



6TH ANNUAL CONFERENCE OF NUCLEAR MEDICINE IN INDIA (NMPAICON-2022)

ABSTRACT BOOK

23RD -24TH APRIL, 2022



Dear friends and colleagues,

Welcome to NMPAICON-2022. It is a great honor and privilege for me to extend warm welcome to all the delegates and the august faculty for the 6th National Conference of Nuclear Medicine Physicist association of Indian (NMPAICON-2022). 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 and scientists 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 five thematic scientific sessions, which will be blend of lectures and presentations. Thematic scientific session comprises of, radiation protection & Dosimetry, Nuclear Medicine Practices & Regulations, radiochemistry & radio-pharmacy, Instrumentation & Image processing, 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-2022.

A handwritten signature in black ink, appearing to read 'Ashish'.

Ashish Kumar Jha



MESSAGE

It is my great pleasure to welcome you to the 6th NMPAICON-2022 Annual Virtual Conference on theme “*Nuclear Medicine: Exploring physiology & Predicting outcome*”, being held on 23rd-24th April, 2022.

This conference is bringing together academic experts, clinicians, industry representatives, and students in the broad spectrum of areas that constitute Nuclear Medicine specialty. The virtual conference covers a number of keynote lectures and oral presentations on newly emerging science and technologies in Nuclear Medicine.

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 the organizers for organizing such an event at this point of time which reinforces our objective of developing an environment for the exchange of ideas towards scientific & technological developments.

I wish the conference would be able to deliberate on current issues of national and international relevance. This conference will be one for us to share our thoughts and exchange ideas on how to chart our journey forward to reach new heights. I hope that you will have a productive and fun filled time at this very special conference.

On behalf of the organizing committee, I would like to thank all of the conference participants for their contributions which are the foundation of this NMPAICON-2022 virtual conference.

Thanks and regard

A handwritten signature in black ink, appearing to read 'Rajnath K Jaiswar', written in a cursive style.

Rajnath K Jaiswar
President, NMPAI



It gives me immense pleasure to write this message for the Souvenir being brought out on the occasion of 6th Annual Conference of NMPAI being hosted by the TMH Mumbai team. I am probably writing my last souvenir message as NMPAI secretary. The conference theme chosen of “Nuclear Medicine: Exploring Physiology and Predicting Outcome” is indeed very appropriate, considering the important role & application of Nuclear Medicine in the modern era.

After serving NMPAI for nearly 8 years, I have seen the growth of NMPAI as one of the foremost associations for Nuclear Medicine professionals. By participating in various activities, NMPAI has always been at the forefront of uplifting the field of nuclear medicine professionals across the country. I hope that this association will reach newer heights in professional development of newcomers, members, and the public in the near future.

Nuclear Medicine Physics has gone through tremendous changes and we are indeed in a time of great innovation in Nuclear Medicine. The annual meet is a unique part of development where participants avail the opportunity of exploring these innovations, professional development, renewing friendships, building up new relationships, to discuss matters of common interest and furtherance of knowledge through various scientific sessions, orations as well as mutual interaction.

I am looking forward to warmly welcoming you to 6th NMPAICON 2022, Mumbai (Hybrid)

Amit Nautiyal

Amit Nautiyal
Secretary (Nuclear Medicine Physicists Association of India)
Organizing Secretary (6th NMPAICON 2022, Mumbai)



It's my honour to invite you to the 6th Annual Conference of Nuclear Medicine Physicists Association, NMPAICON-2022. Due to a slight relief in the pandemic situation we are holding this conference in hybrid mode on the 23rd and 24th April 2022. After wading through two difficult years of the pandemic, we welcome you to a plethora of knowledge and scientific interactions. Our theme for this year's conference is 'Nuclear Medicine Exploring Physiology and Predicting Outcomes. The scientific program focusses on recent advancements in technology and instrumentation in PET/CT and newer radiopharmaceuticals in addition to the advancements in radiation protection and dosimetry. With Artificial Intelligence having a promising role in defining how imaging data will be useful in assisting and predicting cancer research and patient outcomes, it was inevitable to have a dedicated session for this. Considering all these recent advances in Nuclear Medicine, it is also essential to discuss the current practices and regulations in place and the also the need to revisit the human resource requirements in the country. We have invited the best speakers and practitioners in the field and hope the scientific deliberations will be fruitful and appreciated by all. We hope to interact in-person as well as online with our participants.

A handwritten signature in black ink, likely belonging to Mrs. Sneha Mithun.

Mrs. Sneha Mithun
Organizing Secretary
NMPAICON-2022

डॉ. आर. चिदंबरम
Dr. R. Chidambaram



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Former Principal Scientific Adviser to GOI,
Former Chairman, Atomic Energy Commission
Former Director, Bhabha Atomic Research Centre

Message from Dr. R. Chidambaram

In 6th Annual Conference (NMPAICON2022)

Nuclear Medicine Physicists Association of India

Medical physicists play an integral role in improving the quality of health care delivery around the world, while ensuring patient safety. In radiation medicine, for example, medical physicists plan the radiation protocol so that each patient receives the optimal radiation dose for diagnostic or treatment purposes.

There are many nuclear medicine centres in the country and one of the leading ones in the world is the Tata Memorial Centre, which is part of the Department of Atomic energy.

Artificial intelligence is beginning to play an increasingly important role in the medical field, particularly in diagnosing diseases, including in nuclear medicine. In nuclear medicine imaging of benign diseases, artificial intelligence methods are predominantly used for automated and/or facilitated image classification and as a support system for clinical decision making.

I wish the NMPAICON 2022 all success.

R. Chidambaram



भाभा परमाणु अनुसंधान केंद्र, छठी मंजिल, सेंट्रल कॉम्प्लेक्स, ट्रोम्बे, मुंबई - 400 085, भारत
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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 6th Annual Conference on 23rd & 24th April, 2022 on a hybrid platform due to the unprecedented COVID19 pandemic restraints.

I am pleased to note the theme of the Conference - "An insight view on developments in Nuclear Medicine Physics, Chemistry & Biology" is aptly chosen. In today's world, every fruitful advancement or progress happens as a synergetic result of proper amalgamation of basic science inventions with high end technology applications. It is noteworthy that Nuclear Medicine Professionals are practicing the true essence of this kind of amalgamation which contributes to the wellbeing of people besides promoting their continuous education. Organizing specific theme based conferences reinforces the knowledge about advanced developments providing congenial learning environment for the exchange of ideas and experiences.

Atomic Energy Regulatory Board (AERB) is adopting the graded approach in regulating Nuclear Medicine Facilities and incorporated necessary changes in its regulations, whenever required, taking into consideration the advancements in this field. Over the past few years, 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.

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.

(G. Nageswara Rao)

April 5, 2022



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Message

I am pleased to learn that the professional body NMPAI is holding its Annual Conference (NMPAICON) in hybrid mode this year. The field of nuclear medicine (NM) in India has been registering significant progress in many spheres, including more accessibility to NM services in many regions. Among the NM practices, the recent advances particularly in the areas of PET/CT imaging and targeted tumour therapy, and in turn theranostic approach, are the driving forces of growth both globally and in India. The growing use of ^{177}Lu -based therapy has been a notable feature in India. An important development is the recent approval of US-FDA of the product ^{177}Lu -PSMA-617 (Prostate Specific Membrane Antigen binder ligand conjugate) for treatment of prostate cancer, as this will help in its more extensive use in many other countries.

The versatility of the NM contributions is the core strength, and is attributable to, among many reasons, the multi-disciplinary competences underpinning the NM roles. The community of NM physicists is a crucial component of the teams contributing to the growth and sustainability of NM roles, in not only clinical services but also in the development of further advanced protocols and procedures. In line with the same attribute, the annual conference of the NMPAI covers a variety of sessions focussed on different topics. It would be desirable to evolve a tradition of '*a branded structure*' to the NMPAI event so that it can adequately highlight the overall advances as well as the specific progress in NM physics related topics, techniques, instrumentation, etc. I am tempted to advocate this, to avoid the NM-related annual events of the several professional bodies becoming generic and overlapping (repetitive) in their coverage.

We can surely look with pride on the NM accomplishments and delivery of services to patients, while it is also prudent to objectively review the progress to identify potential areas for further strengthening, or consider need-based modifications, so as to continue to remain highly relevant and vibrant. Some examples are cited - to serve as trigger for discussion - keeping NMPAI as focus. Adoption of the Diagnostic Reference Level (DRL) concept for the widely used NM imaging procedures can be fostered by informed discussions and evolving consensus on a range of values. In NM, the global approach for DRL is in terms of administered dose of the product (MBq, mCi), in place of the absorbed dose (followed in other radiation-based medical procedures). There is also an important need for evolving an appropriate scheme to record the assessed dose delivery to patients undergoing radionuclide therapy, keeping in mind the known bio-kinetics variability impacting the absorbed dose and personalised dosimetry. The ICRP publication 'Radiological Protection in Therapy with Radiopharmaceuticals' (Annals of ICRP 140, 2019) can be useful and the expertise of NM physicists valuable in the above context.

Another aspect for consideration of the professional body like NMPAI is the emerging initiative of the Government of India towards formalising the qualification requirements for non-medical professionals engaged in performing specific types of medical procedures on patients. There is much to gain for a professional body like NMPAI by remaining actively engaged with the relevant entities of the Government. NMPAI can objectively represent an important stakeholder community.

The preliminary programme schedule of NMPAICON-2022 shows a range of interesting talks. I am sure all the participants will benefit much, though as an old timer, I am in favour of physical events and personal interactions among participants! I wish all the participants a fruitful time and productive outcome. I compliment the Organising Team for their fine efforts and wish the event every success.

Dr. N. Ramamoorthy, Chief Guest at the Inauguration of NMPAICON-2022



Venue: Hotel Highway view, Navi Mumbai

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SCIENTIFIC PROGRAM

23/04/2022 (Saturday)

8:15-8:30am IST (2:45-3:00am GMT)	Welcome address	Mr. Ashish Kumar Jha, Organising Chairman; Mr. Rajnath Jaiswar, President NMPAI
8:30-9:00am IST (3:00-3:30am GMT)	Inauguration Chief Guest - Dr N. Ramamoorthy Guest of Honour: Shri. Pradip Mukherjee	
Session 1	Radiation protection & Dosimetry	Chairperson: Dr. Aruna Kaushik, Dr Yojana Singh, Mrs Bhakti Shetye
9:00-9:25am IST (3:30-3:55am GMT)	Dr. S Cheenu Kappadath, MDA, Texas, USA	Planning dosimetry for ⁹⁰ Y radioembolization
9:25-9:40am IST (3:55-4:10am GMT)	Mr. Biprojit Nath, TMH, Mumbai	History of Nuclear Medicine
9:40-9:55am IST (4:10-4:25am GMT)	Ms. Amandeep Kaur, BFUHS, Faridkot	Contamination monitoring and decontamination measures
10:05-10:25am IST (4:35-4:55am GMT)	Dr Sneha Shah, TMH, Mumbai	Image gently .. pediatric nuclear medicine (PET CT)
10:25-10:45am IST (4:55-5:15am GMT)	Amit Nautiyal, BCH, London, UK	Dosimetry in ¹⁷⁷ Lu-DOTA-TATE therapy
Session 2	Nuclear Medicine Practices & Regulations	Chairperson: Dr Anshu R Sharma, Dr Sharmila Banerjee, Dr E Prabhu
10:50-11:10am IST (5:20-5:40am GMT)	Mr. Dibyaprakash, VHLLP, Ghaziabad	NABH accreditation of Medical Imaging Services with 2nd Edition of standards and new rule for accreditation validity
11:10-11:30am IST (5:40-6:00am GMT)	Dr. Pankaj Tandon, AERB, Mumbai	Revisit of Human Resource requirement considering recent advances in Nuclear Medicine
NMPAI Oration	Ernest Lawrence Oration	Chairperson: Rajnath Jaiswar, Anindya Roy, Amit Nautiyal
11:30-12:15pm IST (6:00-6:45am GMT)	Dr Shivanand Bhushan, MAHE, Manipal	"Nuclear Medicine Physicist Profession & Professional Journey: Reimagination"
Session 2 (cont)	Nuclear Medicine Practices & Regulations	Chairperson: Dr Anshu, Dr Sharmila Banerjee, Dr E Prabhu
12:20-12:40pm IST (6:50-7:10am GMT)	Mr. Prathamesh Rajai, PDHH, Mumbai	eLORA - powerful platform for regulatory processes in India
12:40-1:00pm IST (7:10-7:30am GMT)	Dr. (Mrs.) Sarika Sharma Prashar, PGIMER, Chandigarh	Pregnant females and radiation exposure
1:00-1:30pm IST (7:30-8:00am GMT)	Lunch Break	
1:35-2:05pm IST	Dr V Rangarajan, TMH, Mumbai	Regulatory aspects of taking a radiopharmaceutical

