1.1 Physical Principles of Positron Emission Tomography and Hybrid Modalities

Positron Emission Tomography (PET) is an imaging technique performed by using positron emitting radiotracers. Positron decay occurs with neutron-poor radionuclides and consists in the conversion of a proton into a neutron with the simultaneous emission of a positron ($\beta^+$) and a neutrino ($\nu$). The positron has a very short lifetime, and after the annihilation with an electron simultaneously produces two high-energy photons ($E = 511$ keV) in approximately opposite directions that are detected by an imaging camera. The PET scanning is based on the so-called annihilation coincidence detection (ACD) of the 511 keV γ-rays after the annihilation. Tomographic images are formed collecting data from many angles around the patient by scintillating crystals optically coupled to a photon detectors used to localize the position of the interaction and the amount of absorbed energy in the crystals (Table 1.1) [1].

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Table 1.1 Properties of PET scintillator crystals

|                    | NaI(Tl) | BGO | LSO | GSO | LYSO |
|--------------------|---------|-----|-----|-----|------|
| Effective atomic number ($Z$) | 50      | 73  | 66  | 59  | 60   |
| $\mu$ (cm$^{-1}$)     | 0.34    | 0.95| 0.87| 0.70| 0.86 |
| Index of refraction   | 1.85    | 2.15| 1.82| 1.85| 1.81 |
| Density (g/cm$^3$)    | 3.67    | 7.13| 7.40| 6.71| 7.30 |
| Photon yield (per kVp) | 38     | 8  | 20–30| 12–15| 25   |
| Peak wavelength (nm)  | 410    | 480 | 420 | 430 | 420  |
| Decay time constant (ns) | 230   | 300 | 40  | 65  | 41   |
| Energy resolution (% at 511 keV) | 7.8% | 20% | 10.1% | 9.5% | 20% |
| Hygroscopic          | Yes     | No  | No  | No  | No   |
The key properties that characterize the PET scanner performances are the spatial resolution, the sensitivity, the Noise-Equivalent Count Rate (NECR) and the contrast [2]. The projection data acquired in the form of sinograms are affected by a number of factors that contribute to the degradation of the final images and hence to the PET scanner performances, as reported in Table 1.2.

Two classes of reconstruction techniques exist: the analytical and the iterative methods [3]. The most used analytical method is the backprojection. To compensate the blurring, a filter is applied to the projections before they are back-projected onto the image (i.e. filtered backprojection (FBP)). In modern scanners, the image reconstruction algorithms are based on iterative methods, which approach the true image by means of successive estimations, in order to converge to an image that best represents the original object. These algorithms are known as expectation maximization (EM) and Ordered Subset Expectation Maximization (OSEM) algorithm [4].

### Table 1.2 The PET scanner performance and the intrinsic PET limitations

| Property                        | Definition                                                                 | Intrinsic limitation                                                                 |
|---------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Spatial resolution              | The minimum distance between two points in an image that can be detected by a scanner | *Positron range:* Error occurs in the localization of the true position of the positron emission resulting in the degradation of the spatial resolution. *Non-collinearity:* The two 511 keV photons are not emitted at exactly opposite directions. This deviation can reach a value of ±0.25° at maximum detector size and its intrinsic resolution: resolution is better in the centre of the FOV than at the edge. |
| Sensitivity                     | Number of counts per unit time detected by the system for a unitary activity | *Geometric efficiency:* the fraction of emitted radiation that hits the detector and it depends on the source to detector distance, on the diameter of the ring and on the number of detectors in each ring. *Intrinsic efficiency:* the fraction of radiation that reaches the detector and is acquired. It depends on the scintillation decay time and the stopping power of the detector. |
| Noise-equivalent count rate     | Parameter used to define the noise and to compare the PET performance      | Takes into account the effects introduced by scatter and random coincidences           |
| Contrast                        | Difference in counts between an area of interest and its surroundings      | Scatter, random and out-of-FOV radiation                                               |

