# MEDICAL PHYSICS CHRONICLE

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## *Editorial*

### Regulatory Aspect of Medical Physics in India

Medical Physics is, in fact, a Clinical Medical Physics with strong research streaks in both basic science and applied clinical science. It has close interaction with technological aspect as well. Medical science with ever-expanding horizon is, now-a-days, being referred as health science alluding its integrating indicator to encompass the interface of pure science and technology with medicine. Medical Physics is one of such interface of Physics (or Radiation Physics to be specific) with medicine. While the Radiation Physics and Radiation Protection aspect in India is regulated by Atomic Energy Regulatory Board its clinical application and education in Medical colleges is regulated by Medical Council of India (MCI). Recently, Association of Medical Physicists of India (AMPI) made a representation to MCI to rectify the qualification for Medical Physicists in MCI documents which presently has Chemistry and Biophysics as well in addition to Physics and Medical Physics. MCI would look into the matter as it is aware of AERB regulation which recognises only Physics with Diploma in Radiological Physics or Medical Physics degree for Medical Physics profession. According to MCI, Medical Physicists in Medical Colleges are teaching designation and in fact these posts are Medical Physicist –cum-Lecturer (or Assistant Professor). For appointment to Lecturer / Assistant Professor Ph.D. is not essential but for promotion it may not be so. AMPI may approach MCI to mention this explanation explicitly in documentation to avoid any ambiguity in interpretation. AMPI may also approach all medical colleges to apprise them about this and work further with them in this direction so that proper designation with remuneration may be incorporated. Radiological Physics is one of a few subjects which are essential for the patient service of radiotherapy, nuclear medicine and radiology. However, there is no regulatory body for regulation of services of medical physicists in medicine. Now-a-days Medical Physics education is being imparted by about 19 institutes but there is no elaborate homogeneous regulation regarding infrastructure for education and training in the country. It is the need of the hour that we apprise the policy makers about the need to bring medical physics clinical services and education under some national regulation. After all, patients undergoing radiotherapy, nuclear medicine treatment and investigations (like PET, gamma camera) and radiological imaging services (which includes CT, x-ray radiography, mammography, angiography, c-arm, o-arm fluoroscopy and DEXA in various departments including radiotherapy, radiology, nuclear medicine, cardiology, neurology, neurosurgery, orthopaedics, urology, gastroenterology, anaesthesiology, endocrinology, dental etc.) deserve the best possible radiation services. Doctors being trained and educated in these streams (subjects and departments) do need qualified and competent teachers in Medical Physics so that they know about the justification and quality of radiation services they are offering to their patients. AMPI should mull about this aspect and approach right quarters to set the ball rolling.

*Pratik Kumar*

# INFLUENCE OF DELETING FEWER MU'S AND SMALL AREA SEGMENTS IN STEP AND SHOOT IMRT IN VIEW OF PLANNING AND QA ASPECTS

*Rajesh R, Narendra Birbiya, Vidya Vitwekar, Shyam L Debnath, Sourav Mojumdar, Department of Radiotherapy, Birla Institute of Medical Research, Gwalior*

## Introduction

IMRT technique in radiotherapy became most sophisticated and matured way of giving treatment to patients. It has grown to the extent that it became minimum requirement to set up a Radiotherapy Department. As advancement of technique like VMAT, IGRT, SRS and SRT increases, precision and accuracy also increases. However, though the technique or modality improves, Step and Shoot IMRT remains baseline for a department. Step and Shoot IMRT is considerably practiced widely. This study was carried out to decrease overall patient treatment time and to achieve good Quality Assurance results with respect to planned fluence in Step and shoot IMRT treatment. This study enables us to delete fewer MUs and small area segments.

## Materials and Methods

The study was carried out in Oncentra Treatment Planning system (OTPS) which supports Analytic Anisotropic Algorithm (AAA) and Collapsed Cone Algorithm (CCA). The Step and Shoot IMRT plans were generated like normal procedure. We used Collapsed Cone Algorithm for all patients' planning. We considered treatment plan of Head and Neck in 5 patients only since there may two or three PTVs be involved. Therefore, in these cases we can come across very few segments of smaller areas not more than 3 x 3 Sq. Cm. Also, we noticed that this small area segment has fewer MU's in range from 2 to 8. For each plan of the patient the plan acceptance criteria were that 95% of PTV should receive at least 95% of prescribed dose and 1% of PTV should not exceed 107% of prescribed dose. Dose for the Organs At Risk (OAR) was respected as per the QUANTEC guidelines. These plans were accepted by oncologist for the patient treatment. Again, the plans were reanalyzed with same criteria by deleting the segments with above said factors like small area segment and fewer MUs. We noticed that there is not much significant or no change in DVH of PTV coverage point of view. Similar was the case for in OARs. This accepted plan which was to be used in treatment of the patient underwent patient specific Quality Assurance (QA) procedure. Here in QA procedure, the fluence generated by these segments did not match with the planned one (executed fluence) due to the resolution of Ion or Diode based detectors (except Film based QA analyse).