(8:05-8:35am GMT)		from bench to bedside
2:05-2:25pm IST (8:35-8:55am GMT)	Dr Shamim A Shamim, AIIMS, New Delhi	Radiation synovectomy
Session 3	Radiochemistry	Chairperson: Dr Meera Venkatesh, Dr M G R Rajan
2:30-2:50pm IST (9:00-9:20am GMT)	Ms. Priya Monteiro, TMH, Mumbai	Generator produced radionuclides: Current scenario & Recent advances
2:50-3:20pm IST (9:20-9:50am GMT)	Dr. Mythili Kameswaran, TMH, Mumbai	Antibody based radiopharmaceuticals
3:20-3:40pm IST (9:50-10:10am GMT)	Dr. Rakhee Vatsa, ACTREC, Mumbai	Theragnostic radiopharmaceuticals
3:40-4:00pm IST (10:10-10:30am GMT)	Dr. Priyanka Gupta, AIIMS, New Delhi	Clinical Applications of Rhenium188
Session 4	Instrumentation & Image processing	Chairperson: Dr. P. S. Soni, Dr B. L. Malpani, Dr D A R Babu
4:05-4:25pm IST (10:35-10:55am GMT)	Dr. Anil Pandey, AIIMS, New Delhi	Image compression of nuclear medicine images
4:30-5:20pm IST (11:00-11:50am GMT)	Prof. Suleman Surti, Penn Medicine, USA	PET Instrumentation and the path towards total-body PET
5:25-5:45pm IST (11:55-12:15pm GMT)	Dr D. Datta, HIT, Kolkata	Analysis of Nuclear Medicine Imaging using Stochastic Fractals
5:45-6:00pm IST (11:15-11:30am GMT)	GE Healthcare sponsored talk	
6-7pm IST (12:30-1:30pm GMT)	General Body Meeting	
24/04/2022 (Sunday)		
8:00-8:55am IST (2:30-3:25am GMT)	Oral/Poster presentations	
Session 4 (cont)	Instrumentation & Image processing	Chairperson: Dr. P. S. Soni, Dr B. L. Malpani, Dr D A R Babu
9:00-10:00am IST (3:30-4:30am GMT)	Dr. David Townsend, SCIRI, Singapore	Development of PET/CT and recent advancement in PET/CT technology
10:00-10:25am IST (4:30-4:55am GMT)	Dr. George Loudos, BIOEMTECH, Greece	Preclinical imaging: The key parameters for efficient and ethical drug research
10:25-10:55am IST (4:55-5:25am GMT)	Dr. S. Kheruka, SQCCRC, Oman	Quality Control of Single Photon Emission Computed Tomography
10:55-11:15am IST (5:25-5:45am GMT)	Dr. Ankit Watts, PGIMER, Chandigarh	Quality Control of Positron Emission Tomography
11:15am-11:35pm IST (5:45-6:05am GMT)	Mrs. Pooja Dwivedi, ACTREC, Mumbai	Non-imaging instrumentation
NMPAI Oration	Hal Anger Oration	Chairperson: Rajnath Jaiswar, Anindya Roy, Amit Nautiyal
11:35am-12:20pm IST (6:05-6:50am GMT)	<i>Dr Rakesh Kumar, AIIMS, New Delhi</i>	Technical Innovations and Sign in Nuclear Medicine Imaging
12:25-1:20pm IST (6:55-7:50am GMT)	Oral/Poster presentations	
1:20-2:00pm IST (7:50-8:30am GMT)	Lunch Break	

Session 5	Artificial Intelligence	Chairperson: Dr. Leonard Wee
<i>2:05-2:30pm IST (8:35-9:00am GMT)</i>	Mr. Ashish Kumar Jha, TMH, Mumbai	Quantitative imaging in precision oncology
<i>02:30-3:10pm IST (9:00-9:40am GMT)</i>	Dr. Sofia Michopoulou, UHS, UK	Dementia diagnosis from nuclear medicine brain scans using AI
<i>03:10-3:45pm IST (9:40-10:15am GMT)</i>	Dr. Alberto Traverso, MAASTRO Clinic, Netherland	What AI can do for lung cancer patients in the next 5 years? Challenges and opportunities
<i>03:45-4:10pm IST (10:15-10:40am GMT)</i>	Mrs. Sneha Mithun, TMH, Mumbai	Natural Language processing in Oncology
<i>4:10-4:40pm IST (10:40-11:10am GMT)</i>	Dr. Inigo Bermejo, MAASTRO Clinic, Netherland	Predicting treatment effects using causal inference
<i>4:45-5:00pm IST (11:15-11:30am GMT)</i>	Vote of thanks & Farewell Tea	

LECTURE NOTES

From evolution to revolution: The development of PET/CT imaging

David W Townsend, PhD, FRCR (Hon), DSc (Hon)

Founding Director, Singapore Clinical Imaging Research Institute

IEEE Lifetime Fellow

The first decade of the 21st century saw the introduction of hybrid imaging technologies such as PET/CT and SPECT/CT into clinical practice. The adoption of these technologies, and in particular PET/CT, has been surprisingly rapid. Over the past two decades, the clinical benefit to the patient of combined anatomical and functional imaging compared with either imaging modality separately has been extensively documented. The second decade of this century saw the introduction of the latest design of hybrid imaging devices, combined PET and MR. However, the clinical role of PET/MR has only slowly been established and overall, the adoption has been gradual, largely due to the significant cost of a PET/MR scanner. Both PET/CT and PET/MR designs have benefitted from the advances in PET detector technology.

Compared with just a few years ago, PET images can now be acquired routinely in less time and with lower injected doses. Parallel advances have been seen in CT technology where considerable emphasis has been placed on dose reduction. Advances in CT dose-reduction techniques, including photo counting CT and iterative reconstruction, now results in PET/CT

studies with a much-reduced whole body radiation dose. Further effort has also focused on quantitative image accuracy and the reproducibility of studies for evaluating treatment response.

The most significant recent development in the technology has been the emergence of Total Body PET imaging by extending the field-of-view (FOV) of the PET scanner to essentially cover the full axial extent of the patient in a single scan. While the first Total Body PET/CT scanner was introduced as a research device, the revolutionary approach motivated at least one vendor to develop a PET/CT with an axial length of just over a meter. This has opened the door to Total Body imaging for routine clinical applications. Consequently, with over two decades of experience, PET/CT is now, and has been for the past several years, the primary clinical imaging modality for staging malignant and other diseases, and monitoring response to various therapeutics. The rapidly growing field of theranostics offers an important role for extended axial FOV PET/CT in monitoring radionuclide therapy response over time. This presentation will review the development of PET/CT imaging, from the evolution of the original concept to the revolution of hybrid, multi-modality imaging in the clinical arena.

PET Instrumentation and the path towards total-body PET

Prof. Suleman Surti,

Penn Medicine, USA

The current generation of commercial PET scanners has excellent performance and diagnostic image quality, but the system sensitivity and dynamic imaging capability are limited by the scanner's axial length. In recent years there has been an interest in developing whole-body PET scanners with much longer AFOV that not only increase the system sensitivity but can also image the whole-body of a patient without bed translation. Currently there are at least two commercial and one research scanner offering at least 1 m long axial field-of-view (AFOV). An important outcome of very high sensitivity is the potential to significantly reduce routine clinical scan times which can be beneficial in reducing patient motion artifacts and increase patient throughput. Alternately, the injected dose can be reduced that is beneficial in areas such as pediatric imaging and serial imaging of patients for monitoring response to therapy. Whole-body imaging with large axial coverage will allow one to perform dynamic imaging for pharmacokinetic studies over multiple organs. In this presentation we will present the design concepts and ideas underlying the development of long AFOV systems, followed by a few example studies illustrating the imaging capabilities and clinical/research potential of such systems. Finally, new design concepts that aim to reduce the cost of these system will be introduced.

Preclinical imaging: The key parameters for efficient and ethical drug research

George Loudos

*Bioemission Technology Solutions
(BIOEMTECH),*

*Lefkippos Attica Technology Park – N.C.S.R
Demokritos*

Greece

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For every new drug, >10,000 candidate molecules are tested for ~15 years and this is the mission of thousands of researchers worldwide. It is well proven that small animal imaging speeds up this work, increases accuracy and decreases costs. Various imaging modalities provide valuable information on the anatomic, metabolic and functional level. Of course each modality has its own advantages and limitations due to physical and other parameters and in most cases the combination of multiple modalities provide superior results. Still, most of the commercial imaging systems have high purchase cost, require high service contracts, special facilities and trained staff. Thus, they are affordable to only few large research centres and not to the majority of small and medium research teams internationally. For this reason, although the benefits of molecular imaging are well recognized, imaging is not yet part of the daily work of all laboratories and many studies still rely on ex vivo biodistributions, while several experimental parameters are selected based on bibliographic data and small pilot studies. However, this process is not efficient, candidate compounds may be misjudged, and several small animals need to be used, increasing studies cost, as well as raising ethical constraints.

Having participated in several projects related to oncology, nanomedicine, regenerative medicine etc, in this talk we will review the main parameters that need to be taken into account during in vivo imaging studies. As highend multimodal imaging systems cannot be available in all laboratories, we will discuss simple tools to obtain both imaging information, as well as time activity curves from a limited number of mice. Progress in instrumentation has made possible the development of such tools, with surprisingly efficient performance. In this way the overall time and cost of a study can be decreased, while the scientific accuracy of the obtained data can be maximized. Furthermore, we will discuss how imaging tools can be exploited to perform research in accordance with the 3Rs principles (Refinement, Reduction and Replacement), thus performing ethical research.

A Brief Introduction to the Session: Artificial Intelligence

Dr. Leonard Wee

Assisstant Professor - Clinical Data Science

Maastric Clinic

Maastricht University

Netherlands

The term “artificial intelligence” (AI) was first coined in the 1950s, well before other contemporary “buzzwords” such as machine learning and deep learning. An exact definition of AI that pleases everyone is rather hard to pin down, since there is so much collateral influence from media, business, politics and pop culture,

in addition to the actual science itself which it evolving rapidly.

A pragmatic, though perhaps partial definition, is still important, since the words “AI” has become a catch-all bucket in which we place any computer-based operation where we feel the internal logic is beyond our comprehension. Where our distant ancestors once invoked gods or magic, we now seem happy to lay the kudos (or the blame) on “AI”. This presents to us a pitfall as healthcare professionals - if we talk about AI in radiation oncology, and how to safely commission a diversity of software applications in a patient care setting - that we are not allowing ourselves sufficient rigour and subtlety to manage complex software with the commensurate risk mitigation strategy.

A historically-cognizant definition of AI could be as follows : a field of human study about systems (usually computer-based) that are able to mimic the cognitive performance of humans in specific occupational tasks, exhibiting varying degrees of autonomy simultaneously with varying degrees of adaptability. The emphasis on mimicry is important, as there is (up to today) no indication that, for example, a computer-based language translation tool actually “understands” languages in exactly the same sense as a human “understands” language and can therefore compose new meanings and new narratives, such as the way Shakespeare wove new meanings into his plays. “Varying degrees” is also an essential concept, since it would be more informative to refer to varying degrees and different levels of complexity in an AI system,

and which subparts of a system might be an application of AI, rather than saying “an AI” or “not an AI”.

