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Introductory Chapter: Role of Nuclear Medicine in Medical Science

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1. Introduction

The science of nuclear medicine (NM) involves the administration of trace quantities of radionuclide's that are used to provide diagnostic information in a diverse range of diseases. In its most basic form, a NM study comprises of injecting a radiopharmaceutical, a combination of specific pharmaceutical tagged with a gamma-ray-emitting radioactive tracer into the body. There are a number of pharmaceutical available which are used for specific organ imaging. Its function is to carry gamma emitting radioisotope into a specific organ. When the radionuclide decays, gamma rays photons are emitted. The energy of these gamma photons is such that a large number of photons are exited from the body without being scattered or attenuated. These photons are later detected by a position-sensitive instruments called gamma camera or scintillation camera and form an image of the distribution of the radionuclide, and hence the compound to which it was attached. There are two classes of nuclear medicine imaging: single photon emission tomography which is essentially a single photon imaging and positron imaging. Single photon imaging usually comprises of either taking a planar image or a series of planar images around the body. A planar image is picture of radionuclide distribution in the patient from one angle. This results in an image having insufficient depth information, but which can still be diagnostically useful. In order to get depth information, data from various views are collected around the patient. This allows cross-sectional images of the distribution of the radionuclide which was later reconstructed employing specialized software's (these software's use highly sophisticated algorithms), thus providing the depth information missing from planar imaging. Positron imaging uses radionuclide that decay by positron emission. The emitted positron usually has a very short lifetime and produces two high-energy photons after interacting with its counterpart electron. The two simultaneously emitted gamma photons having energies of 511 KeV subsequently are detected by an imaging

Material	Density	Atomic number (Z)	μ @511 keV (1/cm) (mean free path-mm)	Photo fraction (%)	Light output (photon/MeV)	Decaytime (ns)	λ (nm)	Energy resolution (%FWHM)	Hygroscopic	Index of ref
BGO	7.1	75	0.95 (10.5)	40	9000	300	480	12	N	2.15
GSO	6.7	59	0.70 (14.1)	25	8000	60	440	9	N	1.85
LSO	7.4	66	0.88 (11.4)	32	30,000	40	420	10	N	1.82
NaI (TT)	3.7	51	0.34 (29.1)	17	41,000	230	410	8	Y	1.85

Table 1. Physical properties of PET scintillators.

camera. Once again, topographic images are formed by collecting information from different angles around the patient, resulting in PET images; however detectors remain stationary and do not move around the patient as it happens in SPECT study. A list of physical properties of different types of scintillator used in nuclear medicine is described in **Table 1**. It is clear from the table the GSO and LSO are quite fast materials with the decay time of 60 ns and 40 ns and are most suitable for PET time of flight measurements. However, NaI (Tl) detectors are more sensitive and give strong output per unit absorption of energy.

Although the amount of radioactive tracers injected into the patient is very small, however, smaller quantities carry risk and therefore assessment of absorbed dose to the organs and whole body become essential. Considerable work has been done internationally so far on the assessment of dose to remnant thyroid tissue and whole body. A high level of radioactivity is usually prescribed in routine to ablate thyroid tissue, therefore, its accurate quantification as well as safety of radiation technologists is a must. Different methods of measuring activity while in shielding were proposed to reduce the extra radiation burden to allied radiation staff. Before giving therapeutic radioiodine, uptake in the thyroid tissue is determined using uptake system that provides an estimation of the remnant thyroid mass. The uptake value is a value that can be reproduced with great accuracy and same will also be made sure that the uptake value is reproducible. Currently the clinical practice of administering radioactivity to treat Differentiated Thyroid Cancer (DTC) varies widely from hospital to hospital and ranges from 1110 to 3700 MBq or even more. This increase in activity although does not confer any therapeutic benefits to the patients. The corresponding absorbed dose to thyroid mass also varies widely from (13–1161) Gy depending on the mass of the remnant thyroid tissue, dose rate and the absorbed cumulated activity. The whole body receives, in this case, an absorbed dose of 0.12–0.23 Gy. Since the radioiodine is a non-specific agent, it also deposits in other parts of the body giving unnecessary radiation dose for example breast, liver, etc. This is particular of important for lactating women. The empirically determined activity without any apparent correlation between absorbed dose and activity depends solely on the experience of the individual groups and can varies by an order of magnitude from the standard practice. High success of non-scientific approach was reported, however, 15% of patients with high-risk DTC have significantly reduced life expectancy even after getting treatment using conventional approach of fixed amount of administered activity. The fixed-activity approach without assessing pretherapeutic lesion absorbed dose and toxicity assessment generally results in administration of low amount of therapeutic radiiodine as compared to with absorbed dose assessment. In this era of personalized and precision medicine, individualized approach to treatment will bring more patient benefits and improve life expectancy. The quantity of activity should be given to patient that is right and as high as safely achievable (AHASA) [1–5].

2. Conclusions

Diagnostic reference levels (DRLs) and achievable doses (ADs), a form of investigation levels, represent an important tool in medical imaging as optimizing the radiation dose delivered to patients. It is essential to ensure that the appropriate clinical information is

available in the image throughout the optimization process. In order to implement optimization process, both patient dose and clinical utility must be taken into account depending on image quality.

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Abbreviations

NM	nuclear medicine
SPECT	single photon emission computed tomography
GSO	gadolinium orthosilicate
LSO	lutetium orthosilicate
PET	positron emission tomography
NaI(Tl)	sodium iodide thallium activated
MBq	mega becquaral
DTC	differentiated thyroid cancer
Gy	gray
AHASA	as high as safely achievable

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