WEBINAR

Imaging Equipment: PET Scanner

Wednesday MARCH 1

3pm UTC | 10am NY

Register for free: https://tinyurl.com/gceazoom

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GCEA is excited to announce the addition of a new **live translation** feature that we believe **will bridge the language gap and enhance your video conferencing experience** through Global Clinical Engineering Alliance programs even further. As part of our commitment to delivering innovative and educational video communications training, we have incorporated a new captioning option that facilitates the ability of our members to elevate their understanding of the spoken content during GCEA education and meeting events, by simultaneously customizing captions in their preferred language.
Simply click on the Captions tab at the bottom of your screen and select the caption language you would like to read from the drop-down menu.

English, French, German, Spanish, Portuguese, Italian, Chinese (Simplified)(Beta), Russian, Japanese (Beta), Korean (Beta), Dutch, and Ukrainian
PET: Basic Principles

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Medical Physicist – Nuclear Medicine Team
Biomedical Engineering Centre
Clinical Hospital
State University of Campinas - UNICAMP - Brazil
emsouza@unicamp.br
University of Campinas - UNICAMP
Nuclear Medicine

- Medicine area that uses radioactive materials + pharmaceuticals for diagnostic and therapeutical purposes.
- Diagnostic: metabolic images of the body
  - PET
  - Scintigraphy
- Therapy: use of radiopharmaceuticals to treat many kind of pathologies (e.g. tumors, thyroid diseases, osteoarticular diseases etc.)

RADIOACTIVE MATERIALS + PHARMACEUTICALS = RADIOPHARMACEUTICALS
PET... Web Searching....

Access: 20/01/2023

Access: 20/01/2023

https://www.acasadoanimal.com.br/empreendedorismo-4-formas-de-investir-no-mundo-pet/
Access: 20/01/2023
What is PET? Positron Emission Tomography
PET-FDG – Applications - $^{18}$F-FDG - Tumors

- Breast Cancer
- Sarcoma
- Melanoma
- Colon Cancer

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PET - $^{68}$Ga-DOTATOC – Neuroendocrine Tumors

PET - $^{18}$F-FDG – Applications – Infection and Inflammation

- Autoimmune Encephalitis
- Osteomyelitis
- Sarcoidosis
- Polycystic Kidney Disease

Bacterial Infection


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PET - Other Applications

$^{18}$F-FDG - Arteritis

$^{11}$C-PIB – Alzheimer’s Disease

$^{68}$Ga-MAA Acute Pulmonary Embolism

https://doi.org/10.1038/s41598-019-48709-w

Access: 10/02/2023

Elements that Contribute to Development of PET Technique

- **Radioactivity**
  - Marie and Pierre Curie (1934)

- **Artificial Radioactivity**
  - Iréne Curie and Frédéric Juliot (1934)
  - [Image of Iréne Curie and Frédéric Juliot](https://www.britannica.com/biography/Frederic-and-Irene-Joliot-Curie) Access: 12/01/2023

- **Cyclotron**
  - Ernest Lawrence (1929-1930)
Elements that Contribute to Development of PET Technique

PET Detection System (1953) - Brownell and Sweet
Described a multidetector system to acquire coincidence images from positron emitter (Cu-64 and As-75)

https://gordon.mgh.harvard.edu/gc/history/#gallery-1
Access: 12/01/2023
Elements that Contribute to Development of PET Technique

Yamamoto, BrookHeaven Lab (1966)

Modern PET Scanners...

First scanner as we know: Phelps and Hoffman (1973) Washington University School of Medicine

https://www.nm.org/conditions-and-care-areas/imaging-services/pet-ct
Access: 10/02/2023

https://www.healthytimes.hk/pet-scan-hong-kong/
Access: 10/02/2023

Access: 12/02/2023

Access: 20/02/2023

Access: 10/02/2023
### Characteristics of the main PET Radionuclides

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Half-Life (min)</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{18}$F</td>
<td>110</td>
<td>Cyclotron</td>
</tr>
<tr>
<td>$^{68}$Ga</td>
<td>68</td>
<td>Radionuclide generator</td>
</tr>
<tr>
<td>$^{82}$Rb</td>
<td>1.2</td>
<td>Radionuclide generator</td>
</tr>
<tr>
<td>$^{11}$C</td>
<td>20.4</td>
<td>Cyclotron</td>
</tr>
<tr>
<td>$^{13}$N</td>
<td>9.97</td>
<td>Cyclotron</td>
</tr>
<tr>
<td>$^{15}$O</td>
<td>2</td>
<td>Cyclotron</td>
</tr>
</tbody>
</table>

