

SPECT/CT Applications

Layla Ali Ph.D.

Assistant Professor

department of Radiologic Sciences

Faculty of Allied Health Sciences

Kuwait University

SPECT/CT Workshop 8-9 Dec, 2009

SPECT/CT Imaging

- CT imaging is based on **morphologic** criteria such as size, texture and tissue attenuation.
- CT provides information regarding changes in organ size and tissue density, also their precise spatial localization and topographic landmarks.
- SPECT imaging is based on the **biodistribution** of a radioactive agent over time and space, thus visualizing physiological and pathophysiological processes of disease.
- Whole body assessment with a single radiation exposure

Morphologic and functional imaging modalities are complementary and not competing techniques, especially if precise image registration is made possible by using a single imaging unit combination.



Cardiac SPECT/CT procedures

- *Myocardial perfusion imaging — CT based attenuation correction*
- *Cardiac SPECT/CTA for assessing the significance of coronary artery lesions*
- *Coronary artery calcium score*

Cardiac SPECT/CT

- Myocardial perfusion imaging (MPI), is at present the main non-invasive modality for evaluation of coronary artery disease
- MPI-SPECT accuracy is limited by image artifacts mainly due to photon attenuation:
 - The breast (anterior wall in women)
 - The diaphragm (inferior wall in obese men)

Cardiac SPECT/CT

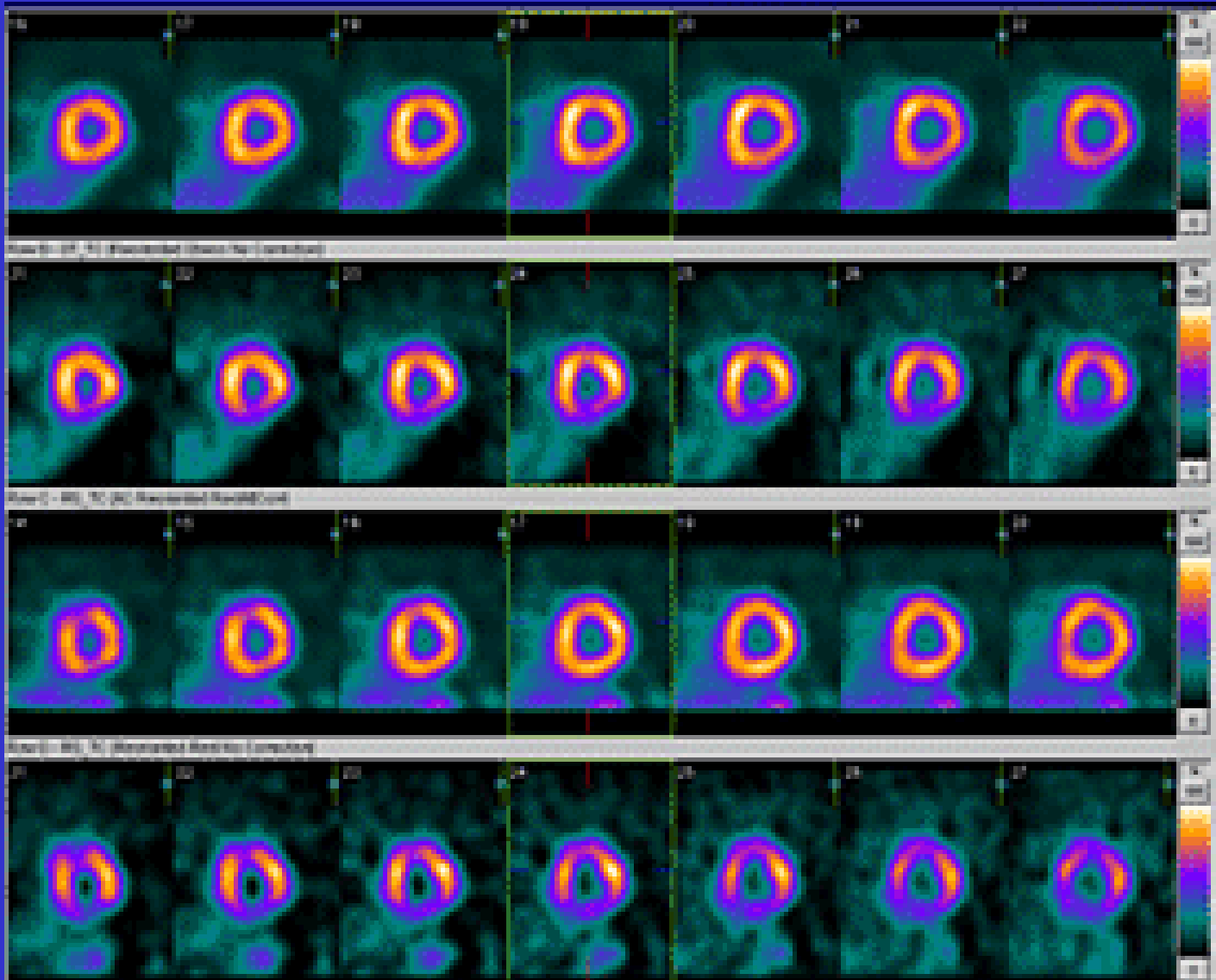
- Several approaches to address false positive results due to attenuation:
 - awareness of their potential occurrence & location
 - routine assessment of raw imaging data
 - Comparative assessment of studies after changing patient's position (supine versus prone)
 - Gated imaging

Historically, SPECT/CT systems have been initially developed with the specific goal of achieving optimal CT based attenuation of

myocardial perfusion scintigraphy
CT based attenuation correction has been shown to provide the most reliable & accurate high quality cardiac SPECT images through

- ❖ high resolution
- ❖ high count-rate

SPECT/CT vs Conventional SPECT MPI

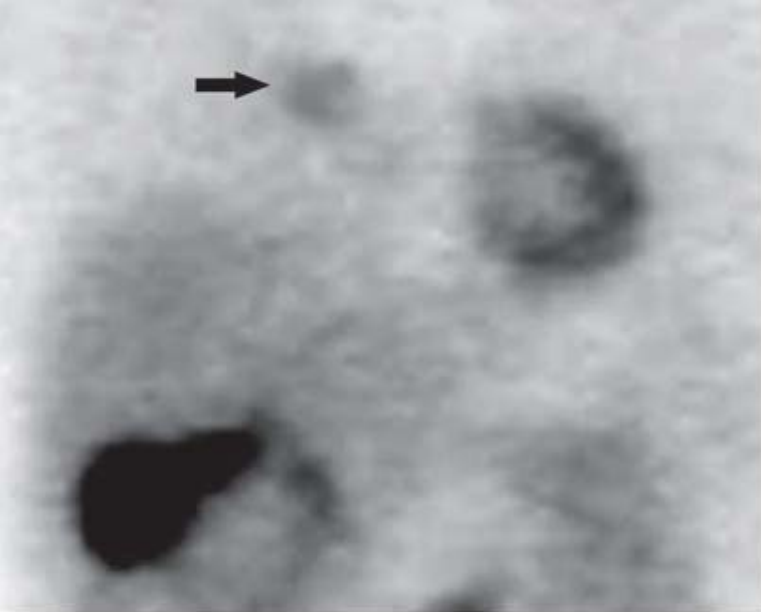


Stress corrected

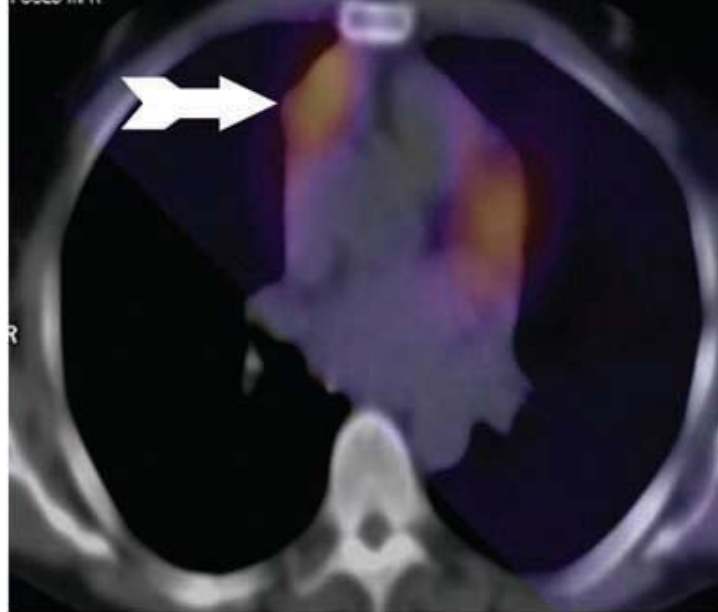
Stress uncorrected

Rest corrected

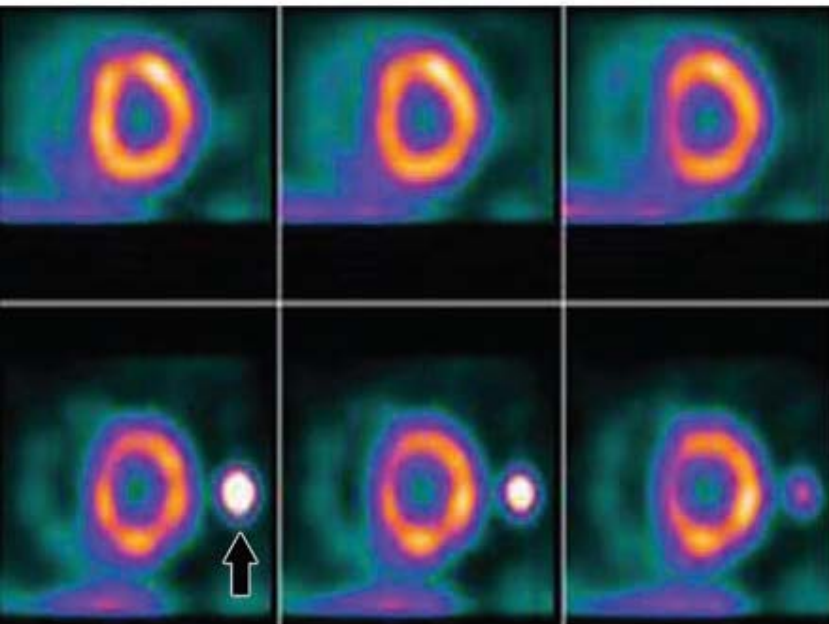
Rest uncorrected



a.



b.



c.



d.