**1.2 Hybrid Scanners: PET/CT and PET/MRI**

Combined PET/CT systems were commercially available from 2001 and in a very short time the dedicated PET scanner was completely replaced by hybrid PET/CT. The ability of hybrid PET/CT systems to accurately identify the anatomic location of diseases and to provide attenuation-corrected images are the main causes of their rapid success and diffusion [5]. Modern clinical PET/CT consists in a high-performance PET scanner in-line with a high-performance CT scanner arranged in sequential gantries. The scanner table moves along the gantry axis in order to subsequently acquire CT and then PET data. A software integrated in the system has to check if the patient bed undergoes some deflections during the translation [6]. Images of tissue attenuation from the CT scan are used to derive the PET attenuation correction factors. The latter depends on the energy of the photons: since CT X-rays and PET γ-rays have an energy of 70 keV and 511 keV,
respectively, the attenuation correction factor obtained from CT must be scaled to the 511 keV photons applying a scaling factor defined by the ratio of the $\mu$ of the 511 keV photons to that of the 70 keV X-rays in a given tissue [1].

PET/MRI is a multi-modality technology combining the functional information of PET with the soft-tissue contrast of MRI. Actually, two approaches are implemented in the commercial PET/MRI scanners: sequential PET/MRI [7–9]. The characteristics of the three commercial PET/MRI scanners are summarized in Table 1.3.

### Table 1.3 The characteristics of the three commercially available PET/MRI scanners

| PET/MR technology | Siemens biograph mMR | Philips ingenuity | GE Signa |
|-------------------|----------------------|------------------|----------|
| PET               | Integrated           | Sequential       | Integrated |
| Scintillator      | LSO                  | LYSO             | LBS      |
| Crystal size (mm) | $4 \times 4 \times 20$ | $4 \times 4 \times 22$ | $4 \times 5.3 \times 25$ |
| Crystal number    | 28,672               | 28,336           | 20,160   |
| Photodetector     | APD                  | PMT              | SiPM     |
| TOF               | No                   | Yes              | Yes      |
| Energy resolution (%) | 14.5          | 12               | 10.5     |
| Energy window (keV) | 430–610         | 460–665          | 425–650  |
| Time resolution (ns) | 2.93              | 0.3              | 0.39     |
| Coincidence window (ns) | 5.86            | 6.00             | 4.57     |
| Transaxial FOV (cm) | 59.4 cm            | //               | 60 cm    |
| Axial FOV         | 25.8 cm              | 18               | 25 cm    |
| Sensitivity (kcps/MBq) | 15.0            | 7.0              | 22.2     |
| Scatter fraction (%) | 37.9              | 26.0             | 43.4     |
| Peak NECR (kcps @ kBq/mL) | 184 @ 23.1  | 88.5 @ 13.7     | 218 @ 17.7 |
| MR                | Field strength (T)   | 3                | 3        |
| Bore (cm)         | 60                   | 60               | 60       |
| FOV (cm$^3$)      | $50 \times 50 \times 50$ | $50 \times 50 \times 45$ | $50 \times 50 \times 50$ |
| Gradient mT/m     | 45                   | 40               | 44       |
| Slew rate (T/m)/s | 200                  | 100              | 200      |

PET/MRI technology Integrated Sequential Integrated

PET

Scintillator LSO LYSO LBS
Crystal size (mm) $4 \times 4 \times 20$ $4 \times 4 \times 22$ $4 \times 5.3 \times 25$
Crystal number 28,672 28,336 20,160
Photodetector APD PMT SiPM
TOF No Yes Yes
Energy resolution (%) 14.5 12 10.5
Energy window (keV) 430–610 460–665 425–650
Time resolution (ns) 2.93 0.53 0.39
Coincidence window (ns) 5.86 6.00 4.57
Transaxial FOV (cm) 59.4 cm // 60 cm
Axial FOV 25.8 cm 18 25 cm
Sensitivity (kcps/MBq) 15.0 7.0 22.2
Scatter fraction (%) 37.9 26.0 43.4
Peak NECR (kcps @ kBq/mL) 184 @ 23.1 88.5 @ 13.7 218 @ 17.7

