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VARIRTY OF BONE DISEASES IMAGING BY BONE SCINTINGRAPHY

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ABSTRACT

Bone scintigraphy is a special type of nuclear medicine procedure that uses small amounts of radioactive material to diagnose and assess the severity of a variety of bone diseases and conditions, including fractures, infection, and cancer. The main agent in current clinical use for bone scanning is (MDP). The imaging technique plays an important role in preoperative evaluation, treatment efficacy evaluation and monitoring of bone metastases. Bone scan is able to evaluate the total body in one study, as well as its availability and low cost, makes it a useful modality to locate, diagnose, and evaluate bone pathology. Scintigraphy can provide early detection of primary cancer and cancer that has spread to the bones from other parts of the body. Bone scan able to pinpoint molecular activity within the body, and it offers the potential to identify disease in its earliest stages. In this research different results of cases of bone disease which detected by using bone scan techniques are visualized, presented and reviewed thus the concluding remarks were abstracted. More work are needed in this area.

KEYWORDS: Bone Metastases, Bone Scan, Diagnose, MDP, Nuclear Medicine.

INTRODUCTION

Bone scintigraphy (Bone Scan) is widely available, relatively inexpensive, easily performed, and quickly completed.**[1]** It helps diagnose and evaluate a variety of bone diseases and conditions using small amounts of radioactive materials that are typically injected into the bloodstream, inhaled or swallowed. The radiotracer travels through the area being examined and gives off energy in the form of gamma rays which are detected by a special camera and a computer to create the images.[2] Phosphate analogues can be labelled with ^{99m}Tc and are used for bone imaging because of their good localization in the skeleton and rapid clearance from soft tissues.[3] Technetium is a standard element used in nuclear medicine imaging, with energy. Due to the low emission of the gamma rays of 140keV and a Short half life of 6 hours.[4] Technetium-99m, a bone seeking tracer, is rapidly deposited to bones ,binds to bone crystal surface by chemisorptions after intravenous injection and shows bone metabolism specifically.[5] Tc methylene diphosphonate (MDP) is the most commonly used radiotracer which accumulates in sites of increased bone turnover. The mechanism of radiotracer accumulation depends on the vascularity and increased osteoblastic activity of bone. The bone scan confirm high sensitivity in detecting bone abnormality, often before any structural manifestation. In addition, the ability to evaluate the total body in one study, as well as its availability and low cost, makes it a useful modality to locate, diagnose, and evaluate bone pathology.[6] Another advantage of bone scan is that it is a non-invasive technique for early diagnosis and localization of bone diseases.

MDP for Bone Scanning

Bone imaging agents ^{99m}Tc-radiopharmaceuticals are the most widely used in diagnostic nuclear medicine. Bisphosphonates are synthetic organic compounds characterized by a P-C-P backbone structure. They are chemically stable analogues of the endogenous metabolites, inorganic pyrophosphates. The biological effects of Bisphosphonates on calcium metabolism were originally ascribed to their physicochemical effects to impede the dissolution of hydroxyapatite crystals.[7] The main agent in current clinical use for bone scanning is ^{99m}Tc methylene diphosphonate (MDP), a phosphate analogue. Its subsequent accumulation in bone is rapid, with excretion of the residual MDP via the urine. Approximately half of the administered dose is eliminated within 4 hours, producing a high bone to background ratio of activity, except in situations where renal function is poor.[8] ^{99m}Tc-MDP undergoes protein binding in blood, which increases over time from around 25% at injection to about 50% at 4 h after injection. Only unbound tracer will be available for bone uptake.[9]

