An Introduction to Nuclear Medicine in Oncological Molecular Imaging

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Introduction

- WHO reported more than 10 million new cases of cancer annually
- Cancer has recently become the leading cause of death in high income countries [1]
- Nuclear medicine :
  - utilizes radiation from the disintegration of unsealed radionuclides, plays a pivotal role in cancer diagnosis and treatment
  - Provide information about the physiology and biochemical condition of organs at the cellular and molecular level.

1. Dagenais GR, Leong DP, Rangarajan S, Lanas F, Lopez-Jaramillo P, et al. The Lancet. (2019).

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CONT'

- REQUIREMENTS :
- Better diagnostic techniques for staging and following up therapy for individual patients : personalized medicine trend
- Combination of treatment strategy with diagnostics : Theragnostics
  - identifies patients most likely to benefit or be harmed by a new medication,
  - target drug therapy
- Monitor the treatment responses
- Eliminate unnecessary treatment of patients :
  - resulting in cost savings to the healthcare system
  - improving the quality of life of the patients.

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- Nuclear Medicine provides tools to fulfil the requirements
- The basis of nuclear medicine imaging in oncology is the use of radiotracers/ radiopharmaceuticals to detect pathological activity.
- They emit gamma and positron particles.
- The images are obtain by detection the radiotracer emission *in vivo* on a cellular and molecular level by using
  - Single Photon Emission Tomography (SPECT)
  - Positron Emission Tomography (PET)
  - These signals are then processed digitally to provide images

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SINGLE PHOTON EMISSION TOMOGRAPHY (SPECT)

- SPECT imaging in oncology purposes:
  - detection, differential diagnosis, staging, assessment of recurrence and therapy response
- Combined with computed tomography (SPET/CT) : anatomical location precission
- Radiotracers :
  - Technetium 99m (^{99m}Tc), 6.02 hours, 142 KeV
  - Radioiodine (^{131}I and ^{123}I), 8.03 days, 13.22 hours, 364 Kev, 159 KeV,
  - Indium-111 (^{111}In), 2.80 days, 171 and 245 KeV
- The radiopharmaceuticals used with SPECT to image cancers in various parts of the body .
- Bone scintigraphy and thyroid scintigraphy are the most widely used SPECT imaging technologies used in oncology.

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Radiopharmaceutical

- Radiopharmaceutical is radionuclide which bonded with
  - drugs or biologically active molecules such as antibody or antigen.
  - It has a specific role in the metabolism of the organ targeted and are administrated intravenously.
  - Radiopharmaceuticals : accumulate in tumour tissue in an abnormal fashion due to changes in vascularity, metabolic rate, receptor expression or changes of permeability.

Radiopharmaceutical	Diagnostic Usage
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

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SPECT technology imaging techniques used in oncology [1,2,3]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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1. Lele RD, *Principal and Practice of Nuclear Medicine and Correlative Medical Imaging* (Jaypee Brothers Medical Publishers, New Delhi, 2009), pp.1-2
2. Mettler FA, Guiberteau MJ, *Essential of Nuclear Medicine Imaging* (Elsevier, Philadelphia, 2012), pp.1-17
3. Hassel SN, Lindenberg ML, Mena E, Turkbey B, Choyke PL, Kurdziel KA, Nucl Med Commun 33, 349-361 (2012)

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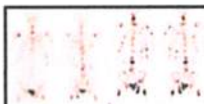

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- Up to 70% of prostate and breast cancer metastases are skeletal.
- Bone scintigraphy is the most commonly utilized diagnostic procedure for bone metastases.
- Radiopharmaceuticals : Technetium-99m Methylene Diphosphonate (99mTc-MDP)
- It has high sensitivity in detecting metastatic foci even in lesions with as little as 5–10% bone loss.
- Bone scintigraphy can detect abnormalities much earlier than x-ray radiography.
- Weakness : Not specific, the assessment needs to be done in clinical context