Autonomy implies that the system is able to execute its tasks in a complex environment (such as a clinic) without the need for continuous human guidance. This ties in with automation, with the important logical distinction that AI applications generally imply some degree of automation, however an automated application is not necessarily an instance of AI. One of the most powerful defining characteristics of AI is adaptability – that is, the system has an in-built ability to modify, update or improve its own performance by learning from experience. This last aspect is what hard-coded non-AI automation applications actually lack, but a true AI application must always have this possibility. From this, we can readily see that machine learning is a sub-field inside AI, that concerns specifically those systems that are highly self-adaptable, that is, they re-programme their own internal state when supplied with more experiences and/or more data. Deep learning is therefore a sub-field inside of machine learning, that uses a mathematical construction called “artificial neurons” stacked up into multiple layers, in order to build extremely adaptable computing systems than can mimic with ease exceedingly difficult cognitive tasks, such as organ segmentation on a CT scan or determining the clinical diagnosis from a large piece of text. Radiation oncology, as a highly technology-dependent and a profoundly technology-driven sub-field of medicine, clearly stands in an

excellent position of advantage. We have the big digital data and the clinical use cases where AI tools, including many emerging from the deep learning and machine learning sub-fields, could make a massive positive impact on diagnosis, prognosis, treatment selection, follow-up and consistency of quality. However, this means that new bridges need to be built with a wider range of professionals – namely, data scientists and computer scientists – that are now asking for entry onto a stage previously dominated by radiation oncologists, medical physicists, clinical nurses and radiotherapy technologists. No doubt there will be challenges ahead, and there are significant risks of harm to our patients if we do not learn to build these professional bridges in a timely and positive manner. However the history of radiation oncology has shown that it can quickly embrace new collaborations with a growing multi-disciplinary circle of professionals, when those professions bring something of great value for the care of our patients.

Our speakers in this session have some enlightening talks for us, as I am sure you agree, and we are all looking forward to hearing about these. I trust that you will enjoy the sessions, with a mind to improve your own understanding of, and deeper subtlety in regards to, the impressive technology that is awaiting for our collaboration and clinical utilization.

What AI can do for lung cancer patients in the next 5 years? Challenges and opportunities

Dr. Alberto Traverso
Maastricht University
Netherlands

Recent advances in medical research have improved the diagnosis and treatment of lung cancer. Some of these advances are related to the introduction of newer hardware technologies such as: faster scanning machines, robotic surgery, or ion therapy. At the same time, newer treatment strategies such as molecular target therapy or immunotherapy hold the promise to revolutionise thoracic oncology, by improving patients' prognosis without hampering their quality of life. We can call this an "explosion of treatments": different treatment paradigms can be offered to both to early and late-stage lung cancer patients.

However, the "explosion of treatments" necessary leads to an "explosion of decisions" that both doctors and patients need to face. The treatment choice should always combine both objective criteria such as maximizing the curative intent while reducing the harm to healthy tissues (toxicities) and subjective criteria based on patients' perspectives (shared decision making).

AI (Artificial Intelligence) is a powerful tool that is changing everyday life with technologies such as self-driving cars, face recognition and the internet-of-things. In the last 10 years, some AI technologies such as machine learning and deep learning have been applied to solve medical problems and support better clinical decisions (decision support systems).

In my presentation I will focus on the clinical challenges and un-met clinical needs in thoracic oncology, spanning from early to metastatic lung cancer.

I will present a portfolio of AI solutions currently under development to solve the above-mentioned issues. I will not only focus on successful stories, but also on on-going trials.

Finally, I will briefly discuss the interaction between patients, doctors, and AI.

Dementia diagnosis from nuclear medicine brain scans using Artificial Intelligence

Dr. Sofia Michopoulou

University Hospital Southampton

This talk will discuss the use of nuclear medicine methods in brain imaging and review the recent literature on artificial intelligence (AI) for dementia diagnosis.

The following topics will be introduced:

Dementia prevalence and diagnostic methods
 SPECT and PET imaging for dementia diagnosis
 Quantitative Analysis of brain scans
 AI: Machine Learning and Deep Learning
 Neuroimaging applications of AI

Learning points:

- Perfusion SPECT and FDG-PET are routinely used in diagnosis and differentiation of dementia types
- Amyloid and Tau PET can provide early insights into Alzheimer's Disease
- Brain quantification applied to SPECT or PET enables objective diagnosis

- There is a rapid growth in AI studies for neuroimaging, but little implementation into clinical application
- In nuclear medicine, AI and particularly deep learning shows promise for early diagnosis of dementia prior to the onset of symptoms
- Validation studies using independent datasets are required to assess generalisation of AI

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Predicting treatment effects from observational data using causal inference

Inigo Bermejo, Maastricht University

Artificial intelligence (AI) and machine learning (ML) have created considerable excitement for their potential to revolutionize healthcare by leveraging the vast volumes of routinely collected data. One way in which AI and ML have been applied in this domain is in the development of prediction models. Prediction models usually estimate the probability (distribution) of a relevant health outcome for a particular patient based on their characteristics. Popular examples include models that estimate the risk of developing cardiovascular disease, or life

expectancy in patients with cancer. While these models can help us predict the future, they cannot tell us how to change it. Prediction models cannot help us make decisions because they rely on correlations, and as the famous adage tells us, ‘correlation is not causation’. Most of the interesting questions are causal in nature. For example, one application of ML and AI that has garnered especial attention is precision medicine, which, in contrast to the common one-size-fits-all approach, has the objective of providing each patient with the right treatment at the right time. In order to fulfil the promise of precision medicine, we need to be able to predict individual treatment effects.

But estimating treatment effects from (routinely collected) observational (i.e. non experimental) data is already a major challenge. A naïve approach would be to compare health outcomes between those who received a treatment and those who did not. The reason why this naïve approach will lead to biased estimates of the treatment effect on observational data is the presence of confounders. Confounders are factors that impact both health outcomes and whether a patient gets a particular treatment or not. For example, a particular treatment might be reserved to severely ill patients, who will on average have worse health outcomes than those who do not get the treatment. Therefore, comparing health outcomes between the two groups would lead to a confounded and therefore biased treatment effect. Randomised controlled trials (RCTs) are hailed as the golden standard because thanks to randomisation, treatment allocation is not

affected by any factor, and therefore differences in health outcomes are (mostly) due to treatment effects. Unfortunately, it is not feasible or ethical to run RCTs for many interventions.

The aim of causal inference is to estimate causal effects by disentangling the effect of an intervention on the outcome from other sources of bias. One way of disentangling the treatment effect from the effect of confounders is to adjust for confounders. One simple way to adjust for a confounder is stratification. We can for example, stratify patients into mild and severe patients and look into the differences in health outcomes within each group.

In clinical practice, a combination of factors affects treatment allocation and health outcomes, so it is not clear which variables to adjust for. We might not know which variables act as confounders. It might be that some confounders are not even measured. Over the last decades, epidemiologists have proposed different criteria to determine which variables should and should not be adjusted for. In this guest lecture we will focus on the causal graphs (also known as ‘causal diagrams’) advocated by Judea Pearl.

Judea Pearl is well known in the AI community for inventing Bayesian networks (BNs) in the 1980s. In fact, BNs and causal graphs have much in common. In both, we represent variables as nodes in a directed acyclic graph (DAG) and links are meant to indicate causal relationships. As a side note, the structures of these graphs can partially be derived using ML algorithms (structure learning or causal discovery), but it is important to note that in some cases, it is impossible to tell

the direction of causality from the data. In the graph we can distinguish two types of paths: causal (following the arrows) and non-causal paths (which cause the confounding). According to this framework, the causal effect of the treatment on the outcome is 'identifiable', meaning we are able to estimate it, if there are no non-causal 'open' paths between the two nodes. Paths in the graph can be closed by adjusting for specific nodes or variables. We can only adjust for variables that we have measured or observed, which means that in some cases, that is, in the presence of unobserved confounders, we will not be able to estimate a treatment effect, only approximate it. The set of nodes that should be adjusted for can be identified by a set of rules called *do*-calculus.

The usefulness of causal inference is not limited to structured clinical data. Also in medical imaging, causal reasoning can help deal with major challenges such as mismatches between training and target populations. As a recent Nature publication highlights, it is important to establish the causal relationships between images and their annotations.

In conclusion, causal reasoning is a key element for AI and ML to be able to leverage observational data. Predicting treatment effects from observational data should only be done considering the causal and confounding mechanisms in place when the data was collected. Causal inference is the field that studies how to disentangle the cause and effects from confounding. Causal graphs or DAGs and the associated techniques, such as Pearl's *do*-

calculus are a powerful set of tool that allow us to identify the adjustment set and estimate treatment effects from observational data.

Natural Language Processing in Oncology

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Natural Language Processing (NLP) is a branch of linguistics, computer science and artificial intelligence (AI). In AI, we use NLP to make human language (spoken or written) into mathematical representations for computers to read, understand or process it and then derive meaningful information from it. NLP has been used to advance oncological research. It has been used for disease/ case identification, staging, extracting clinical outcome, development of decision support systems and prediction modelling. NLP can be used for diagnostic surveillance and auto-generation of emergency alerts, assistive reporting, quality assessment, uncertainty detection in reports, data modelling for clinical support to improve accuracy of diagnosis or disease prognostication or treatment efficacy. Different programming languages like Java, Python, Julia, R etc have been used to develop NLP applications. Development of these NLP models or any AI model is data-driven. Availability of clinical data and data sharing policies worldwide are some of the limitations for

development of NLP applications. Distributed learning using ontology-driven concept mapping is one way to overcome this limitation. Several ontologies have been used for semantic mapping of clinical concepts. NLP has been used for cohort building for epidemiology studies by automatic selection of studies for various conditions. Query-based case retrieval models have been developed which help case retrieval by means of a query with fields specified by the user. Several applications have explored the use of features extracted from free text reports to develop decision support systems and prediction modelling using EMR free text. Several NLP tools have been used for quality assessment of radiological practise and checking adherence to reporting guidelines. Several recent research have also focused on using NLP models to convert verbal transcripts between physician and patients into text. The use of NLP in such data will be useful in furthering and improving research in the field of cancer and aiding in personalized medicine approaches.

Analysis of Nuclear Medicine Imaging Using Stochastic Fractals

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In this research work, analysis of nuclear medicine imaging implies the quantitative analysis in nuclear medicine imaging (QANMI) which is an in-depth review of single-photon and PET nuclear medicine image reconstruction, correction, modeling and analysis techniques with a particular emphasis on quantitative imaging for both diagnostic and therapeutic. Radionuclide imaging, including planar scintigraphy, single-photon emission computed tomography (SPECT) and positron emission tomography (PET) relies on the tracer principle, in which a minute quantity of a radiopharmaceutical is introduced into the body to monitor the patient's physiological function. Conditions diagnosed by nuclear medicine imaging include Blood disorders, Thyroid disease, including hypothyroidism, Heart disease, Gallbladder disease, Lung problems, Bone problems, including infections or breaks, Kidney disease, including infections, scars or blockages. The absolute quantification of radionuclide distribution has been a goal since the early days of nuclear medicine. The apparent complexity and sometimes limited accuracy of these methods have prevented them from being widely used in important applications such as targeted radionuclide therapy or kinetic analysis. The intricacy of the effects degrading nuclear medicine images and the lack of availability of adequate methods to compensate for these effects have frequently been seen as insurmountable obstacles in the use of

quantitative nuclear medicine in clinical institutions. Several research groups have consistently attempted to fill the defined gaps. As a result, many efficient methods are now available that can make quantification a clinical reality. The amount of radiation a patient receives in a typical nuclear medicine scan tends to be very low. In nuclear medicine, the count rates are usually fairly low, and as a result, the data tend to be rather noisy.

One needs to recover the true solution (image) from this noisy data and a 'best solution' is obtained by statistical reconstruction (SR) method. In SR, the best solution is defined as the one that is most likely from the given data. Therefore, reconstruction is obtained by finding the image, 'f' that maximizes the conditional probability ($f|P$), where P signifies the measured projections. Maximum a-posterior method (MAP) based image reconstruction is applied as per Bayes' rule to maximize the objective function and MAP is far better compared to combined effect of maximum likelihood (ML) and expectation maximization (EM). MAP based image reconstruction is constructed using Bayesian supervised learning algorithms. The paper will discuss the application of MAP with various priors. Verification and validation steps of image reconstruction towards clinical evaluation have been carried out using receiver operating characteristics (ROC) curves. Nuclear medicine has a long tradition of incorporating quantitative analysis in its diagnostic procedures. In order to have correct diagnosis, image registration is very much important from

clinical viewpoints. Conventional hardware-software approaches even though are successful to some extent, but in the framework of noisy images due to anatomical and physiological changes, those approaches fail. Hence, an innovative image registration algorithm has been developed using fractal powered machine learning algorithm. Basic objective in this fractal based technique is to identify the noise very accurately and accordingly it is possible to remove or eliminate from the region of interest.

