

NMPAICON2021 Virtual

13th -14th February 2021

*An insight view on developments in Nuclear Medicine
Physics, Chemistry & Biology*

डॉ. आर. चिदंबरम
Dr. R. Chidambaram



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भारत सरकार के पूर्व प्रधान वैज्ञानिक सलाहकार,

पूर्व अध्यक्ष, परमाणु ऊर्जा आयोग एवं

पूर्व निदेशक, भाभा परमाणु अनुसंधान केंद्र



Message

According to a recent report by the *World Nuclear Association*, “over 40 million nuclear medicine procedures are performed each year, and the demand for radioisotopes is increasing at up to 5% annually”. In India also, nuclear medicine procedures are available in a very large number of hospitals. And physics plays a major part in these procedures.

The programme of the 5th Annual (Virtual) Conference (NMPAICON2021) covers all aspects of nuclear medicine, with also a focus on the combination of physics, chemistry and biology. The frontier areas of medicine today synergise with the developments in other disciplines, and nuclear medicine is no exception. I am particularly happy that the emerging techniques of Artificial Intelligence will also be discussed in this conference, along with the latest developments in nuclear imaging, emerging radioisotopes, and radiation safety procedures.

I wish the Conference all success.

R. Chidambaram

R. Chidambaram



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G. NAGESWARA RAO
अध्यक्ष
CHAIRMAN

MESSAGE

It gives me immense pleasure to note that the Nuclear Medicine Physicists Association of India (NMPAI) is organizing its 5th Annual Conference with theme on "An insight view on developments in Nuclear Medicine Physics, Chemistry & Biology" during February 13-14, 2021 in virtual mode considering the prevailing pandemic situation.

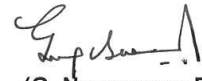
2020 has been a tough year for the whole world. But in these difficult times, humanity witnessed some outstanding unity and a collective faith in science. The world as a whole responded to stay safe and united in pursuit of the vaccine, to restore normalcy in the lives of people.

Organizations like NMPAI are playing a vital role to develop the scientific temper among their members by arranging regular conferences and by participating in the research and development activities. Nuclear Medicine is a rapidly growing field because of advances in technology and introduction of new radiopharmaceuticals for diagnosis and therapy. The number of Nuclear Medicine centers in India are growing at a faster pace. I hope this conference will provide an opportunity to all the participants to exchange and deliberate on latest developments related to Nuclear Medicine.

Over the past few years, Atomic Energy Regulatory Board (AERB) has taken many steps to make regulation simple and effective without compromising on radiation safety. AERB's mission is to ensure that use of ionizing radiation does not cause undue risk to health of people and environment. However, the primary responsibility of ensuring safety at institutional level lies with the licensee. Strict radiation safety standards are adopted for the protection of radiation workers, patients, members of public and environment. Radiation protection is based on the principles of justification and optimization and dose limitation. When applied to nuclear medicine, this translates to justification of nuclear medicine procedures. Dose limitation, of course, does not apply to medical exposure but the principle of dose optimization has to be applied so as to receive desired clinical information and treatment outcome.

I earnestly hope this Conference will provide opportunity to share safe handling of unsealed radioisotopes for Imaging and therapy and provide guidance for the participants to practice these procedures with proper justification and optimization.

I extend my Warm Greetings and Good Wishes to the Organizers and all the distinguished delegates participating in this conference and Wish all the success in achieving their objectives to disseminate the current knowledge in the field of Nuclear Medicine, to serve the needy people.


(G. Nageswara Rao)

February 2, 2021



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डॉ. सुमित सोम
निदेशक
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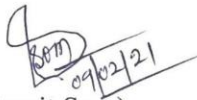
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Message

Despite going through the unprecedented times in 2020, filled with the fear of uncertainty and combating a pandemic situation, it's a great pleasure to know that the 5th Annual Conference (NMPAICON-2021) of Nuclear Medicine Physicist Association of India (NMPAI) is being held in collaboration with Council of Nuclear Medicine Science & Technology (CNMST) during February 13-14, 2021, in virtual mode.

Going through the Scientific Programme of the conference, it is understood that “an insight view on developments in Nuclear Medicine Physics, Chemistry and Biology” will be presented in this virtual platform in this 2-day event.

I am sure that the detail discussion on various topics in this event will help participants understanding up-to-date developments in Nuclear Medicines. I wish the event every success and all the participants a fruitful time.


(Sumit Som)

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MESSAGE

We take great honor and pleasure on behalf of NMPAI to welcome you to 5th NMPAI Annual Virtual Conference on theme "An insight view on developments in Nuclear Medicine Physics, Chemistry & Biology", being held on 13th-14th February, 2021.

The conference aims to provide a scientific platform for all the participants to congregate and interact with subject specialists. The virtual conference covers a number of keynote lectures and oral presentations on newly emerging science and technologies in Nuclear Medicine.

I am sure the deliberations of this conference will be an enlightening and enriching experiences for all the participants. This conference is likely to be one of the finest opportunities for the intellectuals from all over the globe to participate and to share ideas.

I would like to express my sincere appreciation to my teachers, mentors, members and volunteers of various committees and reviewers of CNMST scientific team. I profoundly acknowledge that the organizers have spent all needful corpus of sweat and have appreciably networked with the advisory board members and all others associated with the event. I specially would like to thank Dr Amit Nautiyal & Dr Asheesh Jha whose leadership helped with the overall organization of the conference. Our past President Dr S Kheruka has been always a motivation for NMPAI in achieving the goals of association.

Our sincere gratitude goes to all the mentors and invited speakers, for their participation and providing the intellectual sharing on experiences. I am extremely thankful to all delegates and resource persons for participating in this conference. I believe that all participants enjoy this virtual conference.

On behalf of the organizing committee, I welcome all to NMPAICON-2021_VIRTUAL and hope that the conference in general leaves positive commemorations for you to cherish.

Thanks and regard

Rajnath K Jaiswar

President, NMPAI
Chairman, Organising Committee



Dear Colleagues

On behalf of the Nuclear Medicine Physicists Association (NMPAI), it is an honor and privilege to invite you to the **5th Annual Conference of Nuclear Medicine Physicists Association of India** (NMPAICON 2021) to be held from **February 13th -14th, 2021**.

I hope this letter finds you all in good health. Majority of this year has been spent in adapting to the challenges thrown at us by the corona virus.

Our conference NMPAICON 2021 serves as an excellent forum to explore the advances in instrumentation, role of AI and internal dosimetry. We tried our best to bring together an Outstanding national and international faculty and subject experts from across the globe and exchange their break-through ideas.

Alongside the conference, there will be a virtual exhibition area, providing delegates with exposure to the most cutting-edge technologies. Companies will exhibit the latest innovations in the fields of radiopharmaceuticals and advanced medical technology and resources.

I am grateful to all our organising team members and my colleagues for their support, motivation and encouragement without which this event could not have been organized.

I also believe that NMPAICON 2021 virtual conference will be a new experience for us all, this year despite the obstacles to meet in person, we will celebrate Nuclear science and scintillation in the virtual space.

I once again welcome you all to the **NMPAICON 2021 virtual conference** and I wish you a great and enriching experience!

Thank you

A handwritten signature in blue ink that reads "Amit Nautiyal". The signature is fluid and cursive.

Amit Nautiyal
Organising Secretary, NMPAICON 2021
General secretary, NMPAI
Secretary, CNMST



Ashish Kumar Jha
Chairman,
Scientific Committee
NMPAICON-2021 Virtual
CNMST

Dear friends and colleagues,

Welcome to NMPAICON-2021. It is a great honour and privilege for me to extend warm welcome to all the delegates and the august faculty for the 5th National Conference of Nuclear Medicine Physicist association of Indian (NMPAICON-2021) on virtual platform. This conference will focus on education and training, quality and guidelines and update on several aspects of scientific and routine practice of nuclear medicine and molecular Imaging. The scientific sessions are planned to include areas of tremendous importance and includes luminaries in the field, both national and international. Our faculty comprises the most experienced teachers renowned in their fields from all over the country and overseas. We have speakers with diversified experience, who will not just pass on their knowledge, but the blend of knowledge and expertise in nuclear medicine and advanced technology. The two days brainstorming scientific program promises to be a great delight for all the attendees. Two days scientific program is divided in nine thematic scientific sessions, which will be blend of lectures. Thematic scientific session comprises of, radiation biology & safety, medical physics & instrumentation, radiochemistry & radio-pharmacy, infrastructure development, Artificial Intelligence (AI) and free paper oral & poster presentations. Thematic session will cover the theoretical aspects and newer advance in the field which will provide a great platform to improve our knowledge. This year participation of the audience in the scientific session will be of paramount importance particularly in the panel discussion as it will open an opportunity to discuss their issues directly with the experts and entire audience. I would like to place on records of NMPAI that we have more than 40 faculties who will not only deliver their lectures but their expertise and experience in the field which will make the scientific event more informative and interesting. Also, we have received more than 17 abstract from independent researchers in our field who are going to share their new ideas and findings in the field of research and development. I am sure that you will not only enjoy this conference but the blend of knowledge and experience will also help you to improve your practice back in your work area and place. I take this opportunity to request you for your active participation in this tow days' scientific extravaganza. I thank all our national and international faculties, organizing and scientific committee members, delegates, researchers and trade sponsor for their cooperation and unconditional support for making this scientific feast a great success. On behalf of scientific committee, I wish you a wonderful weekend of knowledge sharing during NMPAICON-2021 Virtual.

Ashish Kumar Jha



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13TH-14TH FEBRUARY 2021

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Mr. Anindya Roy

Joint Organising Secretary,
NMPAICON-2021

Nuclear Medicine Physicist Association India (NMPAI) in joint collaboration with Council of Nuclear Medicine Science and Technology (CNMST) welcome you to the 5th Annual conference of NMPAI



SCIENTIFIC PROGRAMME

NMPAICON 2021

**“An insight view on developments in Nuclear Medicine Physics,
Chemistry & Biology”**

Day 1: 13th February 2021 (Saturday)

Time	Session	Name	Topic
8:30-8:45am IST	Welcome address	Shri Rajnath Jaiswar, Organizing Chairman	
8:45-9:15am IST	Inauguration Chief Guest Dr. R. Chidambaram, DAE -Homi Bhabha Chair Professor, Former Principal Scientific Adviser to Govt of India. Former Chairman, Atomic Energy Commission, Govt of India		
Session 1 (9:30-11:50 am IST)	Chairpersons: Dr. P S Soni & Dr. S Kheruka		
9:30-10:30 am IST	Advanced Instrumentation & AI	Prof Craig Levin, Stanford University, USA	Design and Development of High Spatial Resolution Positron Emission Tomography (PET) Systems
10:35-11:30 am IST	Advanced Instrumentation & AI	Prof Osama Mawlawi, MD Anderson Cancer Hospital, USA	Advances in PET imaging
11:35-11:50 am IST	Advanced Instrumentation & AI	Dr Anil Kumar Pandey, AIIMS, New Delhi	Image Denoising using deep learning
11:50-12:00pm IST	Session break		
Session 2 (12:00-1:00pm IST)	Chairpersons: R Jaiswar (President), Anindya Roy (Secretary HQ), Amit Nautiyal (General Secretary)		
12:00-1:00pm IST	Ernest Lawrence Oration	Dr Subash Kheruka, SGPGI, Lucknow	Quality control and Image quality in diagnostic Nuclear Medicine and PET
1:00-2:00pm IST	Lunch break		

