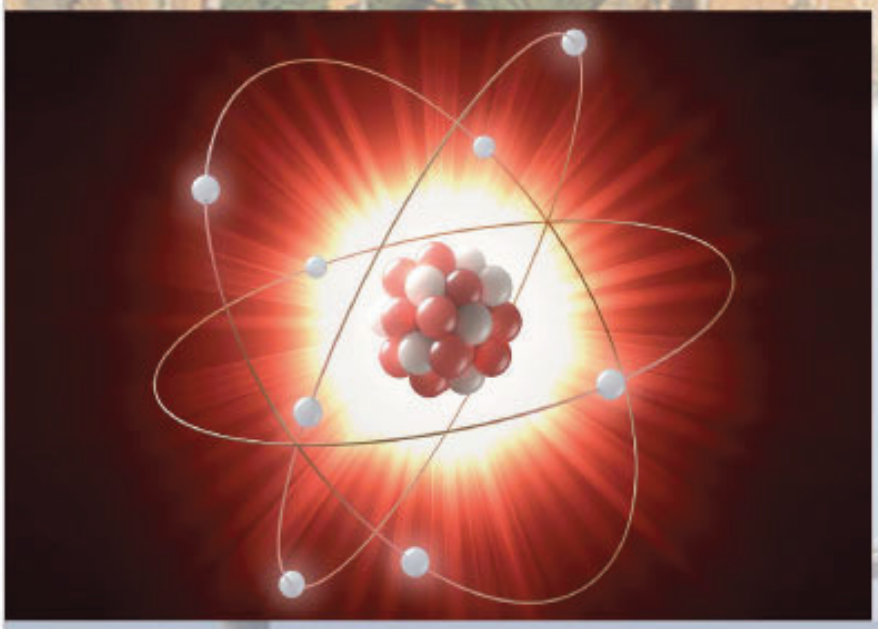
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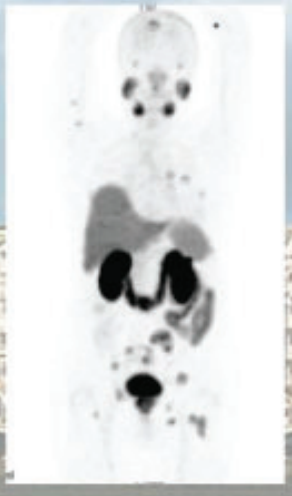
Triumph of Technology

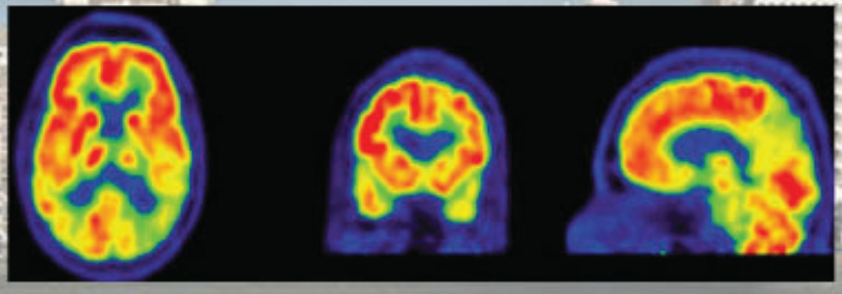


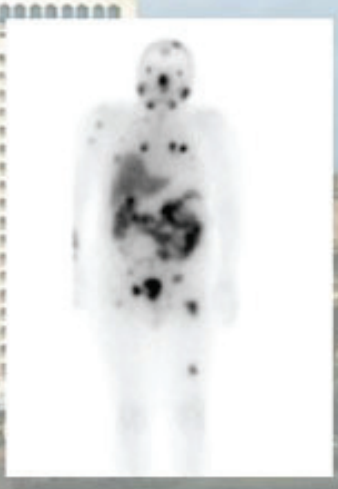
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2nd Annual Conference of Nuclear Medicine Physicists Association of India

Mumbai, 17 & 18 th February 2018







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[2] Based on competitive literature available at the time of publication. Data on file.

[3] Compared to non-hybrid imaging modalities. Addition of PET imaging changes therapy in 33% of cases (2009). The Impact of Positron Emission Tomography (PET) on Expected Management during cancer treatment, National Oncologic PET Registry, 115:410–418, PMID:19016303.

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S. A. BHARDWAJ FNAE
अध्यक्ष
CHAIRMAN



MESSAGE

It gives me immense pleasure to learn that the Nuclear Medicine Physicist Association of India is organizing its 2nd Annual Conference on the theme **"Nuclear Medicine: Quantifying function- Unquantifiable gains"** during February 17-18, 2018. At the outset I congratulate the organizers for choosing this very apt topic taking forward the theme of 1st Conference of NMPAI on "Eruption of Radio-nuclides in Imaging and Therapy".

Nuclear medicine practice is unique in ability to quantify the physiological functions at cellular levels. With the recent advances in molecular imaging, hybrid imaging and computational techniques, Nuclear Medicine has assumed a vital role in diagnostic and therapeutic applications. Evolving from a stand-alone practice, it is now coupled with other imaging modalities such as Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) to improve diagnostic accuracy and optimize radiation exposures to patient. Concurrently, radio-isotope based therapies for cancer and other disorders are also growing, thereby benefitting a large number of patients. On the research front, advances in Nuclear Medicine physics have enriched this field and encouraged research in other aspects of radiotracer imaging, making it an important component of current medical practice. Valuable contribution of NMPAI in this direction is expected in the near future.

With advancements in technology come added responsibilities. Apart from ensuring compliance to regulatory requirements, it needs to be ensured that the technology used is justified, safe and effective. In this context, it is of great importance that this august gathering is going to deliberate upon several key topics and explore new areas for enhancing their professional expertise.

I compliment the Association of Nuclear Medicine Physicists of India for bringing together the specialists in this field for sharing of ideas and knowledge in the "NMPAICON2018" and wish this event a great success.

SBhardwaj

(S.A. Bhardwaj)

Mumbai
02/02/2018

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Message

It gives me immense pleasure to note that the 2nd Annual Conference of Nuclear Medicine Physicists Association (NMPAICON-2018) with the theme *"Nuclear Medicine: Quantifying function- Unquantifiable gains"* is being held at Suba International Hotel, Andheri, Mumbai during February 17th and 18th, 2018. I hope this conference will provide an opportunity to all the participants to interact and deliberate on various topics related to Nuclear Medicine.

Nuclear Medicine is a rapidly growing field because of advances in technology and introduction of new radiopharmaceuticals for diagnosis and therapy and the number of Nuclear Medicine centers in India is growing at a faster pace.

Over the past few years, AERB has taken many steps to make regulation simple and effective without compromising on radiation safety. This includes implementation of online system for consenting process (eLORA) and establishing provisions for Quality Assurance on all Nuclear Medicine equipment's for ensuring proper diagnosis and radiation safety.

The efforts taken by AERB will bear fruits only if there are qualified and trained personnel with up-to-date knowledge to fulfill the required roles and responsibilities for achieving the goal of radiation protection and safety. I appreciate the members of your association for their continuous attempts for enhancing their knowledge through such conferences and seminars towards achieving this goal.

I hope this Conference will shed some light on the risks associated with the use of unsealed radioisotopes for Imaging and therapy and provide guidance for the participants to ensure that these procedures are carried out with proper justification and optimization. I extend my warm greetings and good wishes to the organizers and all the distinguished delegates participating in this conference and wish all the success in achieving their objectives to disseminate the current knowledge in the field of Nuclear medicine.

2.2.18

Mumbai
02.02.2018

(Dinesh Kumar Shukla)
Executive Director, AERB

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जी. गणेश
मुख्य कार्यकारी

G. Ganesh
Chief Executive



MESSAGE

It gives me great pleasure to know that NMPAI is hosting 2nd Annual Conference of Nuclear Medicine Physicist Association of India "NMPAICON2018" at Mumbai, India.

Enormous strides are taking place in the use of radionuclides in the field of nuclear diagnosis and therapy. Also with the emergence of new technology (SPECT–CT & PET-CT) and new molecules (molecular & functional imaging), has given wider possibilities for clinical applications, teaching and basic research in the field of nuclear medicine. This has posed great opportunities and challenges in this field wherein scientists, technologists, radiochemists, medical physicists and doctors have to work in synergy for better management of patients.

BRIT has been making its contribution for past three decades by supplying most of the radiopharmaceuticals to various nuclear medicine centres in India.

The theme of this year's conference is "Nuclear Medicine - Quantifying function – unquantifiable gains". Keeping the theme in mind, the conference will not only provide an opportunity to nuclear medicine team to showcase their work but also get invaluable inputs by experts in the field of nuclear medicine.

I wish the organisers all success for scientific programme along with fruitful interaction with participants.

Sganesh

(G. Ganesh)

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Message

As invited Guest of Honour, I first wish to extend my heartiest congratulations to the oganisers of the 2nd Annual Conference of Nuclear Medicine Physicist Association of India "NMPAICON2018" to be held in Mumbai on 17th and 18th February 2018. It is no mean feat to bring such an event to fruition, and to attract such a diverse and fascinating group of delegates from a various parts India. And to you all, I offer my warmest welcome to this wonderful conference and to Mumbai. There have been significant changes in Nuclear medicine in the last decade with respect to technology and radiopharmaceuticals. These changes in imaging technology SPECT/CT, PET/CT and PET/MR brought great interest of clinicians in the Nuclear Medicine. Nuclear Medicine and Molecular Imaging techniques are all set to change the management of many diseases, from generalised treatment to individualised treatment in the form of targeted therapy. In recent past, we had successful SNM India 49th Annual conference which covered all aspects (Instrumentation, Radiochemistry and Clinical Applications) of our specialty. It is therefore fitting that conferences such as this one should be taking place, providing you with the opportunity to present your latest work to an audience of critical and informed peers dedicated to basics of Nuclear Medicine. Not only will you be considering the teaching and learning aspects of medical physics, instrumentation and radiation biology, but also enjoying social gathering. So, please enjoy the stimulating programme that has been placed before you for the following two days. It is a great opportunity to hear from those taking the lead in the growth of this sub specialty of Nuclear Medicine. I am sure you will also delight in what Mumbai has to offer you as an exciting city, and I wish you every success at the conference.

Wishing all you a pleasant stay in Mumbai and a fruitful conference.

Warm Wishes,

Rakesh..

Rakesh Kumar, DRM, DNB, PhD, FAMS, FICNM
President, SNM India
Professor & Head
Diagnostic Nuclear Medicine Division
Department of Nuclear Medicine
All India Institute of Medical Sciences
New Delhi
Email: rkphulia@yahoo.com

President
Nuclear Medicine Physicist Association of India

Subhash Chand Kheruka
President,
Nuclear Medicine Physicists Association of India
Senior Scientist (Medical Physics)
Department of Nuclear Medicine
Snajay Gandhi Post Graduate Institute of Medical Sciences
Rae Bareli Road, Lucknow (UP), India



Message

On behalf of the Nuclear Medicine Physicists Association of India, It gives me an immense pleasure to welcome you to the 2nd Annual Conference of association (NMPAICON2018) in Mumbai on 17th and 18th February 2018.

The theme of the conference is "Nuclear Medicine: Quantifying function- Unquantifiable gains". The scientific programme under this theme is designed in such a way that it will stimulate both scientific intellect and clinical knowledge in the field of Medical Physics in Nuclear Medicine, Radiobiology, Radiopharmacy and Radiation Protection. I hope that this conference would provide a platform for fruitful interaction among delegates, exchanges of ideas, sharing information and experience among eminent faculties in the field of Medical Physics (Nuclear Medicine), Nuclear Medicine Clinics. Nuclear Medicine Radiopharmacy and Radiation Protection.

Nuclear Medicine Physics profession in India has long history and NMPAI was founded in 2007 with objective of encouraging the application of applied physics in Nuclear Medicine.

NMPAI always been in forefront in keeping the scientific sprit alive and organizing the professional and educational activities in various part of India.

I take this opportunity to sincerely thank all the delegates and faculties who have find valuable time to attend this conference in enhancing scientific acumen for each other.

I extend my best wishes to the organizer of this conference for great success.

With Warm Regards

Subhash Chand Kheruka

Secretary
Nuclear Medicine Physicist Association of India

Amit Nautiyal
Secretary (HQ)
Nuclear Medicine Physicists Association of India
Kolkata



Message

It gives me immense pleasure to send this message for the Souvenir being brought out on the occasion of 2nd Annual Conference of NMPAI being hosted by organising committee of Mumbai. The theme chosen of "Nuclear Medicine: Quantifying function- Unquantifiable gains" is indeed very appropriate, considering the important role of Nuclear Medicine in modern technology.

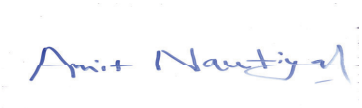
The annual meet is a unique occasion to avail of the opportunity of renewing friendships, building up new relationships, to discuss matters of common interest and furtherance of knowledge through various scientific sessions, orations as well as mutual interaction.

NMPAI had always been in the forefront in uplifting the field of Nuclear Medicine Physicist and Technologist by various activities and understand the need of members across the country. Continuous efforts of present Executive committee and their members lead to recognition of NMPAI by various authorities. In this state we are still in regular communication with Ministry, AERB and various reputed medical institutions.

I congratulate the members of organizing committee for bringing out this Souvenir and also express my thanks to those who have enriched this publication by various contributions.

I wish the conference all the success and send my congratulations to the organizing committee.

I am sure that, this conference will be a grand success.



Amit Nautiyal
Secretary (HQ)
Nuclear Medicine Physicists Association of India
Kolkata

Patron
NMPAICON-2018



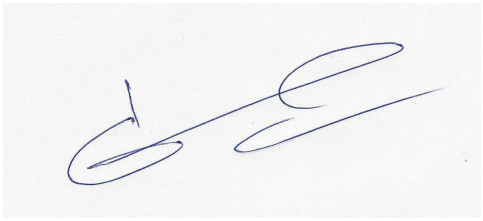
Dr Anshu Rajnish Sharma
DNB, DRM, MNAMS (Nuclear Medicine)
FICNM, FANMB, FRCP (Glasg.), UK
Immediate Past President, SNM, India

It is my pleasure to welcome you in Mumbai city, the financial capital of India on the occasion of 2nd Annual Conference of Nuclear Medicine Physicists Association of India (NMPAICON-18) on February 17-18, 2018. Although the objective of this submit is the deliberation on scientific and technological development in the field of nuclear medicine technology and radio-chemistry, but I personally feel that we should use this opportunity for socializing and making new friends. As the friendship grows amongst co-workers, we start thinking in same frequency and our efforts start showing additive outcome.

The local organizing and scientific committee have been working hard to make this event memorable and I am sure that you will enjoy their hospitality as well scientific agenda of program.

My warm greetings go to distinguished delegates, faculty members, sponsorers and organizers of NMPAI-18, without their indulgence and participation this grand event would have not been possible.

Jai Hind !



Dr Anshu R Sharma
Consultant & Head
Dept of Nuclear Medicine & PET-CT
Kokilaben Dhirubhai Ambani Hospital, Mumbai
Email: anshurajneesh@rediffmail.com
Feb 10, 2018



2nd Annual Conference of NMPAI
(NMPAICON-2018)
"Nuclear Medicine: Quantifying function- Unquantifiable gains"
Date: 17th - 18th February 2018;
Venue: Hotel Suba International, Andheri East, Mumbai-99



First of all, let us take the pleasure of extending our warm greetings to you for being an active participant in the growth of Nuclear Medicine.

With great pleasure we invite you to attend and participate in the 2nd Annual Conference of Nuclear Medicine Physicists Association of India, India (NMPAICON-18) to be held at Mumbai, during Feb 17-18, 2018.

As we all know, Nuclear Medicine has reached a zenith in recent times and will, without any doubt, maintain and improve its position in this country, thanks to the contribution made by each of you. Nuclear Medicine, by its very own nature, is a truly multidisciplinary specialty aiming to deliver the beneficial advantages of Nuclear Energy in Health Sciences.

Nuclear Medicine has grown leaps and bounds with the advent of PET-CT Scans and SPECT Gamma Camera. Availability of newer radiopharmaceuticals like ^{18}F-FDG, ^{18}F-FLT, ^{68}Ga-DOTA, ^{99m}Tc-TRODAT provides it with the teeth to incisively define diseases and disease processes. Therapeutic radiopharmaceuticals like ^{188}Re-HEDP, ^{177}Lu-DOTATATE/PSMA and ^{153}Sm-EDTMP, ^{131}I-MoAb, ^{90}Y-DOTATATE give us the ability to precisely target tumour metastases and improve the quality of life of cancer patients. Nuclear Medicine instrumentation also has undergone a sea change, from the era of single detector Gamma Camera, it now boasts of Dual head systems with Autocontour scanning, Fusion imaging, and Time of Flight PET imaging system. Dedicated equipments like Intraoperative probes and Cardiac Scanners are becoming common place. Newer computer based algorithms like Adaptive Iterative reconstruction algorithm, RAMLA allow obtaining superior quality image. As such, a large number of innovative technologies are making inroads in the detection and positioning of radiation. These technologies carry the promise to boost our unique position in detecting and treating diseases. The theme of our conference "Nuclear Medicine: Quantifying function- Unquantifiable gains" aptly describes our potential.

The organizers of this event, have taken great efforts to bring forth a special package of guest lectures and workshops to advance your knowledge in the field. Needless to say that it will inspire and educate all fraternity members whether they are biologists, chemists, physicists or software developers to the core. Students of nuclear medicine, whether they are budding -physicians, -technologists and -physicists will most surreally benefit by participation in this program. These academic deliberations will enhance their professional skills and allow them to personally interact with each other.

We personally wish to request each one of you to participate and also recommend your colleagues in the field to do so. The organizers are undertaking every effort to make your stay comfortable and memorable one. Eventually the success of our conference will only be assured by your active and earnest participation.

Organising Chairman
Dr. Basant L Malpani &
Smt. Bhakti Sachin Shetye
http://www.nmpaicon.org



Rajnath Jaiswar

Organizing Secretary

2nd Annual Conference of Nuclear Medicine
Physicist Association of India
NMPAICON-2018



Sneha Mithun

Message

Warm Greetings!

It gives me an immense pleasure to invite you for the 2nd Annual Conference of Nuclear Medicine Physicists Association, INDIA. The Organizing Committee has worked hard to make this conference a memorable one. Needless to say that team of NMPAICON-2018 has arranged the academics as well as Trade to provide the best of atmosphere for all delegates.

I assure that our team with professional commitment and great zeal will provide all of us an excellent opportunity to experience innovative and unexplored standards of a high quality conference. It has been a good learning experience and I would like to convey my sincere thanks to everyone concerned for having given us this opportunity.

I hope all the delegates will derive maximum benefit from this conference and take back fond memories of the Mumbai experience.

Best Wishes.

Rajnath Jaiswar

Sneha Mithun



Ashish Kumar Jha
Chairman
Scientific Committee
NMPAICON-2018

Message

Dear friends and colleagues,

Welcome to NMPAICON-2018.

It is a great honour and privilege for me to extend warm welcome to all the delegates and the august faculty for the 2nd National Conference of Nuclear Medicine Physicist association of Indian (NMPAICON-2018) at Mumbai the financial capital of India.

The theme of this conference is *"Nuclear Medicine: Quantifying function- Unquantifiable gains"* which describes the potential of nuclear medicine in narrowing the gap between known and unknown. This conference will focus on education and training, quality and guidelines and update on several aspects of scientific and routine practice of nuclear medicine and molecular Imaging. The scientific sessions are planned to include areas of tremendous importance and includes luminaries in the field, both national and international. Our faculty comprises the most experienced teachers renowned in their fields from all over the country and overseas. We have speakers with diversified experience, who will not just pass on their knowledge, but the blend of knowledge and expertise in nuclear medicine and advanced technology.

The two days brainstorming scientific program promises to be a great delight for all the attendees. Two days scientific program is divided in eight thematic scientific sessions, which will be blend of lectures, panel discussions and small quiz. Thematic scientific session comprises of, radiation biology & safety, medical physics & instrumentation, radiochemistry & radio-pharmacy, infrastructure development, clinical nuclear medicine 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 50 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 20 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, organising 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 and comfortable stay in Mumbai at NMPAICON-2018.

Ashi

Ashish Kumar Jha

Organizing committee NMPAICON-2018

Patron



Dr. Anshu K Sharma

Organizing Committee, NMPAICON-2018

CHAIRMAN



Dr. B. L. Malpani



Mrs. Bhakti S.

