PICTORIAL

MUSCULOSKELETAL SPECT-CT: A PICTORIAL REVIEW

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SPECT-CT being a hybrid imaging scanner provides molecular and anatomical imaging in one go as a one stop shop. The addition of correlative CT scan to the planar skeletal scintigraphy gives better localization of the lesion, its characterization and attenuation correction as well. We present a brief overview of our institutional experience with hybrid SPECT-CT, as an adjunct to planar skeletal scintigraphy. SPECT-CT imaging improves the diagnostic yield and specificity of planar skeletal scintigraphy.

Keywords: Bone scan, planar skeletal scintigraphy, hybrid, SPECT-CT, equivocal bone lesions

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INTRODUCTION

For decades bone scintigraphy has been the mainstay in the evaluation of bone abnormalities providing functional information with high sensitivity. However, bone scintigraphy is not an ideal tool for characterization of bone abnormalities and remains a non-specific examination. Although SPECT images provide better evaluation of abnormal tracer uptake, this technique still lacks accurate anatomic localization.[1]

SPECT is defined as three-dimensional tomographic imaging of radioactive tracer distribution. Whereas, CT is three-dimensional tomographic anatomical imaging performed with an external x-ray source. For co-registration of anatomic and functional images, software algorithms were developed in 1980s.

Initially fusion was performed in the brain with external markers for co-registeration.[2] Hasegawa and his colleagues formed the basis of hybrid SPECT-CT systems for clinical use.[3] Based on that, Hawkeye, the first commercial hybrid system was developed by General Electric in 1999.[4]

Fusion of functional imaging (bone scintigraphy) and anatomical imaging (CT) provides a useful tool to improve diagnostic utility with more precise anatomical reference to bone involvement and morphological characterization. Hybrid SPECT-CT provides accurate attenuation corrected images.[5,6]

Most recently, the utility of SPECT-CT is being extensively evaluated in the areas of malignant and benign bone diseases. We present selected cases in this pictorial review, highlighting the added value of SPECT-CT in oncological and non-oncological indications.

A. SPECT CT in non-skeletal malignancies

Metastatic bone lesions are depicted as areas of increased tracer uptake on Tc99mbone scintigraphy. The differentiation between metastasis and benign pathology on bone scintigraphy is made based on the pattern of random distribution and location of the lesions.[7] However, a solitary lesion is always a challenge and needs to be characterized. With co-registered CT images in SPECT-CT, the sclerotic or osteolytic changes are depicted making the characterization of metastasis easier.[8] Figure 1–4

B. SPECT CT in non-oncological indications

Bone scan is indicated in a wide spectrum of benign musculoskeletal pathologies, mainly including musculoskeletal pain, infection/inflammation and trauma. With SPECT-CT better delineation of bones, joints and soft tissue along with anatomical depiction of soft tissue changes, periosteal reaction, cortical erosions and sclerosis provide diagnostically useful information for characterization.

The evidence for the use of SPECT-CT in benign musculoskeletal pathology is still emerging, but it has been shown to improve specificity.[9] The following cases show the additional value of SPECT-CT in specific clinical settings; infection/Inflammation (Figure 5–7), trauma (Figure 8–10), arthropathy (Figure 11–13), avascular necrosis (Figure 14), bone island (Figure 15), fibrous dysplasia (Figure 16), compression fracture (Figure 17), schmorl's node (Figure 18), enthesopathy (Figure 19), haemangioma (Figure 20).

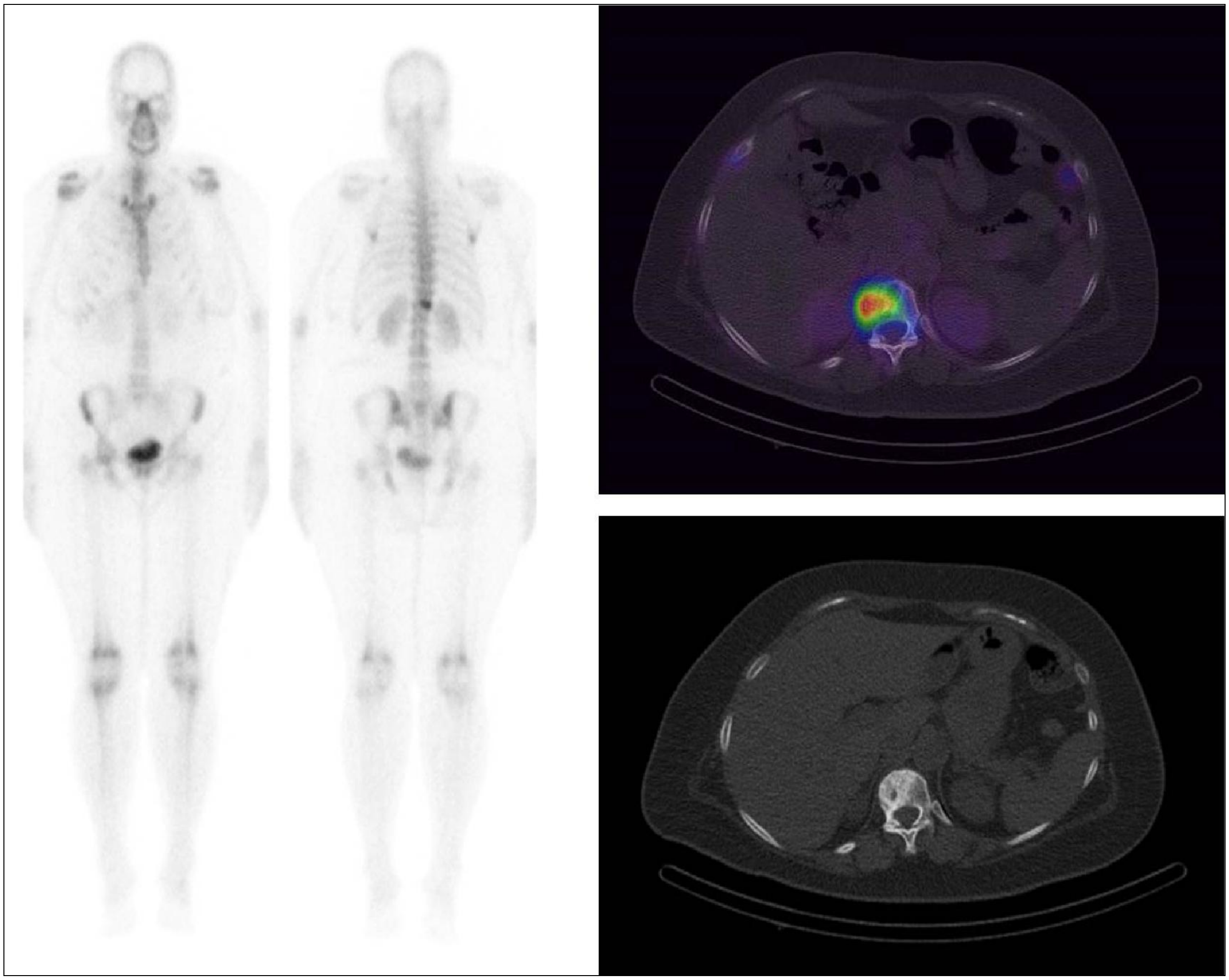

Figure-1: Carcinoma breast. Planar Tc-99m MDP whole body bone scan shows focal increased uptake in the D11 vertebra. Transaxial fusion SPECT-CT and CT images localize this focus of increased uptake to mixed sclerotic/lytic metastatic deposit.

