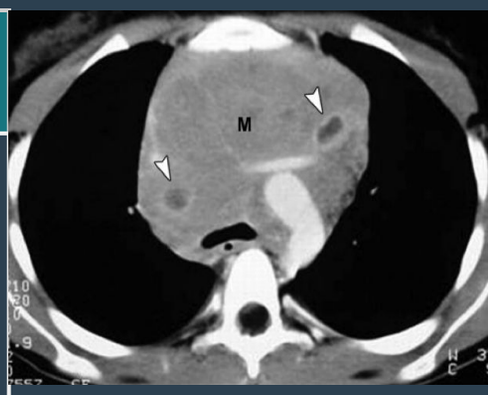


Contrast-enhanced CT scan shows:

- Low-density lesions (arrowheads) in both hepatic lobes, with small nodules in spleen and right kidney.

Lymphoma

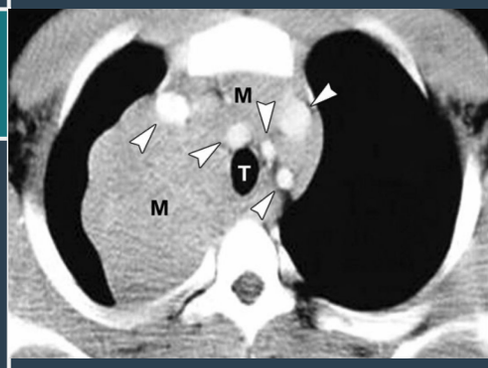
3- NHL in a 14-year-old boy.



Contrast-enhanced CT scan shows:

- Large anterior mediastinal mass (M) that originates from thymus.
- A few cysts with central low attenuation and a peripheral enhancing ring are present (arrowheads).
- Decreased blood supply in the center.

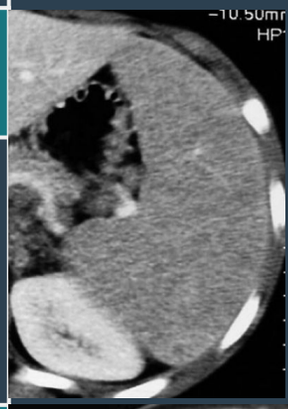
4- HD in a 17-year-old boy.



Contrast-enhanced CT scan shows:

- Large mediastinal mass (M). Trachea (T) is compressed, and great vessels (arrowheads) are displaced.
- Fluffy mass is lymphoma until proven otherwise

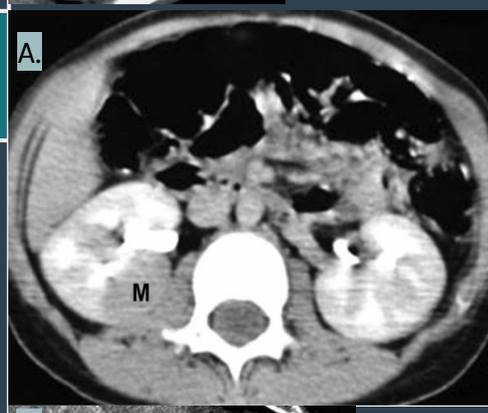
5- HD in a 12-year-old girl.

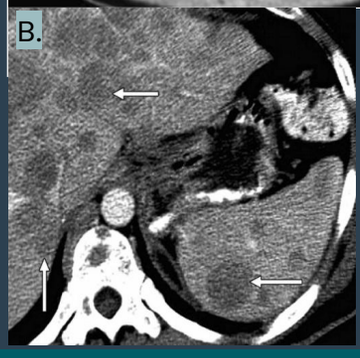


Contrast-enhanced CT scan shows:

- Enlarged spleen with a diffusely inhomogeneous appearance multiple hypodensity of spleen.

6- NHL in a 14-year-old boy.





A. Contrast-enhanced CT scan shows:

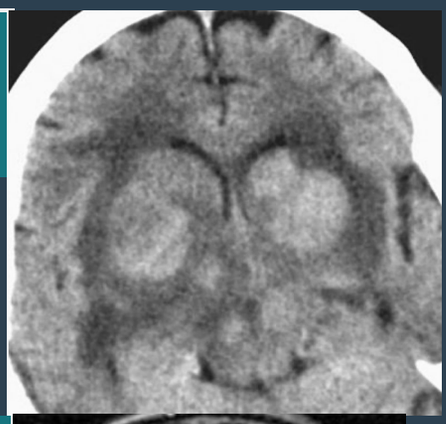
- Single well-defined, low density mass (M) in right kidney.
- Primary renal lymphoma (very rare to find organ involvement without lymph node involvement).
- RCC is first diagnosed when you see a kidney mass but could also be caused by the lymphoma.