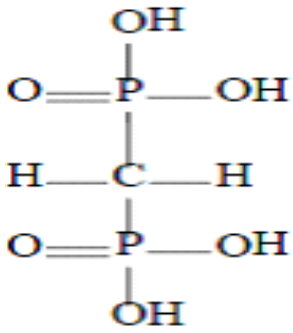

Fig. 1 MDP Bond

^{99m}Tc-labelled diphosphonates are prepared by addition of the required amount of sodium [^{99m}Tc] pertechnetate, diluted in sterile physiological saline, to the vial according to the manufacturer's instructions. The preparation may be diluted with sterile physiological saline if required. These radiopharmaceuticals are subject to oxidation, and care should be taken to avoid introducing air into the multidose vial during preparation or removal of doses. The radiopharmaceutical should be used within 6 h of preparation.[3] Uptake of (^{99m}Tc-MDP), which accumulates on the surface of the bone mineral matrix, depends on blood flow and especially on the rate of new bone formation.[1] The average activity administered for bone scintigraphy by a single i.v. injection should be 500 MBq (300–740 MBq) (8–20 mCi). The organ which receives the largest radiation dose is bone. The activity to be administered to children should be a fraction of the adult activity calculated from body weight. In children a minimum activity of 40 MBq is necessary in order to obtain images of sufficient quality.Recommended injected activities for 99mTc-MDP imaging based on the dosage EANM card are listed in Table 1[10]

Table 1: Recommended activities for ^{99m}Tc-MDP based on the EANM dosage card

Weight (kg)	99mTc-MDP activity (MBq)	Weight (kg)	99mTc-MDP activity (MBq)
3	40	32	255
4	40	34	270
6	60	36	280
8	75	38	295
10	95	40	310
12	110	42	320
14	125	44	335
16	140	46	350
18	155	48	360
20	170	50	375
22	185	52 – 54	395
24	200	56 – 58	420
26	215	60 – 62	445
28	225	64 – 66	470
30	240	68	490

The national diagnostic reference levels should not be exceeded.[10] The estimated adsorbed radiation dose to various organs in healthy subjects following administration of ^{99m}Tc-labelled phosphates and phosphonates is given in Table 2. The data are quoted from ICRP no.80[3]

Table 2: Absorbed radiation dose per unit activity administered (mGy/MBq), for various organs in healthy subjects following the administration of ^{99m}Tc-labelled phosphates and phosphonates.

Organ	Adult	15 year olds	5 year olds
Adrenals	0.0021	0.0027	0.0058
Bladder	0.048	0.060	0.073
Bone surfaces	0.063	0.082	0.22
Brain	0.0017	0.0021	0.0043
Breast	0.00071	0.00089	0.0022
Colon	0.0027	0.0034	0.0061
Gallbladder	0.0014	0.0019	0.0042
Heart	0.0012	0.0016	0.0034
Kidneys	0.0073	0.0088	0.018
Liver	0.0012	0.0016	0.0036
Lungs	0.0013	0.0016	0.0036
Muscles	0.0019	0.0023	0.0044
Oesophagus	0.0010	0.0013	0.0030
Ovaries	0.0036	0.0046	0.0070
Pancreas	0.0016	0.0020	0.0045
Red marrow	0.0092	0.010	0.033
Skin	0.0010	0.0013	0.0029

Small intestine	0.0023	0.0029	0.0053
Spleen	0.0014	0.0018	0.0045
Stomach	0.0012	0.0015	0.0035
Testes	0.0024	0.0033	0.0058
Thymus	0.0010	0.0013	0.0030
Thyroid	0.0013	0.0016	0.0035
Uterus	0.0063	0.0076	0.011
Remaining organ	0.0019	0.0023	0.0045
Effective dose (mSv/MBq)	0.0057	0.0070	0.014

In current practice, approximately 740-1110MBq (20- 30 mCi) of ^{99m}Tc-MDP is injected intravenously for the purpose of bone scintigraphy. Administered MDP is partitioned according to the relative magnitude of these clearances. Therefore, the degree of osseous uptake depends not only on factors relating to bone metabolism but also on renal clearance of MDP, the latter being closely approximated by the glomerular filtration rate. Assuming normal clearance values of 40mL/min for bone and 100 mL/min for renal, wholebody retention of MDP at 24 hours is estimated to be 30%.[11]

^{99m}Tc-MDP Bone Scan Technique

The imaging technique plays an important role in preoperative evaluation, treatment efficacy evaluation and monitoring of bone metastases. gamma camera and single-photon emission-computed tomography (SPECT) are included in imaging techniques. With the new (SPECT) technique, the ability of bone scan to detect small bone lesions and localize them has also improved The Common clinical indications for bone scanning are: (Infection or inflammation - Bone tumours - Aseptic necrosis - Traumatic bone disease - Sudeck's atrophy - Bone scintigraphy-guided surgery - Bone dysplasia and other metabolic diseases - Other clinical situations in pediatrics). The skeletal system imaging consists of three phases Table 3 not all phases are routinely imaged; therefore, the type of information and the anatomic area of interest need to be identified for initial assessment before the examination[12]