[Access: 12/01/2023]

[Access: 04/01/2023]
Some PET Radiotracers and Their Applications

<table>
<thead>
<tr>
<th>PET Radiotracer</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{18}$F-FDG</td>
<td>Tumors detection and staging, inflammation and infection, neurological diseases, cardiovascular diseases etc.</td>
</tr>
<tr>
<td>$^{18}$F-Florbetaben</td>
<td>Detection of $\beta$-amyloid plaques in the brain</td>
</tr>
<tr>
<td>$^{18}$F-Fluorodopa</td>
<td>Dopaminergic receptors evaluation – Parkinson Disease</td>
</tr>
<tr>
<td>$^{18}$F-FMISO</td>
<td>Tumor hypoxia</td>
</tr>
<tr>
<td>$^{68}$Ga-PSMA</td>
<td>Prostate tumors</td>
</tr>
<tr>
<td>$^{68}$Ga-DOTATOC</td>
<td>Neuroendocrine tumors</td>
</tr>
<tr>
<td>$^{11}$C-Choline</td>
<td>Neurodegenerative diseases</td>
</tr>
<tr>
<td>$^{13}$N-Ammonia</td>
<td>Myocardial perfusion</td>
</tr>
</tbody>
</table>
PET - Imaging Formation ($^{18}$F-FDG)

https://www.youtube.com/watch?v=oySvkmezdo0
Access: 12/02/2023
If $\Delta t = t_1 - t_2 < 6 \text{ to } 15 \text{ ns}$
A coincidence is registered to compose the image. The position of events in the patients’ body is calculated based on $\Delta t$ and the speed of radiation in vacuum.

LORs are combined using reconstruction techniques to create the final image.

Signal Detection

https://www.mdpi.com/1424-8220/19/22/5019
Access: 15/02/2023

https://www.youtube.com/watch?v=oySvkmezdo0
Access: 12/02/2023

https://gfycat.com/defensivecharmingborzoi
Access: 20/07/2019

https://gfycat.com/defensivecharmingborzoi
Access: 20/07/2019

https://www.mdpi.com/1424-8220/19/22/5019
Access: 15/02/2023
Signal Detection
View of Detectors

https://www.researchgate.net/figure/Left-6x6-BGO-crystal-array-for-original-Discovery-ST-block-detector-Right-8x6-Crystal_fig2_4224144
Access: 12/08/2022

Access: 12/08/2022
PET/CT and PET/MRI

PET + CT = PET/CT

PET + MRI = PET / MRI

https://www.omegapds.com/pet-mri-scan/
Access: 12/08/2022
Thank You!!
emsouza@unicamp.br
Safety in PET

Clare Jacobs
Clinical Scientist
Nottingham University Hospitals
Risk assessment for PET

- Identifying the hazards
- Provide engineering controls, design features and warning devices
- Provide systems of work to restrict the exposure
- Providing personal protective equipment.
Hazard: Exposure to radiation.

Sources of radiation in PET – CT departments

- X-ray emission from CT scanner
- Radiation being emitted from the patient containing up to 400 MBq
- Radiopharmaceutical vials containing GBq’s of activity
- Sealed sources used for scanner QA~ 100’s MBq’s of activity
**Effects of radiation**

**Deterministic**—occur above a threshold dose (high radiation dose thresholds). The severity increases with increased dose. Examples include radiation induced cataracts, acute radiation sickness syndrome. Possible that high skin doses could result from directly handling vials of radioactivity resulting in erythema—deterministic effect.

**Stochastic**—Assume a linear no threshold model where the probability of the effect increases linearly with radiation dose received. No safe lower limit is assumed. Examples include cancer induction and hereditary effects.

**Deterministic effects:**

**Stochastic effects:**
Who might be harmed and how

Radiation exposure to:

• Staff
• Members of the public
• Contractors
• Visitors

Hazards from external irradiation and contamination - which could get onto the skin or be ingested.
Gamma ray emissions from the radiopharmaceuticals

Most commonly used PET tracer is Fluorine 18
A proton in the nucleus is transformed into a neutron and a positively charged electron (positron).
Annihilation of the positron and electron yields two gamma photons each of 511Kev = rest mass energy of an electron.

