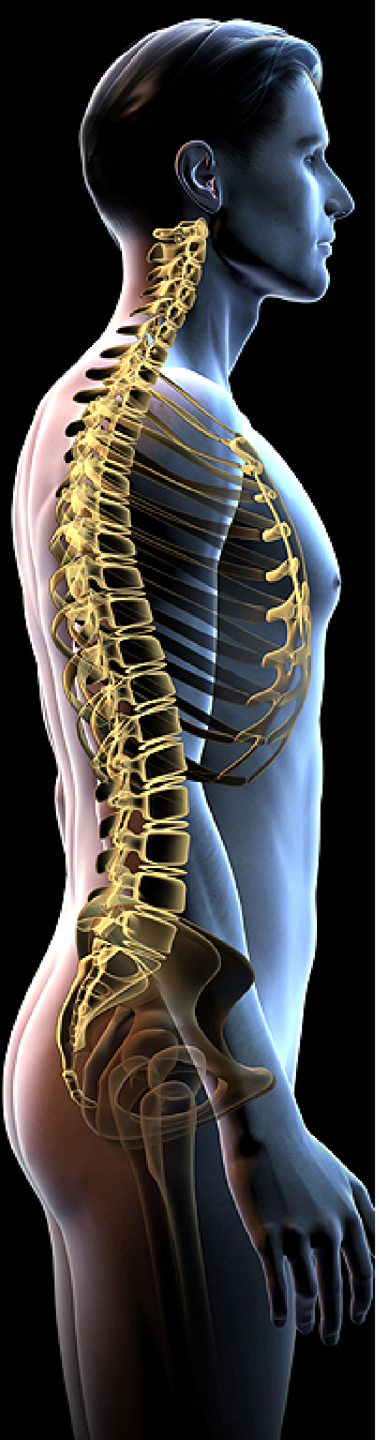
مركز جابر الأحمد للتصوير الجزيئي
Jaber Al Ahmad Center for Molecular Imaging
أنشأته مؤسسة الكويت للتقدم العلمي
Founded by Kuwait Foundation for the Advancement of Sciences

^{18}F-NaF PET/CT: Normal Variants and Pitfalls

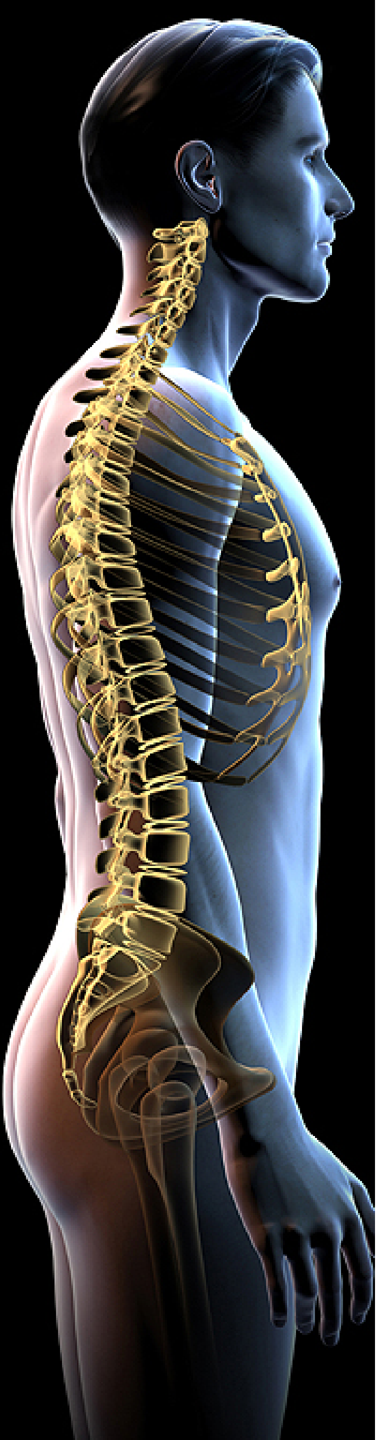
Mariam Al-Daas
Jaber Al-Ahmad Center for Molecular Imaging

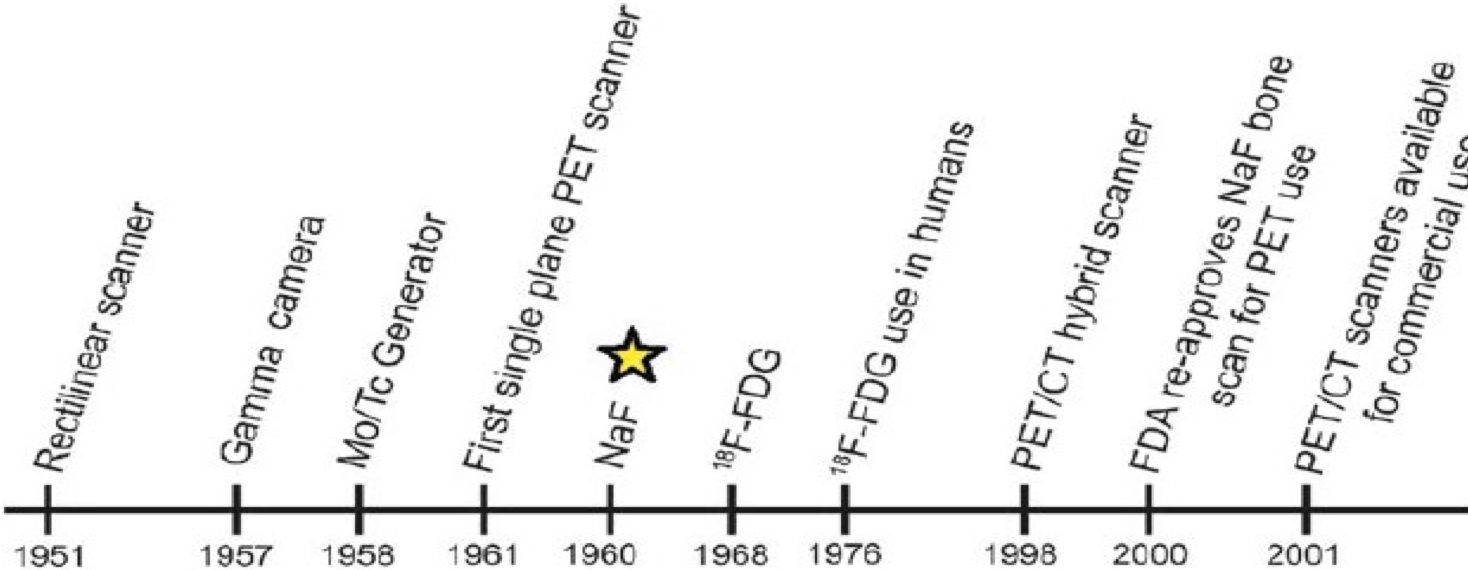


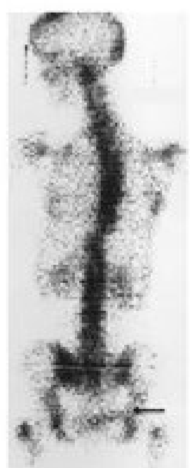
^{18}F-NaF History

- Blau – 1962 "Semin Nucl Med"
- FDA approved ^{18}F-NaF (1972)
- Decreased use in 70's:
  - **Availability of ^{99m}TC generators**
  - **Development of PYP, polyphosphates and finally kit-based bisphosphonates**
  - **Poor imaging of 511 KeV photons with rectilinear scanner and Anger camera**
- Hoh (UCLA) – Early 1990's used for WB PET
- Wide availability of PET/CT accelerated interest.

^{18}F-NaF History

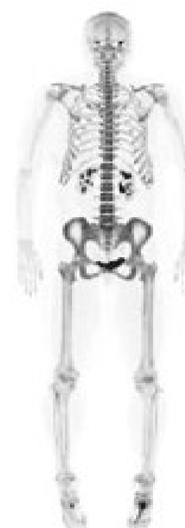




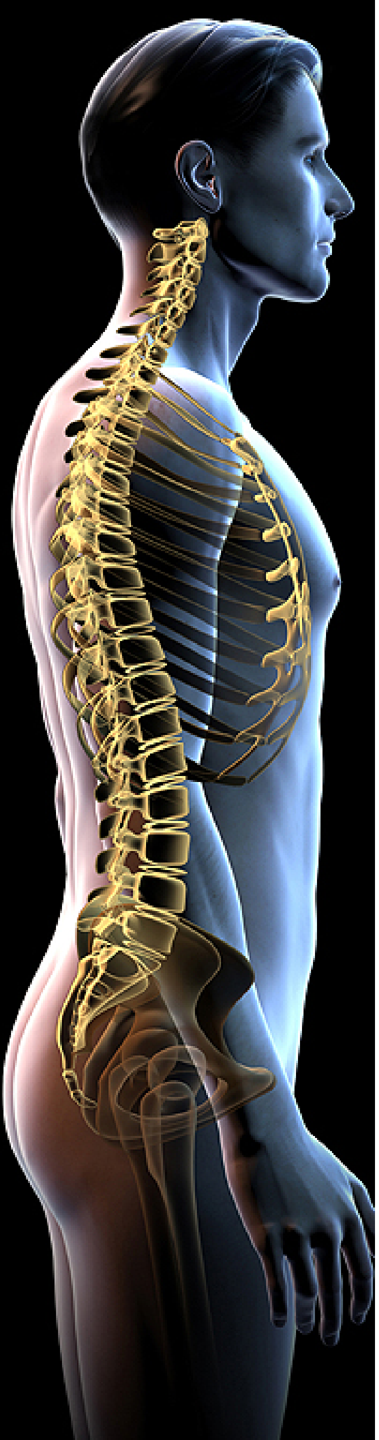


^{18}F-NaF Rectilinear Scanner

^{99m}Tc-MDP Gammacamera

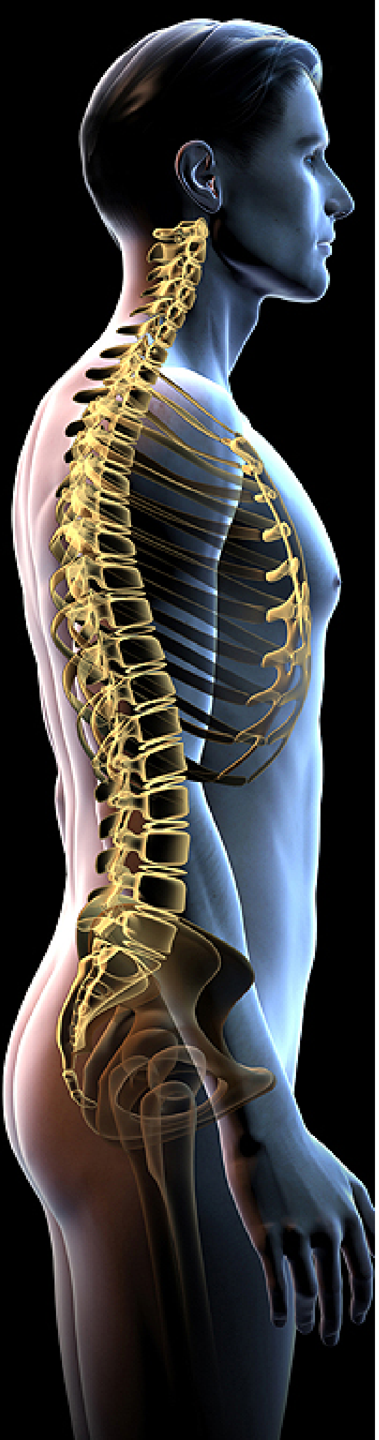


^{18}F-NaF PET scanner



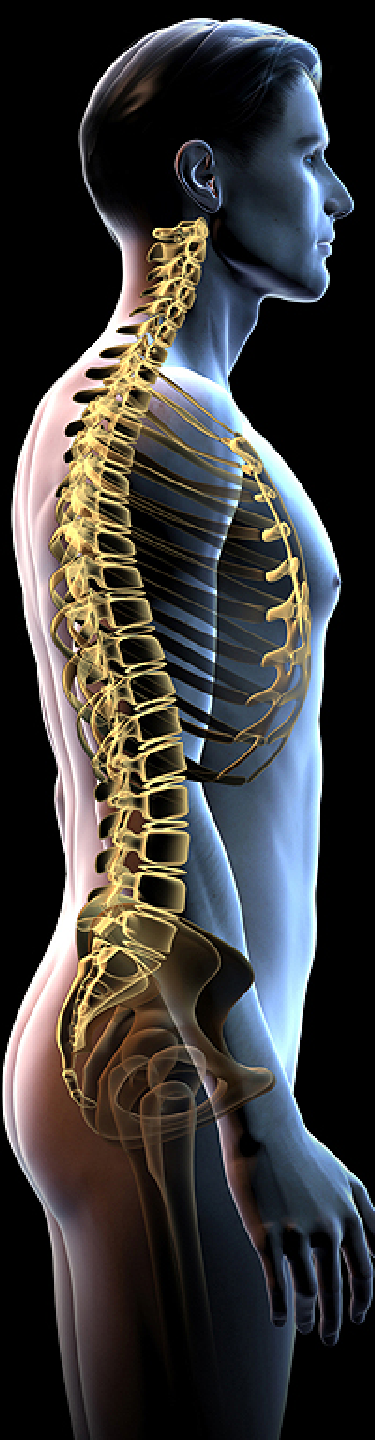
^{18}F-NaF Resurgence

- More sensitivity than MDP
- NEW PET/CT Cameras
- Occasional shortage of ^{99m}Tc Generators.



^{18}F-NaF Clinical Indications

1. **Osteoblastic osseous metastasis** (localization + extent)
   – Diagnosis
   – Following therapy
   – Bony pain/aches
2. **Lower Back pain**



^{18}F-NaF Clinical Indications

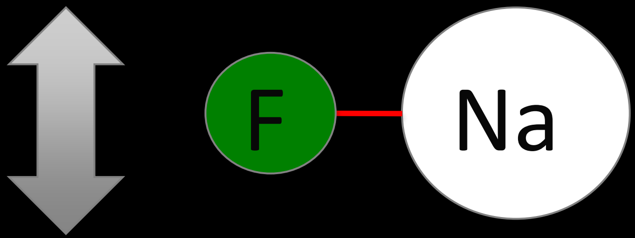
- **Other reported uses: (Research or inefficient information to be in routine use)**

1. Back pain (Ovadia 2007, Lim 2007) and unexplained bone pain (Fischer 2010).
2. Child abuse (Drubach in 2008 and 2010).
3. abnormal radiographs or laboratory findings.
4. Osteomyelitis.
5. Trauma.
6. Inflammatory and degenerative arthritis.
7. Avascular necrosis (Dasa 2008, Aratake 2009)
8. Osteonecrosis of the mandible (Raje 2008, Wilde 2009)
9. Condylar hyperplasia (Laverick 2009, Saridin 2009)
10. Metabolic bone disease (Uchida 2009)
11. Paget's disease (Installe 2005)
12. Bone graft viability (Brenner 2004)
13. Complications of the prosthetic joints (Temmerman 2008, Ullmark 2009)
14. Reflex sympathetic dystrophy .
15. Distribution of osteoblastic activity prior to administration of therapeutic. radiopharmaceuticals for treating bone scans.

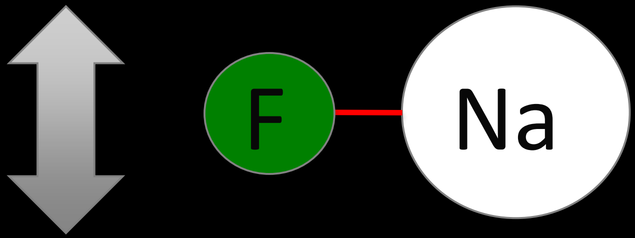
MECHANISM OF UPTAKE

- exchange of 18F-ions with hydroxyl ions (OH) on the surface of the hydroxyapatite to form fluoroapatite

Hydroxyapatite

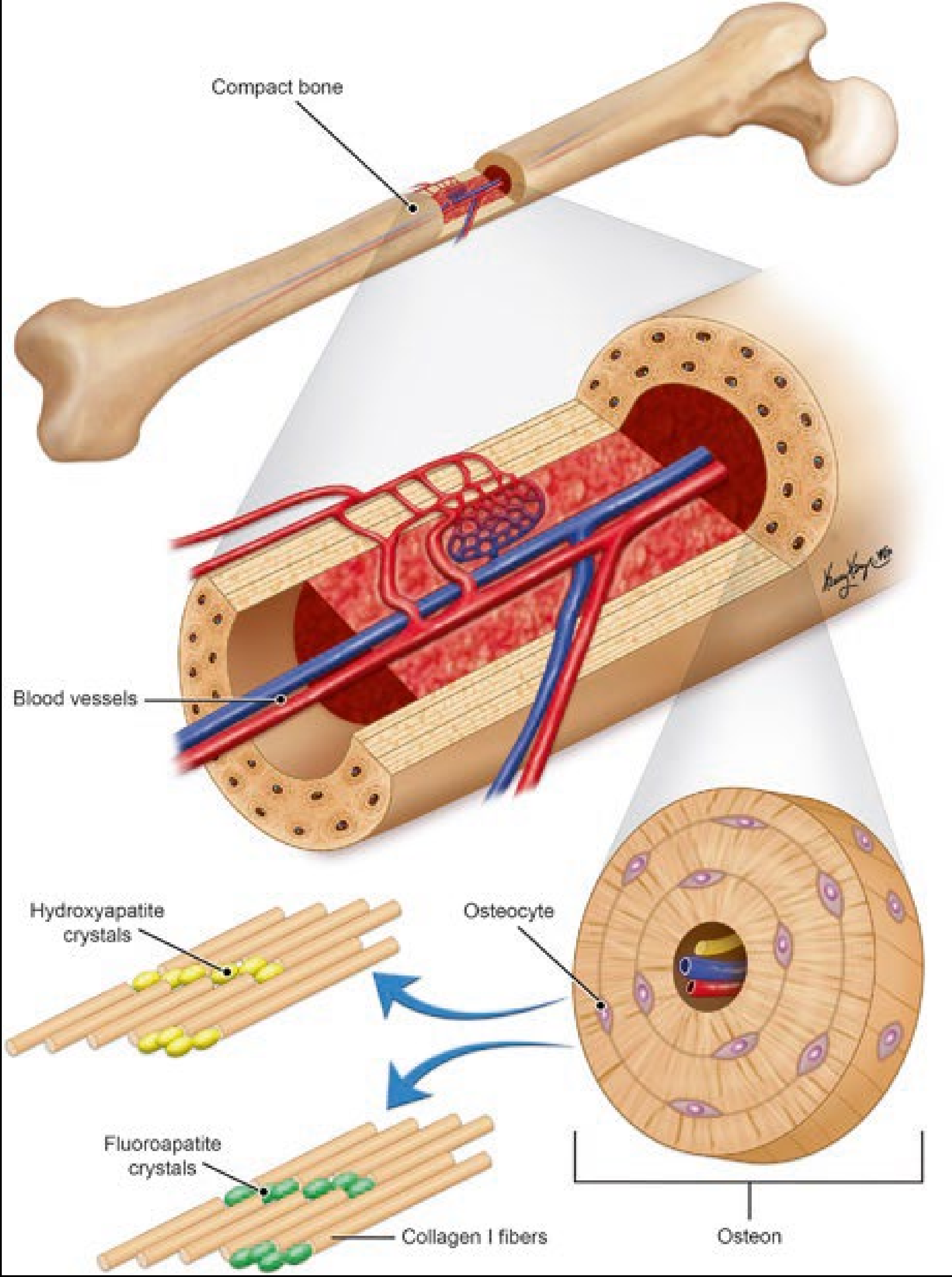


Hydroxyfluorapatite



Fluorapatite

Incorporation of ^{18}F from NaF into the hydroxyapatite crystals of the mineral bone matrix to form the radioactive fluorapatite crystals
(illustration by Kelley Kage)



Nuclear Medicine Radiation Dose Tool

Click Here to View Disclaimer

Select Nuclear Medicine Exam:

---Common exams---
F-18 FDG
Tc-99m DMSA
Tc-99m Pertechnetate
Tc-99m MAA
Tc-99m MDP
Tc-99m MIBI (exercise)
Tc-99m Tetrofosmin (exercise)
---List of all exams---
H-3 Glucose

Input Injected Activity:

25 mCi or 925 MBq

Select patient model:

Adult Male
Adult Female
15-yr-old
10-yr-old
5-yr-old
1-yr-old
early pregnant woman

Recommended Adult Injected Activity:

Minimum	20.0 mCi	740.00 MBq
Maximum	30.0 mCi	1110.00 MBq

Reference for adult injected activity:

Donohoe et al, 'Society of Nuclear Medicine Procedure Guideline for Bone Scintigraphy', 2003

Radiation Dose Estimate:

According to models recommended in ICRP 106, a 925 MBq injection for a Tc-99m MDP study would impart to a Adult Male an approximate effective dose of **5.3 mSv (0.53 rem)**. The critical organ for this study is the Bone surfaces, which would receive 58.3 mGy (5.83 rad).