One of the more successful engineering applications of fractal geometry has been the utilization of fractal image models in processing medical image including nuclear medicine image (PET and SPECT image). These applications have included tissue characterization studies, textural image segmentation, and image restoration using fractal constraints. The class of fractal models used in nuclear medicine image processing and the techniques used to estimate the fractal dimension associated with these models will be reviewed. Fractals are self-similar objects which can define a complex geometry. The analysis of fractal patterns has grown during the past years, mainly due to the wide range of applications to diverse scientific areas where fractals have been explored. It turns out that the key tool to study the complexity of a given system is the Fractal Dimension (FD), since this is its main invariant which throws quite useful information about the complexity that it presents when being examined with enough level of detail. In view of this fractals adaptivity in medical imaging, an

iterative optimization algorithm has been developed to find the deformation that maximizes similarity. The outcome of the algorithm is the optimum deformation defined by a set of parameters. Here in this research work, we have grown fractals using statistical methods such as Brownian motion and in our method, diffusion limited aggregation (DLA) algorithm is developed for growing stochastic fractals that cover the boundary of the images. Image deformation can be easily identified by DLA technique of fractal growing phenomenon. In order to identify and quantify the information gathered from the images, regions of interest (ROIs) must be precisely delineated and separated out for processing and the process is known as image segmentation, one of the most critical step for automated analysis in medical imaging. Segmentation is the first important essential step of low level vision. Image segmentation algorithms generally are based on one of two basic properties of intensity values: discontinuity and similarity. In the first category, the basic approach is to partition an image based on abrupt changes in intensity, e.g., edges. The main approaches in the second category are based on partitioning an image into regions that are similar according to a set of predefined criteria. Thresholding, clustering, region growing are examples of methods belonging to this category. Segmentation is based on sets of feature that can be extracted from the images such as pixel intensities, which in turn can be used to calculate other features such as edges, and texture. In this

paper fractal powered region growing approach is developed for image segmentation.

Keywords: Optimization, image segmentation, image registration, nuclear medicine imaging, stochastic fractals, ROI, Self-similar

QUALITY CONTROL OF PLANAR GAMMA CAMERA AND SINGLE-PHOTON EMISSION COMPUTED TOMOGRAPHY

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The dose of Patient radiation and image quality are primary concerns in the conduct of nuclear medicine procedures. Accurate interpretation of nuclear medicine image data depends on understanding the image patterns and quantitative results. This also applies to both quality control testing and clinical studies. Such understanding comes by learning from different examples, in addition to having in-depth knowledge of the underlying and how to achieve optimal results.

Recognizing quality deterioration and artifacts in clinical images is as important as routine monitoring of system performance with quality controls. Progressive deterioration of image quality may be difficult to determine in clinical

images of a particular type, due to variations in the population of patients.

However, a review of clinical studies and procedures performed over a period of time can help determine consistency and may reveal gradual changes. Although the performance of the instrument should be monitored for routine and periodic quality control testing, it may malfunction unexpectedly at any time. Daily observance continues and vigilance by all involved is vital. When an abnormal situation or deterioration is suspected or immediate action is essential.

A range of protocols are currently used in the acquisition and analysis of quality control testing, National Electrical Manufacturers' methods and protocols are widely accepted to provide a description, accurate measurement, and reporting of camera performance parameters.

Many factors contribute to the final quality including uniformity, resolution, collimation, and hard copy device. Additionally, for some types of studies, other factors such as count rate capability come into play. With the addition of tomographic imaging, comes an additional suite of parameters that can influence clinical images - these are the center of rotation of the system, hole alignment of the collimator, the rotational stability of the detector head, and the integrity of the reconstruction algorithms. On a daily basis, there is a limited amount of time that can reasonably be spent performing system QC. As a result, the primary goal of a QC program should

be to keep track of parameters that are important.

- a) most susceptible to system performance changes and
- b) most likely to have an influence on clinical studies as daily uniformity test (Extrinsic or Intrinsic)

PET CT Quality Control according to NEMA guidelines

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The introduction of PET more than 2 decades ago has revolutionized oncologic imaging and fostered a new understanding of molecular alterations of cancer cells. Interest in PET especially increased after the introduction of PET/CT scanners, which allowed for the collection of both anatomic information and metabolic or functional information in vivo in one scanning session. Diagnostic capability of a PET/CT is dependent upon on the accurate, reproducible performance of the instrument. The complexity of a combined PET/CT system needs to be balanced with rigorous quality control (QC) procedures. An extensive series of parameters has been developed over the years for acceptance testing and performance characterization of PET/CT scanner. National Electrical Manufacturers Association (NEMA) has promulgated the detailed data acquisition and analysis protocols for this purpose. However, the settings, procedures and phantoms to be used are, normally, manufacturer specific. The performance characteristics (specifications)

are provided together with the equipment and should be checked during acceptance testing of the equipment. Daily and periodic test results should be recorded and monitored continuously, so that any significant deviation from the reference values can be detected and corrected for, before affecting clinical results. Both the PET and the CT components should be tested separately as recommended and each parameter's working limits should be considered. The NEMA has revised standard document for PET scanner with the first being NU2-1994 followed by Nu2-2001 to specifically cater for 3-D scanning and the effects of out-of-field radioactivity. In year 2007, then Nu2-2007 document was made to cater for the introduction of PET scanners with intrinsically radioactive components & latest being Nu2-2012 amended to include the time of flight and non-time of flight coincidence systems, discrete and continuous detector designs, single and multiple slice devices and multi-planar and volume reconstruction models.

Before planning a QC procedure it is advisable to prepare a schedule of testing and radioactivity requirements in advance of testing. Depending on the scanner, acceptance testing & complete yearly / scheduled quality controls can be completed in three to five days. Some of the essential tests as recommended by NEMA are:

1. Spatial resolution
2. Sensitivity
3. Scatter fraction, count losses and randoms measurements
4. Energy resolution

5. Image quality and accuracy of attenuation, and scatter correction and quantitation
6. Coincidence timing resolution for TOF

Non-Imaging Instrumentation

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Nuclear medicine has been largely based on imaging modality however non imaging instruments always remains an essential part of it. Therefore these equipments should be operated with clear understanding of their components, applications, limitations and quality control parameters for not only to support smooth functioning of department as well as to meet quality assurance compliance with national and international standards. Non-imaging equipments basically serve as measuring and counting detectors of radiation sources or area and includes survey meter, dose calibrator, wellcounter, thyroid uptake probe, intraoperative probes etc. It should be noteworthy that no detector is suitable for universal detection of all types of radiation. The factors influencing the choice of detector are efficiency, response to different radiation types, energy of radiation, detector volume, source geometry and detector dead time. This lecture will cover operating principle and brief overview on some non-imaging instruments commonly used in nuclear medicine.

Dosimetry in Lu-177 DOTATATE therapy

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Various isotopes are used in nuclear medicine for theranostics purposes. In the past decade, these isotopes have seen an increase in applications. Lutetium-177 (Lu-177) has been widely used as a radiopharmaceutical agent of choice for treatment of metastatic neuro endocrine tumors (NETs) and meningiomas and has become a standard treatment option. Therefore, estimating the risks and benefits of this procedure requires knowledge of the absorbed dose received by body organs and tissues. Nuclear Medicine uses the Medical Internal Radiation Dose (MIRD) method to estimate absorbed dose. Also, dosimetry play an important role in optimization of treatment cycles and activity to be administered. The kidneys and spleen are the organs that receive the highest dose compared to the rest of the body. There are several dosimetry methods has been adopted for the estimation of absorbed dose received by organs and tumor lesions (like direct monte carlo simulations, dose point kernel method, deep learning etc). There have been a variety of imaging approaches to clinical dosimetry, including whole-body planar images, computed tomography/computed tomography (SPECT/CT) images, and hybrid methods that combine WB planar images and SPECT/CT scans. This lecture discusses development of dosimetry procedures, mathematical calculations, the concept of source and target organs, current and future scenario of Lu-177 DOTATATE therapy dosimetry.

Antibody based Radiopharmaceuticals for Cancer Diagnosis and Therapy

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The current modalities for treatment of cancer like surgery, radiotherapy and chemotherapy have failed to cure many cancers in spite of significant advances made till date. Research is now more focused on targeted therapy using antibodies against numerous different tumor antigens that are linked to either radioisotopes (radioimmunotherapy) or toxins (immunotoxins) or drugs (antibody-drug conjugates for photodynamic therapy).

Monoclonal antibodies and their fragments, labeled with therapeutic radionuclides have been used for developing anticancer strategies like radioimmunotherapy (RIT/RAIT) wherein the monoclonal antibody (MoAb) is conjugated to a β - emitting radioisotope which will deliver radiation not only to tumor cells that bind the antibody, but also to neighboring tumor cells inaccessible to the antibody, due to a crossfire effect. Targeted alpha therapy utilizes MoAbs conjugated to α particles that destroy cancer cells. For diagnostic purposes, MoAbs have been labeled with γ emitting radionuclides and imaged with a single photon emission computerized tomography (SPECT) camera. Immuno-PET imaging utilizing MoAbs labeled with positron emitting radionuclides provides option to improve diagnostic tumor characterization, due to the high sensitivity and

image resolution of the positron emission tomography (PET) camera and specificity of the MoAb.

Therapeutic antibodies play an important role in cancer therapy due to their ability to specifically bind to primary and metastatic cancer cells with high affinity. Effective MoAb based therapeutics for the treatment of cancer has proven more elusive than originally envisioned. This was owing to their murine (mouse) origin, resulting in the production of antibodies to mouse antibody called HAMA (human anti-mouse antibody) response. This could be overcome by the generation of chimeric and humanized MoAbs that contain human Fc domains and retain targeting specificity by incorporating portions of the murine variable regions.

Antibody-based therapeutics has emerged as important components of therapies for an increasing number of human cancers. Radioimmunotherapy (RIT) is one among many therapeutic strategies that uses the “magic bullet” concept, whereby an antibody that recognizes tumor-associated antigens carries a cytotoxic radioisotope to target and destroy cancer cells. Targeted radiotherapy is advantageous compared to other systemic therapies as it is based on unique expression of target molecules on tumor cells and the therapeutic agent selectively localizes in the tumor with minimum toxic effects on normal tissues. Cancer cells express high levels of the target molecules than normal cells to which the antibodies selectively bind. Antibody immunoglobulins (IgG) labeled with

radioisotope remain in circulation for a long time thereby exposing the highly sensitive red marrow to radiation and resulting in dose-limiting myelosuppression. Tumor/blood ratios can be improved by use of fragmented antibodies, such as a F(ab')₂ or Fab', and molecularly engineered antibody sub-fragments with more favorable pharmacokinetic properties. Development of new antibody forms through genetic engineering techniques and evolution of higher resolution imaging instruments would help in early diagnosis of cancer.

Contamination Monitoring And Decontamination Measures

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Nuclear medicine involves the handling of unsealed radioactive materials which causes external and internal contamination of staff and patients."The presence of radioactive substances in or on the human body or other places where they are undesirable or could be harmful is known as contamination. The magnitude of radiation contamination depends on the radionuclide, its activity, and the type of work within the department in which the person is involved.

There are basically two types of contamination:

1. Internal Contamination: It occurs when people swallow or breathe in radioactive materials, or when radioactive materials enter the body through an open wound or are absorbed through the skin. Some types of radioactive

materials stay in the body and are deposited in different body organs. Other types are eliminated from the body in blood, sweat, urine, and feces.

2. External Contamination: It occurs when radioactive material, in the form of dust, powder, or liquid, comes into contact with a person's skin, hair, or clothing. In other words, the contact is external to a person's body. Radioactive contamination is spread when people who are externally contaminated with radioactive material can contaminate other people or surfaces that they touch, such as surfaces while sitting in a chair or even walking through a house. Contaminants can easily fall from clothing and contaminate other surfaces. The body fluids (blood, sweat, and urine) of an internally contaminated person can contain radioactive materials. Coming into contact with these body fluids can result in contamination and/or exposure.

Since radiation cannot be seen, smelled, felt, or tasted, people at the site of an incident will not know whether radioactive materials were involved. The following steps can limit the contamination:

- To prevent the spread of contamination, monitoring is essential.
- To detect the failure of containment
- To point out a deviation from proper operating procedure.

In order to maintain the contamination level control standard, the following locations should be effectively monitored:

- Places where there is a possibility of contamination
- The proximity of an entrance or the existence of a controlled area

Decontamination

- The reduction or removal of contaminating radioactive material from personnel, surfaces, equipment, etc. is known as decontamination.

