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The FDG-PET / CT Scan, Normal Uptake, Artefacts, and Pitfalls - A Pictorial Essay

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Abstract: ***A cancer radiologist needs to be well-versed in the normal patterns of uptake, artefacts, and pitfalls of Positron Emission Tomography –Computed Tomography (PET-CT) scan to lessen the incidence of false-positive findings. A normal PET scan will demonstrate fluorodeoxyglucose (18F- FDG) uptake in the brain, kidneys, bladder, and heart. In this pictorial essay, we will be highlighting the areas of normal FDG uptake, non-oncologic causes of FDG uptake – including inflammatory and non-inflammatory causes - that can mimic pathological uptake. These examples are drawn from experience at a tertiary cancer care centre. This can help us to potentially avoid misinterpretation of uptake, unnecessary follow-up imaging, and invasive tests. This pictorial essay is based on retrospective and anonymised imaging data obtained from PET-CT images of the tertiary cancer care centre. No identifiable patient information is included. Ethical approval was not required in accordance with institutional guidelines, since it is an educational, image-based study with no patient data.***

Keywords: Artefacts, FDG (Fluorodeoxyglucose), PET/ CT (Positron Emission Tomography/ Computed Tomography), Uptake, Benign, Malignant.

Normal Uptake[1]

Normal areas of FDG uptake include the brain, kidneys, collecting system, urinary bladder, and heart. Other areas with less intense uptake are also discussed.

Figure 1: Physiological FDG uptake is seen in the brain, myocardium, kidneys, and urinary bladder. Diffuse thyroid uptake is also seen (suggestive of thyroiditis), along with two foci of abnormal uptake in the peritoneal cavity, confirmed to be peritoneal deposits.

Brain

In the brain, the grey matter shows more intense FDG uptake than the underlying white matter. To identify a focal brain lesion, the area must demonstrate either increased or decreased activity compared to the surrounding brain parenchyma. A similar level of uptake is also seen in the spinal cord.

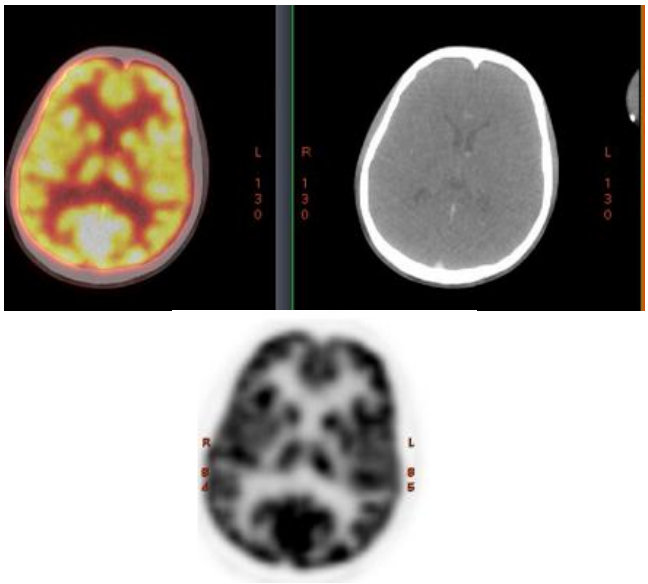

Figure 2: Grey matter shows higher FDG uptake compared to white matter. Fused PET-CT, axial CT, and PET images at the level of the basal ganglia are shown.

Head and Neck:

In the head and neck region, FDG uptake is seen in the extraocular muscles, neck muscles, vocal cords, brown fat, etc. Extraocular muscles show intense uptake as they are fast-twitch muscles with a high glycolytic rate. Among the extraocular muscles, the medial rectus shows increased uptake as it has an additional role in accommodation.

Lymphoid tissue in the Waldeyer's ring - including palatine tonsils, lingual tonsils, and adenoids can also normally show increased FDG uptake.

Figure 3: Grey matter shows higher FDG uptake compared to white matter. Fused PET-CT, axial CT, and PET images at the level of the basal ganglia are shown.

Figure 4: Symmetrical FDG uptake in the neck muscles suggests muscle strain. Intense myocardial uptake is likely due to post-prandial insulin-mediated glucose transport. FDG-avid right paracardiac mass represents a lung carcinoma.

Infection / Inflammation: Any focus of inflammation / infection will show increased tracer uptake. Clinical details are required to interpret the images in such conditions. A few common examples are illustrated here.