To study the nature of the QA procedure, we planned 5 treatment plans. Each plan has 10 beams which are like one smaller segment. There were 10 segments in each plan with each less than 8 MUs. This was done since in Oncentra TPS, inter-segment in each beam cannot be created and once created, segment in IMRT plan cannot be deleted like in other TPSs. The planned beams were exported to IMRT QA phantom (M/S PTW) with 729 array detectors. Here it is scanned and kept like patient CT scanning images. These exported plans in phantom are then planned by keeping gantry 0 degrees, collimators 0 degrees and QA plans are generated.

Fig 1. PTW 729 Array detector.

The PTW 729 array detector consists of 729 ion chambers of placed with 5mm gap making up to 10 x 10 sq. cm. field size. After 10 x 10 sq. cm. each detector was placed at distance of 1 cm gap.

It has water equivalent material as build up of 5 mm. Above the build-up material, a slab of 4.5 cm water equivalent material is placed, so that Source to Surface Distance is 95 cm and chamber is at isocenter. This phantom was scanned and imported into TPS for IMRT QA calculation. The PTW 729 array detector is connected to the system, in which a software Varisoft is installed. This software enables to analyze the data between TPS and executed patient file. The planned IMRT QA plans were delivered in Elekta Synergy Linear Accelerator machine. The data is then collected from QA software after execution. The default settings or protocol followed for gamma index analyze with DTA is 3 mm and 3% dose difference for all plannings.

## Conclusion & Results

Table shows the respective passing result with corresponding MU delivered and segments involved.

**Table: Head and Neck cases of passing results**

| Pat. | 1st Seg MU | 2nd Seg MU | 3rd Seg MU | 4th Seg MU | 5th Seg MU | 6th Seg MU | 7th Seg MU | 8th Seg MU | 9th Seg MU | 10th Seg MU | Tot. MU | Dose (Gy) | QA Result % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.6 | 3.6 | 2.4 | 4.8 | 6.0 | 4.8 | 4.8 | 3.6 | 6 | 3.6 | 43.2 | 0.20 | 84.0 |
| 2 | 4.3 | 4.3 | 2.9 | 5.7 | 7.2 | 5.7 | 5.7 | 4.3 | 7.2 | 4.3 | 51.6 | 0.20 | 29.8 |
| 3 | 4.3 | 4.3 | 2.9 | 5.7 | 7.0 | 5.7 | 5.7 | 4.3 | 7.1 | 4.3 | 51.3 | 0.18 | 95.0 |
| 4 | 3.9 | 3.9 | 2.6 | 5.2 | 6.3 | 5.2 | 5.2 | 3.9 | 6.5 | 3.9 | 46.6 | 0.24 | 86.7 |
| 5 | 3.9 | 3.9 | 2.6 | 5.2 | 6.5 | 5.2 | 5.2 | 3.9 | 6.3 | 3.9 | 46.6 | 0.25 | 93.0 |

From the above table we can infer that passing result is not satisfactory with lesser segments areas and MUs with respect to 3 mm DTA and 3% of dose difference. This result is for the segments which we considered as a separate plan. Even if the segments are to be considered with whole IMRT plans the result of passing rate will decrease. Because, the resolution of detector is limited with 5mm of spacing, the settings in IMRT QA software Varisoft considered for passing criteria is max dose volume so that executed fluence and planned fluence passes. If local dose is to be considered as setting then still the result would decrease. Also, if the lesser MU segments are deleted then overall treatment time reduces.