Session 3 (2:00-2:45pm IST)	<i>Chairpersons: Dr MGR Rajan & Dr Meera Venkatesh</i>		
2:00-2:15pm IST	Radiochemistry	Dr. Natesan Ramamoorthy, BARC, Mumbai	Need for strategies and support for availability of emerging radioisotopes
2:15-2:30pm IST	Radiochemistry	Ms. Bhakti Shetye, TMH, Mumbai	Analytical Separation Tools
2:30-2:45pm IST	Radiochemistry	Dr. Sanjay Bharati, MCHP, Manipal	"Radiolabelled nanoparticles in cancer therapy-current status and future prospects"
Session 4 (2:45-3:45pm IST)	<i>Chairpersons: Dr Shivanand Bhushan and Dr Ashish K Jha</i>		
2:45-3:00pm IST	Radiation Protection	Dr Pankaj Tandon, AERB, Mumbai	Incident Reporting Mechanism During Unusual Incidences in Nuclear Medicine Facilities: The Regulatory Perspective
3:00-3:15pm IST	Radiation Protection	Dr. Rajeev Kumar, IGIMS, Patna	Radiation Safety in Medical Cyclotron
3:15-3:30pm IST	Radiation Protection	Mr. Sachin Tayal, HBCH, Mohali	Radiation safety in Nuclear Medicine practices
3:30-3:45pm IST	Radiation Protection	Dr Aruna Kaushik, INMAS, DRDO, Delhi	ICRP - Nuclear Medicine Perspective
3:45-4:00pm IST	Session break		
Session 5 (4:00-5:30pm IST)	<i>Chairpersons: Dr V Rangarajan & Dr Anshu R Sharma</i>		
4:00-4:30pm IST	Molecular imaging & Radionuclide therapy	Dr Sumit Som, Director, VECC, Kolkata	Overview of 30 MeV medical cyclotron facility setup at VECC, Kolkata
4:30-4:45pm IST	Molecular imaging & Radionuclide therapy	Dr. Parul Thakral Dash, FMRI, Gurgaon	Targeted Alpha Therapy: New Horizons
4:45-5:00pm IST	Molecular imaging & Radionuclide therapy	Prof Debabrata Datta, BARC, Mumbai	Uncertainty analysis of absorbed dose in molecular radiotherapy
5:00-5:15pm IST	Molecular imaging & Radionuclide therapy	Dr Priyanka Gupta, AIIMS, New Delhi	Clinical Applications of Rhenium-188
5:15-5:30pm IST	Molecular imaging & Radionuclide therapy	Dr Sarika Sharma, PGIMER, Chandigarh	¹⁷⁷ Lu-PSMA targeted Radionuclide therapy
5:30-6:45pm IST	Oral/Poster presentations		
7:00-8:00pm IST	GBM		

Day 2: 14th February 2021 (Sunday)

Session 6 (9:00-11:45pm IST)	Chairpersons: Dr.D.A.R Babu & Dr.Pankaj Tandon		
9:00-10:00am IST	Radiation Protection & Dosimetry	Prof Michael G Stabin, Vanderbilt University, USA	'Therapeutic Uses of Radiopharmaceuticals - Applications and Patient Dosimetry'.
10:00-11:00am IST	Radiation Protection & Dosimetry	Prof Roger W Howell, Rutgers New Jersey Medical School, USA	“Dosimetry Guided Radiopharmaceutical Therapy”
11:00-11:30am IST	Radiation Protection & Dosimetry	Prof Madan M Rehani, Massachusetts General Hospital, USA	High patient doses in CT and hybrid imaging
11:30 – 11:45am IST	Radiation Protection & Dosimetry	Amit Nautiyal, TMH, Mumbai	Significance of Biological Dosimetry in Nuclear Medicine
11:45 – 12:00am IST	Session by GE Healthcare on “Clinical Benefits of “Q.Clear” and “Q.Static(motion free)” PET/CT Imaging		
12:00- 1:00pm IST	Lunch		
Session 7 (1:00-3:00pm IST)	Chairpersons: Dr Anil Pandey & Dr D Datta		
1:00-1:15pm IST	Advanced Instrumentation & AI	Mr. Ashish K Jha, TMH, Mumbai	Emerging role of AI in medical imaging
1:15-2:00pm IST	Advanced Instrumentation & AI	Prof Andre Dekker, Maastricht University, Netherland	AI & Medical Physics
2:00-3:00pm IST	Advanced Instrumentation & AI	Prof. Habib Zaidi, Geneva University, Switzerland	The promise of deep learning in molecular imaging research

Session 8 (3:00-4:00pm IST)	Chairpersons: R Jaiswar (President), Anindya Roy (Secretary HQ), Amit Nautiyal (General Secretary)		
3:00-4:00pm IST	Hal Anger Oration	Prof Brian Hutton, University College London, UK	Nuclear Medicine Instrumentation: Current Trends and Future Potential
Session 9 (4:00-4:45pm IST)	<i>Chairpersons:</i> Dr Natesan Ramamoorthy & Dr MRA Pillai		
4:00-4:15pm IST	Radiochemistry	Ms. Sneha Mithun, TMH, Mumbai	68Ga labeled radiopharmaceuticals
4:15-4:30pm IST	Radiochemistry	Dr. Rakhee Vatsa, PGIMER, Chandigarh	Ac-225 production, labelling and Radiochemistry
4:30-4:45pm IST	Radiochemistry	Dr Geetanjali Arora, AIIMS, New Delhi	Quality control of Radiopharmaceuticals
4:45-5:00pm IST	Vote of thanks	Amit Nautiyal, Organizing Secretary	

Lecture Notes

Therapeutic Uses of Nuclear Medicine Pharmaceuticals

M. Stabin¹

NV5/Dade Moeller and RADAR, Inc¹

There are many radiopharmaceuticals used in nuclear medicine therapy. Some are called 'theranostics', which means the integration of a diagnostic test with a specific therapeutic intervention. The diagnostic test should identify patients, who will likely respond to a particular therapy, fail to respond to a given drug or eventually exhibit adverse events, while the therapeutic application seeks to treat a specific disease. This session will describe the applications of several radiopharmaceuticals, including the well-established I-131 NaI in the treatment of hyperthyroidism and thyroid therapy, the use of Y-90 microspheres in the treatment of hepatic cancers, and newer therapies, including several Lu-177 and Re-188 radiopharmaceuticals for a number of cancers and Ra-223 chloride for bony metastases. Clinical successes will be discussed, but the focus will be on the radiation dosimetry aspects.

Nuclear Medicine Instrumentation: Current Trends and Future Potential

Brian F Hutton¹

Institute of Nuclear Medicine, University College London, UK¹

There has been continuous growth in the instrumentation used in Nuclear Medicine, although most instruments still depend directly on the original principles developed by Hal Anger. The gamma camera remains the primary instrument used in Nuclear Medicine (including single photon emission computed tomography (SPECT)) and the event localisation in positron emission tomography (PET) detectors follows similar principles. However, there continues to be significant development in both SPECT and PET instrumentation with continuing improvement in performance. In this presentation we will consider the desirable characteristics of imaging systems (including minimizing radiation dose) and the avenues that are currently being followed to address issues in both SPECT and PET.

In SPECT there has been increased utility of solid state detectors (e.g. CZT), which provide superior energy resolution, intrinsic spatial resolution and

count-rate performance compared to the conventional NaI(Tl) detector. Their compact size provides opportunity for novel designs with a range of objectives; optimised organ-specific imaging, stationary systems suitable for dynamic acquisition, adaptable systems that offer flexibility in use. The primary limitation in SPECT is the collimation, which results in a trade off between sensitivity (noise) and spatial resolution (contrast). Inventive approaches to collimator design, in combination with improved intrinsic detector performance provides opportunities for new improved SPECT systems. A challenge is to maintain flexibility in system design so as to maintain appeal for general clinical use.

In PET there also has been a major shift in the basic detector design, in this case using solid state readout (mainly SiPM) as direct replacement for the photomultiplier tubes of the past. One of the main advantages of these devices is their fast timing which has enabled the improvement of time-of-flight (TOF) and has dramatically improved image quality. This has rekindled an interest in achieving even better TOF timing with a challenge issued to achieve 10ps timing (current best commercial timing is over 200ps), stimulating completely new detector designs. Reaching the target would enable direct event localisation without reconstruction! A further development has been the commercial release of systems with large axial field-of-view extending to cover the total body or complete torso. These systems have very high sensitivity enabling dose reduction, fast scanning and the potential for whole body kinetics which may stimulate novel areas of clinical research.

The importance of image reconstruction as central to the overall performance of both PET and SPECT should not be understated. The flexibility of iterative reconstruction in accommodating complex geometry and timing information within the system model means that it can generally be applied to any configuration. Considerable research continues in refining algorithms so as to optimise imaging performance, accelerate convergence and accommodate additional parameters (e.g. motion, tracer kinetics).

In summary, there are exciting developments in both SPECT and PET which offer potential for expanded utility of both techniques in future clinical applications.

The promise of deep learning in molecular imaging research

Habib Zaidi, FIEEE, FAIMBE, FAAPM^{1,2,3}

*Division of Nuclear Medicine and Molecular Imaging, Geneva University Hospital, Switzerland¹
 Department of Nuclear Medicine and Molecular Imaging, University of Groningen, The Netherlands²
 Department of Nuclear Medicine, University of Southern Denmark, Odense, Denmark³*

This talk presents the fundamental principles and major applications of artificial intelligence (AI), in particular deep learning approaches, in multimodality molecular imaging research focusing mainly on positron emission tomography (PET) and hybrid imaging modalities (PET/CT and PET/MRI). To this end, the applications of deep learning in five generic fields of multimodality medical imaging, including imaging instrumentation design, image denoising (low-dose imaging), image reconstruction quantification and segmentation, radiation dosimetry and computer-aided diagnosis and outcome prediction are discussed. Deep learning algorithms have been widely utilized in various medical image analysis problems owing to the promising results achieved in image reconstruction, segmentation, regression, denoising (low-dose scanning) and radiomics analysis. This talk reflects the tremendous increase in interest in quantitative molecular imaging using deep learning techniques in the past decade to improve image quality and to obtain quantitatively accurate data from dedicated combined PET/CT and PET/MRI systems including algorithms used to correct for physical degrading factors and to quantify tracer uptake and volume for radiation therapy treatment planning. The majority of AI-related works in the literature report on single-institution efforts under controlled conditions (e.g. diversity of patient population or image quality). The challenge of performance/bias assessment of AI approaches under realistically diverse conditions (e.g. multi-centre studies) warrants further investigation. The performance of AI algorithms depends largely on the training data used for model development. As such, the analysis of risks associated with the deployment of AI-based methods when exposed to a different test dataset to ensure that the developed model has sufficient generalizability is an important part of quality control measures that need to be implemented prior to their use in the clinic. Novel deep learning techniques are revolutionizing clinical practice and are now offering unique capabilities to the clinical molecular imaging community and biomedical researchers at large. Future opportunities and the challenges facing the adoption of deep learning

approaches and their role in molecular imaging research are also addressed.