Central Scientific Committee, NMPAICON-2018

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"Nuclear Medicine: Quantifying function- Unquantifiable gains"

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Invited Lecture

Biological effects of radiation: concept behind projection models and linear no threshold model

Dr. Nagesh N. Bhat
Radiological Physics and Advisory Division, Bhabha Atomic Research Centre

Introduction of radiation technology to mankind during end of 18th century and its aggressive gain during beginning of 19th century has lead to invention of extensive applications. Though its use was limited to medicine in the initial days, the momentum got acquired to other areas in very short time. During those days, biological effects of radiation were not well known. This shortcoming has also resulted in many abuses and unregulated uses of these technologies, which resulted in many unwarranted human exposure. Sooner, many health effects of radiation among these exposed individuals were discovered, which resulted in need of regulation and control/regulation over the radiation generating machines and sources. To understand mechanistic details of radiation damage, risk calculations and use these human data to set the limits, it is necessary to have thorough knowledge of effects of radiation.

With very limited knowledge of effects of radiation, during initial days, safety norms were set based on limiting the working hours of technologists. This was only to avoid very serious health hazards. Over the years, it was realized that radiation can also cause many serious health effects such as cancer even at moderate doses. With added human data, dose limits were revised drastically over the years. These dose limits were based on very strong human data from past exposures.

Interaction of radiation with living system is different only from the way the damage are expressed. Information on deleterious effects of ionizing radiation helps us to take necessary precautions and also to set the operational limits for radiation exposure. Such knowledge is also helpful for many medical applications such as cancer therapy and diagnosis.

Extensive information collected over more than a century is based on biological effects observed on human population such as early medical victims of wrong use of radiation, victims of many radiological accidents and war use i.e., Hiroshima and Nagasaki atomic bomb survivors. During early days of observation, it was thought that radiation can cause leukemia type of cancer. However, continued studies lead to the observation that risk is not just limited to leukemia but also many solid cancers with age dependent incidence. While the information gathered on biological effects got refined over the time, it was also realized that the risk estimates based on limited knowledge are grossly inadequate.

During initial days of radiological protection, dose limits were derived based on limited information on deterministic effects such as skin reactions and prodromal syndromes. International X-Ray Protection Committee (IXRPC1928) has recommended restrictions on work load or number of working hours without defining dose. The projected dose of about 1 Sv in a year is now estimated based on these recommendations.

Extensive epidemiological studies were initiated to address the various complexities of risk estimates. Besides, there were many uncertainties with epidemiological parameters such as individual dose, protracted exposure, non-uniform exposure, mixed radiation and dosimetry complexities. It is necessary to follow up the cohort for lifetime to derive life time risk. The purpose of such study is to estimate projected risk on occupational workers. Many cancers having very long latent period are thought to pose life time risk. They are also known to increase background incidence which in turn depend on attained age or the age group of individuals.

An important recommendation during 1990 with document by International Commission of Radiological Protection (ICRP-60) which analyzed limited data till about 1987 has summarized observation on ABS cohort. However, it had major limitations as life span study was incomplete. Hence two projection models were coined to address the complexities of projecting the risk observed using limited data from ABS cohort to derive life time risk and also to project the estimated risk to occupational cohorts, general public and other cohorts if needed.

The first projection model named additive model was formulated with basic assumption that the

estimated risk is uniform throughout the life time of ABS cohort. The additive increment of risk is assumed to be simple function of dose and age at exposure. This was a fairly simple model and could explain majority of early cancers such as leukemia. However after few years, ABS cohort has shown age dependent increase in many solid cancers. Hence it became necessary to formulate a model which takes care of influencing factors such as sensitivity of cohort, age, sex, life style factors which all can influence background incidence of cancer. This projection model named multiplicative model assumed, the risk, besides dose and age at exposure, is a multiplicative function of background incidence of cancer. Upon completion of life span studies, it is possible to completely use the additive model as complication of projecting the risk to remaining living population of ABS cohort does not exist. Currently, in the recent ICRP-103 document, mixed proportion of risk is being used for many cancers while for leukemia type cancer which gets expressed with minimal latent period, only additive model is adopted.

For genetic risk evaluation, due to absence of significant human data for the induction of genetic damage, risk evaluation is based mainly on the results from model experimental system i.e. mice. On the basis of visible genetic disorders like those caused by recessive mutations, dominant skeletal abnormalities and dominant cataract induction, genetic risk for human beings is evaluated. It is estimated that a dose of 1 Gy doubles the incidence of mutations (Doubling Dose). However, since many genetic diseases (over 90%) are multigenic and involve complex interactions, a doubling dose of radiation increases the genetic disorder only by 10-15%. Natural incidence of genetic disorders among human beings is almost 10-20% of all live born. As per the estimates, exposure of the germ cells or parents to a dose of 10 mSv can increase the incidence of genetic disorders by 50-150 cases per million live born. With recent revisions, relative contribution of gonadal dose to overall detriment for genetic effect is brought down to 4% compared to earlier 18%. With due consideration of possible deterministic effects such as temporary sterility, the new tissue weighting factor for gonads is 0.08 compared to earlier 0.2.

It may be concluded that the estimated risk arising from low-level radiation exposure is very small. Present levels of occupational exposure of radiation workers is associated with a mortality risk of 50-100 cases per million per year. These risk figures are based on high dose data by linear no threshold projections. However, it is important to note that at low and moderate doses, none of the epidemiological studies have shown any significant increase of observed cancer and heritable effects. Though it cannot be categorically concluded that low dose effects are negligible, it is indicative that at such doses the risk figures may be substantially lower than anticipated. Many biological observations such as immune-response, adaptive response, low dose sensitivity are being explored. However, these results are not conclusive as of today. In spite, ignoring the possibility of low level effects, assuming the validity of linear no threshold projection conservatively, the mortality risk are calculated such that they conform to the safety norms of industry standards. Maximum allowed annual mortality rate applicable for evaluating occupational limits is 1 in 1000. To account for the morbidity of non fatal cancers, detriment is being used which can be considered mathematical equivalent of mortality. Detriment is a function of incident rate, morbidity associated, quality of life and length of life lost due to the effect. Besides, the principle of ALARA and constraints while optimizing the dose limits have helped to achieve personnel doses to occupational workers to a level much below the recommended ones. Hence radiation industry can be classified as a safe occupation from the point of view of occupational mortality risk.

Both cancer and genetic risk evaluation are based on conservative approach of estimation of maximized risk. Linear-no-threshold (LNT) model which projects estimated risk from high dose data to doses relevant to occupational exposure assumes that the risk is linear throughout and no threshold at low doses may exist. The rationale behind adopting LNT model is not scientific but philosophical in the absence of concrete and conclusive data. There is a possibility of over estimation of risk by this approach. However, it should be noted that these estimates are used only for the purpose of radiological protection and setting the limits. Many misunderstandings surrounding these risk

estimates have lead very serious implications in justification and optimization of radiation technologies. On the other extreme, many investigations have advocated possibility of threshold doses, non-linear response at low doses and even hormesis which predicts beneficial effects of radiation at low doses. The logics behind these studies are not scientifically sound due to unavoidable statistical uncertainties. It is necessary to understand the technicality behind adopting LNT model and should not be misused for predicting risk for low doses such as occupational or diagnostic exposures.

Diagnostic reference level (DRL) in nuclear medicine: Need to develop Loco-regional DRL.

Ashish Kumar Jha,
Department of Nuclear Medicine, Tata Memorial Hospital, Parel, Mumbai-12

Regulations related to professional radiation exposure and exposure to the general public is clear and well established and such regulations are implemented by the national regulatory authorities in their respective countries. National regulatory authority sets the operational limit for occupational workers and general public in their respective countries, in the light of ICRP recommendation. But there is no prescribed limit has been established by the regulators to control medical radiation exposure which contributes majority of radiation burden to the mankind by manmade radiation. As per NCRP report No. 160 approximately 48% of total radiation exposure (including background radiation) to the US population is due to medical radiation exposure. Medical radiation exposure is decided by the doctors treating the patients considering the urgency and requirement of radiological procedure. Hence there is requirement of guidelines or regulations to restrict or minimize the radiation exposure to the patients undergoing various radiological procedures.

For the very first time ICRP Publication 60 (ICRP, 1991) provided the recommendation on optimization of protection of patients in medical exposure. As per ICRP 60, "Consideration should be given to the use of dose constraints, or investigation levels". In ICRP Publication 73 (ICRP, 1996) the term "diagnostic reference level (DRL)," was introduced first time. DRL is recommended to develop for all the radiological and nuclear medicine procedure but it should be advisory in nature and provide a reference exposure level for specific imaging protocol. There are some exceptions like screening tests for breast cancer, where DRL used as "achievable levels" and become more like a constraint. The main objective of a diagnostic reference level for radiological procedure is to help avoid unwanted radiation dose to the patient that does not contribute to the clinical purpose and adds to the diagnosis. This is derived from relevant regional, national or local data and the mean or other appropriate value observed in practice for a suitable reference group of patients or a suitable reference phantom. A reference group of patients is usually defined within a certain range of physical parameters (e.g. height, weight). If an unselected sample of patients were used as a reference group, it would be difficult to interpret whether the observed value for the sample is higher or lower than the diagnostic reference level. A diagnostic reference level is not applied to individual patients but it applies to the practice. DRL serves several purposes like, provides guidelines, radiation exposure limits and harmonize loco-regional radiological diagnostic procedure and practices. Many countries have developed their own diagnostic reference level (DRL) in order to achieve optimal image quality of CT imaging with minimum radiation exposure to the patient. However, the same is not available for whole-body CT acquired in PET/CT or SPECT/CT studies. The utility of CT in PET/CT or SPECT/CT studies in prevalent clinical practice is not limited only to anatomic localization and attenuation correction, but extensively used for the diagnostic purposes. Therefore CT of the PET/CT or SPECT/CT studies poses substantial amount of radiation exposure to the patients, which warrants developing DRL for PET/CT and SPECT/CT studies too. Hence various researchers have tried to generate DRL for CT scan acquired along with whole body PET/CT. In India, our group has tried to generate DRL for CT acquired in whole body PET/CT scans. The average CTDIvol noted in that study was 11.2 mGy. The 60 percentile CTDIvol reported in this work was within one standard deviation range.

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Radiation Emergency in Nuclear Medicine and Preparedness

Rajnath Jaiswar,
Bombay Hospital, Mumbai

Nuclear Medicine is a healthcare facility where large amounts of unsealed radioisotopes are used for the diagnosis of various diseases and the treatment of cancer. Human error or failure of radiation protection will lead to accident/mishap. Radiation accident in Nuclear Medicine can cause the risk to public and personal radiation safety.

Working with unsealed radioactive sources in nuclear medicine carries the potential risk of contamination. Careful design of a department and its operational procedures will minimize but never completely eliminate the possibility of such incidents occurring. Emergency planning is an important part of handling such incidents as the procedures to reduce the hazard once an incident has occurred.

While handling any unsealed radioisotope, it is essential to always be conversant of all radiation health safety. Appropriate care and radiation safety procedure should be ensured at all stages of formulation, handling, injection and imaging. Administered radioisotope is being excreted through urine over a few hours and sometimes patient vomits the administered dose & causes additional radiation exposure burden to the occupational & surrounding personnel.

In general any emergency/accidental situation arises in the Nuclear Medicine Department; it has to be handled in a very careful manner. To handle such situations an Emergency Preparedness program should be available in the institute. The emergencies that one may foresee during radionuclide therapy are spillage, misadministration & sometime death of the patient. Spillage of the radioactivity is a major concern and can be handled safely by decontamination procedure. Assessing the magnitude of the radiation hazard and the effect of decontamination efforts, containing the spread of contamination, minimizing the radiation dose to individuals, and continuing to decontaminate to the lowest level possible are principles to follow in managing any incident. Nuclear medicine staff should be familiar with techniques for decontaminating different anatomical sites on the body; for eliminating or reducing the uptake of radioactivity absorbed into the body; and for decontaminating dry and wet surfaces, equipment, clothing, and bedding.

The regulations governing the disposal of cadavers containing radioactivity are applicable as per guidelines provided by AERB. It should include anticipating where such incidents are likely to occur, training and exercising staff in the appropriate procedures to deal with these incidents, providing a comprehensive decontamination kit, and implementing a routine contamination monitoring survey.

By making & implementing the proper radiation safety program, the radiation exposure to the patient, nuclear medicine physician, physicist, nurses, staff and the public can be kept as low as reasonably achievable.

Overall Implementation of Radiation Safety Programme in Nuclear Medicine Practice

Dr. Pankaj Tandon
Radiological Safety Division, Atomic Energy Regulatory Board, Mumbai – 400 094

Since the beginning of the 20th century, ionising radiation has been employed in medicine for both diagnostic and therapeutic purposes. The belief that radioactive sources could heal many different diseases led to a rapid increase in the usage of radioactive material; in conjunction with the lack of knowledge of the biological effects of radiation, this resulted in many accidents and numerous pathologies in both patients and

operators. Ionising radiation procedures for medical purposes have been invaluable in improving patient care. Accordingly, the use of radiation in medicine has continued to increase over the years, accompanied by improvements in safety standards. Nuclear Medicine (NM) has been deeply involved in this process. Both applications – diagnostic and therapeutic – showed great initial potential and important advances have repeatedly been achieved over the intervening decades.

The development of NM has been accompanied by great responsibility, since the safety of both the professional and the patient depends on the correct use of radiation. The professional should not be harmed by the radiation needed to perform each procedure and the patient should only be exposed to radiation after the benefit/risk ratio has been considered. The benefits of nuclear medicine procedures are immense and certainly exceed the risks. However, this is only true when they are ordered appropriately and studies are optimized to obtain the best image quality with the lowest radiation dose. Since the nuclear disaster at the Fukushima Daiichi Nuclear Power Plant in 2011, radiation safety has become an important issue in nuclear medicine. Many structured guidelines or recommendations of various academic societies or international campaigns demonstrate important issues of radiation safety in nuclear medicine procedures. There are ongoing efforts to fulfil the basic principles of radiation protection in daily nuclear medicine practice.

Medical administrations of radiopharmaceuticals must be performed under the prescription and supervision of an authorized user physician. Recent advances in the field of Nuclear Medicine (NM) are expanding the role and responsibilities of the Medical Physicist / Nuclear Medicine Technologist to include more complex and detailed tasks. New technologies are making the diagnosis, management, and treatment of illnesses more sensitive, more specific, more accurate, and ultimately safer for both the patient and the technologist. The average effective dose from nuclear medicine imaging depends on the test being performed. In general, the amount of radiation from nuclear medicine procedures is similar to that from other radiologic procedures and from natural background radiation.

Exposure to high levels of ionizing radiation can lead to serious adverse effects, including cancer. While there is no direct evidence that the low amount of radiation used in nuclear medicine leads to such effects, it is prudent to assume that every exposure to ionizing radiation carries some risk. However, when warranted, a nuclear medicine test gives your doctor important information that is worth the small possible risk.

It has been noted that provisions for the incorporation of radiation safety features are best made at the facility design stage. The siting and layout should take into account workload and patient flow, both within the nuclear medicine facility and, in cases where the nuclear medicine facility is part of a larger hospital or medical centre, with other departments of the wider facility. The nuclear medicine facility is likely to provide services to both inpatients and outpatients, so the location of the facility should give easy access to both groups. Consideration should also be given to provide easy exit routes for patients, after the examination or treatment has been performed, that minimize movement through the facility. A typical nuclear medicine facility using unsealed sources requires areas for the following: source storage and preparation (radiopharmacy or radioisotope laboratory or “hot lab”), radiopharmaceutical administration to patient, uptake rooms, imaging (in vivo), radioactive waste storage. For those nuclear medicine facilities performing therapy with radiopharmaceuticals, a dedicated ward for patients undergoing such treatments should be considered and a special consideration needs to be done for the patient attendants in a radiation free area. In addition, a nuclear medicine facility requires separate waiting areas for patients before and after radiopharmaceutical administration, changing areas and toilets. The facility will also have areas where radioactive materials are not expected to be found, such as in offices, reporting areas and staff rooms, including cloakrooms, toilets for staff. For detailed guidance on setting up nuclear medicine facilities, the AERB website (www.aerb.gov.in) may be referred.

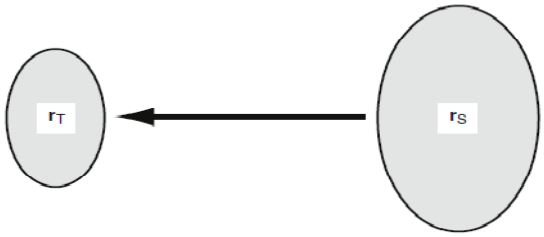
For security purposes, nuclear medicine facilities should be located in areas where access by members of the public to the rooms where sources, including generators, and radiopharmaceutical dispensing equipment are used and stored can be restricted. Further, the proximity of source storage facilities to personnel that may respond in the event of a security breach should also be considered. As a general rule, the design of the nuclear medicine facility should

make provisions for safety systems or devices associated with the equipment and rooms.
Issues to be considered for the design of the nuclear medicine facility include: optimizing protection against external radiation and contamination, maintaining low radiation background levels to avoid interference with imaging equipment, meeting radiopharmaceutical requirements, and ensuring safety and security of sources (locking and control of access). For external exposure, the three factors relevant to dose reduction (time, distance and shielding) should be combined in the design to optimize occupational and public radiation protection. The design of the nuclear medicine facility should include provision for secure and shielded storage for the radioactive sources. Shielding should be appropriate to the type and energy of the emitted radiation. Special consideration should be given to avoid interference with work in adjoining areas, such as imaging or counting procedures, or where fogging of films stored nearby can occur. Signs and warning lights should be available at the entrances of controlled and supervised areas to prevent inadvertent entry on control of public access. Bathrooms designated for use by nuclear medicine patients should be finished in materials that are easily decontaminated. Nuclear medicine facility staff should not use the patient bathrooms, as it is likely that the floors, toilet seats and sink tap handles will be contaminated.
In conclusion, the overall radiation safety in the nuclear medicine department starts from the design of the facility, procurement of radiation protection instruments, appointment of qualified and technical competent staff, ordering and receipt of radioactive materials, dispensing, administration of radioactivity to the patient, scanning and management of radioactive waste generated during the nuclear medicine procedures.

MIRD calculation and uses in current nuclear medicine practice

Chanchala U Kale,
Kokilaben Dhirubhai Ambani Hospital, Mumbai.

Medical internal radiation dosimetry is the discipline of determining the absorbed doses received by an individual as a consequence of intake of radioactive substances. The basic formula for absorbed dose , D= dE/dm , where dE is the mean energy imparted by ionizing radiation to matter in a volume element and dm is the mass of matter in it. The S.I. unit of absorbed dose is joule per kilogram (J/Kg) or gray (Gy)
The three main applications within N M for which radiation dosimetry calculations required are 1.Regulatory requirement to establish the radiation dosimetry profile of new radiopharmaceutical 2.often unexpectedly there is need to calculate the absorbed dose received by specific patient(found to be pregnant after nm procedure) or misadministration. 3. Patient specific dosimetry in therapeutical N.M.
ICRP and MIRD Committee of American Society of Nuclear Medicine had greatest influence in development of N M radiation dosimetry.
Calculation of radiation dose by MIRD method . The MIRD expression is simple and gives the absorbed dose to a target region Rt at time t from the activity contained in the source region rs.
Drt = Ãrs (t) S(rt←rs; t)



Ãrs is total number of nuclear disintegration in the source region that have occurred up to time t. It is nothing but cumulated activity and S(rt←st;t) is the 'S-factor' it is the absorbed dose in the target region per nuclear disintegration in the source region. Or S-factor is fraction of energy released in dintegration within source organ and which is deposited in rt and is normalized to mass mt. Because of the distance separating rs and rt and mass mt, the s-factor is function of radionuclide and sex and age dependent sizes of and distances between source and target regions. In MIRD schema, these are defined as specific organs, tissues or contents of organs. The absorbed doserate at time t due to activity in rs is dDrt(t)/dt = Ãrs(t) S (rt←rs ;t)
Cumulated activity is continuously changing depending on uptake of radiopharmaceutical ,excretion from organ, physical decay. Time activity curve can be drawn to find the value of cumulated activity. residence time r is time radionuclide stay in organ.
If the uptake by the organ is instanteneous and there is no biological excretion

Ãrs = 1.44 TpA0 where A0 is injected activity.Tp is physical half life.so depending characteristics of rps one can calculate Ãrs.
The total absorbed dose to rt is
Drt (T) = 0∫∞dt Ãrs(t) S(rt←rs ;t) ,upper limit for integration is set as ∞ wheras ICRP take as 50 yrs.
From the definition of S-factor,
S(rt←rs ;t) = ∑ ∫ Ei Yi Ø (rt←rs ;Ei ;t)/mt ,where the summation is over all nuclear decay channels.Ei is the energy of the ith decay, Yi is the yield of that particular channel, Ø is the absorbed fraction of the energy Ei emitted at the time t in rs which is absorbed by rt and mt is mass of target organ at time t. substituting in above equation
Drt(T) = ∑ ∫dt Ars(t) ∫ Ei Yi Ø (rt ←rs ;Ei ;t)/mt is generic equation. Summation takes into account the absorbed doses to rt from multiple sources
Evaluation of S-factor- In the conventional MIRD schema ,the source and target region are geometrical approximations of organs, tissues and organ intracavitary contents. Monte carlo code is used to simulate the radiation transport from radionuclide in rs to target region rt and energy deposited to yield the absorbed fraction .The individual energy deposition in target region is summed and normalized to mass of the target region. S –factor have been evaluated typically for reference anthropomorphic phantoms. And are available on MIRD reports, and RADAR website.
In current MIRD schema 24 target organs are explicitely specified. The whole body is considered as target region.The contents of GI tract and urinary bladder are treated as source regions and the wall of G I tract and U Bladder are treated as target regions.
ICRP method : The ICRP developed a dosimetry model almost identical that of MIRD committee. The main difference is because of focus of ICRP is on radiological protectio of workers ,the cumulative dose equivalent(cumulative equivalent dose) is calculated instead of absorbed dose. And is the total dose received by region rt in period of 50 years. Expression is given
H50 ,rt = k ∑ Urs SEE(rt←rs),Urs is cumulated activity in source, SEE the specific effective energy is S-factor multiplied by weighing factor Wr (or quality factor Q),k is constant.
A manual calculation of absorbed doses is daunting and time consuming procedure. Software like OLINDA/EXM, OEDIPE, MABDOSE, CELLDOSE, and RADAR are available in market.

