AFOMP Newsletter

Asia-Oceania Federation of Organizations for Medical Physics

Publisher :Dr.Tae-Suk Suh
Editor : Dr.Arun Chougule
Advisor : Dr. Yimin Hu
Dr. Howell Round
http://www.afomp.org

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Vol.10 No.02– June 2018

Prof. Dr.Arun Chougule

From the desk of editor

"Greeting from the editorial board" I am happy to bring out the June 2018 issue of AFOMP news-letter. It contains an article by **Dr. Jamema Swamidas** on "Clinical Implementation and Quality Assurance of IGABT in Indian scenario.' which is very informative and pertinent in present scenario. The article by **Dr. Carmel J. Caruna** titled **"Leadership in Medical Physics, Development of the profession and the challenges for the MPE (D&IR) – A Mini-MBA in STRATEGIC LEADERSHIP"** for Medical Physicists in Diagnostic and Interventional Radiology" deals with the educational programmers for leadership development for medical physicist. Another article by **Prof. John Damilakis** titled **"The necessity for clinical DRLs and the EUCLID European Commission project"** is very useful and attempts should be made in AFOMP region also. The article by **Prof. Eric Ford and Prof. Govindrajan** titled **"Increasing access to radiotherapy with affordable cancer technologies"** discusses about the affordable radiotherapy technologies and are of high importance to AFOMP countries. This issue also includes report of ICMPROI 2018 held at Dhaka, Bangladesh.

This year we have the "World Congress of Biomedical Engineering and Medical Physics" at Prague during 3-8 June 2018 and hope many of you will take advantage of this mega event held every three years.

I am looking forward for your participation in the forthcoming 18th AOCMP in conjunction with 14th SEACOMP meeting at Kuala Lumpur during 11-14 November 2018. The theme of the conference is **"A Sustainable Future for Medical Physics"**. Further, the sixth IDMP will be celebrated on 7th November 2018 all over the world and hope every one of us must have planned some activity for the day to increase the visibility of medical physicist. The theme of IDMP2018 is " **Medical Physics for Patient benefit"**

I am strong believer of continued communication to enhance cooperation and collaboration among individuals & various organizations in the field of medical physics for improving educational & professional status of medical physicists. I would like to put on record that many of the office bearers of the NMO's of AFOMP do not respond/communicate despite of reminder mails which is disappointing fact and I wish & hope that the situation will improve. Looking forward to your feedback.

Prof. Arun Chougule
Editor, AFOMP Newsletter
Vice President AFOMP
Chair-ETC-IOMP [2018-21]

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18th Asia-Oceania Congress of Medical Physics
16th South-East Asia Congress of Medical Physics

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Important Dates:
Abstract submission deadline: 1st July 2018
Abstract acceptance notification: 1st August 2018
Early bird registration deadline: 1st August 2018

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EUTEMPE-EFOMP MODULE MPE01: Leadership in Medical Physics, Development of the profession and the challenges for the MPE (D&IR) – A Mini-MBA in STRATEGIC LEADERSHIP for Medical Physicists in Diagnostic and Interventional Radiology

Carmel J. Caruana Ph.D., FIPEM,

INTRODUCTION

The EUTEMPE-RX (European Union Training and Education for Medical Physics Experts in Diagnostic and Interventional Radiology) project [1] is an EC funded project for the education and training of young medical physicists aspiring to Medical Physics Expert (MPE) status as defined by EU directive 2013/59/EURATOM [2] and elaborated in the 'European Guidance on the Medical Physics Expert' document [3] and EFOMP Policy Statement 12.1 [4]. The project consists of a set of 12 modules at level 8 (highest level) of the European Qualifications Framework [5]. **This article describes module MPE01, the first module, which aims to help the participants become STRATEGIC LEADERS for the Medical Physics community.**