High patient doses in CT and hybrid imaging

Madan M. Rehani¹

Massachusetts General Hospital, Boston, MA, USA¹

Nuclear medicine physicists are well aware about radiation risks but often the attention goes more to personnel rather than patients. In early 1970's when the author joined nuclear medicine department, he was told that his protection is more important than that of the patient who may have exams only a few times in whole life, but he may be working with radiation for whole of my professional life of 40+ years. That advice or teaching is no longer true. Patients globally on an average get at least 200 times more radiation dose in a cumulative manner than the staff in any department where ionizing radiation is used. If we look at our own records of radiation monitoring badges, our cumulative dose may hardly reach near 50 mSv during 40+ years of professional life. Recent studies have shown that nearly a million patients reach the level of 100 mSv of cumulative effective dose (CED) every year only from recurrent CT exams. There are at least half a dozen papers published in 2020 alone on this issue covering millions of patients. The recent papers chose to focus on CEDs ≥ 100 mSv cohort, not because 100 mSv is a threshold for radiation effect but at that level of effective dose many organs get >100 mGy at which there is high degree of confidence on radiation effects among international and national organization. Several ongoing studies that are likely to be published in 2021 indicate that patients in a typical tertiary care nuclear medicine department who may get 2 or more FDG-PET/CT exam constitute over 15%, those with 3 exams around 5 to 10% and with 4 and more over 2%. Typically, the ratio of number of patients to number of exams for PET/CT and SPECT/CT is 1.5 to 2. A typical FDG-PET/CT may involve about 14 mSv effective dose and thus one can estimate the magnitude of patients in different dose bands. The patients with longer life expectancy and receiving higher doses in PET/CT are those with cardiac disease and lymphoma besides other conditions.

In the last decade when there were sporadic papers giving estimates of patients with high cumulative

doses, it was felt that such patients are restricted only to a few serious disease conditions and thus they did not create concern. But recent studies are population based in the sense that they estimated the percent of all patients who are undergoing imaging exams having such high doses. Moreover, nearly 20% of such patients with high doses are below the age of 50 years and nearly 10% are those with non-malignant disease. As if this was not enough, yet another recent paper showed that 1 out of every 125 patients (0.8%) got 50 mSv or more from a single CT exam. All these results indicate that we are in an unprecedented era, perhaps never witnessed before since the discovery of X-rays and radioactivity. In the past, high patient doses for tissue injuries (deterministic effects) have received significant attention but there is need to give due importance to stochastic risks. Nuclear medicine professionals need to focus their attention to patient radiation doses and use every opportunity to optimize patient radiation safety.

Quality Control and Image Quality in Diagnostic Nuclear Medicine & PET

Subhash Chand Kheruka¹

Department of Nuclear Medicine, SGPGIMS, Lucknow (UP)¹

Nuclear medicine is critically dependent on the accurate, reproducible performance of clinical radionuclide counting and imaging instrumentation. Advances in γ -camera design over the last 5 to 10 years have improved all aspects of image quality, particularly for tomographic imaging. As system complexity increases, it becomes more important that Physicist, technologist and physician be able to recognize the various types of artifacts that can occur in γ -camera systems and their potential impact on clinical studies. A thorough evaluation of the system at installation and a comprehensive quality control program will detect most problems that can occur. The most sensitive indicator of γ -camera performance is uniformity. Because this measurement is performed on a daily basis, it is the principle tool in evaluating the status of the γ -camera. Most artifacts related to the integrity of the detector head, computer system, and hard copy device can be detected on the uniformity image. For tomographic imaging, a quantitative determination of uniformity is needed to ensure that the system will not introduce ring artifacts into the patient data. Unlike planar imaging, the complex nature of tomographic imaging requires additional checks on system performance to ensure

that other components of the system, such as the collimator, gantry, and imaging table, are not a source of artifact in the reconstructed image data. Failure of a system component can occur at any time and may be subtle and difficult to recognize in modern systems. In such an environment it becomes imperative that any unexpected finding in a clinical study be questioned with respect to a possible malfunction of some aspect of data acquisition and analysis. Quality control (QC), which may be defined as an established set of ongoing measurements and analyses designed to ensure that the performance of a procedure or instrument is within a predefined acceptable range, is thus a critical component of routine nuclear medicine practice. An extensive series of parameters has been developed over the years for acceptance testing and performance characterization of γ -cameras, SPECT and PET scanners, and other nuclear medicine instrumentation. And detailed data acquisition and analysis protocols for this purpose have been promulgated by the National Electrical Manufacturers Association (NEMA), the American Association of Physicists in Medicine (AAPM), IAEA, IEC and other regulatory, advisory, and professional organizations.

Proper record keeping greatly facilitates detection of gradual deterioration of performance over an extended period of time, by analyzing the results for degradation and initiating corrective action when necessary.

A baseline set of quality control results should be recorded, after a thorough evaluation of the system at installation and acceptance testing, to serve as a reference for the life of the equipment. These can be used as a basis for developing detailed protocols for individual systems and models of equipment.

As advances in medicine occur at a rapid rate, the review and update of guidelines, such as these, should take place at regular intervals and should be considered to be part of the quality assurance process

Clinical applications of Rhenium-188

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Rhenium is a transition metal having chemical similarity with technetium due to which many technetium analogues can be labelled with Rhenium for several specific applications. The two main isotopes of rhenium that are of clinical use are Re-186 and Re-188. Simple extraction method of Re-188 from Tungsten-188/Rhenium-188 generator makes it

easily and routinely available enabling its more widespread use. Another advantage of Re-188 is its high specific activity due to which it finds clinical role in many therapeutic applications like bone pain palliation with Re-188-HEDP and Re-188(V)-DMSA, labeled antibodies and peptides for tumour therapy with Re-188-RC-160, endovascular radiation therapy with Re-188 perrhenate and Re-188 MAG3 (second generation) filled angioplasty balloons to inhibit coronary restenosis following high pressure angioplasty, Re-188-HDD-Lipiodol and Re-188-DEDC-Lipiodol for non-resectable hepatocellular carcinoma, and Re-188 tin colloid for treatment of arthritis (radiation synovectomy). Recent research has also shown the utility of Re-188 microspheres for liver cancer and Re-188 radioactive patches for treatment of Basal cell carcinoma, Squamous cell carcinoma and Keloids with excellent response

Targeted Alpha therapy: New horizons

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The range of therapeutic radioisotopes, including α , β or Auger electron emission are being used as radionuclide strategies for curative therapy, disease control, or palliation. The primary consideration for maximizing therapeutic efficacy is the matching the particle decay pathway, effective range, and relative biological effectiveness to tumor mass, size, radio sensitivity, and heterogeneity. β -emitting radioisotopes have the longest particle path length (#12 mm) and lowest linear energy transfer (LET) (;0.2 keV/mm), supporting their effectiveness in medium to large tumors. The long β -particle range is advantageous in evenly distributing radiation dose in heterogeneous tumors, it can also result in the irradiation of healthy tissue surrounding the tumor site. Conversely, Auger electrons have high LET (4–26 keV/mm) but a limited path length of 2–500 nm that restricts their efficacy to single cells, thus requiring the radionuclide to cross the cell membrane and reach the nucleus. Finally, α -particles have a moderate path length (50–100 mm) and high LET (80 keV/ mm) that render them especially suitable for small neoplasms or micro metastases. Several alpha emitting radioisotopes such as Ra-223, Ac-225, Bi-213 and At-211 have gained popularity in the recent years and have been used for therapies against several tumors and received favourable responses. However, there are several limitations associated

with alpha therapy such as high cost and availability of the alpha-emitting radionuclides, specific activity of the alpha emitters, dosimetric issues and regulatory approvals which makes the usage of alpha emitters challenging. To overcome these issues there is urgent need to stimulate fundamental research in the field of alpha therapy, particularly radionuclide production and chemistry of alpha-emitting radioelements.

Need for strategies and support for availability of emerging radioisotopes in nuclear medicine

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There are two areas of major growth of nuclear medicine (NM) during the past several years. The first is the wide-spread adoption of PET/CT imaging, attributable to many lesion-specific radiopharmaceuticals (RPh) of positron emitter radioisotopes (RI), as well as advances in hybrid imaging instrumentation. The second is the increasing attraction in using targeted therapy for certain cancers. Apart from the well-established role of ^{18}F in the former case, the following RI are increasingly needed for PET imaging, to varying extent: ^{68}Ga , ^{64}Cu , (^{82}Rb), ^{89}Zr , ^{45}Ti , ^{124}I . Similarly, for targeted therapy, ^{177}Lu (soft beta emitter), ^{90}Y or ^{188}Re (hard beta emitter), and ^{225}Ac (alpha emitter) are of vital importance. There is an urgent and strong need for considering suitable strategies to ensure sustained local accessibility and availability of the above RI. This requires both institutional and national level efforts.

Some of the existing medical cyclotrons (MC), and many of the new ones under planning stage, can help deliver one or more of the positron emitter RI listed above (except ^{82}Rb). For example, SGPGIMS, Lucknow has shown ^{64}Cu (12.7h) production capability. More recent success in production of ^{68}Ga (68min) by $^{68}\text{Zn}(p,n)$ route demonstrated by BRIT lab (and VECC) at Kolkata signals another important step for potential emulation by other interested and resourceful MC centres. ^{89}Zr (3.3d) has advantages for PET imaging involving imaging over longer time periods and its production is based on the mononuclidic ^{89}Y natural target. Solid targetry port in MC, enriched targets (e.g. ^{68}Zn for ^{68}Ga production), radiochemical separation modules, means for recovery and reuse of enriched target, etc. are among the elements of strategic planning in sourcing these RI. Addressing such production -

supply aspects can be managed at institutional level- both private and public (including involving needs-based collaboration), while indigenous sourcing of enriched targets (needed in many cases of RI) will require national-DAE support. The Heavy Water Board (HWB) of DAE has developed technology and built facility for production of enriched ^{18}O (heavy) water target suitable for ^{18}F production. In light of GoI move towards PPP model for reactor-based RI announced in May 2020 (being pursued by DAE/BARC), it is deemed worthwhile for stakeholders in NM to seek similar initiative for sourcing enriched targets (electro-magnetic mass separator system, Calutron) for RI production.

In the case of RI for therapy, the unique scope of DAE/BARC to advantageously exploit its inventory of ^{90}Sr stock for producing ^{90}Y (64h) should be encouraged to be brought to its logical end in near future. The alpha emitter ^{225}Ac (10d) is attracting much global attention (and India is no exception, though the imported product is very expensive) based on the demonstrated success in patients of castration-resistant prostate cancer (large fraction of prostate cancer cases). Its large-scale production is however quite demanding and high-budget efforts are underway in USA, Canada, Europe, etc. The DAE's Cyclone30 facility at Kolkata can be used, in principle, to explore indigenous production of ^{225}Ac by $^{226}\text{Ra}(p,2n)$ route. Fostering an early policy decision by DAE regarding its support to the highly demanding technology for indigenous ^{225}Ac availability and development of ^{225}Ac production capability (i.e. ^{226}Ra target stock; encapsulated targetry system for irradiation; processing and QC systems) would be the beginning step in this context. It will be worthwhile for NM fraternity to remain engaged with DAE management to mobilise support for timely progress in sourcing such RI of vital importance for NM procedures and patient benefits.

An overview of ^{68}Ga labelled radiopharmaceuticals

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Radionuclide generators are distinguished according to the half-lives of parent and daughter radionuclides. The first generator was the $^{132}\text{Te}/^{132}\text{I}$ in 1951. A generator exploits the radioactive equilibrium that exists between the parent and daughter. There are different types of equilibrium. But if the parent half-life is far greater than the daughter half-life there is said to be a secular equilibrium as in the case of ^{68}Ge - ^{68}Ga generator. ^{68}Ge has a half-life of 271 days and ^{68}Ga a half-life of only 67.71 minutes. (1) The very first generator described by Gleason in 1960 was a solvent extraction type. It was followed by several column generators with different types of columns & eluants, the most recent one using organic resins containing N-methylglucamine groups or lauryl gallate which overcomes most of the disadvantages with the other types of columns. (2-9)

There are broadly two major approaches that are followed for preparation of ^{68}Ga radiopharmaceuticals, namely, bifunctional chelate approach (BFCA) and direct complexation approach. The BFCA serves two main purposes: (1) to coordinate radiometal ion; and (2) to provide a molecular backbone that can be modified with functional groups for attachment to the targeting molecule.

