



NUCLEAR MEDICINE IN PEDIATRIC ONCOLOGY

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Outlines

- Conventional nuclear medicine imaging in pediatric oncology
- PET/CT imaging in pediatric oncology
- Nuclear medicine therapies in pediatric oncology

Incidence of childhood cancers

- Relatively rare
 - 130-140 per million (0-15)
 - 157 if we include adolescents (0-19)
 - Approximately 1 out of 500-600 children
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- Second most common cause of death after accidents accounting for 18% of death in children

Mortality rate

- Over the last 30 years, the overall **incidence** has **increased** 0.5-1 % every year.
- However, the **mortality** rate has **decreased** dramatically, probably due to early detection and improved treatment.
- The 5-year survival has increased from **58%** for children diagnosed between 1975 and 1977 to **83%** for those diagnosed between 2001 and 2007.

Introduction to nuclear medicine

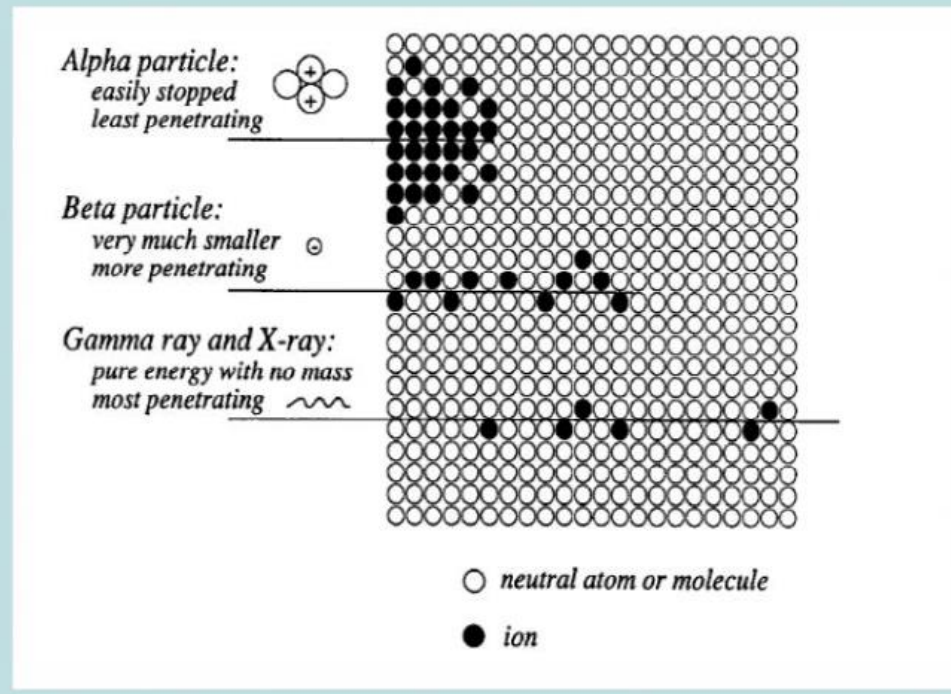
- **Radioactive:**
- An element with Unstable Nucleus (Excess Energy), can achieve to stable status by Radiation (a, b, g)
- **When it is used in medical imaging, named:**
Radiopharmaceutical

Introduction to nuclear medicine

- **Radiation can be as a:**
 - Particle: a & b
 - Or photon: g
- Particles (a, b) have **mass**, and can carry high energy in a short length
- Therefore, radiopharmaceuticals with b decay are used in **therapy**
- Photon (g) has **no mass**, and can carry low energy in a long distance. Therefore, radiopharmaceuticals with g decay are used in **imaging**

Introduction to nuclear medicine

Relative Penetrating Power



Special consideration in paediatrics

- Obtaining high quality studies in children is both challenging and rewarding.