Basic Concept and Evolution of SPECT and SPECT/CT

Dhananjay Kumar Singh,
Department of Nuclear Medicine, Dr. RMLIMS, Lucknow, Email: dkpalam@gmail.com

SPECT is now well established an important and continuously growing imaging modality. SPECT (Single Photon Emission Computed Tomography) is basically single head or dual head gamma camera with a precise electro-mechanical capability to accurately acquire projection data at a different angle in a 360-degree rotation. The basic concept of a gamma camera imaging system is the injection in a patient of a suitable radiotracer or radiopharmaceuticals that able to bind itself in a precise volume and to emit gamma (Y) rays providing information on physiological functionalities and their time evolution or on the localization of pathology. SPECT involves reconstruction of 3D radiotracer distributions from 2D projection images of the radiotracer distributions.
Before the discovery of Anger Camera the radionuclide imaging method was very crude, but with the emergence of Anger camera and development of NaI (Tl) Scintillation crystal was the first major breakthrough in radionuclide imaging field, since then SPECT instrumentation has undergone continuously steady evolution improving various aspects of imaging. Anger original camera consisted of a ¼ inch NaI(Tl) crystal that was the 5-inch diameter and coupled with 7 PMT. NaI(Tl) was the first scientillators developed, yet it remains a nearly ideal scintillator for Tc99m radioisotopes based imaging. Over the period detectors assembly has been improved, FOV (Field of View) of present camera has been increased significantly large and made possible to image any organ and typical performance values for present-day SPECT camera are around 9% FWHM energy resolution for Tc99m and 2-4 mm FWHM spatial resolution on an active camera face area(CFOV).A camera may support high counts imaging up to 0.1 Million per second. Also to increased the light output of the camera, retro-reflective materials have been applied as an alternative surface treatment for entrance face and apart from this standard design continuous crystal read out by

multiple PMT 's and various others configurations have been also employed.
Various scintillator materials have been used to create imaging detectors; however, NaI (Tl) remains the most widely used largely because of high light output and cost-effective. Also, various advancements happen in Collimators technologies, scintillators readouts and also recently introduced semiconductor detectors and its readout technologies as well as signal processing and estimation. Recently with the introduction of SiPMs as optical converters in the scintillation based system now Digital SPECT and SPECT/CT are available. It has improved the camera performance significantly and very soon SPECT/MR will be available commercially.
Also in last one and half decades, small animal imaging has become major research area. The demand for the in vivo imaging in the preclinical arena has grown rapidly with the development of the animal model of human diseases. Animal SPECT required spatial resolution a factor of 10 or better with good sensitivity for good image quality.

Technical challenges in development of PET-MR fusion

Anil Kumar Pandey,
Department of Nuclear Medicine, AIIMS, New Delhi-29

Introduction

A single image obtained as a result of fusion of PET and MR image provides complementary functional and anatomical information about a specific organ or body system at the molecular level. The fused image can be used to understand the molecular biology details, disease mechanisms, and pharmacokinetics in animals and humans.
The first step towards image fusion is the spatial registration of the two images. When the two images are taken from different modalities and also at two different times, the image registration becomes very challenging because of several factors such as patient motion, position etc. Image registration can be performed either manually or automatically. There is no automatic algorithm for image registration that can provide perfect registration. Manual registration is time consuming, and requires skilled man power.

Hybrid PET-MR systems have helped in improving accuracy of registration as this system allows simultaneous acquisition of PET and MR images. However, there were challenges in placing the PET and MR systems next to each other because the performance of PET system is compromised in the presence of MR system or vice a versa. Through extensive research in this field, many technical challenges have been sorted out up to a certain level and still fine tuning is going and is the active area of research in PET-MR fusion.

Technical challenges in PET-MR fusion

1. **PET system affects the performance of MR system when they are placed nearby:**

MR scanners are built to achieve very uniform strength of the main magnetic field (with homogeneity of typically one part per million for a superconducting magnet) so that the protons resonate at virtually the same frequency. Placing materials in the magnet alters the local magnetic field strength, causing the protons to spin at altered frequencies and causing severe geometrical distortion and susceptibility artifact (signal void).
Adding PET detectors within or near the MR bore degrades magnetic field homogeneity and causes image artifacts, particularly if the detectors include magnetic metals. PET detectors have magnetic susceptibility similar to the human tissue. Therefore, PET detector in the MR gantry can affect the homogeneity of the magnetic field. GSO has gadolinium and gadolinium is 1000 times more magnetically susceptible than that of LSO, and BGO. Hence, GSO detectors cannot be used with PET/MR.
Insertion of PET detectors into the MR gantry also compromises the performance of the MR imaging gradient system. During the acquisition of MR data, gradient coils are turned on and off in order to spatially encode the MR signal. A MR imaging gradient is usually built with high spatial linearity and fidelity as well as fast switching time. The presence of additional hardware within the gradient coil significantly alters the MR eddy current characteristics of the system, possibly leading to lengthened switching time and degraded spatial linearity. The gradient imperfection would impact the essential imaging performance, including imaging spatial resolution, scan time and image homogeneity.
Electromagnetic interference (EMI) refers to electrical signals or currents in a circuit that are created by electrical signals flowing in another

circuit or being transmitted. These effects also can occur with PET detectors and all the associated electronics to process counts and have the potential to create signals that are, for example, detected in the MR coils used to create images because the MR scanner is sensitive even to very low levels of undesired electromagnetic signals.
The challenge is then to construct the PET part of the combined scanner in such a way to minimize the impact on the homogeneity of the magnetic field.

2. **MR system affects the performance of PET system when they are placed nearby:**
The emitted photons as a result of positron annihilation interact with crystals, and thereby light photons are emitted. PET system use photomultiplier tubes (PMT) as a light sensor. PMTs convert the scintillation light into an electronic signal. These electronic signals are further processed to form a 3-dimensional image of the distribution radiopharmaceuticals inside the human body.
The strong magnetic field of MR severely affects the performance of PMT. In the presence of strong magnetic field, the electronic signal from the PM tube drops down to zero. How to overcome the PMT signal drop in the presence of strong magnetic field was a challenge. Till date the solution proposed and implemented with their merits and demerits are as follows:

- Transfer the light from crystal to PMT via a 4-5 meter long optical fibre cable and put PMT away from the influence of magnetic field. However, due to loss of scintillation light in the long optical fibre cable, a significant distortion of energy and timing resolution was observed. Moreover, a lot of extra space inside the MRI gantry is required because of huge number of optical fibres connected to the detectors of whole-body PET system.
- As an alternative to PMT use Avalanche Photo-diode (APD). Avalanche photo-diodes are compact and insensitive to the magnetic field. However, APD's have small gain in comparison to PMT. Besides this they have large excess noise, and large performance fluctuation according to bias voltage and temperature.

- Use silicon photomultipliers (SiPMs) as an alternative to PMT or APD: These devices (SiPMs) have a high gain (approximately 10^6) similar to a standard PMT and excellent timing properties down to 100 pico second as well as insensitivity to the magnetic field.

During the acquisition of MR data, gradient coils are turned on and off in order to spatially encode the MR signal. The associated changes in magnetic field induce electronic signals that are eddy currents, in the PET electronics. The faster and stronger the gradients are, the greater the eddy currents. Likewise, the radiofrequency pulses that tip the protons from their alignment with the main magnetic field may induce high-frequency voltage signals in the PET electronics. Both the gradients and the radiofrequency excitations can interfere with the PET signal analysis that includes detecting a photon, determining its energy, and determining if pairs of detected events meet the energy and timing criteria to be considered a coincidence event that would be attributed to photons created in positron annihilation.

3. **Attenuation correction:**
During clinical interpretation of PET images it is assumed that a pixel value is representative of radioactivity concentration independent of the depth of the radiopharmaceutical within the body. Hence it is important that before clinical interpretation the PET image is corrected for the absorption of the annihilation photons by the body.

In PET and CT photon absorption is primarily due to photon interaction with electrons surrounding the atom either due to photo-electric effect or due to Compton scattering. Compton scattering is a shared property underlying photon absorption in PET and CT, and a relatively simple conversion between CT Hounsfield units and PET attenuation factor is feasible. In MR imaging the signal depends on the hydrogen nucleus and its local environment. As such, there is no direct correspondence between the MR signal and photon absorption.
Although vendors have provided acquisition protocols and data processing that infer photon absorption from MR data, doing so robustly remains an active area of research in order to improve quantification accuracy and reduce artifacts.
4. To improve throughput similar to PET/CT
PET/MR acquisition takes approximately 40 – 60 minutes. Multiple pulse sequences are used to

acquire MR image. There is active research going on related pulse sequences that hopefully can reduced the MR acquisition time and hence will improve throughput.

Newer Advancement in SPECT/PET Detector Technology

Basant L. Malpani
Radiation Medicine Centre, Bhabha Atomic Research Centre, TMH Annexe Bldg., Parel, Mumbai-40012

Detectors Systems in Nuclear Medicine Imaging systems are undergoing a sea change in terms of detection materials, detector configurations and electronics. Advancements in material sciences and very selective demands made by the rapid expansion and growth in Nuclear Medicine have made available an array of faster detection system. Not only the development of integrated semiconductor detectors but by rapid adoption of CZT detectors have allowed the industry to move away from the once dependable Sodium Iodide Crystals. Development in the ceramic detector technology have but brought forth applications and instruments based on Multicrystal Cameras and Pixilated devices. These developments have occurred conjointly with evolution of faster position sensitive photomultiplier tubes, compact SiPMT's, Avalanche Photodiodes and Gas Electron Multipliers.

It is important to point out that application of Specific Integrated Chips (ASIC) has lead to multiplying the sensitivity and operational speed of these detectors. Availability of computer based fast processing algorithms and their easy adaptability had led to development of applications based on newer collimator designs like the multi-pinhole designs and the Slit Slat Collimator system. For example, the availibility of analytical fan-beam and cone-beam reconstruction algorithms with uniform attenuation correction for SPECT.

Reduction in the costs of the detector assemblies pushed forth by a larger demand has led to adoption of multi head and multiple ring based detection system. Single detector gamma camera's systems are now likely to become medieval age instruments. Large Field of view Dual Head Detectors are now the new order. Addition of CT for attenuation correction and coregistration have multiplied the clinical reliability of the images obtained.

Tomography is now being performed by fixed detectors fitted with moving collimators as in CardiArc system or in a Cardiac SPECT System with Multiple Collimated Detectors Rotating in an Elliptical Orbit or by locally focussed collimators or by moving beds in X, Y & Z planes. More specifically, in case of SPECT systems for Cardiac imaging, improvements in detector technology and image-forming apertures has greater yielded intrinsically better projection information. Needless to point out that the abilities that multiply with refinements in corrections for scattered radiation, attenuation, and spatial resolution losses will result in more accurate and quantitative reconstructed tomographic slices. Compton gamma imaging is now appearring to be a feasible dream.

Detector technologies like MWPC, HIDAC, RPC have been revisited in the last decade aided by the technological challenges at CERN. For eg. multi-wire proportional chamber (MWPC) was developed as a concept in 1968 by Georges Charpak, but received recognition with a Nobel Prize as late as in 1992. Prototypes of high density avalanche chamber (HIDAC) detectors in a positron camera that operated in coincidence with a resolving time of 40 nsec were demonstrated way back in 1987, but are now being actively persued for developing PET scanners.

Concepts of concepts of Time of Flight PET and point of interaction based PET imaging promise a better and scatter free PET imaging. TOF PET has been revived as PMTs with a short transit time and a fast rise time became more widespread and scintillators such as LSO or lutetium yttrium oxyorthosilicate, that have a short scintillation decay time and a high light yield, became available and cost-effective. Theoretically, an intrinsic detector time resolution of about 15 ps would render the PET image reconstruction algorithm obsolete by identifying the location of an annihilation event to within 2 mm. Increase in detector sensitivity by using thicker crystal leads to worsening of spatial resolution, especially at the edge of the field of view, when no DOI information is provided and the point spread function broadens with oblique penetration. However newer detectors assemblies incorporating, for example, a sandwich of LYSO crystal by SiPMT allow DOI better energy discrimination and improved resolution.

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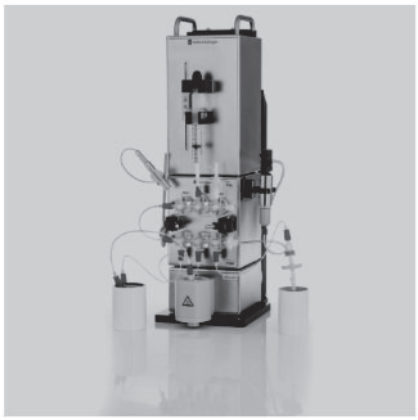




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Image Reconstruction Methods in Nuclear Medicine

Subhash Kheruka
Department of Nuclear Medicine, SGPGIMS, Lucknow (India)

Single photon emission computed tomography (SPECT):

The basic principle of nuclear medicine imaging is the following: a γ-emitter–labeled pharmaceutical is administered to a subject and an external device, the gamma camera, detects the radioactivity stemming from the body, from 1 or several angles of views. The image obtained at 1 angle of view is the projection of the 3-dimensional (3D) distribution onto the 2-dimensional (2D) detector plane. Because of the projection operation, no information regarding the depth at which disintegrations occur is available; moreover, activities stemming from separate structures may overlap each other on the detector plane, and the contrast may be low. With only 1 projection image, it is impossible to determine the activity distribution because an infinite number of distributions can yield the same projection. It is as difficult as to find 2 values knowing only their sum. However, the overlap observed in the projections depends on the relative positions of the detector and of the structures inside the body. So, more information about the relative positions can be obtained by acquiring projections over a large number of angles of view around the subject. The basic idea of SPECT is to obtain, as accurately as possible, an image of the γ-emitter distribution in any slice of the body, using projections of this image acquired by a rotating gamma camera from several angles of view.

Image reconstruction methods in SPECT:

Projections:

When a SPECT camera rotates around a patient it acquires data at different angles called projections. At every angle (step) photons travel perpendiculars to the camera face and pass through the collimator and strike the crystal. These photons originate from various depths in the patient.

After data from all the projections have been acquired, the projections for a single slice can be easily extracted as they occupy the same row in each projection image. These projections for each slice can be ordered into an image called a sinogram, where measurements at a position along a projection are plotted versus projection angle.

The aim of the reconstruction process is to retrieve the radiotracer's spatial distribution from the projection data.

Fourier reconstruction:

It can be shown that the Fourier transform of a one-dimensional projection describes a line in the 2-D Fourier transform of the object (Kak et al. 1988, Cho et al. 1993). If an infinite number of projections is acquired and transformed into Fourier space (F) then by doing the inverse Fourier Transform, reconstructed slices can be obtained. In practice, we are taking only limited projections. Thus, F is only known along a finite number of radial lines and interpolation is required to transform the radial points into a regular Cartesian grid F, before the inverse Fourier transform is taken. As the quality of the reconstructed image is affected by the accuracy of the polar to Cartesian interpolation, accurate and computationally expensive 2-D interpolation is required (Kak et al. 1988, Cho et al. 1993). Thus direct Fourier reconstruction is typically not employed, except when a regular Cartesian grid can be achieved during the projection sampling as with some magnetic resonance imaging (MRI) techniques (Cho et al. 1993).

Data filtering:

Once the data has been transformed to the frequency domain, it is then filtered in order to smooth out the statistical noise. There are many different filters available to filter the data and they all have slightly different characteristics. Some typical filters used are the Hamming filter, Butterworth filter, low pass cosine filter, and Weiner filter. Regardless of the filter used, the end result is to display a final image that is relatively free from noise.

The process of convolution in the spatial domain is equivalent to multiplication in the frequency domain. This means that any filtering done by the convolution operation in the normal spatial domain can be performed by a simple multiplication when transformed into the frequency domain.

Backprojection:

Backprojection is a crude but simple method of obtaining the reconstruction from multiple projections. The backprojection is a composite of all the ray sums of multi-angled, 2D views, and when projected onto an image field the result of the ray sums represent a cross section of the original source. In the backprojection technique,

the data are collected from the source at different angles and projected back as sum of all the pixels along the path at each angle. The intersection of these lines from different angles represent areas which contain higher concentration of radiopharmaceutical. In this technique the reconstructed image is severely blurred and star artefacts further degrade the image quality. Filtering is necessary to remove these artifacts that are a direct result of the backprojection.

Filtered backprojection:

Increasing the views by backprojection (BP) improves the tomographic effect but the final image still remains blurred. This blurring effect is proportional to *1/r* as described by the point-spread function, where *r* is the distance from the center of the point source. The relationship between the BP image and true image can be given by:

BP image = 1/r ⊗ True image

A correction filter can be applied by taking the Fourier transform of the scan profiles and multiplying each frequency component by a factor proportional to the spatial frequency.

The correction filter has a ramp shape in the frequency domain, so it is called the ramp filter. But the problem with the ramp filter is that it amplifies the higher frequencies and produces a noisy result in the image, which is clinically unacceptable. To remove the noisy effect from the image, a different smoothing filter can be used separately or combined with the ramp filter during the backprojection e.g. Butterworth, Hamming, Shep-Logan, Gaussian etc. Changing their cut-off frequency (and order) can modify the parameters of the smoothing filters further. These parameters determine the shape of the smoothing filters. By decreasing the cutoff frequency in the filter, noise in the data can be reduced which results in a smoother image. By increasing the cut-off frequency in the filter, resolution can be enhanced resulting in a sharper image. The filtration or smoothing of data involves multiplication in the frequency domain and it can be applied before or after the ramp filtering.

Iterative methods:

Photons emitted at some positions in the image do not necessarily reach the detector because they can be scattered, attenuated in the body, or absorbed by the collimator and not detected. The accurate modeling of these physical processes is best achieved using an iterative algorithm.

The basic concept of all iterative algorithms is to find the estimate of the object where projections match the measured projections. The estimated projections are determined from an initial reconstruction and are compared to the original data. At each iteration, differences between the measured projections and estimated projections are used to correct the current estimate of the object. This cycle is repeated until the differences between measured and estimated projections becomes small. The result is an approximate solution near to the true activity distribution. The steps in the iterative process are illustrated diagrammatically in Fig. 1.

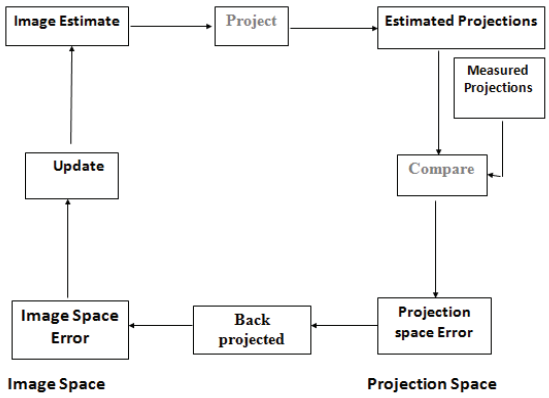


Figure: **A flow diagram for iterative reconstruction**

The final goal is to get a transaxial image whose projections are within some statistical difference of the actual measured projections. The number of iterations required depends on the complexity of the data.

There are a number of iterative algorithms that have been developed e.g. algebraic reconstruction technique (ART), the iterative least squares techniques (ILST), the simultaneous iterative reconstruction technique (SIRT) and the maximum likelihood-expectation maximization (ML-EM) algorithm.

In our case we used the maximum likelihood method using the expectation maximization algorithm which is the most commonly used ML algorithm. There are two-steps in this method: first the E-step, which computes the expected projection data for the current estimate and is equivalent to a forward projection; second is the M-step, in which the expected value is compared to the measured projection data and then the estimated reconstructed image is updated by

effectively "backprojecting" the ratio of the measured to estimated projections.