Bifunctional chelate approach



Direct complexation approach



There are two major requirements to be fulfilled by Ga-complexes to be qualified for use as radiopharmaceuticals. 1) These complexes should be resistant to hydrolysis (the formation of insoluble complexes with OH^-) and 2) should be more stable than the Ga(III) -transferrin complex ($\log K = 20.3$). Large formation constant of Ga(III) -transferrin and the high plasma concentration of transferrin (0.25 g/ favour ligand exchange reactions of Ga(III) complexes in-vivo with transferrin. (11)

Characteristics deciding the chelators

The major characteristics that decide the chelators are its denticity, coordination geometry, thermodynamic stability of the complex and kinetic inertness of the complex in-vivo. For in vivo applications, kinetic inertness of metal-chelator complexes or conjugates are relevant than their thermodynamic stability. Acyclic chelator complexes are less kinetically inert than macrocyclic complexes of comparable stability. Acyclic chelators are known to have faster metal-binding kinetics as opposed to their macrocyclic analogues, which can be a significant advantage for shorter-lived radiometals. There have been efforts to enhance the binding rate of macrocycles by incorporation of an acyclic polydentate pendant. (10)

When labelling chelators with ^{68}Ga it is important to ensure following:

1. entire labelling should be possible in short time,
2. under mild conditions (pH & temperature)
3. provide quantitative yields >95%,
4. possible to complete the radiolabelling process at low concentration of ligand. A huge excess of precursor concentrations may easily shift labelling to high yields. However, utilization of large amounts of bi-functional chelating ligands is detrimental in terms of costs and specific activities
5. possible to have efficient labelling even in presence of traces of competing metals.

Assays for metal-chelator complex integrity maybe performed by Proton and ^{13}C NMR spectroscopy, Acid decomplexation (aqueous kinetic inertness), Competition assays of complexes, Serum stability studies (inertness assay), In-vitro uptake studies using specific cell lines and Animal biodistribution. Competition assays are performed with excess metal ions and biochelators and use concentrations of orders of magnitude higher than the radiopharmaceutical complex, ensuring high chelator selectivity for the radiometal. Serum stability studies are performed using TLC, HPLC and LC-MS. Although cell line studies simulate the in-vivo environment to some extent but still do not efficiently mimic the exact in-vivo process. Animal biodistribution and pharmacokinetic study are essential to observe the actual in-vivo behaviour of the complex.(10)

Some common chelators with their donor group and stability constant values have been listed in table1. Tetradentate Ligands like NO_3 (iminodiacetic Acid derivatives) or NS_3 donor set have distorted octahedral or tetrahedral structure, N_2S_2 chelator

(BAT-TM) have distorted square pyramidal structure. Hexadentate Ligands like $\text{N}_2\text{O}_2\text{S}_2$ have distorted octahedron (EC, EDTA), N_2O_4 donor set (HBED/HBED-CC, DTPA, SBAD), N_4O_2 have pseudo octahedral structure ($\text{CHX-A}''$ -DTPA, BAPEN), N_3O_3 donor set show distorted octahedral structure (TACN, TACN-TM, NOTA); DOTA shows distorted octahedral coordination; DOTA-D-PheNH $_2$ (NODASA) pseudo-octahedral; DOTA-TOC; DO3A-TPP pseudo-octahedral; TETA lower stability constant than Ga-DOTA; CB-TE2A (cross-bridged cyclam of TETA) good acid inertness (10-14)

Chelators	Donor atoms	Stability constant value
Transferrin	NO_5	20.3
EC	$\text{N}_2\text{O}_2\text{S}_2$	31.5
EDTA	N_2O_4	21.0
HBED	N_2O_4	37.7
DTPA	NO_3	25.5
NOTA	N_3O_3	31
DOTA	N_4O_2	21.3
TETA	N_4O_2	19.7
SBAD	N_4O_2	28.3

Table 1

^{68}Ga radiopharmaceuticals with their applications are listed below: (10)

1. Oncology
 - a. Somatostatin Receptor Imaging (^{68}Ga -DOTA-D-Phe1-Tyr3-octreotide (DOTA-TOC), ^{68}Ga -DOTA-TATE, ^{68}Ga -DOTA-NOC)
 - b. Prostate membrane specific antigen: (^{68}Ga -HBED-CC-PSMA)
 - c. Integrin Imaging (angiogenesis) (^{68}Ga -NOTA-(RGD)/ (RGD)2or4 / (RGDyK))
 - d. HER-2 Receptor Imaging (^{68}Ga -NOTA-Trastuzumab(Fab fragments)
 - e. Gastrin Releasing Peptide Receptor Imaging (^{68}Ga -NOTA-Bombesin(BBN2), ^{68}Ga -BZH3, ^{68}Ga -RM2(Bombesin)
 - f. Epidermal Growth Factor Receptor Imaging (^{68}Ga -DOTA(L39)-hEGF, ^{68}Ga -NOTA-cetuximab)

- g. Vascular Endothelial Growth Factor Receptor Imaging (68Ga-NOTA-VEGF 121, 68Ga-NODAGA-VEGF121, 68Ga-HBED-CC-PEG-scVEGF)
- h. Melanoma Imaging (68Ga-Labeled α -Melanocyte-Stimulating Hormone Derivatives, 68Ga-DOTA-GGNle-CycMSHhex)
- i. Chemokine receptor imaging (68Ga-NOTA-Pentaxifor)
- j. Hypoxia (68Ga-tris(2-mercaptobenzyl)amine, 68Ga-DOTA-nitroimidazole (MN) agents)
- k. Apoptosis imaging (68Ga annexin5)
- l. Glucagonlike peptide-1 (GLP-1) receptors (68Ga-NOTA-Exendin-4 or 68Ga-DOTA -Exendin-4)
2. Gene expression (68Ga]WL12 PDL1 binding peptide for imaging mRNA expression)
3. Infection & Inflammation (68Ga-Citrate, 68Ga-Pentixafor)
4. Perfusion (68Ga-MAA for lung perfusion, 68Ga-ECD for Brain perfusion)
5. Renal function (68Ga-EDTA)
6. Cardiac function (68Ga-BAPEN (Tris(4,6-dimethoxysalicylaldehyde)-N,N -bis(3-aminopropyl)- N,N -ethylenediamine))
7. Hepatobiliary agent (68Ga-IDA)
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²²⁵Ac: Production, Radiochemistry and Labelling Rakhee Vatsa¹

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Alpha emitters like ²²⁵Ac, ²²³Ra, ²¹³Bi, and ²¹¹At are now being considered for targeted radionuclide therapy of various tumors in patients. The high LET associated with these alpha particles results in deposition of energy within the microscopic tumor cell clusters leading to DNA damage which is difficult to repair. Actinium, discovered by a French-chemist AL Debierne in 1899 is a rare silvery metallic element of group III of periodic table. Of its 32 known radioisotopes, Actinium-225 (²²⁵Ac) has emerged as a potential candidate for targeted alpha therapy (TAT) of various cancers. ²²⁵Ac has a physical half-life of 9.9 days. During the chain decay to stable daughter Bismuth-209 (²⁰⁹Bi), total of 4 α particles are emitted along with β - and γ emissions. ²²⁵Ac presently used for TAT is primarily derived from the build-up Thorium-229 via decay of Uranium-235 stockpiles. ²²⁵Ac in aqueous solution exists as a trivalent cation and forms thermodynamically stable complex with polydentate macrocyclic bifunctional chelators (BFC) like DOTA, PEPA, HEHA etc. These macrocyclic

chelators are covalently coupled to a tumor targeting vector usually peptide or protein. Of the various BFC chelators present, DOTA having octadentate coordination number via 4 tertiary amine nitrogen atoms and 4 carboxylic acid pendent arms is used for the stable chelation of $+3$ actinium ion. Commercially available clinical grade ^{225}Ac comes in the form of $^{225}\text{AcCl}_3$ solution with radionuclide purity of $>99.9\%$. At present DOTATATE and DOTA-PSMA-617 labeled with ^{225}Ac have been used for the treatment of neuroendocrine tumors and castration resistant prostate cancer, respectively. The radiolabeling requires heating of the $^{225}\text{AcCl}_3$ solution with the peptide and use of buffer for attaining the reaction pH of 5.5. Depending upon the radiochemical purity (RCP) of the labelled solution, solid phase extraction based purification can be used to obtain the clinical grade product (RCP $>95\%$). Since DOTA prefers smaller ions for thermodynamically stable complex formation and $^{225}\text{Ac}+3$ ion is considered as the largest known cation, research is still going on to explore a more suitable BFC for the development of ^{225}Ac based radiopharmaceuticals. Although promising results have been observed in patients in both cases, however the long-term side effects are still to be ruled out. Clinical trials with ^{225}Ac -labeled humanized anti-CD33 (HuM195) mAb has also been reported for the treatment of advanced myeloma are under progress. The use of ^{225}Ac as a targeted alpha therapy radioisotope shows immense potential but the limited availability and the cost associated with ^{225}Ac , hinders the global use of this radioisotope on routine basis. The newer routes for production of ^{225}Ac for meeting the increasing global demand are still under exploration along with development of more stable coordinating ligands.

Radiolabeled nanoparticles in cancer therapy-current status and future prospects

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Abstract: The current concepts of cancer therapy has seen tremendous growth in the last decade. With the merge of nanoparticle's engineering and biology, now we are moving towards the development of treatment modes where molecules can be engineered to deliver cancer therapy. These nanoparticles can be labelled with radionuclides with very high specific activity. However, as with every new modality, this approach is also facing several challenges such

reticulo-endothelial uptake and subsequent radiotoxicity. Here, we will discuss the areas where these particles are currently employed and challenges that lie ahead. We will also discuss about nanoparticles which are being developed in our laboratory and their future applications.

Overview of 30MeV Medical Cyclotron Facility Setup at VECC, Kolkata

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The Variable Energy Cyclotron Centre (VECC) is one of the R&D Institutions under Department of Atomic Energy (DAE). Besides accelerator development, operation and research in nuclear physics, VECC is also engaged in societal applications, like the production of radioisotopes/radiopharmaceuticals, which are used for nuclear imaging of patients.

A 30 MeV Proton Cyclotron (IBA# Cyclone-30) with beam current up to $350\mu\text{A}$ has been established at Chakgaria campus of VECC, Kolkata. This cyclotron accelerate H- beam and finally proton beam is extracted with energy ranging from 18 to 30 MeV. The cyclotron is equipped with five beam lines, one for PET isotope & two for SPECT isotopes along with necessary hot cells, one for material science research and the other for ADSS target study. The cyclotron has been already installed and commissioned. After obtaining RPC clearance, commercial production and delivery of PET radiopharmaceuticals like, FDG and ^{18}F -NaF, started. SPECT radioisotopes like Gallium-67, Gallium-68, Thallium-201 have been produced by BRIT on trial basis and its commercial production will start soon after obtaining RPC clearance. Besides the above, beam testing for the other two research beam lines has been carried out successfully.

Incident Reporting Mechanism During Unusual Incidence in Nuclear Medicine Facilities: The Regulatory Perspective

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The International Nuclear and Radiological Event Scale (INES) was developed in 1990 to communicate in a consistent way the safety significance of events at nuclear installations. Since then INES has been expanded to meet the growing need for

communication on the safety significance of events giving rise to radiation risks. INES applies to events associated with the transport, storage and use of radioactive material and radiation sources, whether or not the event occurs at a facility. It covers a wide spectrum of practices, including industrial use such as radiography, use of radiation sources in medical and research facilities, activity at nuclear facilities, and transport of radioactive material. When radiation source is used in medical facilities, the current guidance on INES methodology is used to rate events resulting in actual exposures to workers and public or involving degradation of the device or deficiencies in the safety provisions but does not cover the actual or likely consequences for patients. There are only few countries that are actually following the mechanism of reporting the incidences related to the patient exposure to their regulatory authorities. In 2015, IAEA has made a draft document on Additional Guidance for Rating Medical Events on INES.