$^{18}_F \rightarrow ^{18}_O + \beta^+ + \nu$

$^{18}_F$ has a half life of 109 minutes
CT Scanner X-rays

- X-rays generated from orbital electron interactions

Peak of Bremsstrahlung is ~ 1/3 to ½ of the max X-ray energy ~ 40-50KeV
Lowering radiation dose in practice

• TIME- minimise time
• DISTANCE- maximise this
• SHIELDING- barrier between radioactive source and person
• CONTAINMENT
• GOOD Housekeeping
Facility design - shielding in walls

Engineering brickwork

Code 4 lead rolls

Multiple Layers of code 4 lead on the walls.
Typically aim to have ~1cm lead equivalence in walls
Engineering controls - Shielding

Lead shielding in facilities used to draw up the activity. Few cm of lead are used in shielded cupboards and body shields.
Staff Dose reduction in PET

- Syringe shield
- Lead glass several cm thick in body shield
- Lead transport trolley
- Automatic PET injector cart
Principles of Radiation Protection

- Minimise time in close proximity to radioactive materials (patients and radiopharmaceutical preparations)
- Only remain in vicinity of exposure for as long as you need to be there
Principles of Radiation Protection

Distance: Assuming a point source of radiation
Doubling the distance results in a $\frac{1}{4}$ of the radiation flux intensity over the same area

Inverse Square Law

Maximise distance from patient when setting up for the scan
Warning signs
Principles of Radiation Protection

Containment

• Use drip trays when manipulating radioactive material
• Ensure the work area is clutter free
• Ensure work area is easy to decontaminate- consider surface finishes
Local Rules- written procedures

• Must identify the main working instructions intended to restrict any exposure in controlled or supervised areas.
• They should include steps needed to control exposure in the event of a radiation accident
Spill kits & rehearsal

PPE to minimise skin contamination
Monitoring for contamination

Contamination monitor

Hand and foot monitor
Monitoring staff for radiation exposure

Occupational dose limits for whole body, eye and extremity doses

Whole body badge

Finger ring

Finger Stall

Electronic personal dosimeter
Question: What are the three main methods which we use to lower the radiation dose received?

Question: What are the shielding materials used most commonly in PET facilities

Figure 4.7  Broad beam transmission of 511 keV photons through lead, concrete and iron.

Reference: Radiation Shielding for Diagnostic Radiology, 2nd Edition (birpublications.org)
Thank you for listening
PET CT Center: the model of technology/service organization and delivery

Giulio Iachetti
Health Tech & Innovation Manager
Medipass S.p.a.
Partnership Service Model

Feasibility analysis

Analysis and assessment of clinical target and mid – long term goals to focus tech needs and best solution to be set up:
- assessment of catchment area considering clinical performance band,
- selection of methods and devices, IT requirement & systems included
- organization model to guarantee feasibility and sustainability of the project

Design and building

Building up of site:
- accurate design, considering site constraints and optimization of work and patient flow (both physical flow and data flow)
- leading of building phase to guarantee budget and timeline constraints
- management of legislation compliance and regulatory constraints to minimize time gap from site «ready to start» and clinical go live
- project Management from design to «first patient»

Tech procurement

Heath tech procurement:
- customer support in equipment selection considering tech specifications related to clinical performance of Customer Service
- negotiation with OEM taking benefit from Medipass position as large number of high tech devices owner and manager
- management of commissioning, SAT, installation & training for a faster and safer usage of devices in operations

Maintenance

Management of:
- full risk maintenance,
- full life cycle of devices, with activities strictly related to monitor & control quality & productivity
- upgrading plan, even considering HW & SW platform

Clinical management

Selection and employment of qualified professionals (for clinics, tech management and support) to:
- reduce start up time
- improve Service to higher workload and productivity
- encourage knowledge transfer
- ensure a full exploitation of tech device and diagnostic capabilities

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Partnership Service Model

Service

SERVICE ELEMENTS
Technology
Organization
Professionals

SERVICE STANDARD
Tasks & Actions
Information flow
Quality

Information flow
Tasks & Actions
Quality
Medipass provides its services through long-term partnerships - between 8 and 30 years - to more than 15 public and private hospitals in Italy and the UK.