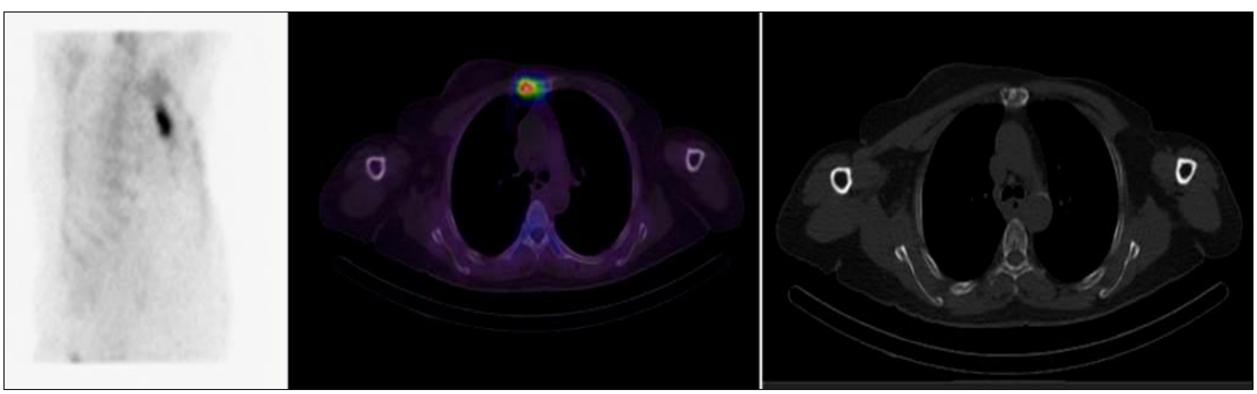

Figure-2: Carcinoma breast. Anterior oblique chest view on planar Tc-99m MDP bone scan shows focal increased uptake in the sternum. On transaxial Fusion SPECT-CT and CT images, this corresponds to an osteolytic metastatic deposit.

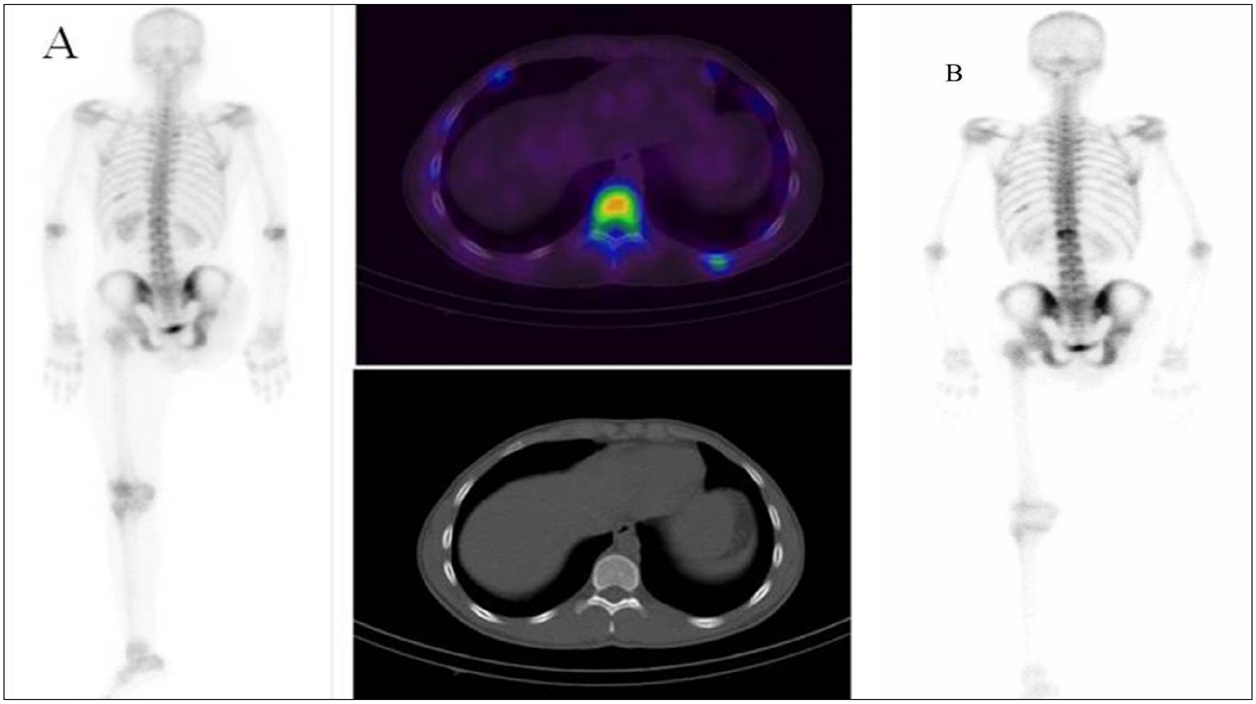

Figure 3: Synovial sarcoma of right thigh. Baseline planar Tc-99m MDP bone scan (A) shows mild uptake in the left 7th rib posteriorly. On fusion SPECT-CT axial images this corresponds to subtle sclerosis representing metastatic deposit. Follow-up bone scan (B) shows additional metastasis in the spine.

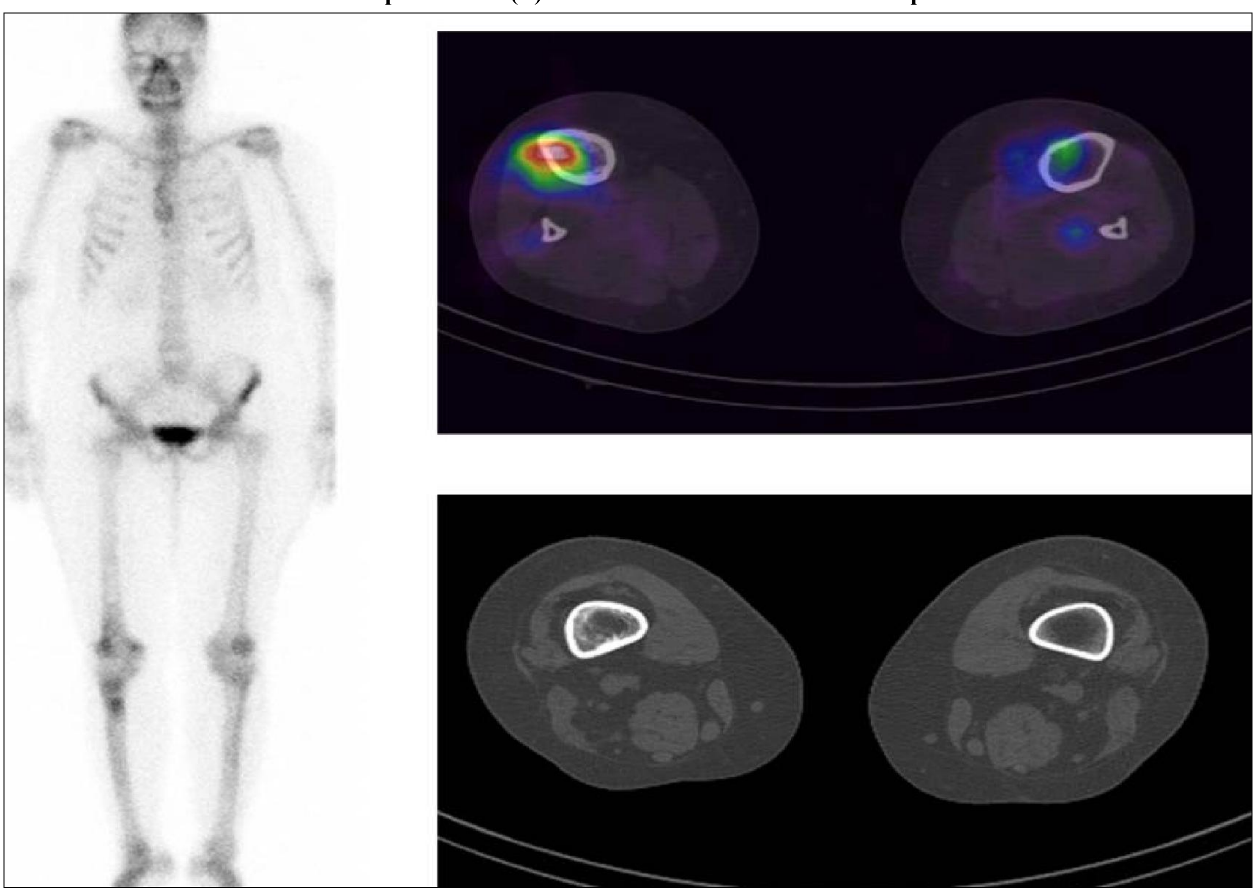

Figure-4: Carcinoma prostate. Planar whole body Tc-99m MDP bone scan shows focal increased uptake in the proximal shaft of right tibia. On Fusion SPECT-CT transaxial images, this corresponds to an intramedullary sclerotic metastatic deposit.