Radiation dose

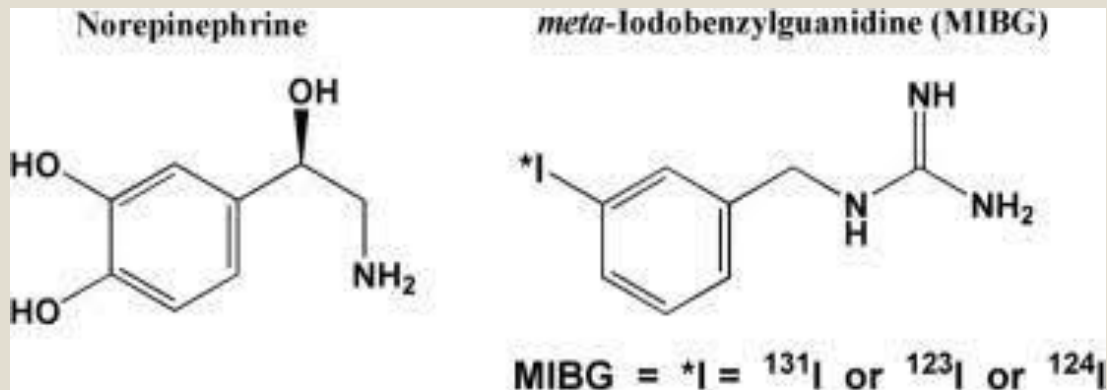
- A child is not simply a small adult.
- The organs of children are smaller and closer together, the absorbed dose to different organs differs from those of adults.
- The lowest dose of x- or γ -radiation for which good evidence exists of increased cancer risks in human is about 10 to 50 mSv for an acute exposure
- Effective dose estimation for many pediatric nuclear medicine procedures is less than 10 mSv. The effect of low dose radiation has not been proved in pediatric.
- Considering these controversies, however, it is recommended to select a more conservative approach for children.

Radiopharmaceuticals

- $^{131}\text{I}/^{123}\text{I}$ -MIBG
- ^{201}Tl and $^{99\text{m}}\text{Tc}$ -MIBI
- $^{99\text{m}}\text{Tc}$ -MDP

MIBG

- Structurally similar to norepinephrine
- Enters and stores in neuroendocrine cells
- Detection of neuroectodermal tumors including pheochromocytoma and NBL
- labeled with ^{131}I , ^{123}I

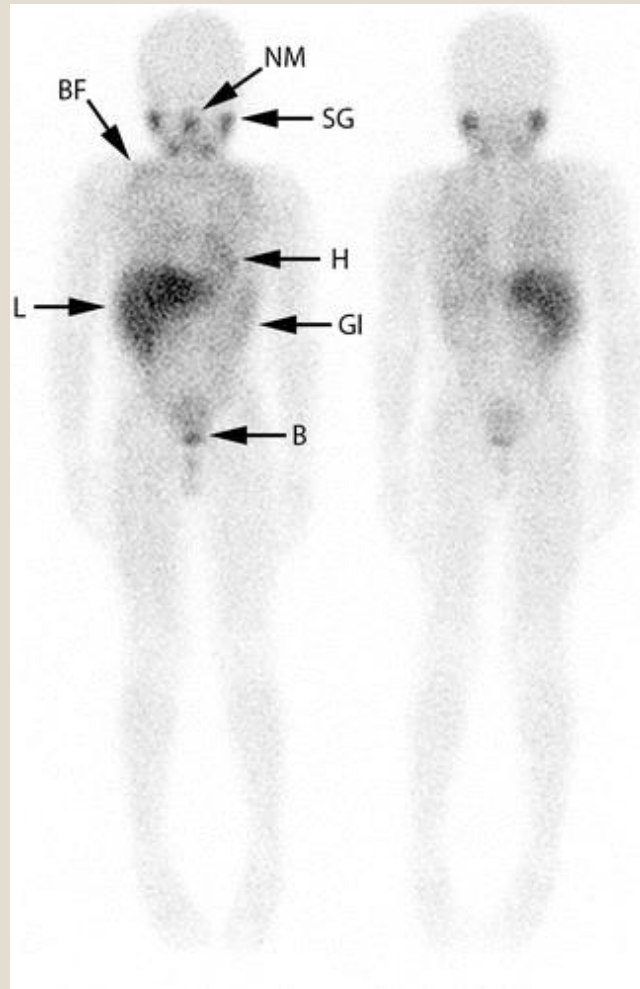


131I-MIBG Scintigraphy

- Patient preparation:
 - Thyroid blockade with sodium or potassium perchlorate or Lugol iodine solution
 - Certain foods restriction
 - Drug interference:
 - ✓ TCA
 - ✓ Certain antipsychotics
 - ✓ CNS stimulants
 - ✓ Calcium channel blockers
 - ✓ Labetalol