a. Myocardial perfusion

SPECT image

b. Low dose SPECT/CT

image

c. Myocardial perfusion

SPECT images

d. CT image shows no

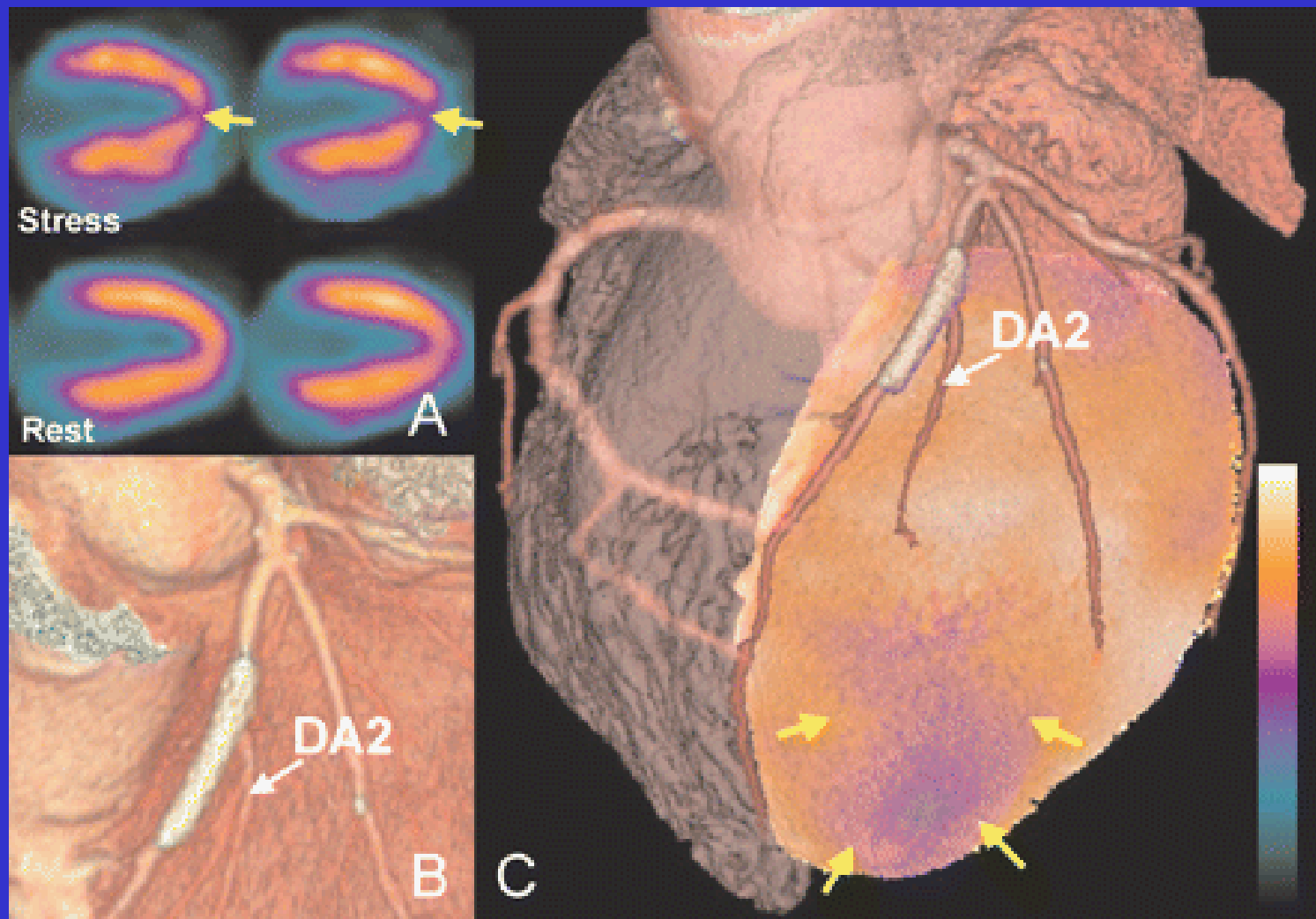
abnormality

Cardiac SPECT/CTCA

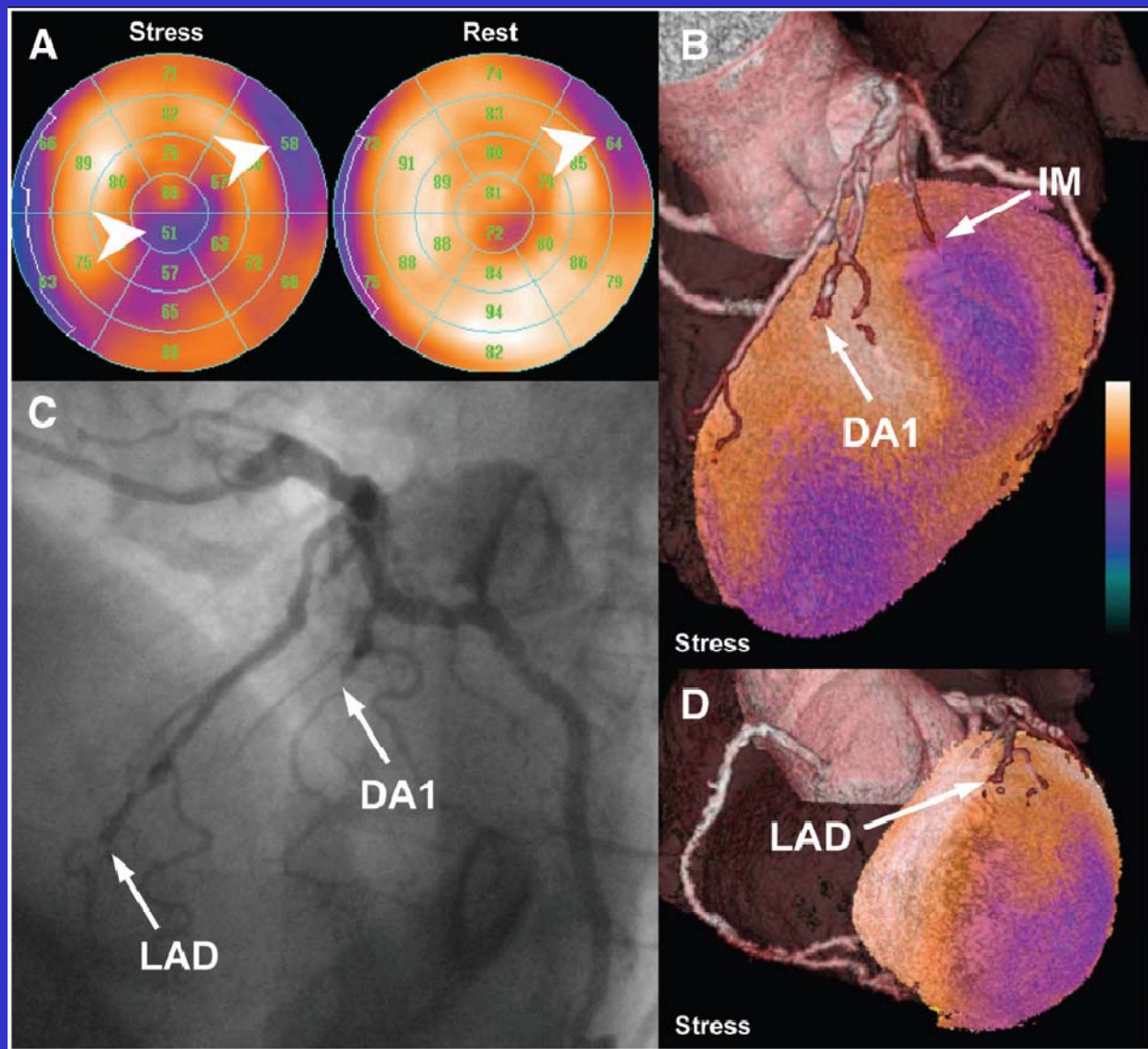
- MPI defines the presence of viable but dysfunctional, hypoperfused myocardium (**borderline stenosis**)
- MPI cannot diagnose early atherosclerosis and often underestimates the extent of coronary artery disease
- MPI does not provide accurate anatomical information, essential prior to coronary revascularization

Cardiac SPECT/CTCA

- Multi-detector CT (MDCT) technology (64 slices) as non-invasive CT coronary angiography (CTCA)
 - high spatial resolution
 - high Contrast resolution
 - High temporal resolution
- It provides location & morphology of coronary lesions
- Eliminates major false negative MPI results in patients with advanced 3-



This patient had undergone percutaneous transluminal coronary angioplasty and stenting of a significant stenosis in the LAD at the origin of a thin second diagonal branch (DA2) six months ago. SPECT images showed apical ischaemia (A). Cardiac CT angiography (CTA) on a 64-slice CT scanner provided visualization of the intracoronary stent in the middle LAD and the thin DA2 arising from the stent lumen (B). The fusion images showed a match of the apical perfusion defect with the territory of the DA2, whereas the LAD could be seen throughout its whole course to the apex and was not causing any ischaemia (C).



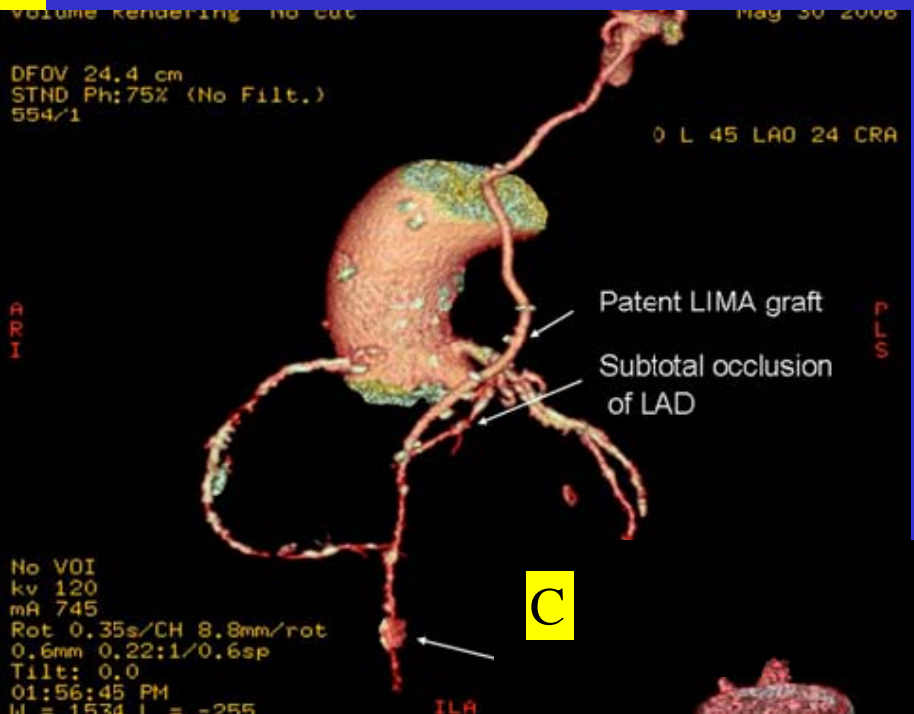
(A) Stress and rest perfusion on polar maps of SPECT-MPI study show mixed basal anterolateral defect and reversible inferoapical perfusion defect (arrowheads). (B and D) Fused SPECT/CT images reveal total occlusion of LAD and subtotal occlusion of first diagonal branch (DA1), which are confirmed by conventional CA (C). Anterolateral perfusion defect is caused by lesion of partially calcified small intermediary branch (IM)

Coronary Artery Calcium Score

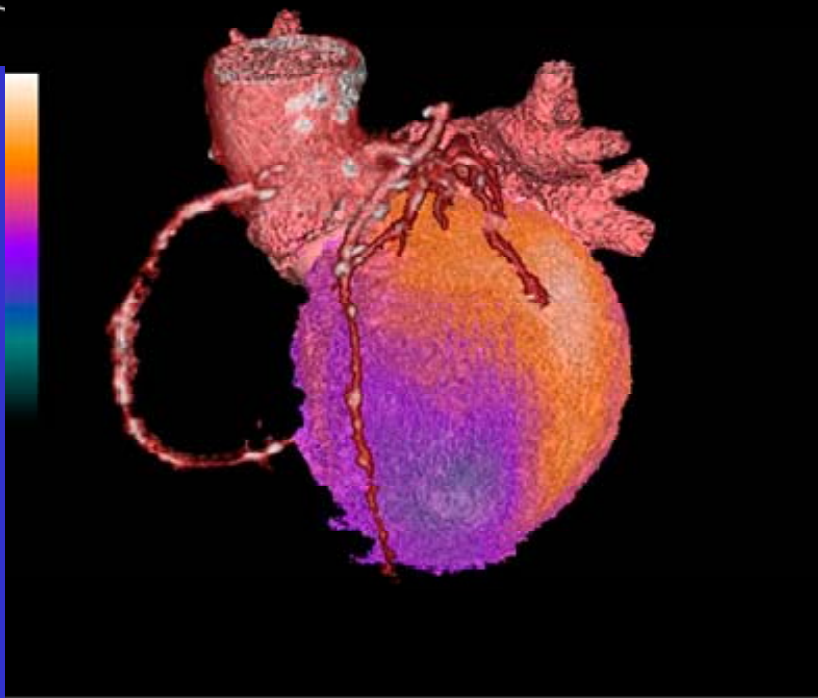
- Calcium accumulates in CA as a result of the body's response to contain & stabilize inflamed coronary plaques.
- CAC reflects an advanced stage of plaque development

The score is calculated as the product of the CAC area by the peak Hounsfield unit (1 for 131–199 HU, 2 for 200–299 HU, 3 for 300–399 HU, and 4 for >400

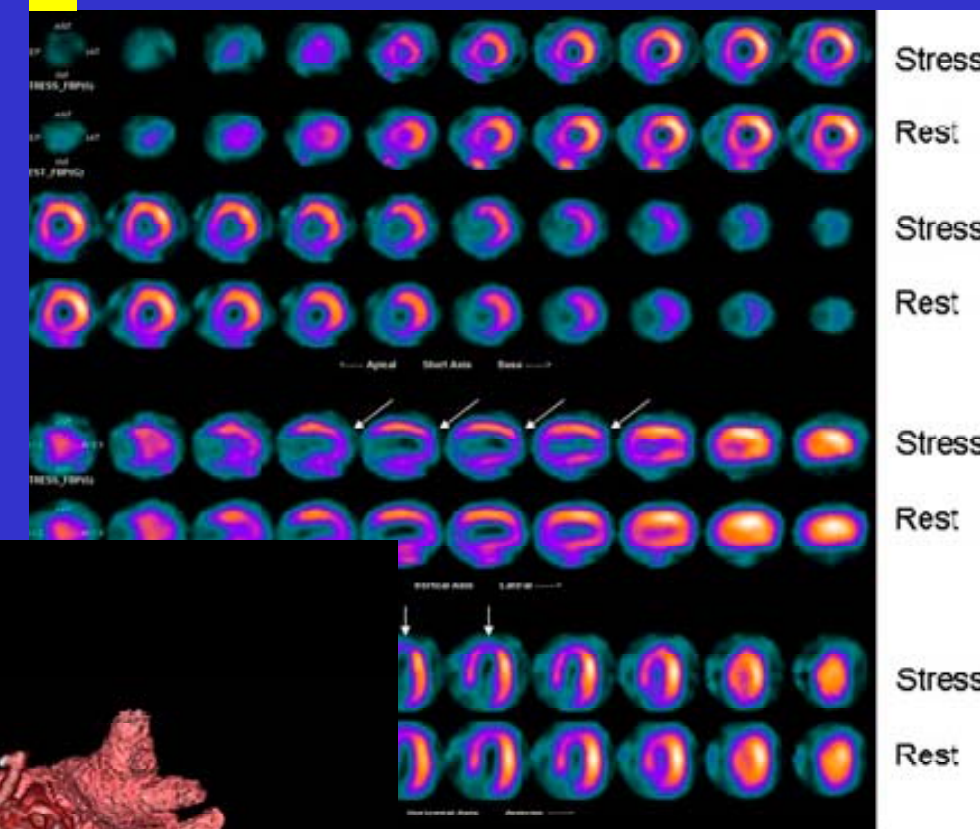
A



C



B



(A) CT angiogram of patient demonstrating multiple calcium deposits,

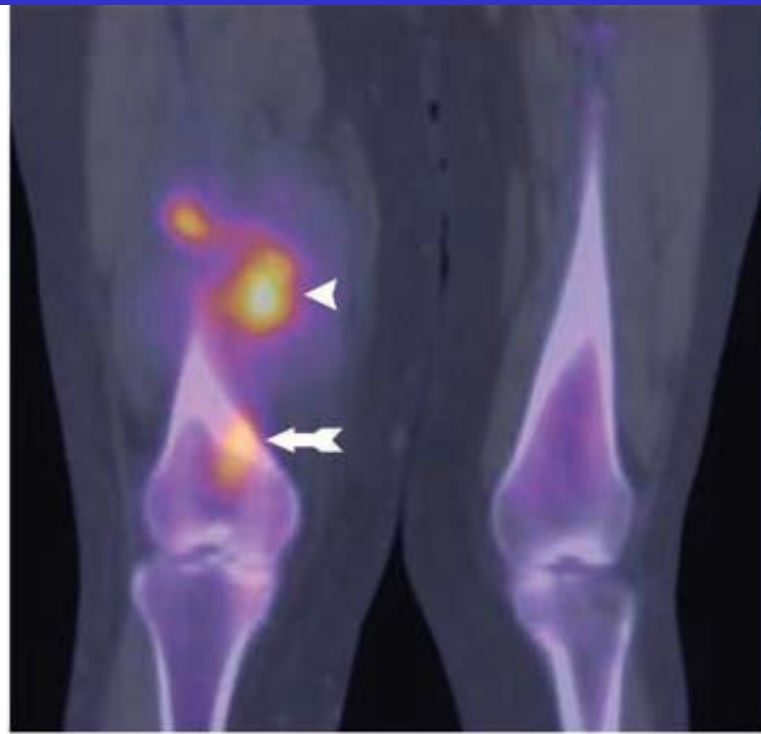
(B) Attenuation-corrected rest and stress perfusion studies
(C) 3-D fusion of CT angiogram and stress perfusion study