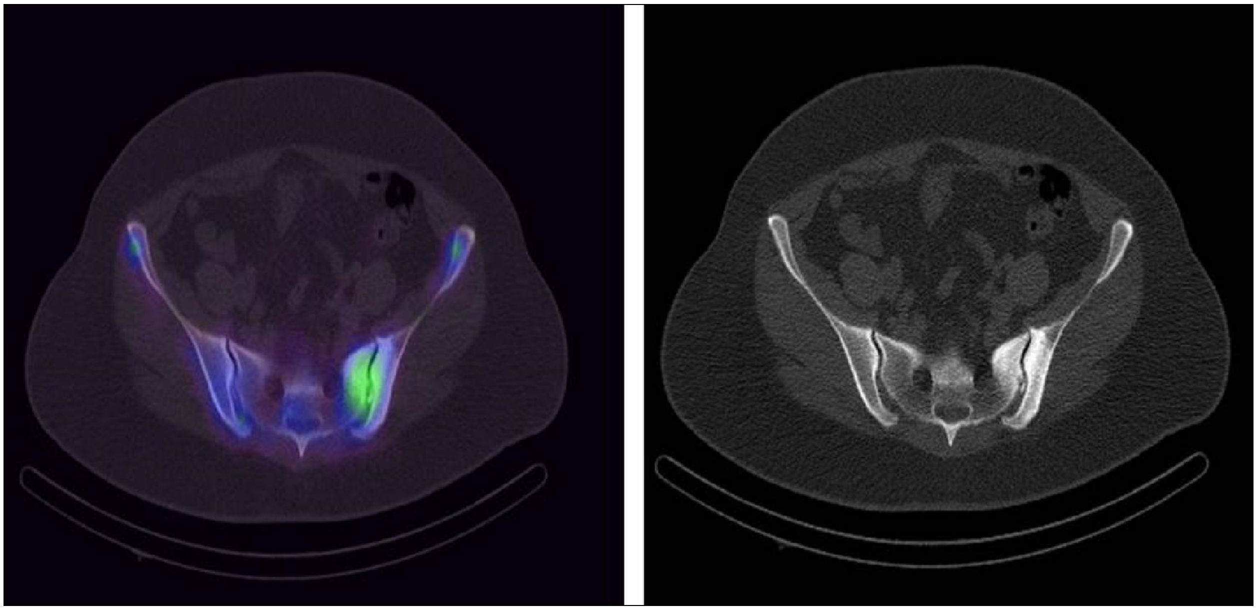

Figure-5: Localized low backache. Transaxial fusion SPECT-CT and CT scan of pelvis demonstrates increased uptake in the left sacroiliac joint corresponding to diffuse sclerosis of sacral and iliac components of the joint, characteristic of sacroilitis

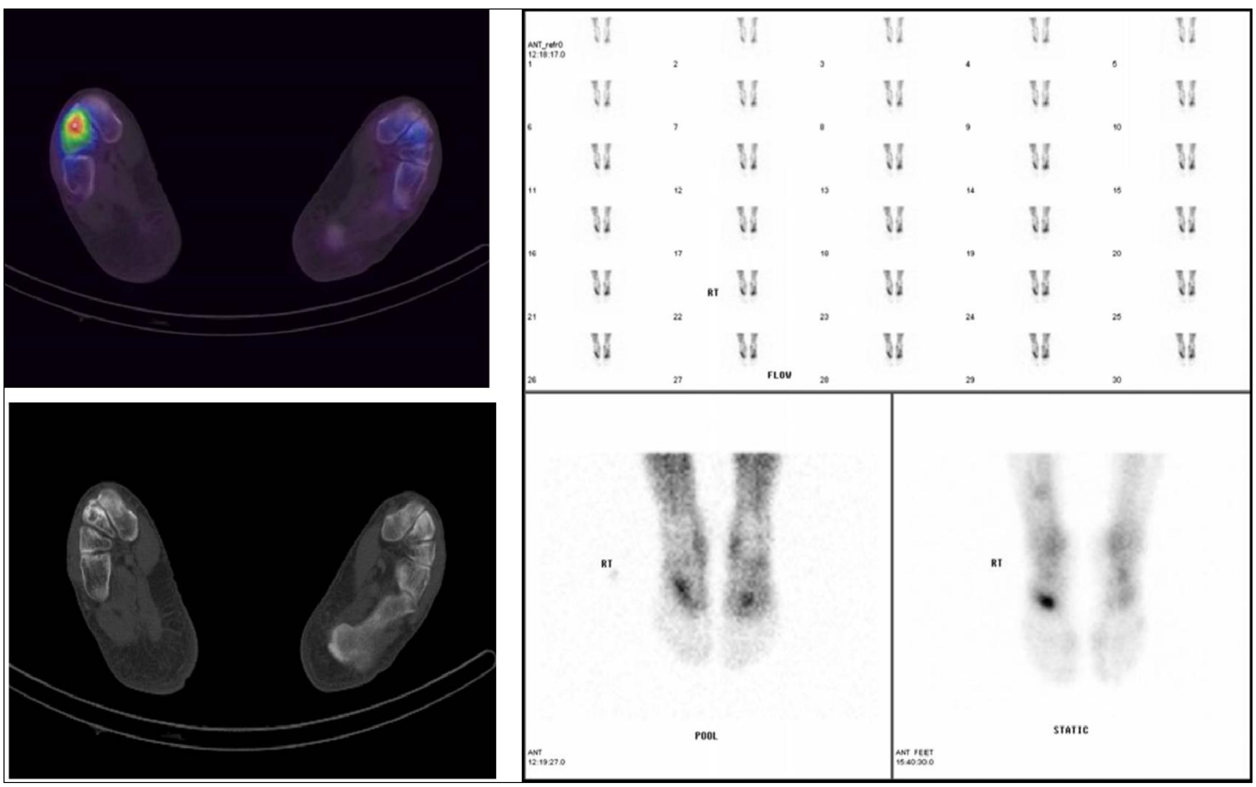

Figure-6: Pain and swelling of right mid-foot in a diabetic patient. Three phase planar bone scan [A] of feet shows hyperemia, increased blood pool and delayed uptake in the right mid-foot. Mild blood pool activity is also seen in the left mid-foot as well. Transaxial fusion SPECT-CT images localize this focal uptake of right mid-foot to erosive sclerotic changes in the second metatarsal bone, favoring chronic osteomyelitis. Subtle increased uptake with mild sclerosis of second metatarsal on the left side demonstrates early bone changes secondary to inflammation.