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# OUR MEDICAL PHYSICS FACILITY

## DEPARTMENT OF MEDICAL PHYSICS, TATA MEMORIAL CENTRE, MUMBAI

*Prof. D. D. Deshpande, Head, Deptt. of Medical Physics, TMH*

### About Us

The Department of Medical Physics works in association with Department of Radiation Oncology for the radiation treatment and has expertise in related areas. The department is engaged in Treatment planning, Commissioning, calibration, QA and maintenance of treatment machines, Radiation Safety, room designing, and education. The Department also advises and assists allied departments like Plastic Surgery, Radiology, Transfusion Medicine and the ACTREC regarding matters of Radiation safety, Radiation source procurement and radiation waste disposal. At ACTREC separate team of physicists takes care of equipment and treatments, mainly project cases. The outreach efforts of the department is comprised of Research, Education, Internships and Practical training designed to guide Radiation oncologists, Medical Physicists and Radiotherapy Technologists of Institutions having Radiation treatment facilities. The department comprises 15 physicists [TMH 11, ACTREC 4), 6 technical staff and 1 secretary.

### Departmental Activity

**Vision**

The Deptt. of Medical Physics has premier Radiation Physics program by delivering the best clinical physics service powered by research, advanced technology, education and conductive learning environment.

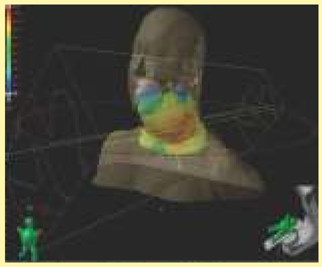
**Mission**

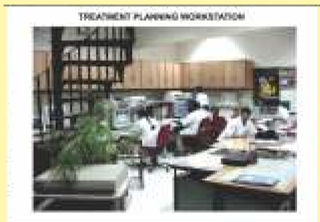
The mission of the department is highest quality patient care and to train medical physics professionals. Department will accomplish this mission by adopting and implementing advanced radiation technology, education and training.

1. Provide outstanding Medical physics service for the effective, safe and efficient delivery of cutting edge radiotherapy treatments achieved through research, process improvement, technology, and automation.
2. Conduct innovative and highest quality research and development leading to new and more effective radiation treatment methodologies.
3. Offer an environment that encourages and supports learning and intellectual development; provides educational and training programs for students, post-doctoral fellows, residents and faculty to enhance their productivity; and to produce professionals and leaders for the needs of profession.
4. Attract and foster the most talented staff who, share the vision and the core values of the Department, Division, and the Cancer Center and have common goals.

**Equipment**

Teletherapy at the Tata Memorial Hospital started in 1941 with two "200 KV Deep X-ray machines" and Radium brachytherapy. This was followed by the first Cobalt-60 teletherapy machine "Theratron Junior" which was commissioned in 1959. The era of linear accelerators and advanced technology treatment planning and treatment delivery machines in the country and at the Tata Memorial Hospital was started in 1978 with the commissioning of the first linear acceletator "Mevatron-12". In 1981 the first







treatment-planning computer "TPS TP-11" was inducted into the department. The first radiotherapy treatment simulator "Therasim 750" was commissioned in 1982.

The remote afterloading brachytherapy with Cs-137 pallets and first introduction of Ir-192 wire for interstitial implants was initiated in early 80's. Later in 1994 we established first remote afterloading system Micro-Selectron HDR with Ir-192. In the last two decades the department has developed into a state-of-the-art facility comparable to any advanced center worldwide. We have added 3 IGRT Linear Accelerators Tomotherapy, Novalis TX and

Trilogy and performing all advanced techniques like IMRT, IGRT,SRT/SRS etc. Recently we have ordered True Beam and Unique Linacs replacing our old ones.

We have got latest dosimetry equipment including 3D Scanner, Octavious, Imatrix, Quasar phantom etc. In ACTREC we have one indigenous Telecobalt machine Bhabhatron-II, one Tomotherapy and new True Beam being installed.