Musculoskeletal Imaging

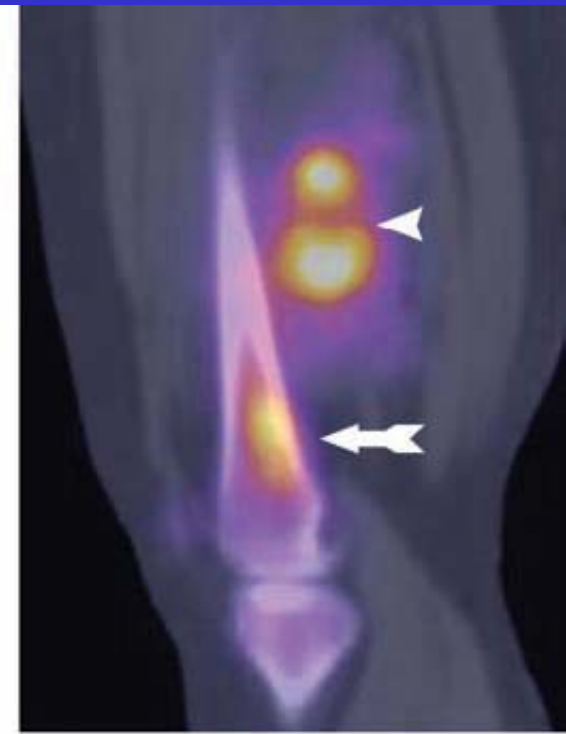
- Bone Scintigraphy is sensitive but nonspecific
- Although SPECT bone scintigraphy provides better evaluation of abnormal tracer uptake, it still produces less than ideal anatomic localization
- SPECT/CT is useful for:
 - localization of infection or inflammation
 - evaluation of bone trauma such as



a.



b.

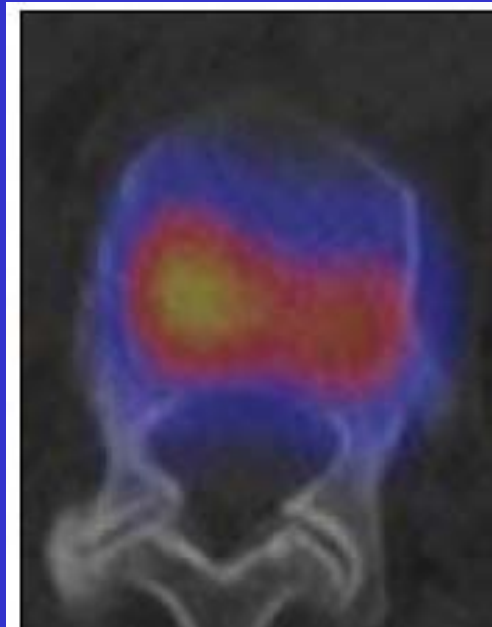
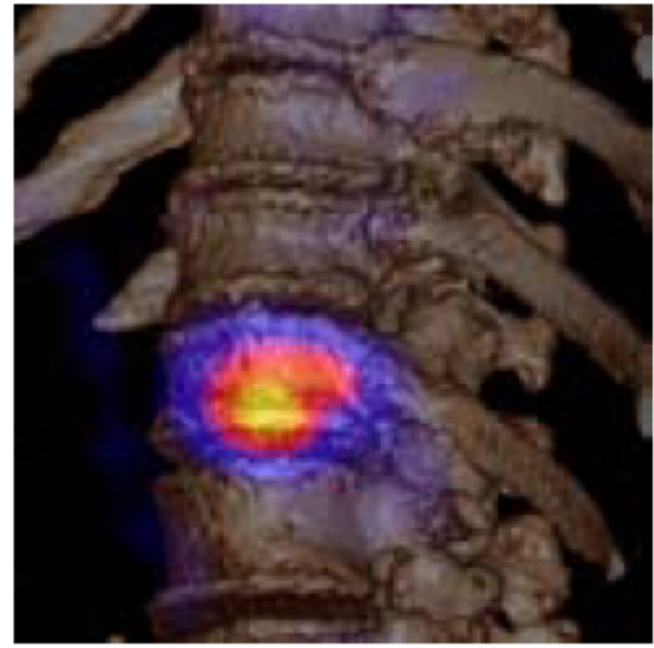


c.

Demonstration of the extent of malignancy in a young male patient with sarcoma. (a) Anterior whole-body scan shows definite involvement of the medial soft tissue in the lower right thigh. However, the presence of bone involvement is less certain. (b, c) Anterior (b) and lateral (c) fused SPECT/CT images show the soft-tissue involvement (arrowhead) along with osseous disease (arrow).

(A)

(B)



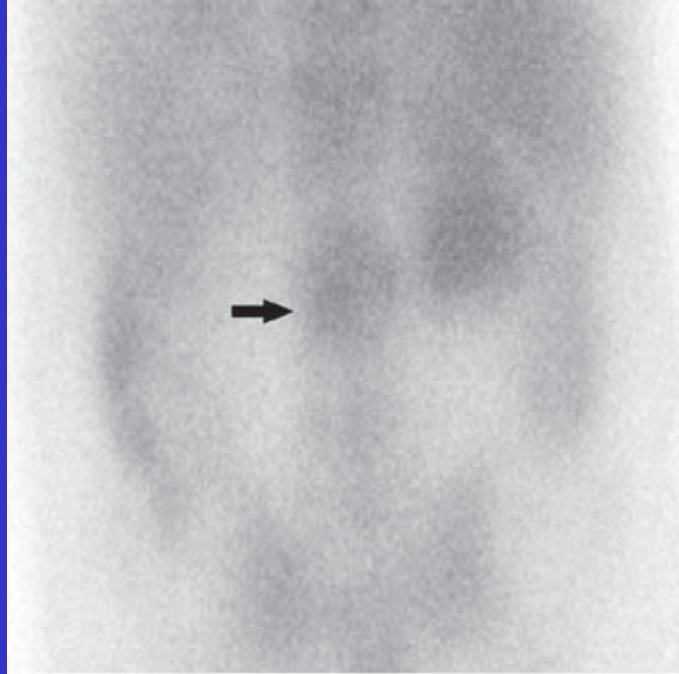
C



(A) Early and late posterior planar skeletal scintigrams of a 74 year old patient after recent trauma, showing enhanced uptake of ^{99m}Tc -MDP in a vertebral body of the lower thoracic spine. (B) 3-D-volume rendering of the spine showing a focal area of increased uptake in the lower thoracic spine. (C) Early and late anterior planar skeletal scintigrams of the same patient showing a focal area of increased uptake in the lower thoracic spine.

Imaging of Infection

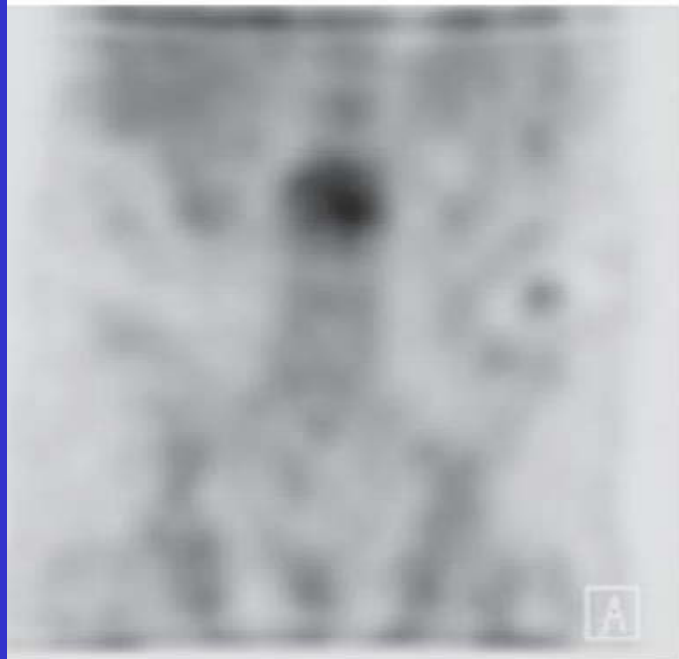
- Gallium imaging and white blood cell imaging have been used to evaluate infection and inflammation.
- They reflect mainly functional data
- SPECT/CT is useful to define fine anatomic detail that is critical in discriminating between pathologic and



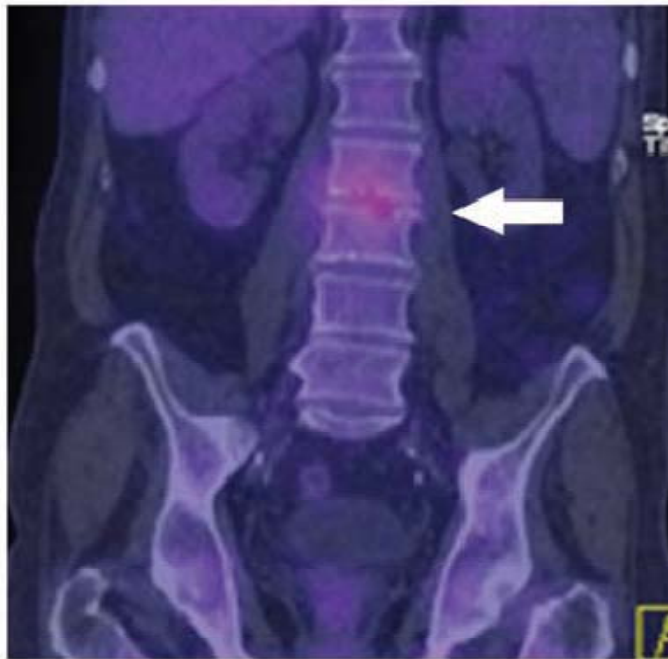
a.



b.



c.



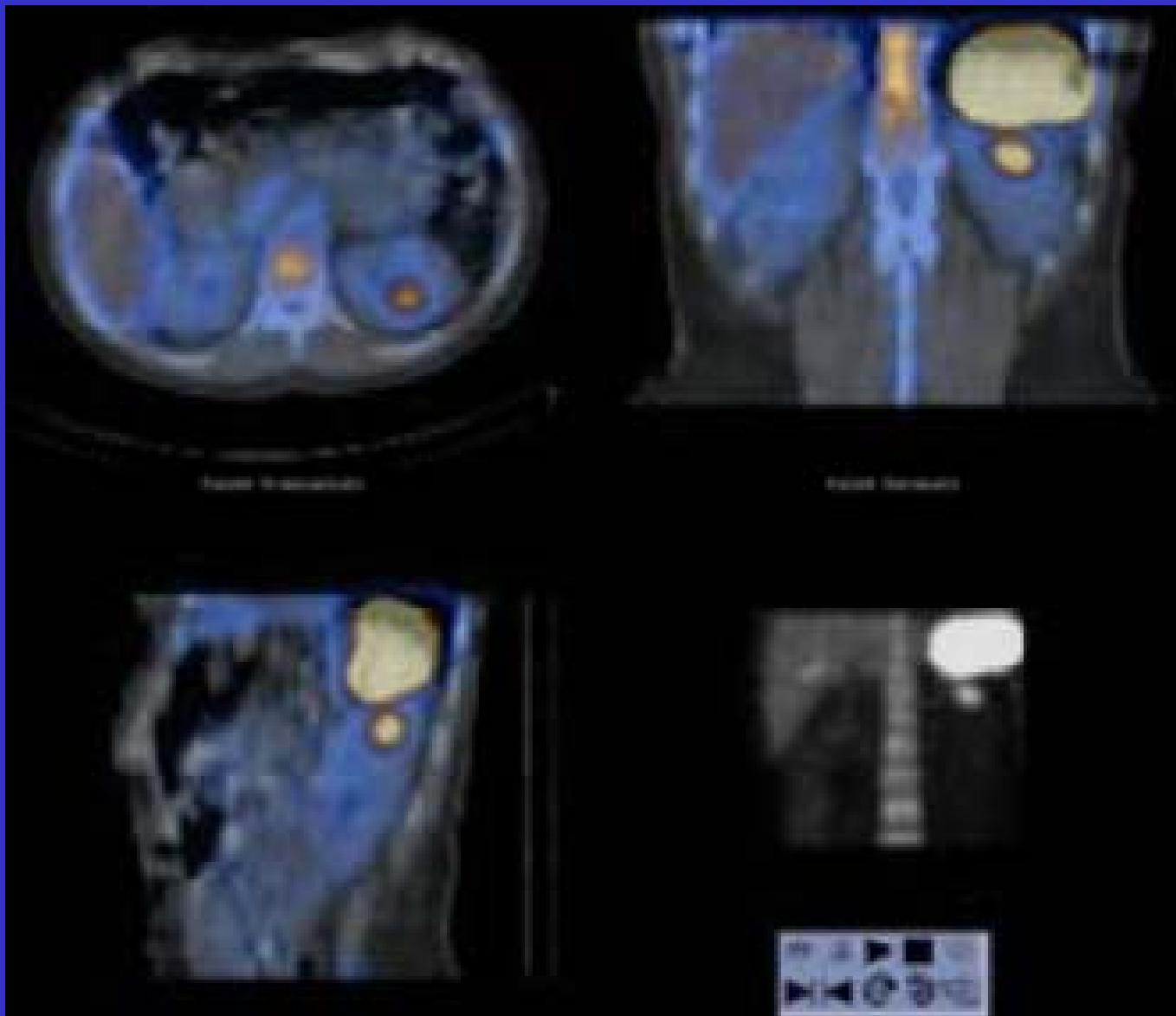
d.