MIBG Scintigraphy

- Normal study

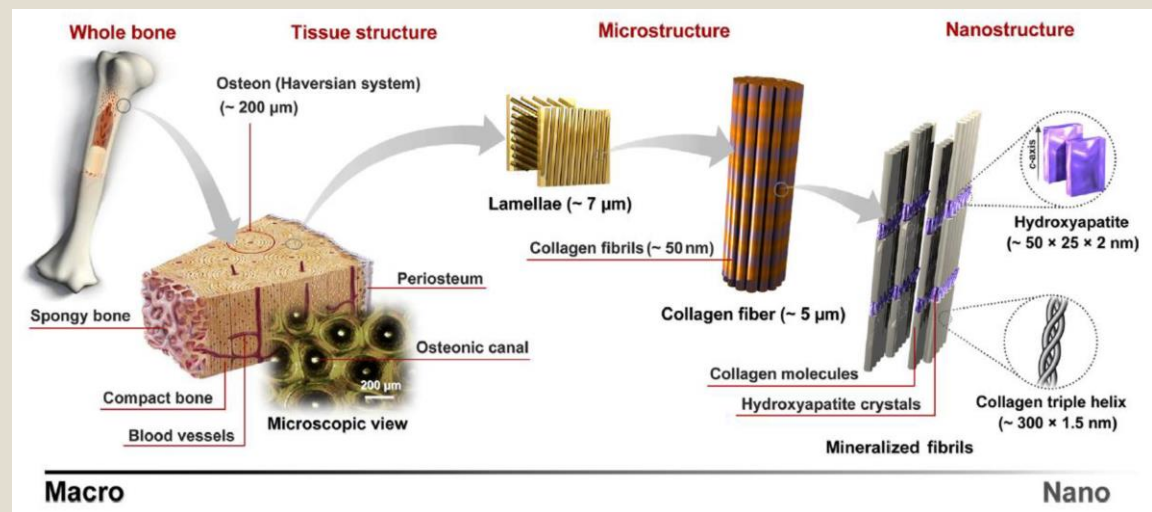


201Tl and 99mTc-MIBI

- Indicators of **viability**
- 99mTc-MIBI is lipophilic and attracts to negatively charged **mitochondria** inside the cells
- Thallium-201 (^{201}Tl) is potassium analog. The uptake of ^{201}Tl predominantly involves **Na^+/K^+ ATP** transport system.
- The patient should be fast for 4 hours for both

^{99m}Tc -MDP bone Scintigraphy

- $\text{Tc}^{99\text{m}}$ -MDP complexed with the **hydroxyapatite**; mineral component of the osseous matrix
- Accumulation of $\text{Tc}^{99\text{m}}$ -MDP shows:
 - Blood flow of the region
 - Osteogenic activity



^{99m}Tc -MDP bone Scintigraphy

- Normal study



Neuroblastoma

- Neuroblastoma is the **most common extra-cranial solid** tumor
- Most frequently diagnosed malignancy during **infancy**
- The incidence of neuroblastoma is rare after the age of five.
- Almost one half (46%) of neuroblastomas develop in the **adrenal gland**
- Long term survival is about 40%, in infants up to 83%