PET/MRI

Radiopharmaceuticals are radiolabelled molecules consisting in a molecular structure and a radioactive nuclide. The first one defines the pharmacokinetics and dynamics within the organism, while the latter is responsible for a detectable signal and for the consequent image visualization [10]. To maintain the stability of these two components, a linker may be necessary. The most important PET nuclides and their physical characteristics are summarized below:

- Carbon-11 ($^{11}$C) has a physical half-life of about 20 min and decays by $\beta^+$ emission (99.75%) and by electron capture (0.25%) to the ground state of the stable nuclide Boron-11 ($^{11}$B). $\beta^+$ average energy is 386 keV, corresponding to a mean range in water of 1.3 mm. $^{11}$C can be produced by different nuclear reactions; however, the main production mode is targeting Nitrogen-14 ($^{14}$N) with cyclotron accelerated protons: $^{14}$N(p,$\alpha$)$^{11}$C.
- Fluorine-18 ($^{18}$F) has a physical half-life of about 110 min and decays by $\beta^+$ emission (96.86%) and electron capture (3.14%) directly to the ground state of the stable
nuclide Oxygen-18 ($^{18}$O). $\beta^+$ average energy is 250 keV, corresponding to a mean range in water of 0.6 mm. $^{18}$F can be produced by different nuclear reactions; however, the main production mode is targeting Oxygen-18 with cyclotron accelerated protons: $^{18}$O(p,n)$^{18}$F.

- Gallium-68 ($^{68}$Ga) has a physical half-life of about 67.8 min and decays by $\beta^+$ emission (88.88%) and by electron capture (11.11%) into $^{68}$Zn. $\beta^+$ average energy is 830 keV, corresponding to a mean range in water of 3.6 mm. $^{68}$Ga can be produced by different nuclear reactions; however, the main production mode is using a Germanium-68 ($^{68}$Ge)-$^{68}$Ga generator.

- Iodine-124 ($^{124}$I) has a physical half-life of about 4.2 days and decays by $\beta^+$ emission (23%) and by electron capture (77%) to the excited level and the ground state of Tellurium-124 ($^{124}$Te). $\beta^+$ average energy is 836 keV, corresponding to a mean range in water of 3.4 mm. $^{124}$I can be produced by different nuclear reactions; however, $^{124}$Te(p,n) reaction gives the purest form of $^{124}$I.

- Copper-64 ($^{64}$Cu) has a physical half-life of about 12.7 h and decays by $\beta^-$ emission (38%) to Zinc-64 ($^{64}$Zn) and by $\beta^+$ emission (17.4%) or electron capture (44.6%) to the excited level and the ground state of Nickel-64 ($^{64}$Ni). $\beta^+$ average energy is 278 keV, corresponding to a mean range in water of 0.7 mm. The main $^{64}$Cu production modes are the following: $^{63}$Cu(n,γ)$^{64}$Cu, $^{65}$Cu(n,2n)$^{64}$Cu, $^{64}$Zn(n,p)$^{64}$Cu, $^{64}$Zn(d,2p)$^{64}$Cu.