Localization of gallium uptake with SPECT/CT in a patient suspected to have a spine infection.

(a) Planar image shows findings indicative of a spine infection (arrow).

However, the location of the infection is not clear.

(b) CT, (c) SPECT, (d) fusion images show clear correspondence between the abnormal scan findings and the defects seen on CT.



Patient had fever of unknown origin. During ^{99m}Tc -HMPAO-leukocyte scintigraphy, it is only SPECT/CT that reveals location of an abscess at the upper pole of the left kidney, which on planar scan could only be generically located below the lower pole of the

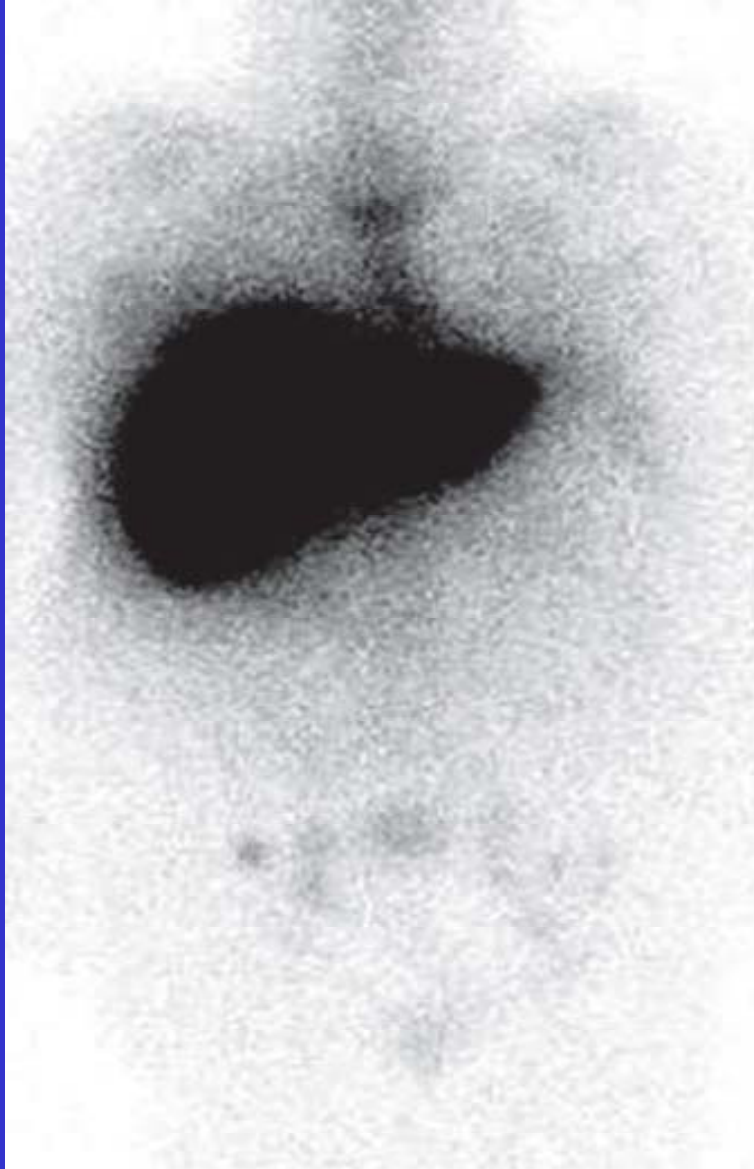
Oncology

- Most neuroendocrine tumors secrete metabolically active substances that are similar to the analogs used for imaging (MIBG) or related to their receptor expression (Somatostatin or Octreotide)
- Despite the high sensitivity of most neuro-endocrine tumor imaging, this technique is limited by:
 - small tumor size (poor spatial resolution)
 - Lack of anatomic localization
 - Specificity is reduced because of the high binding affinity of small molecules

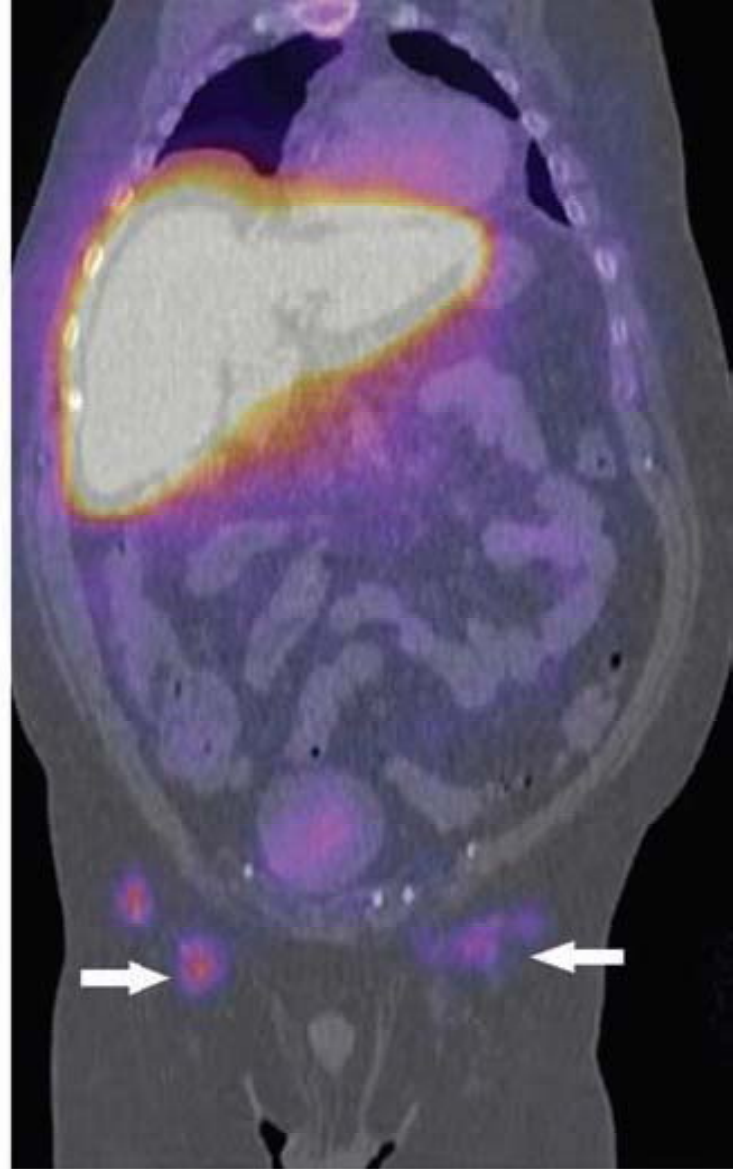
Oncology

- SPECT/CT imaging provides
 - accurate localization of radiopharmaceutical accumulations
 - detection of occult disease sites
 - Characterization of metabolically active areas of known lesions
 - quantifying tracer uptake for measuring the tumor response to therapy
 - Allows the prediction prior to treatment of whether the proposed therapy is likely to be effective

^{131}I -MIBG, ^{111}In -Octreotide, monoclonal antibody, ^{201}Tl chloride, ^{67}Ga

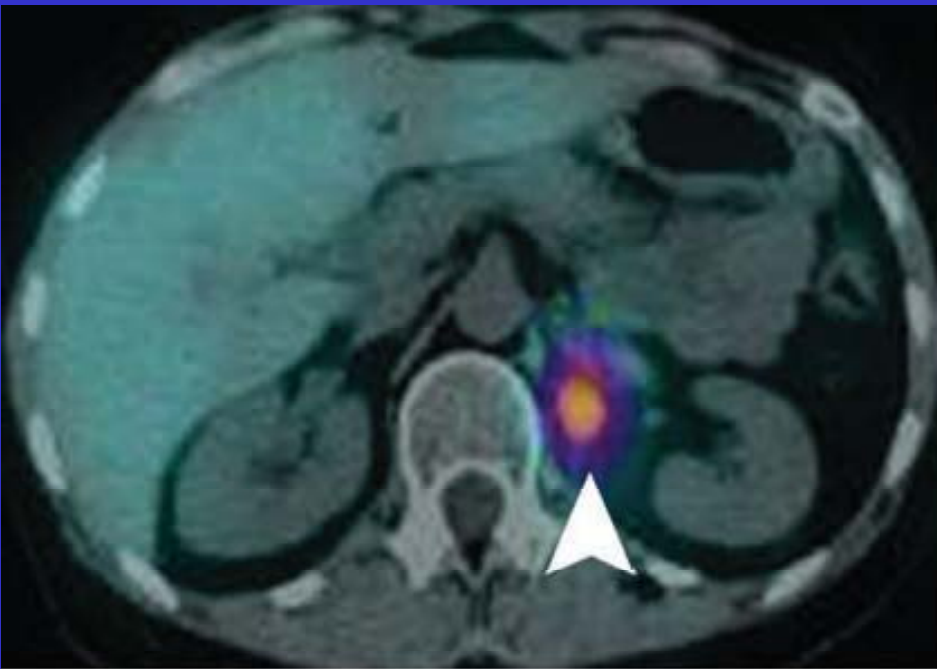


a.

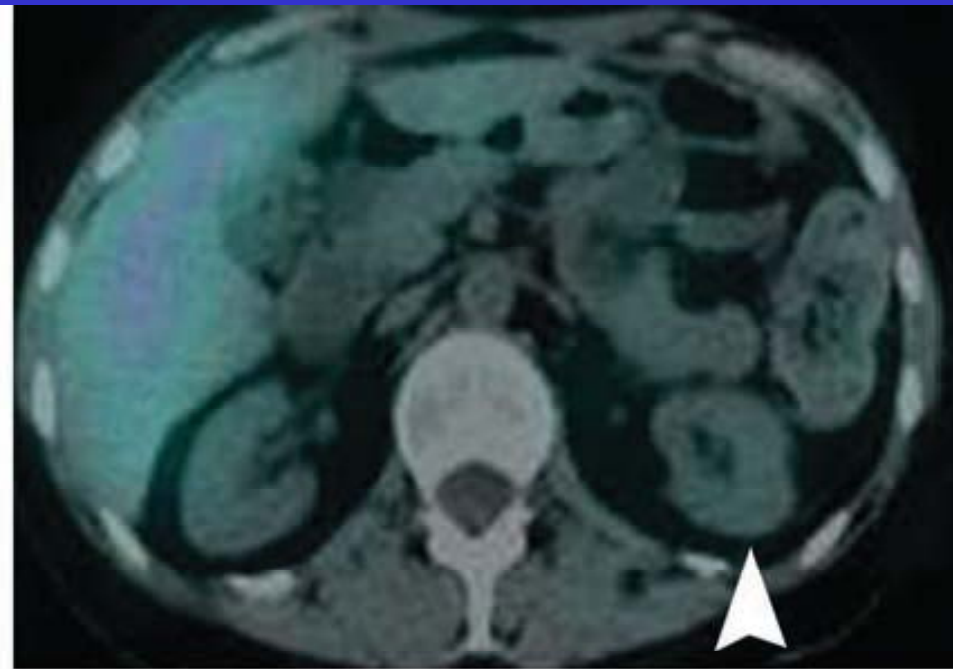


b.

Localization of malignant disease in an elderly man with a history of prostate cancer and an increasing prostate-specific antigen level. (a) Anterior ^{111}In ProstaScint (Cytogen) whole-body scan shows subtle uptake in the pelvis. (b) Fused SPECT/CT image shows probable