VERSION: 1.04; 16-May-2015

Nuclear Medicine Radiation Dose Tool

Click Here to View Disclaimer

Select Nuclear Medicine Exam:

---List of all exams---
H-3 Glucose
C-14 Urea, Normal
Co-57 Cyanocobalamin
Cr-51 Sodium Chromate RBCs
F-18 FDG
F-18 Sodium Flouride
Ga-67
I-123 Hippuran
I-123 Ioflupane (DaTscan)

Input Injected Activity:

7.5 mCi or 278 MBq

Select patient model:

10-yr-old
5-yr-old
1-yr-old
early pregnant woman
3 month pregnant woman
6 month pregnant woman
9 month pregnant woman

Recommended Adult Injected Activity:

Minimum	5.0 mCi	185.00 MBq
Maximum	10.0 mCi	370.00 MBq

Reference for adult injected activity:

Segall et al, 'SNM Practice Guideline for Sodium 18F-Fluoride PET/CT Bone Scans 1.0', JNM 2010

Radiation Dose Estimate:

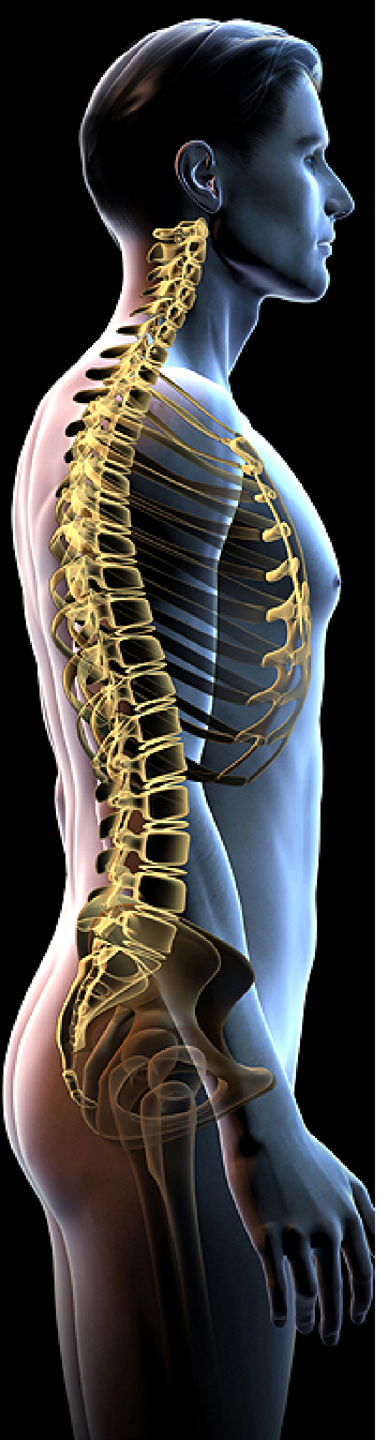
According to models recommended in ICRP 106, a 278 MBq injection for a F-18 Sodium Flouride study would impart to a Adult Male an approximate effective dose of **7.5 mSv (0.75 rem)**. The critical organ for this study is the Bladder wall, which would receive 61.2 mGy (6.12 rad).

VERSION: 1.04; 16-May-2015

Pharmaceutical	Effective dose/unit of administered activity for an adult patient			Activity		Total effective Dose
	Total-Body (mGy/MBq)	H (mSv/MBq)	E (mSv/MBq)	mCi	MBq	mSv
F^{18} NaF	2.64E-03	6.08E-03	4.75E-03	4.2	155	**3.5**
Tc^{99m}MDP	8.75E-03	2.70E-02	2.31E-02	25	925	**4.4**

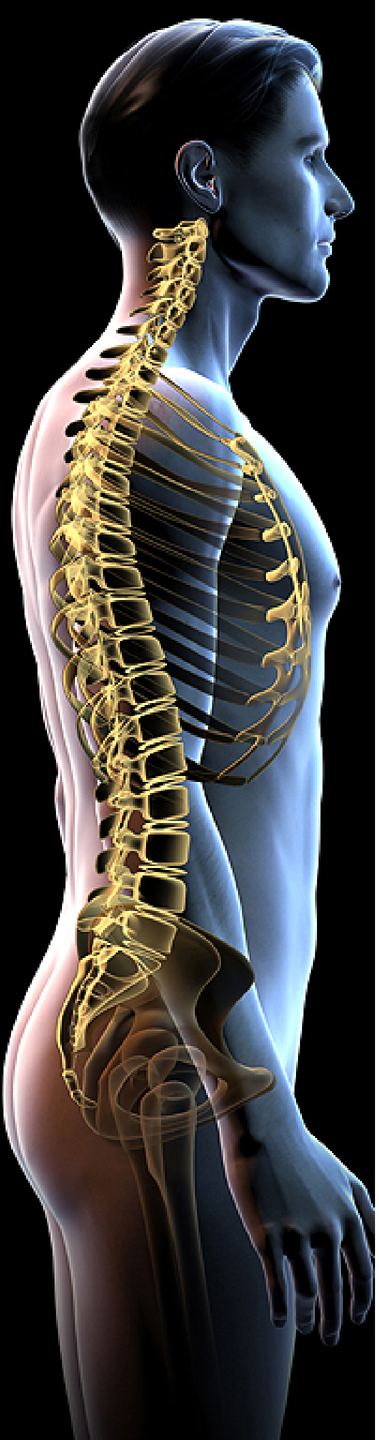
	MDP	NaF
RBC Uptake	Negligible	30 – 40 %
Protein Binding	25 – 70 %	Negligible
First Pass Extraction	40 – 60 %	70 – 100 %
Renal Excretion	GFR	GFR – Tub.Reabsp

RP DOSE AND ACQUISITION PROTOCOL (BED/MIN)



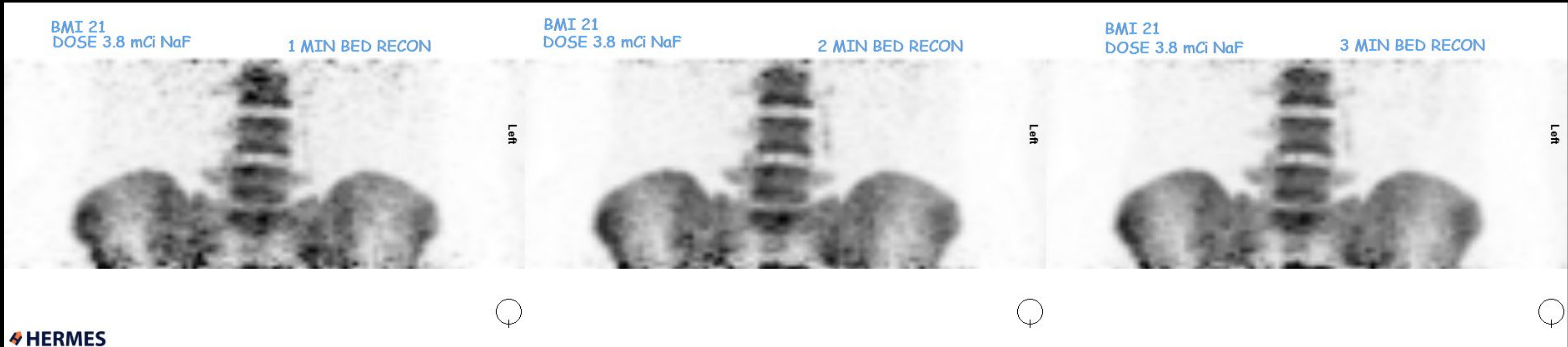
^{18}F-NaF Imaging Protocol

- **Dose**
  - **Adult:** activity is (5-10 mCi). A higher activity (10 mCi) may be used in obese patients.
  - **[JACMI: 0.06 mCi/Kg]**
  - **Pediatric:** activity should be weight-based (0.06 mCi/kg) , Min-Max = [0.5 to 5 mCi].
- **Acquisition**
  - **Axial:** 30-45 min post injection
  - **WB/Extremities:** 90-120 min post injection
- **2 – 5 min/bed position**
- **[JACMI: BMI-based 2 - 3 min/bed = 40 or 50 min]**
- **3D acquisition mode recommended**
- **Diuretics or bladder cath. can be considered if needed.**



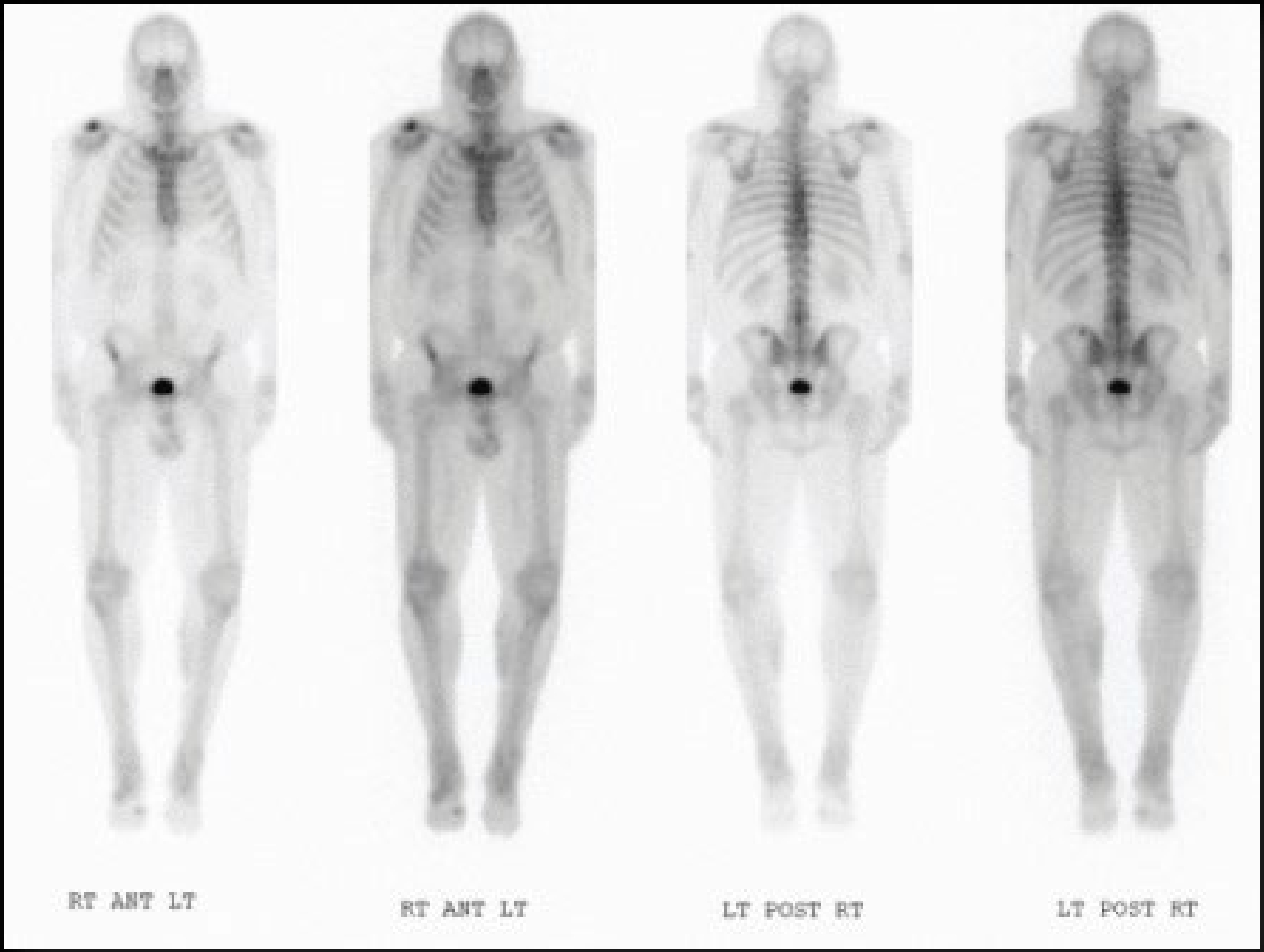
^{18}F-NaF Imaging Protocol

- **Processing**
  - 128 x 128 (or 256 x 256) matrix
  - Same reconstruction iterations and subsets as with ^{18}F-FDG
  - MIP
  - AC images

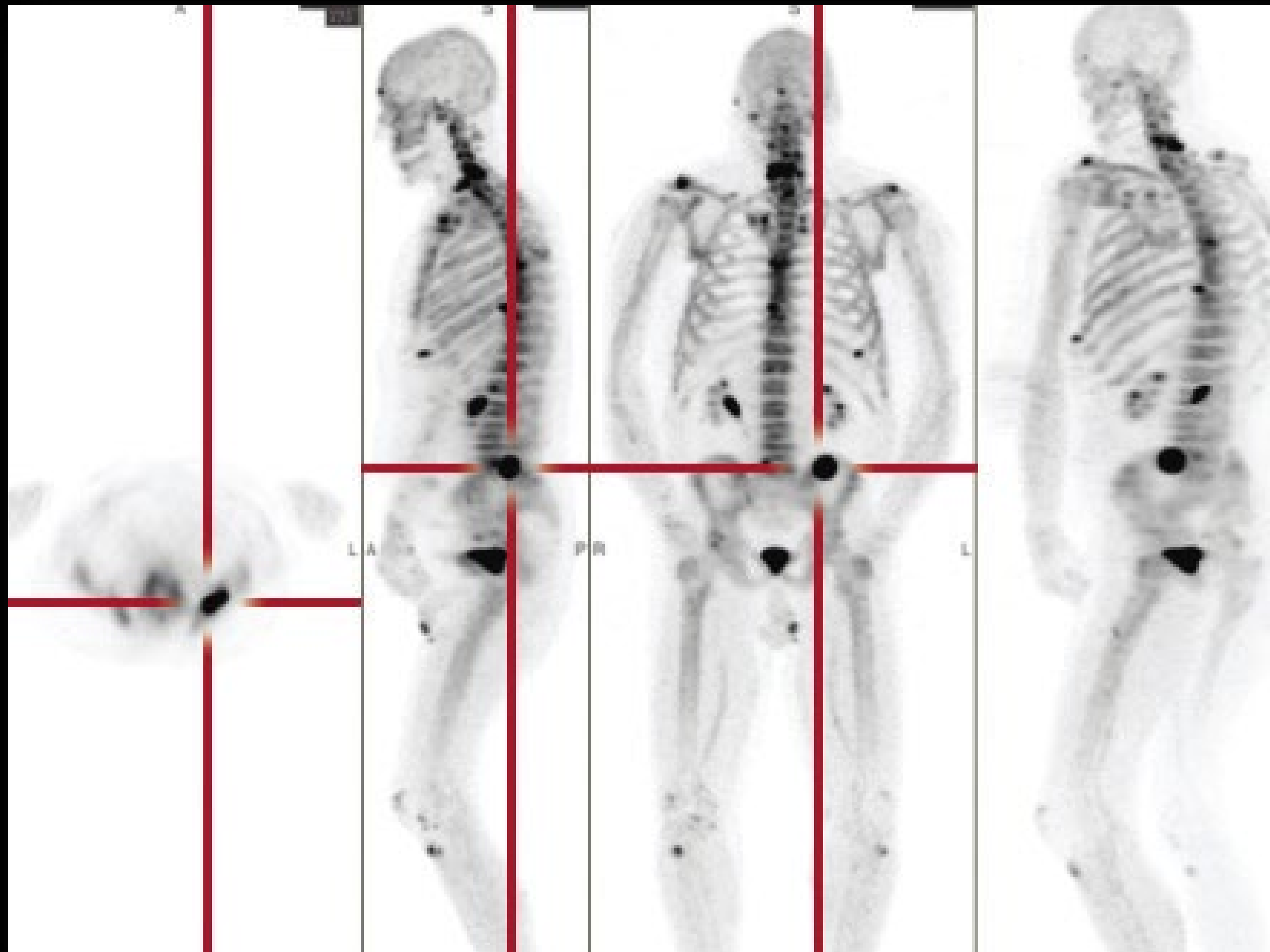

BMI 21
DOSE 3.8 mCi NaF
1 MIN BED RECON
Left
BMI 21
DOSE 3.8 mCi NaF
2 MIN BED RECON
Left
BMI 21
DOSE 3.8 mCi NaF
3 MIN BED RECON
Left
HERMES


BMI 21
DOSE 3.8 mCi NaF
4 MIN BED RECON
Left
BMI 21
DOSE 3.8 mCi NaF
5 MIN BED RECON
Left
BMI 21
DOSE 3.8 mCi NaF
6 MIN BED ACQUISITON
Left
HERMES

^{99m}Tc-MDP in case of Prostate cancer



^{18}F-NaF in the same case of Prostate cancer



Sensitivity in detecting osseous lesions depends on anatomic localization: planar bone scintigraphy versus 18F PET. Schirrmeister H, et . Al . J Nucl Med. 1999 Oct;40(10):1623-9.

^{18}F-NaF in Prostate cancer HIGHER SEN

Skeletal Metastases Detected by ^{18}F PET and Radionuclide Bone Scanning (RNB) in Patients with Osteoblastic (Prostate Cancer) or Osteolytic (Lung and Thyroid Cancer) Metastases

Metastases	^{18}F PET	RNB	RNB/PET (%)
Osteoblastic	67	33	49.3
Osteolytic	29	13	44.8

Sensitivity in detecting osseous lesions depends on anatomic localization: planar bone scintigraphy versus 18F PET. Schirrmeister H, et . Al . J Nucl Med. 1999 Oct;40(10):1623-9.