The content of module MPE01 was developed by the author following an extensive literature search on curriculum development for leadership, management and strategic planning and an in-depth study of the relevant learning outcomes for MPEs in Diagnostic and Interventional Radiology from the 'European Guidelines on the MPE' document [3]. The module consists of a **preparatory ASYNCHRONOUS (which means one can participate from anywhere and anytime) ONLINE phase followed by an intensive 3 – 5 day ONSITE phase (held in PRAGUE, one of the most beautiful cities in Europe). This blended learning mode of curricular delivery ensures that the participants can take part without undue disruption to their clinical duties. The module ends with an optional assessment for those who would like to boost their CPD points.**

DESCRIPTION OF THE MODULE

The resulting module is best described by its abstract and learning outcomes.

Abstract

This module aims to help the future MPE in Diagnostic and Interventional Radiology (including imaging outside the D&IR department proper) acquire the knowledge, skills, competences and attitudes necessary to exercise a strategic leadership role within the profession in own country and in Europe both in terms of professional issues faced by the profession and own personal development as a leader. The content of the module will provide a framework for discussions for all the other modules. In the onsite phase participants will have the opportunity to interact with and discuss issues facing the profession and personal development directly with European leaders. The participants would also be updated with the latest EU directives, guidelines and policy statements impacting the role to ensure they are at the forefront of these developments. The module will achieve its learning objectives using a combination

of online and onsite readings, fora, presentations and case studies. The online component will consist of sets of compulsory readings. Each set of readings will be accompanied by an online forum for difficulties and real world case studies to promote reflection on their own attitudes towards leadership and discussion in preparation for the assessment. The online phase will be asynchronous so that participants would not need to take time off their clinical duties and there will not be a problem with time zones. Module participants can put forward the issues they are facing in their own country and receive feedback and advice. As preparation for the assessment, further case studies will be discussed with the panel. Onsite presentations will be sent to the participants 2 weeks before the start of the onsite phase.

Learning Outcomes

MPE01.01 Take responsibility for researching, evaluating, leading, and offering vision for the development of the role of the MPE (D&IR,) in the ambit of European and national legislation and a holistic vision of healthcare.

MPE01.02 Implement and evaluate strategic solutions to the challenges facing the MPE (D&IR) in own country and Europe.

MPE01.03 Evaluate the various models of management in terms of suitability for a Medical Physics Service and the use of project management tools.

MPE01.04 Learn the meaning of strategic leadership/negotiation and the importance of emotional intelligence for driving leadership performance.

MPE01.05 Take responsibility for the development of the role of the MPE (D&IR) in health care governance and management in D&IR.

MPE01.06 Discuss the role of the MPE (D&IR) in service development, health technology assessment (HTA), innovation and expert consultancy.

MPE01.07 Research, develop and lead the development of the role of the MPE (D&IR) in the education and training of medical physics trainees and other healthcare professionals.

MPE01.08 Manage the relationship of the MP/MPE with other healthcare professions in D&IR, with patients and with the general public and acquire better communication skills.

MPE01.09 Manage priorities regarding radiation protection research and medical physics input to clinical research projects needing the support of MPEs.

MPE01.10 Take responsibility for ethical issues in medical physics particularly in the areas of research and radiation protection in D&IR and apply them in practice.

MPE01.11 Learn how to participate in networks for research and development at the European and internation-

al level.

MPE01.12 Take responsibility for management of a Medical Physics Service in D&IR (including providing leadership, quality accreditation, staffing levels, clinical audit)

MPE01.13 Interpret the significance of liaising with the Radiation Protection Expert

ASSESSMENT

The examination is open book and consists of real world case studies involving challenges facing the profession. Sample questions are shown below:

• **Case Study 1**: Up to now there have only been Medical Physics Experts in Radiation Oncology and Nuclear Medicine in your country. However, EU Directive 2013/59/EURATOM has recognized the importance of an expanded role of the Medical Physics Expert also in Diagnostic and Interventional Radiology. You are having discussions about this issue with your healthcare

authorities. One representative from the Ministry of Health tells you: "I cannot understand why Medical Physicists are required in Diagnostic and Interventional Radiology as you don't have the high doses you have in Radiation Oncology"

How would you tackle it?