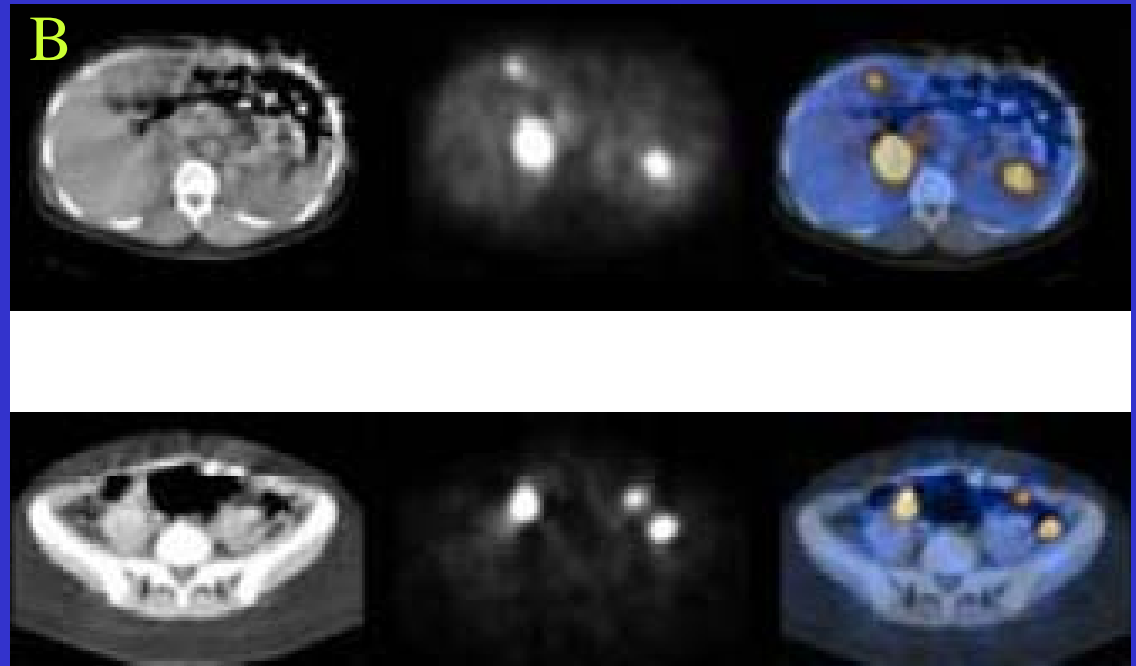
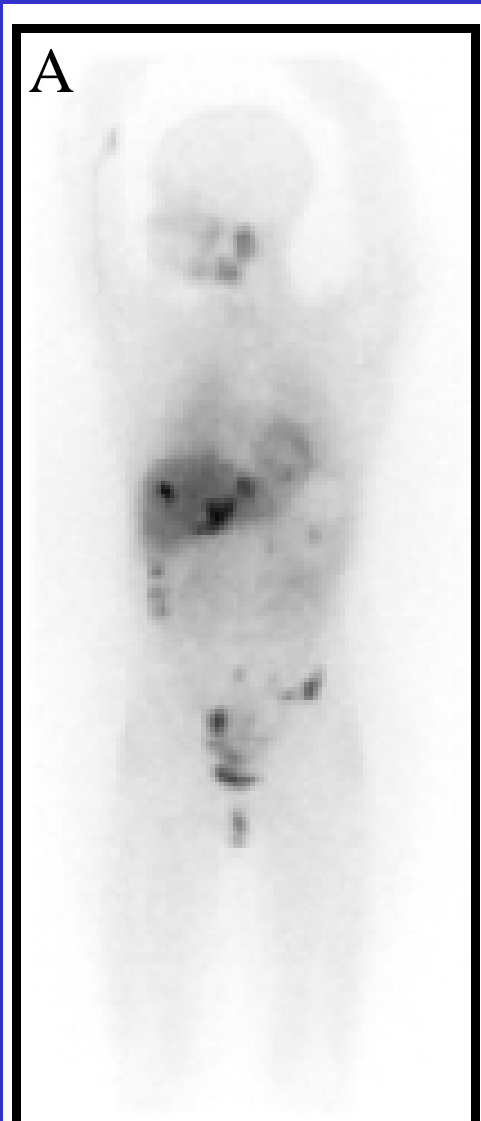


a.



b.

Evaluation of uptake with SPECT/CT in a patient suspected to have a left-sided paraganglioma and a left renal mass at CT. Planar imaging showed a focus of uptake in the left abdomen, but there was uncertainty whether the focus correlated with the renal mass or the paraganglioma. SPECT/CT images show that the focus of uptake corresponds to the paraganglioma (arrowhead in a) with no uptake in the renal mass (arrowhead in b), which proved to be a renal cell carcinoma at biopsy.



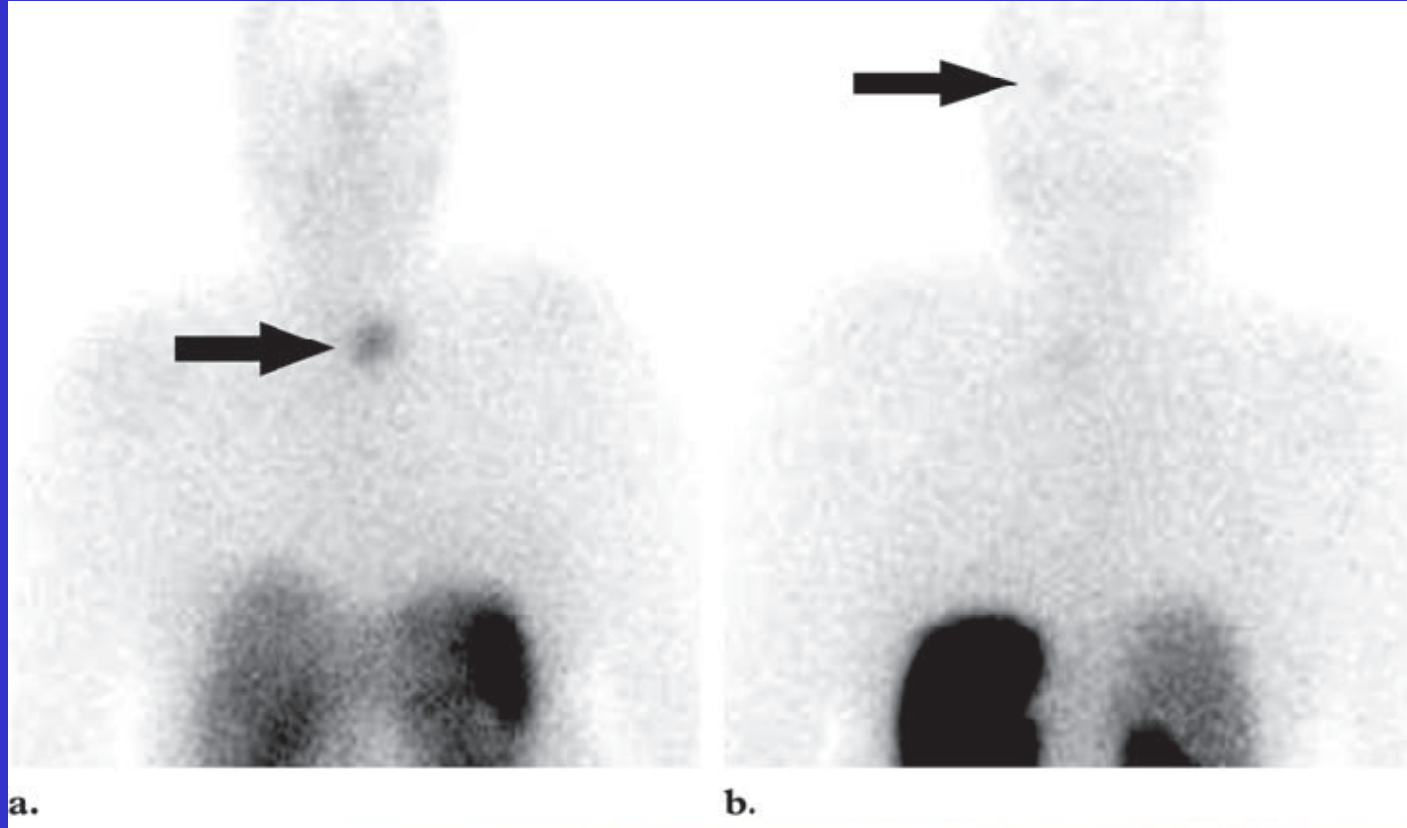
^{123}I -MIBG scintigraphy in a 26 year old woman who had undergone left adrenalectomy because of pheochromocytoma. The whole body planar scan (A) shows multiple foci of tracer uptake in the abdominal area, mainly in liver and in other areas suggesting possible lymph node metastases (A). However, SPECT/CT images (B) (upper and lower right panels) show that such foci represent peritoneal implants rather than visceral or lymph node metastases, possibly

Octreotide-SPECT/CT provides information regarding the functional status of the tumour, its precise localization and the whole extent of disease.

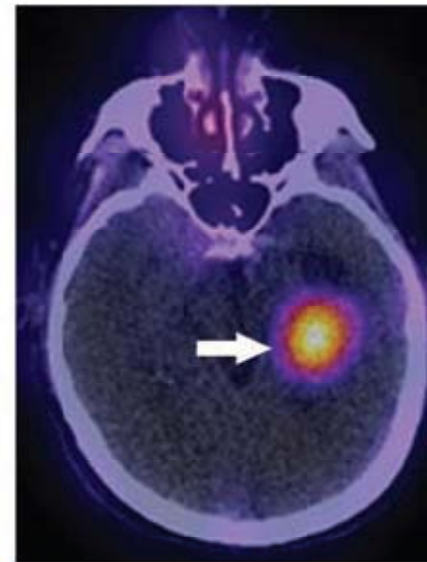
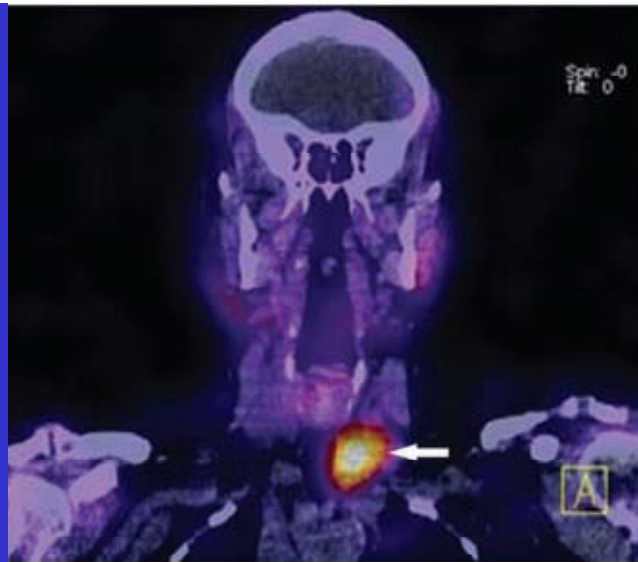
Fused images are useful tools to choose the optimal treatment strategy, mainly in patients with advanced disease.

SPECT/CT provides greater accuracy in localization of findings than functional SPECT imaging alone and greater specificity than anatomic CT as

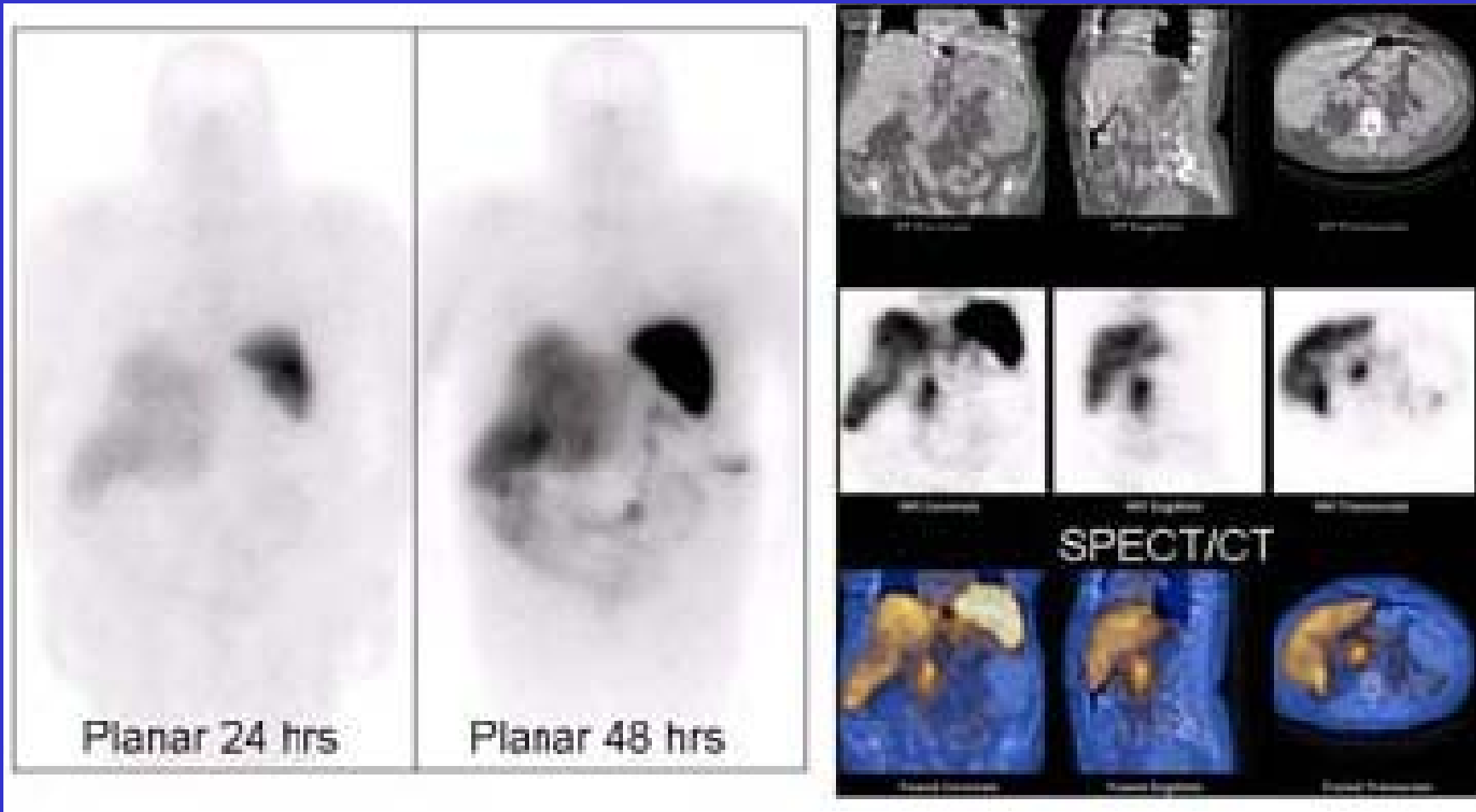
An octreotide study of a left temporal intraventricular lesion was performed to evaluate for a possible meningioma.