^{18}F-NaF in Prostate cancer HIGHER SEN

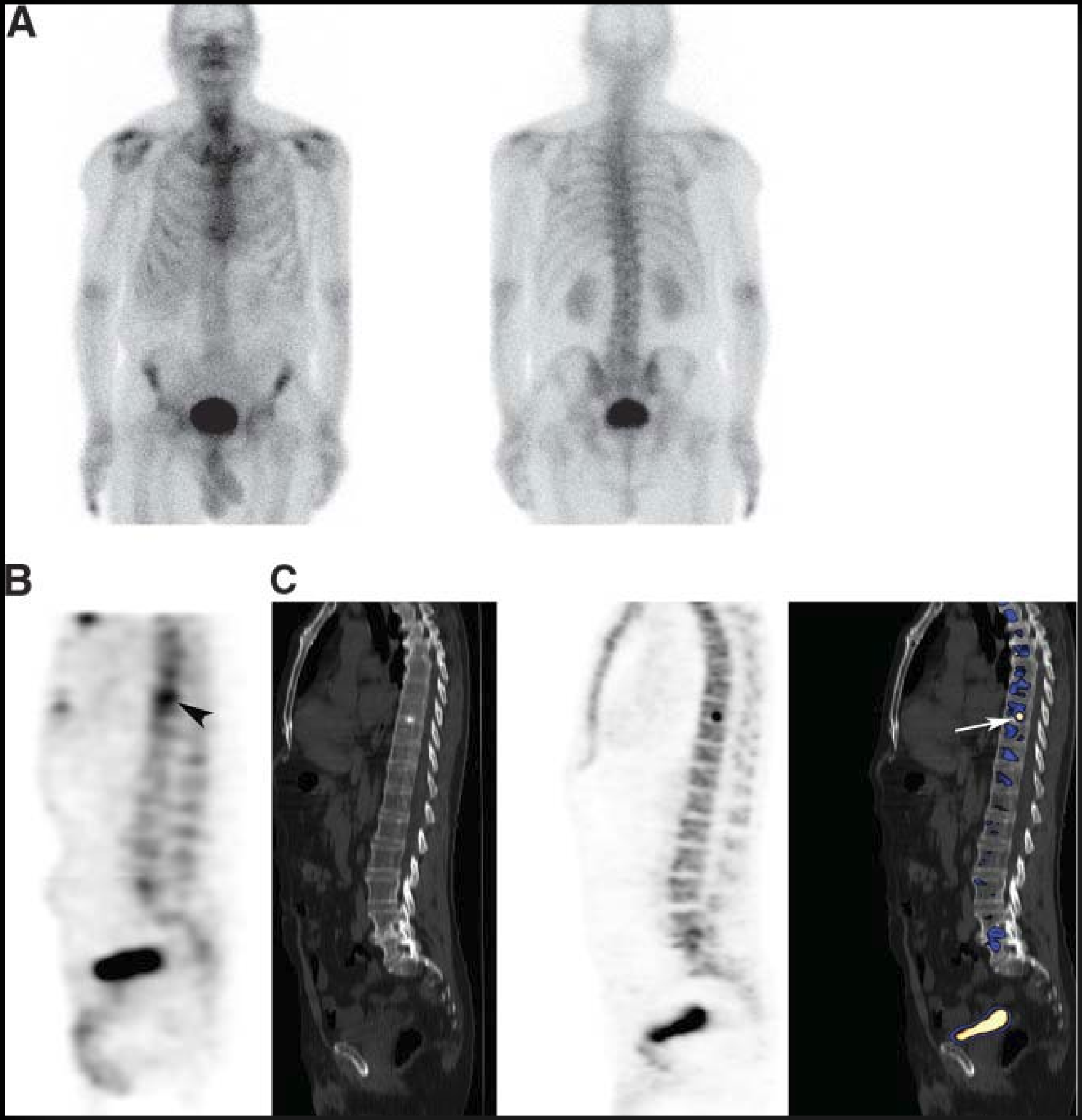
Osseous Lesions Detected at Different Sites by Radionuclide Bone Scanning (RNB) Compared with ^{18}F PET

Region	^{18}F PET	RNB*
Skull	5	4 (80.0)
Upper extremity	18	16 (88.9)
Ribs and sternum	24	19 (79.2)
Spine	135	55 (39.6)
Cervical	39	8 (20.5)
Thoracic	59	21 (33.6)
Lumbar	37	16 (43.2)
Pelvis	12	5 (41.7)
Lower extremity	11	9 (81.8)

*Values in parentheses indicate percentage of lesions detected by ^{18}F PET.

The detection of bone metastases in patients with high-risk prostate cancer: 99mTc-MDP Planar bone scintigraphy, single- and multi-field-of-view SPECT, 18F-fluoride PET, and 18F-fluoride PET/CT. Even-Sapir E, Metser U, Mishani E, Lievshitz G, Lerman H, Leibovitch I.
J Nucl Med. 2006 Feb;47(2):287-97.

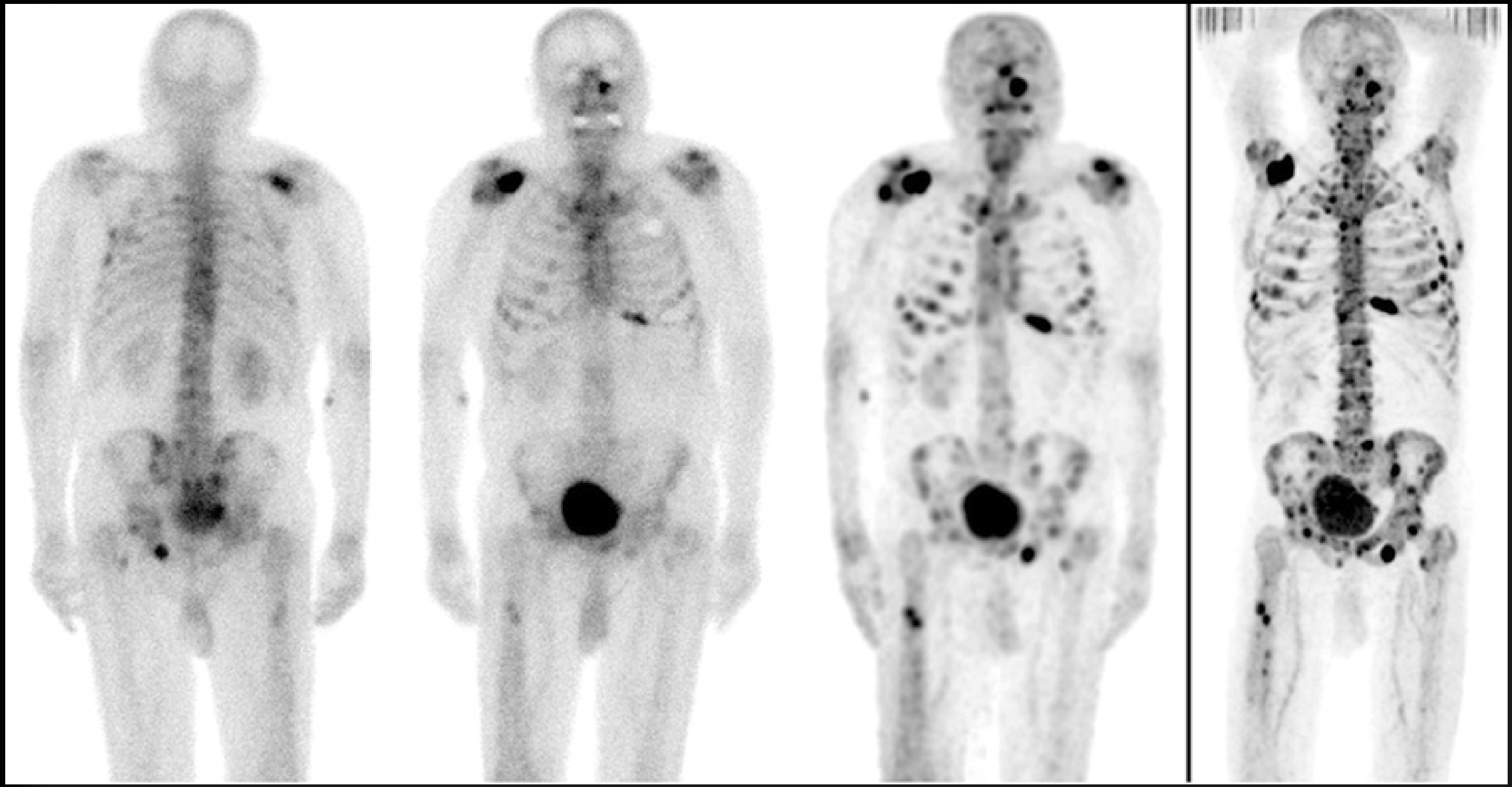
A. BS Planar
B. BS SPECT/CT
C. ^{18}F-NaF PET/CT



PET vs. PET/CT

The detection of bone metastases in patients with high-risk prostate cancer: 99mTc-MDP Planar bone scintigraphy, single- and multi-field-of-view SPECT, 18F-fluoride PET, and 18F-fluoride PET/CT.
Even-Sapir E, Metser U, Mishani E, Lievshitz G, Lerman H, Leibovitch I.
J Nucl Med. 2006 Feb;47(2):287-97.

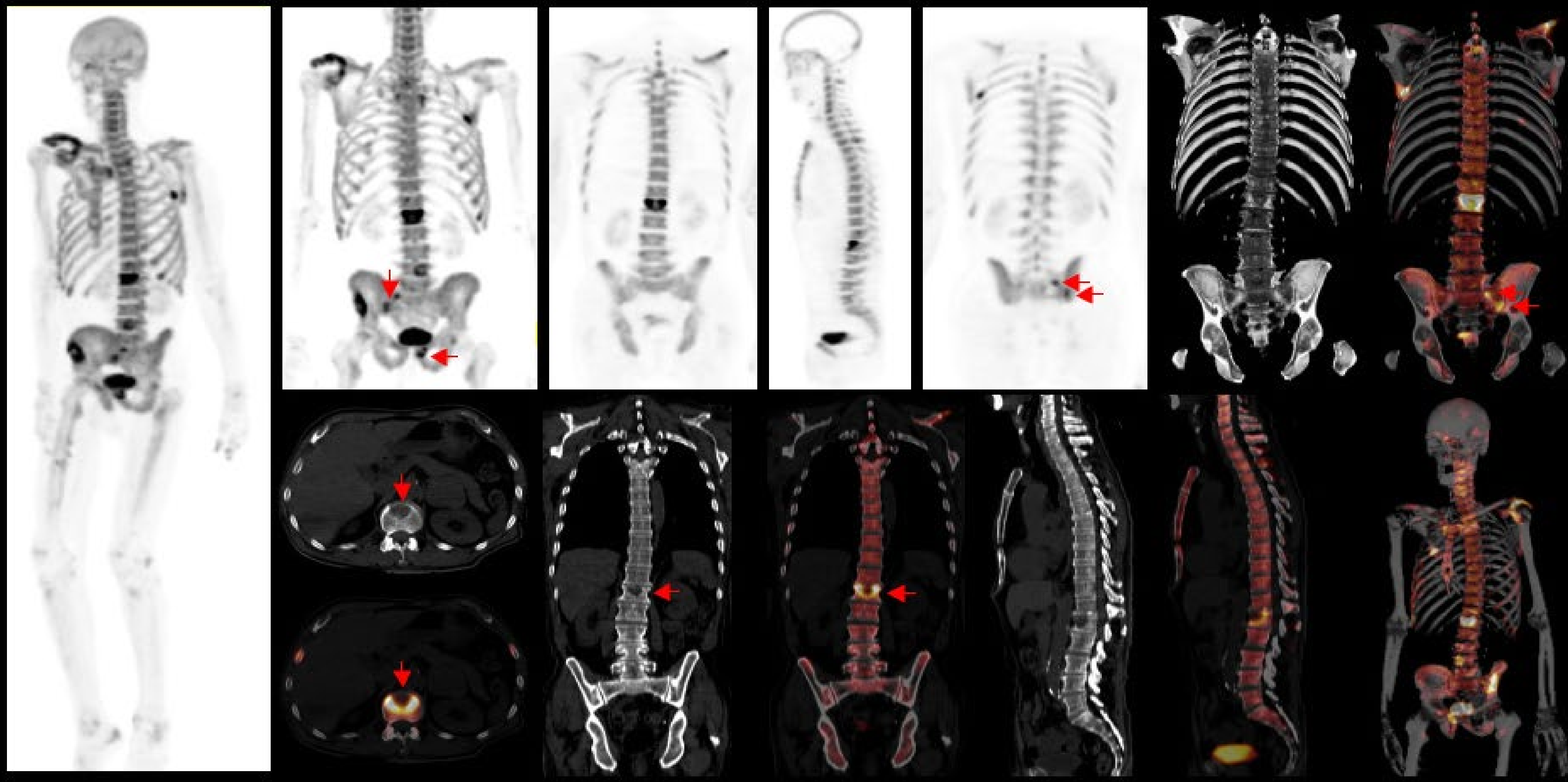
Lesion to lesion analysis	Sensitivity (%)	Specificity (%)
Planar Bone Scan	70	57
WB SPECT	92	82
^{18}F-NaF PET only	100	62
^{18}F-NaF PET/CT	100	100



***Skeletal PET with 18F-Flouride: Applying new technology to an old tracer*.**

Grant FD, Fahey FH, Packard AB, Davis RT, Alavi A, Treves ST.

J Nucl Med. 2008 Jan;49(1):68-78. Epub 2007 Dec 12



Literature Review

^{18}F-NaF PET/CT enables performance of whole-body imaging in a single examination but is **costly and not readily available**. A practicable and cost-effective strategy that had a significant effect on patient management in our study was the combination of planar BS with SPECT, complemented by MRI in unclear lesions.

Prospective Evaluation of the Clinical Value of Planar Bone Scans, SPECT, and 18F-Labeled NaF PET in Newly Diagnosed Lung Cancer.

[JNM] Dec 2001.

Literature Review

Conclusion: Our prospective pilot-phase trial demonstrates superior image quality and evaluation of skeletal disease extent with 18F NaF PET/CT over 99mTc MDP scintigraphy and 18F FDG PET/CT.

Prospective Evaluation of 99mTc MDP Scintigraphy, 18F NaF PET/CT, and 18F FDGnPET/CT for Detection of Skeletal Metastases

[J Mol Imaging Biol April 2011].

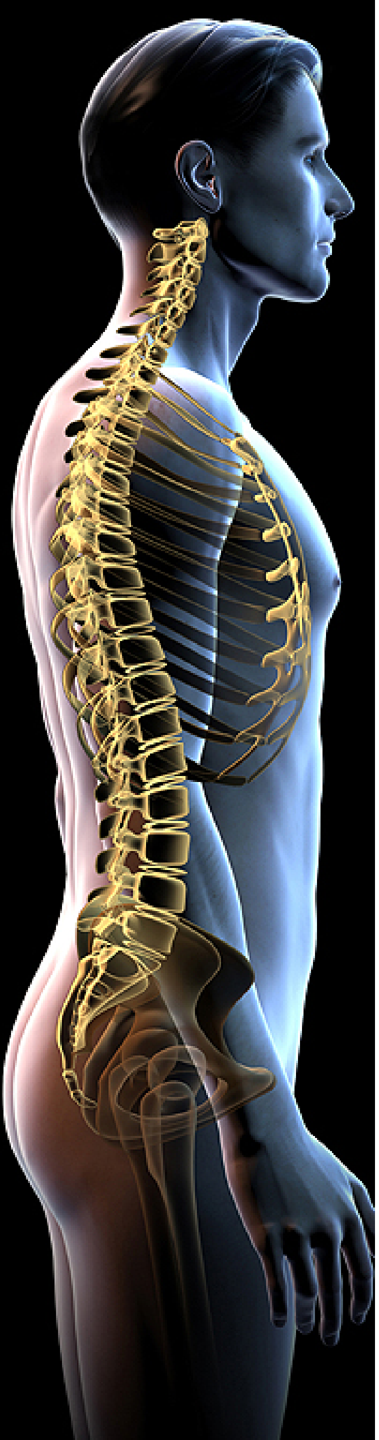
Literature Review

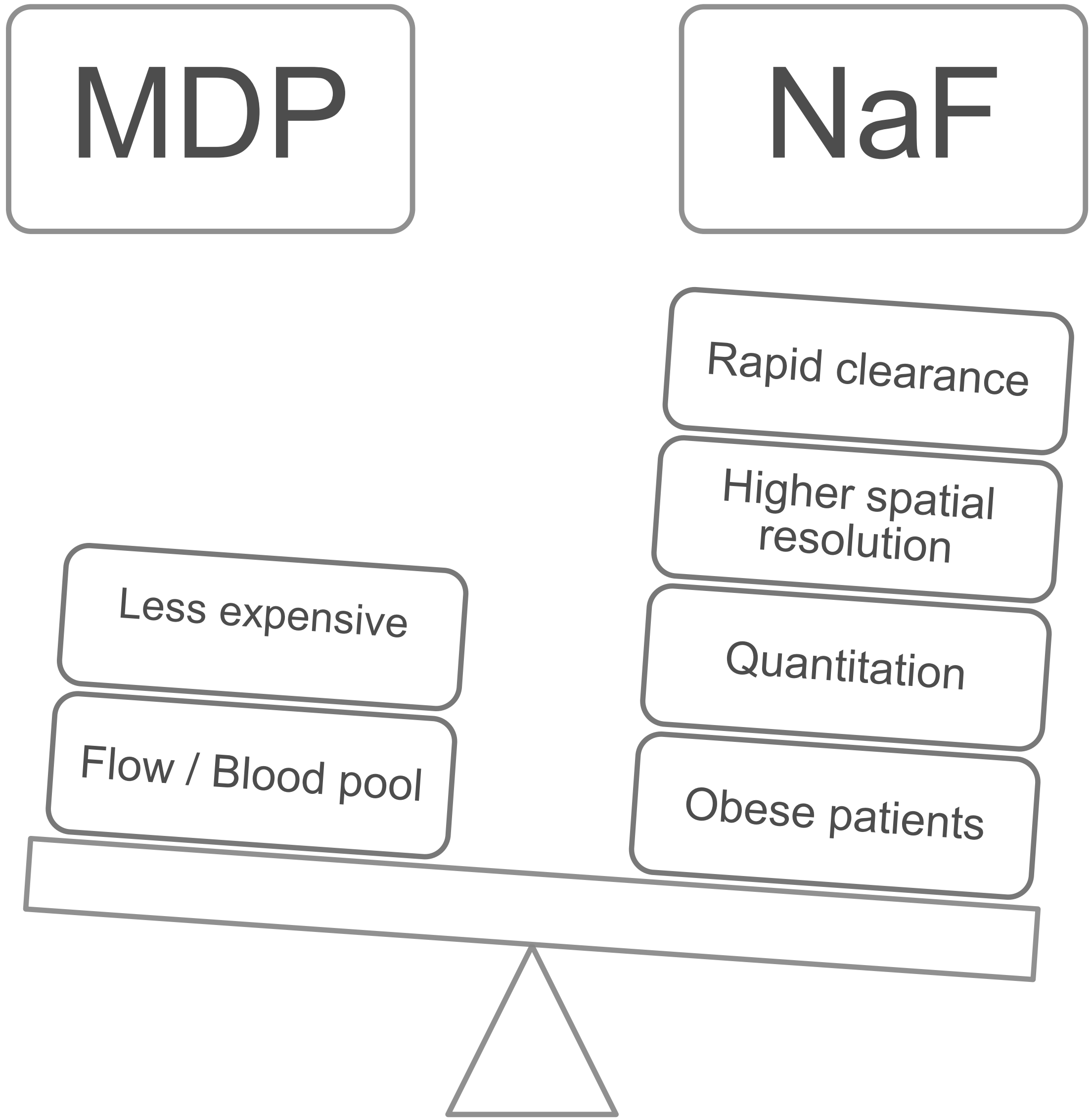
CONCLUSION:

We believe 18F-NaF PET/CT is a sensitive modality for detection of bone metastases caused by prostate cancer. **Whole-body DWI shows a higher specificity but lower sensitivity than 18F-NaF PET/CT**. Future studies with a larger patient cohort along with analyses of costs and clinical availability are needed before implementation of these methods
can be considered.