Decontamination kit

- A decontamination kit should be kept near a radiation monitor.
- The location of the kit should be indicated by a notice in each laboratory.
- The decontamination kit should comprise the following items:
- Protective clothing, plastic overshoes, plastic disposable aprons, or disposable oversuit, boxes disposable face masks and gloves

The radioactive contamination in a laboratory is minimised by: in the laboratory, it needs careful design, selecting proper handling equipment, and following correct operating procedures. In addition to strict management, disposal of radioactive waste, good housekeeping, and routine contamination monitoring, Smoking, consuming food and drinks, chewing pans and gums, using cosmetics, etc. must be prohibited in laboratories.

Theragnostic Radiopharmaceuticals

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The therapeutic application of radiopharmaceuticals (RPs) dates back to the 1930s, much before knowing the term theragnostic or theranostic radiopharmaceuticals. Radioiodine-131 (^{131}I) was the first theragnostic radiopharmaceutical used to diagnose and treat thyroid cancer. The word theragnostic, embracing "therapy" and "gnosis," is a treatment strategy combining diagnosis and therapeutics. Similar to other RPs, the theragnostic RPs also consist of two main components: i) Pharmacophore and ii) Radionuclide. The pharmacophore can be a small molecule, peptide, or protein that targets a specific pathway or receptor over-expressed in a malignancy. Depending upon the nature of radiations emitted by the radionuclide, it can be used either for diagnostic imaging (γ or β^+) or therapy (α , β^- , auger electrons). The diagnostic RPs help patient selection for radionuclide therapy, staging, and post-therapy response evaluation. On the other hand, the high linear energy transfer (LET) of therapeutic radioisotopes' kills the cancers cell efficiently. Radioisotopes of the same elements or different elements in pairs can be used for diagnostic and therapeutic purposes.

The success of peptide receptor radionuclide therapy (PRRT) using radiolabeled octreotide analogs to treat somatostatin receptors (sstrs) over-expressing neuroendocrine tumors (NETs) has popularised the theragnostic

radiopharmaceuticals globally. Prostate-specific membrane antigen (PSMA) antagonists tagged with gallium-68 (^{68}Ga) are used for PET-CT imaging of prostate cancer. Whereas, Lutetium-177 (^{177}Lu) and Actinium-225 (^{225}Ac) tagged PSMA inhibitors are used to treat the patients. Patients who have exhausted all the other available treatment options have shown encouraging results for PRRT.

Unlike radiotherapy, the theragnostic radiopharmaceuticals are commonly administered intravenously and a few times loco-regionally, like radiation synovectomy. Radionuclide therapy has shown efficacy and less toxicity than all other available forms of systemic cancer treatment options. Also, less number of treatment cycles are required for radionuclide therapy in comparison to the conventional ones. The therapeutic radionuclides, which emit gamma rays or positrons along with α and β^- , can be used for post-therapy imaging to observe the distribution of administered radiopharmaceuticals. Also, dosimetry can be performed to know the dose delivered to the tumor and other non-targeted organs.

Many new RPs are under developmental or pre-clinical stages, and few targeting chemokine receptors, cancer cell-associated fibroblast, PD-L1 have reached early clinical trials. Theragnostic radiopharmaceuticals are connecting imaging and therapy more than ever as we can treat what we can see. The limited availability and high cost associated with these radionuclides (^{177}Lu , ^{225}Ac) hinder the

widespread use of these radiopharmaceuticals. Research is going for newer production methods to meet the global demand for such radionuclides. Newer theragnostic radionuclides like terbium and scandium are also being explored. Good collaboration between industry and academia is needed to fulfil practical needs. Theragnostic, once named magic bullets by Paul Elrich, is the future of personalised treatment bringing hope and impacting the lives of thousands of patients worldwide.

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 labeled 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.

NABH accreditation of Medical Imaging Services with 2nd Edition of standards and a new rule for accreditation validity

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On 9th August 2020, under The Council of Nuclear Medicine Science & Technology, India (CNMST) banner, we discussed "Quality Accreditation of Nuclear Medicine centres/departments, their need and How to set up Indicators" (the same is uploaded on YouTube under the channel "Nuclear Medicine Solutions" with <https://youtu.be/D6pAF5SGAKw>). "The National Accreditation Board for Hospitals and Healthcare providers (NABH)" has brought many changes since then in accreditation policies and rules for the accreditations. They have issued the 2nd Edition of standards for the accreditation of medical imaging services effective from Jan 2021. The rule of accreditation period is also revised and effected now.

In 2005, the NABH was established as a constituent board of the Quality Council of India to construct an accreditation programme for healthcare organisations. It was founded to improve the health system and foster continuous quality improvement and patient safety. It has been accredited by the International Society for Quality in Healthcare (ISQua). The first version of accreditation standards was published in 2006, and the first hospital in Kerala was accredited in 2007. So far, over 8000 healthcare organisations have been accredited.

They are divided into seven chapters, with 214 objective items, 34 of which are in the Core category and must be assessed during all assessments. 157 elements in the commitment category are evaluated at the final assessment, 17 elements in the achievement category are evaluated during surveillance, and six elements in the excellence category are evaluated during re-accreditation. These standards have been divided into seven chapters:

- Access, Assessment and Care of Patient
- Imaging Procedures and Interpretation
- Facility Management Services
- Equipment, Material, and Medications
- Human Resource Management
- Management of Quality and Safety
- Information Management System

The scoring methodology has been modified to a graded scheme to help smooth the implementation of the standards. A bibliography for reference has been added at the end of all chapters, which will provide organisations with

a resource for taking quality beyond the requirements of the objective elements. The standards and the document on Key Performance Indicators have been made available free of charge as a downloadable document on the NABH website.

The accreditation period has been revised to 04 years instead of 03 years earlier. The surveillance assessment is to be carried out within 21-24 months from accreditation. The renewal application for accreditation continuation is to be started 06 months before the expiration date, i.e. on 42 months.

Radiation Exposure during Pregnancy in Nuclear Medicine

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Nuclear medicine imaging modalities provide important information about disease and pathology and are often a critical component of patient management. In pregnant females, the NM procedures are contraindicated. Still, accidentally if they are exposed, it is important to know the fetal absorbed dose, as the detrimental effects of radiation are well known. In general, prenatal radiation exposure of approximately 10 mGy might enhance the risk of fetal disorders, such as prenatal death, microcephaly, reduced intelligence quotient, organ malformation, mental retardation, intrauterine growth

retardation, and childhood cancers.[ICRP, 2001]
The annual radiation dose limit of 1 mSv was accepted worldwide for general public, and the risk of fetal damage at doses lower than 1 mGy is assumed negligible and riskless.

Since many radiopharmaceutical agents are utilized in nuclear medicine investigations, the variation in the radionuclide biokinetics and excretion rate complicates estimating dose to the embryo/fetus. The international and national Regulatory authorities such as International Commission on Radiological Protection (ICRP) and the Atomic Energy Regulatory Board (AERB), reported that fetal doses below 100 mGy should not be used as justification for terminating pregnancy.[ICRP,2001 and AERB, 2011] According to the American College of Obstetricians and Gynecologists, potential health risks may arise after cumulative radiation exposure exceeding 50 mSv, depending on the dose and stage of pregnancy. [ACOG Committee, 2004]

ICRP Publication 84 states that radiation-induced malformations have a threshold of 50–100 mGy (5–10 rad). Accordingly, the diagnostic nuclear medicine examinations often results in fetal dose less than the dose threshold (50–100 mGy) of the teratogenic effects reported by ICRP 84. [ICRP-2000] Thus, fetal doses below 100 mGy should not be considered a reason for terminating a pregnancy after radiation exposure. AERB Directive No. 01/2011 states the dose limits for exposures from ionizing radiations for workers and members of public. The directive also states that

once pregnancy is declared, the equivalent dose limit to embryo/fetus shall be 1 mSv for the remainder of the pregnancy. For pregnant patients and/or women of childbearing age, questioning them prior to nuclear medicine scintigraphy is the first-line strategy to avoid accidental radiation exposure and the arising stochastic effects.

In the past few decades, the involvement of females in the nuclear medicine fraternity has increased, and thus, understanding radiation exposure and risks is important part of the job profile of a medical physicist and radiological safety officer. The general notion that it is not safe for pregnant workers to work in the nuclear medicine and radiological center is thus only a myth. Practically, pregnant workers can work safely by following appropriate shielding and radiation safety practices.

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ABSTRACT

ABS11401: Difference between Lu 177 peptide having low and high specific activity using chromatographic peaks*Sonit Mitra**Jaslok Hospital & Research Centre. Mumbai 26*

Aim: To study Lu ¹⁷⁷ peptide chromatography peaks with different specific activity

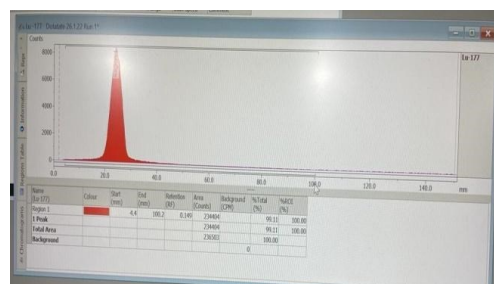
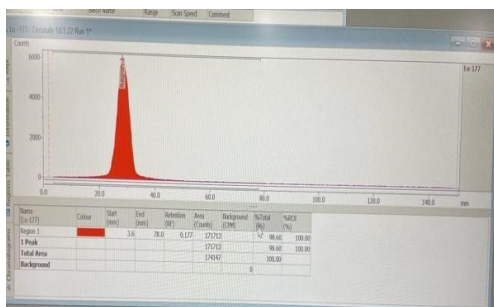
Materials: Drop of Lu ¹⁷⁷ peptides product, TLC scanner from lab-logic, chromatography strip solvent (Sodium citrate for imported ¹⁷⁷Lu as having high specific activity, acetonitrile and water mixture ratio (1:1) for Lu¹⁷⁷ with low specific activity

Method:

A drop of concentrated labeled product was placed on chromatography strip and the chromatographic strip was developed for 20 minutes and then dried .further it was analyzed on TLC scanner.

Observations

For Lu¹⁷⁷ with High Specific activity, we see sharper peak of labeled product resulting in better the resolution(as specific activity>3000GBq/mg)



And Lu¹⁷⁷ with low specific activity

It was seen that Lu¹⁷⁷ with low specific activity have broad peaks. Shouldering and Tailing patterns of the peak were also observed with Lu¹⁷⁷ having low specific activity

The Causes of broad peak

- 1) Due to mass transport broadening of Mobile phase and stationary phase (2) Longitudinal diffusion and eddy diffusion
- 2) Higher particle size (Due to low specific activity more peptide is consumed) affecting the resolution Small columns and high amounts of sample lead to peak broadening.
- 3) Peak broadening or tailing occurs if is temperature is too low

Role of Buffer

You can reduce peak broadening by using different types of buffers such as acetate or phosphate buffer solutions, these adjusted to the suitable pH as per the pKa value of the molecule.

Sno	Lu ¹⁷⁷ Peptide	Specific Activity (mCi/ug)
I	Lu ¹⁷⁷ PSMA	22.9
II	Lu ¹⁷⁷ PSMA	21.4

III	Lu ¹⁷⁷ PSMA	22.6
IV	Lu ¹⁷⁷ Dotatate	17
V	Lu ¹⁷⁷ Dotatate	19.8

Above we see 5 Lu177 peptides with different specific activity

Discussion and Conclusion:

Higher the Specific activity, smaller the particle size, sharper the peak resulting in better the resolution.

ABS57845: Automated synthesis of 68Ga-FAPI-04 for routine clinical practice under GMP guidelines

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Objective: 68Ga-FAPI-04 has become a promising PET radiopharmaceutical for the in-vivo detection of different kinds of cancer, myocardial infarctions etc. [1,2]. The synthesis of 68Ga FAPI-04 has gained much attention in the recent 1-2 years. Until now, the synthesis was carried out by manual operations. We aimed to evaluate the synthesis of this radiopharmaceutical via an automatically synthetic module and its Quality control analysis.

Method: In this study, we evaluate a method of synthesis of 68Ga- FAPI-04, using Eckert & Zeigler,Äôs Modular lab pharm tracer automated synthesis module with an in-line connected 30

mCi 68Ge/68Ga generator (E&Z, Germany). The radiolabeling was carried out at 95°C with a crude mixture of [68Ga]GaCl₃ and FAPI-04 precursor (kind gift by M/S B . J Madan, New Delhi) in the presence of a suitable buffer and optimum radiolabeling conditions. At different parameters such as variation in precursor amount, temperature and reaction time, the radiolabeling yield was studied. This crude mixture was purified by a C-18 light cartridge and followed by a 0.22 µm sterile filter. All the quality control parameters (Stability and radiochemical purity) were performed for being used as a clinical product.