In India, AERB, the national regulatory authority has developed the mechanism of reporting the unusual incidence by the radiation facilities through e-Licensing of Radiation Applications (e-LORA). The purpose of reporting the incidence is not to take any stern action against the utilities but to initiate necessary steps to mitigate the incident in a safe manner through the nodal agencies. Moreover, the experience and lesson learnt from such incidence can be shared with other utilities involved in similar activities to avoid/prevent such incidences in the near future and in turn create deterrence. It has been observed that there is some kind of psychological fear in the minds of utility that reporting of such kind of events may lead to regulatory actions against them. In view of the above fact, the regulatory authority of India i.e. AERB has started creating awareness among the radiation facilities so as to educate them about the safe use of radiation, which would not only benefit the authority but also benefit the utilities.

¹⁷⁷Lu-PSMA Radionuclide Therapy

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Prostate-specific membrane antigen (PSMA) is a receptor on the surface of prostate cancer cells which is revolutionizing the way of imaging and treatment of the prostate cancer patients. ¹⁷⁷Lu-complexed with the PSMA-binding small molecule inhibitor, when administered intravenously gets internalized in

the cell and remains over the 6.7-day half life of the ¹⁷⁷Lutetium. ¹⁷⁷Lutetium being a gamma and beta emitter provides favorable characteristics for image acquisition, dosimetric calculation and radionuclide therapy and thus termed as therasnostic agent.

The earlier efforts with PSMA targeted using antibodies yielded low efficacy with high toxicity [Calopedos et al], the newer antibodies targeting the extracellular structure of PSMA exhibit improved activity with reversible haematological toxicity [Benesova et al]. The recent development with radio-labeled small molecule inhibitors targeting PSMA demonstrate high efficacy with low toxicity. Currently, PSMA-617 [Benesova et al] and PSMA I&T [Weineisen et al] are the two ligands exhibiting these characteristics and thus are widely used in the imaging and treatment of the prostate cancer patients. Rahbar et al (2017) published the results of German multicenter study investigating ¹⁷⁷Lu-PSMA-617 radioligand therapy in 99 patients, demonstrating 50% decline in PSA from baseline to 8 weeks after the one therapeutic dose in 45% of patients. A recent meta-analysis performed by Calopedos et al. evaluated ten studies (with more than 300 patients), demonstrated PSA response in ~ 70% and PSA-decline of greater than 50%, in approximately two-third of the patients.

Practically ¹⁷⁷Lu-PSMA is easy to administer without any significant symptoms at the time of injection. In our institute a fixed dose of 7.4 GBq (200 mCi) ¹⁷⁷Lu-PSMA per injection is administered. ¹⁷⁷Lu PSMA is excreted via renal route in the first 48 h following injection, thus it is recommended that the patients are hydrated pre- and post-administration of ¹⁷⁷Lu PSMA with 1–1.5 L of water and encouraged to void as frequently as possible. Instructions are given to patients and families on managing potential radioactive spills at home (if any) till 48 hrs post-therapy. Overall, toxicities related to ¹⁷⁷Lu-PSMA therapy include low-grade (Grade 1) xerostomia/dry mouth, fatigue and nausea. Haematological toxicity is the most common serious side-effect of the ¹⁷⁷Lu-PSMA therapy, which is mainly a bystander effect in males patients with a heavy burden of bone-metastasis, border-line marrow function and direct radiation effect on the bone-marrow [Yadav et al].

A recent example from Baum et al. in 56 metastatic castrate-resistant prostate cancer patients found an average kidney dose of 0.8 mGy/MBq based on wholebody temporal data (approximately 4.6 Gy per cycle based on the reported median administered

activity of 5.76 GBq). Kidney absorbed dose ^{177}Lu -PSMA, has generally been reported as being well below the 23 Gy dose-limiting threshold. The parotid glands received higher dose than kidney, with an average parotid absorbed dose per cycle of 7.5 Gy (based on the reported median injected activity) and 5.1 Gy respectively. However, in our institution, patients were recorded to be below the recommended radiation level (25 μSv) at the time of discharge from the hospital.

There is limited published literature regarding the use of ^{177}Lu -PSMA for the treatment of metastatic castration resistant prostate cancer (mCRPC) patients with limitations like retrospective trials, small patient cohorts etc. Still uniformly, the literature demonstrates that a high proportion of patients treated with ^{177}Lu -PSMA show significant treatment response with low-grade toxicities, thus suggesting the treatment appears well tolerated.

Summarizing, ^{177}Lu -PSMA radionuclide therapy is showing exciting treatment responses in patients with mCRPC and certainly has an important future role in the treatment of prostate cancer.

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ICRP – Nuclear Medicine Perspective

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Since the discovery of X-rays and radioactivity more than 100 years ago, many different applications of radiation and radioactive materials have been developed. Nuclear medicine is one such application that involves use of radioactive sources for the purpose of diagnosis and therapy. There has been rapid increase in the annual frequency of diagnostic procedures due to introduction of hybrid imaging PET-CT and SPECT-CT to conventional nuclear medicine procedures and diagnostic radiology and hence contributing significantly to the population exposure.

A benefit from the use of radiation was established very early but the potential risks of radiation became apparent much latter. The need for a protection committee was discussed in 1925 by the first International Congress of Radiology which it established at its second congress in Stockholm in 1928. The International Commission on Radiological Protection (ICRP) is a premier international organisation for the protection of workers, patients, and the public against ionising radiation. ICRP was established to advance the science of radiological protection for the benefit of public. The name 'International Commission on Radiological Protection' was adopted in 1950. Scientific data about the biological effects of ionizing radiation are converted into ICRP recommendations. The Radiation Protection System has evolved over many years until the formulation of a shared approach as ICRP System of Radiological Protection. The three fundamental principles of radiological protection are Justification, Optimisation of protection and Dose Limitation.

ICRP recommendations have evolved from previous process-based protection approach using practices and interventions to situation - based approach to all controllable exposure situations characterized as

planned, emergency, and existing exposure situations. The use of radiation in nuclear medicine is a planned exposure situation. ICRP publication 60/103 classifies radiation exposure into three categories: occupational, medical and public. An individual person may be subject to one or more of these categories of exposure. In a Nuclear Medicine Facility, all these exposures occur. The details regarding the evolution of Radiation Protection System, various exposure situations, categories of exposures, ICRP Principles of Radiation Protection and the 2007 Recommendations of ICRP relevant to nuclear medicine would be presented during the lecture.

Analytical Separation Tools

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Analytical chemistry is a branch of chemistry which deals with assessment of composition and quantification of variety of compounds. It is performed by using different techniques and tools. It caters information related to chemical analysis and interprets analytical results. Tools like mass spectrometer, HPLC, gas chromatography nuclear magnetic resonance spectrometer, particle size analyzer are commonly used.

In nuclear medicine our daily work involves use of different chromatographic techniques. These are used for estimation of radiochemical purity, purification of product, separation of compounds having similar functional groups. Commonly used chromatographic techniques are

- 1) Paper chromatography
- 2) Thin layer chromatography
- 3) Size exclusion chromatography
- 4) HPLC
- 5) Ion exchange chromatography

Paper Chromatography: It is a technique in which separation is carried out based on difference in partition coefficient of molecules. Stationary phase is a special chromatographic paper and mobile phase is polar or non-polar solvent. Whatman filter paper of different grades like 1,2,3,4 etc. is used as stationary phase more commonly.

Thin layer chromatography: It is a method of separation or identification of mixture of components into individual components by using finely divided adsorbent solid/liquid spread over a plate (stationary phase) and liquid as a mobile phase.

Size exclusion chromatography: Used for separation of proteins, monoclonal antibodies and their fragments, peptides and oligonucleotides.

Molecules move through a bed of porous beads, diffusing into the beads to greater or lesser degrees. Smaller molecules diffuse further into the pores of the beads and therefore move through the bed more slowly, while larger molecules enter less or not at all and thus move through the bed more quickly.

HPLC: High performance liquid chromatography (HPLC) is basically a highly improved form of column liquid chromatography. Instead of a solvent being allowed to drip through a column under gravity it is forced through under high pressures of up to 400 atmospheres.

Ion exchange chromatography: It is used for separation, determination of ionic compounds like peptides, proteins, nucleic acid and related biopolymers. Two distinct mechanisms as follows; ion exchange due to competitive ionic binding (attraction) and ion exclusion due to repulsion between similarly charged analyte ions and the ions fixed on the chromatographic support, play a role in the separation in ion chromatography

Using these different techniques one can achieve profile of a sample with precision and accuracy.

Uncertainty Analysis of Absorbed Dose in Molecular Radiotherapy

Debabrata Datta¹

The medical internal radiation dose computation scheme has become the most widely accepted formalism for internal dose calculation. Internal dosimetry is a prerequisite for radiation protection, optimization for imaging, patient specific administration of nuclear medicine and treatment planning. A subset of phantom experiments is unable to validate the accuracy of measurements made for an invitro population because of diversity of dosimetry dataset. Accuracy is improved by carrying out an uncertainty analysis of absorbed dose in molecular radiotherapy. The fundamental model used in absorbed dose calculation constitutes the cumulated activity and a dose factor. The cumulated activity is defined as the area under the time-activity curve obtained through time sequence of activity values. Activity value is formulated as the product of count rate, calibration factor and a recovery coefficient. Literature study shows that model uncertainty of absorbed dose calculation in molecular radiotherapy

can be quantified using European Association of Nuclear Medicine Practical guidelines. However, with the advent of technology in the said domain uncertainty of all the parameters of the model cannot be achieved by Monte Carlo simulation only. Hence a hybrid method for model uncertainty of absorbed dose calculation in molecular radiotherapy has been formulated and will be presented. An uncertainty estimate should address all systematic and random sources of error and characterize the range of values within which the measured value can be said to lie with a specified level of possible confidence. Hybrid methodology of model uncertainty will explore the Monte Carlo simulation based probabilistic uncertainty and Dempster-Shafer evidence theory based possibilistic uncertainty (systematic part of uncertainty) of absorbed dose received by patient during molecular radiotherapy.

Keywords: Absorbed dose, Molecular radiotherapy, Monte Carlo, Evidence theory

Emerging role of AI in medical imaging

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Artificial intelligence is the process of development of intelligent machine to perform designated task [figure 1]. Machine learning and big data are the integral part of artificial intelligence. Machine learning can be categorized as i) supervised and ii) unsupervised learning. In the supervised learning, computer algorithm is trained on labeled data sets (the input data is mapped to the desired output). In contrast, unsupervised learning is the method to train the machine algorithm on unlabeled/unmapped dataset [1]. Deep learning is a sub type of machine learning system in which the algorithm learns and extracts a composition of features that represented in a hierarchy of structures in the data. Complex representations of data are expressed in terms of simpler representation of data in deep learning [2]. The role of artificial intelligence is increasing in all walks of life and medicine is no exception. The role of artificial intelligence in medicine has been demonstrated by many researchers in last two decades and several AI applications are available for use in various fields of medicine

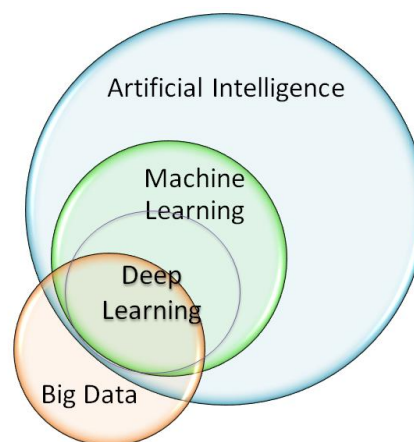


Figure 1: Artificial Intelligence

Medical imaging plays a significant role in medicine. Medical imaging has become an integral part of patient management in oncology. In the process of patient management in oncology, huge amount data in the form of image and text is generated.