Whole-Body Diffusion-Weighted MRI Compared With 18F-NaF PET/CT for Detection of Bone Metastases in Patients With High-Risk Prostate Carcinoma

[AJR11-2012]




MDP
NaF
Rapid clearance
Higher spatial resolution
Quantitation
Obese patients
Less expensive
Flow / Blood pool

BONE METASTASES

18F-FDG

>90%

Lytic lesion

Blastic lesions

18F-NaF

>90%

F-18 Soduim Fluoride vs FDG

A. Osteoblastic

B. Osteolytic

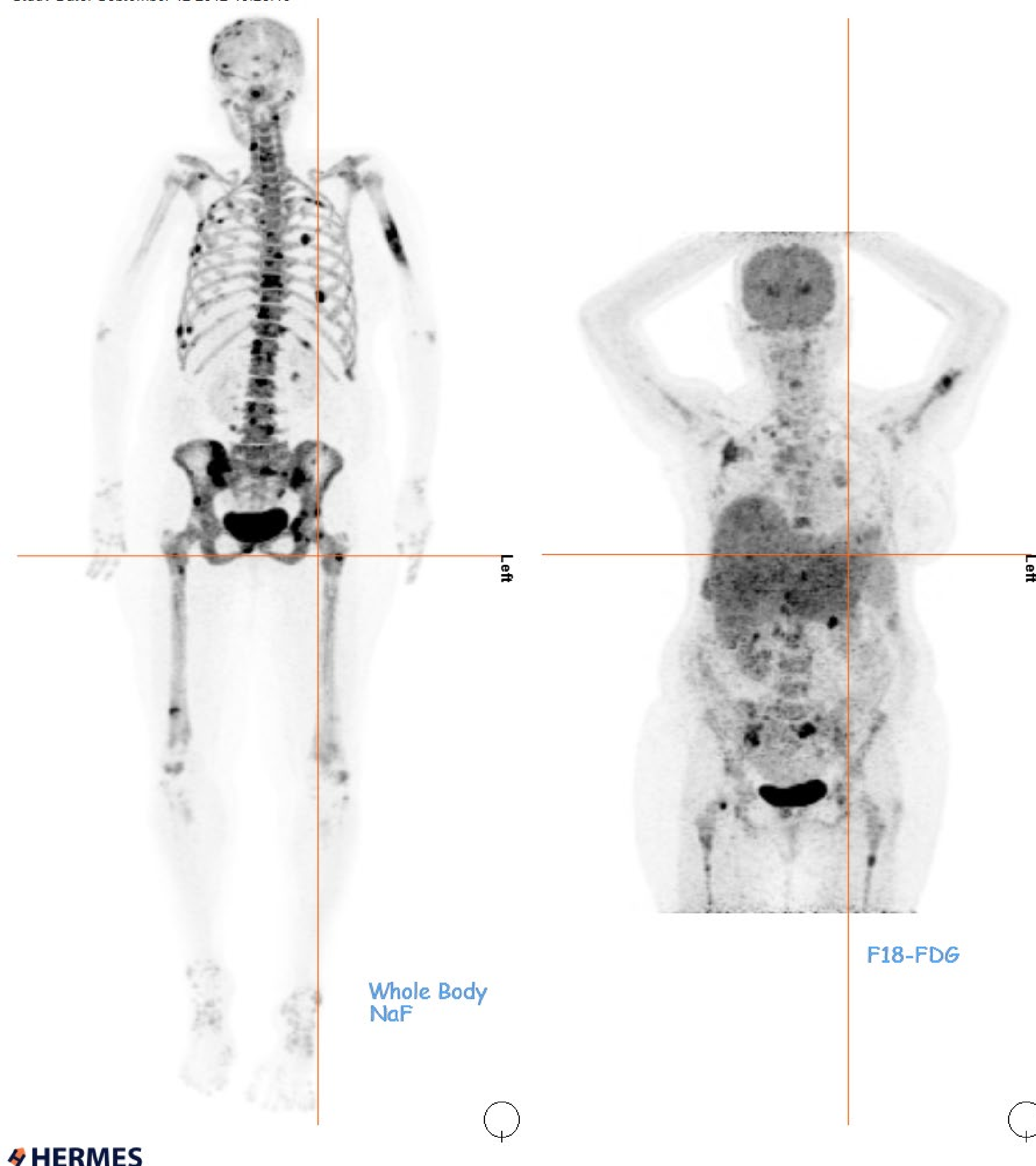
NaF

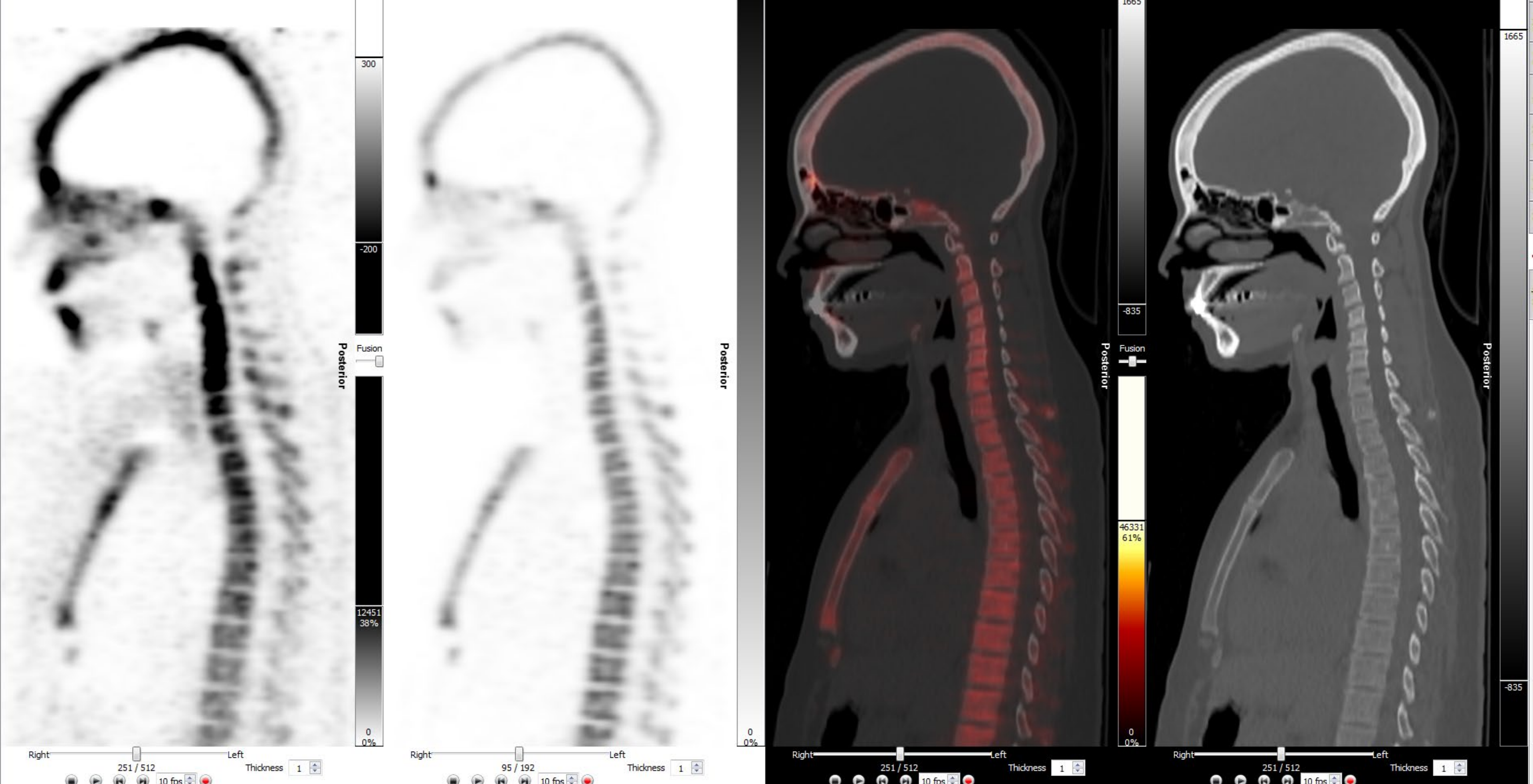
FDG

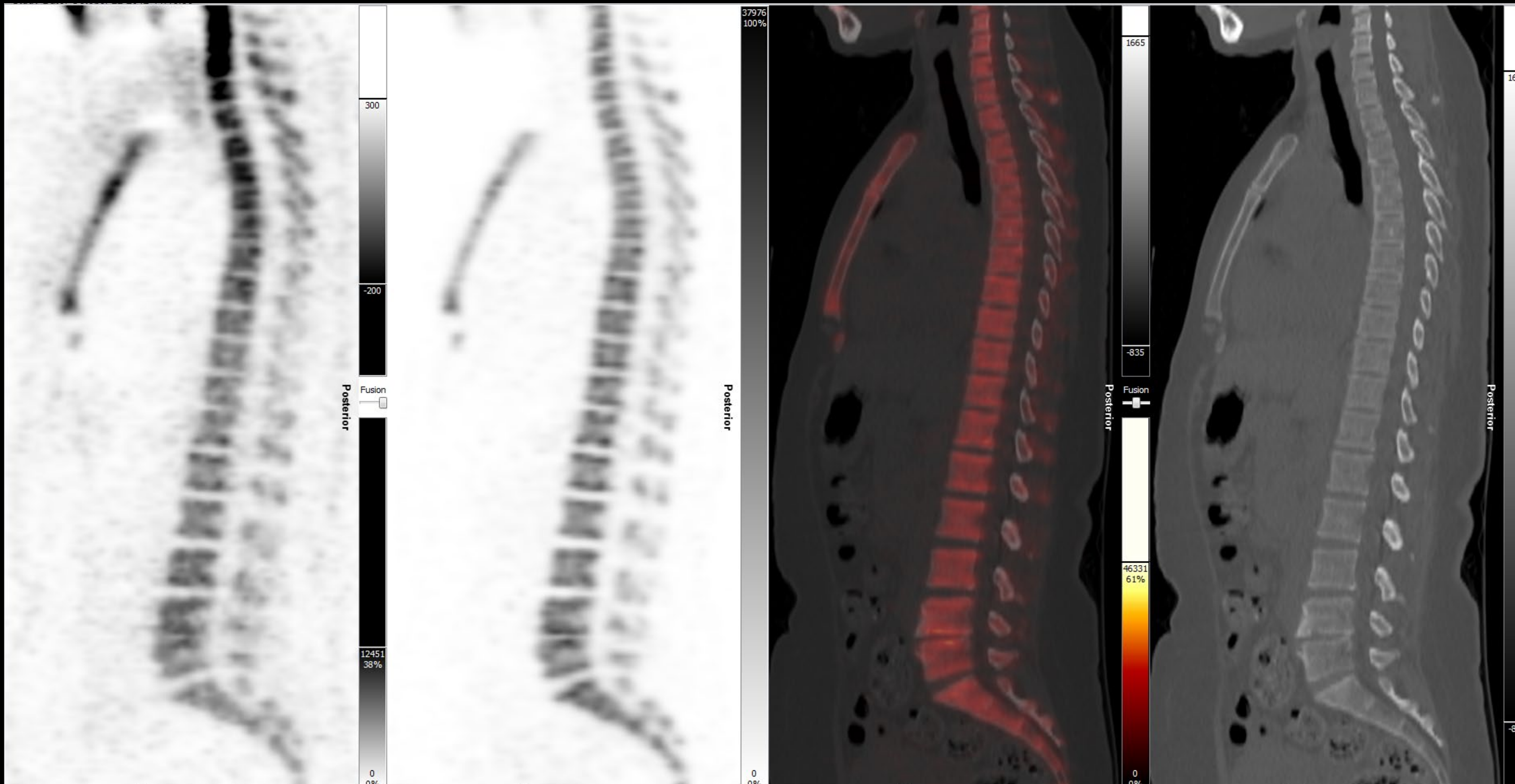
NaF

FDG

F-18 Soduim Fluoride vs. FDG




300
-200
Fusion
12451
38%
0
0%
Posterior
Right
Left
251 / 512
Thickness
1
10 fps
95 / 192
1665
-835
46331
61%


300
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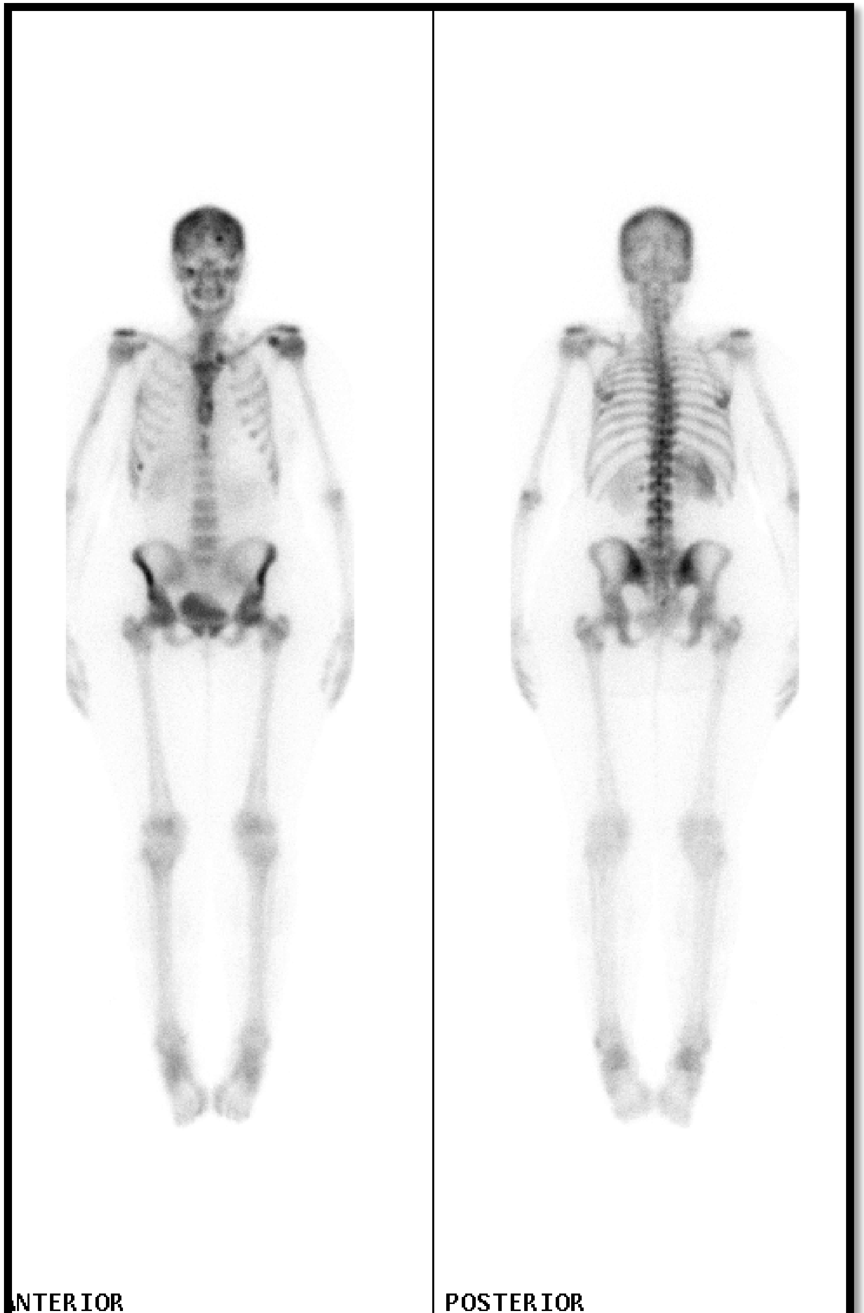
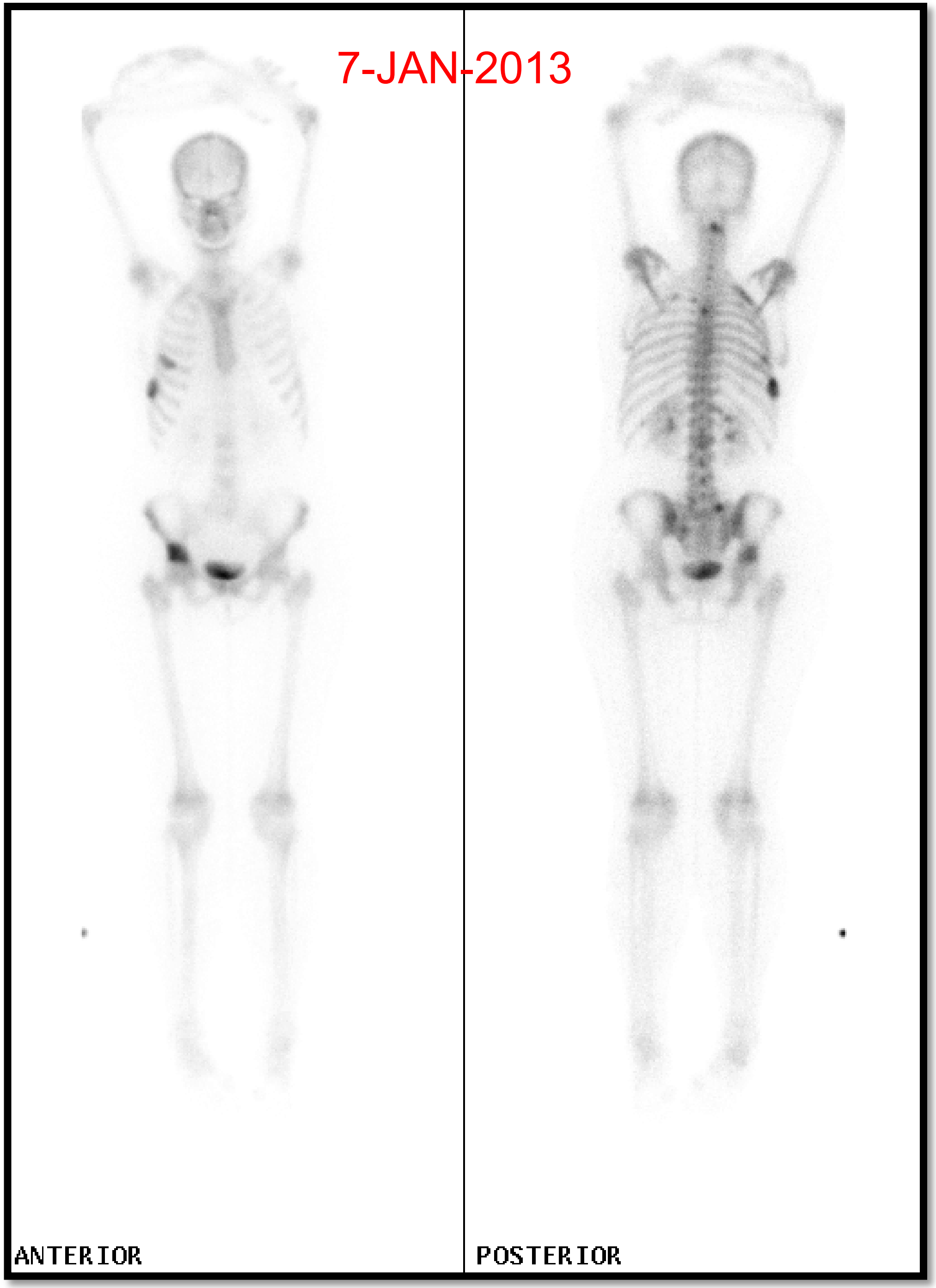