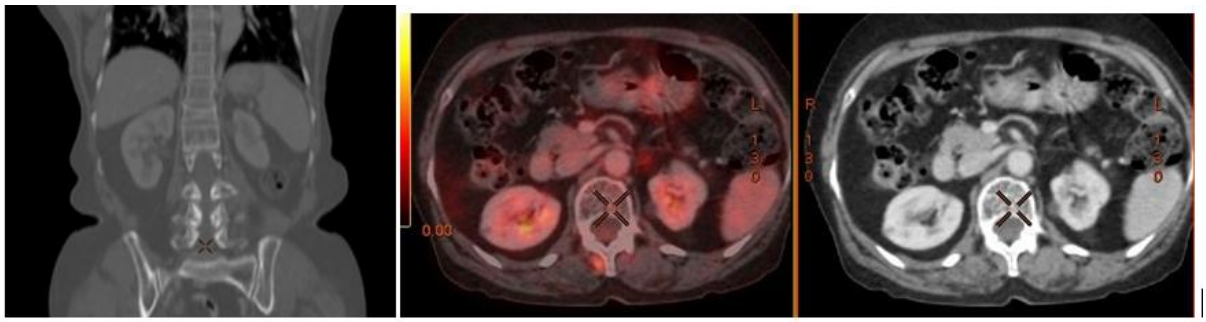

Figure 5: Coronal CT (bone window), fused PET/CT, and axial CT images at the D12 vertebral level show FDG uptake in the right paraspinal muscle, attributed to compensatory overstrain from left-sided vertebral collapse.

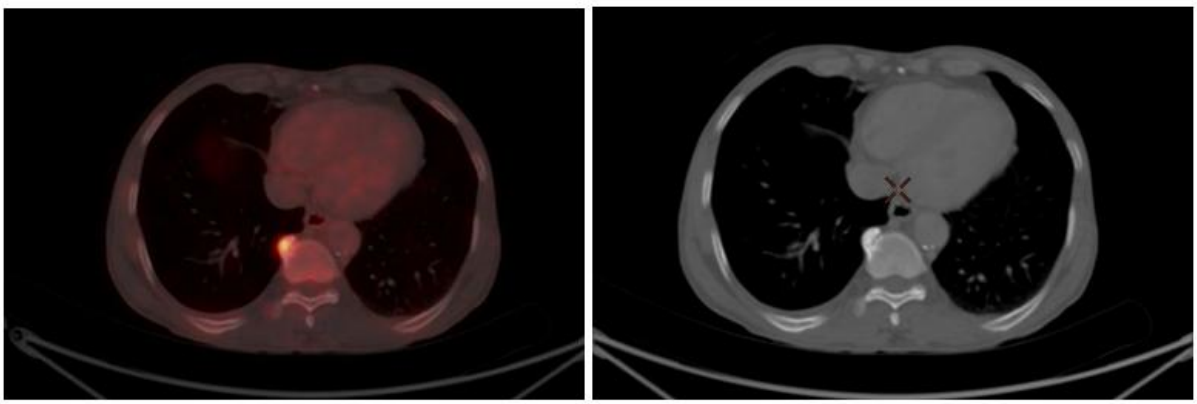

Figure 6: Fused PET/CT and axial CT images show increased FDG uptake corresponding to a vertebral osteophyte at the mid-dorsal level.

Bone fractures can appear similar to bone metastases, as discrete foci of FDG uptake within the bone. Unfused CT images in bone window should be reviewed to look for any fractures in such cases. Differentiating between benign and

malignant causes of fracture can be challenging, although malignant causes tend to show higher standardized uptake values (SUV). Follow-up PET-CT after 3 months is often helpful in such cases. FDG uptake in benign fractures typically returns to normal within this period, whereas malignant lesions usually persist or progress.