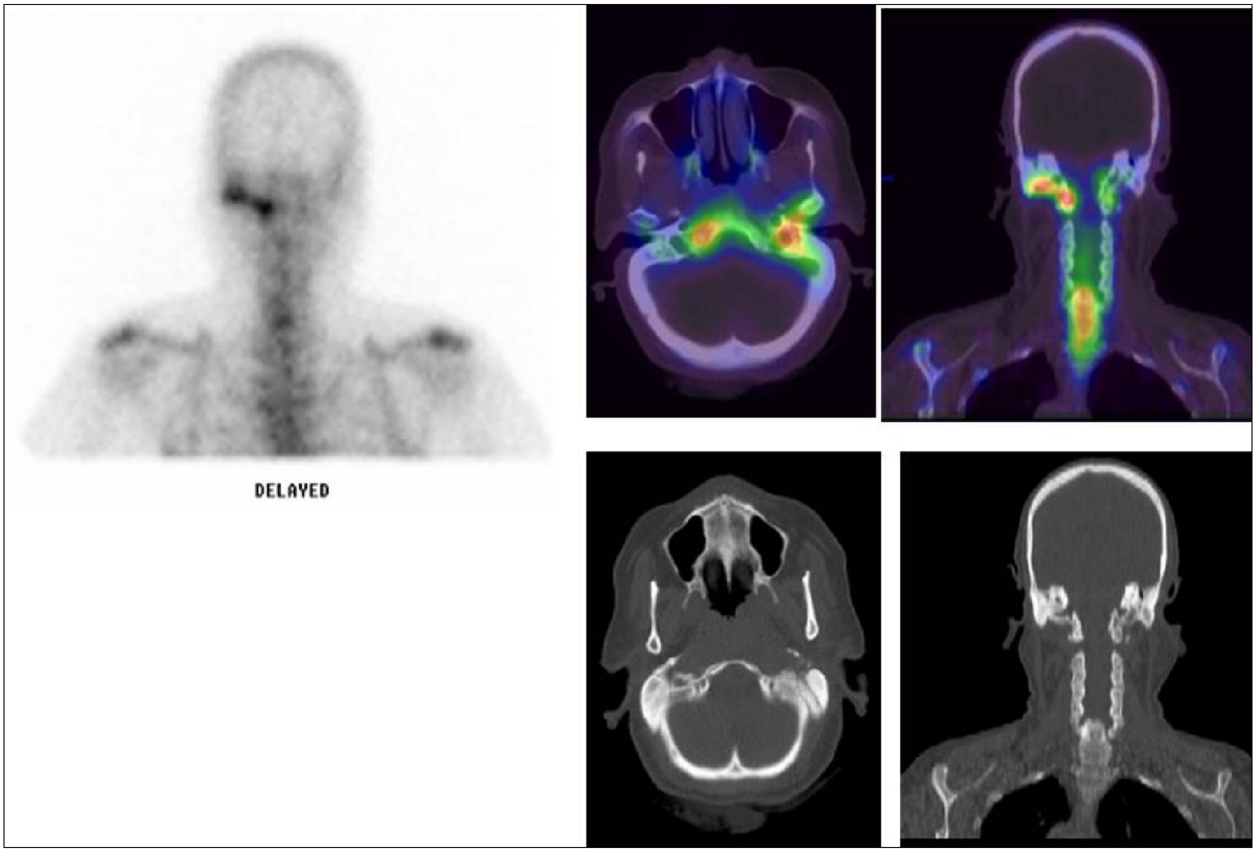

Figure-7: Left earache and purulent discharge. Posterior view of head, neck and upper chest on planar bone scan shows increased uptake in the left skull base. Fusion SPECT-CT and CT in transaxial and coronal views demonstrate sclerotic changes in the left mastoid process and loss of air cells in the left petrous part of temporal bone favouring osteomyelitis.

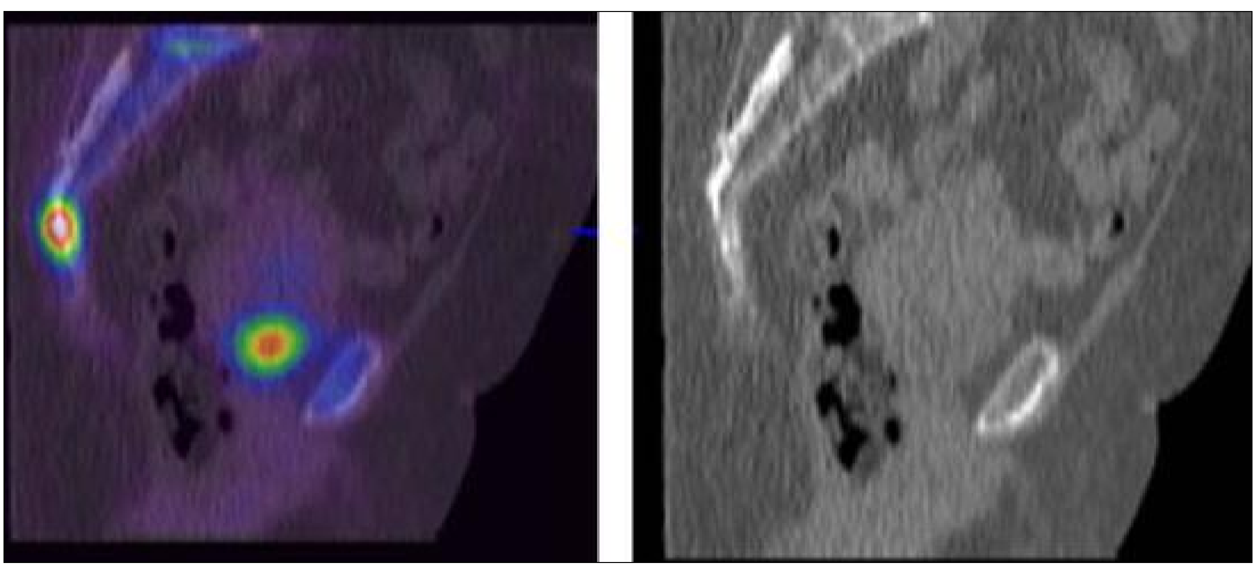

Figure-8: Low backache. Fusion SPECT-CT and CT scan of pelvis in sagittal views show focal increased uptake in coccyx with an underlying fracture.