## Research

- Dose Accumulation using deformable image registration for Adaptive Radiotherapy (ART).Dosimetric characteristics of flattening filter free (FFF) beams from True Beam linear accelerator and Hi-Art II Tomotherapy.
- Evaluation of MVCT image quality and co-registration software for IGRT planning and verification in Hi-Art Tomotherapy.
- Image Guided Brachytherapy: Dosimetric studies and Quality Assurance.
- Study of helical Tomotherapy based radiation therapy for the treatment of cancers.
- A phase II Randomized Trial comparing IMRT with conventional RT in stage IIB Ca. Cx.
- Radiation therapy to the metabolic active target volume in paranasal sinus: Feasibility study of image fusion of PET-CT with MRI and radiation dose escalation.
- Determining the functional status of lung from 4D-CT using ventilation based imaging of thoracic tumours - A feasibility study.
- Dosimetric Comparison of Helical TomoTherapy and Conventional IMRT for the Treatment of PNET of the Chest Wall based on PTV shape
- Determining the functional status of lung from 4D-CT using ventilation based imaging of thoracic tumours - A feasibility study
- Spatial movement of high dose regions based on bladder filling during intracavitary brachytherapy for cervical cancers
- Gamma dose distribution performance evaluation of planned and delivered fluences for IMRT Dosimetric comparisons of TomoTherapy and Conventional IMRT for the treatment of Pancreatic Cancer
- Predicting rectal and bladder overdose during the course of prostate radiotherapy using dose-volume data from initial treatment fractions

## Accreditation for Dosimetry

The department is accreditated for precision dosimetry by International quality assurance centre, IROC, M. D. Anderson Cancer Centre, USA to qualify globally for participation in clinical trials. The department is involved in national and international clinical trials (lung, prostate etc). The medical physicists have successfully completed Good clinical practice (GCP) certification program as well. The department is also collaborating with Bhabha Atomic Reasearch Centre (BARC) in IAEA Quality Assurance and Dosimetry Program for IMRT.

## Education & Courses

The department imparts training, conducts courses and has approved faculty for the courses conducted by allied departments.

- Ph. D. in Medical Physics under HBNI
- One year Internship program for Medical Physics students.
- MD(Radiotherapy), under HBNI
- Advance Diploma in Radiotherapy Technology, Recognized by MSBTE.
- Short Term training for Radiological Physics trainees of HBNI
- Short Term training for Medical Physics students of different universities.
- Short Term training for radiotherapy professionals within country.
- Short Term training for radiotherapy professionals from neighboring countries through IAEA/WHO.

## Staff

| SR. NO. | NAME | Design |
|---|---|---|
| 1 | Dr. D. D. Deshpande | Professor & Head |
| 2 | Dr. R. A. Kinhikar | Associate Professor |
| 3 | Mrs. S. V. Jamema (ACTREC) | Medical Physicist E |
| 4 | Mrs Ph. Reena Devi (ACTREC) | Medical Physicist D |
| 5 | Mr. RituRaj Upreti | Medical Physicist D |
| 6 | Mr. Suresh Chaudhari | Medical Physicist D |
| 7 | Mrs. Siji Nojin Paul (ACTREC) | Medical Physicist D |
| 8 | Mr. Yogesh Ghadi | Medical Physicist C |
| 9 | Mr. Shrikant Kale | Medical Physicist C |
| 10 | Mr. Ritesh Mhatre | Medical Physicist C |
| 11 | Mrs. Udita Upreti | Medical Physicist C |
| 12 | Mr. Kishore Joshi (ACTREC) | Medical Physicist C |
| 13 | Mrs. Dheera | Medical Physicist C |
| 14 | Mr. Dipak Chikane | Medical Physicist C (Adhoc) |
| 15 | Mr. Devraj S. | Medical Physicist C(Adhoc) |

# MEDICAL PHYSICISTS: RESOURCES AND STATUS ISSUES

*Prof. (Dr.) Ramamoorthy Ravichandran, Senior Consultant in Medical Physics, Royal Hospital, Muscat, Sultanate of Oman*

## Introduction

Medical physics is the ongoing efforts for implementation of procedures involving physics, standardization and quality management,understanding the physics parameters for the better delivery of diagnostic and therapeutic medical patient care and research[1, 2]. Medical physics in the true sense covers all applications of physics in medicine wherever physics parameters assume significance; but in most of the institutions in India as well as abroad medical physics applied to radiotherapy services remained a good bulk because of availability of position for therapy patient care requirements, impact in nuclear medicine and diagnostic x-rays remained marginal. This lacunae is mostly because of less available trained medical physics manpower resources, and priority need for radiotherapy applications.