Results: The synthesis of 68Ga-FAPI-04 was synthesized successfully by using an in-house automated synthesizing module (modular lab Pharm tracer). Overall radiochemical yield was found more than 95% with the labeling purity more than 98%. We have developed a protocol for radiolabeling of 68Ga-FAPI-04 for routine clinical applications.

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ABS30187: Comparison of Radiation Exposure to Radiation Health Worker from the patient undergoing Myocardial Perfusion Imaging in a Single Day versus Dual Day Protocol.

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The MPI study whether performed in a Single Day or Dual Day Protocol (SDP or DDP) is a potential source of radiation exposure to radiation health workers (RHW) who tends to be in close proximity of injected patients.

The present study compared two different MPI protocols to find out which protocol resulted in more radiation exposure to RHW. The radiation exposure rate was measured with an ionization chamber-based portable survey meter.

A total of 53 patients were referred to our department for a $^{99\text{mTc}}$ -Sestamibi MPI scan during the study period. The patients were divided into two groups: Group A patients

undergoing MPI in DDP (34 patients) and Group B undergoing MPI in SDP (19 patients).

1st set of readings was taken immediately post-injection at a distance of 30cm, 50cm, and 100cm from injected patients. 2nd set of readings was taken at 1hr and 2hrs post-injection at a distance of 100cm from injected patients for both groups. Data were analyzed using the Student t-test.

Mean radiation exposure rate recorded in Group A immediately post-injection, on 1st and 2nd day at a distance of 30cm was $15.58 \pm 0.84 \mu\text{Sv/hr}$ and $15.6 \pm 0.67 \mu\text{Sv/hr}$, at 50cm was $11.77 \pm 0.64 \mu\text{Sv/hr}$ and $11.65 \pm 0.46 \mu\text{Sv/hr}$ and at a distance of 100cm was $8.14 \pm 0.67 \mu\text{Sv/hr}$ and $8.55 \pm 0.48 \mu\text{Sv/hr}$ respectively.

Similarly mean radiation exposure rate recorded in Group B immediately post 1st and 2nd injection at a distance of 30cm was $15.05 \pm 0.54 \mu\text{Sv/hr}$ and $46.53 \pm 1.21 \mu\text{Sv/hr}$, at 50cm was $11.68 \pm 0.84 \mu\text{Sv/hr}$ and $31 \pm 0.75 \mu\text{Sv/hr}$ & at a distance of 100cm was $9.47 \pm 0.71 \mu\text{Sv/hr}$ and $19.82 \pm 0.82 \mu\text{Sv/hr}$ respectively.

A statistically significant difference in mean radiation exposure rate from injected patients was observed in both groups with increases in the distance when measured immediately post-injection.

Mean radiation exposure rate was also recorded at a distance of 100cm immediately after injection than after 1hr and 2hrs post-injection in both groups respectively.

On comparing the immediate reading with 1hr post-injection reading taken at 100cm in both the groups, a statistically significant difference in reduction of Mean radiation exposure rate with time was observed. However, no such difference was observed between 1hr and 2hrs readings in both groups.

We conclude that DDP is better than the SDP as it results in lesser radiation exposure to RHW. Secondly, the significance of the reduction in radiation exposure rate with time and distance is reinforced as a key radiation safety principle.

ABS72173: Is Occupancy factor a major point of consideration in minimising radiation exposure from Low Dose Iodine Therapy patients to family members/ comforter?

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Low dose ^{131}I (<30mCi) is given to hyperthyroid patients on an outdoor patient basis. While the radioactive iodine is beneficial for these patients, it is a potential source of radiation exposure to their comforters and family members which need to be minimized.

As per NCRP Report Number 37, The occupancy factor (OF) is defined as the fraction of the time a person is close to the patient, with the distance during this time assumed to be an average of 1meter.

In this present study we tried to find out the Total Accumulative Exposure (TAE) to the family members/ comforters and from the patient treated with low dose iodine therapy (LDIT) using OF as 0.25.

LDIT was administered to 51 hyperthyroid patients based upon clinical history, TFT values, and thyroid scan uptake.

Depending upon the activity given to the patient, they were divided into 2 groups:-

Group A included 31 patients and Group B included 20 patients with activity administered 5-15mCi & 16-29mCi respectively.

The radiation exposure rate for each patient was measured using an Ionizing Chamber-based survey meter at a distance of 1meter from the patient immediately post LDIT. The mean Radiation exposure rate was then calculated for Group A & B patients.

TAE for complete decay at a distance r from the patient was calculated using this formula:

$$D(\mu\text{Sv}) = 34.6 \cdot i$$

ABS31642: Challenges, Impact and Future of Artificial Intelligence in Medical Imaging

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Introduction: Artificial intelligence (AI) term is often defined as ,ÀÒ,ÀÒintelligence demonstrated by machines, in contrast to the

natural intelligence displayed by humans and animals. A typical medical imaging workflow starts with planning, image acquisition, data reconstruction, interpretation and reporting. Application of AI range from automated data processing, image reconstruction, result analysis to correlation with clinical outcomes. In recent years, AI has created a significant impact on medical Imaging and evidence based medicine (EBM).

How AI Works: AI systems work by learning from patterns and features from the input data by combining large sets of data with intelligent, iterative processing algorithms. It runs multiple rounds of data processing, it tests-retests, measures its own performance and develops additional expertise for the next task.

Challenges: Applications of artificial intelligence in medical imaging are the most promising with respect to other Healthcare facilities. AI can decode the complicated algorithm of Imaging be it CT, PET/CT, SPECT/CT, MRI or other testing modalities. Its advanced data analytics tools can demonstrate their ability to extract meaningful information for enhanced decision-making, which is sometimes with greater precision than humans themselves.

Although AI has shown an apparently limitless ability to collect new information from clinical images, however, enforcing the technology in medical settings comes as a main barrier. This can be overcome with the combined efforts of

computational science, advanced data instrumentation, mathematics, medicine etc.

Impact of AI: AI increases access to image reporting where the availability of radiologists is less, especially for people/patient living in the developing countries. It enables remote medical service providers to access higher level medical care. Use of AI will reduce delays in identifying and reporting abnormal imaging results. This is especially important in chest and brain imaging where time is critical. In this way, it has the potential to improve clinical outcomes and further enhance the value of AI in medical imaging.

Future of AI in medical imaging: AI along with deep learning can help extract the best information from the humongous pool of data. Deep learning is basically the subpart of AI technology based on artificial neural networks being able to automatically detect what it has learnt.

Healthcare experts see a bright future for AI in medical imaging. As the technology continues to advance, and availability of advanced diagnostic tools, AI has a great potential to enhance all aspects of Medical Imaging.

ABS43795: Locally advanced adenocarcinoma of rectosigmoid with incidentally detected metastatic left cervical lymphadenopathy on F-18 FDG PET - CT scan

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Introduction: Rectosigmoid carcinoma is a common malignant pathology which requires multimodality approach of management. The treatment depends on the stage of cancer during detection, ranging from surgery, locoregional radiotherapy and even systemic chemotherapy in the presence of distant metastatic disease.

Case Report: We present a case of 65-year-old female who presented with complaints of rectal bleeding. On evaluation with CECT and USG abdomen, she was found to have an infiltrative soft tissue density lesion involving the rectosigmoid, which on biopsy was diagnosed as adenocarcinoma. Local radiation therapy was planned for the patient following an F-18 FDG PET-CT scan to rule out the presence of distant metastatic disease. Whole body PET-CT scan was performed for the patient which showed an infiltrative soft tissue density lesion of the rectosigmoid with evidence of pelvic and retroperitoneal lymph nodal metastases, and also a mildly FDG avid centimeter-sized left cervical level IV lymph node. FNAC of the lymph node revealed the presence of metastatic adenocarcinoma. The presence of distant metastatic disease changed the management to palliative chemotherapy.

Conclusion: FDG PET-CT is very important in the staging of colorectal malignancies as it can detect rare distant metastatic disease which might not be possible with conventional regional radiological imaging modalities.

ABS40824: In-vitro stability and bio-distribution of 188Re-N-DEDC lipiodol in

trans-arterial radionuclide therapy (TART) for treatment of hepatocellular carcinoma (HCC)

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Background: TART with 188Re- lipiodol is an emerging agent for treatment of intermediate and/or advanced HCC due to its simple and on-site labelling procedure, cost-effectiveness and least radiation induced side effects. Indigenously developed new lipophilic chelating agent N-DEDC (Nitrido-diethyl-dithiocarbamate) is more easily available and has lesser labelling time that can reduce the personnel radiation exposure. The present study aimed to check in-vitro stability upto 24 hrs and biodistribution of transarterially injected 188Re-N-DEDC lipiodol through femoral artery in advanced HCC patients.

Materials and Methods: Indigenously produced lyophilized freeze dried kits (containing 2 vials) of diethyl dithiocarbamate (DEDC) were obtained from Bhabha Atomic research center (BARC), Mumbai, India and labelled using freshly eluted 188Re-sodium perrhenate from commercial W-188/Re-188 generator. In-vitro stability of 188Re-N-DEDC complex was checked at 0, 0.5, 1, 2, 3, 6, 12 & 24 hrs at room temperature. Following the QC & labelling procedure, the therapeutic activity was injected under fluoroscopic guidance through femoral branch in super-selective artery of tumor. Planar and SPECT/CT Imaging was performed at 2, 6, 12, 24, 48, and 72hrs in nuclear medicine

department to see tumor uptake and biodistribution of ^{188}Re -N-DEDC lipiodol.

Results: Mean observed radiochemical purity (RCP) of Rhenium- ^{188}Re -N-DEDC complex prepared was $90.81 \pm 3.24\%$. At room temperature, ^{188}Re -N-DEDC complex was almost stable till 1 hr and there was very less detectable impact on the radiochemical purity of ^{188}Re -N-DEDC complex till 1 hr. Mean radiochemical purity at 0.5, 1, 2, 3, 6, 12 & 24 hrs was observed as 89.78 ± 3.67 , 89.22 ± 3.77 , 83.57 ± 3.2 , 74.71 ± 5.18 , 62.57 ± 3.20 , 47 ± 4.43 , 30.28 ± 4.54 respectively. Twenty one (21) patients have been treated with ^{188}Re -N-DEDC lipiodol so far. Biodistribution showed localized tracer uptake inside the lesion with only 3 patients (~14%) showing mild lung uptake due to hepato-pulmonary shunt (<20%). Small intestine showed increased ^{188}Re -N-DEDC/lipiodol uptake over time due to their lipophilic characteristic and slow elimination through hepatobiliary tract. There was faint visualization of kidneys and high bladder uptake due to urinary excretion. Mild uptake of free perrhenate was seen in thyroid of only 4 patients (~19%).

Conclusions: Thus, the present study concluded that DEDC Kits have some advantages in terms of high in-vitro stability of intermediate complex (^{188}Re -N-DEDC). Higher in-vitro stability of ^{188}Re -N-DEDC is a particularly useful feature for patient dose preparation when there is gap between dose preparation and interventional procedure. The biodistribution of DEDC was

seen in liver, lungs & small intestine and clearance by urinary route.

ABS43209: Effect of Gastroesophageal Reflux Disease on Body Weight Percentage of Children

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Gastroesophageal reflux (GER) is the most commonly seen digestive disorder in infants. It affects about 50% of infants at the age of 2 months, and it is often physiological, which tends to resolve with age. Simple physiological GER becomes a disease, gastroesophageal reflux disease (GERD), when it causes troublesome symptoms and/or complications such as irritability, excessive crying, failure to thrive, poor weight gain, wheezing, recurrent chest infections, and stridor. Children with severe GERD and recurrent vomiting may have delayed weight gain and growth.

In this study, we attempted to find out the effect of GERD on the bodyweight% of children and the relationship between their presence and the severity of reflux using the scintigraphic scoring system. A total of 95 patients were undergoing scintigraphy imaging for the scanning of GER and their staging. We included 40 out of 95 patients whose ages ranged from 0 to 12 years, and body weight and height percentiles were recorded.

