• Positron emitters and radiochemistry
• Imaging technology
• Imaging targets and radiotracers
• Quantitation
PET Radiochemistry

Organic synthesis/Radiolabeling:

- $^{11}C$, $^{18}F$, $^{124}I$
- $^{64}Cu$, $^{89}Zr$, $^{68}Ga$

Chelation/Conjugation:

PET/CT Hardware

Current clinical PET performance:
- Spatial resolution ~5 mm
- Sensitivity <pM

TOF PET

Early PET scanners utilized coincidence detector timing to localize events along a line-of-response, however these detectors were abandoned due to poor sensitivity.

Philips introduced the Gemini TF in 2006 taking advantage of detector improvements to revisit time-of-flight PET.

TOF resolution 300-500 ps (9-15 cm)

S. Vandenberghe et al., EJNMMI Phys. 2016
Increasing PET detector thickness is a standard approach to improving sensitivity. However, this comes with an increase in parallax error.

DOI detectors are capable of measuring the location of interaction of a 511 keV photon within a scintillation crystal.
2-nitroimidazole uptake is dependent on:

- Vascular delivery
- Cell number
- Reductase expression
- Oxygen
- Excretion pathways

D. Rischin et al., J Clin Onc, 2006

Hypoxia PET and RT Response

Radiotracer Design

Small molecules
- Require organic synthesis/radiolabeling
- Short blood half life/clearance time
- Can use short-lived positron emitters
- Unsuitable for conjugation to large labels such as chelators

Biologics and Nanoparticles
- Typically expensive to manufacture
- Long blood half life/clearance time
- Require long-lived positron emitter
- Suitable for non-specific labeling, chelators

Quantitation

- Maximum intensity
- Minimum intensity
- Mean intensity
- Median intensity
- Integrated intensity
- 75th percentile
- 90th percentile
- Standard deviation
- Variance
- Skew
- Kurtosis
- ROI volume
Variability in PET


Variability in PET


Image Segmentation

Q. Black et al., Int J Rad Oncol Biol Phys, 2004
The QIN is an NCI-sponsored collective of 21 research teams spanning 19 institutions working to standardize imaging acquisition and analysis methods in order to facilitate the widespread use of imaging as a quantitative biomarker for cancer research and treatment.

Summary

- Radiochemistry of a large number of PET probes is established and translatable.
- Clinical PET/CT scanners are capable of imaging positron-emitting probes at sub-picomolar levels with spatial resolutions of 4-5 mm.
- A variety of molecular and cellular processes are imageable with PET.
- Current challenges to integration of PET images in radiotherapy planning are establishment of robust segmentation methods and the cost of multicenter deployment and evaluation of these methods.