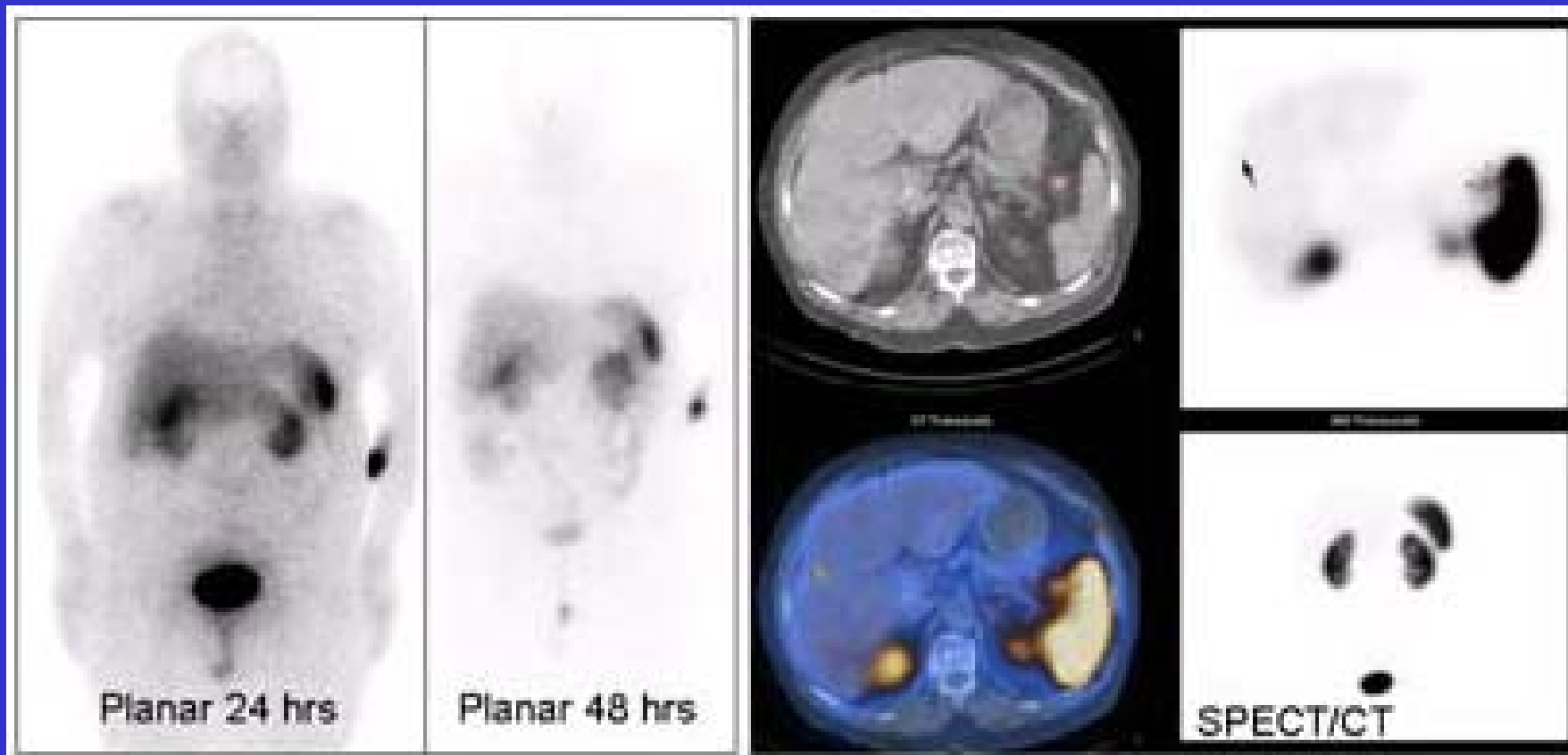
(a, b) Planar images show an unexpected finding in the neck (arrow in a) and faint uptake in the head (arrow in b). (c) SPECT/CT image shows the neck lesion (arrow), which was found to be recurrent Hürthle cell cancer at histologic analysis. (d) SPECT/CT image shows a somatostatin-positive lesion (arrow) at the site of the CT



d.



^{111}In -octreotide SPECT/CT in duodenal carcinoid. A 56 year old woman with duodenal carcinoid diagnosed following biopsy of a duodenal ulcer was referred for defining extent of disease prior to treatment planning. Whole body planar scans performed at 24 and 48 h after tracer injection are normal. SPECT demonstrates a small focus of abnormal tracer activity in the right mid-abdomen, localized by



¹¹¹In-octreotide SPECT/CT in pancreatic insulinoma. A 68 year old woman had severe hypoglycemia. CT indicated a suspicious lesion in the tail of the pancreas. Whole body planar scans performed at 24 and 48 h after tracer injection are normal. SPECT demonstrates a small focus of abnormal tracer activity in the left upper abdomen, in close proximity to the high uptake in the spleen. This suspicious lesion is localized by SPECT/CT fused images to the tail of the pancreas. CT in the tail of the pancreas indicated a small lesion.

^{67}Ga -citrate SPECT/CT in lymphoma

- SPECT/CT for distinguishing spinal lesions from adjacent nodal involvement.
- Clarify the tracer uptake at the edges of the lower chest, projecting over the hepatic dome, ribs or sternum

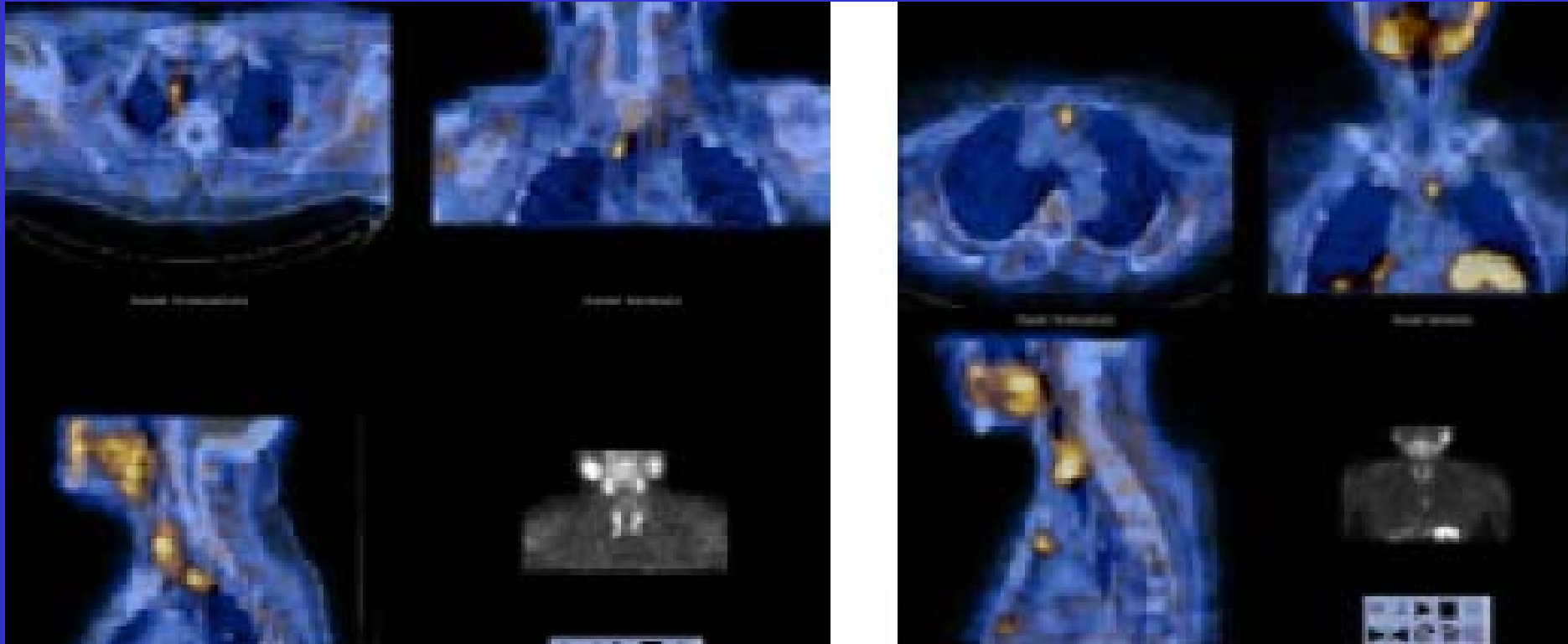
SPECT/CT in the localization of parathyroid adenomas

- SPECT is superior to planar ^{99m}Tc -MIBI for localizing parathyroid adenomas, especially ectopic adenomas, mainly located in the mediastinum
- Multimodality co-registration is useful for better localization of adenomas relative to critical

- In secondary hyperparathyroidism, it is crucial that all parathyroid tissue showing $^{99m}\text{Tc-MIBI}$ uptake is removed
- These parathyroid glands are those responsible for the increased production of parathyroid hormone
- Better localization with

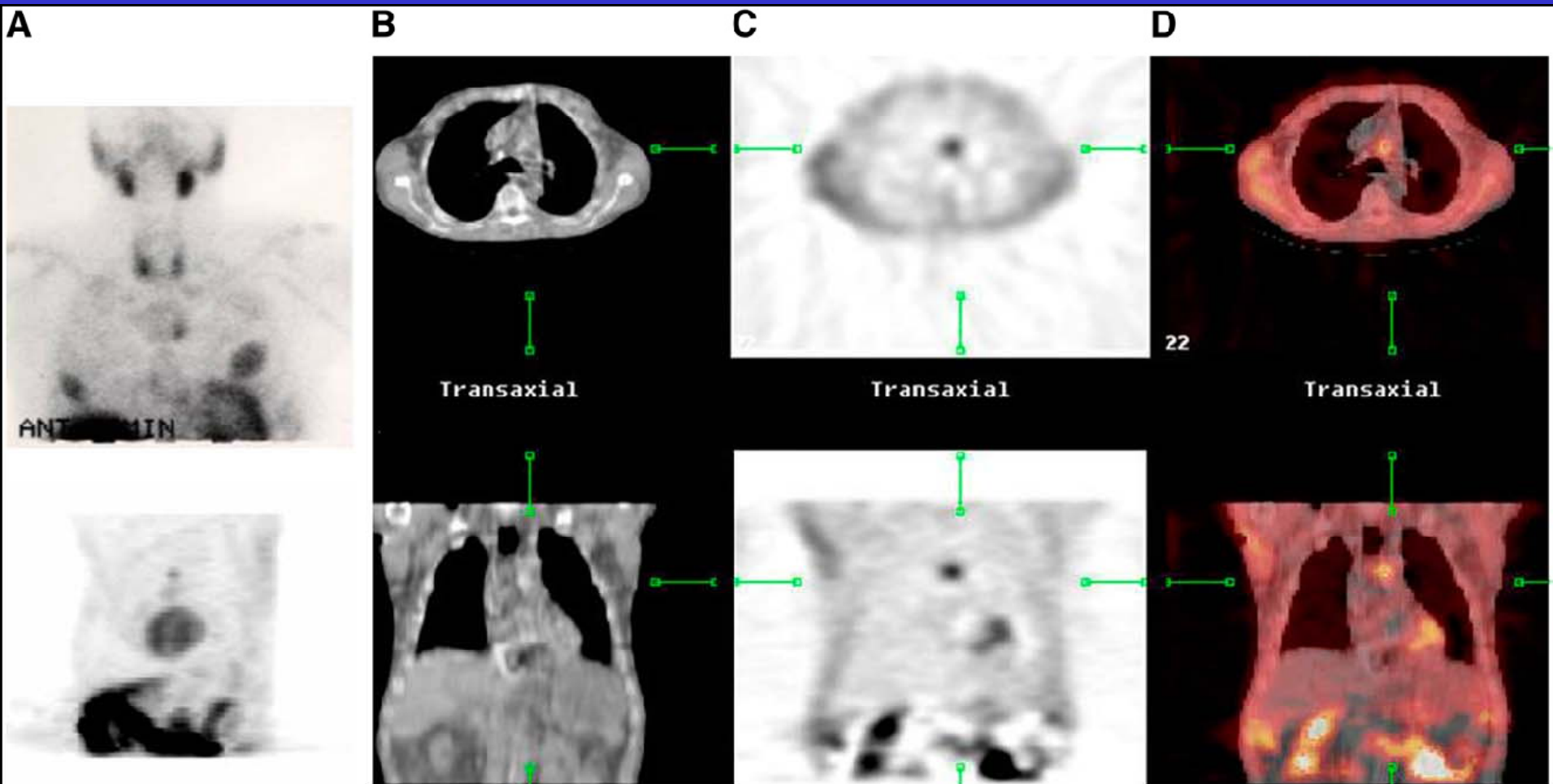
Pt #1

Pt #2



In Pt #1 the adenoma was located adjacent to the right wall of the trachea, while in Pt #2 the adenoma was located in the anterior mediastinum.