The wide and feasible availability of positron emitters radionuclides is a prerequisite for successful application on a routine basis. Fluorine-18 and Gallium-68 are the most used in a clinical setting, so far. Due to its versatility, $^{18}$F-Fluorodeoxyglucose (FDG), namely a radio-labelled analogue of glucose, is the by far most widely used PET radiopharmaceutical worldwide. FDG is very useful to detect malignant tumours characterized by increased glucose metabolism. However, FDG remains a non-specific tracer and its uptake is also been observed in many benign conditions, such as infective and inflammatory processes. Therefore, over the last decade, there is a growing interest in researching and using new radiopharmaceuticals, such as radiolabelled amino acids, nucleoside derivatives, choline derivatives, nitroimidazole derivatives and peptides, able to carefully target specific biomarkers. These new generation radiopharmaceuticals allow the analysis of several molecular pathways in tumour biology including metabolism, proliferation, oxygen delivery and protein synthesis as well as receptor and gene expression (Tables 1.4, 1.5 and 1.6). Some examples of PET images with different radiopharmaceuticals are showed in Figs. 1.1 and 1.2.
| Metabolic tracers | Clinical indication in oncology | Uptake mechanism | Physiological biodistribution | Patient preparation | Time from injection to acquisition | Recommended activity in adults | Paediatric recommended activity | Effective dose for adults (mSv/MBq) |
|------------------|--------------------------------|------------------|-----------------------------|---------------------|---------------------------------|-----------------------------|-----------------------------|----------------------------------|
| $^{18}$F-FDG     | – Differentiation of benign from malignant lesions<br>– Searching for an unknown primary tumour<br>– Staging patients with known malignancies<br>– Monitoring the effect of therapy<br>– Detecting tumour recurrence<br>– Guiding biopsy<br>– Guiding radiation therapy planning | Depends on the expression of GLUT1 transport and hexokinase phosphorylation. | *Intense uptake:* grey matter, myocardium, urinary tracts, bladder<br>*Mild uptake:* Liver, spleen, bowel and bone marrow | Fasting (4 h)<br>No physical activity (1 day)<br>Empty bladder | 60 min | Dependent on the system, time per bed position and the patient’s weight | 3.7–5.2 MBq/kg<br>for a body PET/CT scan | 1.9E – 02 |
| $^{18}$F-Choline | – Detecting prostate cancer recurrence<br>– Staging of high-risk prostate cancer<br>– Monitoring the effect of therapy in advanced or castration-resistant prostate cancer | Depends on the expression of choline transporters and choline kinase activity. | *Intense uptake:* salivary glands, liver, pancreas, spleen, kidney, urinary tracts, bladder<br>*Mild uptake:* Lacrimal glands, bowel and bone marrow | Fasting (4 h)<br>No physical activity (1 day)<br>Empty bladder | Dual phase procedure: a static acquisition of the pelvis immediately after injection followed by a whole body scan 60 min after injection | 3–4 MBq/kg | Not applicable | 3.0E – 2 |