Table 3: Three phase skeletal scintigraphy

Phase	Frame-Mode Acquisition	Matrix Size	Timing with Injection	Stop Parameters	Indications
Vascular Phase (nuclear angiogram)	Dynamic	128 x 128 pixels x 16 bits	Simultaneous with intravenous injection	1 sec / frame for 120 sec; reformat into 3 ,4 ,or 5 sec/frame study	Evaluation of vascular integrity in area of soft tissue of bone injury
Soft tissue (blood pool) hase	Static (dynamic for motion correction)	256 x 256 pixels x 16 bits	5 min after injection	60 – 90 sec/image	Evaluation for abnormal concentration of ^{99m}Tc-MDP within

					soft tissue
Bone Phase	Static (dynamic for motion correction)	256 x 256 pixels x 16 bits	2 – 4 hr after injection	60 – 90 sec/image	Evaluation for abnormal concentration of ^{99m}Tc-MDP within osseous areas of interest

The patient is advised to maintain good hydration with oral fluids and to empty their bladder regularly to reduce unnecessary radiation dose to the pelvic organs. Although the patient should empty his bladder prior to commencement of imaging, refilling inevitably takes place during the examination, promoted by the good hydration. 2 to 4 hours after injection whole body imaging takes place. This is performed either on a dual-head gamma camera, acquiring anterior and posterior views simultaneously, or on a singlehead facility, performing spot views. Additional views are obtained as necessary, depending on the clinical problem being investigated and the findings on the initial images. A strict quality control programme should be routinely performed, according to the rules of each country. Whole body bone scintigraphy can be accomplished with multiple overlapping (spot) images or with continuous imaging (whole-body scan) obtained in both anterior and posterior projections. In adults, whole body studies are currently preferred. In children, spot views are commonly used. When spot views are used as the primary method of acquisition, the regions of the skeleton covered by each spot view must overlap, to avoid missing any area. The sources of error are in this techneque are: (Patient movement – Greater than necessary collimator-to-patient distance – Imaging too soon after injection, before the radiopharmaceutical has been optimally cleared from soft tissues – Injection artefacts – Radiopharmaceutical degradation – Urine contamination or a urinary diversion reservoir – Prosthetic implants, radiographic contrast materials or other attenuating artifacts which may obscure normal structures – Homogeneously increased bony activity (superscan) – Restraint artefacts caused by soft-tissue compression – Prior administration of a higher energy radionuclide – Changing bladder activity during SPET of the pelvic region – Purely lytic lesions – Pubic lesions obscured by underlying bladder activity – Renal failure). The more common causes of extra-osseous uptake are: (Normal breast tissue - Breast carcinoma -liver metastases - osteosarcoma metastases - soft tissue sarcomas -tumoral calcinosis - pleural effusion - ascites - calcified uterine fibroids - injection sites - surgical scars -old hematomas)

Different Cases for Bone Scan Technique

the uptake in the normal adult skeleton individual bones is symmetrical about the midline (Fig. 2).

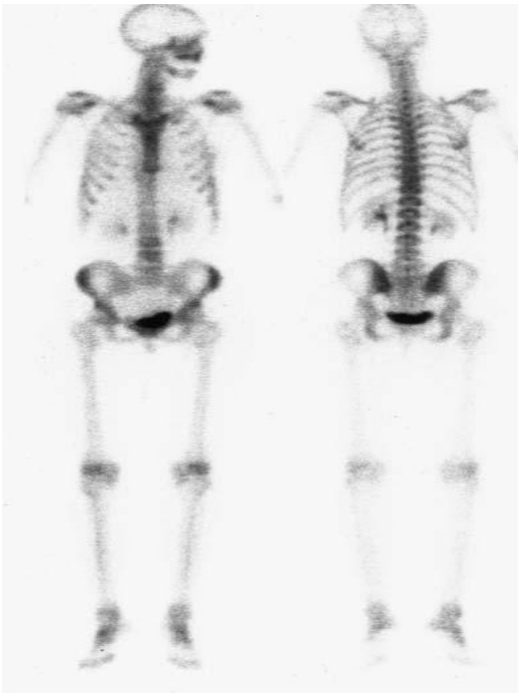

Fig. 2: Normal adult ^{99m}Tc-MDP bone scan, anterior and posterior views.