Role of qualified medical radiation physicists (QMRP) is well recognized in the era of significant advancements in high precision radiation dose delivery in radiation therapy cancer care. The qualification requirement, need for certified medical physicists in radiation oncology have been highlighted in recent documents[3,4,5]. Many countries have implemented residency program for QMRPs[6]. In India, growth of medical physics dates back to 1962, enumerated in scientific presentations earlier[7,8,9]. Recently, under the College of Medical Physicists of India (CMPI) certification program for QMRP has been introduced. When the qualification and experience requirements are enhanced by statutory bodies and profession in the light of higher responsibilities, present days the position and status of these personnel are not commensurate enough, and not in order vis-à-vis their medical colleagues. The positions of medical physicists remain as stray positions, without promotional avenues and self development. Medical Physics community has to take note of the situation, to make strong recommendations to equate physicists to medical post-graduate doctors at the time of entry, and later assure time-bound rise, in steps with the same promotional avenues like a medical personnel. An attempt has been made to highlight the relevant documents and stress national organizations to take up with governmental and corporate personnel departments on this issue.

## Present status and recognition issues

The medical physicists are unique scientific personnel involved in the accuracy related applications in medical field, and they are to be classified in scientific human resources. Medical physicists have advisory role in most of the radiation oncology process[7] (AAPM Monograph 15, 1986). Optimized application and management of available equipment resources and quality assurance in treatment execution have become major responsibilities of medical physicists[10]. The Medical Council of India defined 'radiological physics' as a subject of study in medical colleges, mainly for medical radiology post graduates Table-1(MCI, 1998)[11] but in many medical college hospitals, faculty positions are not available. When the same MCI document[10] underwent subsequent amendments[12], anomalies have come in such as 'MBBS qualification for Radiological Physics Tutors' and 'MD(Radiodiagnosis), MD(Radiology), MS(Radiology)' qualifications for faculty positions in the dept of radiotherapy.