(continued)
| **Table 1.4 (continued)** |
|---------------------------|

| **11C-Choline** | - Detecting prostate cancer recurrence  
- Staging of high-risk prostate cancer  
- Monitoring the effect of therapy in advanced or castration-resistant prostate cancer | Depends on the expression of choline transporters and choline kinase activity | **Intense uptake**  
Salivary glands, liver, pancreas, spleen, kidney  
**Mild uptake**  
Lacrimal glands, bowel and bone marrow | Fasting (6 h)  
Empty bladder | 0–15 min | 370 MBq | Not applicable | 4.9E \( -3 \) |
|---------------------------|------------------------------------------------|------------------------------------------------|------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **18F-Fluciclovine** | Detecting early prostate cancer recurrence | Depend on the expression of l-type amino acid transporter–alanine-serine-cysteine transporter 2 (LAT/ASCT2) | **Intense uptake**  
Liver and pancreas  
**Mild uptake**  
Lacrimal glands, salivary gland, bowel and bone marrow | Fasting (4 h)  
No physical activity (1 day)  
Empty bladder | 3–5 min | 370 MBq | Not applicable | 2.2E \( -2 \) |
|---------------------------|------------------------------------------------|------------------------------------------------|------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **18F-DOPA** | - Detection of insulinomas, paragangliomas and pheochromocytoma  
- Detecting medullary thyroid cancer recurrence  
- Staging of medullary thyroid cancer  
- Staging and restaging of neuroblastoma | Depends on the expression of large neutral amino acid transporter (LAT) | **Intense uptake**  
Basal ganglia, pancreas, gallbladder, kidney and bladder  
**Mild uptake**  
Salivary gland, liver, bowel and bone marrow | Fasting (4 h)  
Empty bladder | 10–60 min | 2–4 MBq/kg | 4 MBq/kg | 2.5E \( -2 \) |
| Pure isotopes as PET tracers | Clinical indications in oncology | Uptake mechanism | Physiological biodistribution | Patient preparation | Time from injection to acquisition | Recommended activity in adults | Paediatric recommended activity | Effective dose for adults (mSv/MBq) |
|-----------------------------|---------------------------------|------------------|-----------------------------|-------------------|---------------------------------|-------------------------------|-----------------------------|----------------------------------|
| $^{18}$F-NaF                | Detection of bone metastases    | Chemisorption of fluoride ions onto the surface of hydroxyapatite depending on bone blood flow and osteoblastic activity | Uniform tracer distribution throughout the skeleton | Empty bladder | 30–45 min | 1.5–3.7 MBq/kg | 2.2 MBq/kg | 2.4E – 2                          |
| $^{124}$I- NaI              | – Detect differentiated thyroid cancer (DTC) recurrence  
  – Select patients for further radioiodine treatment  
  – Dosimetric studies for radioiodine treatment | Depends on sodium/iodide symporter (NIS) expression | Intense uptake Salivary glands, oral cavity, gastrointestinal tract, bladder | Injection of recombinant human TSH or 2–4 weeks of thyroid hormone withdrawal | 24,72, 96 h | 24–80 MBq | 22–60 MBq | 9.5E – 2 (for 0% thyroid uptake) |
| $^{64}$CuCl$_2$            | Detecting early prostate cancer recurrence | Depends on human copper transport 1 (HCTR1) | High uptake in the liver and less intense uptake in salivary glands, biliary tract, pancreas, spleen and kidney | Fasting (4 h) | 1 h | 250 MBq | Not applicable | 2.9E – 2                          |
| Receptor tracers              | Indications (oncology)                                                                 | Uptake mechanism                                                        | Physiological biodistribution                      | Patient preparation                              | Time from injection to acquisition | Recommended activity in adults | Paediatric recommended activity | Effective dose for adults (mSv/MBq) |
|------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------|----------------------------------|----------------------------------|-------------------------------|----------------------------------|
| $^{68}$Ga-DOTA-conjugated peptides | – Localization of neuroendocrine tumours and detection of metastatic disease (staging)  
  – Monitoring the effect of therapy in these patients  
  – Select patients with metastatic disease for somatostatin receptor radionuclide therapy | Depends on the expression of somatostatin receptors (SSTR)            | Intense uptake  
  Liver, spleen, kidney, bladder  
  Moderate uptake  
  Pituitary gland, salivary glands | No need for fasting before injection  
  No consensus on discontinuation of cold octreotide therapy | 60 min                        | 100–200 MBq                  | Not applicable                  | 2.2E – 2                          |
| $^{64}$Cu-DOTA-conjugated peptides | – Localization of neuroendocrine tumours and detection of metastatic disease (staging)  
  – Monitoring the effect of therapy in these patients  
  – Select patients with metastatic disease for somatostatin receptor radionuclide therapy | Depends on the expression of somatostatin receptors (SSTR)            | Intense uptake  
  Liver, spleen, kidney, bladder  
  Moderate uptake  
  Pituitary gland, salivary glands, bowel | No need for fasting before injection  
  No consensus on discontinuation of cold octreotide therapy | 60 min                        | 200 MBq                       | Not applicable                  | 3.2E – 2                          |