Some background soft tissue uptake may be appearances, particularly in an obese patient. Both kidneys and the urinary bladder should be readily identifiable. To avoid misinterpretation knowledge of skeletal and urinary tract normal variants should be necessary understood (Fig. 3).

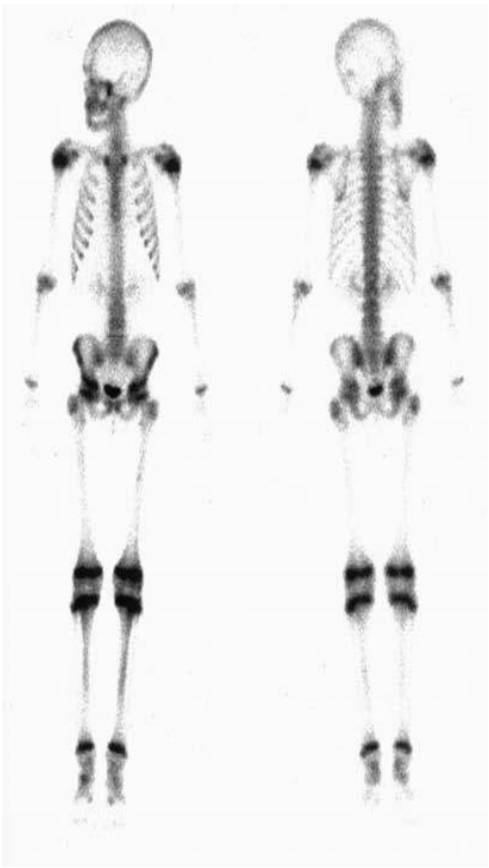

Fig. 3: Normal immature skeleton, anterior and posterior views, with horseshoe kidney.

In the normal immature skeleton the greatest uptake of MDP occurs at the epiphyseal plates, the sites of active bone growth. Uptake fades when the epiphyses fuse and growth ceases. This phenomenon can be useful when early or delayed epiphyseal closure is suspected. If further imaging of an area is deemed necessary, plain films are still the best first-line investigation. In view of the increased sensitivity of the bone scan over plain film, if the radiographs are normal, CT or MRI should be considered.

(99mTc-MDP) bone scintigraphy in Erdheim-Chester disease reveals a symmetrically increased uptake of the distal ends of the long bones of the lower limbs and sometimes of the upper limbs. Besides, in Erdheim-Chester disease, symmetric 99mTc-MDP uptake is observed in progressive diaphyseal dysplasia (Engelmann-Camurati disease) and in systemic mastocytosis (Fig.4).[13]

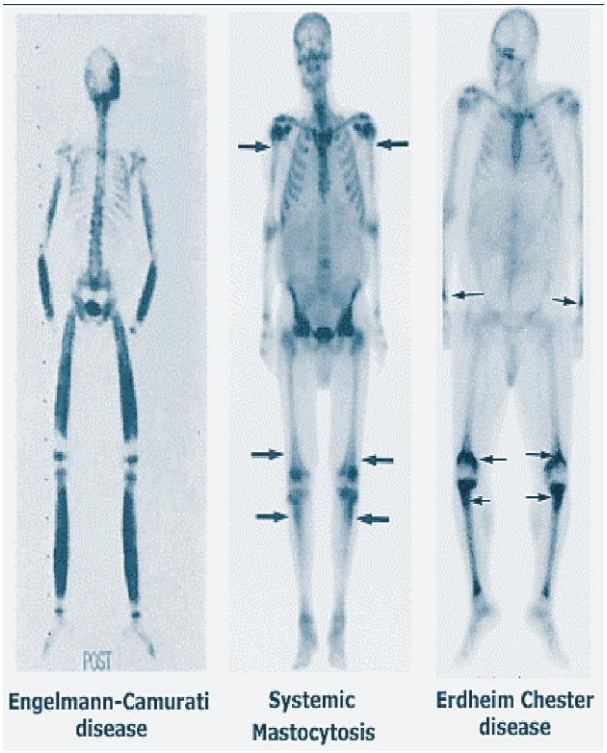

Fig. 4: Symmetric uptake in 99mTc-MDP bone scintigrams is encountered in progressive diaphyseal dysplasia (Engelmann-Camuratti disease), in systemic mastocytosis and in Erdheim-Chester disease

Examples of dystrophic calcification which are often associated with MDP uptake include infarctions of the brain, heart, and muscle, including uterinemyomata. Overexertion of skeletal muscle has also been associated with MDP uptake, presumablyowingtomild degrees of damage and necrosis (Fig.5). Splenicuptake may be observed in auto infarction associated with sickle cellanemia (autoinfarction) (Fig.6), but it can be due to other causes ,such as lymphoma, as well.