WB Bone Scintigraphy

WB PET/CT


7-JAN-2013
ANTERIOR
POSTERIOR

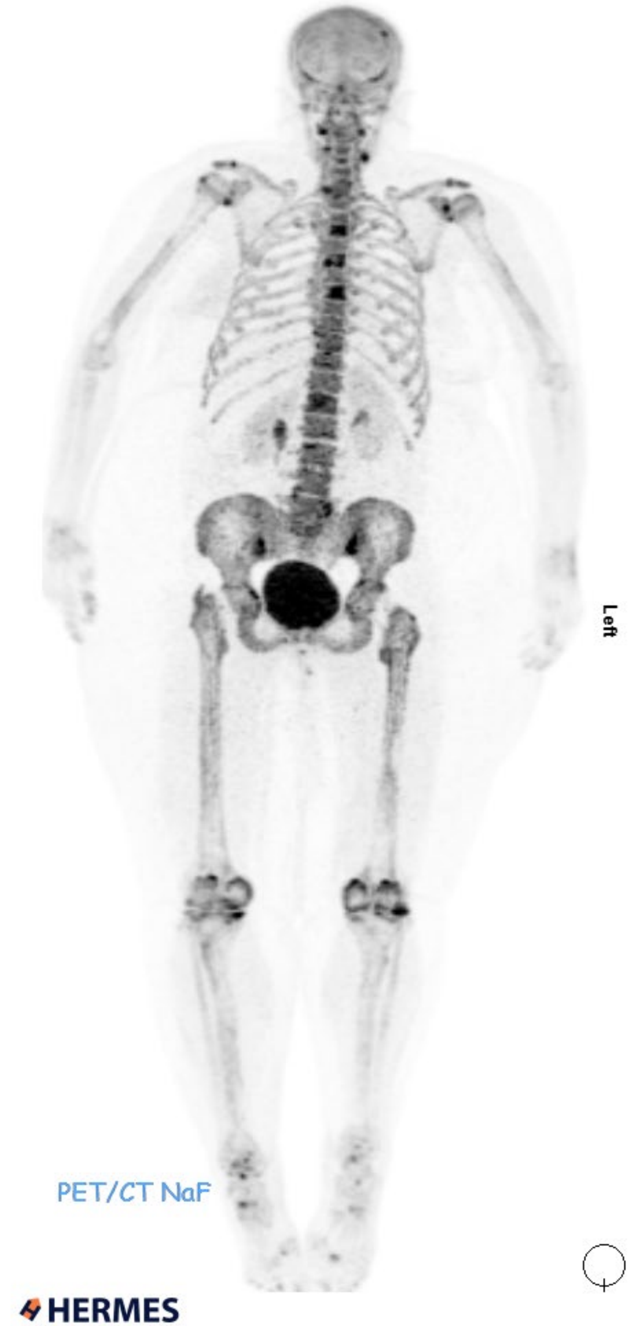

6-FEB-2013
Left
HERMES

OBESITY AND SOFT TISSUE ATTENUATION

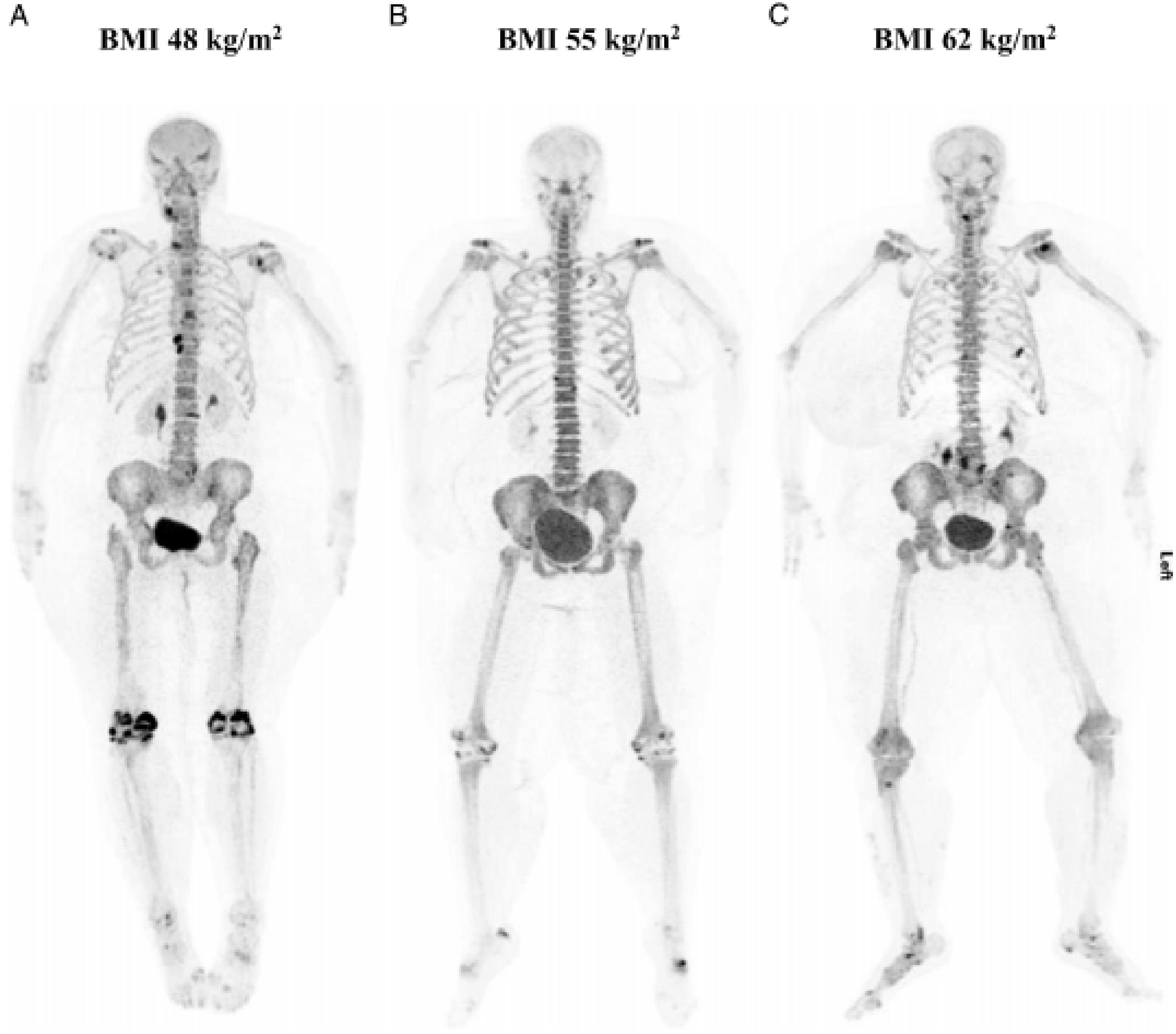
WB Bone Scintigraphy

WB PET/CT NaF


ANTERIOR
POSTERIOR


Left
PET/CT NaF
HERMES

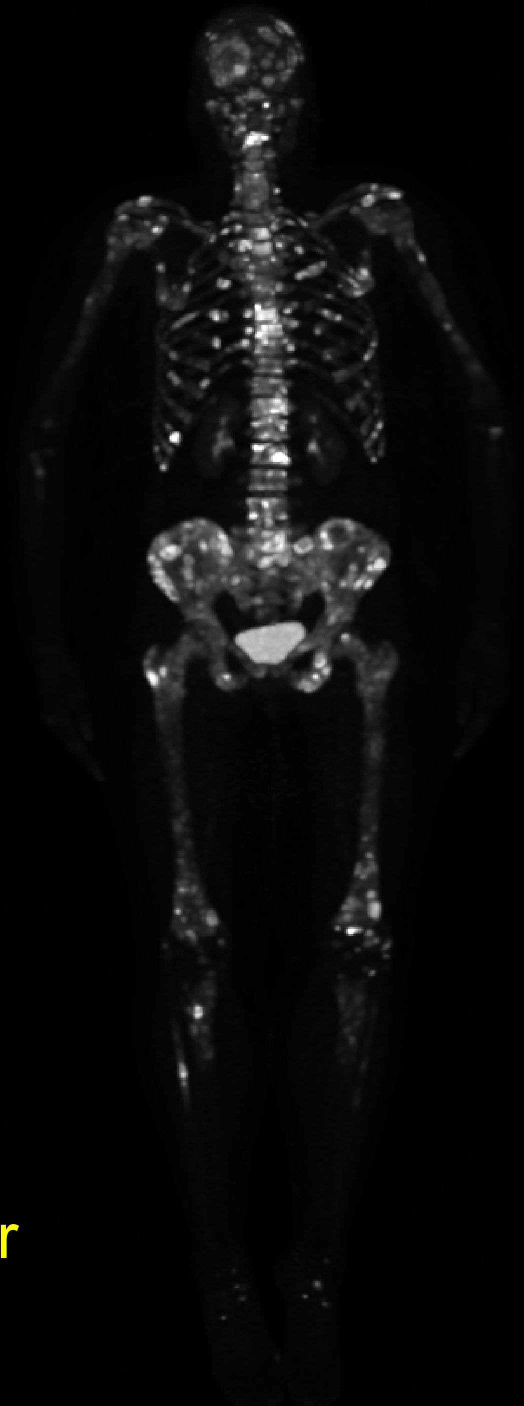

Left


A
BMI 48 kg/m2
B
BMI 55 kg/m2
C
BMI 62 kg/m2
Left

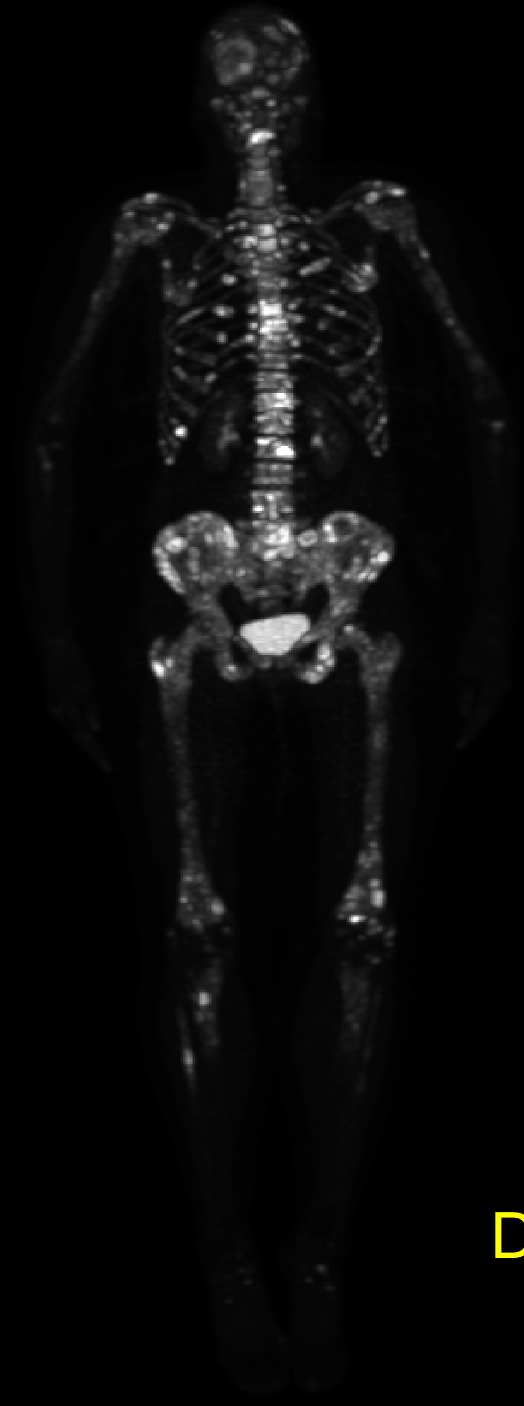
DIFFERENCE BETWEEN TWO CAMERA SYSTEMS

Disocovery 690

Biograph 2



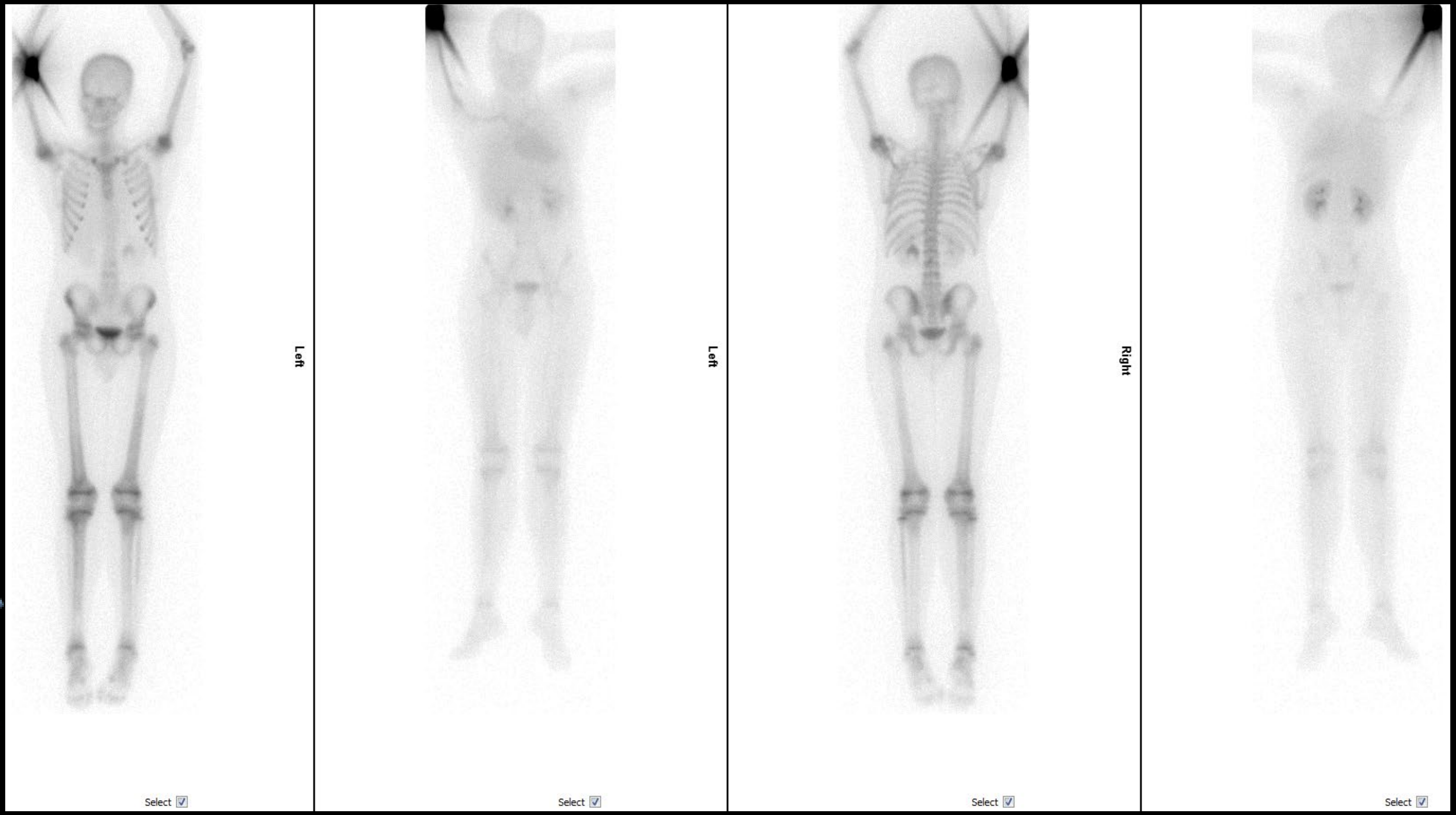
Q.Clear



Discovery 710

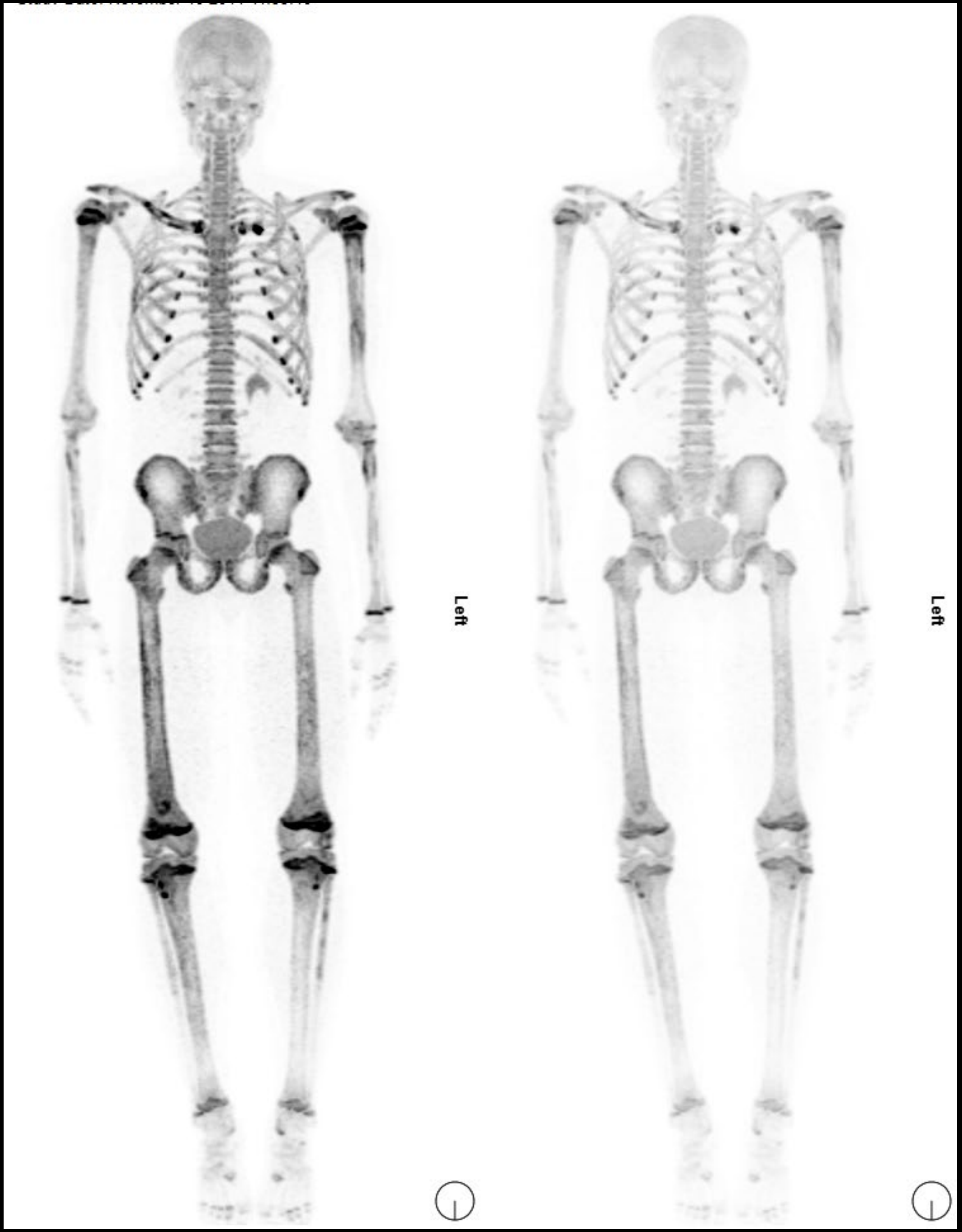
99Tc-MDP Bone Scan

-AVN Hip Right side



- ^{18}F-NaF PET/CT