In the algorithm, geometric response, attenuation, and scatter can be accounted for and modeled. Thus it gives a quantitatively more accurate reconstruction. EM always converges to a more likely solution. It is slower than filtered backprojection. The increase of computer speed and introduction of the accelerated EM algorithms have decreased reconstruction time to a level that is acceptable in routine clinical SPECT procedures (Murase et al. 1994, Hutton et al. 1997).

The ordered subset-expectation maximization (OS-EM) algorithm (Hudson and Larkin 1994) involves a simple modification of ML-EM. Initially forward-backprojection is performed only for the projections belonging to the first subset of the projections. At the next update, a different subset of the projection data is used. Generally, one update in this OS-EM algorithm is called a sub-iteration and one pass through all of the subsets is referred to as an iteration of OS-EM. Organizing the subsets in this algorithm is very important. Subsets are organized in well-spaced groups of projection bins to maximise the information added in each iteration.

Image Segmentation Technique Used in Molecular Imaging

D. Datta

Radiological Physics& Advisory Division, Bhabha Atomic Research Centre, Trombay, Mumbai 400085

Introduction: Cancer research has been significant in the medical imaging community. Early detection, more accurate diagnosis, better treatment planning, and treatment monitoring in early stage are thrust areas advanced research in Cancer. Modern imaging technology, such as molecular imaging has already enhanced cancer management. Molecular imaging is the in vivo visualization and measurement of biological process at the cellular and molecular level. It allows not only localization of tumor lesions but also visualization of the expression and activity of specific molecules, which have great influence on tumor behavior and response to treatment. Many different modalities, such as MRI, SPECT, and PET, have been used for noninvasive molecular imaging and also have played a central role in clinical oncology.Image processing techniques have been widely applied to the detection of cancer, characterization and segmentation of tumor lesions, planning of cancer treatment, evaluation of the effectiveness of treatment, and prognostication of cancer, etc. Hence, in order to improve the application of molecular imaging in clinical oncology, an advance image processing technique in the field of medical domain technique is required. PET, a noninvasive functional imaging method at the molecular level, provides detailed quantitative information about many diseases and is often used to evaluate inflammation, infection and cancer by detecting emitted photons from a radiotracer localized to abnormal cells. In order to differentiate abnormal tissue from surrounding areas in PET images, image segmentation methods play a vital role; therefore, accurate image segmentation methods is often necessary for proper disease detection, diagnosis, treatment planning and follow-ups. Markov model of images may help us to make better image restoration, enhancement or segmentation. However computational loads for segmentation methods based on Markov Random Field (MRF) model are very high. For this reason, MRF methods are usually used in a real-time processing environment. The talk will highlight the MRF model based image segmentation technique used in molecular imaging. PET/CT image will be focused for segmentation.

Image Segmentation: The primary goal of any segmentation algorithm is to divide the domain R of the input image into the disjoint parts Ri such that they belong to distinct objects in the scene. The solution of this problem sometimes requires high level knowledge about the shape and appearance of the objects under investigation. A new type of stochastic process appeared in the theory of probability, called Markov random field (MRF) very popular tool in image processing. Segmentation is considered in a common framework, called image labeling, where the problem is reduced to assigning labels to pixels. In a probabilistic approach, label dependencies are modeled by Markov random fields (MRF) and an optimal labeling is determined by Bayesian estimation, in particular maximum a posteriori (MAP) estimation. The main advantage of MRF models is that prior information can be imposed locally through clique potentials. The primary goal is to demonstrate the basic steps to construct an easily applicable MRF segmentation

model and further develop its multiscale and hierarchical implementations as well as their combination in a multilayer model. MRF models usually yield a non-convex energy function. The minimization of this function is crucial in order to find the most likely segmentation according to the MRF model.

Results and Discussion: Combination of positron emission tomography (PET) and CT images provides complementary functional and anatomical information which has been used for tumor volume definition in radiation treatment (RT) planning for lung cancer patients [1]. Different types of tumors and image modalities have different image features, and thus different segmentation strategy should be developed for effective and accurate tumor segmentations. CT images provide anatomical information with high spatial resolution. Lung tumors can be distinguished from the adjacent tissues on PET images, but the segmentation accuracy is still limited due to the coarser spatial resolution of the image data and motion artifacts as the result of time-consuming procedure of data acquisition. Therefore, one of the key points of lung tumor segmentation on PET/CT images is to combine the advantages of the two image modalities effectively. The combination of PET and CT image information is achieved by using a proper joint posterior probability distribution of observed features in MRF model. Segmentation results obtained with the two methods were similar and Dice's similarity coefficient (DSC) was 0.85 ± 0.013.

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Concept of Radiomics and Possible Utility in Nuclear Medicine

Anil Kumar Pandey,
Department of Nuclear Medicine, AIIMS, New Delhi-29

Radiomics is a field of medical study that aims to extract large amount of quantitative features from medical images using data-characterisation algorithms. This field is based on the concept of texture which is a property that refers to the surface and structure of an image. In broader terms, it has been defined as a regular repetition of an element or a pattern on a surface. However, in purview of Medical Imaging, textures can be defined as complex visual patterns that are composed of entities or regions of sub-patterns with algorithms for characterization of various entities such as the brightness, color, shape, size etc. Texture analysis refers to a variety of mathematical methods that may be applied to describe the relationship between the grey level intensity of pixels or voxels and their position within an image. The mathematical procedures that are used for texture analysis broadly fall into Structural, Statistical, Model-based and Transform methods. Gray level Co-occurrence Matrices (GLCM) which employs statistical methods to define the texture features of an image is the most commonly used approach for texture analysis. This tool has emerged into a powerful basis for usage in texture classification. Also known as a Gray level Dependency Matrix, it is defined as "A two dimensional histogram of gray levels for a pair of pixels, which are separated by a fixed spatial relationship."

As the field of Radiomics continues to evolve, it has been recognized that medical images contain more information than is utilized by clinicians and researchers in a routine clinical setting. This has given rise to new possibilities in identifying factors that can predict, prognosticate and help in planning the treatment of the diseases they are applied to in medical images. Texture analysis is being increasingly identified to play these roles with a good reliability in comparison with conventional tools for medical imaging.

Recently, PET image texture analysis was proposed to characterize the heterogeneity of tumor F18-FDG uptake. F18-FDG uptake is not homogeneous across the tumor because of necrosis, cell proliferation, microvessel density, and hypoxia. It has been shown that tumor heterogeneity can be associated with disease progression, response to therapy, and malignant behavior of the tumor. An advantage of measuring textural parameters is that it is a post processing technique that can be applied to data acquired during standard clinical imaging protocols thereby maximizing the information that can be derived from standard clinical images. A number of textural features can be derived that provide a measure of intralesional heterogeneity e.g. angular second moment, inverse difference moment, entropy, correlation etc. Texture analysis has been extensively used in CT images and has given promising results as a predictor of survival and in treatment response assessment in

various carcinomas including NSCLC, breast cancer, esophageal carcinoma etc., but it is still new and emerging field in PET/CT. Studies have shown the utility of texture parameters evaluated from F18-FDG PET in prediction of prognosis/survival of patients and treatment response assessment in various solid tumors. Texture parameters has shown to have their importance in the prediction of response and survival at the baseline PET/CT scans, before the start of treatment. But still, a lot of work is required to be done with regard to the utilization of texture parameters/ radiomics in routine clinical practice.

"eyes-series": New benchtop, low cost scanners for planar imaging of SPECT and PET isotopes that change the workflow of every radiochemical group

George Loudos
Bio Emission Technology Solutions, Athens, Greece

Molecular imaging using radioisotopes is a high performance, non invasive way of studying the biodistribution of new tracers including biomolecules and nanoparticles. BioEmission Technology Solutions (www.betsolutions.gr) has launched the "eyes-series", the only completely portable, affordable, small animal full-body imaging systems, which can help facilitate and improve the quality of studies of numerous groups having access to radioisotopes.
"β-eye" is a unique coincidence PET imaging system, which offers a spatial resolution of 3mm and a sensitivity of 14kcps/MBq and "γ-eye", is a scintigraphic system with a spatial resolution of 1.7mm and sensitivity of 120cps/MBq. Both systems provide fast-screening, at a very competitive cost, at least 5 times lower than a multimodal system, thus making it easily accessible to a wider number of researchers. They are benchtop and fully portable, very ease to operate by non-experts, and fully designed based on end-user needs.



Although biodistributions are a standard part of a preclinical study, several animals need to be sacrificed at different time points to have accurate statistics. Planar imaging, allows to obtain a series of images from the same animal, draw regions of interest on the organs of interest and extract semi-quantitative curves, by just using a small number of animals.
Even if a group has access to a multimodal imaging system, it is clear that tomographic imaging is not the methodology of choice for answering questions such as: accumulation in target or other organs; blood circulation time and route of elimination; optimal administration root; effect of different animal preparation conditions; best injected concentration and optimal time points for biodistribution or imaging. Especially following a fast tracer at the first minutes post injection -including first blood pass- is not possible to be performed in tomographic mode, although this information is critical.
This talk will demonstrate the benefits of using the "eyes" by groups conducting biodistribution studies, users that have access to clinical cameras, limited access to high resolution multimodal systems, but also those that own such a high performance system. Indicative applications and good practices will be given in detail proving that they can change the workflow of every group.

Introduction and overview of chemical, biological & Practical aspects of bringing Radiopharmaceuticals from bench to bedside

Anil Kumar Mishra
MIRC, Institute of Nuclear Medicine and Allied Sciences, Brig SK Mazumdar Road, Timarpur, Delhi-110054

Molecular imaging, first developed to localize antigens in light microscopy, now encompasses all imaging modalities including those used in clinical care: optical imaging, nuclear medical imaging, ultrasound imaging, CT, MRI, and photoacoustic imaging. Molecular imaging always requires accumulation of contrast agent in the target site, often achieved most efficiently by steering nanoparticles containing contrast agent into the target. This entails accessing target molecules hidden behind tissue barriers, necessitating the use of targeting groups. For imaging modalities with low sensitivity,

nanoparticles bearing multiple contrast groups provide signal amplification. Nanoparticles also have the inherent capability in principle to deliver both contrast medium and drug together, allowing monitoring of biodistribution and therapeutic activity simultaneously (theranostics). Nanoparticles have multiple sites for target recognition and binding and they share functionalities with many sub-cellular organelles (ribosomes, proteasomes, ion channels, and transport vesicles) and are of similar sizes. The materials used to synthesise nanoparticles include natural proteins and polymers, artificial polymers, dendrimers, fullerenes and other carbon-based structures, lipid–water micelles, viral capsids, metals, metal oxides, and ceramics. Signal generators incorporated into nanoparticles include iron oxide, gadolinium, Fluorine, iodine, bismuth, radionuclides, quantum dots, and metal nanoclusters. We are synthesizing and functionalizing the nanomaterial for applications specifically to develop specific nanoprobes for molecular imaging

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Drug delivery studies using radioisotopes and their relevance in current era

Pradip Chaudhari

Comparative Oncology Program and Small Animal Imaging Facility, Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), Navi Mumbai 410210

In the era of nanotechnology, pharmaceutical industry is working hard towards developing novel methods to improve target specific safe delivery of drugs to the area of interest. Thesenovel systems are intended to increase therapeutic dosage and ultimately improvising the efficacy. After designing new drug delivery system optimization is carried out with the help of various in-vitro and in-vivo assays. These drug delivery systems need a validation prior to its clinical application in human subjects. There are also more innovatory and effective drugs are being developed consisting single chain fragments, proteins / or DNA / nano-based delivery of RNAi for targeting malignant disease. These novel systems need through and robust preclinical validation. In the process of validation

of these new entities, sophisticated non-invasive technologies such as nuclear medicine imaging procedure has important role to play. The radioisotopic procedures are sensitive, quantitative with strong translational value. The nuclear medicine preclinical imaging modalities such as single positron emission computed tomography (SPECT) and positron emission tomography (PET) is playing significant role in new drug development. The molecular and functional data obtained from SPECT and PET can be co-registered with anatomical data obtained from Computed tomography (CT) for better understanding of area of interest. The other modalities such as magnetic resonance imaging, ultrasound, and optical techniques such as fluorescence and bioluminescence imaging are non-radioisotopic procedures act as a complimentary for these studies. The molecular imaging modalities have several advantages over conventional screening methods such as quantitative monitoring drug distribution, uptake and excretion at cellular and molecular level in living system in real time. Strong preclinical data is the backbone of novel drug delivery strategies. The nuclear medicine modalities have several applications in drug discovery and can be very well used for understanding the safety and toxicity of novel formulations. This presentation covers use of dedicated preclinical molecular imaging modalities used for pharmaco-scintigraphy.

Key words: Pharmacoscintigraphy, preclinical, non-invasive imaging, translational research

An overview of ^{68}Ga labelled radiopharmaceutical synthesis in Hospital radiopharmacy

Bhakti Shetye
Department of Nuclear Medicine and Molecular Imaging, Tata Memorial Hospital, Mumbai-12

Nowadays variety of 68Ge/68ga generator based synthesis modules either semi-automated or automated are commercial available in the market. In 1960, first 68Ge/68Ga generator based on solvent extraction technique was developed by Gleason.one year later Green and Tucker introduced generator based on chromatographic technique. 68Ge was adsorbed on alumina column and 0.05M EDTA used as an eluant. 68Ga-EDTA radiopharmaceutical used for functional diagnosis of brain. But labelling with other radiopharmaceutical using 68Ga-EDTA final product of generator is not convenient procedure. It involved dissociation of 68Ga-EDTA complex and complete removal of traces of EDTA. It was tedious and time consuming procedure. Taking into account short half-life of 68Ga it was not useful also.

It leads to further development of 68Ge/68Ga generator systems. Introduction of metallic column generator ushered new era in the synthesis of 68Ga labelled radiopharmaceuticals in nuclear medicine. Short half-life, easy availability of on sight production, favorable radiochemistry, excellent binding characteristic with chelating agent and easy availability of PET-CT scanner made 68Ga as a choice of radiotracer. 68Ga labelled radiopharmaceutical like DOTANOC, DOTATATE, DOTATOC and PSMA have got wide application in the imaging of somatostatin receptor positive tumours and ca prostate patients resp. Eluate from metallic column generator (TiO_2 and SnO_2) contains chemical and radionuclidic impurities. Zn^{2+} by decay of 68Ga and Fe^{3+} as general chemical impurity in the eluate can compete with $68Ga^{3+}$ for coordinative labelling of radiopharmaceutical precursors. Recently introduced non-metallic silica based resins columns overcomes these problems and its 68Ge breakthrough is very minimal.

Quality assurance and quality control tests plays important role in successful synthesis of 68Ga labelled radiopharmaceuticals. One has to ensure proper implementation of approaches, techniques, methods and designing protocols. Quality control activities monitor and verify that desired product meet defined quality standards. Radiopharmaceutical synthesis procedures should accompany good manufacturing practices. Generally three major steps are involved in quality assurance of radiopharmaceutical synthesis programme.

1. Selection of Reagents
2. Preparation of stock solution
3. Storage of required materials

Use calibrated analytical balance for weighing of reagents Also use analytical grade reagents for preparation of stock solution. Stock solution should not be prepared in bulk amount. Use calibrated micropipette for dispensing of reagents. Take small quantity of required material in a separate container. After dispensing the desired amount of solution discard the remaining solution. It will prevent contamination of stock

solution. Always follow procedural instruction provided by manufactures for proper use of micropipette. Periodic calibration of micropipette should be done at regular intervals. Peptides are stable in lyophilized form but not in solution form. Hence, it should be stored at appropriate temperature. Any portion of aliquot unused after thawing should be discarded. Aliquot of peptides should be stored in low binding micro centrifuge tubes to ensure full recovery of peptide. DOTA derived pharmaceutical are heat sensitive. Hence to optimize reaction yield it should be carried out at desired temperature only. To achieve this temperature of the heater should be routinely checked and it should be monitored continuously during the entire labelling procedure. Conditioning of reversed solid phase extraction cartridge like C-8, C-18 should be done to remove impurities and minimize sample matrix. Cartridge should not be dried before administration of sample. Quality control tests can be performed by paper chromatography, thin layer chromatography and high performance liquid chromatography. Gamma ray spectrometer should be properly calibrated before counting the sample. Its linearity and energy resolution should be assessed periodically.

Record keeping of quality control tests like elution yield, labelling yield, radiochemical purity, certificates of reagents quality, calibration certificate of instruments are mandatory requirements for in-house labelled 68Ga radiopharmaceuticals.

Newer radiopharmaceuticals in diagnosis and therapy

Tapas Das
Radiopharmaceuticals Division, Bhabha Atomic Research Centre,Trombay, Mumbai-400085, India

The increasing importance of nuclear medicine's unique ability to delineate anatomical depictions with physiological functions without perturbing the human body assures nuclear medicine's ongoing and significant role in medical sciences and in the practice of medicine. Radiopharmaceuticals play a crucial role in maintaining the nuclear medicine's importance as an integral and essential component of current medical practice. To maintain the uniqueness of this medical specialty as well as to increase its importance as an indispensable forte in the medial armamentarium, it is essential to develop new radiopharmaceuticals with superior and improved characteristics. In the recent past, quite a few new radiopharmaceuticals have been developed and brought into clinical domain. These newer agents have made remarkable imprint in the current diagnostic and therapeutic interventions of various types of medical maladies, specially cancer.

Prostate cancer is presently the sixth leading cause of cancer related deaths and is estimated to be the second most frequently encountered cancer in males worldwide [1] . Even a few years back, detection of primary and metastatic prostate cancer for staging and risk-satisfaction was usually done through a battery of tests, which include use of conventional imaging modalities such as, computed tomography, ultrasound imaging and magnetic resonance imaging along with bone scintigraphy as well as by the determination of biochemical markers [2] . However, the recent success of 68 Ga-labeled PSMA (prostate specific membrane antigen) ligands has opened up a new avenue in detecting, staging as well as post-therapy monitoring of prostate cancer, as the agent is capable to delineate the presence of prostate cancer metastases with high contrast anywhere in the human body. The success of 68 Ga-PSMA, has brought complete change in the management of prostate cancer as it has led to the development of 177 Lu-PSMA- 617, an agent which is nowadays increasingly being used for the treatment of disseminated prostate cancer [2,3] . It is predicted that use and importance of 177 Lu-labeled PSMA in the management of prostate cancer is expected to increase manifold in the coming years [2] . Further development in this direction is reported in the form of 177 Lu-labeled by RM2 (4-amino-1-carboxymethyl-piperidine- d-Phe- Gln-Trp-Ala-Val- Gly-His- Sta-Leu- NH 2), as RM2 and other GRPr (gastrin-releasing peptide receptor) antagonists have shown a more favorable biodistribution than GRPr agonists for imaging of prostate cancer in pre-clinical models.

Developments of newer radiopharmaceuticals have not only improved diagnostic and therapeutic applications, but also marked its importance in the arena of palliative care. Radium-223-dichloride (alpharadin/xofigo) is an alpha-particle emitting agent, whose use has been approved by US-FDA (in May 15, 2013) for the treatment of patients suffering from skeletal

metastases. This is the only bone pain palliation agent known till date which apart from pain palliation has provided survival benefits to the patients and delayed skeletal-related events [4] .

It is evident from the above examples that development of newer radiopharmaceuticals in the recent past has already started playing a key role in the management of various ailments – starting from detection of diseases to the end-stage palliative care. The presentation will encompass similar recent developments in the field of radiopharmaceutical sciences, which have made or expected to make significant impact in the field of nuclear medicine.

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Quality Assurance in Nuclear Medicine

Sneha Mithun
Department of Nuclear Medicine, Tata Memorial Hospital, Mumbai-12

Quality Assurance is the maintenance of a desired level of quality in a service or product, especially by means of attention to every stage of the process of delivery or production. Hence the focus of Quality Assurance is on Process improvement.

Quality assurance is essential-

- to ensure good quality of everything that has a bearing on quality of end product/service
- to ensure accuracy and reproducibility consistently
- to ensure uniform quality and effectiveness
- to ensure scope for improvement and upgradation of processes and quality of end product

In order to ensure a good Quality Management System it is very important to perform quality control of all the pertaining instruments or products at specified time points.