**Italy**
- Humanitas S. PioX Milano – 12 years* Radiotherapy - SC (2 Linac)
- AO S. Antonio e Biagio Alessandria – 8 years * Radiotherapy - SC (MRL, CT, US)
- Elsida Bologna Outpatient Clinic (DI)
- AUSL Bologna - DAB 8 years *-5 Outpatient Clinic (DI)
- Ecomedica Empoli Outpatient Clinic + Radiotherapy & Radiology
- Ospedale Mater Olbia 10 years - Radiotherapy - SC (3 Linac)
- Policlinico Gemelli Roma – 22 years* Radiotherapy, PET e Radiofarmacia - SC (3 Linac, 2 PET-CT, 1 Radiopharmacy with Cyclotron + 1 Hybrid OR)
- I.O.V. Padova 12 years* Radiofarmacia (1 Ciclotrone)
- Ospedale dell’Angelo Mestre – 16 years* Radiology - MES (MRL, CT, US, RX)
- Belfast City Hospital – 25 years Radiotherapy - MES (10 Linac + Radiology)
- New Cross Hospital Wolverhampton – 29 years Radiology - MES
- Churchhill Hospital Oxford – 30 years Diagnostica per Imm. e Radioterapia - MES (6 Linac + Radiology)
- Ospedale Muti Bari – 12 years Radiotherapy - SC (2 Linac)
- Ospedale Miulli Bari – 12 years Radiotherapy - SC (2 Linac)
- Ospedale dell’Angelo Mestre – 16 years* Radiology - MES (MRL, CT, US, RX)
- Norfolk & Norwich NHS Trust – 10 years Radiotherapy - MES (6 Linac + Radiology)
- Campus Biomedico Roma – 10 years Nuclear Medicine - SC (2 PET-CT + 1 Spect)

**UK**
- St. James Institute Leeds – 15 years Radiotherapy - MES (10 Linac + Radiology)
- Norwich & Norfolk NHS Trust – 10 years Radiotherapy - MES (6 Linac + Radiology)

SC: Clinical Service
DI: Diagnostic Imaging
MES: Managed Equipment Services
Medipass – Ongoing Services

RON AT A GLANCE

RON is one of the German market leaders for outpatient physician services in radiotherapy, nuclear medicine and oncology

Overview

- RON is a leading and fast-growing operator of a radiation therapy practice network providing its services in 19 different locations in Germany, having grown from one practice to a supraregional healthcare network.
- The company operates radiotherapeutic practices and oncology outpatient centers offering patients and employees the advantages of a networked corporate structure, as well as state-of-the-art technical equipment and great professional expertise at all practice locations.
- Founded in 2008 (the first practice in Aalen, “Strahlentherapie Ostalb”) by a team of renowned physicians that still lead the group today, RON has a strong track record of growth driven by (i) acquiring and integrating practices into the network and (ii) opening new practices (greenfield projects).
- The group includes a licensed basic care hospital – Einbecker Bürgerspital (“EBS”) – that functions as holding vehicle for the MVZ network according to §108 SGB V.
- RON employs c. 600 employees and is expected to generate c. €108m revenues and €28m EBITDA (c. 30% margin) in 2021 (Run rate).

Locations

- The group consists of:
  - 7 MVZs – legal entity for medical centres
  - 16 radiotherapy practices and 2 oncological practices
  - 1 clinic as carrier vehicle according to §108 SGB V
- The group mainly operates in Western Germany – Germany wide expansion is planned.

Services offered

- **Radiotherapy**
  - Innovative technology enable complex & modern procedures
  - Various areas of treatment (e.g. tumors, arteriosis)
- **Nuclear medicine / MR**
  - Several different MR and nuclear medicine services including mammography, angiography and thyroid
- **Oncology**
  - Services are focused on the area of hematology and internal oncology
**General layout of a PET CT Center**

- **Anamnesis** (medical «history» visit)
- **Diagnostic Imaging analysis and reporting**
- **PET CT diagnostic room**
- **PET CT Center**
  - «Cold» area
  - «Hot» area
- **Injection & biodistribution**
- **«one way» patient path**
- **Dept. standard safety layout**
- **Patient related flow**
- **Physician related flow**

[Diagram of a PET CT Center]
General layout of a Diagnostic Nuclear Medicine Dept.
Question 1

• Why is important to keep in consideration a «cold» and a «hot» area, planning the layout of a PET CT Center?
  • For higher safety of patient
  • For higher safety of operators
  • Both
General layout of Hospital Radiopharmacy

- Each room has tasks that can be done inside
- Each room has its own asepsis «grade» (like in an operating room)

- Workflow
- Design considering asepsis and radioprotection issues
Radiopharma: Manufacturing or compounding?