| $^{68}$Ga-PSMA                | – Detecting prostate cancer recurrence  
  – Staging of high-risk prostate cancer  
  – Monitoring of systemic expression in metastatic prostate cancer | Depends on increased PSMA expression                                  | Intense uptake  
  Salivary glands, kidney, bladder, liver, spleen, bowel | Patients do not need to fast and are allowed to take all their medications | 60 min                        | 1.8–2.2/kg                    | Not applicable                  | 2.0E – 2                          |
| Radiopharmaceutical | Application | Mechanism | Uptake | Patient Preparation | Imaging Time | Activity | Notes |
|---------------------|-------------|-----------|--------|---------------------|--------------|----------|-------|
| $^{18}$F-PSMA       | Detecting prostate cancer recurrence, Staging of high-risk prostate cancer, Monitoring of systemic treatment in metastatic prostate cancer | Depends on increased PSMA expression | *Intense uptake* Salivary glands, kidney, bladder, liver, spleen, bowel | Patients do not need to fast and are allowed to take all their medications. | 90 min | 350 MBq | Not applicable | $1.3 \times 10^{-2}$ |
| $^{64}$Cu-PSMA      | Detecting prostate cancer recurrence | Depends on increased PSMA expression | *Intense uptake* Salivary glands, kidney, bladder, liver, spleen, bowel | Patients do not need to fast and are allowed to take all their medications. | 60 min | 315 MBq | Not applicable | $2.5 \times 10^{-2}$ |
| $^{18}$F-FES        | Detecting disease relapse in breast cancer patients with high levels of oestrogen receptors, Predicting response to endocrine treatment in metastatic breast cancer patients | Depends on the expression of oestrogen receptors | *Intense uptake* Liver, bile duct, intestinal tract and bladder | Discontinuation of oestrogens receptor antagonist for 5 days. Aromatase inhibitors are allowed. Premenopausal patients might have impaired uptake of $^{18}$F-FES because of competitive binding by endogenous oestrogens | 60 min | 200 MBq | Not applicable | $2.2 \times 10^{-2}$ |
| Brain tracers | Clinical indications | Uptake mechanism | Biodistribution | Patient preparation | Waiting time from radiopharmaceutical administration | Recommended activity in adults | Paediatric recommended activity | Effective dose per administration activity for adults (mSv/MBq) |
|--------------|---------------------|-----------------|----------------|--------------------|-----------------------------------------------|-----------------------------|-----------------------------|-----------------------------------|
| $^{18}$F-FDG | Neurology<br>– Early and differential diagnosis of dementia<br>– Epilepsy<br>– Differentiation between Parkinson’s disease and atypical parkinsonian syndromes<br>Neurooncology<br>– Differential diagnosis of cerebral lesions, detection of viable tumour tissue and for grading | Depends on the expression of GLUT1 transport and hexokinase phosphorylation | Intense uptake<br>Grey matter | – Fasting (4 h)<br>– Empty bladder<br>– Centrally acting pharmaceuticals should be discontinued on the day of the PET scan according to the clinical status of the patient | 30–60 min | 150–250 MBq | 0.1 mCi/kg | 1.9E-02 |
| $^{18}$F-DOPA | Neurology<br>– To differentiate essential tremor from parkinsonian syndromes<br>– Differentiation between Lewy body disease and other dementias<br>– To differentiate degenerative from non-degenerative parkinsonism<br>– To detect early presynaptic parkinsonian syndromes<br>Neurooncology (glioma)<br>– Differentiation of grade III and IV gliomas from nonneoplastic lesions or grade I and II gliomas<br>– Prognostication of gliomas<br>– Definition of the optimal biopsy site<br>– Diagnosis of tumour recurrence<br>– Disease and therapy monitoring | Depends on the activity of enzyme aromatic amino acid decarboxylase converting 6-$^{18}$F-L-dopa in fluorodopamine<br>– Depends on the expression of large neutral amino acid transporter (LAT) | Intense uptake<br>Basal ganglia<br>Low-moderate uptake<br>Grey matter | – Fasting (4 h)<br>– Empty bladder<br>– Premedication with carbidopa (2 mg/kg) 1 h before the injection | Neurology<br>70–90 min<br>Neurooncology<br>10–30 min | 185 MBq | 74–111 MBq | 2.5E-02 |
| PET Radiopharmaceutical | Application | Imaging Modality | Uptake | Administration | Imaging Time | Activity | Activity/kg | Result |
|-------------------------|-------------|-----------------|--------|----------------|--------------|----------|-------------|--------|
| $^{18}$F-FET | Neuroradiology (glioma) | PET/CT | Low uptake Grey matter | Fasting (4h) & Empty bladder | 20 min | 185 MBq | 100 MBq | 1.6E-2 |
| $^{11}$C-MET | Neuroradiology (glioma) See $^{18}$F-FET | PET/CT | Low uptake Grey matter | Fasting (4h) & Empty bladder | 10 min | 370 MBq | 11 MBq/kg | 5.0E-3 |
| $^{18}$F-Flutemetamol | Patients with a diagnosis of possible Alzheimer disease or mild cognitive impairment when the diagnosis is uncertain after morphological and functional neuroimaging | PET/CT | High affinity amyloid-beta neuritic plaques | Empty bladder | 90 min | 185 MBq | Not applicable | 3.5E-2 |
| $^{18}$F-Florbetaben | Patients with a diagnosis of possible Alzheimer disease or mild cognitive impairment when the diagnosis is uncertain after morphological and functional neuroimaging | PET/CT | High affinity amyloid-beta neuritic plaques | Empty bladder | 90 min | 300 MBq | Not applicable | 1.9E-2 |
References