Quality Control is a set of procedures intended to ensure that a manufactured product adheres to the defined set of quality criteria. The purpose therefore is to ensure that quality requirements are met. Any Quality control process constists mainly of 3 components, namely, Sampling, Testing, Monitoring and Reporting

Following are the important areas for Quality assurance in a Nuclear Medicine Department:

1. Personnel & Premises
2. Equipment/ Instruments
3. Radiopharmacy
4. Radiation, Regulation and Safety Compliance
5. Procedure/ Preparation and Process controls
6. Clinical Services
7. Documentation and Record Keeping
8. Complaint Handling
9. Internal and External Audits

It is essential to setup a quality assurance unit comprising of personnel involved in the entire process. This unit should ensure that all necessary parameters are updated. They should ensure that the preparation and control operations are clearly specified and implemented in accordance with the regulations. This unit should also ensure quality control and timely calibration of the instruments and equipments involved in the processes. A system of planned preventive maintenance and calibration should be insitu and proper log and records of the same should be maintained. It is important that several parameters be considered, addressed as well as verified, prior to, during and after completion of the process like-

Personnel and Premises: It is important to employ trained and qualified personnel and also ensure continuous updation of their training and knowledge in relevant subjects. It is also necessary to demarcate sufficient space for the facility. Personnel safety (radiation as well as biological) should be ensured. Ensuring radiation safety and good quality end product/service begins with infrastructure development. Hence the premises, the space available and regulatory compliance is of utmost importance.

Equipment/ Instruments: It is necessary that all purchase of all equipment should be made against technical specifications should be prepared by competent person. For any PET/CT, SPECT/CT equipments QC must be performed as per NEMA standards. QC of other related instruments like , uptake probes/gamma probes, Dose Calibrator, Survey Meter, TLC scanner, etc must be

conducted as per standard recommendations at frequencies mentioned below-

1. For acceptance testing, i.e., before commissioning of the equipment
2. For periodic testing of the equipment (as per manufacturer instruction for the device)
3. After any major repairs or servicing
4. When any part or parts of the equipment is suspected to be defective

For Quality Checks for all equipments and instruments will have to involve following

1. Acceptance & Reference tests
2. Routine tests (Daily/ Weekly/ Monthly)
3. Record keeping of QC results
4. Frequent review and action taken reports
5. Procedures
6. Predefined Test frequencies

It is also important to define the list of tests to be performed daily/ weekly/ monthly/ annually

Radiopharmacy: It is necessary to have dedicated and self-contained facilities for handling of radiopharmaceuticals. It is recommended by the current good radiopharmacy practise (cGRPP) guidelines to use clean rooms or laminar flow work areas and fume hoods where relevant. It also gives clear recommendations about the air quality within the clean room or laminar flow workbench as per the European Union classification. The asceptic workstation should be cleaned at appropriate intervals and timely microbial monitoring should be carried out. Validation before release of each preparation, dispensing of radiopharmaceutical dose with respect to patients age and weight and specified examination should be ensured. For distribution of radiopharmaceuticals proper packaging and transportation regulation specified by the competent authority should be adhered to.

Radiation, Regulation and Safety Compliance: It is important that department has been licensed by the regulatory body and has all the necessary regulatory permissions, all radioactive handling, usage and disposal is as per rules and regulations. It is important to ensure that all the professionals employed in the radiation area are certified to handle the sources and are routinely monitored. All sealed or unsealed radioactive sources available in the department should be recorded and routinely monitored. SOP's should be created for safe handling, decontamination, transport and disposal of all radioactive sources and all records for the same should be maintained.

Procedure/ Preparation and Process controls: It is recommended to use controlled materials and approved procedures along with qualified equipment. Timely validation of processes and analytical methods by preparing standard operating procedures (SOPs) also ensures end quality. Visual inspection of all equipments/materials is essential. Preparation of QC monographs and SOP's for all clinical procedures and their timely updation of the same as per recent advances are also essential.

Clinical Services: There has to be a periodic assessment of timelines from placing an appointment, scanning/ giving therapy, to reporting/maintaining follow-up of the patient. It is essential to have a standard specified format for reporting and an operational flowchart describing the clinical process. The department should regularly perform self-assessments/audit of their clinical services including the procedures and reporting. There should be clear SOPs for the same and for handling instances of non-compliance and also corrective as well as preventive measures taken for the same. There should be a defined method for monitoring data to ensure quality. It is most essential to have a patient feedback and complaint handling system in order to ensure improvement in the entire patient service. It is also essential to monitor whether the clinical services follows the criteria of evidence based medicine according to local and/or international standards check for conformance with Good Clinical Practise.

Documentation and Record keeping: A complete, relevant, sequential and systematic documentation to ensure traceability of raw material/ resource and each preparation is essential. Written instructions, standard operating procedures and quality control monographs should be maintained after approval and reissued every 2years. Records of purchase and check on arrival of all resources and equipments including RA products should be maintained. Records of all processes carried out during the preparation, quality assurance and audit should be maintained for the legally required period.

Complaint Handling: Through good documentation and proper traceability of services and proper method of patient and professional feedback/complaint-handling it will be possible to identify relevant issues or complaints. Any failure identified during or after any of the process should be subject to audit and recorded for future reference.

Internal and External Audits: Timely internal audits of practices, procedures, personnel, equipment and records should be carried out in a periodic manner. It is the responsibility of the Nuclear Medicine Physician to set up an internal audit team. It should consist of atleast 2 people from the Nuclear Medicine department, a representative from the hospital administration, a several staff members from a range of disciplnes. The responsibility of the internal audit team is to collect documental proofs of the evaluations like SOPs, study reports, quality control data for equipments and instruments, complaint records, etc. An internal or external audit may either be partial or comprehensive. It is recommended that a comprehensive internal audit be performed annually and an external audit (peer review) be performed atleast every 3years.

Thus, through a continuous process of teamed effort and following current good radiopharmaceutical practise guidelines, it is possible to ensure good quality product consistently.

Effective planning of Nuclear Medicine Facility in India:

Ashish Ramteke,
RSD, AERB, Mumbai

There are about 276 functional Nuclear Medicine (NM) Centers in the country as on date. The number approximately 8 years ago was like 162 NM facilities. However, as compared to the first world countries there is lot more yet to come in this regards as quality of diagnosis is one of the parameters of competent health industry in developing countries. One may conclude that NM is growing with a good pace and above all without any contraindications i.e. no major incidents pertaining to radiation safety have yet been reported since the advent of NM in the country.

Safety is "DYNAMIC" process of improvement involving contribution from every single participant in picture. It can be attributed to two aspects of safety; Built-in Safety and Operational Safety. Establishment of a safe NM facility depends on the sturdiness of its foundation. It is therefore necessary that all the safety measures are implemented at the planning stage itself, keeping in view the anticipated accidental scenarios. This includes the shielding adequacy of the installation depending on types of radionuclides used, workflow of various activities in the facility etc. Whereas, for operational safety adherence to safety culture should meets the purpose. It includes protection of workers, patients, member of the public and environment, implementation of measures for keeping exposure and contamination levels as low as reasonably achievable (ALARA). Though there is plenty of literature on safety culture, however, unless safety culture is imbibed in every radiation facility the objective won't be achievable.

As per the Atomic Energy (Radiation Protection) Rules 2004 promulgated under Atomic Energy Act 1962, the Atomic Energy Regulatory Board has the mandate to enforce rules and regulations for ensuring Radiological Safety in the country to achieve its ultimate goal to protect the workers, the members of the public and the environment from undue hazards of ionizing radiations. The AERB Safety code for Nuclear Medicine facilities Code [No. AERB/RF-MED/SC-2 (Rev. 2)] is formulated on the basis of the nationally and internationally accepted safety criteria for design, construction and operation of specific equipment, system and components of Nuclear Medicine facilities.

Factors affecting the radiation safety while planning a NM facility are Half-life and emissions, volatility of the radionuclide to be used, amount of administered activity, uptake time and scan time, dose rate from the patient and number of patients per week. Apart from these, the occupancy factors, detection instrumentation and Dose Limits form the other inputs for effective planning of the NM facility.

Regulatory steps for setting up of NM facility through e-Licensing of Radiation Applications (e-LORA) portal of AERB include Institute Registration, Approval of Layout Plan of Nuclear Medicine Facility, Appointment of Staff for the Nuclear Medicine Facility in institution profile, Procurement of Personnel Monitoring Badges, Nomination and Approval of Radiological Safety Officer, Measuring and Monitoring Instruments and other Associated Handling Accessories, Equipment and Source Procurement Permission for QA/Radiological Survey, Equipment Receipt Intimation, Quality Assurance (QA) tests and Radiological Survey Report, Application for License for operation along with the pre-commissioning checklist and Permission for procurement of sources for clinical use.

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dhanaji.mohite@greenashram.org

Regulation aspect of planning of medical cyclotron facility in India

Subrata Pathak,
Radiological Safety Division, Atomic Energy Regulatory Board, Mumbai – 400 094

With the introduction of Medical Cyclotron technology a new era of diagnostic Nuclear Medicine has started. Medical Cyclotron produces mainly positron emitters, which can be used in PET scanning. A typical Medical Cyclotron Facility (MCF) consists of the medical cyclotron in a vault alongwith associated facilities such as Radiopharmacy and Quality control laboratories.Inside a Medical Cyclotron, particles such as protons/deuterons are accelerated and made to bombard to a suitable target material to produce positron-emitting radioisotopes. The medical cyclotrons are mainly classified as self-shielded and non-self-shielded. The self-shielded medical cyclotrons are provided with heavy shielding around the cyclotron. Whereas, for non-self-shielded medical cyclotrons additional structural shielding is provided to reduce the radiation levels to safe limits.

The positron emitters are produced by the (p, n) or (d, n) reaction. Such nuclear reactions are the major source of radiation in a cyclotron engaged in production of positron emitters for medical application. The neutron activation of the surrounding medium is a concern for radiological safety.The accelerated particles may also lead to activation of materials around the target and leave residual radioactivity.Use of medical cyclotron poses radiation risk to the user, general public and the environment if operated in aunsafe or improper manner.

To establish a Medical Cyclotron facility, the user institute must go through the Regulatory requirements as mentioned in the Atomic Energy (Radiation Protection) Rules, 2004 and AERB Safety guide on medical cyclotron facility AERB/RF-RS/SG-3, 2017 and shall obtain requisite regulatory consent from AERB as per AERB Safety Guide for Consenting process for Radiation Facilities (AERB/SG/G-3). Various stages of clearances needed for establishing medical cyclotron facility from Atomic Energy Regulatory Board (AERB) are as follows:

1. Site Assessment and Approval
2. Design and Construction Approval
3. Equipment procurement and equipment receipt intimation
4. Appointment of RSO and other trained staff, procurement of personnel monitoring badges, monitoring instruments.
5. Pre-Commissioning & Trial run permission
6. Licence and Renewal of licence
7. Decommissioning

AERB has launched e-LORA (e-Licensingof Radiation Applications), its e-governance application system to facilitate online submission ofapplications for regulatory consents and establish channel of communication with AERB forother regulatory requirements. All User Institutes having Medical Cyclotron facility are requiredto use eLORA for obtaining relevant consents and approvals from AERB.

NEMA and other quality control of SPECT systems

Dibya Prakash
Nueclear Healthare Limited, Tribhuvan Complex, New Friends Colony, New -Delhi – 65

Quality assurance is a crucial part of all aspects of Nuclear Medicine practice. Three types of quality tests such as Acceptance, Reference and Routine tests are carried out for obtaining optimum image quality and quantitative data in Single-Photon Emission Computed Tomography (SPECT) and planar imaging. The acceptance of an instrument following its receipt and installation is a critical step towards the achievement of high quality performance. At the time of acceptance testing, reference tests should be carried out and be compared during routine testing. National Electrical Manufacturers Association (NEMA) NU 1-2012 establishes measurements of performance characteristics of the following Gamma camera parameters for planar systems: • Intrinsic spatial resolution • Intrinsic spatial linearity • Intrinsic energy resolution • Intrinsic flood field uniformity • Multiple window spatial registration • Intrinsic count rate performance in air • System spatial resolution without scatter • System spatial resolution with scatter • System planar sensitivity and collimator penetration and scatter • System count rate performance with scatter • Tests specific to gamma camera whole-body scanning systems Tomographic system is much more sensitive to poor performance with respect to the parameters measured in conventional planar

imaging. Therefore additional parameters are required to be carried out for optimum tomographic performance: (1) Tomographic uniformity (2) Tomographic resolution (3) Linearity of tomographic response (4) Quantitative accuracy in tomography (5) Precision of estimation of the centre of rotation (6) Tomographic sensitivity — slice and volume (7) Tomographic signal-to-noise ratio (8) Tomographic contrast (9) Slice thickness Methodology for SPECT quality control: (1) Tomographic uniformity: Tomographic uniformity is the uniformity of the reconstruction of a slice through a uniform distribution of activity and performed with ECT (Jaszezak) phantom using 360◦ of angle of rotation, 800K counts per projection on 128 x 128 matrix and 120 projections. (2) Tomographic resolution: Tomographic resolution is defined in terms of the FWHM determines the sharpness of the image. (3) Linearity of tomographic response: linearity activity response of a SPECT system can be constructed with a collection of tubes and are estimated from plot obtained. (4) Quantitative accuracy in tomography: The quantitative accuracy of the system is described by the deviation from the true value and estimated by the system is compared with the actual value at some point within the object. (5) Precision of the estimation of the axis of rotation: The perpendicular line passing through the axis of rotation and can be estimated as a function of the angle of rotation and is critical in setting up a tomographic system. (6) Tomographic sensitivity — slice and volume: The tomographic sensitivity is estimated in terms of number of counts detected for known activity in a standard phantom and expressed as counts detected per second per unit of activity concentration. (7) Tomographic signal-to-noise ratio: It depends on a number of parameters such as counts acquired, distribution of the counts, reconstruction process and other components of the reconstruction algorithm such as scatter and attenuation correction. (8) Tomographic contrast: Tomographic contrast determines the detectability of small lesions and is compared with background activity to know the value of contrast. (9) Slice thickness: Slice thickness describes the spatial resolution of the system along the Z axis for that reconstruction. FWHM, measured from the response of the system to a point source placed at known radial distance from the axis of rotation, along a line parallel to the axis of rotation determines the slice thickness and is not constant with respect to position within the transaxial slice. Important values are the slice thickness at the centre and 10 cm from the axis of rotation.

NEMA and other Quality control of PET system

Mr. Ankit Wats
Department Nuclear Medicine & PET, PGIMER, Chandigarh

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

Working in PET Radioisotope Medical Cyclotron Facility

Mohite D Y
IBA cyclotron Noida

Introduction :Positron emission tomography: Cancer is one of the leading causes of death worldwide. Accurate diagnosis, staging and restaging are essential for the optimal therapeutic management of cancer patients. Positron Emission Tomography (PET) is fast emerging as a new technology which finds wide applications in nuclear medicine. PET is especially useful in the fields of Oncology, Neurology and Cardiology.
2-deoxy-2-[fluorine-18]fluoro-D-glucose (18F-FDG), an analogue of glucose, provides valuable functional information based on the increased glucose uptake and glycolysis of cancer cells and depicts metabolic abnormalities before morphological alterations occur. 18F-FDGPET/CT acquires PET and CT data in the same imaging session and allows accurate anatomical localization of the lesions detected on the 18F-FDG PET scan.
Accurate diagnosis and staging are essential for the optimal management of cancer patients. Positron emission tomography with18F-FDG-PET/CT has emerged as a powerful imaging tool for the detection, staging and restaging of cancer.
Heart of technology is cyclotron (proton accelerator), accelerates proton for nuclear reaction.
When, for example, O-18 water is used as a target, it is converted into radioactive F-18 which is used for production of FDG.
Cyclotron facility- Establishing cyclotron facility is challenging job, it needs specialized manpower to designed facility, most of the old facility where non GMP because of no proper regulatory norms, but now regulatory norms demands GMP facility.
Installation and commissioning of Cyclotron facility- It is mostly done by equipment supplier with the help of specialized trained manpower.
Daily operation and reliable supply chain management: -It dedicated job done by specialized manpower. All operations are running with time, because of nature of isotopes. Works started in mid night, completed in early morning to deliver radiolabelled compounds to hospitals for patient used, it is highly complex operation completed in tight time schedule without fail.

In India lot of facilities become operational, new facilities are comming in one or two years, Isotopes are available all over country, PET technology is spearing rapid space. Next 20 years this technology will see almost 20 % growth.

Technical Challenges in Operation of Cyclotron Facility & Role of Nuclear Medicine Physicist in Cyclotron Operations

Rajeev Kumar
Department of Nuclear Medicine and Cyclotron Facility, AIIMS, New Delhi

Medical cyclotron is a particle accelerator used in producing short lived radioisotopes (18F, 11C, 15O, 13N, and $18F_2$ Gas) in the medical field. The produced radioisotopes are used in production of PET radiopharmaceuticals for diagnostic purposes. The daily running of the medical cyclotron involves a number of problems and challenges faced by the operator. Foremost among these would be target window rupture which is considered as a major emergency needing immediate attention. The second cause for concern during cyclotron operation is chiller temperature followed by air compressor and RF fuses. The optimum environmental conditions, gas cylinder pressure, parameters ideal and its feedback values, rinsing plays important role in uptime of the cyclotron facility.

The experience helps us gain working knowledge of cyclotron operations, which may help in improving 18F yield, minimizing the breakdown, and help in the prevention of the occurrence of unusual events.
For PET radiopharmaceuticals chemicals refrigeration, preparations of chemicals, availability of chemicals, charging of cartridge, malfunction of MVP valve, leak from delivery tube and purification column are crucial.
Medical physicist plays very important role in operations of medical cyclotron. As they are qualified by competent authority, fulfill all the criteria and take any immediate decision during any mis-happening and avoid mishandling of the equipments. Optimal handling of the emergencies also enables reducing personal radiation exposure and breakdown time of the equipment by medical physicist

Nuclear Medicine protocols: Expectation of Nuclear Medicine Physician form NM Physicist

Deepanjan Mitra
AMRI Institute of Nuclear Medicine, Kolkata

Nuclear Medicine is a unique discipline where right coordination between a physician and technical colleagues is of paramount importance for meaningful work. Unlike many clinical disciplines; ours is one, which does value the contribution of a good technical colleague in appropriate terms. It is indeed commendable that the basic tenets of the specialty lie in the hands of a good physicist and technical staff. A physician is surely required to deliver the clinical aspect of the field; however, (s)he is unable to perform his(er) duties properly in absence of sound technical colleagues.

Of late, the spectrum of practice of Nuclear Medicine has increased to range from diagnostic to therapeutic domains. Hence it has also increased the demand of technical colleagues to fulfill the requirement. With increasing number of teaching institutes offering technical courses, there is an increase in supply of qualified professionals. However, in real scenario, degree in itself is not sufficient to do sound clinical or technical job. It is important thus to recognize the standard operating principles of any department and to follow good clinical practice in day to day's work.

Often times, it is perceived that a technical colleague would only be involved in routine paper work and scan acquisition. However, in growing job markets and with increasing remunerations, it should be acknowledged that it is only a person with multi-tasking capabilities who would be recognized and honored. The duties as defined by general guidelines should definitely be followed but it is important to realize that any employee must demonstrate his (er) worth to the employer.
Apart from the textbook knowledge and laboratory experience of Nuclear Medicine, it is important for any physicist to practically know the nuances of the subject once in a job. The list can be enormous if we have to put down every possible contribution that a physicist can make in a department. Whatsoever, we need to recognize at least certain parameters that any physicist should be able to perform in day to day practice.
The duty may start with the very stage of planning a department to help in commissioning. This surely falls in the domain of radiation safety officer. However, it is very important for the person to exactly be aware of the details of the scheme required and thorough update about the developments in instrumentation fields without which anyone would be fooled by the multinational companies and lose the opportunities to make a good department.
Secondly, a technical colleague must be aware of the practice procedures of each scan with scientific detailing for which (s)he should be aware of the peer reviewed guidelines. There is no scope of so-called individualized protocol to render. It is expected from each member of the department to follow the same practice-procedure-protocol laid down.
There is a lot of demand of technical colleagues due to increasing number of PET CT installations. Hence one has to update his(er) knowledge of radiological modalities failing which a CT technician would be employed in the department and enjoy the pie. A Nuclear Medicine physicist should independently be able to perform the procedures without the intervention of any other colleagues from other specialties.
Radiation safety protocol is to be followed as per standard guidelines and a technical colleague needs to maintain a log book along with other details so that timely interventions can be done. While doing such, it is also important to note that patient counseling about the radiation burden of a

procedure should also be a part of the technical procedure, particularly if the person acts as a radiation safety officer.

As a whole, a Nuclear Medicine physicist can be the workhorse of any good department. In fact, it is (s)he who would be considered as an asset for any organization if (s)he demonstrates his(er) abilities as desired. The continuous collaborative effort of a physician and physicist can thusenable a department doing good work and that should remain our motto.

ARTIFACTS IN PET/CT IMAGING

Archi Agrawal
Department of Nuclear Medicine, Tata Memorial Hospital, Parel, Mumbai-12

PET/CT combines both anatomical and functional imaging and thus is called hybrid imaging. There are many advantages in combining both form and function and benefits the patients in multiple ways. But it has its own disadvantages – one of which is artifacts that arise due to PET, due to CT and also because of fusion of both these technologies. We as Nuclear Medicine technologists and physicians who are performing and reporting these scans should be aware of these artifacts and ways to reduce them. If these are un-avoidable and occur – we should be able to interpret correctly so as to avoid false-negative and false-positive scans. These artifacts are as follows –

1. **Artifacts due to failure of attenuation correction model** – Eg – artifacts due to metallic implants and CT contract media.
2. **Artifacts due to patient motion and due to difference in respiratory phase between the CT and PET scan** – Eg – Mis-registration and Respiratory artifacts.
3. **Truncation artifacts** – due to patient outside the CT field of view.