Neuroblastoma

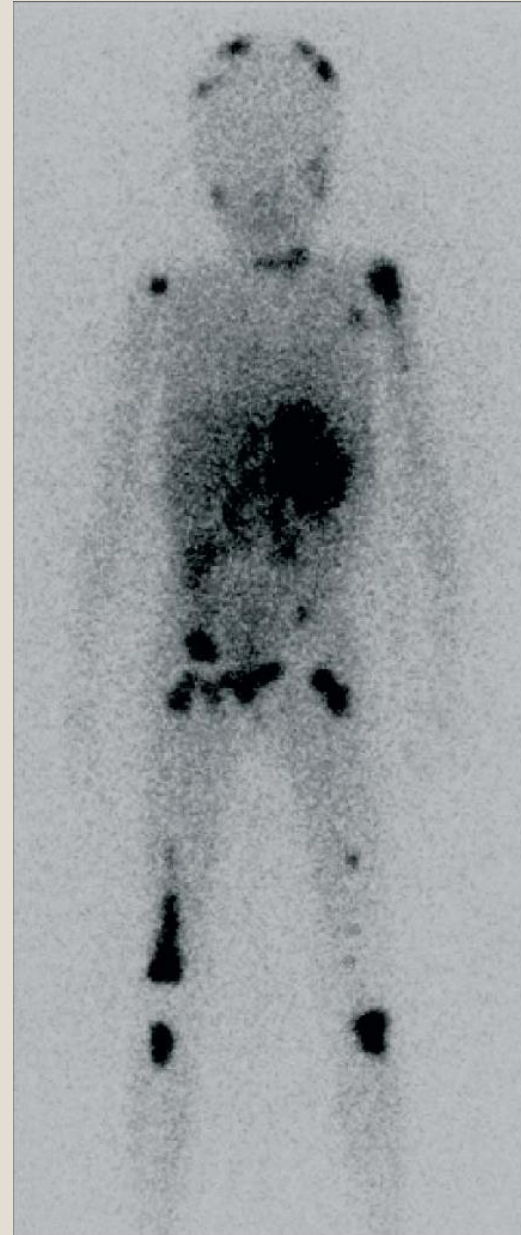
- Accurate staging: Multimodality including US, CT scan, MRI, bone scan, MIBG
- Bone scan:
 - **Not** recommended routinely
 - Less sensitive and less specific than MIBG
 - However in some studies omitting bone scan has led to up to 10% incorrect staging
 - Recommended when MIBG is not available or MIBG is negative but other finding like X Ray is suspicious

Neuroblastoma

- MIBG:
 - The **sensitivity** of MIBG to detect NBL (primary tumor and metastases) is about 80% on a lesion-by-lesion basis and 90% to 95% in terms of staging.
 - MIBG is highly **specific** (~100%) for the detection of primary tumor and metastases in NBL.

Neuroblastoma

- Bone and soft tissue metastases in a NBL case detected with MIBG Scintigraphy

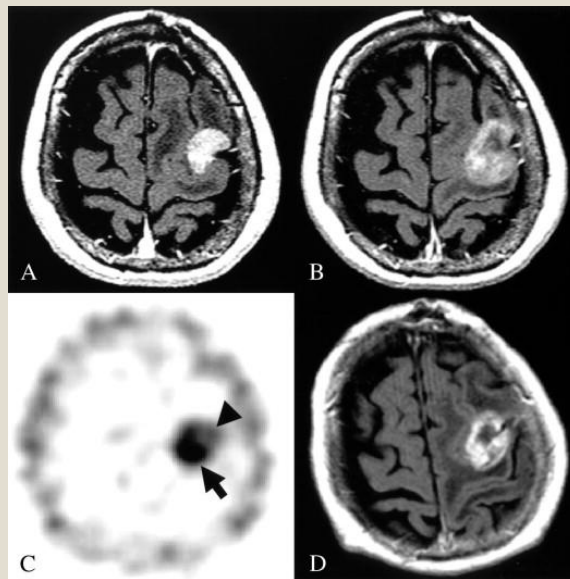


CNS tumors

- 16% to 20% of all malignancies during childhood and adolescence
- Leading cause of cancer deaths in pediatric oncology patients.
- MRI and CT are the principal imaging modalities used in staging and surveillance of children with brain tumors.
- Main limitation of CT/MRI: inability to differentiate between **viable residual** tumor or recurrence and postsurgical or postradiation changes
- ^{201}Tl or $^{99\text{mTc}}$ -MIBI for evaluation of viable tumor
- FDG PET/CT limitation: high brain uptake

CNS tumors

- The sensitivity and specificity of ^{201}Tl for the detection of childhood recurrence brain tumor are approximately 80% and 90%.
- $^{99\text{m}}\text{TcMIBI}$ has the advantages of better image quality and no significant brain uptake.



A patient with high-grade glioma who underwent gamma knife surgery (GKS).