Artificial Intelligence in Imaging:

Recent literature has witnessed the emerging role of artificial intelligence in medical imaging. In coming years we are going to witness the use of AI in entire workflow of medical imaging department. The implementation of AI in medical Imaging is summarized in figure 2.

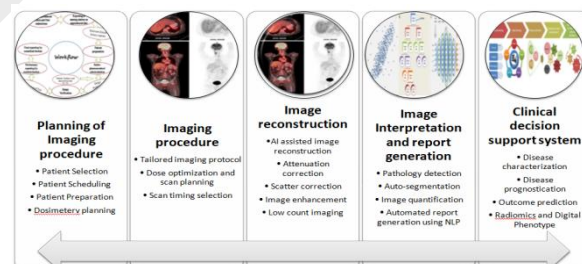


Figure 2: AI implementation in medical imaging

Planning of imaging procedure:

Several studies have been performed to establish the role of AI algorithm in patient scheduling, procedure selection, patient preparation and dosimetry.

Medical imaging procedure:

AI can assist in many ways in optimization of image quality, scan time, scan range, radiation exposure in diagnostic procedure.

Image reconstruction:

Image reconstruction in radiology and nuclear medicine has been a challenging task and several iterative reconstruction techniques have been developed and used. AI assisted reconstruction has been tried by many researchers in last few years to improve the image quality [3-6].

Image Interpretation and report generation:

Image interpretation and reporting is one of the most important tasks in medical imaging performed by the imaging experts. Image interpretation is comprised of finding clinical history, image reading, extraction of quantitative data from image, comparison of scan with earlier scan, quantitatively and qualitatively, reporting of the findings, and finally interpretation of finding.

Clinical decision support system:

Oncology treatment is complex and very unproductive; to circumvent this problem oncology practice becoming more and more personalized medicine to offer tailored treatment to the patients [7]. Various literature published in last few years are suggestive of major role of AI in development in advanced decision support system in oncology. Several researchers are working on development of various kinds of prediction model for various end points like; overall survival, progression free survival, loco-regional recurrence, distance metastasis, treatment outcome, toxicity, treatment selection and disease prognostication.

AI is going to make major contribution in medical imaging and diagnostics to solve the persistent issues and improve the workflow of the imaging departments. Initial research is also very encouraging and suggestive of increasing role of AI in medical imaging.

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Abstract

Control of Hazards in High Dose Iodine Therapy Facility

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Nuclear medicine is a medical specialty involving the application of unsealed radioisotopes in the diagnosis and treatment of disease. Single Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET) are the two most common imaging modalities used in nuclear medicine. Nuclear medicine has found its application in most of the medical specialities such as cardiology, neurology, haematology, endocrinology, oncology, urology, nephrology, respiratory system etc. by using of short half-life radioisotopes such as ^{99m}Tc, ²⁰¹Tl, ⁶⁷Ga, ¹²³I, F-18 etc. Radionuclides are being extensively used for treatment of various benign and malignant conditions like hyperthyroidism, thyroid carcinoma, neural crest tumors, painful bone metastases & so on. I-131, P-32, Sr-89 are mostly commonly used in therapeutic applications. Some new radioisotopes such as Re-186, Er-169, Sm-153, Y-90 have been added to the list of radioisotopes used in therapeutic applications. Out of all these, I-131 is the most widely used unsealed source of radionuclide for treatment of thyroid cancer & hyperthyroidism. In general, I-131 activity ~ 200 mCi is administered orally to a patient undergoing thyroid cancer treatment. During administration of such activity, it is essential to always be conversant of any forbidden radiation health safety practices. This need is amplified while dealing with such therapeutic amount of radionuclides, as the use and handling of such high activity of I-131 involves a major risk of irradiation & contamination for medical & paramedical staffs, laboratory personnel, patients & also the general public. Radiation hazards are classified into two categories - (a) External hazard which is due to radioactive sources present outside body, such as during storage, transportation, use etc. & (b) Internal hazard which is due to radioactive sources get into the body by way of ingestion, inhalation or through subcutaneous absorption. External hazards can be controlled by use of any one or all the three of the factors namely a) Time, b) Distance & c) Shielding. On the other hand, factors

that affect the internal radiation hazard of a radioisotope are a) Chemical nature, b) Organs/tissue in which it is concentrated, c) Effective half-life, d) Energy of radiation emitted by the radioisotope under consideration, e) Mode of intake etc. Radioiodine solutions being highly volatile require special handling. Iodide solutions are easily oxidized and the elemental iodine will become airborne. While handling therapeutic quantities of I-131, in addition to external radiation hazard, the risk of internal contamination is also magnified & thus stringent precautions should be taken to avoid this type of contamination. Contamination on the skin or inhalation from air containing iodine vapors will result in internal deposition. In addition, since the patient is administered with therapeutic quantity of radioactivity, utmost care of patient is very important to prevent any contamination hazard, because patient itself is a source of radiation & thus there is a chance of spreading of contamination originating from patient excreta, urine, saliva, patient bed linen, cooking utensils, clothing used by patient etc. In addition, there are other sources of hazard associated with operation of high-dose therapy unit like misadministration, death of a patient during treatment, spillage, fire etc. Misadministration is considered to have occurred in many ways like administration of a radionuclide other than the one intended, excess activity. In addition, potential hazard for I-131 intake by the occupational workers in a nuclear medicine department has been very well recognized & appreciated. Control of all such hazards associated with use of I-131 in high dose therapy (HDT) facility is a challenging task. Atomic Energy Regulatory Board (AERB) is responsible to ensure safe use of ionizing radiation in high dose Iodine therapy facility in our country for safety of the staffs and members of the public, Atomic Energy Regulatory Board (AERB) exercises the powers conferred by the Atomic Energy Act, 1962 and rules made under the Act like the Atomic Energy (Radiation Protection) Rule- 2004 for regulatory control in high dose therapy facility. According to Rule 3 of Atomic Energy (Radiation Protection) Rules 2004, consent is required for layout approval, source procurement, operation and decommissioning of a HDT facility. In order to control hazards associated with operation of high dose iodine therapy facility, several aspects like availability of qualified manpower including technologist, radiation safety officer & physician; proper room layout with isolation wards; provision of delay tank; adequate

safety accessories; calibration of dose calibrator as well as other radiation monitoring instruments; dose monitoring of staff; proper patient management, access control, optimization of radiation dose, patient release criteria etc. are required to be looked into. In addition, proper management of I-131 source & different types of radioactive waste generated, emergency plan & procedures also play an important role for controlling hazards of high dose therapy facility. This paper brings out different hazards and control mechanisms for high-dose iodine therapy facility so as to minimize radiation exposure to the occupational staffs and member of the public.

A Dosimetric Study with RapidArc and Intensity-modulated Radiotherapy in Cervical Cancer
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The method of radiotherapy has moved away from two-dimensional and three-dimensional conformal radiotherapy towards volumetric-modulated arc therapy (VMAT) for advanced carcinomas. VMAT treatments often result in significant clinical advantage, particularly when concave dose distributions are required as is often the situation since these tumors are in close proximity to several critical structures. Objective: The present study aims was to investigate the potential clinical role of volumetric arc therapy on cervical cancer patients and its comparison with fixed-field intensity-modulated radiotherapy (IMRT) was used as a benchmark. Materials and Methods: Retrospectively, fifteen patients of cervical cancer were selected for this study. These patients were previously treated with IMRT techniques during January 2020 to November 2020 and it was reoptimized for VMAT/RapidArc. The prescription dose to planning target volume (PTV) was 50.4 Gy in 28 fractions (1.8Gy/fraction) for the 6 MV photon beam. Comparison of each plan done on the basis of organs at risk (OARs) sparing, coverage index (C), conformity index (CI), homogeneity index (HI), dose gradient index (GI), and unified dosimetry index

(UDI). This study utilized UDI scoring for evaluation and comparison of RapidArc and IMRT plans. Treatment time (TT) for patient comfort and the number of monitor units (MUs) for long term side effects was also taken into consideration. A paired two-tailed t-test was executed for the dosimetric study of Volumetric Arc Modulation with RapidArc and its comparison with the IMRT technique in the radiotherapy treatment of cervical cancer patients. The P-value < 0.05 was contemplated for the level of statistical significance. Results: Comparable target coverage and better sparing of OARs were achieved with the RapidArc technique in comparison to IMRT. Values of CI, C, HI, GI, and UDI were also in favor of the RapidArc plan. MUs and TT were much higher for IMRT. Conclusion: From this study, it is clear that a similar planning goal can be achieved by RapidArc in comparison to fixed-field IMRT with less normal organ toxicity. RapidArc is a faster and precise treatment technique. The most significant change comes to see in the number of MUs and TT, which is much lesser in RapidArc. Keywords: Intensity-modulated radiotherapy, RapidArc, Conformity index, Homogeneity index, Gradient index, Unified dosimetry index

Initial experience of radiation protection aspects of nuclear medicine during COVID-19 pandemic

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Background: Human coronavirus (SARS-CoV-2) is associated with respiratory illness that leads to acute respiratory distress syndrome (ARDS). Handling unsealed radioisotopes in Nuclear Medicine inherently calls for special precautions; additionally COVID pandemic has led to more challenges in Clinical Nuclear Medicine. Aim and Objectives: To describe the experience of radiation protection while working as Nuclear Medicine Technologist during COVID-19 pandemic. Methodology: Patients which underwent Nuclear Medicine procedures in initial months of COVID pandemic patients were included in the study. Results: A total of 261 patients were included in the study during the initial months of pandemic in 2020 & 2021 of which 6 were therapeutic procedures. Radiation protection aspects were divided into three groups: i.e. Radiation worker related, ii. Patient related iii. General aspects. Personnel Related aspects: The physicians and

technical staff worked on rotation basis. All working technical staff wore personal protection equipment including gloves, mask and face shield for entire duration of patient handling. Staff not directly handling patients wore face mask, face shield and gloves all the time. Hand hygiene / hand sanitization procedures and social distancing was maintained all the time in working hours. ii. Patient related: During imaging, plastic sheets were used on patient's couch. Technical Staff who wore PPE kit during injecting and later maintained 1-1.5 m social distancing with patients and spent minimum time near to the patients. iii. General Aspects: Reports were dispatched in a non-contact method mostly online and gave the reports with proper hand sanitization and face shielding whenever manual. Staff used separate pen for this work. After completing the work, workplace was sanitized by housekeeping staff with hypochlorite solution. Auxiliary staff was trained for collection of radioactive consignments in non-contact mode. Time, distance and shielding are the key principles for radiation protection. In COVID-19 pandemic distance and shielding are mainly followed which overlap with the principles of radiation protection. We found that it was easier for radiation workers to adapt to safe work practices during COVID-19 pandemic due to this overlap in protection principles and none of the personnel were infected with COVID-19. Conclusion: Radiation protection aspects majorly overlap with COVID protection aspects. It is easier for personnel working in Nuclear Medicine to protect them from COVID in view of this overlap which was seen in our study. Routine clinical work was performed effectively and none of the staff were infected with COVID 19 during the period of this study

Should patients of Hyperthyroidism be made to wait in the department post Low-Dose I-131 therapy?