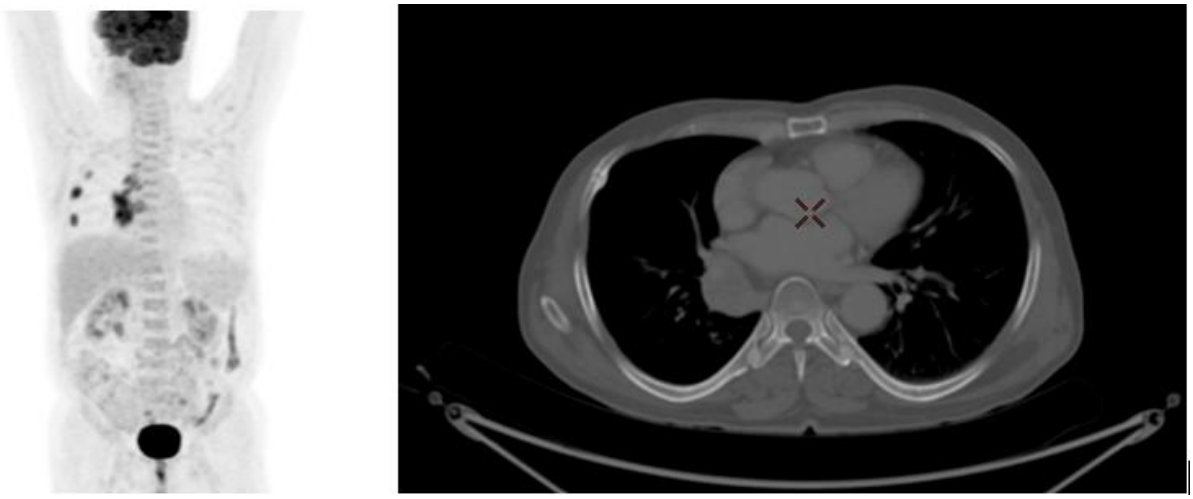

Figure 7: Linear distribution of FDG uptake along multiple ribs indicates healing rib fractures with callus formation. Corresponding CT confirms a right 4th rib fracture. An FDG-avid right hilar mass is also noted.

Bowel Uptake[2]: The bowel shows various patterns of FDG uptake - diffuse, segmental, or focal. Focal areas of uptake often warrant further evaluation to rule out malignancy.

Figure 8: Coronal PET, CT, and fused PET/CT images show FDG uptake in the ascending colon. The corresponding CT shows no abnormality, indicating physiological bowel uptake.

The esophagus can show increased uptake in the thorax. It can be either physiological or secondary to the gastro-esophageal reflux.

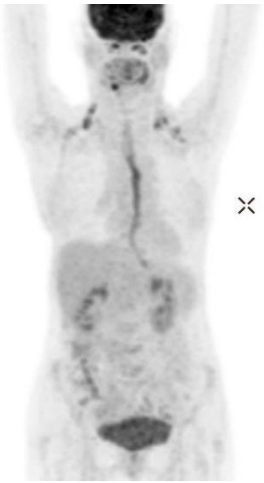

Figure 9: PET image demonstrates FDG uptake in the mid-to-distal esophagus, which may be physiological or related to reflux. Uptake also noted in the bilateral cervical lymph nodes.

Areas of mildly increased uptake can be seen in lactating breasts, nipple, various intra-abdominal organs such as liver, spleen, adrenals, pancreas, uterus (and uterine fibroids), ovaries, male reproductive organs, etc.

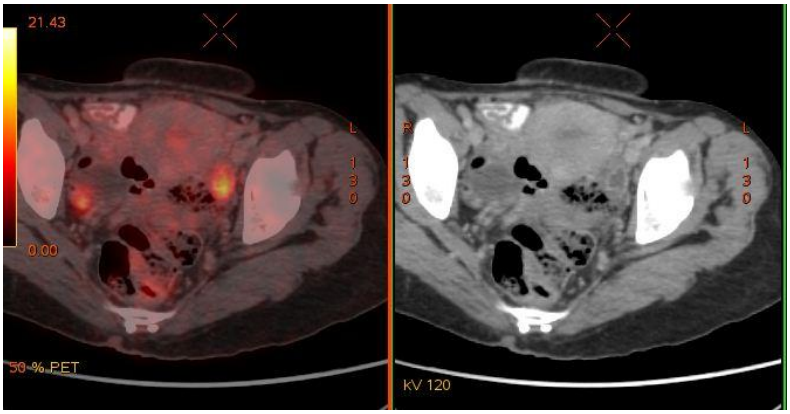

Figure 10: Fused PET/CT and CT images show physiological ovarian uptake and mild tracer accumulation in the endometrium

Brown Fat Distribution[3]:
Separate mention is required for brown fat distribution due to its ability to mimic pathological uptake. Correlating the areas of FDG uptake with the localization CT images are required to assign tracer uptake to that of fat density (-50 to -150 HU) as opposed to soft tissue density.