-in the same case of AVN **Right side**



NORMAL BIODISTRIBUTION PATTERNS

Super scan
-no bladder

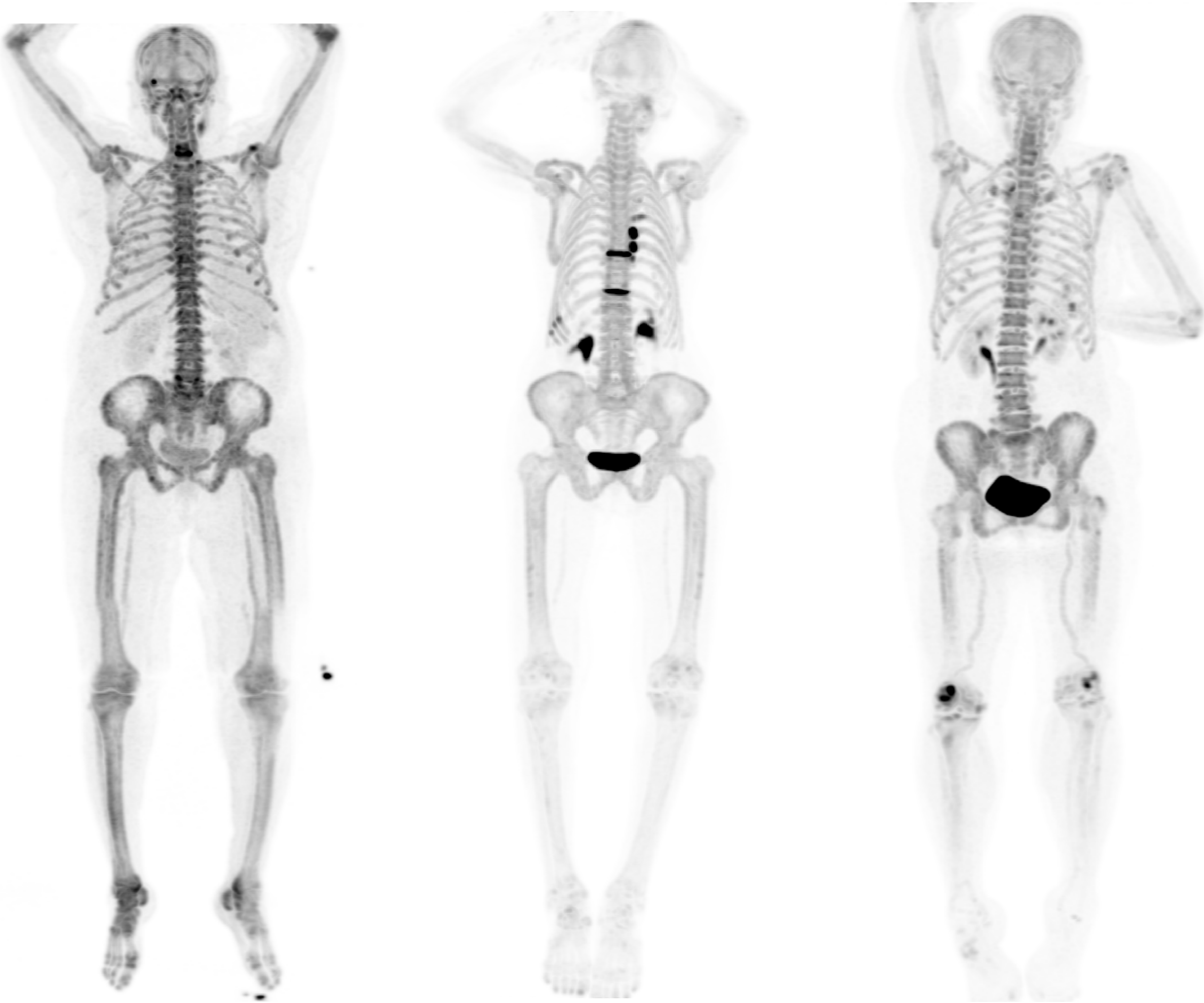
No extremities uptake

Axial uptake

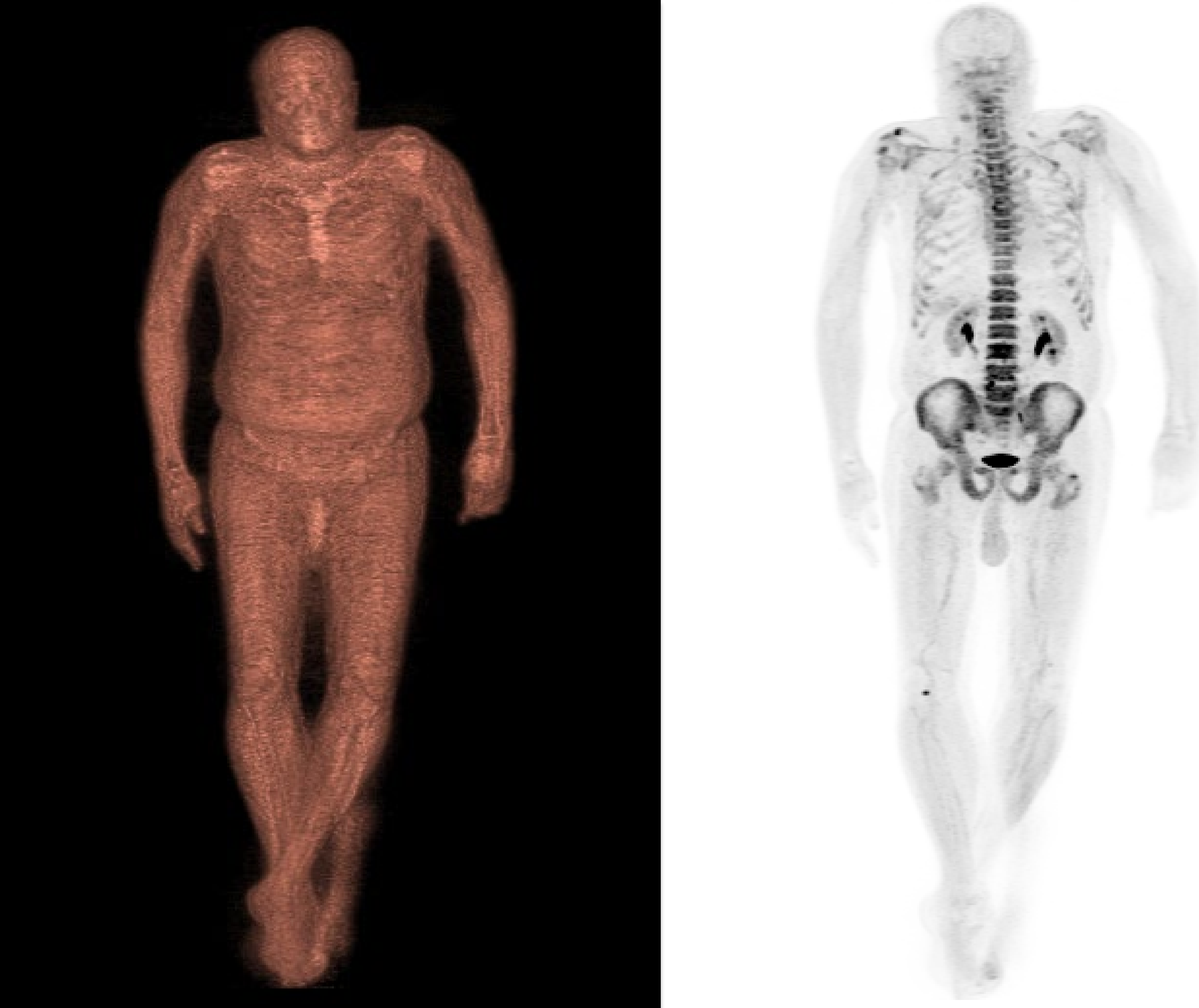
Pitfalls:

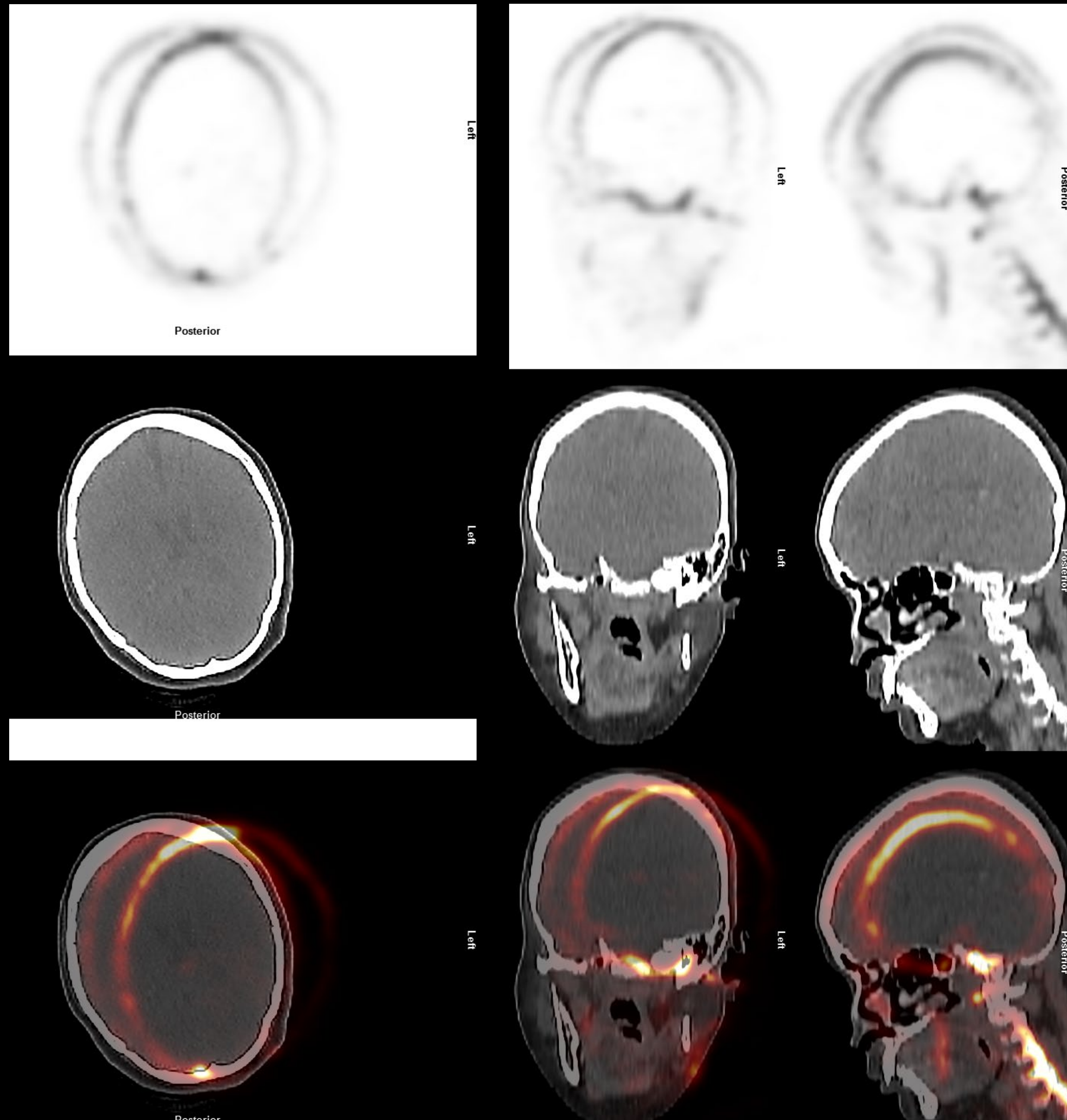
- Patient Motion
- Truncation
- Urinary Catheter
- Dose Infiltration
- Contamination
- Metal Artifact

PITFALLS: MOTION




NAC
AC




Left
Posterior
Left
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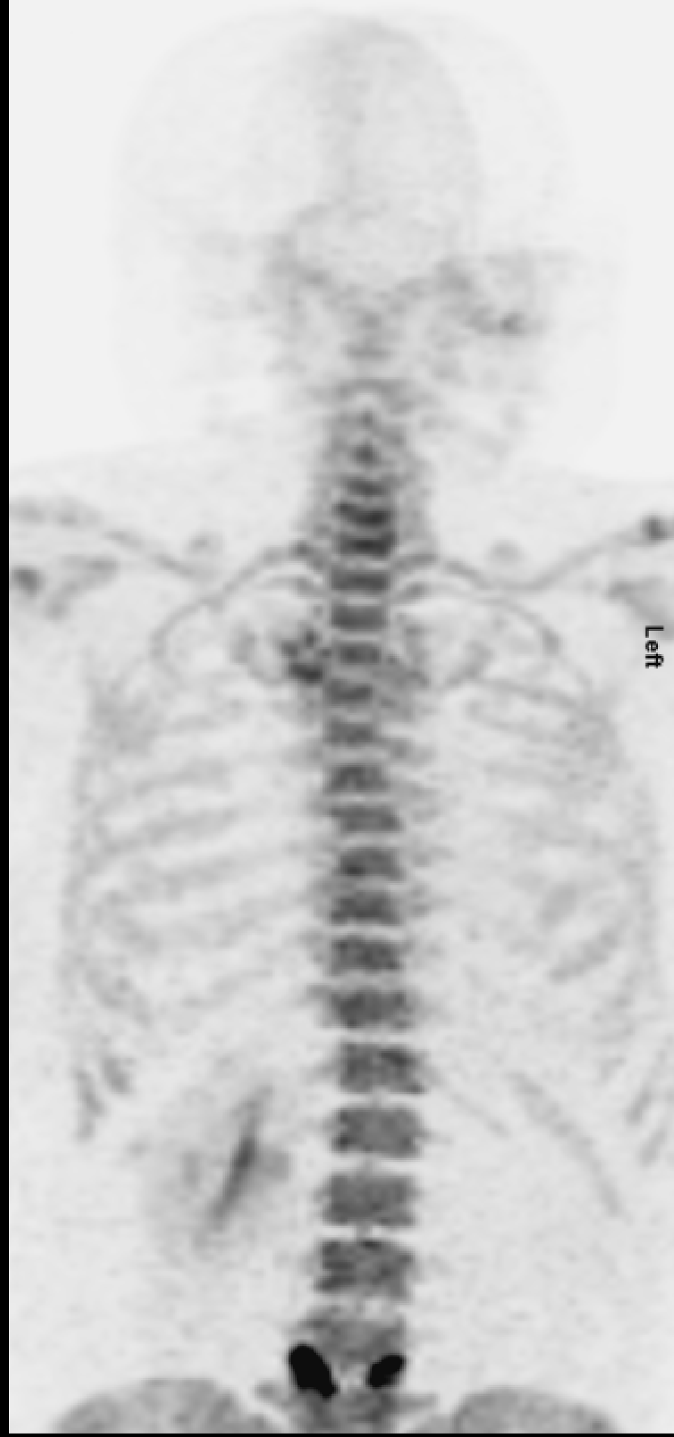
Posterior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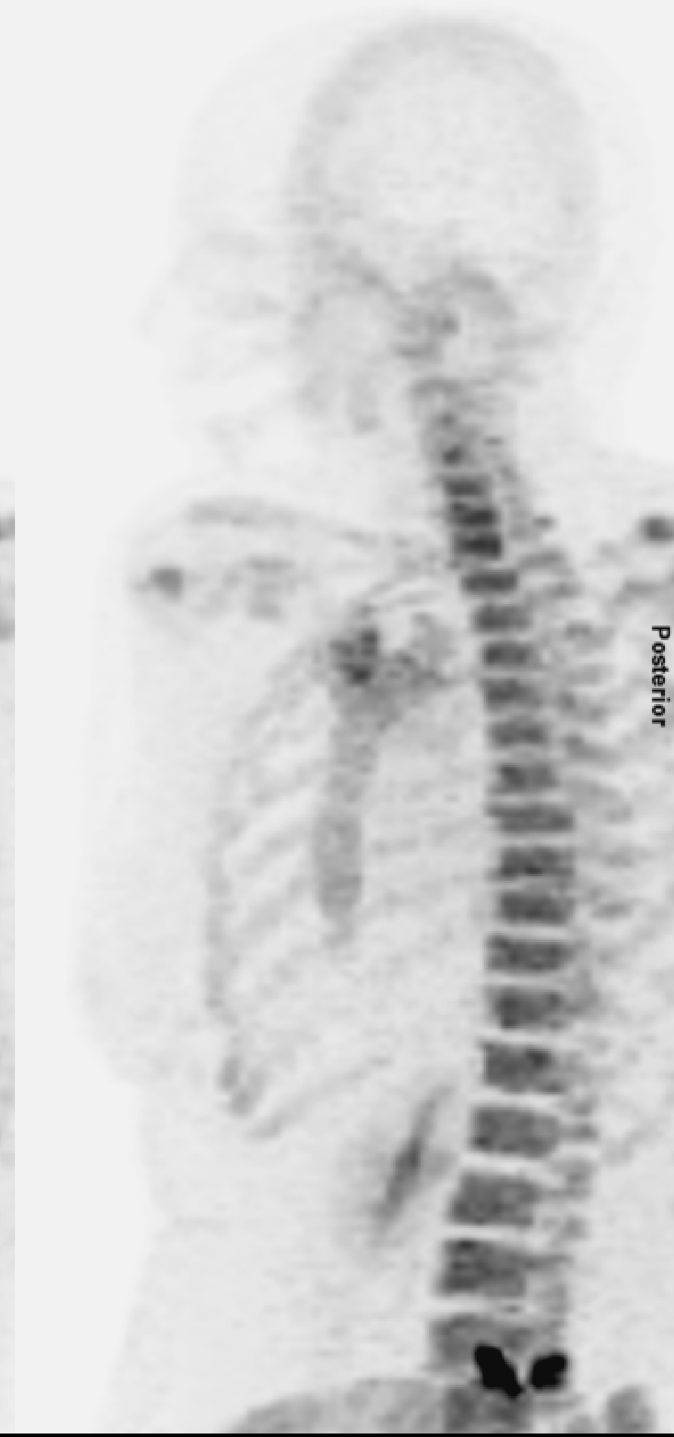
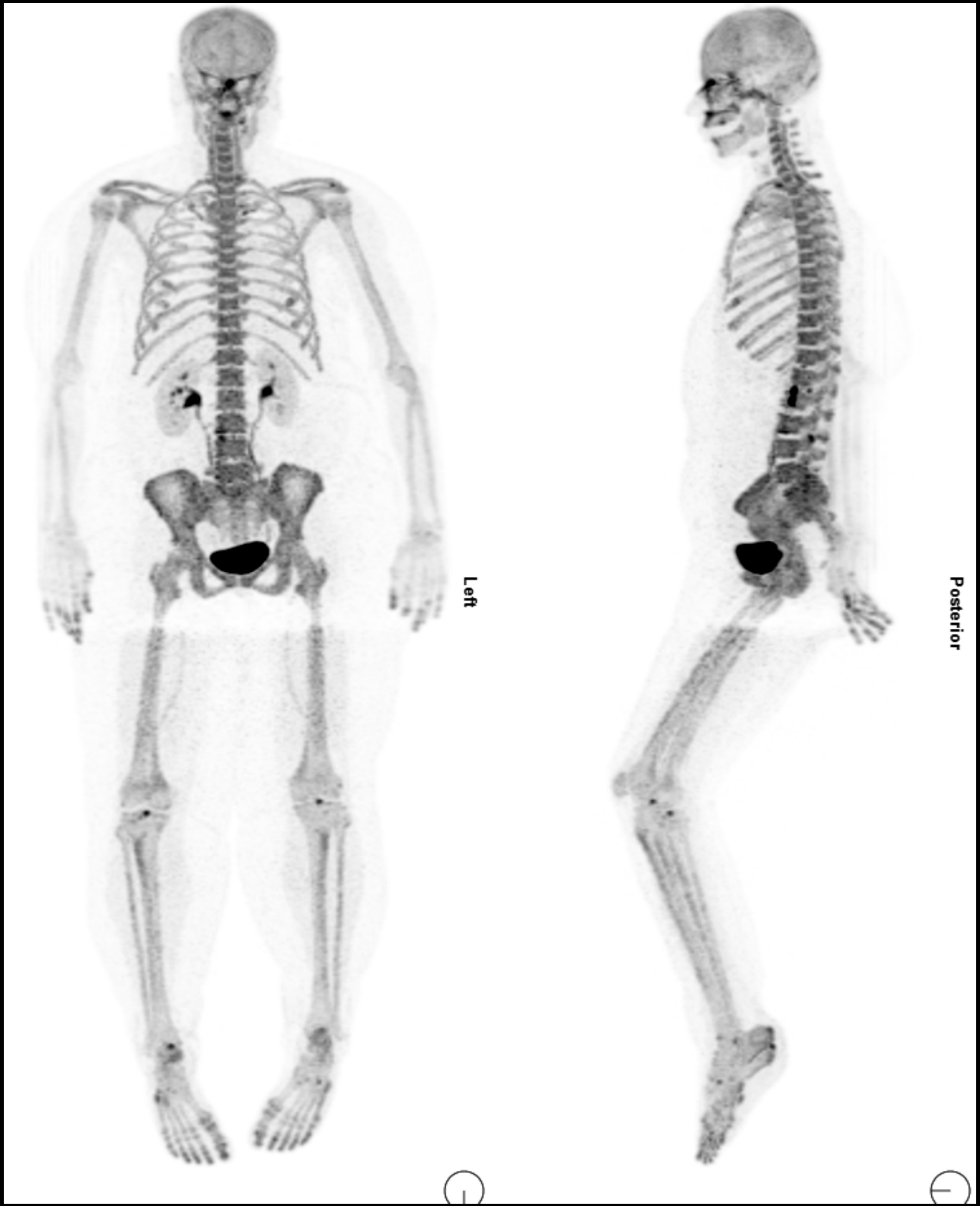