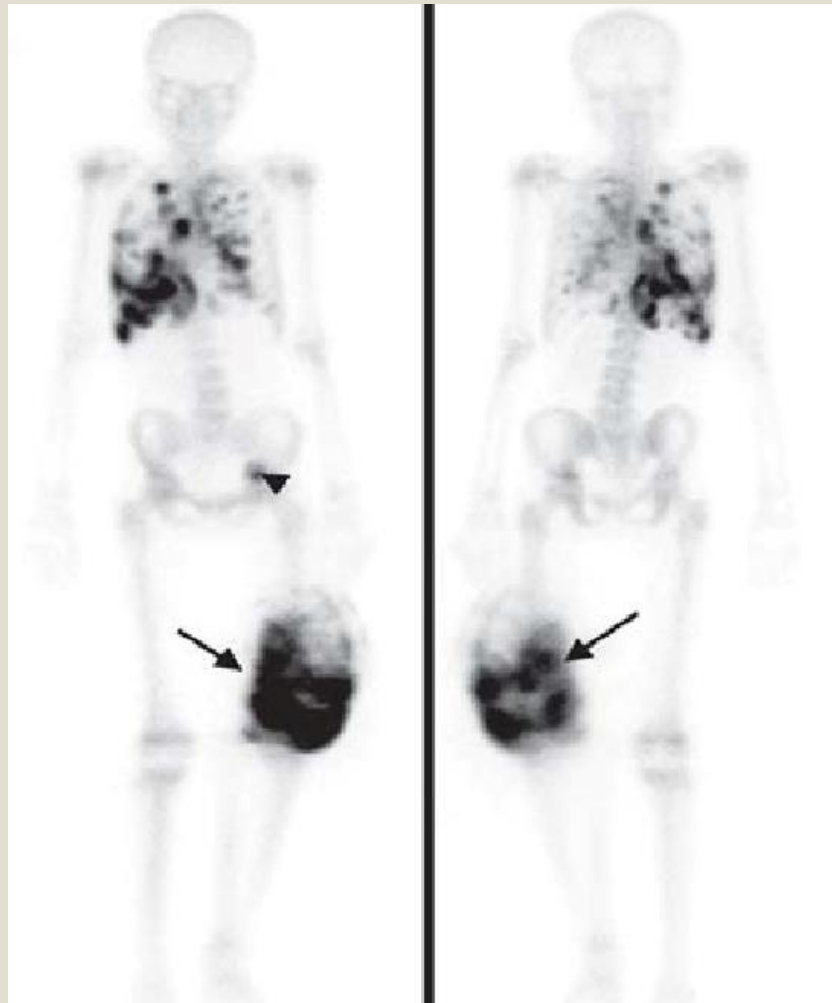
Bone tumors

- 6% of childhood cancers
- Osteosarcoma and Ewing sarcoma are the most common types of malignant primary bone tumors in children.
- **Osteosarcoma**: The first investigation is usually a plain X ray followed by further evaluation with CT scan, MRI, Chest CT scan, bone scan.
- The main indication for bone scan is to detect distant bone metastases.
- ^{201}Tl usually accumulates in OS and can be used as a marker for detection of viable tumor . Decrease ^{201}Tl uptake after treatment is indicative of a good response to therapy.

Osteosarcoma

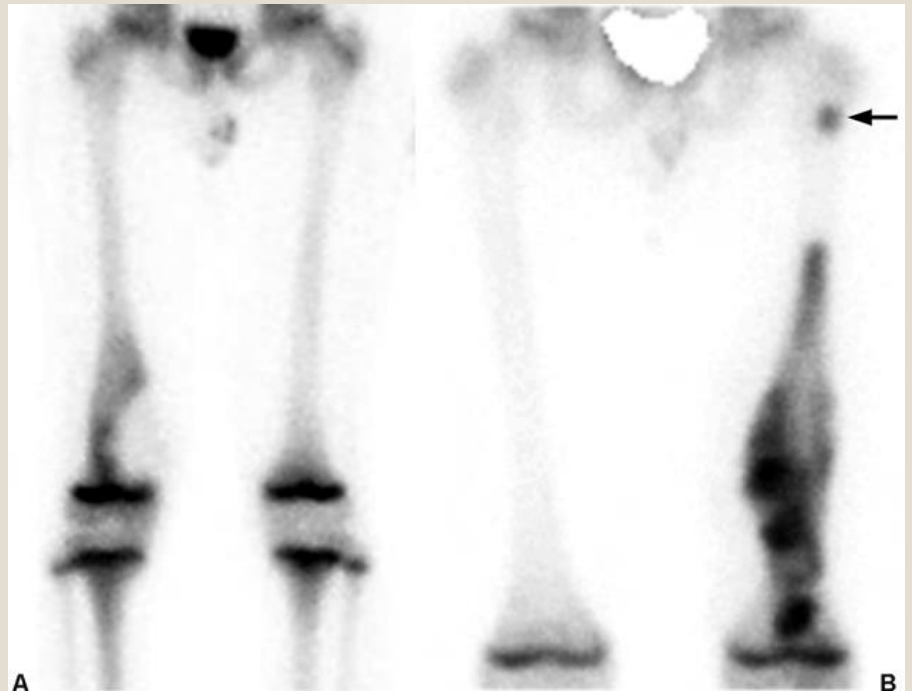
- Bone scintigraphy:
 - Multifocal bone lesions or skip metastases
 - Distant bone metastases
 - Osteogenic pulmonary metastatic sites