The most common locations for brown fat distribution are the neck and supraclavicular area, with or without extension to the shoulders. It can be symmetrical or rarely asymmetrical. The mediastinum can show brown fat surrounding the major vessels. Paravertebral areas can show brown fat along the intercostal space. The perinephric area can show focal uptake along the upper poles of the kidneys. The atypical areas of brown fat distribution often cause diagnostic uncertainty.

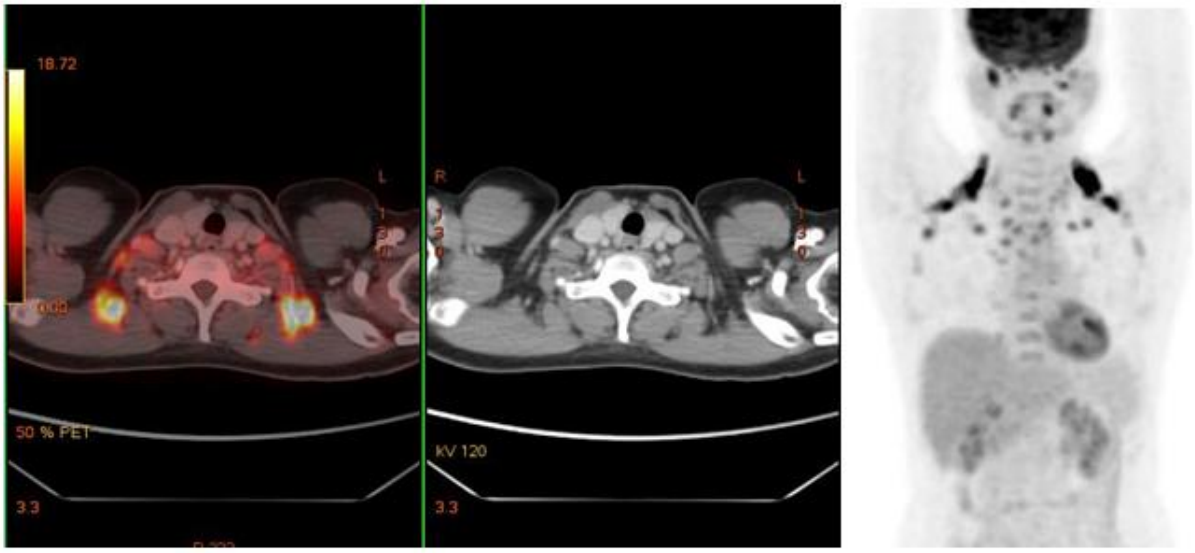

Figure 11: Fused PET-CT and axial CT images show FDG uptake in the supraclavicular area, corresponding to the fatty tissue density, indicative of brown fat. PET images also show additional foci of uptake in mediastinal nodes and lung metastases

CT Attenuation Correction and Related Artefacts[4]:
Misregistration artefacts are commonly due to the movement of the patient between acquisition of CT and PET images.

Figure 12: Misregistration artefact between PET and CT acquisitions is seen, with vertical misalignment at the skull base and diaphragm. A curvilinear cold artefact due to respiration is visible at the diaphragm

High-density areas in the CT, such as metallic implants or Iodinated contrast, can lead to overcorrection of the PET data. This will be interpreted as the areas of increased FDG uptake. These artefacts become significant when they are near the area of interest.

Linear IV Contrast Artefact:
Linear artefacts can occur from the presence of increased concentration of IV contrast in the upper limb veins or central veins. Due to attenuation correction errors, these can appear as linear areas of falsely increased tracer uptake.

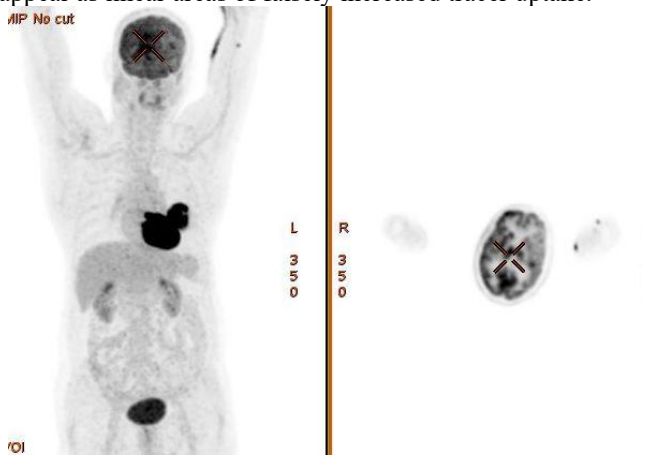

Figure 13: Linear artefact is seen in the left upper limb vein due to intravenous contrast. A left lower lobe FDG-avid mass is also noted. Coronal and axial PET images are shown.