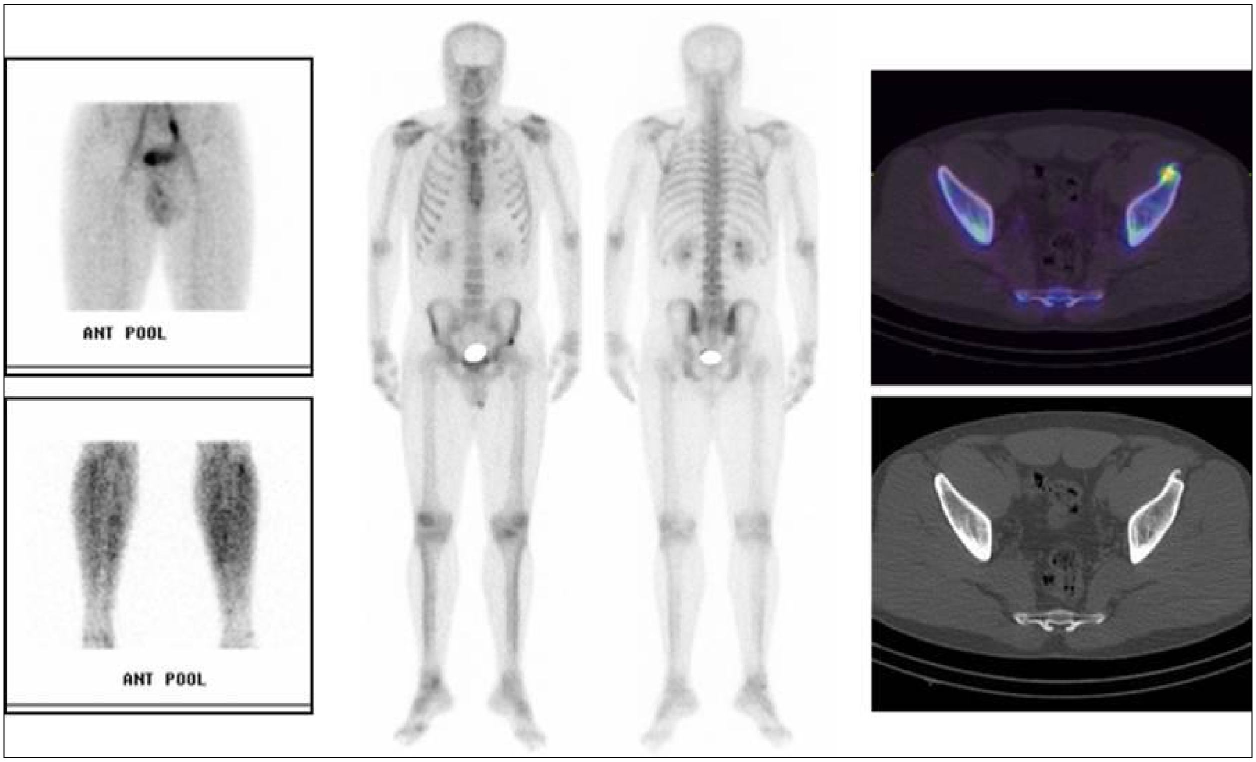

Figure-9: Pain in left calf. Three phase scan of lower limbs demonstrated normal pool activity in the legs. However, focal uptake in left proximal thigh is identified on pool views of anterior pelvis. Delayed planar bone scan also shows focal increased uptake in left anterior superior iliac spine. Transaxial fusion SPECT-CT and CT images of pelvis localize an avulsion fracture of left anterior superior iliac spine.

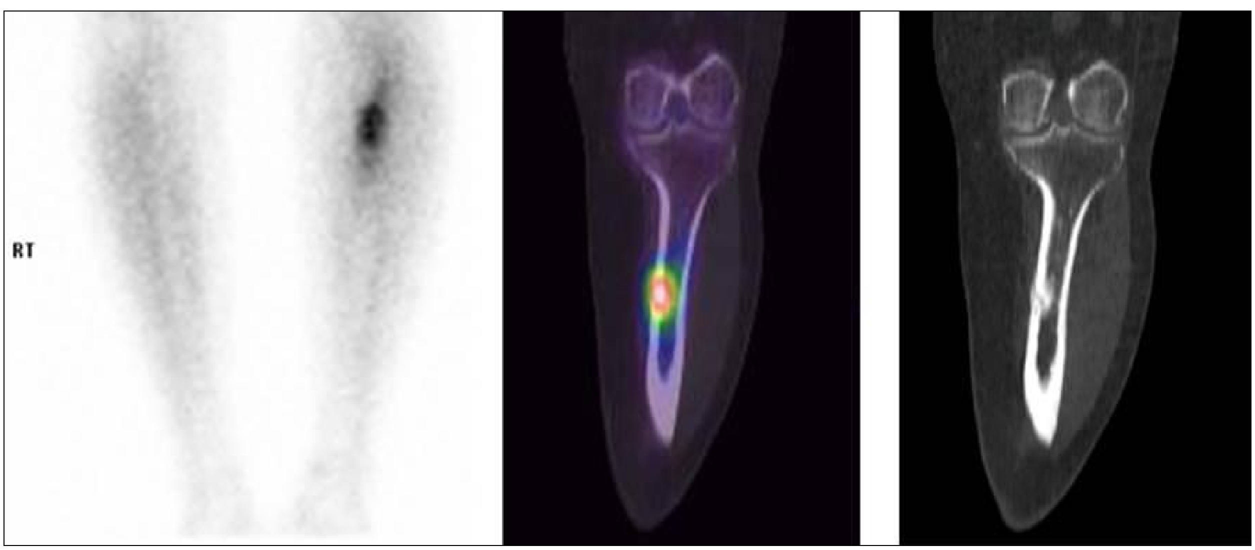

Figure-10: Pain in left calf in a marathon runner. Initial phase pool images of legs on Tc-99m MDP bone scan show abnormal focal increased uptake in proximal left tibia medially. Coronal fusion SPECT-CT and CT images localize this focal uptake to a stress fracture of mid-shaft of left tibia along the medial cortex.

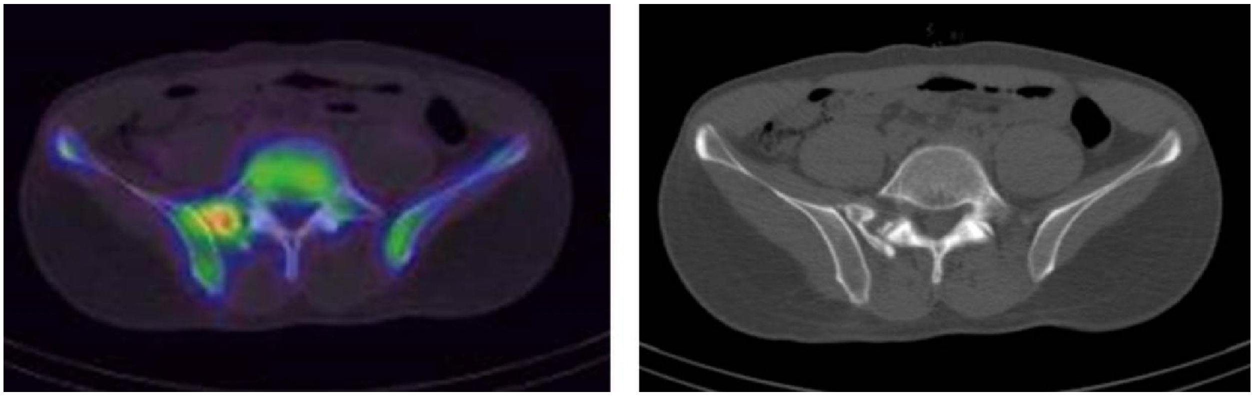

Figure-11: Spindle cell sarcoma of right forearm. Transaxial fusion SPECT-CT and CT scan through the lower lumbar spine shows focal uptake at pseudoarthrosis at right sacroiliac joint with sacralization of lateral process of L5 vertebra.

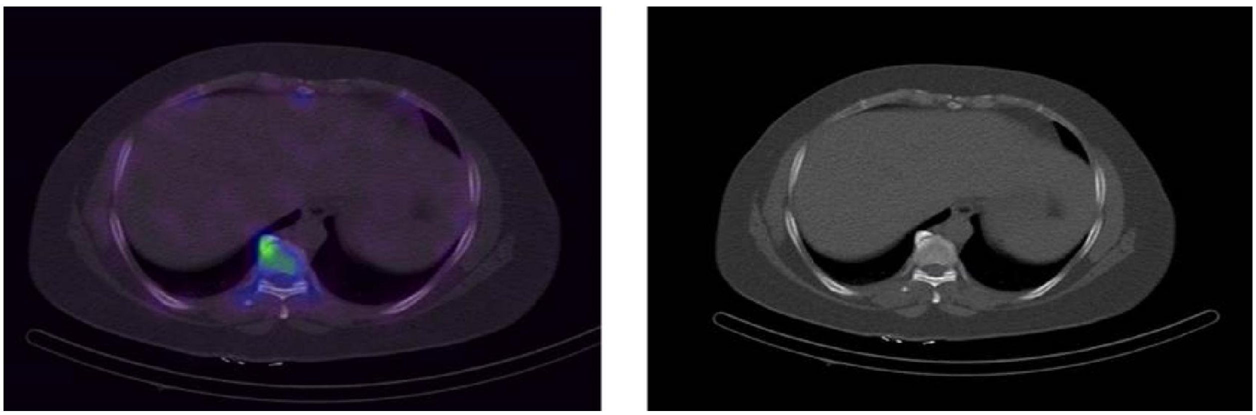

Figure-12: Low backache. Transaxial fusion SPECT-CT and CT scan through lower chest shows an anterior osteophyte at the D11 right hemi-vertebra with focal increased tracer uptake.