Curvilinear cold artifact (arrow) due to different respiratory phasesduring PET and CT acquisition.

Peptide Receptor Radionuclide Therapy (PRRT) of neuroendocrine tumors: Current state and future perspectives

Ameya D Puranik
Dept of Nuclear Medicine, Tata Memorial Hospital, Mumbai-12

Introduction: Neuroendocrine tumors (NETs) are relatively rare tumors originating from neuroendocrine cells, distributed ubiquitously throughout the body. The term "neuroendocrine" relates to a peculiar characteristic or phenotype of these cells, namely the ability of synthesize, store and secrete neuro-hormones, neurotransmitters or neuromodulators, substances produced by both the endocrine and nervous systems. Gastroenteropancreatic neuroendocrine tumors (GEP-NET) constitute 75% of all NETs. Current WHO classification distinguishes 3 groups of GEP-NET; reflecting roughly the different biology of tumors – highly differentiated neuroendocrine tumor with a proliferation rate (Ki-67) of less than 2%; highly differentiated neuroendocrine carcinoma with Ki-67 greater than 2% and low differentiated neuroendocrine carcinoma with Ki-67 greater than 20%. The heterogeneous nature of neuroendocrine tumors, their indolent course and lack of therapeutic options for the management of advanced cases - together form the Achilles heel for oncologists. Therapeutic strategy in NETs is multidisciplinary and includes surgery, interventional radiology, medical and palliative care.

The conventional imaging modalities like CT, MRI and USG provide excellent morphologic information, but frequently miss the localization of the primary tumor. A recent study showed a

59% detection rate of unknown primary NET (CUP-NET) by ^{68}Ga DOTANOC receptor PET/CT (1). The metabolic dimension increases the likelihood of picking up even small volume disease, often considered equivocal on anatomical imaging; this can often impact the management.It is a known fact that molecular events precede morphologic changes by days to months. The functional information provided by PET/CT along with the possibility to do semi quantitative / quantitative evaluation has resulted in the conceptualization of a 'tailored regime'.Also, the state of the art PET/CT scanners, apart from providing functional information about the whole body in one sitting, makes it possible to perform diagnostic CT wherever needed and give vital information regarding the morphology of NET - keeping in mind that not all the tumors are SSTR positive (1,2). The high success of octreotide scintigraphy using ^{111}In labeled octreotide (OctreoScan) encouraged the development of positron emitter based sstr specific radiopharmaceuticals. ^{68}Ga is a radio metal and a positron emitter with a half-life ($T_{1/2}$) of 68 min and produced from a ^{68}Ge/^{68}Ga-generator ($T_{1/2}$=271 day) in aconvenient, fast, "in-house" preparation (3). The same peptides labeled with ^{68}Ga for diagnosis can be labeled with ^{177}Lu or ^{90}Y for radionuclide therapy (4), a form of personalized treatment which has been given the term THERANOSTICS.

PRRT – Basic principles

The biological basis of PRRT is the receptor-mediated internalization and intracellular retention of the radio peptide. Several clinical trials indicated that PRRT with radiolabeled somatostatin analogues is among the promising newly developed targeted tools in neuroendocrine tumors (5). Peptide receptor radionuclide therapy (PRRT) can deliver radiation doses to tumors, which are adequate to achieve volume reduction or even cure.

Initial studies were performed with high doses of the radiopeptide [^{111}In-DTPA^{0}]-octreotide. Objective responses were rare or questionable due to the short range (nanometers to micrometers) of the emission and therefore the short tissue penetration of the emitted Auger electrons. The radiopeptides that have been proven effective and which have been extensively studied are the ^{90}Y labeled peptide - [DOTA^{0}, Tyr3]-octreotide (DOTATOC) and the ^{177}Lu labeled peptide [DOTA^{0}, Tyr3]-octreotate (DOTATATE) (6,7).

DOTATATE has a nine-fold higher affinity for the somatostatin receptor subtype 2 compared to DOTATOC (8). In a preliminary report, 35 patients with neuroendocrine gastroenteropancreatic tumors were treated with escalating doses of ^{177}Lu DOTATATE, resulting in complete and partial responses in 38% of patients. No serious side-effects were observed. In addition, ^{177}Lu DOTATATE significantly improved the global health/quality of life and various function and symptom scales in patients with metastatic gastroenteropancreatic tumors (9).

Due to their marked radiosensitivity, the kidneys are the critical organs in PRRT. Proximal tubular reabsorption of the radiopeptide and the subsequent retention in the interstitium results in renal irradiation. Given the high kidney retention of radiopeptides, positively charged molecules, such as L-lysine and/or L-arginine, are used to competitively inhibit the proximal tubular reabsorption of the radio peptide (6). Cumulative and per-cycle renal absorbed dose, age, hypertension and diabetes are considered as contributing factors to the decline of renal function after PRRT (10).

Besides renal toxicity, bone marrow involvement must be considered although it appears not to be a principal dose-limiting factor. Acute hematological toxicity is not uncommon, especially after ^{90}Y-labeled peptide therapy, and the possibility of a mild, but progressive impoverishment in bone marrow reserves has to be considered in repeated cycles. In addition, myelodysplastic syndrome (MDS) or overt leukemia may develop in patients receiving high bone marrow doses, especially in those previously treated with alkylating agents (5).

Future directions

- PRLT (Peptide Receptor Ligand Therapy for other malignancies, e.g. prostate cancer treatment using Lu-177 PSMA)
- DUO-PRRT(PRRT with
- TANDEM-PRRT (administration of 177Lu and 90Y labeled sstr analogues concurrently on the same day)
- Intra-arterial PRRT (for improved dose delivery to liver metastases)
- Combined PRRT (in combination with other treatment modalities)

Summary

PRRT is highly effective in the management of NETs, even in advanced cases and lends a benefit in overall survival from time of diagnosis, of

several years. There is a significant improvement of clinical symptoms and excellent palliation can be achieved.

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Special Techniques in PET/CT Imaging

Rakesh Kumar

Department of Nuclear Medicine, All India Institute of Medical Sciences. New Delhi

Contrast-enhanced computed tomography (CECT), Magnetic resonance Imaging (MRI), and Positron Emission Tomography (PET/CT) are widely used to determine the presence and extent of the tumors before and after treatment. However, PET/CT is superior to CT and MRI in detection of carcinoma of unknown primary, lymph node metastasis, distant metastasis, residual tumor, recurrent disease, and second primary tumors resulting in alteration in treatment planning. Thus, PET with fluorodeoxyglucose F 18 (FDG)/CT plays a significant role in the management of cancer patients in whom treatment is often expensive and associated with a significant morbidity. However, many a times, the interpretation of FDG PET/CT studies is challenging because of the inherently complex anatomy, physiologic variants, and unusual patterns of FDG uptake after radiation therapy and surgery. Because FDG is not a tumor-specific tracer, it can accumulate in a variety of benign processes including benign tumors, inflammatory, posttraumatic, and iatrogenic conditions. In addition, there is physiologic uptake of FDG uptake in brown fat, muscles, vocal cords, and lymphatic system in the head and neck region and other parts of body. Lesion characterization on the CT portion of the PET/CT study is therefore of utmost importance because it increases the specificity of PET/CT reporting. However, despite its improved capabilities, PET/CT does not always accurately depict the tumor or demonstrate its margins. Apposed anatomic structures are sometimes difficult to distinguish from each other, and the exact outline of the tumor may still be undefined. In the case of a small tumor, apposition could almost hide the lesion. Physiologic uptake of FDG in areas of brown adipose tissue (BAT) and muscles of the neck, physiological intestinal FDG uptake also make interpretation of FDG PET/CT

studies difficult. In such cases, specific interventions, such as use of different dynamic maneuvers and pharmacologic interventions may provide useful information about the lesion. These techniques facilitate providing information concerning lesion size, location, volume, and relationship with surrounding structures to the nuclear medicine physician and help to differentiate physiologic uptake of FDG from the pathologic uptake. In this lecture I will reviews and discuss the use of different techniques in FDG PET/CT imaging for their possible applications in whole body imaging for various cancers.

Role of Nuclear Medicine in Gastroenterology

Shwetal Pawar,
Dept of Nuclear Medicine, Seth G S Medical College and KEM Hospital, Parel, Mumbai.

The gastrointestinal tract is one of the most complex organs in the body with more neurones than the brain. It is uni-directional and has a very complex immune system.The Nuclear Medicine techniques for evaluation of gastrointestinal abnormalities provide reproducible and reliable quantitative information with much less radiation exposure than conventional radiology.There is racial and regional variation in the transit time that are dependent on the type and constitution of meal and is highly influenced by hormones secreted.

Gastroenterology application of Nuclear Medicine requires study protocols that are specified and standardised for the regional population especially for estimation of various transit times. Thus the Nuclear Medicine physicist or technologist needs to standardise the technique meticulously for the particular department and population to be addressed. The solid and liquid gastric emptying study and colonic transit time are the main studies that need regional standardisation.The standardisation of transit time in paediatric population has always been an ethical issue due to additional radiation exposure.

The Salivary scans to assess salivary gland function, Meckels scan to detect ectopic gastric mucosa, Gastrointestinal bleed study using Tc-99m RBCs, Gastroesophageal reflux studies, Oesophageal transit study, Hepatobiliary scintigraphy to detect biliary function are the unique and only studies providing useful information. Various drug interventions such as Ranitidine for Meckels scan, Phenobarbitone or ursodeoxycholic acid for hepatobiliary scintigraphy etc. improve the specificity.

Gastrointestinal infections and inflammation detection has always been a challenge; however FDG PET/CT and Tc-99m labelled WBCs have been used successfully in India for this purpose.

The unavailability of isotopes in India has limited the performance of bowel transit time studies. In-111 chloride performs excellently for determining small and large bowel transit studies. The simultaneous dual isotope studies for determining liquid and solid emptying will also improve the performance and reduce time with availability of In-111 Chloride and better protocol development.

The gastrointestinal malignancies are well diagnosed with various PET radiophamaceuticals such as FDG and Ga-68 labelled peptides. They are treated with the Y-90 and Lu-177 labelled peptides and Y-90 spheres are gaining popularity. However the dosimetry of these therapies should be encouraged by providing additional training.

Newer challenges for developing and expanding Nuclear Medicine practice in gastroenterology involves availability of In-111 Chloride, antibody imaging radiopharmaceutical for infection and oncological imaging. The development of capsule based radiopharmaceuticals for evaluation of gastrointestinal motility may add further information. This may be achieved with the research projects in the years to come.

Abstract

Abstract ID: NMPAICONAbs8523
PET Imaging Radioprobes as potential tool in Pathophysiologies: A Emerging Paradigm in Translational Science

Satish Nigam
Department of Nuclear Medicine & PET-CT, Nayati Healthcare and Research Private Limited,NH-2 Delhi -Agra Highway,Mathura-281004(UP),India

Molecular imaging originated from the field of radio pharmacology due to the need to better understand fundamental molecular pathways inside cellular system in a noninvasive manner. Molecular imaging differs from traditional imaging in that probes known as biomarkers are used to help image particular pathways. Biomarkers interact chemically with their surroundings and in turns alter the image according to molecular changes occurring within area of interest. Physiology is important process in all normal eukaryotic cell and change in physiology leads to various type of disease, radiotracer involve the action of various protein based receptors, ion channels, transporter and enzymes. The ability to interrogate the location, abundance and activity of these entities, involve noninvasive molecular imaging can provide unprecedented information about the spatio-temporal dynamics of cellular system. Positron emission Tomography (PET) is a radiotracer imaging method that yields quantitative images of regional in-vivo biology and biochemistry. PET, now used in conjunction with computed tomography (CT) in PET/CT biomedical devices has had it greatest impact to date on cancer and is now an important part of oncologic clinical practice and translational cancer research. In this presentation of current application and future directions of PET/CT in cancer. We first highlights the basics of translational research followed by a discussion of principle of PET including tracer kinetics, radioprobe characteristics and biochemistry and current application of the most commonly used PET imaging agent.18F-flurodeoxyglucose (FDG), then emerging methods for PET imaging of other biologic process relevant to cancer ,neurogenerative disease myocardial and infection inflammation are reviewed ,including cellular proliferation, tumor hypoxia, apoptosis, amino acid and cell membrane and imaging of tumor receptors and other tumor – specific gene products. The purpose of this presentation is to summarize well known established radiotracer physiological cellular activity and draw attention to recent developments in PET radiotracers for imaging signal transduction pathway in disease. This presentation is organized by target class and focuses on structural chemistry of the best established radiotracer identified in each class. The focus of presentation is on methods in current clinical practices as well as those that have been translated to patients and are currently in clinical trials.

Abstract ID:NMPAICONAbs8734
Fractionation of radiopharmaceutical kits and its impact on cost of scan: Truth Vs Myth

Vishwa Dipak Tripathi, Narvesh Kumar
Department of Nuclear Medicine, Shri Ram Murti Smarak Functional Imaging and Medical Centre, CP-2/3, Vishwas Khand, Gomti Nagar, Lucknow-226010,

Objective: Radiopharmaceutical cold kits contains radiopharmaceutical, reducing agent buffer and stabilizing agents etc. These kits are prepared according to GMP guidelines in a freeze dried form. Usually these kits have long self-life upto 1 year. When vial is reconstituted with radioisotope we can use it for few hours only. As nuclear medicine is still a growing branch so most of the departments in private setups have low patient volume, if we use a cold kit for single day it will not be cost effective and will increase the cost of scan. Many nuclear medicine personal have tried cold kit fractionation technique but most of the techniques yet not standardized. We tried fraction of various commonly used kit and our success rate is almost 100 percent. Materials and
Methods: We have used the fractionation technique for commonly used radiopharmaceutical cold kits like MDP, Sestamibi, DTPA, DMSA and EC and used the same vial for formulating the radiopharmaceutical doses up to 10-12 days and necessary quality control test for labelling using paper chromatography was performed before administration to patients. We compared images of both methods i.e. single kit method and fractionation method, Images were observed by two experienced nuclear medicine physician,

there was no difference in image quality and uptake pattern. Most of the cold kits are packed in lyophilized powdered form in a vial. We prepare a solution of 2 ml with 0.9% of NaCl under full aseptic precaution and used only a quarter part of it, remaining solution was stored in deep freezer compartment of refrigerator (-18℃ to -20℃ Temperature) and was used for the next 2 weeks. We used following methods to prepare different radiopharmaceuticals: Tc-99m-MDP: We took Tc-99m sodium pertechnetate of 25 to 80 mCi per ml concentration in a 2.0 ml syringe and added 0.5 ml of MDP aliquot, after shaking well, we kept this mixed solution for 15 minutes for proper labelling before use. Tc-99m-Sestamibi: We took 0.5 ml of Sestamibi aliquot in a reaction vial and added Tc-99m sodium pertechnetate of 25 to 80 mCi per ml concentration and kept the same in boiling water bath for 10 minutes, followed by cooling for 5 minutes before use. Tc-99m- DTPA: We took Tc-99m sodium pertechnetate of 10 to 75 mCi per ml concentration in a 2.0 ml syringe and added 0.5 ml of DTPA aliquot, after shaking well, we kept this mixed solution for 15 minutes for proper labelling before use. Tc-99m- DMSA: We took Tc-99m sodium pertechnetate of 10 to 25 mCi per ml concentration in a 2.0 ml syringe and added 0.5 ml of DMSA aliquot, after shaking well, we kept this mixed solution for 15 minutes for proper labelling before use. Tc-99m- EC: EC contains three components as A, B in lyophilized powdered form and C in liquid form. The component A and B were diluted in 1.5 ml 0.9% of NaCl. We took 0.5 ml of component A in a reaction vial, added 10 to 15 mCi per ml concentration of Tc-99m sodium pertechnetate in it and waited for 10 minutes for proper labelling, 0.5 ml of component B was added in same reaction vial. This solution was kept for boiling water bath for 10 minutes, after cooling for 5 minutes we added 0.2 ml of component C in the reaction vial before use.

Results: Study was done on more than 500 patients over 1 year and results were surprising that fractionation techniques can reduce running cost of low volume nuclear medicine centers and reduce the cost of procedure for patient without loss of any diagnostic information and image quality. We have also tried to fractionate the other radiopharmaceutical cold kits like Sulphur Colloid, MAG-3 but it was a failure and reason was unknown and we are still trying for the best

Conclusion: Study was done on more than 500 patients over 1 year. We try to standardize the methods to fractionate commonly used cold kits. We conclude that fractionation of commonly used cold kits can be practiced as a cost saving method in low volume departments. As reduced cost of scan will make nuclear medicine procedures affordable for poor patients also.

Abstract ID:NMPAICONAbs3998
Important Moments in the History of Nuclear Medicine

Saumya Shrivastav, Subhash Kheruka, Sanjay Gambhir
Department Of Nuclear Medicine, Sgpgims, Rae Bareli Road, Lucknow (Up), India Pin:226014

The development of nuclear medicine has resulted in several effective routine methods in diagnosis and therapy. There is an ongoing discussion about the future of the activity based on the fast development of ultrasound, CT and MR. In such discussions, it is often forgotten that nuclear medicine is also a dynamic diagnostic tool under continuous progress. As seen from this historical review, nuclear medicine has grown from quite simple in vitro tests to very advanced methods to image organ function. This is the result of the development of radiopharmaceuticals and instrumentation. Today, development is moving towards what is called receptor scintigraphy, i.e., the use of radiopharmaceuticals which are very specific to certain diseases, for instance, tumours. Even at present there is no other method for early detection of bone metastases than bone scintigraphy. Also, there is no other method to determine the regional myocardial blood flow both at stress and at rest, than myocardial scintigraphy. Nuclear medicine will remain an important diagnostic tool as long as it employs people with engagement and interest.

Abstract ID:NMPAICONAbs8477
The contribution of Medical Physics in Nuclear Medicine: looking back and Future - a physicist's perspective

Priyanka Yadav, Subhash Kheruka, Sanjay Gambhir
Department Of Nuclear Medicine, Sgpgims, Rae Bareli Road, Lucknow (Up), India Pin:226014

Nuclear Medicine has its basis in 'the use of radioactive tracers for medical diagnosis, therapy'. Since the inception of the discipline, the adoption of scientific methods and instruments has been central to its development and practice.. The strength of Nuclear Medicine continues to be its unique sensitivity to picomolar concentrations of radiotracer that can be used to probe underlying physiological, biochemical and molecular processes. The exploitation of this capability continues to rely on joint ingenuity of scientific and clinical specialists. The focus in this article is on this latter group of scientists, collectively referred to as 'medical physicists', but including physicists, engineers, computer scientists, mathematicians and statisticians who all contribute to the technological development that underpins Nuclear Medicine. A full review of the contributions of Medical Physics to Nuclear Medicine is well beyond the scope of this poster ; instead, selected historical examples will be used to highlight the continuing significant clinical impact that medical physicists contribute to the field.

Abstract ID:NMPAICONAbs8406
Impact of Iterations on image quality and quantification (SUV) using iterative reconstruction and Q.clear.

Sarika Paunikar, Amrita Kasat, Swatantramani Dubey
Jeeyo PET-CT and Nuclear Imaging Centre, Sarvodaya Hospital Premises, Ghatkopar west, Mumbai .400086

Objectives : The new PET-CT Discovery IQ at JEEYO Pet-ct and Nuclear Imaging Centre, Mumbai uses BGO light bursting detector with Q.clear reconstruction software. The objective of this study is to compare the SUV and image quality between the Q.clear (25 iteration) and no. of iterations in VPHD.
Methods: F18-FDG PET/CT images of Image Quality phantom (NEMA phantom) and cancer patients diagnosed at Jeeyo PET CT centre were chosen. Raw data of Image Quality phantom and each patient were altered by changing the number of iterations to 2,5,10,15,20,25,30,35,40,50 with subset 12 and filter cutoff 5.4 mm and for the comparison system's own reconstruction method Q.clear. Identical regions of interest were drawn around the cancer lesions at the same slice on each of the images. The Max SUV values were recorded and compared image quality and measured size of lesion.
Results: Upon analysis of the resulting data it was discovered that the number of iterations did change the SUVs and SUV recovery over VPHD.
Conclusions: Based on the resulting data it was determined that the resulting data were statistically significant. According to the results the number of iterations in VPHD does impact the SUV and image quality. But Q.clear provides excellent image quality and consistent and accurate quantification.