16-year-old male with osteosarcoma of left femur. (A and B) shows mass in left femoral shaft with heterogeneous tracer uptake (arrow). In addition it showed bone metastasis (arrowhead) and osteogenic pulmonary metastasis



Osteosarcoma

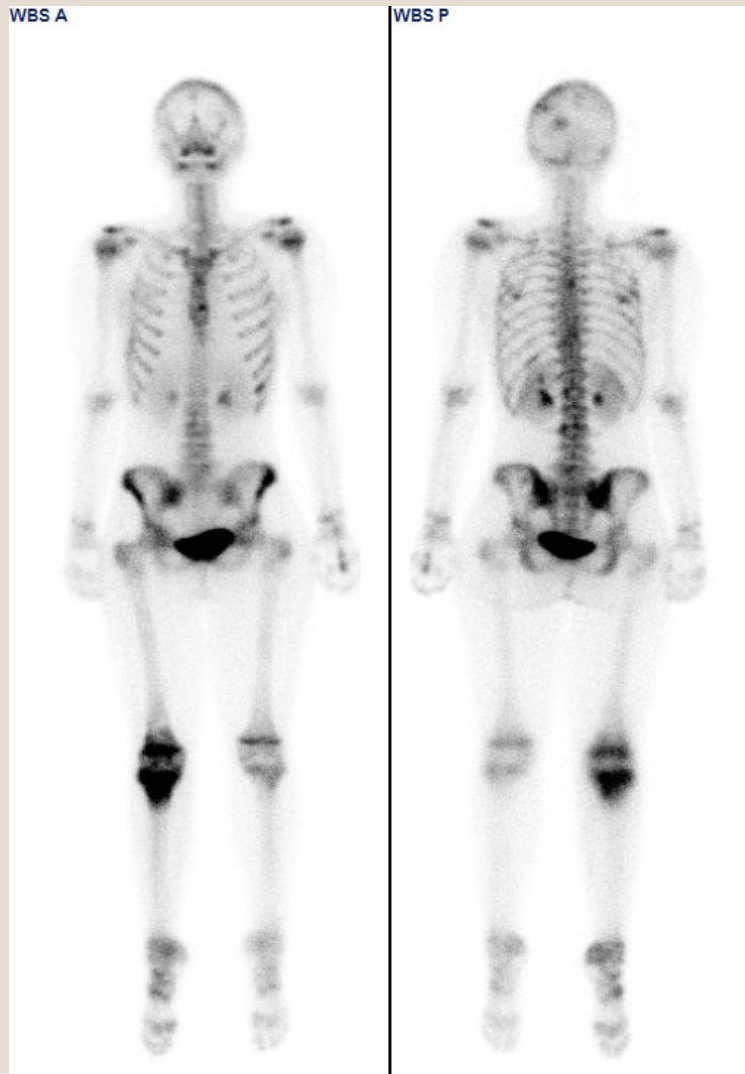
- The lesion may be cold.
- Skip lesion may be seen on bone scan



Ewing Sarcoma

- EWS of bone is the second most common primary bone tumor in children.
- Bone scan usually shows intense increased activity.
- Bone scan is indicated **at diagnosis** because of asymptomatic metastases.
- Close follow up studies (including serial bone scan) are also needed during the first **two years** because of a high risk of bone metastases which was not detected at diagnosis.
- Detection of bone metastases on F/U bone scan have been reported in 33 to 45% of patients who were free of metastases at presentation .

- Bone scan in a 14-year old girl with Ewing sarcoma of the proximal right tibia with multiple bone metastases.



Rhabdomyosarcoma

- **Most common soft tissue** tumor in children accounting for approximately 4-8%.
- The peak age is 2-5 years old. The second peak age is 15-19 years old.
- The overall survival rate is approximately 70%, which has increased from about 20% in the 1960s.
- The sensitivity of bone scan to detect bone metastasis in RMS is more than 95%.

Thank you for your attention