• **Case study 2**: There are 5 chest radiography rooms in your hospital each run by a different team of radiographers. You have noticed that one of the rooms is repeatedly exceeding the local DRLs which you have established. How would you tackle it? You know that the team of radiographers don't like people investigating their techniques.

• **Case study 3**: You are the head of the Medical Physics department at a large hospital which is expanding its Diagnostic and Interventional facilities owing to a large population increase in the region. You want to employ additional medical physics staff but the human resources manager tells you that you have enough staff. How would you tackle it?

PARTICIPANT FEEDBACK

The quality survey completed anonymously by the participants produced high satisfaction scores and comments were very positive: "Online content was excellent, great overview. The use of case studies throughout the online phase was very useful to focus on specific learning outcomes. The onsite phase reinforced knowledge from the online phase, complemented it with additional information and gave a great insight into what is required of one in order to be a successful Medical Physics Expert"

THIRD EDITION OF THE MODULE

The module has already been held successfully twice and each time it is developed even further following feedback from participants or new developments. Figures 1 and 2 show the first two groups. Figure 3 shows one of the groups

relaxing in beautiful Prague center after a hard day's work. We work hard but we want to enjoy the beauty of this beautiful city too! 3rd edition of this popular module for MPE starts online Nov 1st 2018, Onsite Prague 4 – 6th Feb 2019 (optional exam for extra EBAMP credits 8th Feb)

The faculty for the third edition will consist of:

- Prof. Carmel J. Caruana (Malta), Module Leader, Past-Chair E&T Committee EFOMP
- Dr V. Tsapaki Ph.D. (Greece), Module Leader, Past-Chair Projects and Publication Committees EFOMP, Secretary General IOMP
- Prof Hilde Bosmans Ph.D. (Belgium) Coordinator EUTEMPE (D&IR) project, Formerly Chair Projects Committee EFOMP
- Dr Marco Brambilla Ph.D. (Italy) President EFOMP, Past-Secretary General EFOMP
- Johan Sjöberg (Sweden) M.Sc. Past-Participant in the module who will provide input and perspective from the next generation of leaders

Here are some NEW presentations from the onsite phase of the third edition in Prague:

- Strategic leadership and planning: what is it and how to do it? (CJ Caruana)
- Total Medical Physics: going beyond a limited meaning of dose optimisation - an overview (H Bosmans)
- Total Medical Physics: going beyond a limited meaning of dose optimisation - application to CT (M Brambilla)
- Project Management Tools (J Sjöberg)
- Emotional intelligence for driving leadership performance (CJ Caruana)
- Standards for Medical Physics Services and ISO accreditation: EFOMP Policy Statement 13 and British Standard BS 70000:2017 (J Sjöberg)
- Strategic negotiation (CJ Caruana)
- Expanding your personal horizons: Involving yourself in your national NMO and EFOMP committees (V Tsapaki)
- Communication skills for effective education of physicians and healthcare professions (CJ Caruana)

CONCLUSION

In today's rapidly changing and highly competitive world, being a good scientist is simply not sufficient for a professional to develop; good leadership, managerial and strategic planning skills have become essential [6]. It is therefore suggested that such a module be considered for adoption by medical physics educators worldwide.

Come and join us in this interesting module. Write to Carmel at carmel.j.caruana@um.edu.mt For complete module

details go to http://eutempe-net.eu/mpe01/ To apply go to http://eutempe-net.eu and click on APPLY NOW. Application deadline: 20 October 2018.

Prof. Carmel J. Caruana, Head Medical Physics Department, University of Malta.

Carmel has been active in International MP for fifteen years: former Chair EFOMP E&T- Committee, author role and E&T chapters 'European Guidelines on the MPE', EFOMP policy statements, Associate-Editor EJMP, Accreditation Committee IMPCB. He has promoted leadership in Medical Physics worldwide. In Malta helped develop the profession from it's inception.