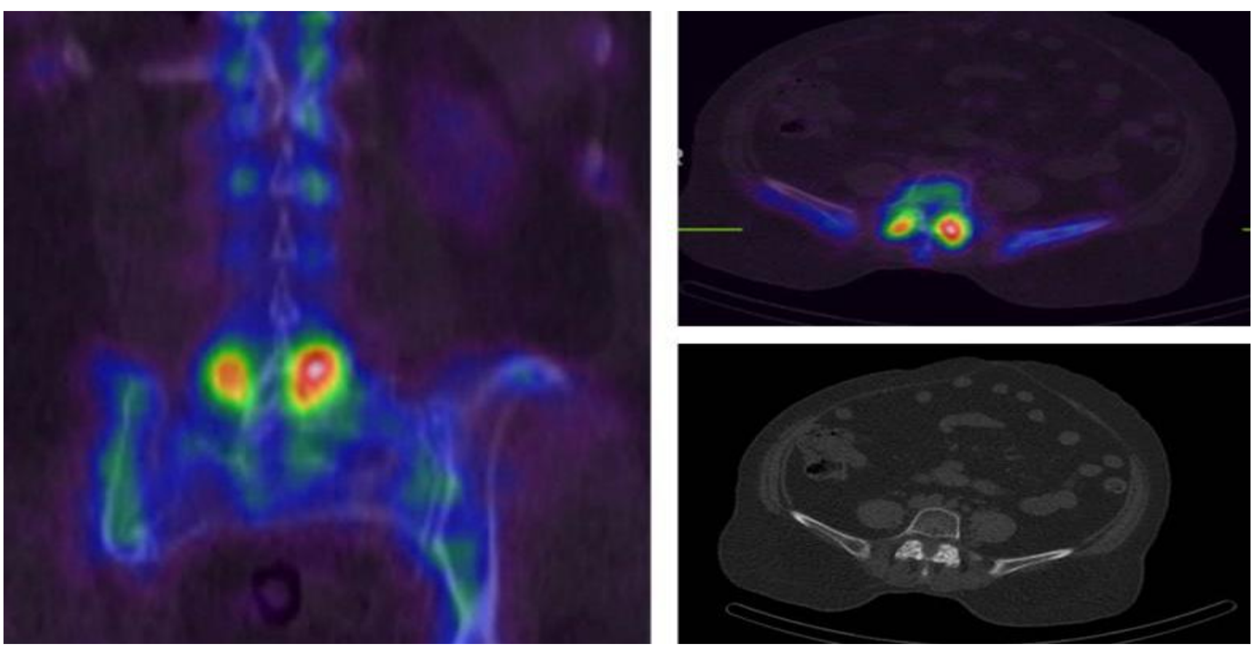

Figure-13: Low backache. Transaxial and sagittal fusion SPECT-CT and CT images localize symmetrical foci of increased uptake to bilateral facet joint arthritis at L5/S1 vertebrae.

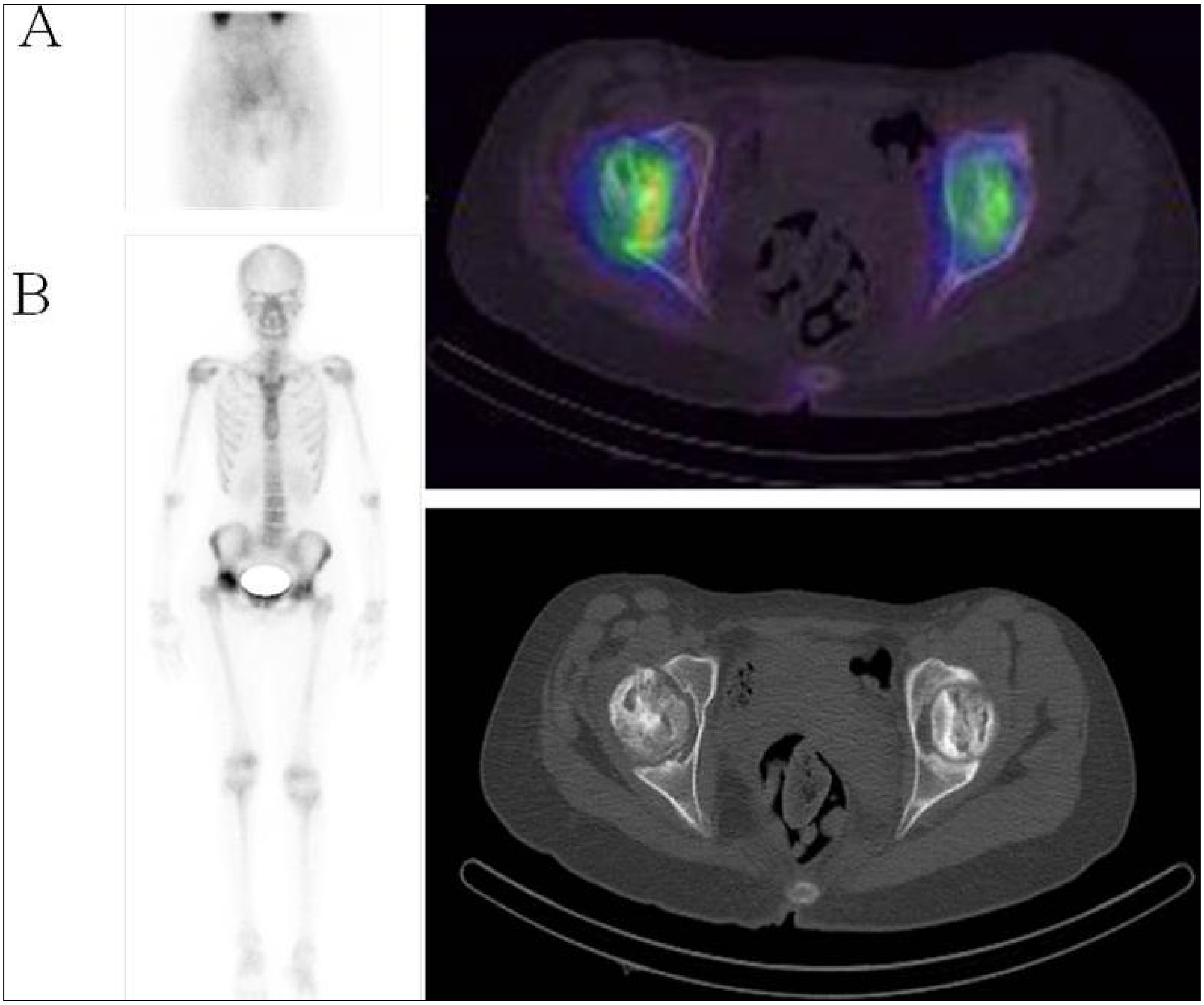

Figure-14: Pain in right hip joint. Blood pool images of pelvis show subtle soft tissue uptake in the region of right hip joint. Planar whole-body scan shows increased uptake in femoral heads bilaterally. Transaxial fusion SPECT-CT and CT scan demonstrates erosive sclerotic changes of advanced avascular necrosis [AVN] with scattered lucencies in femoral heads bilaterally.