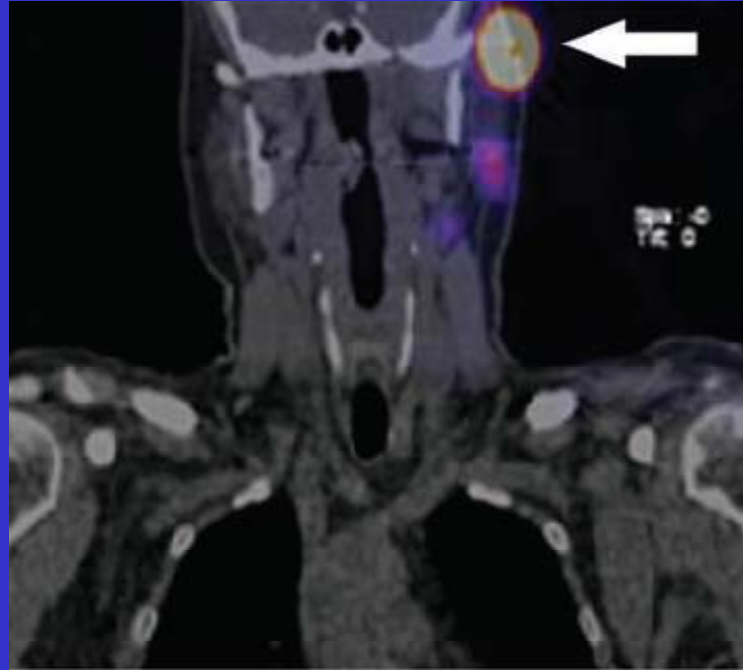
Availability of multiple fused images from transverse, sagittal, & coronal planes provided surgeon with accurate anatomic roadmap for use in operating



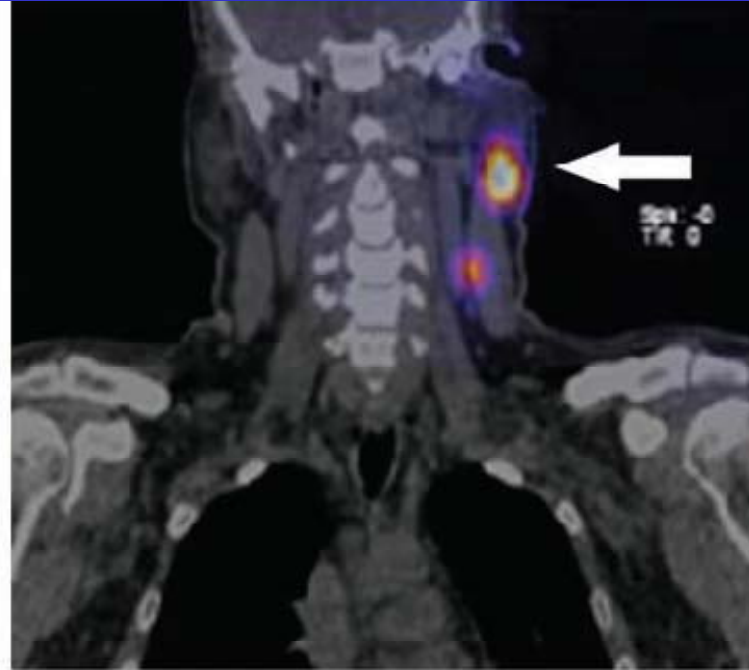
(A) Anterior and lateral planar ^{99m}Tc -MIBI images of patient with parathyroid adenoma. (B) CT in transverse and coronal images. (C) Corresponding transverse and coronal images of emission distribution with SPECT clearly identified presence of adenoma. (D) Fused images of 2 datasets provided precise anatomic location of lesion in left mediastinum.

Surgical Oncology

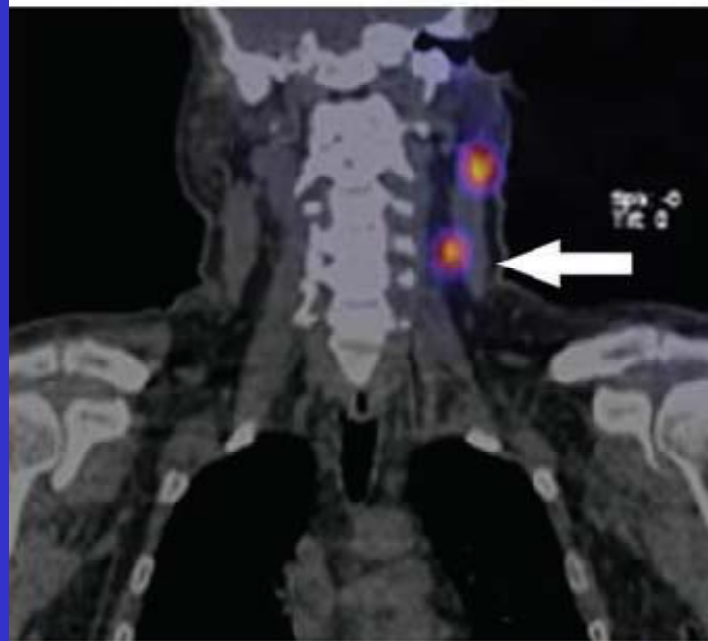
- Lymphoscintigraphy for pre-surgical localization of sentinel lymph nodes, mainly in breast cancer and melanoma patients
- Imaging is limited due to lack of anatomic detail
- For patients with lesions in the head and neck or pelvis, SPECT/CT imaging provides:
 - Localization of sentinel nodes
 - Allows to minimize the extent of surgical intervention while avoiding incomplete removal of the sentinel



a.



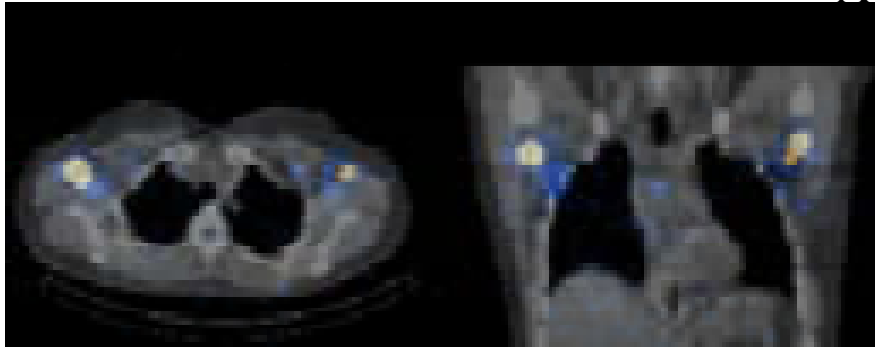
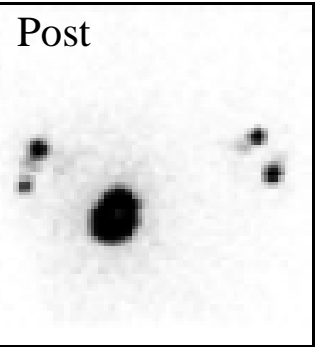
b.



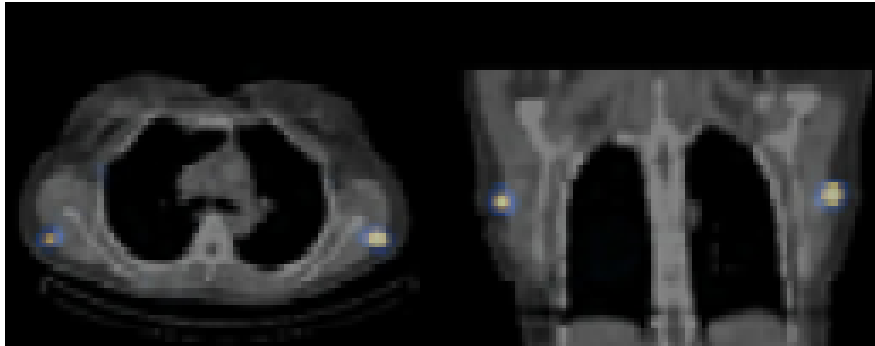
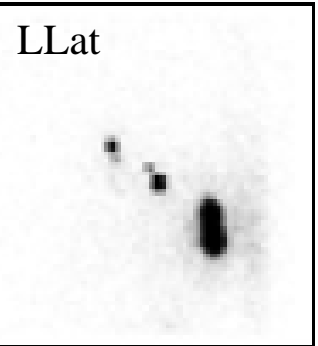
c.

Location of sentinel lymph nodes with SPECT/CT in a patient with a melanoma of the left ear. (a) Image from sentinel lymphoscintigraphy shows the injection site in the left ear region (arrow). (b, c) Coronal fused SPECT/CT images show the locations of

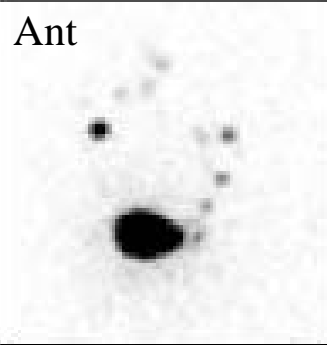
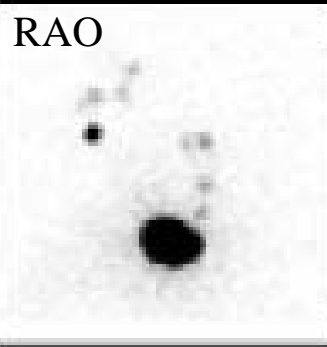
A



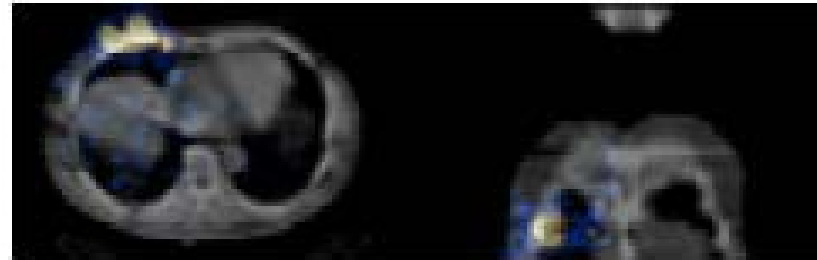
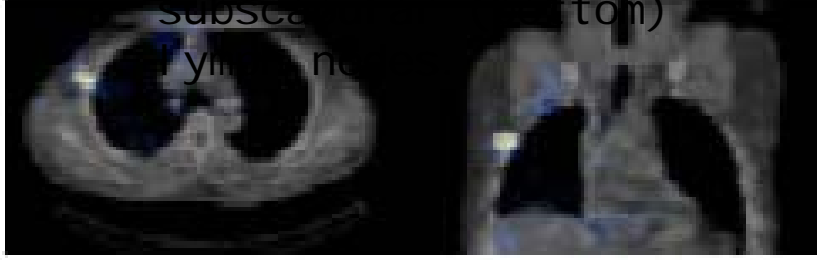
(A) patient with melanoma located on her back: with multiple bilateral lymph nodes, without clear reference to precise anatomic structures. Right panels show SPECT/CT sections at different levels, demonstrating bilateral lymphatic draining to both axillary (top) and subscapular (bottom) lymph nodes.



(B) a patient with melanoma located on his anterior right chest: multiple lymph nodes can be detected. Right panels show SPECT/CT tomographic sections at different levels, demonstrating lymphatic draining to both axillary and internal thoracic lymph nodes.



B

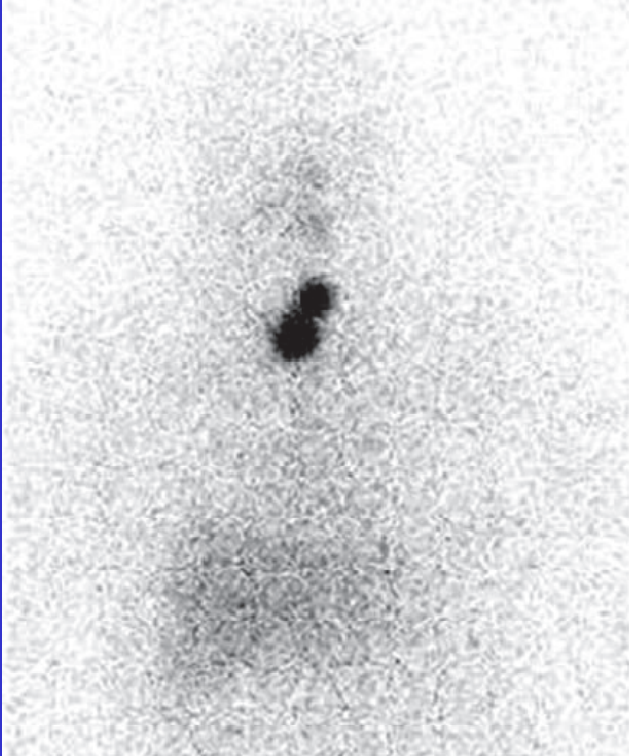


Whole body I-131

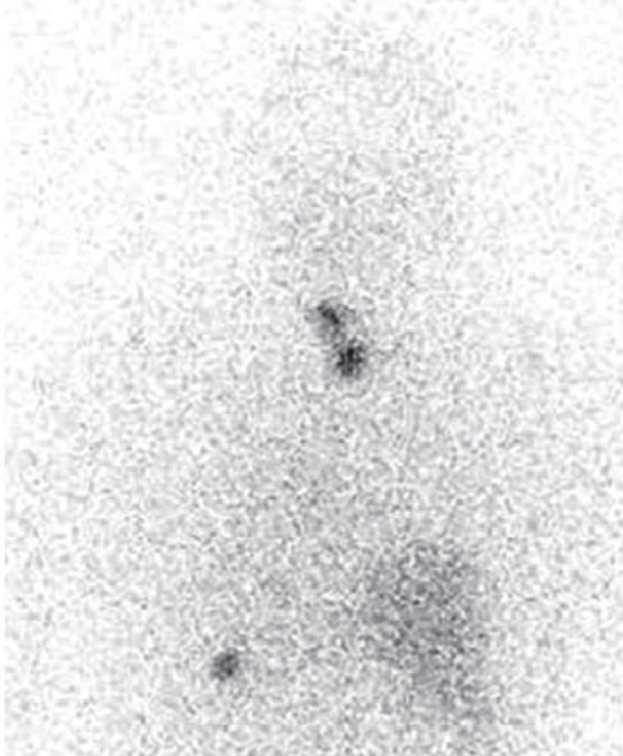
- Imaging with ^{131}I is useful for detection of residual, recurrent, and metastatic thyroid cancer & limited by:

- *Abnormalities on wholebody planar images are difficult to interpret:*
- *poor anatomic landmarks*
- *a relatively low count density*
- *physiologic activity in the salivary glands, gastric mucosa, intestinal*

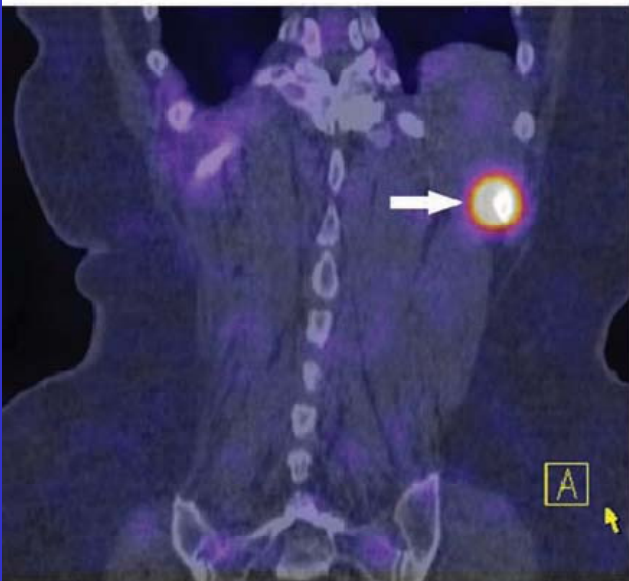
SPECT/CT provides anatomic & additional information e.g. differentiation of focal uptake between malignant & benign causes



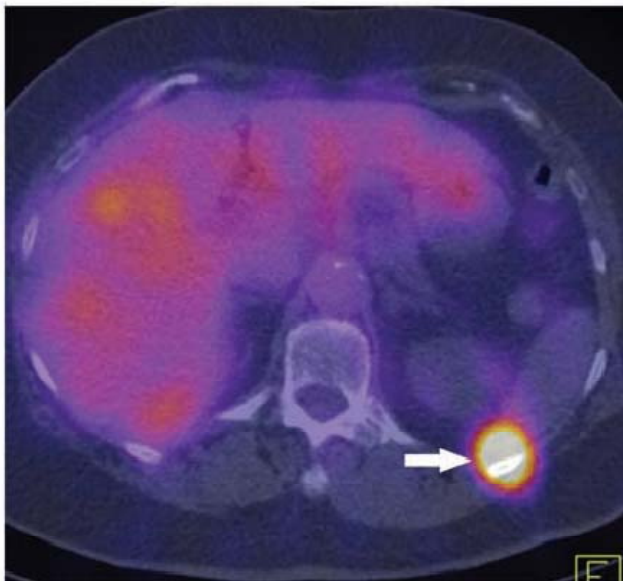
a.



b.



c.