ACKNOWLEDGMENT

The EUTEMP-RX project was funded by the European Commission under the 2012 FP7 EC call for European Fission Training Schemes (EFTS) in 'Nuclear fission, safety and radiation protection'. Grant Agreement 605298

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Picture1: The first leadership group

Picture2: The first leadership group

Picture3: Relaxing in Prague center after a hard day's work

The necessity for clinical DRLs and the EUCLID European Commission project

John Damilakis, MSc, PhD, FIOMP

Professor of Medical Physics , University of Crete, Crete, Greece

Interventional radiology refers to a wide range of minimally invasive fluoroscopically-guided procedures for the diagnosis and treatment of various diseases. Although there are many advantages associated with these methods, it is also true that there are disadvantages including relatively high patient and staff radiation doses. To avoid unnecessary radiation risks, dose optimization of these procedures is needed. Several organizations recommend that dose reference levels (DRLs) could be used to optimize radiological protection in interventional radiology.

CT is a valuable imaging modality that can be used to examine organs and tissues, detect abnormalities and guide procedures. However, radiation dose associated with CT examinations and the potential of developing cancer due to radiation is an issue of concern. To reduce doses, CT examinations should be optimized. Different image quality is needed for different clinical indications of the same anatomical area. Kidney stone evaluation, for example, can be performed by using lower radiation doses than those used in evaluation of appendicitis because detection of high-contrast structures is affected less by high image noise than low contrast structures. Clinical indications dictate the main parameters that affect patient dose from CT such as scanning length, collimation and number of phases. Therefore, DRLs should be specified for a given clinical indication.

The European Commission (EC) launched the 'European study on clinical diagnostic reference levels for x-ray medical imaging' (acronym: EUCLID) project to provide up-to-date clinical DRLs. The main objectives of the project are to a) conduct a European survey to collect data needed for the establishment of DRLs for the most important, from the radiation protection perspective, x-ray imaging tasks in Europe and b) specify up-to-date DRLs for these clinical tasks. Moreover, a workshop will be organized to disseminate and discuss the results of this project with Member States and the relevant national, European and international stakeholders and to identify the need for further national and local actions on establishing, updating and using DRLs.

To fulfil these objectives, this project relies on:

1. An External Advisory Panel that will be set-up to be consulted on the main project activities and outcomes;

2. A Scientific Board that will be set-up to verify the used data sources;

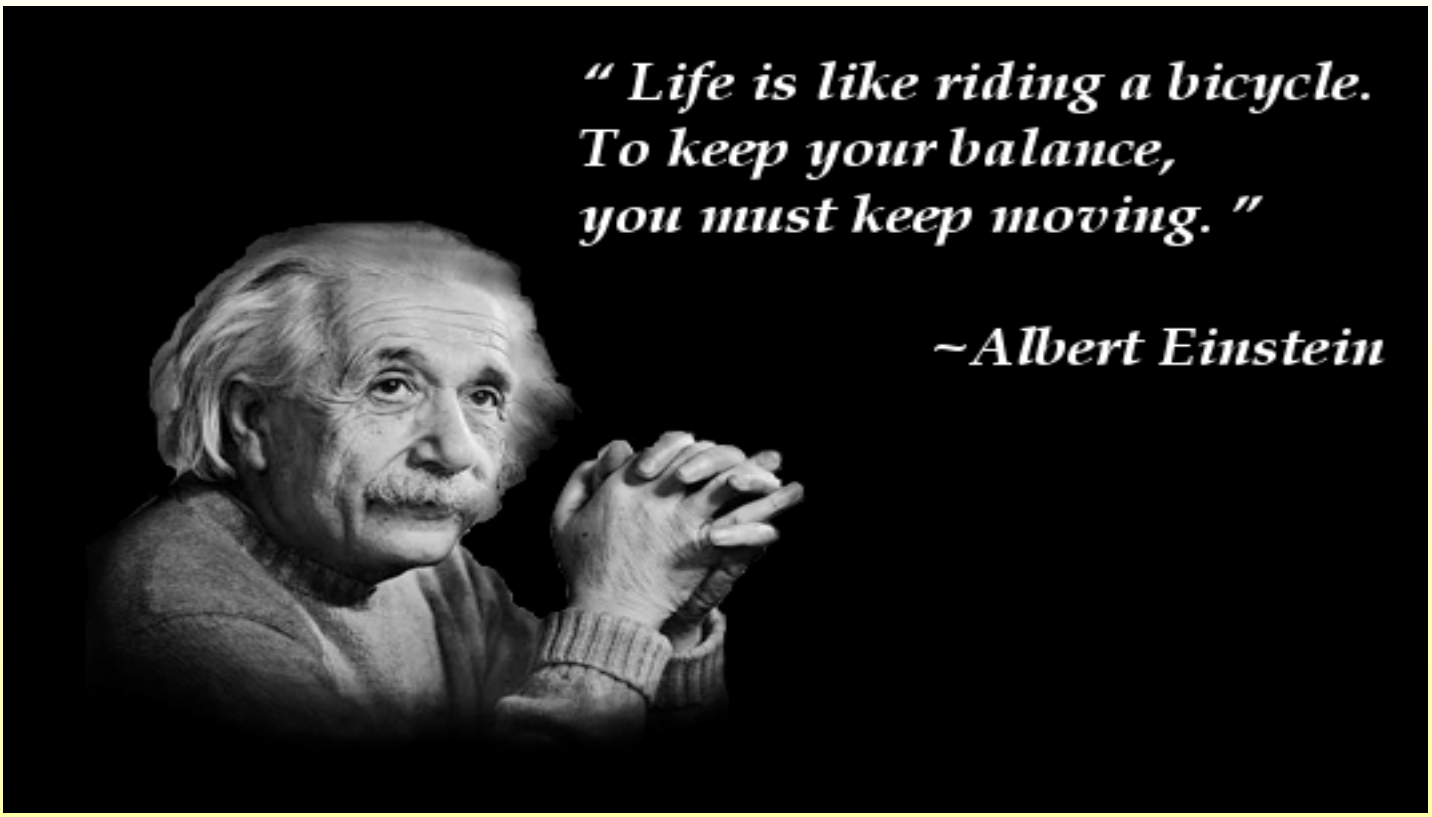
3. Interaction with the Steering Group established by the Directorate-General for Energy from the EC with other Directorates concerned to review and approve the reports and the study

4. A network of EuroSafe Imaging (http://www.eurosafeimaging.org/) hospitals and their experts.

The project is divided into 5 work packages (WPs). Each of these WPs covers specific tasks leading to the common objective to carry out a European study on clinical DRLs for x-ray medical imaging. The 5 WPs are the following:

WP1 is responsible for the management and general coordination of the project, as well as for dissemination. WP2 is responsible for the identification of procedures and clinical indications for which DLRs will be established, as well as for review of existing DRLs. WP3 is responsible for conducting a European DRL survey for computed tomography and interventional radiology following a predefined methodology. WP4 is responsible for specifying/determining up-to-date European clinical DRLs for the protocols/imaging tasks identified under WP2 and stakeholder consultation/validation of the DRLs. WP5 will organise a workshop to disseminate and discuss the results of the project with Member States and relevant national, European and international stakeholders and to identify the need of further national and local actions on establishing, updating and using DRLs.

EUCLID started in August 1, 2017 and the duration of the project is 33 months. During the first months of the project, a comprehensive review was carried out to identify the status of existing clinical DRLs for CT, interventional radiology and radiography in Europe and beyond by analysing recent studies, standards and publications. Information about existing clinical DRLs has also been collected from national competent authorities and other organisations involved in the project. A few national radiation protection authorities, only, have defined a limited number of DRLs for different clinical indications, so far. Although a large number of studies on doses from x-ray imaging are available, there is very limited information about clinical-indication specific DRLs. Moreover, a survey has been developed for collection of data needed for DRLs determination. Data will be collected for CT clinical indications and fluoroscopically guided interventional procedures identified by WP2.