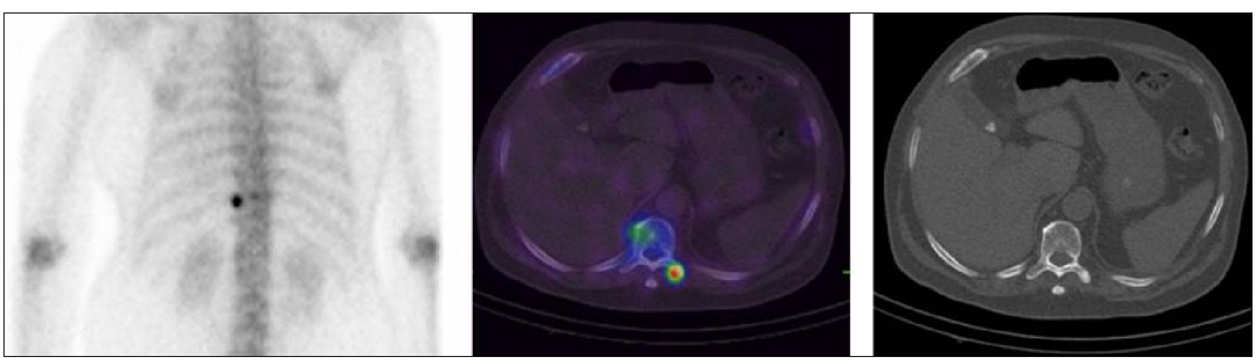

Figure-15: Carcinoma prostate. Spot view of posterior chest on planar bone scan demonstrate focal increased uptake in the left lateral process of D10 vertebra. Transaxial fusion SPECT-CT and CT images localize a bone island with sclerotic focus

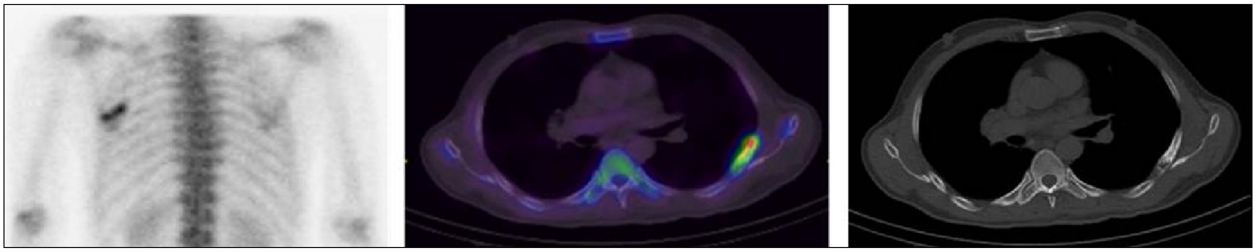

Figure-16: Squamous cell carcinoma of upper lip. Spot view of posterior chest on planar bone scan shows abnormal increased uptake along the left sided 5th rib postero-laterally. On fusion SPECT-CT axial images fibrous dysplasia is localized, with expansile fusiform enlargement of bone and cystic lucencies.

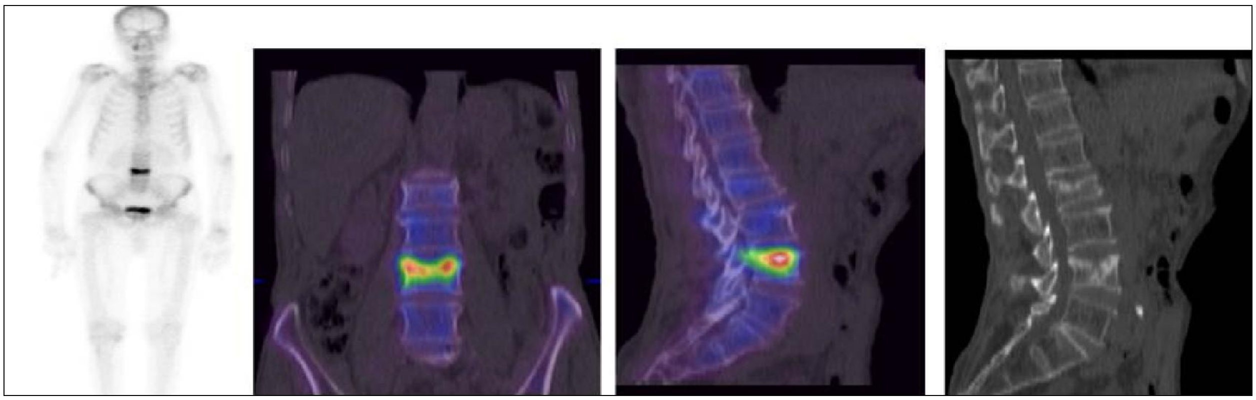

Figure-17: Low backache. Whole body planar bone scan show abnormal increased linear uptake along the L3 vertebral endplate with additional mild increased uptake along the L1 vertebra. Coronal and sagittal fusion SPECT-CT and CT scan through lumbar spine localize degenerative compression fractures of L1 and L3 vertebrae.

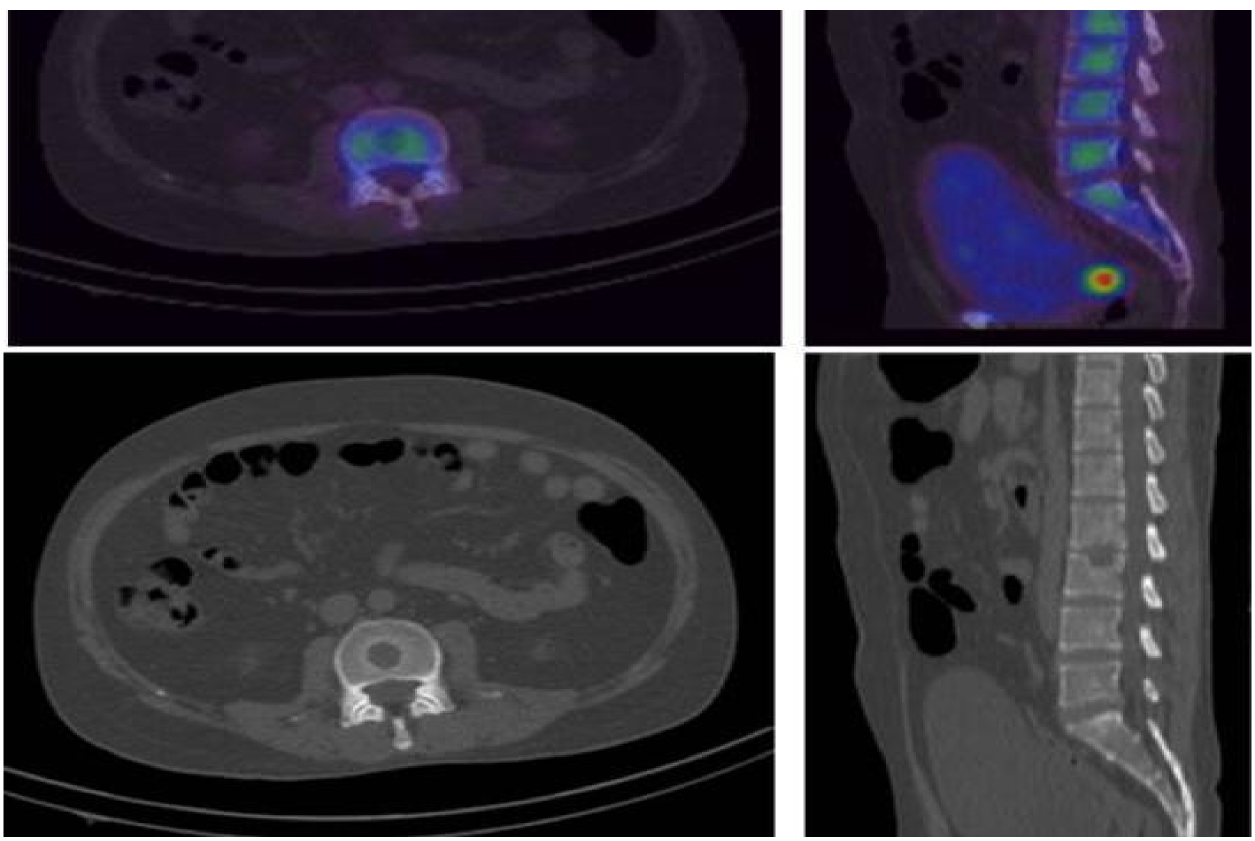

Figure-18: Low backache. Transaxial and sagittal fusion SPECT-CT and CT axial images depict Schmorl's node as a circumscribed lucent lesion centralized in the body of L3 vertebra with mild tracer uptake.