Lymphangiogram Effect:
Part or whole of the tracer administered can enter the subcutaneous tissue instead of the intravenous route, causing a lymphangiogram effect. The nodes will also take up the tracer which is a source of diagnostic confusion, especially when the nodes are in the region of interest.

Increased uptake is seen in the sentinel lymph node (in Fig.13) in addition to the linear IV contrast artefact in the left upper limb vein, both of which are attributed to the lymphangiogram effect.

Artefacts due to High Density Implants[5]:
High-density implants, such as surgical hardware, cause artefactual increased uptake in the PET images due to attenuation correction errors.

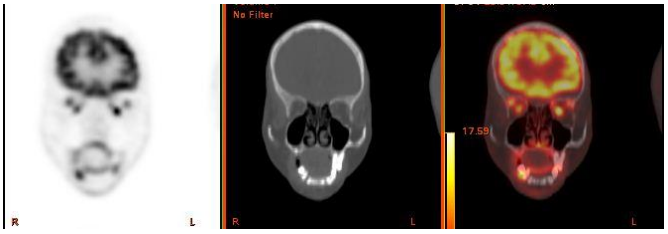

Figure 14: Dental metallic implants in the right lower alveolus cause artefactual increased FDG uptake. Coronal PET, CT (bone window), and fused PET/CT images are shown.

Effect of Elevated Blood Glucose and Insulin Administration on Image Quality:
FDG competes with glucose for entry into the cells. When the blood sugar is elevated, the chance of FDG to get into the cells is less and more is excreted via the kidneys, resulting in degraded image quality.

When insulin is administered to control the elevated blood glucose levels, the insulin will stimulate glucose uptake into the cells, often leading to diffuse FDG uptake.

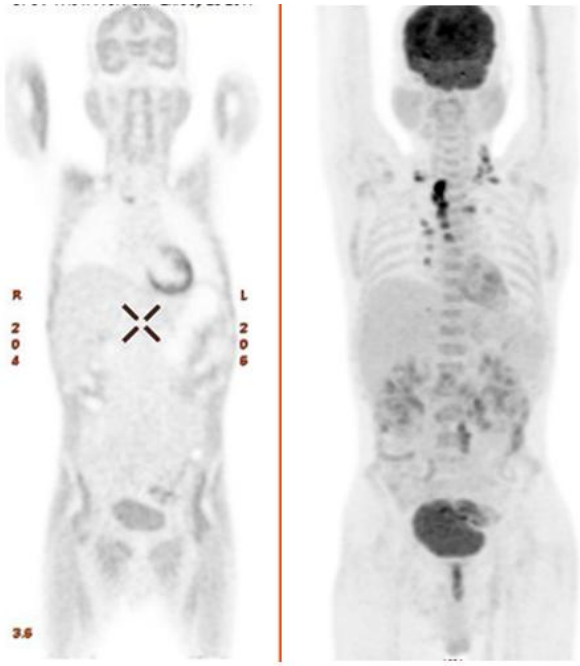

Figure 15: Initial scan in a hyperglycaemic patient shows poor image quality due to reduced FDG uptake. A repeat scan after glycemic optimisation reveals normal physiological uptake in the brain and urinary system, along with FDG-avid cervical and mediastinal lymph nodes

Conclusion

In FDG-PET CT interpretation, one has to be familiar with the patterns of normal physiological uptake, non-oncological causes of uptake and the common artefacts. This will help us to avoid misinterpretations leading to unnecessary biopsies and follow-up imaging. Necessary steps should be taken to avoid artefacts during attenuation correction. Glycemic control and keeping the patient warm will help us to avoid deterioration of the image quality associated with hyperglycemia, hypoglycaemia and brown fat uptake, respectively.

Ethics and Approvals

- Statement of Institutional Review Board (IRB) approval: Approval not required for pictorial essays.
- Declaration of Helsinki: This study conforms to the ethical principles of the Declaration of Helsinki.
- Clinical trial registration is not required.

Disclosures and Support

There are no conflicts of interest or financial disclosures to declare.

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