Abstract ID NMPAICONAbs3934
Common Motion Artifacts in PET/CT Images due to Attenuation-Emission misregistrations: Causes and Possible Solutions

Sutapa Rakshit, Basant L. Malpani, Sunita Sonavane, Nawab Singh Baghel
Radiation Medicine Centre, BARC, TMH Annexe Building, Parel, Mumbai, India

Introduction: Multimodality PET/CT images can be performed with integrated or hybrid PET/CT scanner or with software fusion of dedicated PET and CT. Regardless of applied method, precise alignment between CT and PET component of an image is a prerequisite for accurate anatomic correlation and good image quality. Misregistration between attenuation and emission PET/CT is not uncommon and when it happens, the artifactual abnormalities may compromise image interpretation resulting in lesion mislocalization, false positive defects and inaccurate SUV quantitation. Misregistration due to motion can be categorized as preventable and non-preventable type.
Methods: Few case studies were evaluated in PHILLIPS GEMINI-TF 16 slice PET/CT scanner with usual acquisition protocol of CT scan followed by PET scan. Image misregistration was observed in various organs like head and neck, cardiac, diaphragm border, liver upper border, urinary bladder, legs etc. After careful image analysis along with clinical history, patterns of misregistrations were identified as preventable (non-physiologic movement) and non-preventable (physiologic motion). Case study 1: 8 year male with wilms tumor of right kidney, rotated his head between two scans resulting in significant misregistration in attenuation corrected PET/CT image. This is preventable

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patient motion. Case study 2: 49 year female with renal cell carcinoma showed misregistration in thoracic cavity due to movement of diaphragm during respiration. This is non-preventable physiologic motion. Causes and possible solutions: Physics of positron emission impose limitation on spatial, temporal. Any misregistration higher than spatial resolution of current scanner may result in interpretation dilemma. Current design of PET/CT only matches spatial resolution of CT and PET data by blurring CT images so that spatial resolution of CT images matches with PET images. There has been no attempt from manufacturers to match the temporal resolution of CT and PET for a routine whole-body PET/CT scan. For any measure to match temporal resolution of PET and CT data, additional acquisition time cannot be too long and post processing cannot be too cumbersome. Spatial co-registration throughout the extended coaxial imaging range is compromised by involuntary motion due to patient discomfort during combined examination having long acquisition time. This is caused due to relaxation of muscles during the said study. Respiratory, cardiac pulsating and bowel motion are unavoidable and physiologic in nature. Misregistration is typically identified by a curvilinear white band or photopenic region in PET images and observed in diaphragm/lung interface, liver upper border, variable heart size. Various breathing protocols, respiratory gating have been recommended for CT and PET. But majority of the PET/CT clinic do not use respiratory gating due to complexity and challenges involved in the gating. Misregistration due to non physiologic motion in head and neck, pelvis, leg area can be minimized by carefully instructing patient not to move during the study, placing them in comfortable position before the start of the study, empty their bladder before the start of acquisition and providing proper positioning aids. Most importantly, observing non-attenuation corrected PET images allows quick recognition of motion artifacts and thus improves accuracy of diagnostic information. **Conclusions:** Literature survey shows frequency of significant misregistration in head and neck is 67%, arms 85%, diaphragm 86%, bladder 98% and leg 86%. It can be said that if one carefully reads PET/CT images, at least one form of misregistration is present in 100% of PET/CT studies. Proper patient instructions, use of positioning aids and gating techniques could significantly minimize the frequency of misregistration in PET/CT. Simultaneous display of both CTAC and NAC PET images side by side with CT images can minimize false findings.

Abstract ID:NMPAICONAbs2502
"Extrinsic Quality control Test of gamma camera mounted with medium energy collimator ":- A feasible approach

Biju K, Awasare Sushama, Basant Malpani, Nawab Singh Baghel
Radiation Medicine Centre (BARC) , Tata Annex Bldg. , Parel, Mumbai 400012

Aim: - To find out a feasible method to perform extrinsic quality control of gamma camera with 5/8 " NaI(Tl) crystal (suitable for medium energy imaging) mounted with medium energy collimator with low energy 141Ce flood source. Introduction Daily quality control test of gamma camera is an essential procedure to be performed to check the function integrity of the instrument. Use of 99mTc ,57Co or 141Ce filled flood source to check the daily extrinsic quality control parameter of gamma camera with 3/8 " NaI(Tl) crystal mounted with Low energy collimator is well established. Due to non availability of medium energy flood source, extrinsic QC of gamma camera designed for medium energy imaging mounted with medium energy collimator is difficult to perform. As an alternate method but not as substitute, a low energy flood source of 99mTc, 57Co and 141Ce can be used to check the extrinsic QC parameter of gamma camera. Materials and Methods 141Ce flood source have been used to perform extrinsic uniformity, linearity and resolution of 5/8" NaI(Tl) crystal gamma camera (SIEMENS Symbia E.Series). Uniformity test of gamma camera was performed by acquiring 5 million counts using 256 X 256 matrix and zoom 1 with energy window of 144Kev. Resolution and linearity test of the gamma camera were also performed using four quadrant bar phantom and linearity phantom. Images were acquired for 5 million counts with acquisition parameter of 256 X 256 matrix and zoom 1. Linearity was checked visually and resolution was evaluated by finding the resolvable slit in the four quadrant bar phantom. Result Uniformity test have showed good extrinsic uniformity for both the detectors. Linearity was observed in both X and Y

direction. Spatial resolution of 7 mm was observed for this gamma camera. Conclusion:- Extrinsic quality control of thicker NaI(Tl) detector gamma camera mounted with medium energy collimator can be performed with low energy flood source like 141Ce where medium energy flood source is not available. Good uniformity, linearity and resolution were observed for the gamma camera which is evaluated. Extrinsic quality control test with medium energy flood source if available will be an ideal option to evaluate extrinsic QC parameter.

Abstract ID:NMPAICONAbs9481
Interesting history of particle accelerator and beginning of positron emitting radioisotopes.

Dayesh Patil, B. L. Malpani, Sharmila Banerjee
Radiation Medicine Centre (BARC), Tata Annex Bldg. , Parel, Mumbai 400012

In the early 1930's, the Cockcroft-Walton accelerator was developed by John Cockcroft and Ernest Walton at the Cavendish Laboratory in Cambridge, England, and the Van de Graaff Accelerator was developed by Robert Van de Graaff whilst working as a post-doctorate research assistant at Princeton in the US. Both accelerators simply accelerated charged particles by generating very high voltages. The Cockcroft-Walton accelerator generated a high voltage by creating a complex electrical circuit called a voltage multiplier cascade. Using their generator, Cockcroft & Walton were able to generate a voltage of 800kV.This voltage then accelerated protons along an 8 foot vacuum tube, where they then collided with a Lithium target achieving the first artificial nuclear disintegration in history.A Van de Graaff accelerator is a very big with an accelerator tube contained within it. By 1933 a Van de Graaff accelerator was in operation that could accelerate hydrogen ions to an energy of 0.6MeV.The first development in Linear Accelerators came from Rolf Wideroe in 1927 when he built a linear accelerator using an alternating current (AC) voltage and a series of drift tubes.In 1928 Ernest Lawrence of the University of California, inspired by the work of Wideroe, had the idea of utilizing a curved path for a particle accelerator. A magnetic field perpendicular to the plane of motion of an accelerated particle will result in the particle taking a curved path. By studying the simple relationship between the forces acting on the particle, Lawrence realised that the increase in the radius of the path taken by the particle is compensated for by the increased velocity of the particle if the magnetic field, the charge of the particle and the particles mass remain constant. With this in mind, he built what became known as a Cyclotron.Lawrence's first accelerator, built in 1931, was able to accelerate beams of Hydrogen ions to 80keV. After some modifications to the original design, Lawrence was able to ramp up the energy of the output beam to 1.22MeV and repeat Cockcroft & Walton's result of nuclear disintegration of Lithium by 1932. The Cyclotron became the accelerator of choice across the world from many years as it was more cost and size effective than other accelerators.It was Ernest Laurence's brother, John, who realized the implication of the cyclotron for medicine. John Lawrence was interested in the application of radioisotopes for the treatment of cancer. John proposed that an intravenous or intramuscular injection of radioactive sodium chloride around the site of the tumour could selectively attack the cancer. In 1935, He carried out the first biological experiments with neutrons and discovered that they were five times more harmful than X-rays. This caused the first safety regulations the be drawn up for the use of radioisotope and particle beams. The physical principles governing the Betatron were first described by Wideroe in a 1928 paper and put in to practice in 1940 by Donald Kerst. The development of the Betatron was driven by the demand for high energy X-rays and gamma rays for medical and research use.

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Radionuclide Generators - A Historical Perspective

Aneesh A, B L Malpani, Sharmila Banerjee
Radiation Medicine Centre (BARC) , Tata Annex Bldg. , Parel, Mumbai 400012

Radionuclide Generators - A Historical Perspective Abstract: Radionuclide generator systems continue to play a key role in providing both diagnostic and therapeutic radionuclide for various applications in nuclear medicine, oncology, and interventional cardiology. Although many parent/daughter pairs have been evaluated as radionuclide generator systems,

there are a relatively small number of generators, which are currently in routine clinical and research use. Essentially every conceivable approach has been used for parent/separation strategies, including sublimation, thermo chromatographic separation, solvent extraction, and adsorptive column chromatography. The first generator for life sciences application was developed in 1920, providing 222Rn (T½ = 3.825d) to obtain radon seeds for radiation therapy as a daughter of 226Ra (T½ = 1.60) (Failla 1920). However, practical importance of radionuclide generators was achieved in 1951 by the 132Te (T½ = 3.26 d)/132I (T½ = 1.39 h) generator (Winsche et al. 1951) and much more in 1957 by the pioneering development of the 99Mo/99mTc generator at Brookhaven National Laboratory (BNL) (Stang et al. 1954, 1957). The technetium daughter radionuclide was soon envisioned for medical use (1960), and indeed its first clinical application was reported in 1961 (Richards 1960; Harper et al. 1962) and has revolutionized radiopharmaceutical chemistry and nuclear medicine. Since that time, various other generator systems have been developed, and some of them received significant practical application. Generator parent radionuclide are obtained from uranium fission products (i.e., 99Mo and 90Sr) or as decay products from 233U (229Th/225Ac) are produced directly in nuclear reactors (188W, etc.) or at accelerators (82Rb, 62Zn, etc.). Radionuclide generator systems relevant for life-sciences application : 42Ar/42K, 47Ca/47Sc, 44Ti/44Sc, 52Fe/52mMn, 66Ni/66Cu, 62Zn/62Cu, 68Ge/68Ga, 72Se/72As, 77Br/77mSe, 80mBr/80Br, 81Rb/81mKr, 83Rb/83mKr, 90Sr/90Y, 87Y/87mSr, 89Zr/89mY, 97Zr/97Nb, 99Mo/99mTc, 103Ru/103mRh, 103Pd/103mRh, 112Pd/112Ag, 109Cd/109mAg, 118Te/118Sb , 132Te/132I , 122Xe/122I. The most widely used radionuclide generator for clinical applications is the 99Mo/99mTc generator system, but recent years have seen an enormous increase in the use of generators to provide therapeutic radionuclide, which has paralleled the development of complementary technologies for targeting agents for therapy and in the general increased interest in the use of unsealed therapeutic radioactive sources. More recently, use of the 68Ge/68Ga generator is showing great potential as a source of positron-emitting 68Ga for positron emission tomography (PET)/CT imaging.

Abstract ID: NMPAICONAbs7608
Interesting History of Radionuclide Therapy

Sunil Kumar, B L Malpani, Sharmila Banerjee
Radiation Medicine Centre (BARC) , Tata Annex Bldg. , Parel, Mumbai 400012

In March 1936, Hamilton & Stone in California employed the first artificially produced radioisotope for therapeutic trials. They used 24Na in three patients with leukemia and allied diseases. They also investigated the uptake and excretion of radio sodium in these patients. A few months later J.H. Lawrence at Berkeley initiated the therapeutic use of 32P for the treatment of leukemia and polycythemia. In the years to follow, several reports on the successful use of 32P in therapy were issued. This method of utilizing radio phosphorus in the treatment of polycythemia Vera is still in use. In Sweden, the first report on use of radionuclide's in the treatment of leukemia was issued by E. Lindgren in 1944. L.-G. Larsson used 32P in the treatment of mycosis fungoides . Radio phosphorus has been used extensively in both diagnosis and therapy. One important application is colloidal 32P in the treatment of patients with pleural effusion and ascites . This kind of intracavitary use of radioactive colloids, mainly 198Au, for palliation treatment of malignant effusion began in 1945 . Although radio colloid instillations have been made in other closed cavities, the primary application is still in the chest and abdomen. Another use of colloids labelled with 32P, 90Y. 198Au and other radionuclides, is for performance of medical synovectomies. This work began in the early 1960s and the results were promising with an improvement rate of 50-60%. Early works by Hahn et al. and Lawrence et al. revealed that 32P was metabolized by the skeleton, especially by neoplastic tissues. Hence the concept of treatment of bone metastases arose. This method dates back to the early 1950s and in particular the work by Storaasli et al. and that by Maxfield et al. They used 32P which unfortunately had the disadvantage of a high absorbed dose to bone marrow. This led to the introduction of 89Sr which gave the same pain relief as 32P but without marrow suppression. The use of 89Sr is still an important routine method for treatment of pain from bone metastases, especially in patients with prostatic carcinoma. The most extensive use of unsealed

sources has been in the treatment of the thyroid with radioactive iodine. Already in 1941, Hertz & Robert used 130 I in the treatment of a patient with hyperthyroidism. They administered only 1 mCi and observed no effect. Therefore they increased the activity to 16 mCi and treated 29 patients with this dose. They concluded that the treatment was effective in 80% of the cases. With the introduction of 131 I the therapy developed. The uptake measurement and scintigraphic imaging made it possible to make an individual dosage of the radionuclide meaning an increased accuracy in the treatment. This method is still the method of choice today in the treatment of hyperthyroidism. Early experiments using radioactive iodine in the treatment of thyroid cancer were also performed. Although the majority of thyroid carcinomas can be removed surgically, it is often uncertain afterwards whether or not the resection will be complete and if local or distant metastases are present. In these cases, treatment with 131 I can be used as a supplement. In 1943, Frantz et al. treated a child who had had a total thyroidectomy. They found a good uptake in a metastases in the right pharyngeal wall and noted that an effective 131 I therapy of metastases might well depend upon the removal of the functional thyroid gland. Seidlin et al. then demonstrated that metastatic carcinoma of the thyroid can be successfully treated with radioactive iodine, provided of course, that the lesion accumulates iodine.

Abstract ID: NMPAICONAbs4844
Interesting history of 'Gamma Camera'

Joohee Rai, B L Malpani, Sharmila Banerjee
Radiation Medicine Centre (BARC) , Tata Annex Bldg. , Parel, Mumbai 400012

The field of nuclear medicine, one of the most sensitive methods for obtaining information on biological function for the purpose of medical diagnoses, precedes the development of image-forming radiation detectors by several decades.The development of radiation detectors capable of delivering spatial information about gamma-ray interactions was one of the key enabling technologies for nuclear medicine imaging. Until 1949, the only counting device for external detection of a radioactive substance was the Geiger-Muller (GM) tube. Unfortunately, the tube was very insensitive to penetrating gamma-rays from such radionuclides as I-131. Nevertheless, attempts were made to use collimated GM tubes for the study of thyroid function and morphology.Rectilinear scanner(The first scintillation counter for medical use) was invented by B. Cassen and ass. in 1949 at UCLA, when first scintiscans were obtained. Technical improvements have been made 1950-1956 (B. Cassen and ass., R. Newall and ass., P. Bell, D. Kuhl). The instrument originally performed well and its effectiveness was further enhanced by the introduction of large sodium iodide crystals and end- windowed photomultiplier tubes.Hal Oscar Anger (May 20, 1920 – October 31, 2005)was an American electrical engineer and biophysicist at Donner Laboratory, University of California, Berkeley, who is known in his field for inventing the gamma camera, which was first exhibited in 1958 at a meeting of the Society of Nuclear Medicine. The device, also known as a scintillation camera and later as the Anger camera, produced images of internal processes by tracking tiny amounts of radioactive substances. In 1994, the Society of Nuclear Medicine gave him its $25,000 Cassen Prize, which is awarded to "a living scientist whose work has made a major advance in nuclear medicine science." In 2006, the Society of Nuclear Medicine's Education and Research Foundation received $6 million from the Hal Anger Estate, the largest gift ever received for advancing the field of nuclear medicine, leading to the development of a Hal Anger Prize and Lecture.

Abstract ID:NMPAICONAbs9505
History of Radioisotope in Nuclear Medicine

Shashank Hinge, B L Malpani, Sharmila Banerjee
Radiation Medicine Centre (BARC) , Tata Annex Bldg. , Parel, Mumbai 400012

Nuclear medicine is associated with a long history, to which scientists from various different fields such as physics, medicine chemistry and engineering have contributed over the decades. This multidisciplinary involvement means it has been difficult for historians to determine the origins of nuclear medicine. However, researchers believe the birth of this medical speciality probably occurred somewhere between 1934 when artificial radioactivity was first discovered and 1946 when radionuclides were first produced for medical use by the Oak Ridge

National Laboratory. George de Charles de Hevesy, a Hungarian radiochemist developed radioactive tracers to study chemical processes such as in the metabolism of animals. It was here he began the use of radioactive isotopes in studying the metabolic processes of plants and animals, by tracing chemicals in the body by replacing part of stable isotopes with small quantities of the radioactive isotopes. Nuclear medicine first became recognised as a potential medical speciality in 1946 when it was described by Sam Seidlin in the Journal of the American Medical Association. Seidlin reported on the success of radioactive iodine (I-131) in treating a patient with advanced thyroid cancer. Later, the use of I-131 was expanded to applications such as thyroid gland imaging, hyperthyroidism treatment and quantification of thyroid function. By the 1950s, the clinical use of nuclear medicine had become widespread as researchers increased their understanding of detecting radioactivity and using radionuclides to monitor biochemical processes. Several researchers worked tirelessly to establish the efficacy, safety and diagnostic and therapeutic potential of this speciality. In 1938 Emilio Segrè and Glenn T. Seaborg isolated for the first time the metastable isotope technetium-99m, after bombarding natural molybdenum with 8 MeV deuterons in the 37-inch (940 mm) cyclotron of Ernest Orlando Lawrence's Radiation laboratory. This was a form of radioactive decay which had never been observed before this time. An element with the atomic number 43 decayed with a half-life of 6.6 h [later updated to 6.0 h] and that it was the daughter of a 67-h [later updated to 66 h] molybdenum parent radioactivity. This chain of decay was later shown to have the mass number 99, and the 6.6-h activity acquired the designation ‘technetium-99m. Tc-99m remained a scientific curiosity until the 1950s when Powell Richards realized the potential of technetium-99m as a medical radiotracer and promoted its use among the medical community. Dramatic advances in nuclear medicine technology and instrument manufacturing took place in 1960s. It was during this time that nuclear medicine became a seperate medical speciality.

Abstract ID:NMPAICONAbs9920
Nuclear Imaging: From Autoradiography to PET Scanners

Rahul M, B.L Malpani, Sharmila Banerjee
Radiation Medicine Centre (BARC) , Tata Annex Bldg. , Parel, Mumbai 400012

One of the early mysteries of medical science was to study the functioning of brain. Angelo Morosso is responsible for the idea that brain function is related to blood flow. His findings were strengthened by neurophysiologists Charles Roy and Charles Sherrington in 1890, where they found that blood flow would be directed to a stimulated portion of the brain according to its function. Autoradiography was used along with gas radiotracers in 1948, initializing the beginning of brain imaging. The scintiscanner, invented in 1949 by Benedict Cassen, was the first instrument to create images by detecting radioactivity within the body. It used a radioisotope emission glow lamp (photorecorder) that produce images on X-ray film. The Anger scintillation camera was made in 1957 by Hal O. Anger, which became a milestone in the field of nuclear medicine. The first safe radiotracer to be used in humans was 2-deoxyglucose (DG), developed by Louis Sokoloff. It competitively inhibits a portion of the glycolytic pathway, making it a useful molecule to measure the use of glucose in the brain, which is analogous to brain activity. Initially this molecules was radio labelled with 14C but in 1976 Sokoloff along with Dr. Alfred Wolf and Joanna Fowler they synthesized 2-fluoro-2-deoxy-D-glucose (FDG), which is radiolabelled with 18F and is one of the mostly widely used radiotracers today. It has a longer half time (110 minutes) than carbon (20 minutes) and thus allows more flexibility in the measurements. In 1973, Edward Hoffman, Michael M. Ter Pogossian and Michael E, Phelps established a new imaging system called Positron emission tomography (PET) imaging using sodium iodide (NaI) as the detector. Alternatives to the NaI detector were necessary since this detector had high scatter and low density which limited its resolution and efficiency, respectively. An alternative was found in the 1980s in bismuth germanite (BGO) which had a high density and a similar decay constant as NaI. With this crystal the first commercially available PET scanner was made. A strong effort has been under place to improve PET technology. The search for better detectors and different radiotracers has and continue to be explored. A combination of CT and PET is a common technique used due to CT's high anatomical detail. MRI also has that

attribute though is not as commonly used in conjunction with PET. The next step would be to combine all three technologies for a better detection of disease and monitoring of neurological and cancer drug treatments.