B. Axial CT scan shows:

- Diffuse hepatosplenic involvement in lymphoma.
- Multiple round, homogeneous, low density nodules (arrows) in liver and spleen.
- There is involvement of bone, liver, and spleen here.

Lymphoma

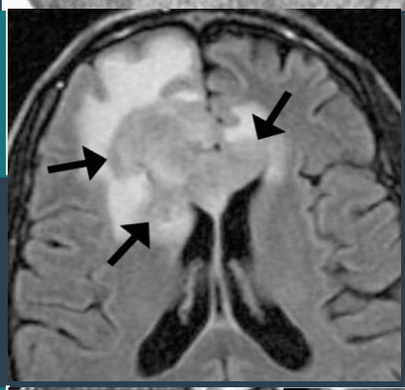
7- 72-year-old immunocompetent woman with primary CNS non-Hodgkin's B-cell lymphoma.



Unenhanced CT image shows:

- Classic hyperdense masses involving deep white and gray matter & basal ganglia.

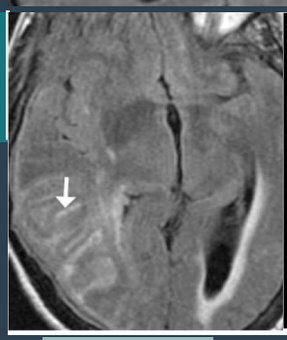
8- 44-year-old HIV-positive woman with primary CNS non-Hodgkin's B-cell lymphoma.

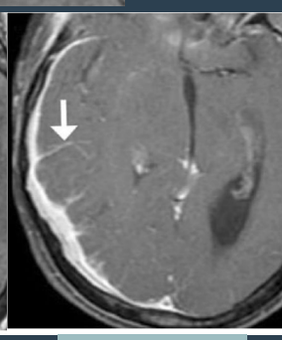


Axial FLAIR MRI shows:

Lesion isointense to gray matter (arrows).
Expansion of white matter.

9- 63-year-old woman with primary meningeal lymphoma.





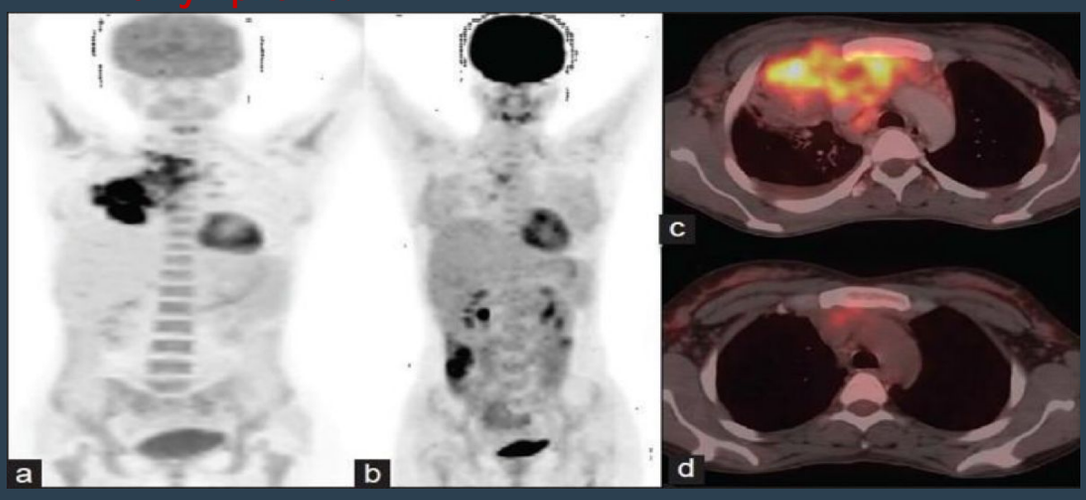
Axial Flair MRI images

Post contrast T1 weighted MRI images

MRI shows:

- hyperintensity and enhancement (arrows) involving sulci and leptomeninges.
- First differential diagnosis is infection (meningitis).