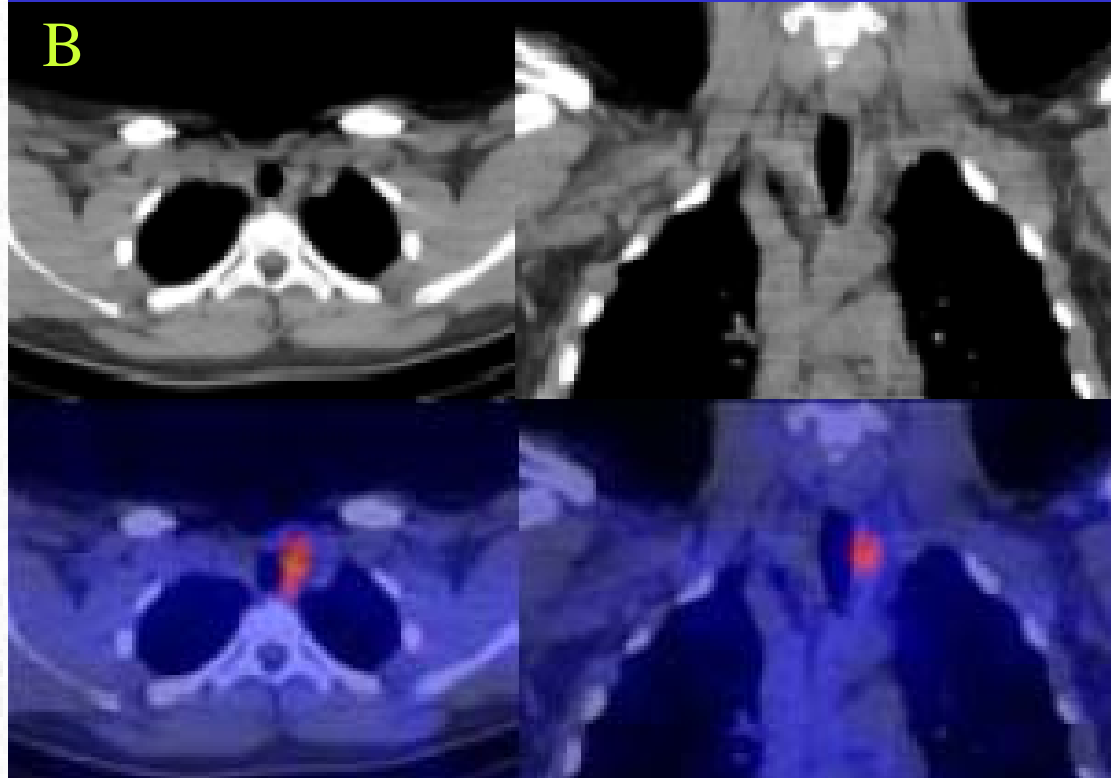
d.

a patient with thyroid cancer who underwent whole-body ^{131}I scanning to assess for residual recurrent disease. (a, b) Anterior (a) and posterior (b) ^{131}I scans show focal activity in the left suprarenal region. (c, d) Coronal (c) and axial (d) SPECT/CT images show that the focus of activity corresponds to metastatic disease in a left lower

A

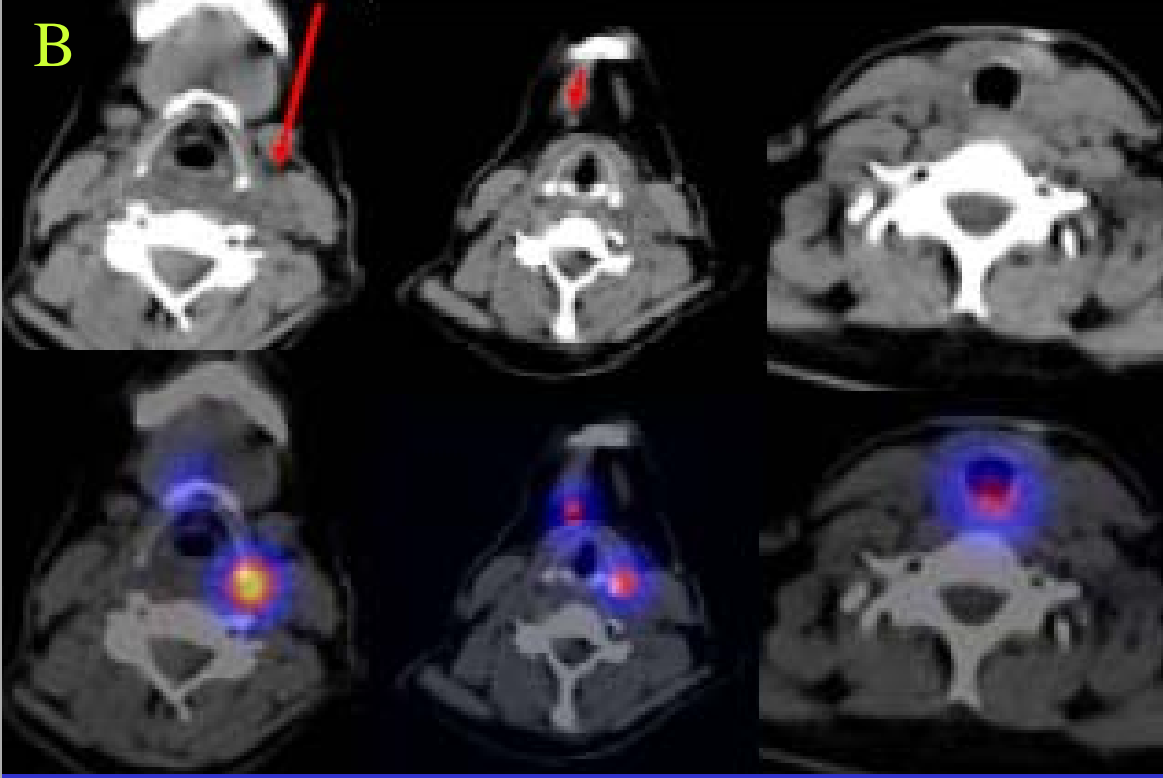


B



The planar ^{131}I -iodide scan in a 16 year old patient with thyroid cancer discloses an iodine-avid focus (arrow) (A). The patient had had three surgical procedures (including total thyroidectomy) and 37 GBq of ^{131}I , so that this focus indicates the presence of a further lymph node metastasis.

Considering scarring from prior surgeries, exact localization of this lesion is an essential requisite for its surgical resection. This anatomic information can only be achieved by SPECT/CT (B)

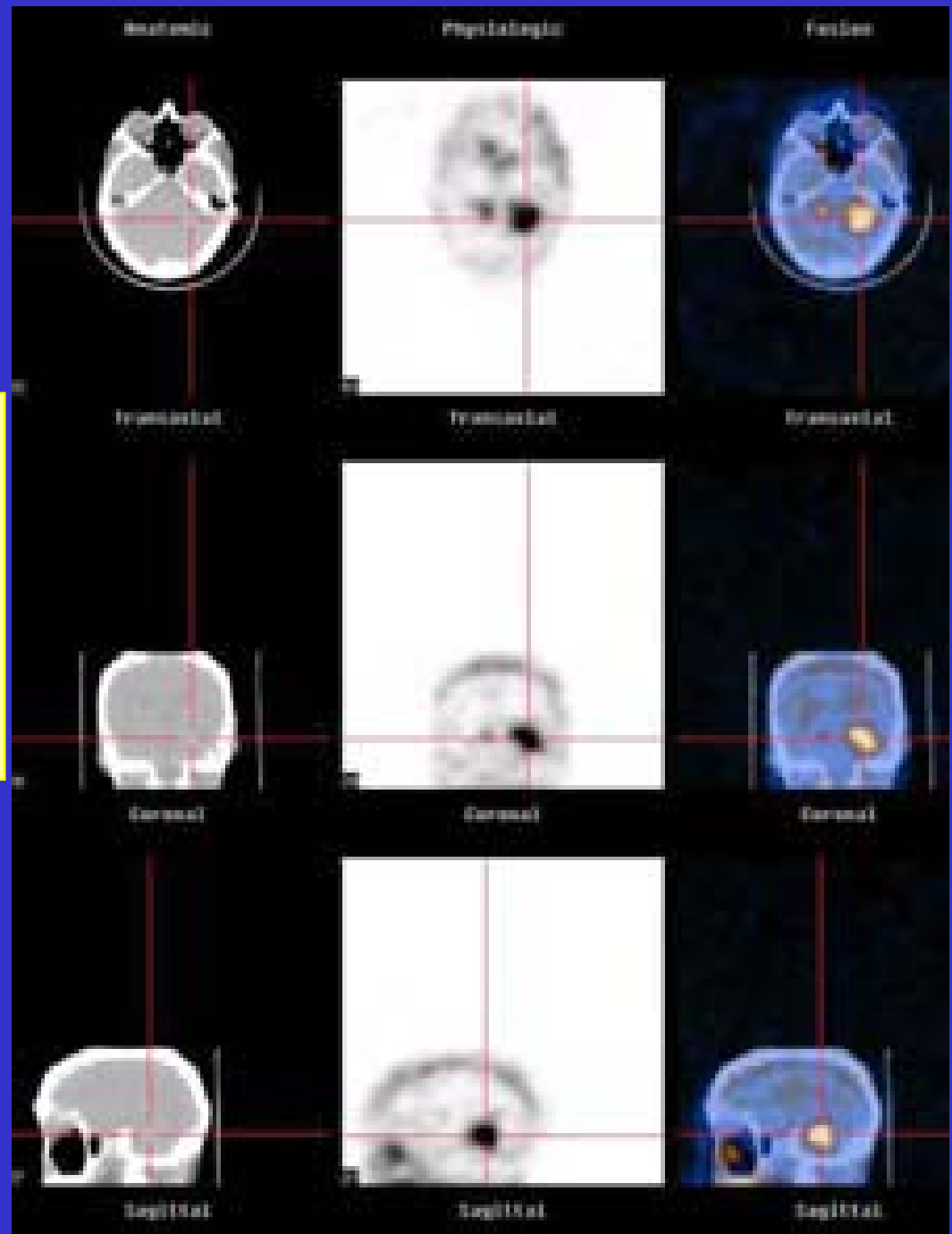
A**B**

The planar scan post-radiiodine ablation of thyroid remnants shows radiiodine-avid tissue in the neck of a patient after total thyroidectomy (A), without the possibility of discriminating ¹³¹I uptake in remnant normal thyroid parenchyma from possible lymph node metastasis. (B) SPECT/CT demonstrates two cervical lymph nodes in this patient (arrows) that cannot be differentiated from benign

201Tl-chloride in cerebral masses

- Postoperative 201Tl SPECT demonstrates better accuracy than contrast enhanced CT in detecting residual tumour
- disruption of the blood-brain barrier during the postoperative period leads to uncertainty in CT & T1 MRI interpretation.
- Image fusion allows accurate determination of the anatomic

SPECT/CT performed after administration of ^{201}Tl -chloride in an HIV infected patient referred for differential diagnosis between primary lymphoma and cerebral toxoplasmosis. ^{201}Tl accumulation in the left hemi-cerebellum supports the diagnosis of primary lymphoma.



Selection of CT

- 16-slice SPECT/CT
 - Oncology application
 - If not 16-slice, then 8-slice
- 16-slice CT
 - Cardiology application without CACT imaging
- 64-slice CT
 - Cardiology application with CACT imaging
 - Perfusion CT imaging

Use of SPECT/CT data for estimating internal radiation dosimetry

- Accurate dosimetric estimates are critical in radiometabolic therapy for
 - calculating radiation dose to the target organ/tissue (e.g. tumor)
 - defining dose-limiting toxicities to normal tissues with high physiologic accumulation of radioactivity (e.g. bone marrow, kidneys).
- absolute concentration of radioactivity in a given organ/tissue, is estimated roughly
- SPECT/CT enabled accurate

SPECT/CT Imaging

The future value of SPECT/CT in terms of both clinical impact on patient care and cost effectiveness, as compared to PET/CT may be enhanced

The development of better instruments, newer computer based procedures for image analysis

New ^{99m}Tc labeled agents for visualizing biologically significant events (such as cellular

Thank you