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Thyroid scintigraphy

- Using the radiotracers ^{99m}Tc-99m-Pertechenetate ($^{99m}Tc\text{-}O_4^-$) or ^{131}I.
- It can detect thyroid tissue remnants or metastases in well differentiated thyroid cancer.
- Radiopharmaceutical evenly distributed in a normal thyroid gland
- Detection of nodule :
  - Hot nodule : more radiopharmaceutical than the surrounding tissue
  - Cold nodule : absorbs less radiopharmaceutical than the surrounding tissue
  - Warm nodules have no significant clinical value
- Around 10-30% cold nodule are associated with malignancy. [1,2]

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positron emission tomography (PET)

- PET imaging uses nucleotides that emit positrons.
- PET is generally combined with computed tomography (PET/CT) or magnetic resonance imaging (PET/MRI).
- A positron will collide with an electron , causing an annihilation reaction occurs that generates two gamma photons (511 KeV) which travel 180° from each .
- Radiotracers : the positron emitters
  - fluorine-18 (^{18}F), 110 mins
  - gallium-68 (^{68}Ga), 68 mins

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Radiopharmaceuticals are commonly used for PET imaging

Radiopharmaceutical	Indication
18F - FDG 50% of human PET studies	
68Ga- DOTA-TATE/- TOC/-NOC	
68Ga/18F- PSMA ligands	

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CONT'

- PET images provide information
  - Staging (detect distant metastases),
  - Diagnose recurrence,
  - Differentiate between benign and malignant tumors,
  - Detect a previously unknown primary tumor,
  - Localize tumors for subsequent invasive diagnostic methods.
- ^{18}F-FDG PET :
  - a sensitivity of 95% and a specificity of 82% in the diagnosis of malignant nodules in the body. [1]

1. Dedin T, Grünwald V, Steinbach J, Wester HJ, Ross TL, Dtsch Arztebl Int 115, 175-181 (2018)

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CONT'

- PET imaging provides a functional assessment at the molecular level.
- The radiotracer ^{18}F-FDG is trapped intracellularly in proportion to glucose metabolism rate which allows imaging of the distribution of in both normal and abnormal tissues.
- Weakness : ^{18}F-FDG uptake
  - Not tumor specific
  - Also accumulate in many benign inflammatory processes leading to a false-positive diagnosis.

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- ^{68}Ga has become more popular for PET imaging in oncology diagnostics.
- The advantage of ^{68}Ga is it can be produced from a long lived parent isotope using a generator (contrast to ^{18}F which requires cyclotron production).
- ^{68}Ga is able to label :
  - Biological macromolecules as well as nano, micro particles.
  - Receptors, enzymes, and antigens and can identify proliferation, apoptosis, hypoxia, glycolysis, and angiogenesis.

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Conclusions

- Nuclear Medicine provides the oncologist with many more weapons than the traditional radiation therapy.
- A modern army general depends on an efficient intelligence ministry to determine the position and activities of the enemy
- The modern oncologist now can use SPECT/CT and PET/CT to pinpoint a pathological lesion in body.
- SPECT and PET can predict therapy results and forecast the disease's progress (Like an intelligence network which provides reports about the battle)
- This allows the oncologist to tailor cancer management to the individual patient. (Personalized Medicine)
- Improve patient outcomes and quality of life
- Cost effective by avoiding unneeded financing

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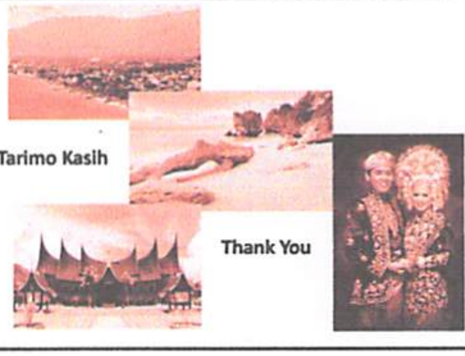

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CERTIFICATE

3rd International Conference on Nuclear Energy Technologies and Sciences

This certificate is proudly presented to

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Convention Hall - Universitas Andalas
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