1. Saha GB. Basics of PET imaging: physics, chemistry, and regulations. New York: Springer; 2010.
2. Zanzonico P. Positron emission tomography: a review of basic principles, scanner design and performance, and current systems. Semin Nucl Med. 2004;34(2):87–111.
3. Slomka PJ, Pan T, Germano G. Recent advances and future progress in PET instrumentation. Semin Nucl Med. 2016;46(1):5–19.
4. Alessio A, Kinahan P. PET imaging reconstruction http://faculty.washington.edu/aalessio/papers/alessio-PETRecon.pdf.
5. Waterstram-Rich KE, Christian PE. Nuclear medicine and PET/CT: technology and techniques. St. Louis: Elsevier Mosby; 2012.
6. Li S, Tavares JMRS. Shape analysis in medical image analysis, 51. Lecture notes in computational vision and biomechanics, vol. 14; 2014.
7. Zaidi H, Ojha N, Griesmer J, et al. Design and performance evaluation of a whole-body ingenuity TF PET–MRI system. Phys Med Biol. 2011;56(10):3091–106.

Fig. 1.1 Biodistribution of PET tracers: $^{18}$F-FDG (a), $^{18}$F-FCH (b), $^{18}$F-DOPA (c), $^{18}$F-Fluociclovine (d)

Fig. 1.2 Biodistribution of PET tracers: $^{18}$F-NaF (a), $^{64}$CuCl$_2$ (b) $^{68}$Ga-DOTATOC (c), $^{68}$Ga-PSMA (d), $^{18}$F-FES (e)
8. Delso G, Furst S, Jakoby B, et al. Performance measurements of the Siemens mMR integrated whole-body PET/MR scanner. J Nucl Med. 2011;52(12):1914–22.

9. Grant AM, Deller TW, Khalighi MM, et al. NEMA NU 2-2012 performance studies for the SiPM-based ToF-PET component of the GE SIGNA PET/MR system. Med Phys. 2016;43(5):2334.

10. Wadsak W, Mitterhauser M. Basics and principles of radiopharmaceuticals for PET/CT. Eur J Radiol. 2010;73:461–9.

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