Posterior

PITFALLS:
TRUNCATION

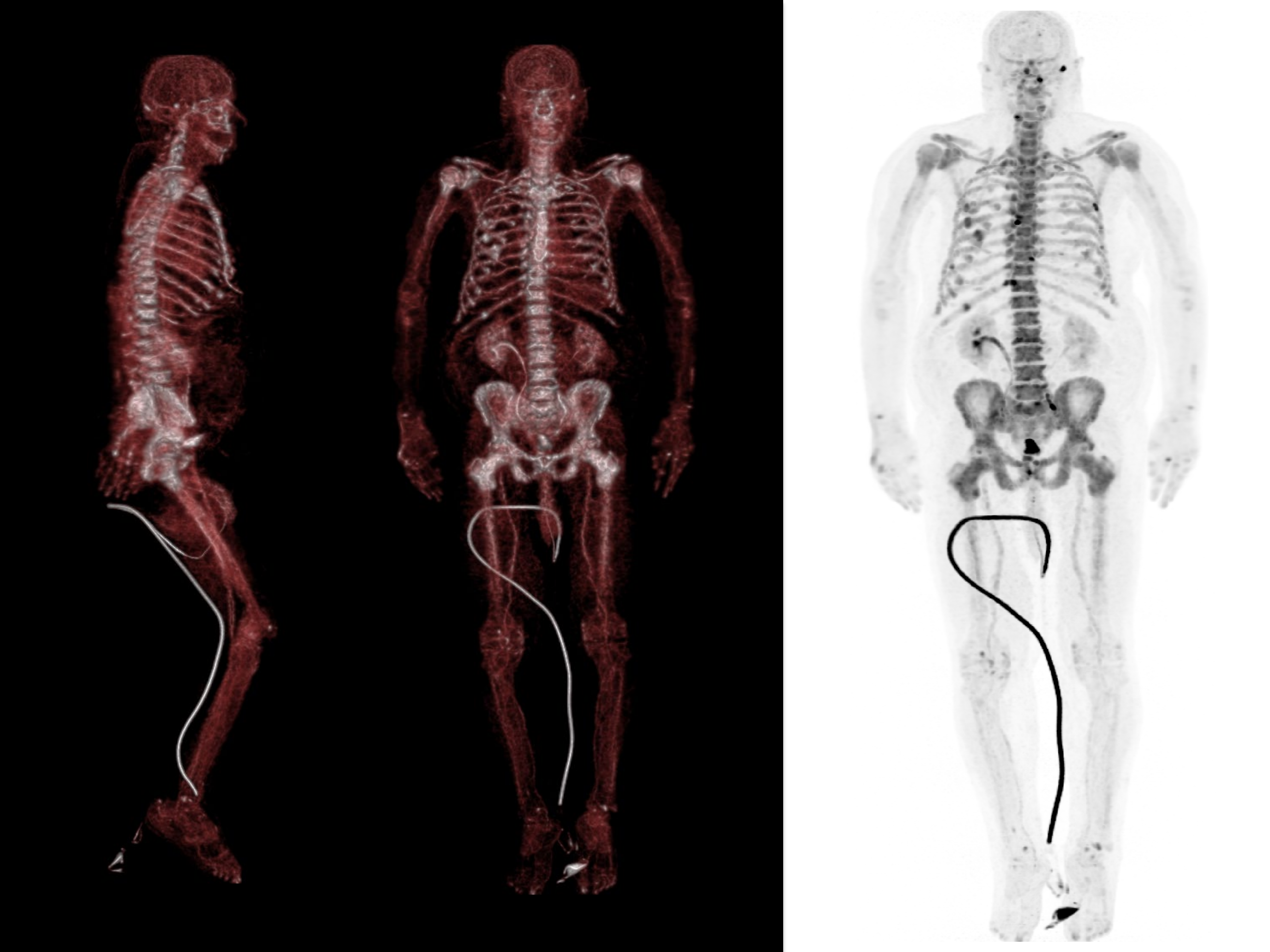
When imaging extends beyond the CT FOV



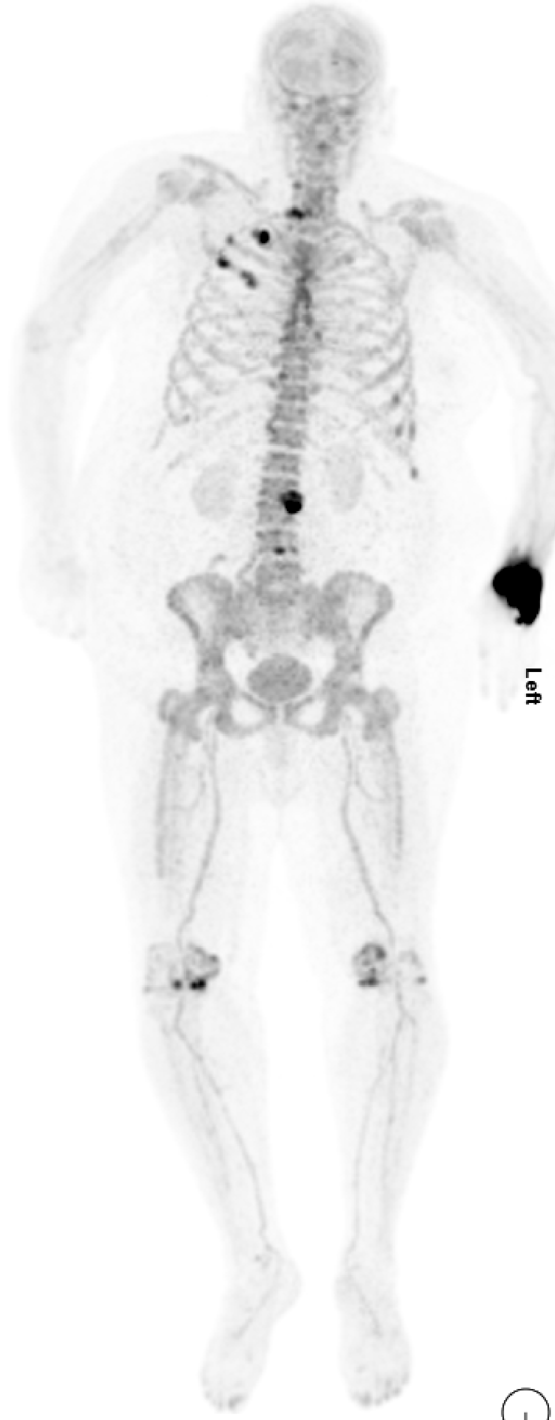

Left


Left

PITFALLS:
URINARY CATHETER



PITFALLS:
DOSE INFILTRATION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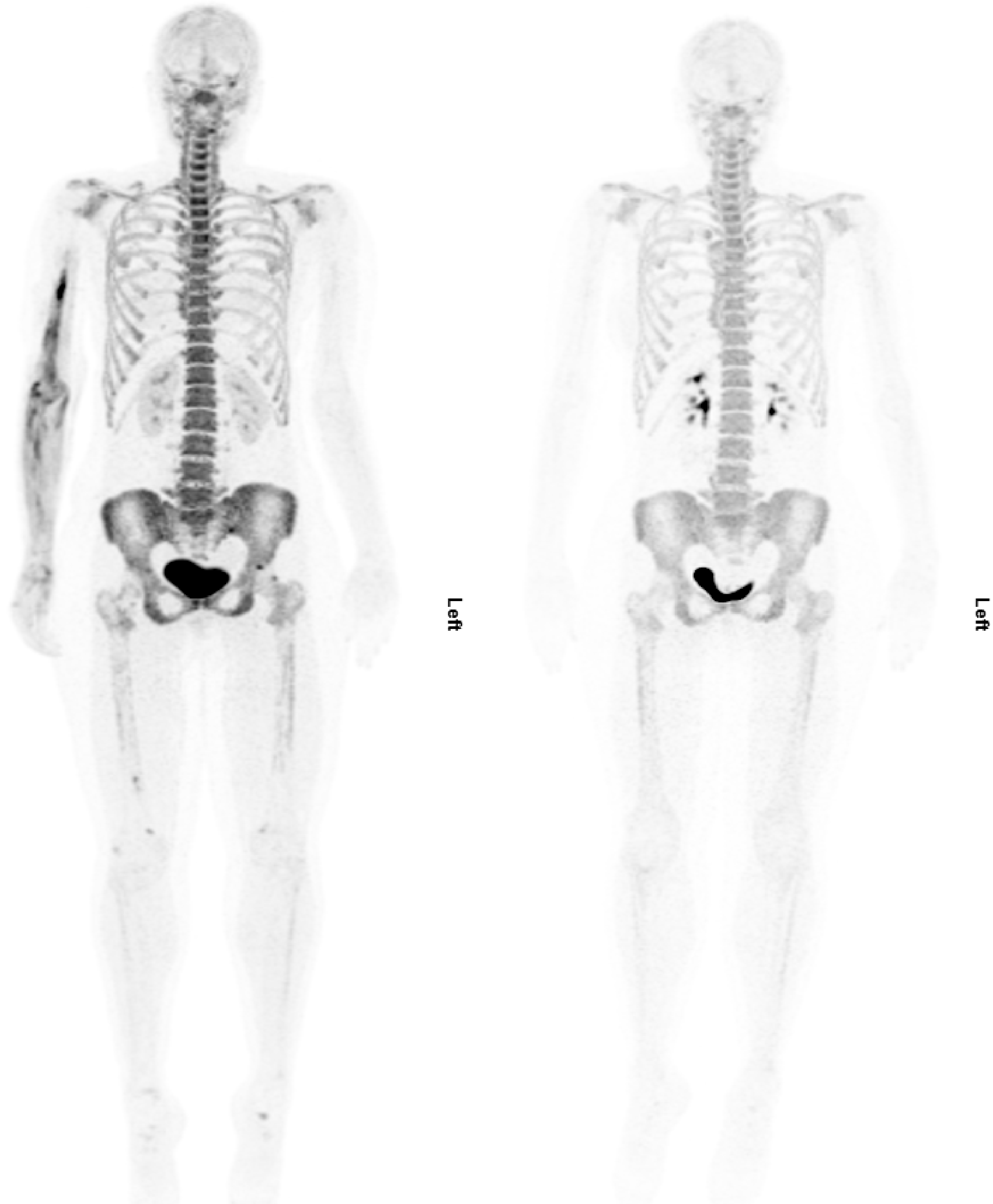
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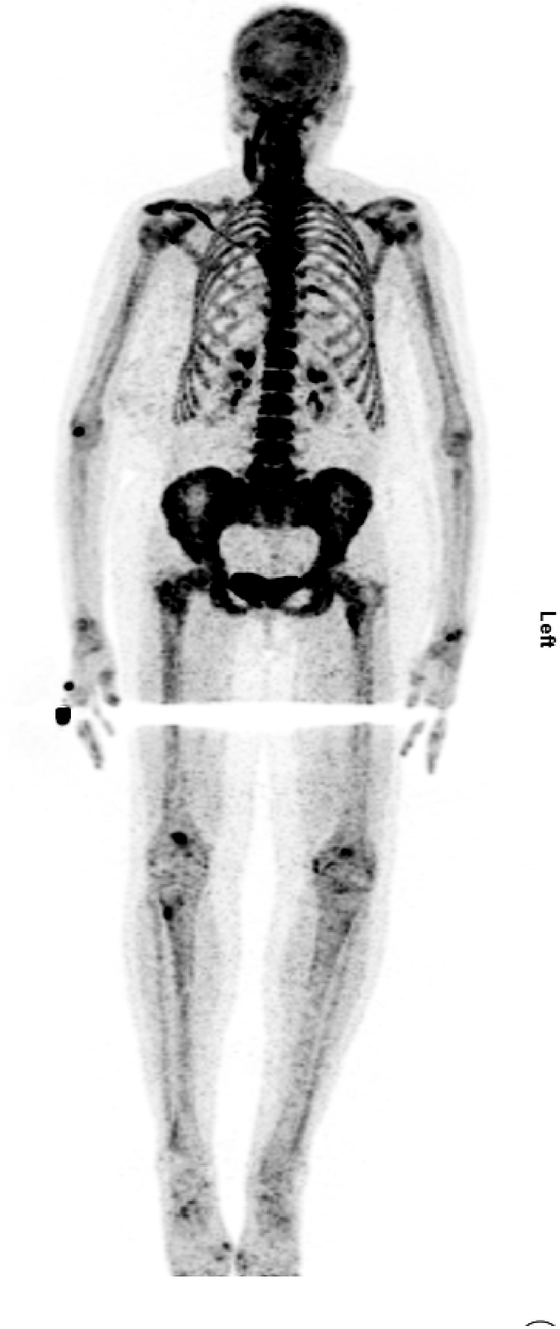
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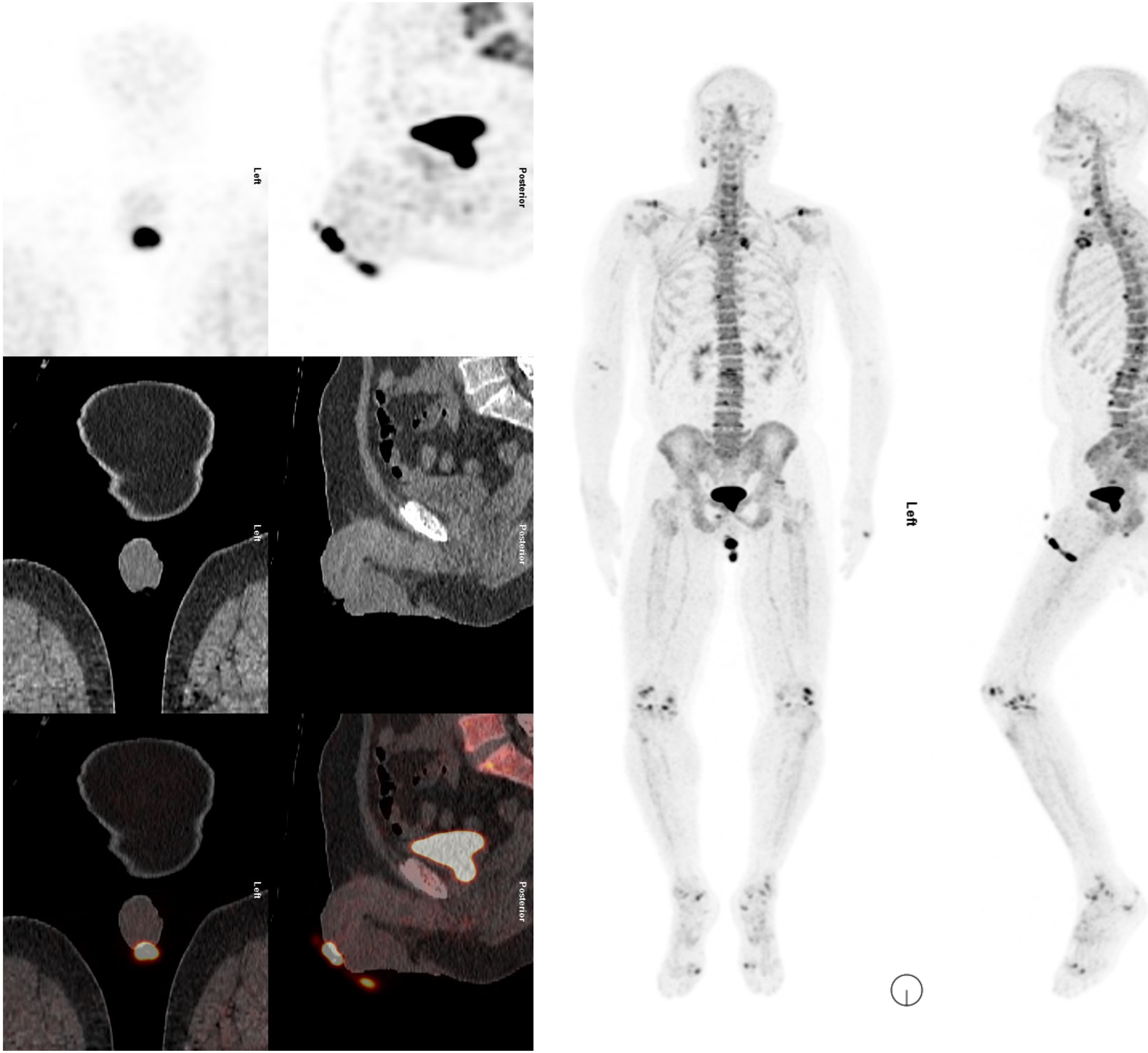
PITFALLS: CONTAMINATION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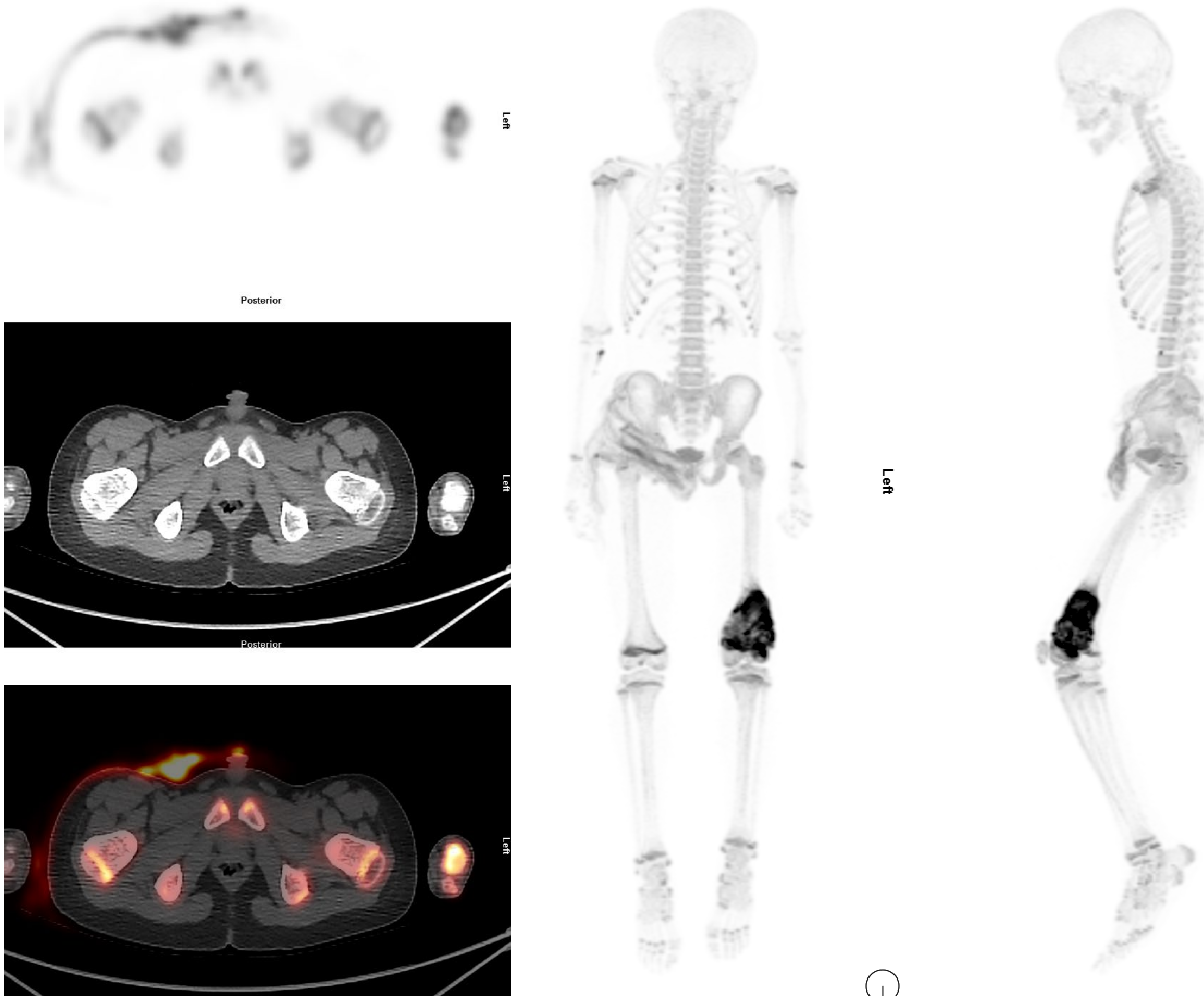
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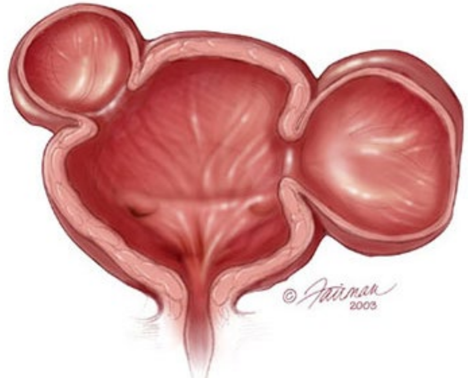
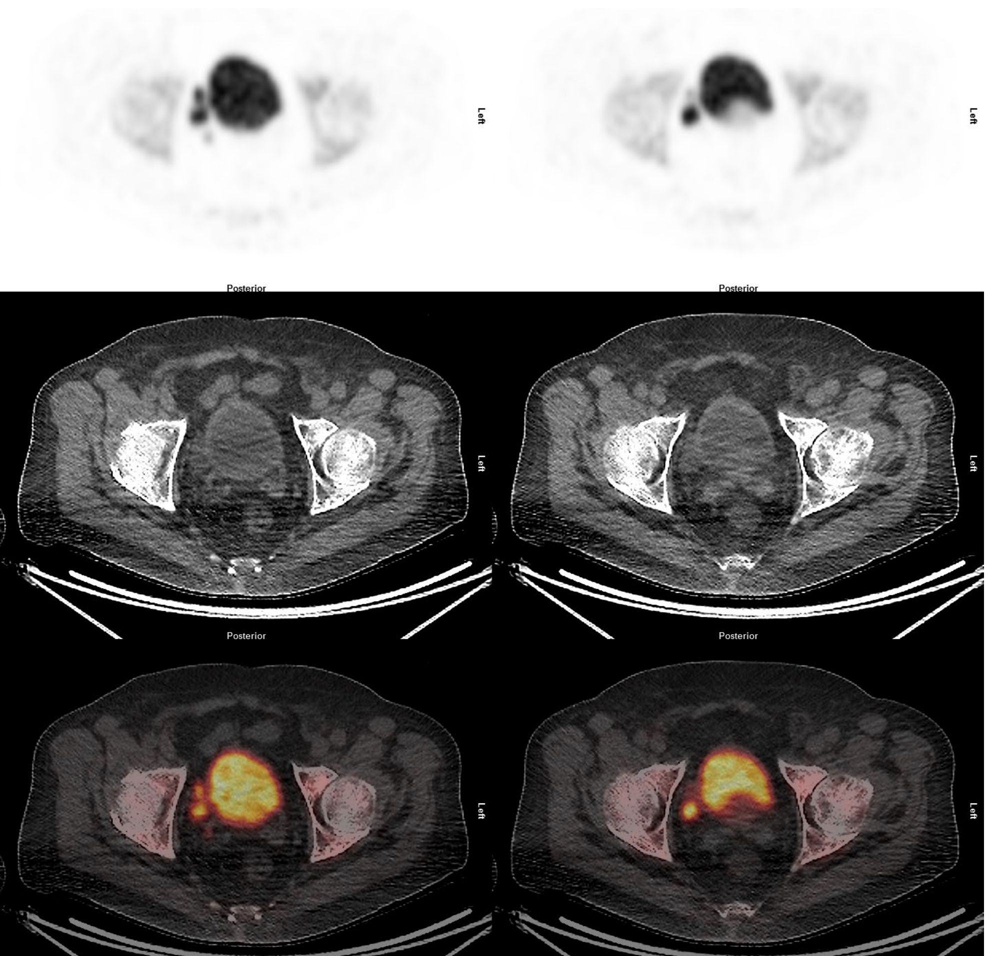
PITFALLS: BLADDER

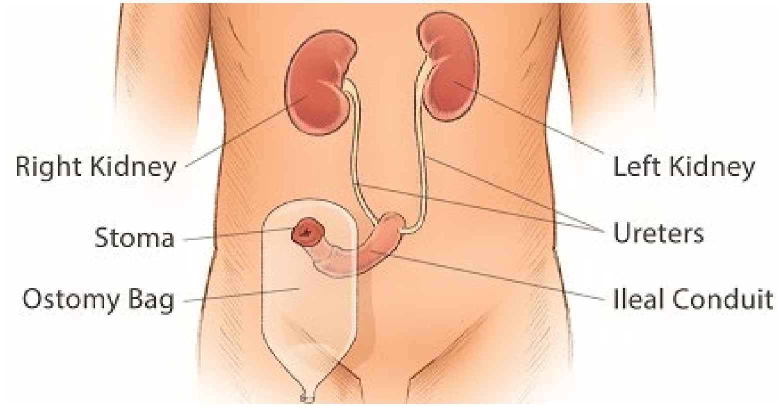
Urinary Bladder Diverticulum

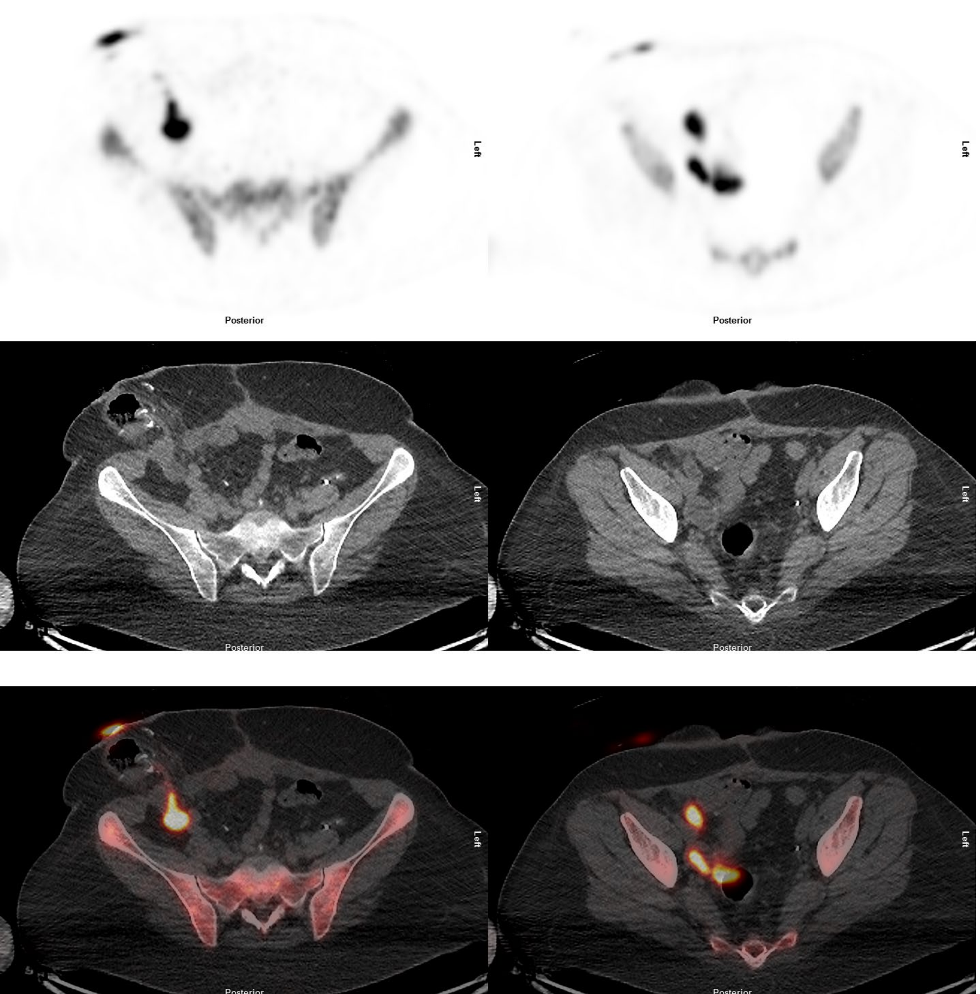




ileal conduit

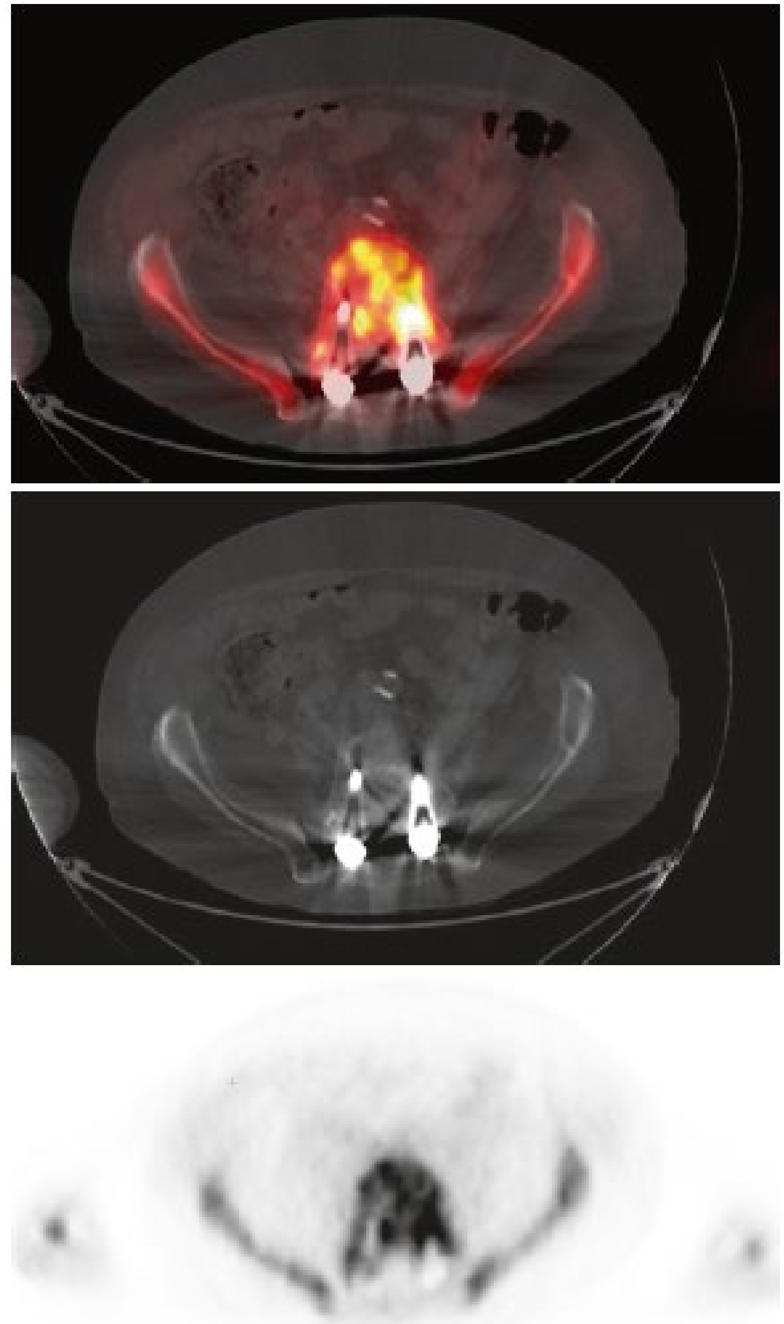
cystectomy

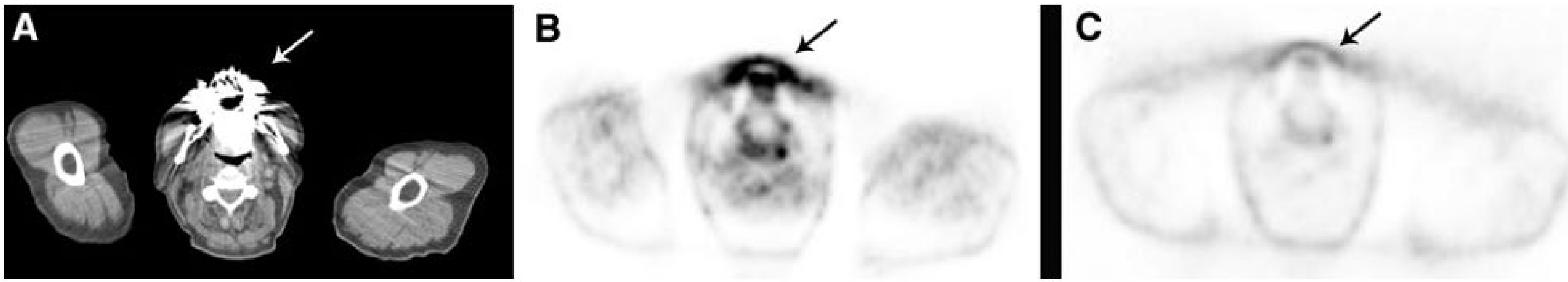




PITFALLS:
Metal Effect

Metallic implants such as dental fillings, hip prosthetics, or chemotherapy ports result in high CT numbers and generate streaking artifacts on CT images





(A) High-density metallic implants generate streaking artifacts and high CT numbers (arrow) on CT image.

(B) High CT numbers will then be mapped to high PET attenuation coefficients, leading to overestimation of activity concentration.

(C) PET images without attenuation correction help to rule out metal-induced artifacts

References:

- Sodium Fluoride PET/CT in Clinical Use. Kalevi Kairemo, Homer A. Macapinlac.
- Diagnostic Challenge of Staging Metastatic Bone Disease in the Morbidly Obese Patients. Sharjeel Usmani, Fahad Marafi,Najeeb Ahmed, Abdulredha Esmail, Fareeda Al Kandari, and Tim Van den Wyngaert.
- Stanford University Sodium Fluoride PET/CT Bone Imaging: Theory and Practice, George Segall.
- PET/CT Imaging Artifacts. Waheeda Sureshbabu and Osama Mawlawi.
- https://www.snmmi.org/ClinicalPractice/doseTool.aspx?ItemNumber=11216&navItemNumber=11218

Thank you