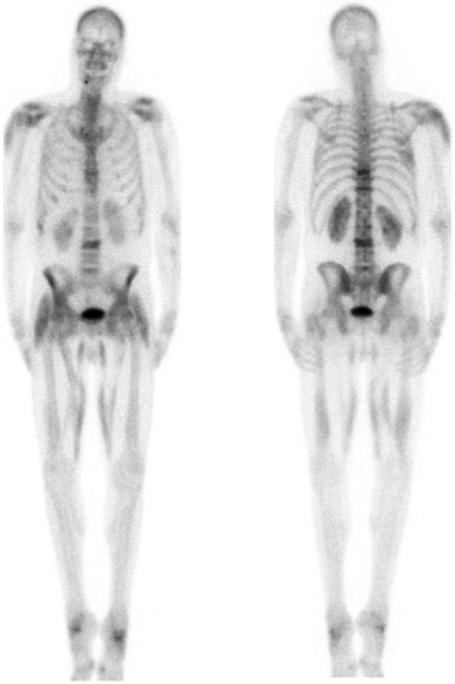

Fig. 5: Anterior and posterior MDP images of a48-year-old man with a brain tumor. Recent seizure resulted in multiple fractures of the thoracolumbarspine. In addition, uptake of MDP in the right deltoid and muscles of the legs bilaterally is consistent with soft tissue injury after seizure.

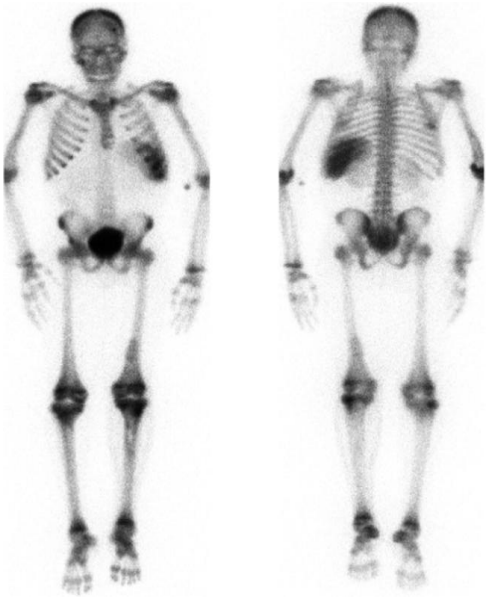

Fig.6: An 18 - year - old with sicklecellanemia. Characteristic findings include prominent activity in the calvarium and at the end of long bones due to marrow expansion, as well as intense activity within the spleen, consistent with auto infarction, related to dystrophic calcification.

The bone scan can be useful in myeloma, as lesions may present themselves by virtue of associated pathological fracture and subsequent healing (Fig.7).

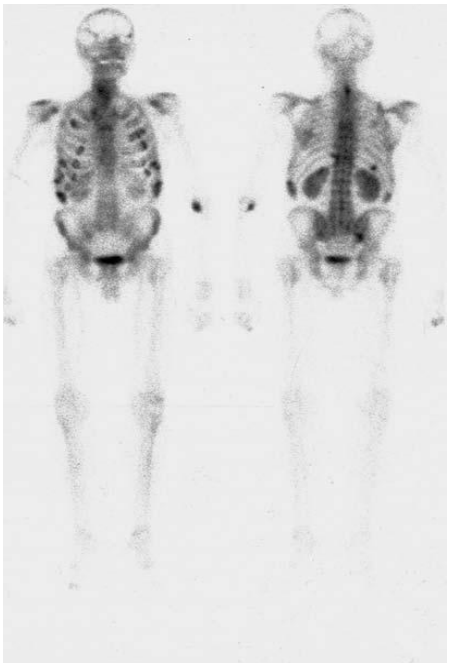

Fig.7: Myeloma with multiple rib and vertebral pathological fractures.

Vertebral compression fractures are the hallmark of this disease (Fig.8).