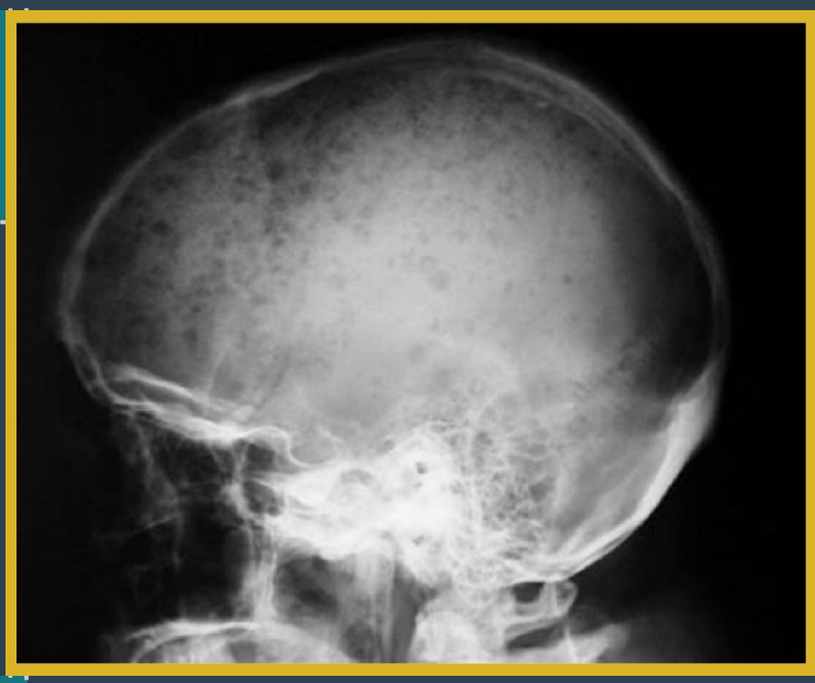
- Diagnosis of lymphoma:
  - If accessible area, then open-surgery-Biopsy is often performed (e.g. Axilla and groin).
  - If not accessible, CT guided biopsy is done to reach final diagnosis.
  - MRI is not commonly used unless you suspect a lymphomatous lesion in a specific area (e.g.brain)!! (forget about MRI, it's NOT used to assess lymphoma (patient can't wait for 3-4 hours for you to visualize his body, while you have an excellent modality (CT scan) that takes only 2-3 mins!!!).
  - Diagnosed by histopathology.
  - **PET-CT IS GOLD STANDARD FOR (diagnosing) STAGING AND FOLLOW UP THERAPY of lymphoma.**



C: Active disease.
D: After chemotherapy.

Multiple Myeloma

Multiple Myeloma Case



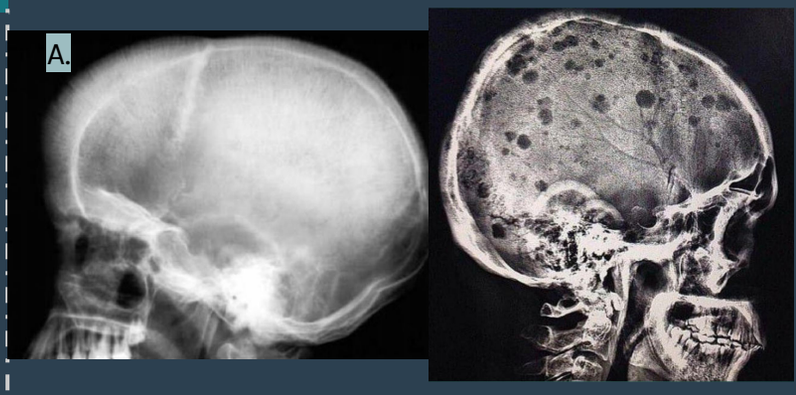
Lateral skull radiograph shows:

- Multiple very sharply outlined (punched out) lytic lesions of multiple myeloma.
- This sign appears late in advanced stage and we don't see it because we usually diagnose it early.