The study was carried out after 4-6 hrs of fasting, and the feeding volume of milk was calculated as per the standard feeding formula,

i.e., 4-6 ml/kg body weight. The standard imaging protocol was used to administer 18.5-37MBq of ^{99m}Tc labeled Sulphur Collides. The results were analyzed as per the scintigraphic scoring system.

36 out of 40 patients showed GER positivity. We discovered that 52.78% of GER-positive patients had recurrent chest infections, 30.56% had recurrent vomiting, and 27.78% had regurgitation. 30 out of 36 GER-positive patients suffered from Grade III reflux. 9 out of 30 patients, grade III voluminous persistent reflux of long duration causes great loss of ingested calories with a resultant failure to thrive in 6/9 patients. Grade III persistent reflux episodes were seen in 27 patients, and 14 out of 27 patients who were anemic had poor weight gain and repeated episodes of chest infection.

We concluded that children with persistent Grade III voluminous reflux were suffering from repeated episodes of chest infections, poor weight gain, which restricts their physical development.

ABS25796: Intelligent Imaging in Nuclear Medicine: Age-Dependent changes in Thyroid Uptake and Area of Thyroid Tissue.

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Thyroid nodules are a common occurrence in the general population, and the incidental ones are often referred for ultrasound (US) evaluation. In order to save some bucks and form the trouble to visit an ultrasound facility, we are designing a

digital model which can detect the abnormalities present in the Thyroid nodules by using machine learning over the imagery data of the patient. The images used for our model is collected in the process of Thyroid Scan (25micro-curie) which is detected by the Gamma camera. This model will provide the value of the Thyroid Uptake and the effective area of the Thyroid tissue which participates in the thyroid uptake process. The software associated with the Gamma Camera provides the imagery data in DICOM (Digital Imaging and Communications in Medicine) format.

The image is parsed and read by our library and the tiny dots are resolved into multiple pixels. These pixels are then processed by an algorithm to find out the value of the Thyroid uptake and the area covered by the Thyroid tissue.

In this study, we are providing the algorithm which allows us to find the above features under Region of Interest (ROI) which is drawn by us. We are going to collect and process a very large number of DICOM images of different Patients to improve our machine learning model. The ML model will be mapped according to the Thyroid Uptake and Area of Thyroid tissue further grouped by age of the patients. The model will help us find out the accurate therapy dose for abnormal cases of the thyroid. Nowadays we are using some empirically decided Therapy dose which often damages non-targeted tissues, so we are going to minimize this by using our results and conclusion based on the statistical data which will keep improving for each patient.

Moreover, this big data can be used for de-noising the image, registration and translation between the different modalities. On the basis of this data, Artificial Intelligence applications may be developed for the medical image analysis including but not limited to abnormality detection, segmentation and computer-aided diagnosis.

ABS19027: Classification of Ca Rectum and Ca Cervix from features extracted from the Fourier Spectrum of CT image-A Pilot Study

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Aim and objective: Disease classification is an important part of computer-aided diagnosis. Radiomics aims at extracting mineable quantitative features from medical images which are used for imaging biomarker research in oncology. In this study, we propose disease classification based on features extracted from the 2D Fourier Spectrum of CT images.

Methodology: This study is approved as a retrospective study by the institutional ethics committee (IEC) of our hospital with a waiver of informed consent. In total 60 patients pretreatment, CT images, 30 patients from each disease group i.e. cervix cancer (Class-1), and rectal cancer (Class-0) were used for this study. Two best representative transaxial slices of tumor for each patient were selected by an experienced radiologist and were used for the analysis. The 2D axial slices were reshaped and

normalized followed by the forward Fourier transform was performed on an in-house developed python script. The Fourier transformed spectrum is further converted to an 8-bit image on which the mean method of thresholding was performed on ImageJ software. ROI was drawn on the image post thresholding. Subsequently, 33 shape and first-order statistical features were extracted from images. A chi-squared test was performed with SelectKBest class of sci-kit-learn package of python to select the top features based on the chi-squared value. Train and test split of the dataset was performed. A random forest model was developed for multiclass classification on the training dataset and validated on the test dataset.

Results: Five optimum features were selected using SelectKBest class. The accuracy of the random forest model validated on the test dataset was 0.87, precision (weighted average) was 0.89 and recall was 0.88. The area under the curve-ROC for the model was 0.96.

Conclusion: Our preliminary results show the excellent predictive power of features extracted from the Fourier spectrum in classifying diseases viz Ca Rectum and Ca Cervix. This proof of concept study will be further validated on external datasets.

ABS95144: Evaluating the quality and reliability of educational videos on YouTube for the resident doctors and students of Nuclear Medicine.

Biprojit Nath, Akhilesh Tripathi, Ashish Kumar Jha, Sneha Mithun, Grace M. Mehta, Shreyash Panchal, Amit Nautiyal, Umeshkumar B.

*Sherkhane, Vinay Jaiswar, Nilendu Purandare,
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Aim and Objective: Nuclear Medicine is a multi-disciplinary specialty that uses state of art instruments and radiopharmaceuticals for the diagnosis and treatment of patients suffering from cancer and other diseases. The evolution of Nuclear Medicine Science and Technology over the years has created a need for qualified personnel and hence several medical and nonmedical courses were established to impart Nuclear Medicine education for the professionals. In recent years, innumerable nuclear medicine educational content was created on the YouTube website which is being used by students for their learning. The objective of this study is to examine the quality and reliability of educational videos pertinent to Nuclear Medicine for the resident doctors and students globally.

Methodology: We searched for the term Clinical Nuclear Medicine lectures, Radiopharmaceuticals lectures, Radiation Safety lecture, Nuclear Medicine instrumentation lectures on YouTube on 21st January 2021. 45 videos were analyzed (15 videos each from Clinical Nuclear Medicine, Radiopharmaceuticals, Radiation Safety and Medical Physics, and Nuclear Medicine Instrumentation).

We included videos that were relevant academically and more than 10 min in duration. Whereas, videos that were non-English, poor

quality, and advertisement were excluded from the study. Quantitative metrics (views, subscribers, comments) were recorded. The videos were evaluated and blindly scored by three independent reviewers (experienced nuclear medicine physicians, radiochemists, and nuclear medicine physicists) based on the Journal of American Medical Association (JAMA) Benchmark Criteria and Global Quality Score (GQS) criteria. Cronbachs alpha was calculated to measure the inter-rater reliability using Python (library: pingouin).

Results: The mean JAMA Score (0-4 scale) was found to be 3.26 ± 0.08 and the mean GQS (0-5 scale) was found to be 4.06 ± 0.07 . Cronbachs alpha value for the JAMA score was 0.96 (0.94-0.96) and for GQS was 0.97 (0.95-0.98). The high-rated videos were published by domain specialists viz nuclear medicine physicians, physicists, and researchers.

Conclusion: Our study shows that the quality and reliability of the educational video were of high quality and optimal for students to learn globally

ABS65420: Understanding the Role of Exosomes in Propagating Non-targeted effects in Peripheral Blood Mononuclear Cells from Patients Undergone 177Lu-DOTATATE Therapy

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^{177}Lu based targeted radionuclide therapy (TRT) or ^{177}Lu -DOTATATE therapy, is an important emerging treatment modality for the management of neuroendocrine tumors resulting in enhanced survival rates in subjects with this ailment. However, with the advancements in radiation based treatment modality, the risk of radiation treatment related complications is becoming a growing challenge in the times to come. It is well documented that redox mechanisms play a key role in non-targeted effects (bystander effects, abscopal effects) through transmission of reactive oxygen species (ROS) and reactive nitrogen species (RNS), particularly with regard to conventional radiotherapy. However, there is a lack of evidence on the redox status of subjects who underwent radionuclide therapy and thus the associated non-targeted effects. Researchers have also shown that in multicellular organisms extracellular vesicles known as exosomes help in exchanging information by sending out signals. Therefore, it is highly probable that there exists a finely tuned intricate communication via exosomes through systemic circulation originating from the target site of the radionuclide therapy and spreading the non-targeted damages at the distant sites. Hence, the present study is conceived to investigate the phenomena occurring at the interface of the radionuclide and ROS generation via exosomes. In the same light, the present performed quantitative analysis of the exosomal content and elucidated the redox state of peripheral blood mononuclear cells (PBMCs) in untreated

verses treated patients (^{177}Lu -DOTATATE). Further, in vitro investigations were performed in untreated verses exosome treated PBMCs so as to affirm the role of exosomes in altering the redox status. The study exhibited significant increase in exosomal content of untreated verses treated patients (^{177}Lu -DOTATATE) and significantly enhanced ROS production after therapy as well as after exosome treatment. Further, the DNA damage was assessed by checking the accumulation of phosphorylated $\gamma\text{-H2AX}$ (phosphorylation of the Ser-139 residue of the histone variant H2AX) and was found to increase after ^{177}Lu -DOTATATE therapy. Therefore, the present study concludes that exosomes play a crucial role to propagate ROS generation at non-targeted sites following ^{177}Lu -DOTATATE therapy and further studies are warranted to investigate its mechanistic insights to improve the outcome of TRT in cancer patients.

ABS77464: Radiosynthesis and Bio-evaluation of $5\alpha\text{-reductase}$ Inhibitor for Targeting Androgen Receptor in C6 Glioma Cell Lines: A Preliminary Study

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Testosterone levels and Androgen receptor (AR) expression are reported to be higher in patients with Glioblastoma (GBM) and thus AR has also been reported to be a novel therapeutic target in the treatment of GBM, although its role is not

clearly understood in the progression of the disease. Testosterone is also reported to promote GBM progression, invasion, and migration. Finasteride and Dutasteride are two marketed drugs for the treatment of Benign prostatic hyperplasia (BPH) and are known to inhibit 5α -reductase, an enzyme that mediates the expression of AR by converting Testosterone to di-hydro-testosterone (DHT) which has a higher affinity to AR. The structure-activity relationship of 5α -reductase suggests that modifications in the basic steroidal nucleus and variations in its substitutions, particularly at C-3 and C-17 increase the 5α -reductase inhibitory activity as exemplified by high antiandrogen activity of progesterone esters synthesized in Mexico laboratories. Taking in consideration the 5α -reductase inhibitory activity of the reported esters and based on the observation of importance of electronegative group at C-6 of the steroidal skeleton, it was considered of interest to synthesize 5α , 6β -dibromo derivatives of 17-Oxo-5-androsten- 3β -yl esters to determine its specificity in targeting AR in C6 glioma cell lines. The newly synthesized compound has shown higher binding affinity to AR than Finasteride in-silico. To access its in-vitro cytotoxicity, MTT assay was performed using the C6 rat glioma cell line and it has shown 50% inhibition at a concentration of 22- μ M in 24 hours. The compound is radiolabelled with ^{99m}Tc using stannous reduction method and ITLC was performed to confirm its radiolabelling. The concentration of chemical constituents and physical conditions

were optimized to obtain maximum yield. The radiochemical yield of ^{99m}Tc labeled 5α , 6β -Dibromo-17-oxo-androstane- 3β -yl-phenylacetate was observed to be $\sim 90\%$. Further for evaluating its potential as a radionuclide probe for the diagnosis of GBM in-vivo studies will be carried out in the rat glioma model. In conclusion, ^{99m}Tc - 5α , 6β -Dibromo-17-oxo-androstane- 3β -yl-phenylacetate has the potential to be exploited as an in-vivo radionuclide probe for glioma imaging.

ABS21325: Prediction of EGFR status from CT radiomics signature using machine learning.

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Epidermal growth factor receptor (EGFR) mutation is an important factor in the prognosis of lung cancer. Radiomics (quantitative imaging features) have been gaining traction in cancer research in the recent past and is being used in prognosis and diagnosis of cancer. We used CT radiomics of 282 Lung cancer patients for predicting EGFR status. We used 6 different machine learning models to assess the predictability of EGFR status from radiomics features. 1093 radiomics features were extracted from CT dicom and RT structure set images using PyRadGUI tool, which is based on pyradiomics. The data was split into 70:30 ratio, where training data was 70 percent and test

data was 30 percent. Logistic regression model showed the best performance with AUC 0.99, while Random forest, decision tree, Adaboost, XG-boost (AUC=0.98) also showed similar performance followed by K-nearest neighbor with AUC 0.79.

ABS73458: A quick workflow to quantify lung metastasis on oncology mouse models

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PET imaging is widely used in oncology research, as it accelerates the development of targeting molecules for novel diagnostic and therapy schemes.