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As per Atomic Energy Regulatory Board (AERB) guidelines, patients of hyperthyroidism post low-dose I-131 therapy (LDIT) can be sent home when administered less than 30mCi activity of I-131, as this amount of activity gives an exposure of less than

5mR/hr at a distance of 1 meter from the patients. However, in context of socio-economic & psychological conditions of the patients and the mode of travel undertaken, it is not possible to maintain desired distance of 1 meter from the patients at all times. Thus, a patient acts as source of unnecessary radiation exposure to their family members and general public. In this present study, we evaluated the minimum time hyperthyroid patients should be made to wait in the isolation room of the department after LDIT in order to reduce the radiation exposure to family members and general public. We divided the patients into two different groups depending upon the percentage uptake on 99mTc-perchnetate scan by the thyroid gland. In Group A we included patients with uptake value of <20% and were administered 12-15 mCi of I-131 activity; whereas Group B included patients with uptake value of ≥20% and were administered 18-29 mCi of I-131 activity. After administration of I-131 activity, the patients were kept under observation for 2 hours in isolation room. Reading was measured with ionizing chamber based survey meter at a distance of 1 meter from the patients at 1 hour and 2 hours time interval. Paired sample t-test was done to determine any significant difference in exposure from patients at 1 hour and 2 hours time interval in both groups. A total of 51 patients of hyperthyroidism were treated with LDIT during the period of March 2019–April 2020. Group A and Group B included 31 and 20 patients with radiation exposure level at 1 hour and 2 hours being 1.97 mR/hr & 1.82 mR/hr and 3.60 mR/hr & 3.43 mR/hr respectively. Significant difference was observed in exposure level in both the groups in readings taken at 1 hour and 2 hours time interval (p value: <0.01) From observations of this present study, it is desirable that after LDIT, patient should be made to wait in isolation room of the department for 2 hours in order to minimize radiation exposure to their family members and general public.

Metabolic super scan on ¹⁸F FDG PET/CT in patients undergoing oncological workup - is it real

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A 'superscan' is a popular terminology used in routine practice to denote an intense symmetric preferential tracer uptake in bones with diminished

renal and soft tissue activity on a Tc99m bone scan. A similar picture of preferential FDG uptake in primary and metastatic sites and reduced uptake in brain and myocardium has been frequently noted in whole body FDG PETCT studies. There are anecdotal case reports of this finding in 2 cases i.e lymphoma and non small cell lung carcinoma. This study was undertaken to determine whether an entity of metabolic super scan possibly exists and to assess its incidence in our population. **MATERIALS & METHODS:** 250 consecutive patients who underwent FDG PETCT imaging in our institution in recent weeks were analyzed. Dietary details of all patients prior to FDG PETCT scan were noted. Dose and timing of FDG were maintained constant for all these cases. 53 patients (age 44-70 yr, M : F = 23:30) with no myocardial uptake on FDG PET were analyzed. Patients were grouped into 3 as follows: Group I (normal pts with no FDG avid lesions) = 22, Group II (with ≤ 5 foci of FDG avid lesions) = 20 Group III (with ≥ 5 FDG avid lesions) = 11. SUV max of brain, mediastinum and myocardium of all patients in each group were determined. Ratio of SUV max of brain to mediastinum (B : M) and Myocardium to mediastinum (Myo: M) was calculated. Kruskal-Wallis Test was performed to determine whether B: M SUV max and Myo : M SUV max ratios were different among Group I,II and III. **RESULTS:** Statistical analysis did not show any significant difference between the B:M ratio or Myo : M ratio within each groups (p value= 0.935 and p value =0.315 for B:M and Myo : M values respectively). **CONCLUSION:** 4.4 % patients with suspected metastases undergoing FDG PETCT for oncological workup can show 'metabolic super scan appearance'. This is found to be more common in patients with more than 5 metastatic lesions. Quantitative indices do not correlate with the visual analysis possibly due to variation in malignant potential of lesions, body habitus and biological distribution of FDG and calculation of SUV max.

Comparing Radiation Exposure to Radiation Health Workers (RHW) From the Patient Undergoing Myocardial Perfusion Imaging (MPI) In a Single Day Protocol

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The MPI study is performed with 99mTc labelled radiopharmaceuticals such as Sestamibi or Tetrafosmin in a Single day or Dual day protocol. Sequence of Rest/Stress or Stress/Rest depends upon clinical indication and departmental logistics. Administered activity in Dual day protocol remains same in both studies i.e. 8-10 mCi and in Single day protocol dose administered is 8-10 mCi in 1st study and 24-30 mCi in 2nd study. In this present study, we compared the radiation exposure received by the RHW standing in the proximity of the injected patients while performing Rest and Stress part of the MPI scan. We divided the patients into two different groups as Group A: - Rest study was performed 1st followed by Stress as 2nd study and in Group B: - Stress study was performed 1st followed by Rest as 2nd study. Radiation exposure was measured with the help of Ionization chamber based portable survey meter. Reading was taken immediately, 1 hour and 2 hours post injection at a distance of 1 meter from injected patients. A total of 54 patients were referred for 99mTc-Sestamibi MPI study to our department from the period March 2019-April 2020. Out of these 54 patients 19 were underwent MPI scanning in the Single day protocol. Group A included 13 patients. Radiation exposure from the patient to RHW undergoing Rest and Stress part of the MPI study immediately after injection, at 1 hour and 2 hours post injection was 1.75 μ Sv/hr, 1.1 μ Sv/hr, 0.65 μ Sv/hr and 21.01 μ Sv/hr, 12.24 μ Sv/hr, 8.22 μ Sv/hr respectively. Group B included 6 patients. Radiation exposure from the patient to RHW undergoing Stress and Rest part of the MPI study was immediately after injection, at 1 hour and 2 hours post injection was 2.18 μ Sv/hr, 0.97 μ Sv/hr, 0.53 μ Sv/hr and 21.77 μ Sv/hr, 12.77 μ Sv/hr, 8.75 μ Sv/hr respectively. From the above observation of this present study, we observed that in second part of the MPI study the RHW received maximum radiation exposure. Also we know that the RHW have to stand in close proximity to the patient while performing physical/pharmacological stress before injecting radioactivity at peak stress level. Thus we recommend that stress part of the MPI study should be performed first as far as clinically possible in order to minimize the radiation exposure to the RHW.

Significance of biological dosimetry in Nuclear Medicine

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Medical internal radiation dosimetry is an established method to assess the physical radiation dose from patient organs and tissue post diagnostic and therapeutic Nuclear Medicine procedure. Biological dosimetry is an area based on investigations of induced biological response with aim of correlate them with radiation dose. Evaluation of dose is mainly related to scoring of number of double strand breaks (DSBs) from PMBC post ionising radiation exposure. There are several applications of biodosimetry in Nuclear medicine for example: Estimate radiosensitivity of cancer tissues in order to find out desired absorbed dose to tumour, assessment of bone marrow toxicity with response to radiation dose, determine radiation dose from patients post nuclear medicine investigation and evaluation of suspected over exposure in nuclear medicine. There are number of biological and biochemical parameters available to perform biological dosimetry for example: karyotyping, Micronucleus assay, Gamma H2AX assay, single gel electrophoresis technique etc. Among the indicators employed in biodosimetry, scoring of chromosomal aberrations is the most reliable method to quantify individual exposure to ionizing radiation. Beside this, the dose response relationship obtained after in vitro irradiation of blood has been widely used for estimation of individual radiation exposure. This abstract presents an overview of strengths, applications, techniques, limitations and future perspectives on biodosimetry.

Quality Control of Radiopharmaceuticals

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Radiopharmaceuticals should undergo stringent quality control procedures before being administered to patients. The procedures are broadly categorized as physicochemical and biological tests that ensure purity and safety of the radionuclide as well as the pharmaceutical part. The tests include visual inspection of the final product, radionuclide purity, radiochemical purity, sterility, apyrogenicity and toxicity. While few tests are carried out by the manufacturer for kit based radiopharmaceuticals, most of them need to be conducted on-site on the final product after labelling.

Radiation Safety in Nuclear Medicine Practices

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Radioactive materials are being used in various industries and one such is healthcare setup. National and International organizations are working together for peaceful use of radioactive materials. One such organization is IAEA, known as the world's "Atoms for Peace and Development" organization within the United Nations family, the Agency works with its Member States and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies.

When working with radioactive materials, radiation safety is a major concern, especially when handling unsealed sources. Nuclear Medicine is one such department handling unsealed sources in various forms- solid, liquid and gas. In providing diagnostic information along with therapeutic application, the safety of patient, staff and public is always kept in mind. We at India follow the set guidelines of Atomic Energy Regulatory Board (AERB), our competent authority to ensure the use of ionizing radiation and nuclear energy does not cause undue risk to the health of people and the environment.

The three cardinal principles of time, distance and shielding is used for radiation safety with, justification, optimization and dose limitation for carrying out the study. The safety of environment and surrounding is kept under control by regular monitoring and safe disposal of radioactive waste.

Gallium-68 Chemistry of PET Radiopharmaceuticals -Practical & Simplified Approach

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Gallium-68 (⁶⁸Ga) Radiopharmaceuticals (RPs) are new and recent RPs for PET-CT imaging. Gallium-68 element chemistry is very much similar to the technetium. The potential applications of ⁶⁸Ga-comprising imaging agents include targeted, pre-targeted and non-targeted imaging eg. PSMA, DOTAs, Exindin, FAPI etc. The key aspects of the labeling methods and understanding the chemistry behind the production of ⁶⁸Ga-based radiopharmaceuticals. The presentation will include the various Gallium-68 generators, their specifications and various modes of radiolabeling, challenges in labeling, quality controls, labeling efficiencies and an easy practical approach for the PET pharmacy for Gallium RPs. Simplified

approaches are need of time especially in case of Indian scenario where we are in lack of trained radio pharmacists and whereas a NMT is all-rounder worker for technical and radio pharmacy as well and illustration of easy labeling methods and SOPs. The contribution of ^{68}Ga to the promotion and expansion of clinical research and routine positron emission tomography (PET) for earlier better diagnostics and individualized medicine is considerable

^{68}Ga -EDTA as a Potential PET Agent to Evaluate Renal Function using PET Scanners and plasma sampling method

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Glomerular filtration rate (GFR) estimation is performed using Nuclear medicine procedures like $^{99\text{m}}\text{Tc}$ -DTPA Renogram, and plasma sampling method using $^{99\text{m}}\text{Tc}$ -DTPA and ^{51}Cr -EDTA for various clinical indications. $^{99\text{m}}\text{Tc}$ -DTPA Renogram is performed with the help of Gamma Camera and GFR is estimated using Gate's method. However, GFR estimation with Gate's Method is not reliable for pediatric and old patients due to the error in calculation of renal depth by Tonnesen Equation, which significantly underestimates renal depth in such patients. Plasma sampling with exogenous glomerular filtration markers is considered as the gold standard for GFR estimation, and is routinely performed with $^{99\text{m}}\text{Tc}$ -DTPA, since it is easily available in Nuclear Medicine departments. However, plasma sampling GFR estimation using ^{51}Cr -EDTA is considered superior to that of $^{99\text{m}}\text{Tc}$ -DTPA, because EDTA has the least amount of in-vivo plasma protein binding.