Dr. questions

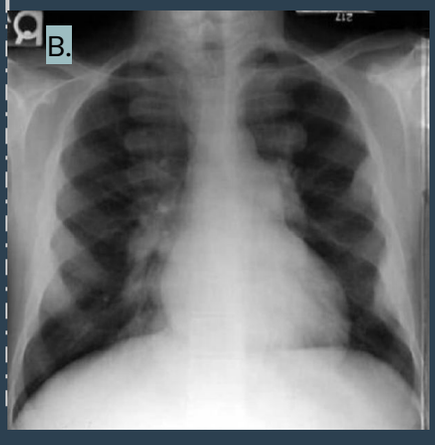
- A.Findings shown here can be seen in?
  - 1. any severe chronic anemia
  - 2. thalassemia
  - 3. Sickle cell anemia
  - 4. Lymphoma
  - 5. Lymphoma
- ans:
  - Any severe chronic anemia.

findings: Hair on end, Normal occipital bone & Expansion of diploic space



- B.Findings shown here can be seen in?
  - 1. any severe chronic anemia
  - 2. thalassemia
  - 3. Sickle cell anemia
  - 4. Lymphoma
- ans:
  - Any severe chronic anemia.

findings:Widening of ribs = hyperactive red marrow

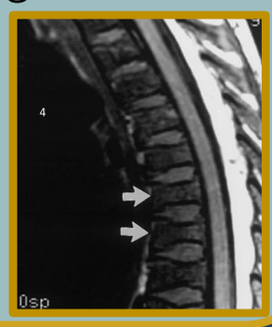


Summary

Intramedullary hyperplasia	can be seen in Thalassemia, Sickle cell anemia, Iron deficiency anemia, Any severe chronic anemia except bone marrow failure. Signs of INTRA medullary hyperplasia include: 1. Expanded bone marrow in bones including long bones of hands, feet, limbs, skull. 2. Decreased T1 MRI bone marrow signal than adjacent discs.
Extramedullary hematopoiesis	can be seen in all severe chronic anemias. Sites of extramedullary hematopoiesis include Liver, Spleen, Paraspinal areas with possible extension into spinal canal outside the Dura, Kidneys, Meninges, Skin, Lymph nodes, Thymus. Extramedullary hematopoiesis appears as homogeneous soft tissue masses on imaging.
INFARCTS and INFECTIONS	additional findings in Sickle cell anemia. • Bone infarct vs infection it is important to diagnose early so that antibiotics can be started early to prevent complications. MRI with contrast and ultrasound/CT guided aspiration of fluid collections are very helpful if imaging is unable to differentiate these two.
Multiple myeloma	produces punched out lytic lesions in bones with background bone appearing normal. Opposite to bony metastases, myeloma more often involves intervertebral discs and mandible, and less often involves pedicles.
Lymphoma	• can produce a mass anywhere in the body. CT is often used to scan whole body to evaluate the disease extent (staging), and to do CT-guided biopsy to make tissue diagnosis if not already diagnosed. Rest is all by laboratory and clinical based.

Quiz

1- Which of the following diseases is supported by the finding on this image?



a. Thalassemia
b. Lymphoma.
c. Intramedullary hyperplasia
d. Sickle cell anemia

2- What is the first sign we can appreciate in response to reduction of RBCs?

a. New marrow areas in potential organs.
b. Reactive increase in red bone marrow.
c. Transfusion iron overload.
d. Punched out lytic lesions.

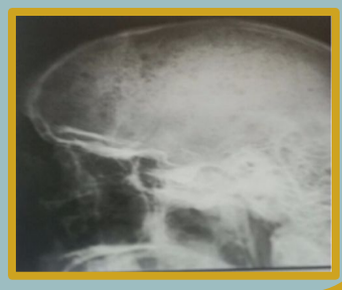
3- AH shaped vertebra is seen in:

a. Sickle cell anemia
b. Thalassemia
c. Chronic severe anemia
d. Cancer

4- What is the gold standard for staging and follow up of lymphoma?

a. MRI
b. CT with contrast
c. CT without contrast
d. PET-CT scan

5-Findings in the shown skull radiograph can be seen in which ONE of the following:



a. Multiple myeloma
b. Lymphoma
c. Leukemia
d. Thalassemia

Answers
1)D
2)b
3)a
4)d
5)a