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Compounding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer</td>
<td>Manufacturer/Industry</td>
<td>Hospital radiopharmacy</td>
</tr>
<tr>
<td>Setting</td>
<td>Commercial</td>
<td>Clinical</td>
</tr>
<tr>
<td>Standard</td>
<td>GMP</td>
<td>Code of practice</td>
</tr>
<tr>
<td>Regulation</td>
<td>National medicinal regulatory authority (e. g. FDA)</td>
<td>Professional bodies/istitution</td>
</tr>
<tr>
<td>Distribution</td>
<td>Public distribution</td>
<td>Practitioner-patient</td>
</tr>
<tr>
<td>Marketing</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Permission</td>
<td>Investigational authority</td>
<td>Ethic committee</td>
</tr>
<tr>
<td></td>
<td>New drug application</td>
<td></td>
</tr>
</tbody>
</table>

https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1342/Pub1342_web.pdf
General workflow - a question of coincidence...

Automatic scheduling

Patient communication system

Radiopharma workflow in the same RIS platform

Radiopharma production workflow

LOGISTICS
PRODUCTION PLANNING
PRODUCTION
QUALITY CONTROL

DISPENSING
BATCH RECORD
FINAL APPROVAL

INJECTION
BODISTRIBUTION
DIAGNOSTICS

DICOM worklist integration with automatic dispensing system

Dicom worklist integration with automatic dispensing system

Customized RIS data with timing of injection

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Question 2

• What is the main issue in patient-dose pairing?
  • Patient recognition related to dose delivered
  • Timing of injection considering calibration activity and patient preparation
  • Both
General Protocol – syntetic dashboard

[¹⁸F] FDG (FLUORODESOSSIGLUCOSIO)

Protocol name/code

- **a. Globale Corporea**
  - **i. Standard (PRO.823)**

Protocol in acquisition workstation

- Siemens Biograph mCT
- Siemens Vision
- PET/CT_WHOLEBODY (ADULT)
- PET/CT_WHOLEBODY, CBM,ADULT

Radioactive dose quantification related to protocol and patient

- **dose prescritta secondo BMI**
- **Per pazienti pediatrici vedi tabella dedicata**

General workflow (biodistribution, acquisition, reconstruction)

- **Biodistribuzione**
  - **50’-70’**

- **Acquisizione**
  - **Statica (base cranio – rotula)**
  - **VISION: 1.4 mm/s (base cranio-collo-torace), 1 mm/s (cupsula diaframmatica-piccolo trocantere), 2 mm/s (Arte Inferiore) (Flow Motion Velocity) – 15’ – 18’**
  - **BIO: 15’-18’ (acquisizione non inferiore a 120 s/lettino base cranio-pelvi)**

- **Ricostruzione**
  - **VISION: TrueX+tof(ulta HD-PET) - Utilizzo IMAR dove previsto (protesi, device cardiaci)**
  - **BIO: TrueX+tof(ultaHD-PET)**

- **Congedo paziente**
  - **5’**

TOTALE 70-100 MINUTI BIO/VISION
Patient exam main phases – scheduling optimization

TEMPI SLOT TYPE:
- Timing for patient acceptance
- Timing for anamnesis
- Timing for patient preparation
- Timing for injection
- Timing for biodistribution
- Tempo for diagnostic acquisition
Productivity – EU data

Availability of PET scanners, 2010 and 2020 (per 100 000 inhabitants)

Note: Liechtenstein, no PET scanners.
(‡) 2020: provisional.
(‡) Break in series.
(¬) Hospitals only.
(*2010: not available.
Source: Eurostat (online data code: nhb_rs_eqn)
Question 3

• What is a high productivity PET CT Center?
  • Less than 1,000 patient/year/tomograph
  • From 1,000 to 3,000 patient/year/tomograph
  • More than 3,000 patient/year/tomograph
Next steps...


Long axial field of view PET scanners: a road map to implementation and new possibilities


Journal of Clinical Medicine

ConferenCe Report

Imaging Bacteria with Radiolabelled Probes: Is It Feasible?

Alberto Signore 1, Vera Artiko 1, Martina Conserva 1, Guillermfera Flerro-Flores 2, Mick M. Welling 1, Sanjay K. Jain 1, Soren Hess 1 and Mike Sathkeg 1

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Thank you

Giulio.iachetti@medipass.it
linkedIn.com/in/giulioiachetti
A list of additional topics and dates for next webinars will be soon announced through email campaign and on our website www.GlobalCEA.org.

THANK YOU for your participation.