Abstract ID: NMPAICONAbs2396

Influence of non-ionic Computed Tomography (CT) contrast agent in DNA double strand break (DSBs) formation using Fluorine-18 (18F) gamma ray exposure on V79 cancer cell line.

Tanmoy Mondal1*, Amit Nautiyal2, Deepanjan Mitra2, Subrata Kumar Dey1

1Department of Biotechnology, Maulana Abul Kalam Azad University of Technology, BF 142, Sector 1, Salt Lake, Kolkata, West Bengal, India. 2Institute of Nuclear Medicine & Molecular Imaging, Advance Medical Research Institute, Kolkata, West Bengal, India.

Background: Contrast media are medical drugs used to improve the visibility of internal organs and structures in X-ray based imaging techniques. They may have side effects ranging from itching to a life-threatening emergency, known as contrast-induced nephropathy. Though the frequency of side effects has fallen significantly since the introduction of non-ionic, monomeric contrast agents, however, side effects remain an important issue. The aim of the present study is to observe the influence of DNA double strand break (DSBs) formation by iodinated contrast agents in presence of low dose of ionizing radiation by in vitro experimental model. **Material and method:** In this study V79 a type of Chinese hamster lung fibroblast cell was mixed with 0.5 ml iodinated contrast media (Omnipaque-300mg/ml) and irradiated with 18F gamma ray exposure at a dose rate of 28.53 mGy/hour for 15 min. Another sample of V79 cell was used as a control and irradiated without mixing of the contrast agent with same dose rate and same period of time. DNA double strand break formation observed by comet and micronucleus formation assay. Total damage was calculated by comparing comet head radius, head DNA percentage, tail DNA percentage, tail length (TL) and olive tail moment (OTM) of the individual irradiated sample that is, with and without containing contrast media and number of micronucleus count determined by micronucleus assay. A negative control (without any treatment or irradiation) was kept during the study and student-t test was performed for statistical analysis.
Result: In comet assay comet head radius and head DNA percentage was decreased and tail DNA percentage, TL and OTM significantly increased in the sample which is irradiated in the presence of iodinated contrast media. Another side, the frequency of micronuclei formation also increased in a sample containing contrast media as compared to control group.
Conclusion: The increasing comet length and number of micronucleated cell in cell line mixed with contrast agent indicates that radiation dose is not the only factor affecting the amount of DNA damage. The use of contrast media in the radiological investigations is also another key factor in amplification of DNA damage.

Abstract ID:NMPAICONAbs8925

Evaluation of glomerular filtration rates and effective renal plasma flow using dose calibrator for activity measurement of pre and post syringes on gamma camera as an alternative method.

Swati Satamkar, Nawab Singh Baghel & Sharmila Banerjee.

Radiation Medicine Centre, BARC, TMC Annexe Bldg. Parel, Mumbai- 4000 12

Introduction: Conventionally, glomerular filtration rate (GFR) and effective renal plasma flow (ERPF) is estimated by planar gamma cameras by injecting 99mTc-DTPA and 99mTc-EC respectively. The pre and post syringe counting is done under gamma camera. Alternatively pre and post syringe counts can be measured in dose calibrator to save time and inconvenience of data acquisition related problems. Aims and objectives: To evaluate GFR and ERPF using dose calibrator for pre and post syringe measurement using gamma camera. **Materials and Methods:** 99mTc-DTPA Renogram and 99mTc-EC studies were performed using gamma camera and the data was analysed using gates protocol and modified gates protocol for GFR and ERPF evaluation respectively. Pre and post syringe activity was measured using dose calibrator in mCi and time was noted in 24 hour time format. The calibration factor was calculated for the gamma camera acquiring 1 mCi 99mTc-DTPA/99mTc-EC point source for 60 seconds at 10 cm distance from detector. Pre and post syringe counts from gamma camera were not used for GFR and ERPF

evaluation and pre and post syringe activity their respective time of measurement was used for GFR and ERPF evaluation. The calibration factor was entered and the selected collimator was LEHR. The GFR and ERPF were calculated by drawing region of interest (ROI) on both kidney and background. Area under the curve was kept constant in both analyses.

Results: GFR and ERPF were calculated using both the methods using Gates protocol and modified Gates protocol respectively and statistical analysis was carried out for comparison. There was no significant difference between both the values with good correlation coefficient >0.99. Conclusion: The requirement of pre and post syringe counting under gamma camera can be avoided and time can be saved using this method. In addition, the issues related to time mismatch between pre and post syringes also can be eliminated.

Abstract ID:NMPAICONAbs6692

Delayed regional FDG PET/CT imaging improves image quality in tumour imaging.

Nathan Parvathi , Sagar Chaudhari, Apurva Gokhale Priyanka sawant, Roshani waghela, Arvintho, Bhakti Shetye, Priya Monteiro, Mejhabeen Pathan, Rutuja Parab, Manoj R Chauhan, V. Rangarajan

Department of Nuclear Medicine and Molecular Imaging , Tata memorial Hospital , Mumbai

Aim: FDG PET/CT is extensively used in oncological imaging. It is common practice to obtain regional delayed images to improve the quality of the image. In this retrospective study we have studied the impact of delayed imaging in image quality by comparing the ratio of standard uptake value (SUVmax) of lesion to background (T/B ratio) in whole body imaging and in delayed image.

Material and methods: Data of all patients in whom delayed imaging was performed were retrospectively analysed.PET/CT acquisition was done on Philips medical systems, GEMINI TOF 64. PET in 3D mode. All patients underwent whole body imaging after around one hour of injection of FDG (5Mbq/kg). Whole body PET acquisition time was 1 min /per bed position. Images were reconstructed iteratively using RAMLA algorithm. Delayed images were acquired around 3 hours post injection. Delayed PET acquisition time was around 2 min /per bed position. T/B ratio were calculated in whole body images and in delayed images and was analysed for increase in the T/B ratio by using paired T-test.

Results: Total of 50 patients were available for analysis. 15 Patients had tumour in brain, 8 in urinary bladder and 27 in liver. Mean T/B ratio of the delayed images was more than that of the whole body images. The increase in the T/B ratio of statistically significant in all organs i.e brain, bladder and liver (p value <0.05 by paired T test. Mean difference in the T/B ratio of whole body image and delayed image was greater in urinary bladder than liver and brain. (3.3 vs 1.5 vs 1).

Conclusion: Delayed regional FDG PET imaging can improve the image quality by increasing the uptake of tumour to background ratio.

Abstract ID:NMPAICONAbs4090

Artifacts frequently encountered in Ga-68 PSMA PET/CT

Nathan Parvathi, Sagar Chaudhari, Apurva Gokhale, Priyanka Sawant, Roshani waghela, Arvintho, Priya Monteiro,Mejhabeen Pathan, Rutuja Parab, Manoj R Chauhan, Bhakti Shetye, V. Rangarajan

Department of Nuclear Medicine and Molecular Imaging , Tata memorial Hospital , Mumbai

Learning objective: Recognize potential artifacts observed in Ga-68 PSMA PET with appropriate illustration. Outline few acquisition techniques and interventions that can minimize artifacts. Halo artifacts: Photopenic region (halo) surrounding the bladder and the kidneys in the scatter-corrected PET images,

Cause: Increased tracer uptake in kidney and radioactivity in urine (especially in hydro-ureteronephrosis) leads to overestimation of the scatter contribution. Pathologies may be masked by halo-artifacts leading to false-negative diagnoses. Recommendations: Reducing the maximum scatter fraction was found to efficiently suppress halo-artifacts. Routine use of Furosemide administration at the time of injection can decrease occurrence of halo artifacts by flushing out the activity in urine. Movement artifacts: In addition to misregistration between CT and PET image, patient motion causes blurring of images. More apparent especially in the region around the diaphragm, where a sharp transition exists on CT between liver and lung tissue. Longer range of the Gallium 68 isotope also contributes the degradation of image quality

during slight motion. Even though one cannot completely prevent artifacts due to respiratory movement, shallow breathing is recommended. Respiratory gating though technically demanding can prevent artifact due to respiration. The most common type of breathing artifact results in curvilinear cold areas. This artifact appears when CT scans are acquired at full inspiration, which results in a downward displacement of the diaphragm because of the expansion of the lungs. This downward displacement causes the CT attenuation coefficients in the normal location of the diaphragm region to be underestimated because they represent air rather than soft tissue . The resulting underestimation of activity on the PET image thereby produces a curvilinear cold area at the lung Recommendations: Use of fixation masks, belts or cushions and good instructions by technologists may help in minimizing the overall patient movement. Urine activity mimicking lesion: PSMA PET/CT is highly sensitive scan able to detect abnormality that not appreciated in morphological scan (CT/MRI). So small focal uptake in excretory system (ureter and prostatic urethra) can mimic uptake in pelvic nodes or prostate respectively. Recommendation: Routine use of furosemide injection can flush out the urine activity. Performing CT scan after delay of 15 minutes following intravenous contrast agent (excretory phase) can delineate the excretory system.

Abstract ID: NMPAICONAbs3856
Role of SPECT-CT in Parathyroid Scintigraphy

Mamta Singh, Abdul Sathar G, Tushar Tambe, Mehjabeen Pathan Priya M, Bhakti S and V. Rangarajan
Department of Nuclear Medicine, Tata Memorial Centre, Mumbai-12

Introduction: Technetium-99m (99mTc) sestamibi has been used as a parathyroid imaging agent by many investigators and it as shown excellent results for localization of parathyroid adenomas. The advantage of using 99mTc sestamibi single photon emission computed tomography (SPECT) in combination with (CT) allows localization of parathyroid adenomas in three dimensions and improves the specificity .

Methods: For parathyroid scintigraphy, the patients were injected with 99mTc-sestamibi intravenously, approximately 815 MBq; range, 640–990 MBq). Sequential static images acquired, the first at 15 min after injection (1 million counts static image with a 256 × 256 matrix and a zoom factor of 2.0) and the second at 120 min after injection from the level of the submandibular glands through the basal third of the heart by using a LEHR collimator and SPECT images were acquired immediately after the planar imaging (128 × 128 matrix, a total of 64 frames, 30 s per frame, was acquired over a 360° orbit) on Infinia Hawkeye SPECT/CT system (GE Healthcare). The CT component used for lesion localization and attenuation correction.

Results: We analyzed 35 patients referred to our nuclear medicine department to rule out parathyroid adenoma using 99mTc-sestamibi planar and SPECT imaging with CT fusion. Statistical analysis using showed following results,

Statistic	Value (%)	95% CI
Sensitivity	90.9	58.72 to 99.77
Specificity	95.83	78.8 to 99.89
Accuracy	94.29	80.84 to 99.30

Discussion: SPECT/CT in the management of parathyroid adenomas has the potential to improve accuracy rates for localization of parathyroid adenoma and help in surgical decisions.

Conclusion: Information of SPECT with the anatomic information of CT, thereby improved the overall accuracy rates of parathyroid examination in our department. SPECT/CT imaging method showed statistically superior results in our department. These findings strongly suggest that SPECT/CT should be part of the routine evaluation of patients with primary hyperparathyroidism and patients with suspected parathyroid adenomas especially in negative static images.

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Abstract ID: NMPAICONAbs8514
Generation of a brain database of depressive subjects

Upadhye Trupti, Malhotra Gaurav, †Karishma Rupani
Radiation Medicine Centre, Bhabha Atomic Research Centre, † King Edward Memorial Hospital, Mumbai, Maharashtra India

Introduction: A control brain database is created by acquiring ^{18}FDG brain scans of 50 normal subjects without identified neuropsychiatric disease and compiling their review files to make a statistically significant assessment of regional glucose metabolism. NeuroQ^{TM} serves as a processing tool for all of our ^{18}FDG brain scan analysis. It is used for automated quantification of relative activity in different regions of the brain and measures the standard deviations from mean activity values of the brain regions in the database. The patient data is compared with a normal database also called as asymptomatic control(AC) group in the software(which is validated by University of California Los Angeles) for any deviations from the normal brain uptake of ^{18}FDG. A region with an uptake below 1.65 standard deviation of the mean (which is established) from the control database is considered abnormal.

Aim: The aim of the study was to generate an in-house database of depressive subjects.

Methods: Thirty-three subjects with suicidal behaviour pattern were assessed using Columbia Suicide Severity Rating Scale(CSSRS) and Beck's Depression Inventory(BDI). Eighteen among the thirty-three were confirmed of having depression along with suicidal tendencies. The study was approved by Institutional Ethics Committee. Subjects were recruited from "Suicide prevention Clinic" that runs weekly exclusively for patients with suicidal behaviours. Consecutive sampling was undertaken and study period was six months. Inclusion criteria were age group of 18-65, either gender with attempted suicide in the last seventy-two hours, not on psychotropic medication since atleast one month, willingly cognitively stable to give consent. Females not known to be pregnant/lactating and those with last menstrual period less than one month from time of assessment were included. Subjects on therapy, severe cognitive impairment, active suicidal ideations, medically unstable and on substance abuse were excluded from the study. The BDI were used to evaluate depressive symptoms. These subjects were then injected with 3-5 mCi of ^{18}FDG and brain scan was acquired on a Philips Gemini TOF PET/CT scanner. The scans were then processed with NeuroQ^{TM} software and the review files having an extension .nrq were saved in the same folder (C:\Pms\PET\configuration\Application Data\NeuroQ\userdb\NeuroQDep) on the disk. From the **NeuroQ^{TM}** software we select - **Control Database** then go to **Create a New database** browse to NeuroQ Dep folder for example -> select all .nrq review files. After selecting all files enter the name of the new database created and click on **Create DB** option.

The database(NeuroQDep) created in such a way is then saved onto a flashdrive which is initialized as F drive. The .nrq review files are then copied to F drive and given a folder name. The NeuroQ process is then launched and a different database is selected by choosing **Control database** and then **NeuroQDep**.

Conclusion: A new database can be successfully generated in the NeuroQ^{TM} software used. The applications lie in comparison with different neuropsychiatric disorders. By comparing a raw data with a database the confidence level in reporting a hypo-metabolic area increases and hence sensitivity improves. (This database created needs to be used with caution and in specific cases.)

Caution: Generation of a database is the sole responsibility of the USER. SYNTERMED/UCLA has no responsibility for any results generated by using the same.

The flash drive used should be a new one as the system is susceptible to viruses which may crash the processing console.

The database can be used in limited clinical queries.

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Abstract ID: NMPAICONAbs9891
Identification of cause of unusual reconstruction artifact in attenuation corrected PET image.

Rousani Bhaghel, Priyanka Sawant, Sneha Mithun, Ashish Kumar Jha, Bhakti Shetye, V. Rangarajan
Department of Nuclear Medicine, Tata Memorial Centre, Mumbai-12

Introduction: Positron emission tomography / computed tomography (PET/CT) is an established diagnostic tool for oncological imaging. Previously the CT scan of PET/CT was utilized to perform attenuation correction during PET reconstruction and anatomical localization of tumor and did not have much diagnostic value addition in the fusion imaging. In last few years CT scans are being utilized as diagnostic CT, which has provided true value of the fusion modality and improved the diagnostic value of the PET/CT scanner tremendously. Integration of diagnostic CT with PET system and its ability to perform whole body scanning has allowed this modality to establish itself as staging and follow-up imaging tool in oncology. But maintenance of the fused scanner is of paramount importance to achieve maximum diagnostic outcome from the scanner. Hence any scanner has to be well calibrated and ensure that it can give good quality clinical images. In spite of this there is a possibility of visualization of several artifacts, either due to some kind of system failure or software or reconstruction issues as well as due to patient movements or metallic implants within the patient.

Technical Note: We encountered unusual kind of image artifact in the attenuation corrected PET image. Posterior part of the pet images had low intensity in comparison of anterior part of the body in most of the patient scanned in supine position. Previously we thought it might be because of breathing artifact but that confusion got cleared when we checked pelvis and thigh area image. Following this revelation we perform phantom image and we encountered same problem. But when we checked non-attenuation corrected images of the same patient and phantom we found no issues with non attenuation corrected image. We concluded that there is problem in the reconstruction when it is performed with attenuation correction. We informed online engineer and they verified any problem in CEAC series or in CT detector and it found to be good. We were discussing the possible cause of the problem with service engineer and in our discussion we found that we had not restarted our system for months together. So we identified that this issue might be related to booting of the system. Since rebooting of the entire system is the time consuming process, hence we decided to perform PET daily QC first. When we were performing daily PET QC we received a message from the system "baseline collection was not run today and running now" . PET Daily QC completed successfully. Following that we performed phantom scan first and we reviewed the attenuation corrected image. We found no artifact in the image. That scan was reviewed by several technical and clinical experts from our department and we started clinical scan on our satisfaction. We repeated the same patient and reviewed the attenuation corrected image and no artificat was identified and image quality was acceptable to the Nuclear medicine physician.

Conclusion: We would like to conclude that as its very important to perform the daily QC of the equipment so is the periodic maintenance like complete shutdown equally important.

If we encounter any such problem in our routine practice, it is mandatory to discuss the problem, sequence of event and possible cause; it might be possible that the major problem like this might be

resolved by simply performing daily QC of the scanner.

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Performance evaluation of PET system of PHILIPS TF64 PET/CT 5years after installation by NEMA specified standard procedure.

Manoj Kumar R. Chauhan, Bhakti Shetye, V. Rangrajan

Department of Nuclear medicine, Tata Memorial Hosptal, Parel , Mumbai 12

AIM: The aim of our study was to evaluate the performance of PET system of PHILIPS TF64 PET/CT 5years after installation by NEMA specified standard procedure.

METHODS: Performance measurement parameters like spatial resolution, sensitivity, scatter fraction, NECR, random coincidence estimation, image quality and count rate performance were evaluated as per standard procedure of NEMA NU2-2012.

RESULTS:

Average Transverse Resolution

	FWHM	FWTM
Radial	5.08mm	9.76mm
Tangential	5.02mm	9.98mm
Central	4.79mm	9.72mm

Average Axial Resolution

	FWHM	FWTM
Offset	5.15mm	10.26mm
Central	4.71mm	9.51mm

The ratio between FWTM and FWHM for PET scanner is in the range of 1.8-2.0. The measured sensitivity was 6.6kcps/MBq both at the centre of FOV and 10 cm off centre. The measured Noise Equivalent Count Rate (NECR) peak was 99.250kcps at 20.69KBq/ml. The scatter fraction was 28.391%. The measured peak coincidence count rate was 253.557kcps at 0.016MBq/ml. Image contrast recovery values with scatter were between 34.71% (1.0cm sphere) to 77.11% (3.7cm sphere). Image contrast recovery values without scatter were between 31.91% (1.0cm sphere) to 78.24% (3.7cm sphere).

Conclusion

As per the performance evaluation we have found that the parameters are well within the acceptability limit of the reference values.

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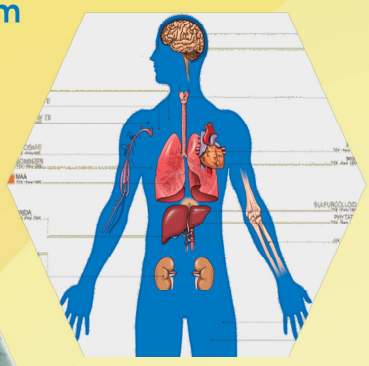
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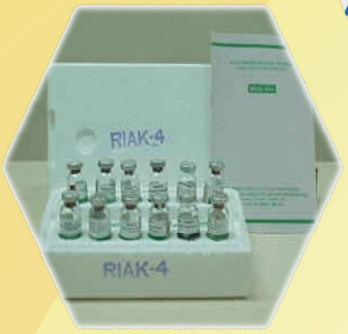


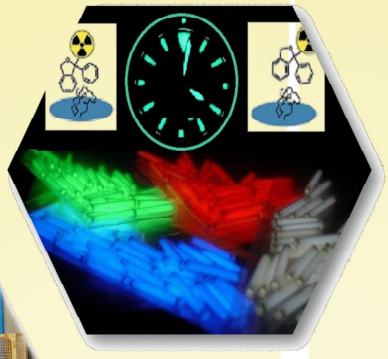
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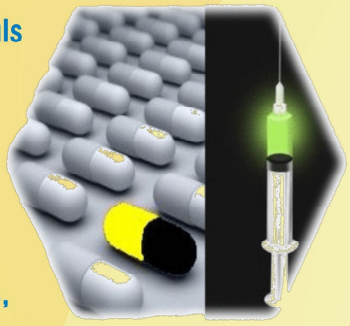
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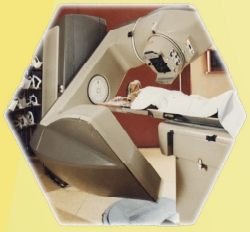




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