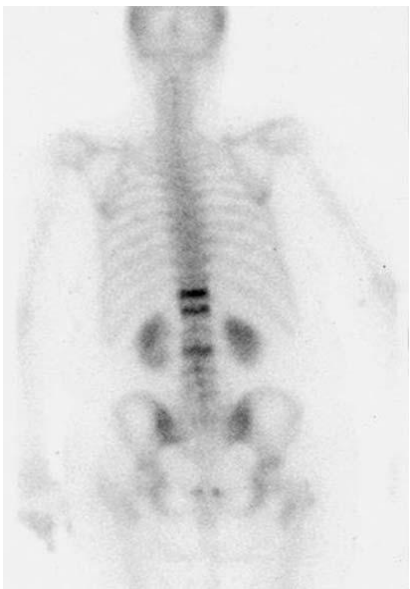

Fig. 8: Posterior view of multiple vertebral fractures due to osteoporosis.

When presented with a patient who has multiple collapsed vertebrae, the bone scan can assist in identification of the symptomatic level, which can guide therapeutic intervention such as vertebroplasty. Demonstration of the entire skeleton has the added advantage of detecting other fractures which may coexist in this vulnerable patient group, or may suggest an alternative diagnosis to account for the patient's pain. In many cases, bone scan is a complementary modality to radiography to detect the Vertebral Fracture and coexistent disease or to exclude a recent Vertebral Fracture. In the growing period infection in either the epiphysis or metaphysis produces similar bone scan appearances with increased uptake on all phases.

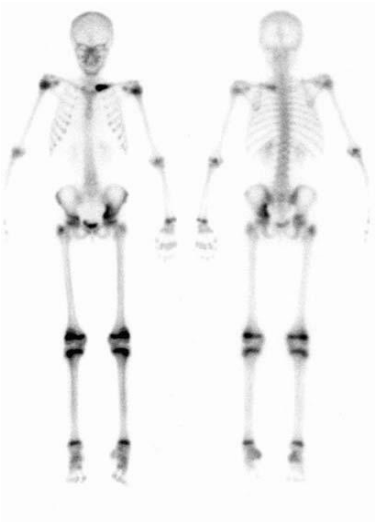

Fig.9: Multifocal osteomyelitis in a child involving medial left clavicle and pelvis.

This is a non-specific pattern which may also be seen in some bone tumors, such as osteoid osteoma or Ewing's sarcoma. Clinical history and radiographic correlation are essential for differentiation. The bone scan's strength lies in its ability to demonstrate the presence of multifocal infection (Fig.9). Fig.10 demonstrates the effect of increased blood flow on 99mTc-MDP uptake to the entire lower extremity secondary to the presence of a primary bone malignancy.

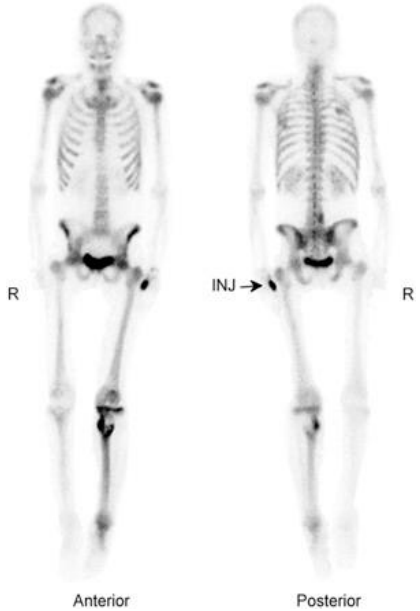

Fig.10: Diffusely increased ^{99m}Tc-MDP uptake of left lower extremity on delayed-phase whole-body bone scan (anterior and posterior projections) as result of increased blood flow due to osteosarcoma in proximal tibia. INJ 5 injection site.

Clearly positive findings of ^{99m}Tc-MDP bone scintigraphy in detecting periprosthetic joint infection of the knee are shown in Fig.11.

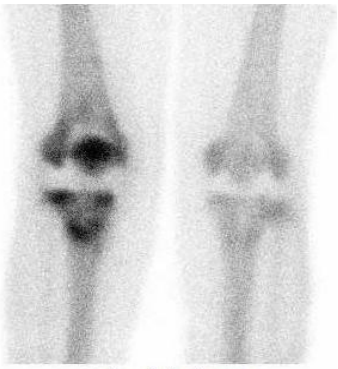

Fig. 11: A 72-year-old female patient with bilateral knee joint replacement.