This study presents a workflow for oncology studies, for quick in vivo and ex vivo assessment of novel compounds. Live dynamic in vivo screening of PET-labelled compounds is used to establish uptake regions, find the optimal accumulation times and quantify the targeting efficiency of compounds. Following the optimal selected parameters, in vivo imaging is performed, and tumor regions are established and quantified. After this is performed, animals are euthanized and selected extracted organs are imaged and quantified, using the same system,

to quickly export the %ID/organ, just after the experimental procedure, with no need to wait for the organs to decay.

The oncology model is created by injecting intravenously HT-29 colorectal adenocarcinoma cells on nude mice. Tumors are allowed to grow for up to 3 weeks. When they are ready, imaging is performed, to study the cancer occurrence sites and the highest accumulation of the clinical tracer [18F]-FDG, with a focus on lung metastasis. Dose of 40 uL, having an average activity of 1 MBq of [18F]-FDG administered intravenously via tail vein for the imaging purpose. The mice are first imaged in vivo, and the lung uptake is quantified by delineating regions of interest around the lung and subtracting the heart region. This results in the %ID in the lung for the selected time points. Then the mice are euthanized, and the organs of interest are imaged on the same system (Æ≤-eye), to export the %ID in the lung and other organs, through a second method. The two methodologies are compared to achieve more robust results. For all in vivo and ex vivo scanning, Æ≤-eye imaging system (BIOEMTECH, Greece) is employed.

The rapid establishment of tumour occurrence regions and uptake quantification, along with reduced acquisition and processing time renders this workflow optimised for oncology research.

ABS13947: Alternate Method for Protein Estimation with Bovine Serum Albumin as Standard

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Introduction: Determination of protein concentrations is important for research applications that involve proteins. The choice of protein estimation assay depends largely on the sensitivity and specificity of detection. Assays like Bradford's, Lowry s, BCA assay, and UV absorption are generally the methods of choice for estimation of protein concentration. This study deals with the estimation of concentrations of proteins (monoclonal antibodies) generated from the standard curve using Bovine Serum Albumin (BSA) as the standard in an HPLC system.

Method: Standard solutions of varying known concentrations were prepared using commercially available BSA (Sigma-Aldrich) and chromatograms were generated using HPLC system (Synthra) wherein a TSK gel column was used. The sample volumes were kept constant at 15µl. A calibration curve was then generated by plotting the concentrations versus absorbance and an equation for the best fitted linear regression line was generated. As test samples, different concentrations (calculated) of trastuzumab were injected into the HPLC, and chromatograms were generated using the same protocol under identical

conditions. Their absolute concentration was estimated using the equation generated for the regression and its correlation to the known concentration was estimated.

Results: Table 1 represents the value of absorbance for all standard concentrations of BSA obtained from the chromatograms. Figure 1. represents the standard curve generated along with the equation for the best-fit regression line. The percentage error observed between the calculated trastuzumab sample concentration and their known concentrations was significantly higher for higher concentrations. The average percentage error observed was $44.17 \pm 24.95\%$.

Table1: Absolute Concentration of BSA injected (in ug) and the Absorbance observed (in mV)

Absolute Concentration (ug)	Absorbance (mV)
100	140.36
75	95.93
37.5	49.375
15	22.04
7.5	11.17
5	7.442
1.5	2.115
1	1.3
0.75	0.99

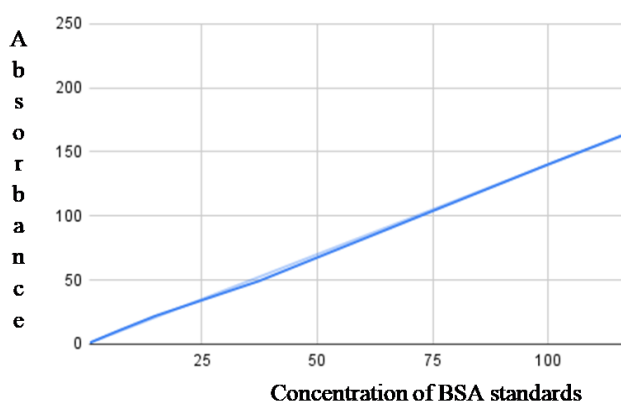


Figure 1: Standard curve generated with BSA standards

Conclusion: Our study reveals that the concentration of monoclonal antibodies estimated using the standard curve generated using BSA gives a higher percentage error in the concentration. Future experiments using IgG as a standard is being explored. This method using HPLC and UV spectroscopy could be an alternate method for protein estimation.

ABS15047: Preparation and Quality Control of ^{99m}Tc -EDTA

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AIM: Glomerular Filtration Rate (GFR) has been considered as a basis for clinical investigations

involving assessment of renal function. ^{99m}Tc -DTPA has been commonly used as a radiotracer for determination of GFR with the help of planar imaging. ^{51}Cr -EDTA plasma sampling has been established as a superior method for GFR estimation due to low plasma protein binding with EDTA. However, ^{51}Cr -EDTA is expensive and not readily available in India. This study aims to optimize the reaction pH and evaluate the radiolabeling efficiency of the ^{99m}Tc -EDTA complex.

METHODS: EDTA was weighed and dissolved in the relevant buffers to obtain solutions with different pH. 1M Phosphate buffer was used for pH 6 & 7 and 1M sodium bicarbonate buffer for pH 8 and pH 9. Freshly eluted $^{99m}\text{TcO}_4^-$ was added to the EDTA solution in presence of stannous chloride as reducing agent, and incubated for 15mins at room temperature. The radiochemical purity (RCP) of the labeled products was determined using Thin Layer Chromatography with Whatman paper as the stationary phase, saline and acetone as mobile phases. The RCP was determined immediately after preparation.

RESULT: ^{99m}Tc -EDTA has Rf of 0 in acetone and 1 in saline. Free pertechnetate was resolved at Rf 1 in acetone and reduced hydrolysed technetium at Rf 0 in saline. The % RCP for ^{99m}Tc -EDTA at various pH in acetone and saline was obtained. (Table 1)

Table 1: % RCP of ^{99m}Tc -EDTA at different pH

	% RCP $\pm$ SD	% RCP $\pm$ SD
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	(ACETONE)	(SALINE)
pH 6	99.28 % (± 0.88)	89.75% (± 2.86)
pH 7	99.175% (± 0.89)	93.44% (± 8.08)
pH 8	98.23% (± 0.04)	90.87% (± 3.65)
pH 9	97.54 (± 2.14)	93.46% (± 10.09)

CONCLUSION: In-house labelled ^{99m}Tc -EDTA showed good radiochemical purity at pH 6 & 7. Stability of these formulations at the respective pH need to be further explored at various time points.

ABS15029: Optimization of Incubation Temperature for Radiolabelling of ^{68}Ga -MAA

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Introduction: ^{99m}Tc labeled Macroaggregated Albumin (MAA) has been used conventionally since 1965 as lung perfusion imaging agent. ^{68}Ga -MAA as opposed to the commonly used ^{99m}Tc -MAA, provides advantage of higher sensitivity, improved spatial resolution, needs lesser time for acquisition, and improved specificity of PET compared to SPECT. Inhouse preparation of ^{68}Ga MAA was performed using the procedure stated in (1). Since ^{68}Ga has a significantly shorter physical half-life (68 minute), the prolonged heating time leads to drastic decay of the formulation. This study aims

to further reduce the duration of heating and while increasing the temperature at which it is performed. The resultant radiopharmaceutical is checked for its radiochemical purity and in-vitro stability over a period of 4 hours.

Method: Commercially available lyophilized MAA kits (BRIT) were reconstituted in saline, centrifuged and the supernatant was discarded to remove additives from the kit. The extracted macroaggregates were resuspended to 1 ml in 0.9% saline and stored in a freezer (-4°C). For radiolabeling, approximately 2.5lakh MAA particles were transferred into the vial containing ~ 5 mCi of $^{68}\text{GaCl}_3$ eluted from $^{68}\text{Ge}/^{68}\text{Ga}$ generator (iTG GmbH) at a reaction pH of 4.5. The reactants were then incubated in an oscillating water bath in 2 different settings- 85°C for 20mins and 90°C for 10 minutes. Radiochemical purity (RCP) of the preparation was measured by instant thin layer chromatography (ITLC). 0.1 M Sodium Citrate mobile phase and silica gel ITLC strip as stationary phase were used to determine RCP immediately after reconstitution, 1 hour, 2 hour, 3 hour and 4 hour post preparation and compared for both reaction temperatures.

Results: Average RCP for ^{68}Ga -MAA preparation after heating at 85°C for 20min was 99.23 ± 1.1 immediately after preparation. The RCP of the preparation till 4hours is shown in table 1. Average RCP for ^{68}Ga -MAA preparation after heating at 90°C for 10min was 96.95 ± 2.9 immediately after preparation. The RCP of the preparation till 4hours is shown in

table 2. % radiochemical yield for 85°C was 73.65% and for 90°C was 85.82%.

Table1: Mean percentage radiochemical purity(±SD) obtained by heating at 85°C for 20min

	0 hr	1 hr	2 hr	3 hr	4 hr
MEAN	99.23±	97.94±	96.16	97.13	97.74±
% RCP (±SD)	1.1	1.7	±6.3	±1.75	1.69

Table2: Mean percentage radiochemical purity(±SD) obtained by heating at 90°C for 10min

	0 hr	1 hr	2 hr	3 hr	4 hr
MEAN	96.95	95.88±	96.42±	96.24±	95.72±
% RCP (±SD)	±2.9	2.8	2.6	3.8	4.2

Conclusion: The ^{68}Ga MAA preparation gave >90% RCP on heating at 90°C for 10min as well as for 85°C for 20min and stable up to 4 hours after preparation. However, preparations heated at 85°C had higher RCP than the preparation at 90°C. The radiochemical yield was higher for 90°C owing to the reduced heating time.

ABS18001: Radiolabelling and stability of ^{68}Ga -NOTA-(Fab')₂-Trastuzumab

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Introduction: Trastuzumab is a monoclonal (anti-human epidermal growth factor receptor 2 protein) antibody used to treat HER2-positive breast cancers. Targeted PET imaging of HER2 with radiolabelled trastuzumab may be a useful probe to determine HER2 expression and to guide in therapy selection. Fragmented antibodies with lower molecular weight are useful for imaging with short-lived radioisotopes due to their faster kinetics and shorter biological half-life. The aim of our study was to check the stability of (Fab')₂-NOTA-trastuzumab over a period of time by radiolabelling with Gallium-68

Methodology: Trastuzumab was enzymatically digested by pepsin to yield (Fab')₂ fragments.

The conjugation of (Fab')₂-trastuzumab fragment with p-SCN-Bn-NOTA was carried out at a molar ratio of 1:10 at pH=9. Radiolabelling was performed using the NOTA-(Fab')₂-trastuzumab conjugate with $^{68}\text{GaCl}_3$, obtained from ^{68}Ge - ^{68}Ga ITG generator, over a period of 3 weeks. The reaction was performed at room temperature for 15mins at pH 4.5. Quality control of the formulation was performed using paper chromatography using Whatman paper no.3 as the stationary phase and 10mM Sodium Citrate (pH=5) as mobile phase immediately after formulation and 2h post radiolabeling. Radiolabelling was repeated weekly for 3 weeks after conjugate preparation.

Result: The mean % RCP $\pm$ SD obtained for ^{68}Ga -NOTA-(Fab')₂-Trastuzumab for up to 3 weeks is given in table 1.

Table 1:

^{68}Ga -NOTA-(Fab') ₂ -Trastuzumab	% RCP $\pm$ SD		
	Week1	Week 2	Week 3
Sodium Citrate (0 hrs)	98.63 $\pm$ 1.33	98.4 $\pm$ 0.71	97.93 $\pm$ 0.37
Sodium Citrate (2 hrs)	97.01 $\pm$ 0.16	96.86 $\pm$ 0.84	96.49 $\pm$ 0.21

Conclusion: The % RCP of ^{68}Ga -NOTA-(Fab')₂-Trastuzumab was > 95 % up to 2 h post radiolabelling indicating the stability of the radiolabelled formulations. Further, the same conjugate aliquots were used over a period of 3 weeks and the radiolabelled formulations prepared showed RCP of >95%, indicating the stability of the cold conjugate too.

The background is a dark blue gradient. In the four corners, there are white line-art patterns resembling electronic circuit boards or neural networks, with lines and small circles connecting them.

Abstract Book

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