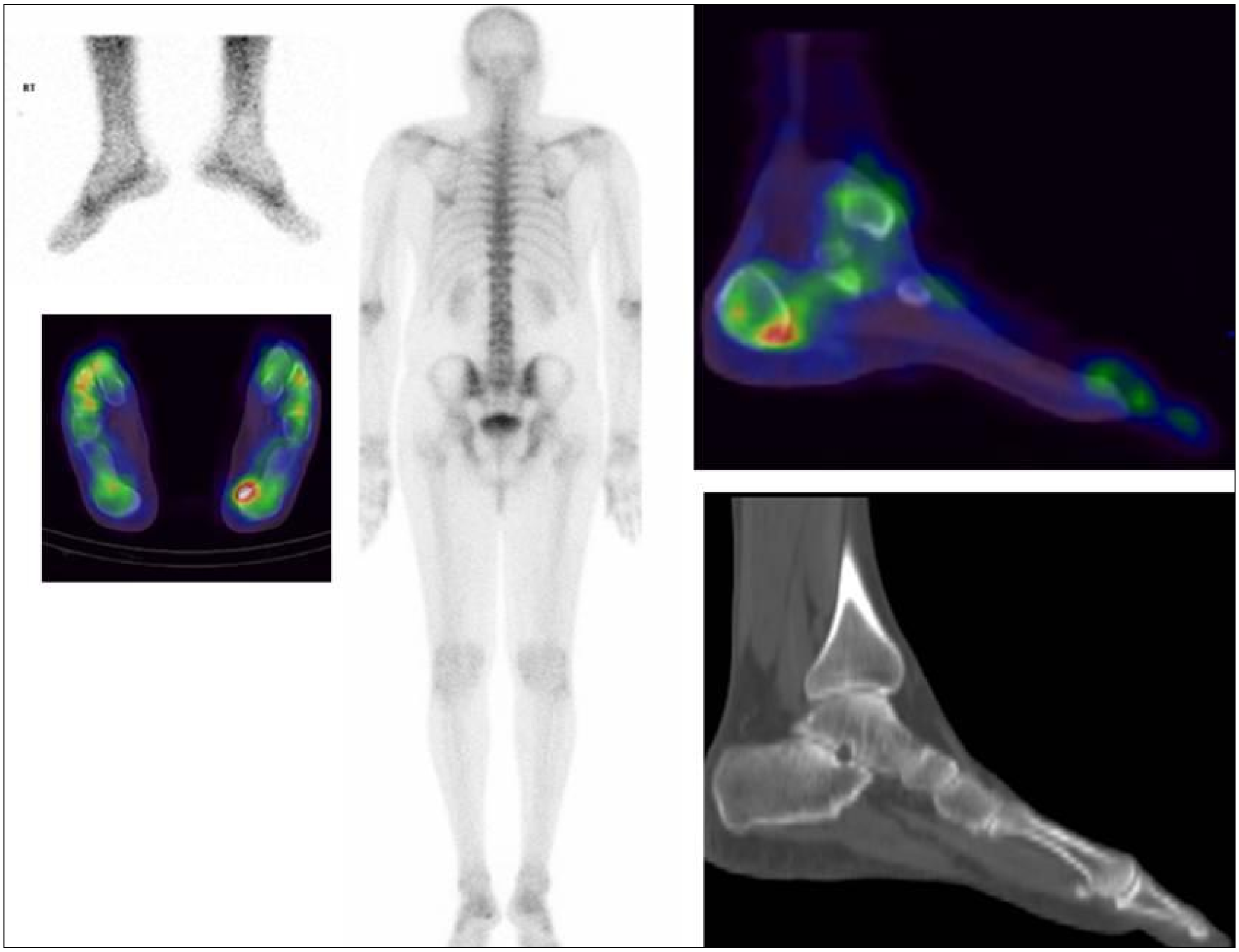

Figure-19: Pain in left heel. Three phase planar bone scan of feet shows normal blood pool activity. Delayed planar images show mild focal uptake on the medial aspect of left calcaneus posteriorly. Transaxial and sagittal fusion SPECT-CT and CT images display focal plantar enthesopathy, with no morphological abnormality on CT scan.

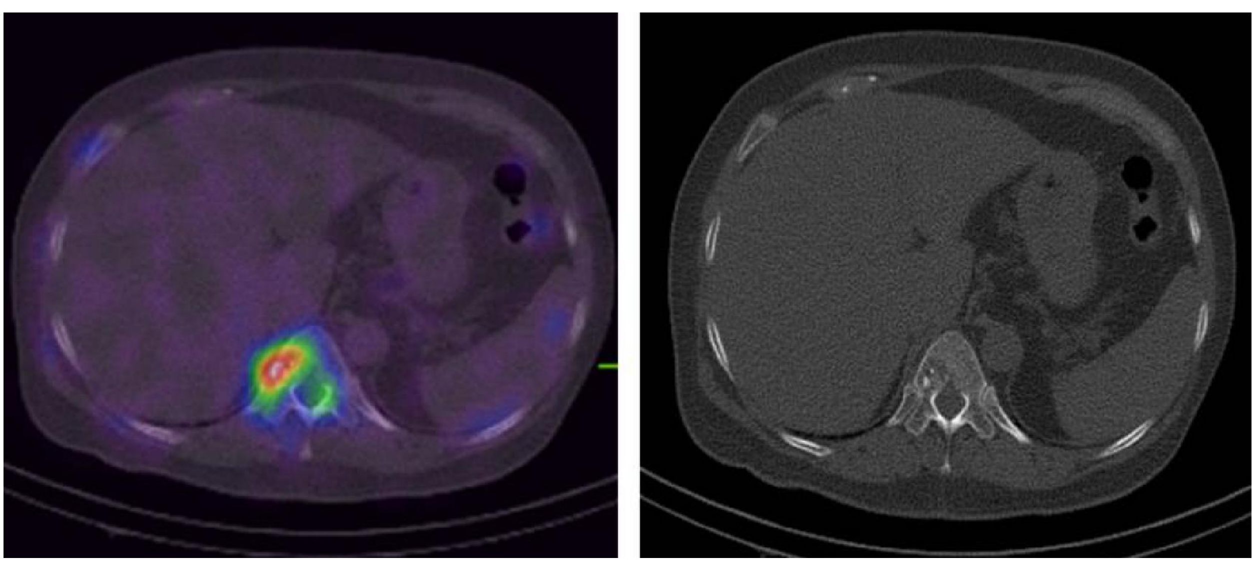

Figure-20: Carcinoma breast. Fusion SPECT-CT axial images display focal increased uptake in the right hemi-vertebral body at D11 with underlying dotted punctate sclerotic foci, characterizing a hemangioma.

DISCUSSION

With the provision of functional and anatomical details in single imaging, SPECT-CT has shown promising results as a diagnostic tool and is increasingly being used in clinical practice. Potential applications for non-oncologic bone imaging include the evaluation of infective or inflammatory bone pathology, traumatic lesions and differentiation of benign from malignant processes. The most advantageous feature of SPECT-CT is the characterization of bone processes in equivocal osseous lesions.[10,11] The precise lesion localization, higher contrast and attenuation correction helps in better image interpretation with higher diagnostic confidence.[12] With fusion of SPECT and a non-diagnostic low-dose CT Palmedo H *et.al* have reported a 97% sensitivity, 94% specificity, 97% negative and 88% positive predictive values for the evaluation of skeletal lesions in oncological patients.[13] Similarly, for degenerative benign disk disease, bone SPECT-CT is more reliable (Kappa=0.81) than bone SPECT (Kappa=0.60).[14]

We have presented a collection of cases representative of common clinical indications of bone scintigraphy, where we found added benefit of SPECT-CT with conclusive characterization. SPECT-CT has brought diagnostic confidence to image interpretation. M. Donald Blaufox has beautifully written in the foreword of 'Radionuclide & Hybrid Bone Imaging' that with SPECT-CT, "the power of bone scan has increased logarithmically".[15]

CONCLUSION

In summary, SPECT-CT imaging improves the diagnostic yield and specificity of planar skeletal scintigraphy. Accurate localization and morphological characterization leads to better patient management.

Ethical statement: This article does not contain any studies with human participants or animals performed by any of the authors.

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