In the region of right knee replacement extensive increased activity is observed in all three phase of bone scintigraphy indicating infection.

Numerous studies have documented the usefulness of 3- phase bone scans for evaluation of avascular necrosis of the femoral head due to trauma, a slipped capital femoral epiphysis, steroid use, radiation effects, sickle cell disease, or Perthes disease, with accuracies exceeding 95% (Fig. 12). Initial photopenia of the femoral head indicating interruption of blood flow is followed either by necrosis or subsequent reossification and healing response if revascularization occurs.

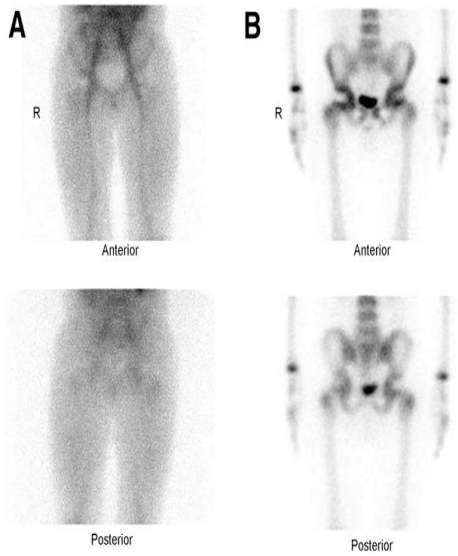

Fig. 12: An 8-y-old boy with right hip pain and avascular necrosis of right femur head (Legg-Calve-Perthes disease). Anterior and posterior projection soft-tissue (A) and delayed-phase images (B) show focally decreased 99mTc-MDP uptake in right femoral head.

A 57-year-old-man with lung mass and left pleural effusion was referred to the nuclear medicine department for Tc-99m MDP bone scan to assess the bone metastases. Bone scintigraphy revealed diffuse accumulation of Tc- 99mMDP on extrathorasic soft tissue in the left hemithorax (Fig.13). On examination, there was extensive subcutaneous edema along the lower chest wall corresponding Tc-99m MDP uptake on bone scan.[14]

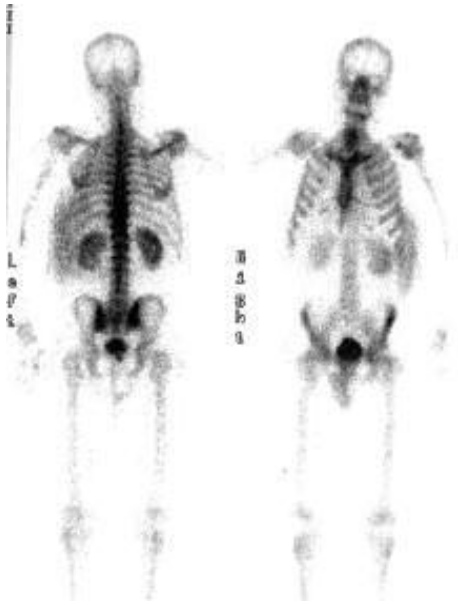

Fig.13: A bone scintigram was performed 3 h after the intravenous injection of 740 MBq (20 mCi) Tc-99m MDP using a large-field-of-view gamma camera equipped with a low energy-high resolution collimator. Posterior and anterior whole body images demonstrated diffuse accumulation of Tc-99m MDP on extrathorasic soft tissue in the lower left hemithorax correspond to subcutaneous edema along the lower chest wall.

Conclusion

Skeletal scintigraphy (bone scan) is a sensitive technique in decteing a wide variety of bone pathologies including fractures, infection, and cancer. The choice of modality will depend on the area of the body in question, and the suspected pathology. Technetium-99m radiopharmaceuticals play an important role in wide range of applications in nuclear medicine. Bone scan technique, use radioactive nuclides with low doses compared by (CT). Bone can can identify disease in its earliest stages, it can often find bone abnormalities much earlier than a regular x-ray exam. In many cases, bone scan is a complementary modality to radiography to detect some disease. When evaluating and interpreting the bone scan images, some points should be taken into considerations, like patient history and patient age. Knowledge of skeletal and urinary tract normal variants is necessary to avoid misinterpretation.

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