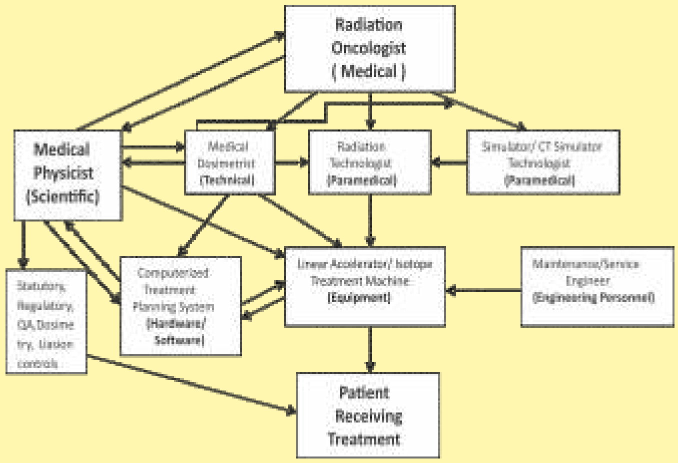



Fig.1. Staff Interaction Process for radiotherapy patient management

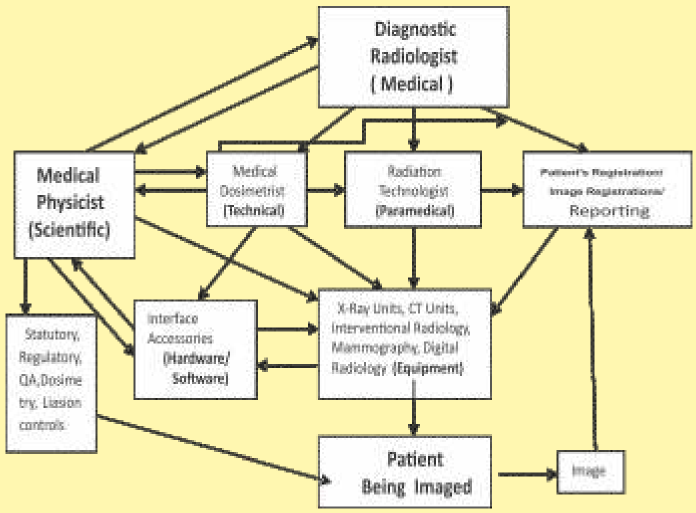



Fig.2. Staff Interaction Process for diagnostic radiology patient management

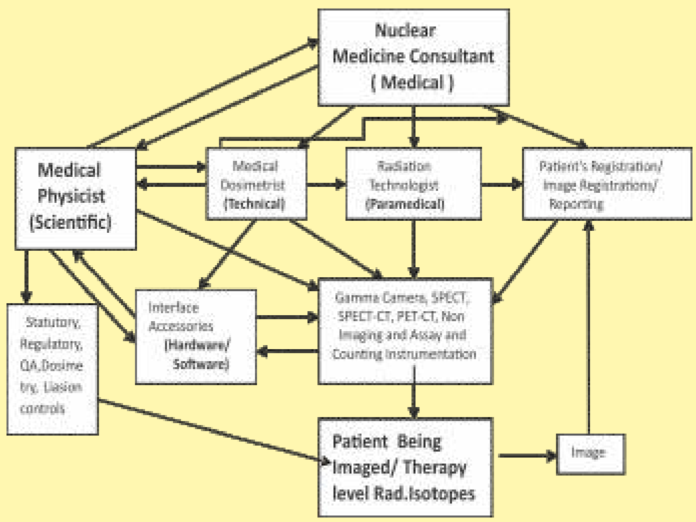



Fig.3. Staff Interaction Process for nuclear medicine patient management

Table 1: Teachers in Radiological Physics (MCI 1998)

| Position | Basic Qualifications | Other Requirements |
|---|---|---|
| Professor | M.Sc(Phys/Chem/Biophys) with Ph.D(Phys/Chem/Biophys) | 4 yrs experience as Assoc.Prof In Radiological Physics<br>Desirable:<br>4 Res.Publications Indexed. in National Journal<br>+1 Res.Publication in Intl. Journal |
| Associate Prof. | ,, ,, ,, | 5 years experience as Assistant Professor or Lecturer in Radiological physics in a recognized medical college.<br>Desirable:<br>Minimum of 4 research publications indexed/ National Journal |
| Assistant Professor/ Lecturer | ,, ,, ,, | Requisite recognized post -graduate qualification in the subject.<br><br>3 years teaching experience in the subject in a recognized medical college as Resident Registrar/Demonstrator / Tutor |
| Tutor/Demonstrator/ Resident Registrar | M.Sc (Physics/Chemistry/ Biophysics (1998)[10]<br>**Assoc. Medical Physicists of India in 1997 represented to MCI to remove Chemistry Subject for basic qualification . Also to include M.Sc Medical Physics & DipRP qualifications*<br>**MBBS (2012)**[11] | --------- |

For a medical institution and medical administrator in countries like India, any position other than a medical doctor is considered 'paramedical' and this has created enough damage to the 'medical physicists' all along in the past. Even a bachelor degree holder (MBBS in India, and MD in some of countries) is given a social status whereas a Doctorate degree holder (Ph.D) in medical physics has not been given their dues in terms of designation nor in terms of promotional avenues. Their responsibilities involve a) procedure approval b) beam approval c) execution approval d) document approval. Non-clinical, or non-teaching medical doctors do not undergo parity issues, in contrast physicists as non-medical basic scientists, remain un-recognized and this needs urgent attention. International Atomic Energy Agency (IAEA) and International Organization for Medical Physics (IOMP) observed this anamoly, and try to bring awareness and try to promote the need for implementing proper status to medical physicists. International Standard Classification of Occupations (ISCO-08)13 recommendation has been interpreted by International Labour Organization (ILO) that medical physicists shall be considered part of health work force, as 'physicists' under 'health professionals'. President, IOMP recommended[14] to national member organizations (NMOs) that they should consider taking up the issue of the identification of the number of medical physicists working in health care with their national Ministry or Department of Health, through cross-tabulation by occupation and industry and in administrative data on the health service work force using ISCO.

New training programmes are being initiated in many universities, without streamlining the status aspects, forcing many of the medical physicists performing as 'dosimetrists' in radiation oncology departments and 'glorified technicians' in radiation safety and nuclear medicine departments. Recently residency has becoming compulsory similar to medical personnel, therefore medical physicists should claim similar status vis-à-vis other staff. In the recent past, high technology radiotherapy dose delivery aspects have brought in the need for 'development of sophisticated treatment plans', which try to give incentives in renumeration to these medical physics human resources. Unless recognition of 'medical physics as a dedicated science by itself' takes place, which is the only way for an administrator to look at its potentials in human patient care and research

## Medical physics personnel

World Health Organization (WHO, 1968)3 brought out the responsibilities of medical physicists in radiology, radiation therapy, nuclear medicine and radiation safety; qualification requirements and role in radiation oncology was re-emphasized by International Commission on Radiological Protection (ICRP, 1984)[4]. In this context, these work force shall be given correct status in their positions, and local professional bodies shall ensure this. Radiotherapy is well accepted modality as a cost-effective, localized treatment delivery, with less morbidity. Medical physics plays a crucial role as an important service component, and due to lack of these specialists, many new installations could not be added to benefit the community in the advent of increase of number of cancer cases globally. Table 2 elucidates International recognition (ISCO-2008) of medical physicists vis-à-vis medical specialists, which should be brought to notice of policy makers and institutions. As an universal guideline, except for qualification requirements and experience criteria, there should not be any bias and parity issues in their placements as per administrative guidelines, despite their designations. Residency programme and its need for residency for the clinical services is emphasized by an editorial (SD Sharma 2009)[6].