But, ^{51}Cr -EDTA is expensive and not readily available in India, hence, ^{68}Ga -EDTA has emerged as a suitable agent for GFR estimation using PET/CT Scanners as well as with Plasma Sampling method, due to the easy availability of ^{68}Ge - ^{68}Ga generators in Nuclear Medicine set-ups. Therefore, in patients with complex anatomy, in whom planar imaging may prove non-diagnostic or difficult to interpret owing to overlying structures containing radioactive urine that cannot be differentiated, 3-Dimensional dynamic renal imaging with ^{68}Ga -EDTA using a PET/CT

Scanner can be performed if suitable software are made available. Other advantages include accurate and absolute camera-based quantification, superior spatial and temporal resolution and integrated multi-slice CT providing anatomical co-relation. Furthermore, ^{68}Ge - ^{68}Ga generator enables on-demand production at low cost.

Considering all the good characteristics and availability of ^{68}Ga and EDTA, we have performed in-house ^{68}Ga -EDTA labeling using analytical grade EDTA and ^{68}Ga elute from ^{68}Ge - ^{68}Ga generator. We tested labeling efficiency every hour starting from just after preparation till 5 hours. We found average labeling efficiency of $\geq 95\%$. We are able to demonstrate the stability of labeled product up to 5 hours, which can make it potential PET radiopharmaceutical for GFR estimation and renogram.

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Dependency of labelling efficiency in radiolabelling of ^{68}Ga -Macroaggregated albumin on number of particles

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$^{99\text{m}}\text{Tc}$ -Macroaggregated Albumin (MAA) is a lung perfusion agent used in Nuclear Medicine. Due to better image resolution and sensitivity of ^{68}Ga labelled radiopharmaceuticals using PET systems we have explored radiolabelling of MAA with ^{68}Ga . (ref)

Aim: The aim of this study is to determine if there is any variation in labelling efficiency of ^{68}Ga -MAA

with varying number of particles and fixed amount of ^{68}Ga -chloride activity

Method: The labelling was performed by protocol mentioned by S. Mithun et al. (1) MAA kit (TCK56) supplied by BRIT was used for the experiment. A fixed activity of $^{68}\text{GaCl}_3$ was used for labeling along with the required amount of Sodium Acetate buffer to maintain the pH between 4 to 4.5. The fractions were prepared by dividing the extracted macroaggregates by volume to get different fractions with calculated number of particles. The Labelling efficiency for both protocols were determined by ITLC using ITLC-SG as stationary phase and 0.1M Tri-Sodium Citrate as mobile phase. Average radiochemical purity and standard deviations were obtained.

Results: The overall labeling efficiency of the method was found to be $92.76 \pm 0.88\%$. The results for individual fractions were found to be as follows.

Number of Particles	50K	100K	200K	250K
Percentage RCP($\pm$ SD)	92.8 ± 0.3	95.4 ± 1.2	93.3 ± 0.24	94.3 ± 0.71

Conclusion: There was no significant variation in labeling efficiency with the number of particles. We obtained more than 90% labelling efficiency for all fractions of particles.

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Radiomics as an advanced tool to extract high level mathematical features from medical images

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Medical imaging is used for initial diagnosis, treatment planning and follow-up of cancer patients. Usually medical images are qualitatively interpreted by expert to diagnose the disease. Radiomics is the extraction of high number of quantitative features from medical images like CT, MRI PET or SPECT. These features have capabilities to characterize the tumour and predict the treatment outcome. Machine learning algorithms are used to identify the features

associated with tumour characterization and outcome prediction.

Radiomic features can be broadly classified as shape based, first order features and textural features. In addition to that various image filtering and image transformation can also be applied prior to extraction of these features. **Shape based features:** these features mainly describe about the shape and volume of the tumour. **First order features:** these features describe the distribution of intensity within tumour segment. **Textural features:** these features mainly describe statistical relationships between pixels and/or voxels.

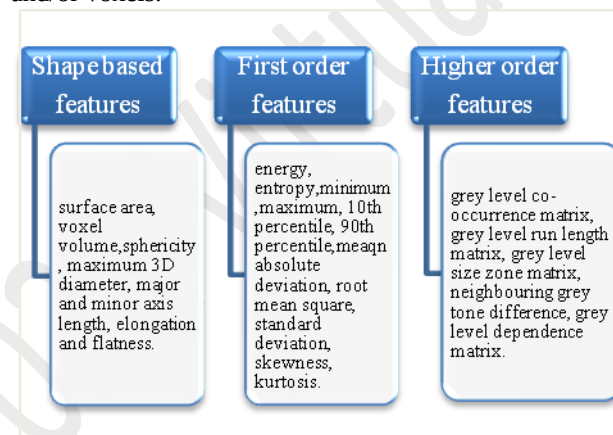


Figure 1: Few examples of features in all three feature types.

The radiomics process can be broadly divided in the following steps 1) image segmentation, 2) pre-processing of image, 3) feature extraction and 4) feature selection/reduction.

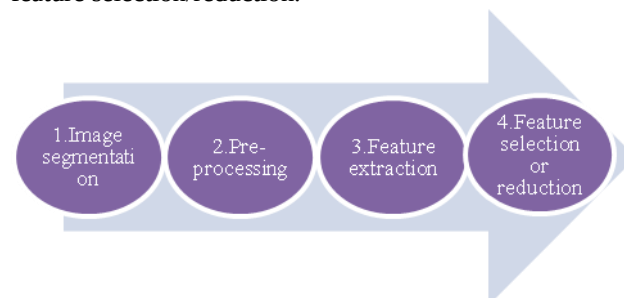


Figure 2: Radiomic process

As first step, tumour segmentation is performed using either by manual or auto-segmentation method. Image and segmentation both are stored together for further processing. During the pre-processing step, image filtering, image transformation, image resampling and binary masking is performed. Various features are calculated from the tumour segment using pre-defined mathematical formulas in feature extraction step. Finally, important features are

selected using machine learning algorithm for the prediction end point in the feature selection step. Radiomics is a promising tools and it can be used for digital phenotyping of the disease in oncology.

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Evaluation of radiolabelling of 68Ga-DOTA RGD and its Performance Characteristics

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INTRODUCTION: 68Ga labelled RGD is a radiopharmaceutical used for angiogenesis imaging. Angiogenesis imaging is an important tool for diagnosis and therapeutic treatment planning of various malignant and non-malignant diseases. The process by which new blood vessels are formed from pre-existing vessels is called angiogenesis. Tumour and metastasis growth is believed to some extent be dependent on this phenomenon. Radiolabelled peptides containing Arg-Gly-Asp (RGD) domain, has affinity towards the $\alpha\beta_3$ integrin receptors. As they are over expressed on tumour undergoing angiogenesis, be used for the diagnostic imaging, pretherapy dosimetry evaluation, therapy planning and response evaluation. To radiolabel peptides such as RGD derivatives, bifunctional chelating agents should be used to conjugate 68Ga and the peptide. These chelating agents have been termed “bifunctional chelating agents” since they have a metal binding moiety function and then also possess a chemically reactive functional group. The most widely used bifunctional chelating agents are traditionally DOTA derivatives. **MATERIAL AND**

METHODS: • For synthesis of 68Ga labelled DOTA-RGD 68Ga was obtained from 68Ge/ 68Ga ITG generator by elution with 4 ml of 0.05M HCl as an eluant. • The optimal Ga-labelling conditions for the peptide were evaluated as follows: 25 µg of peptide (1 µg/µL) dissolved in 0.25 M sodium acetate was taken for labelling purpose. 975 µL of 0.25 M sodium acetate trihydrate was added in it. • First the peptide was heated in a reaction vessel for 5 minutes at 95 °C followed by heating the mixture (peptide and eluate) for 10 min at 95 °C. Then it is passed through C-18 SPE cartridge for purification purpose. • pH, radiochemical purity, stability of 68Ga-DOTA-RGD were evaluated. **RESULT:** • Characters/appearance: The quality of the final product in terms of absence of particulate matter and turbidity were ensured. • pH determination: pH of the product was 5-5.5 and of waste product was 4-4.5. • Radiochemical purity: RCP was evaluated using 0.1M sodium citrate and 1M Ammonium Acetate Methanol (1:1) solution ITLC method. Radiochemical stability was evaluated for four hours. It had shown encouraging result as there was no dissociation or presence of free gallium. The table below shows the mean and standard deviation for both the solvents at different time points: 0.1M Sodium Citrate 1M Ammonium Acetate Methanol (1:1) 30 minutes (N=8) 98.95% ± 0.75 30 minutes (N=6) 98.8% ± 0.69 2 hours (N=8) 98.016% ± 2.04 2 hours (N=6) 97.38% ± 0.91 4 hours (N=8) 97.135% ± 2.87 4 hours (N=6) 95.84 ± 2.93 **CONCLUSION:** The results show that 68Ga DOTA-RGD is a very promising compound for non-invasive monitoring of $\alpha\beta_3$ integrin expression used in angiogenesis imaging and its applications. Though literature survey shows DOTA is not very stable cheating agent but our result showed good radiochemical stability till 4 hours.

Single Formula For A Volume (Two Dimensional To Three Dimensional

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An exact single equation is derived first time to find the volume of any regular shape (ellipse, sphere, cone etc.) object (2) This equation is simple to remember and so saves one from having to remember a separate equation for every separate regular shape figure (3) It also avoids having to use lengthy integral calculus used in modern mathematics The equation will be useful in all branches of sciences.

Quantification Of Kidney absorbed dose using ^{177}Lu -DOTATATE in patients undergoing PRRT.

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Aim Peptide receptor radiotherapy (PRRT) has employed ^{177}Lu -DOTATATE in the past one decade for the treatment of metastatic neuroendocrine tumors and meningioma as it has been successfully used to target metastatic or inoperable neuroendocrine tumours expressing the somatostatin receptors subtype 2. Kidneys are the major critical organ in this treatment. In this study we estimate the kidney absorbed dose in each patient to warrant safe tolerability of treatment. **Method** 10 Patients (age: 53 years $\pm$ 15.2 yrs; BMI: 22.7 $\pm$ 5.64) with metastatic neuroendocrine tumours were evaluated for suitability for PRRT with ^{177}Lu -DOTATATE after their assessment by ^{68}Ga -DOTATATE PET/CT. The patients administered with ^{177}Lu -DOTATATE (administered activity: 196.71 mCi $\pm$ 10.06 mCi) and planar whole body scans (head-to-toe) were acquired at multiple time points. Scan acquisition was performed using a GE Discovery 670 pro SPECT/CT at 5 time points for organ dosimetry. Kidney dosimetry was estimated by drawing regions of interest outlined on the planar whole body images for all the time points using dosimetry toolkit. Subsequently, normalized cumulated activity of the radionuclide in the kidneys was estimated using automated curve fitting. **Results** Mean mass of the kidneys was estimated to be 310.11 grams $\pm$ 56.11 grams. Mean normalized cumulated activity was 2.85 $\pm$ 0.8. Mean kidney absorbed dose was found to be 4.9 Gy $\pm$ 1.66 Gy (range 2.4 Gy-6.7 Gy). **Conclusion** From this study, we therefore demonstrated that ^{177}Lu -DOTATATE therapy is a safe treatment option for the patients to undergo PRRT therapy up to 5 treatment cycles, since the limit of cumulated absorbed dose to the kidney is 23 Gy. Individualized absorbed dose estimation is essential to optimize the treatment cycles. **References** Kwekkeboom DJ, de Herder WW, Kam BL, van Eijck CH, van Essen M, Kooij PP, Feelders RA, van Aken MO, Krenning EP. Treatment with the radiolabeled somatostatin analog [^{177}Lu -DOTA 0,Tyr3]octreotate: toxicity, efficacy, and survival. J Clin Oncol. 2008. Bodei L, Cremonesi M, Grana CM, et al. Peptide receptor radionuclide therapy with

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