**Table 2: Role of Medical Physicist in Medicine and ISCO 2008 Recognistion**

| | |
|---|---|
| **Radiodiagnosis** : | Optimization in Imaging, ALARA in<br>Occupational exposures, Patients and<br>Population Radiation Dose,<br>Reference Levels, dose records, research |
| **Radiation Oncology:** | Accuracy in Dose Delivery; Dose Delivery Algorithms; Absolute and Clinical Dose Estimates,<br>Radiation Safety in patients and personnel, research |
| **Radio Nuclide Imaging:** | Optimization in Imaging; QA, Radiation Internal Dosimetry; ALARA in Occupational and patient radiation<br>doses, Health Physics and Radiation Safety, research |
| **International Standard Classification of Occupations 2008 (ISCO-08)** | |
| 2111 | Physicists and Astronomers ; 2111 Includes Medical Physicists |
| 2212 | Specialist medical practitioners (Medical) |
| **Occupational Recognition:** | In addition to qualification criterion,<br>Certification Requirements by IOMP,<br>AAPM, HPA, IAEA, Various Boards |

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### MOVERS AND SHAKERS

**Dr. S. D. Sharma,** Head, Medical Physics Section, RPAD, BARC recived DAE Scientific and Technical Excellence Award - 2013 for his excellent contributions in the field of Medical Physics and Radiation Dosimetry towards development of radiotherapy devices, dosimeters, phantoms and dosimetry methods on 30th October 2014, Mumbai, India. He also received IARP Dr. A. K. Ganguly Felicitation Prize - 2014 for his outstanding contributions in the field of radiation protection and radiation safety on 19th March 2014. Congrats!!!

### MOVERS AND SHAKERS

**Mr. Birendra Kumar Rout,** Chief Medical Physicist, Aditya Birla Memorial Hospital, Pune received Dr M.S. Aggrawal Young Investigator Award from AMPI at AMPICON-2015 at Loni, Maharshtra. Congrats !!!

## Web-sites of Relevant Organization & Online Resources

Association of Medical Physicists of India: ampi.org.in
American Association of Physicists in Medicine (AAPM): www.aapm.org
American Board of Radiology (ABR): www.theabr.org
American College of Radiology (ACR): www.acr.org
American Institute of Ultrasound in Medicine (AIUM): www.aium.org
American Journal of Roentgenology (AJR): www.ajronline.org
American National Standards Institute (ANSI): www.ansi.org
American Roentgen Ray Society (ARRS): www.arrs.org
American Society of Radiologic Technologists (ASRT): www.asrt.org
British Institute of Radiology (BIR): www.bir.org.uk
Conference of Radiation Control Program Directors (CRCPD): www.crcpd.org
Food and Drug Administration(FDA): www.fda.gov
FDA whole-body CT scanning: www.fda.gov/cdrh/ct
Health Physics Society (HPS): www.hps.org
Health Protection Agency (formerly NRPB): www.hpa.org.uk
International Commission on Non-Ionizing Radiation Protection: www.icnirp.de
International Commission on Radiation Units and Measurements (ICRU): www.icru.org
International Commission on Radiological Protection (ICRP): www.icrp.org
Medical Physics Journal: www.medphys.org
Joint Commission for Accreditation of Healthcare Organizations: www.jcaho.org
National Council on Radiation Protection and Measurements (NCRP): www.ncrponline.org
Physics and Astronomy Online Education: www.physlink.com
Radiation Research Society: www.radres.org
Radiographics and Radiology Journal: www.rsnajnls.org
Radiological Society of North America (RSNA): www.rsna.org
Society for Imaging and Informatics in Medicine (SIIM): www.scarnet.org
Society of Nuclear Medicine (SNM): www.snm.org
U.S. National Institute of Standards and Technology (NIST): www.nist.gov
U.S. Nuclear Regulatory Commission (NRC): www.nrc.gov