Clinical Implementation and Quality Assurance of Image Guided Adaptive Brachytherapy in Indian scenario. (IGABT)

Jamema Swamidas PhD, Umesh Mahantshetty MD,

Department of Radiation Oncology, Tata Memorial Centre, Mumbai, India.

Introduction:

Cancer of the uterine cervix is the leading cancer among the female population in India (1,2). External beam radiotherapy (EBRT) with concomitant chemotherapy and brachytherapy (BT) forms the mainstay of the treatment. Especially BT plays a pivotal role in the management of carcinoma of the uterine cervix (3,4). Last two decades has seen major advances in EBRT, resulting in improved target dose while reducing the dose to the organs at risks (OARs). However there is a lack of development in BT as compared to EBRT.

Conventionally, BT planning was carried out by means of a pair of orthogonal radiographs. The major limitation of the conventional imaging modalities is the lack of information on the tumor volumes and OARs. Conventionally, point doses are calculated for rectum and bladder according to ICRU 38 recommendations (5). But, point doses may not represent the dose received by the volume of the organs (6, 7). Due to which the doses to the OARs were not known accurately, hence the treatment related side effects / toxicities were high (8). In addition, tumor cannot be seen in the radiographs, hence local control of the disease also was a challenge especially in large tumors (9).

In the recent past, the advent of advanced imaging modalities such as magnetic resonance (MR) and availability of computed tomography (CT) / MR compatible applicators have paved the way for Image guided Adaptive Brachytherapy (IGABT) (10). Various imaging modalities like ultrasound (11, 12), CT, MRI (13) and PET (14) scan etc. have been explored. Among all the imaging modalities, MR imaging is becoming increasingly popular for diagnosis and treatment planning for EBRT and brachytherapy for cervical cancer. IGABT in gynaecologic brachytherapy was mainly possible due to MR imaging, where it is possible to image the applicator with tumor volume and other normal tissues. Promising results in terms of increased local control and reduced toxicities have been reported which made this technique popular during the last decade (15).

Although IGABT is widely practiced in centers in Europe and USA, it is still in its infancy in India. It could be quite challenging to implement IGABT in India and in other developing countries due to the constraints on resources or expertise and, at times, both. However, there is growing interest in our country to implement IGABT for cervical cancer. As any other advanced techniques like IMRT, IGRT in radiotherapy, IGABT too requires systematic clinical implementation which includes, familiarization of the processes which includes applicator selection, insertion, imaging, contouring, applicator reconstruction, dose optimisation and specific quality assurance

procedures to adhere to. In appropriate implementation of IGABT and change of clinical practice based in this could be damaging to the patients.

For a successful implementation of IGABT program, a high level of confidence must be ensured at each of the above steps. Errors of different kinds such as choosing an incorrect applicator, incorrect imaging sequences, incorrect contouring and applicator reconstruction could produce dose results not accurate enough to be used in clinical routine. The contouring procedure has been shown to carry some of the most significant uncertainties in the IGABT procedure . Therefore, specific training remains one of the most important pre-requisites for high quality IGABT. Furthermore, in the past, lack of proper TPS QA procedures has led to some serious accidents. ICRP report 2 states that lack of understanding of the TPS and lack of appropriate commissioning are the major contributory factors for the accidents associated with TPSs (16). Unlike treatment delivery errors, which are usually random in nature, the errors from the treatment planning systems and applicator commissioning are more often systematic and can be avoided. Hence, quality assurance and proper understanding of the whole process is essential to ensure accurate dose delivery and to minimize the possibility of uncertainties in the treatment delivery.

The purpose of this report is to summarize the processes and quality assurance test procedures that lead to a clinical implementation of an IGABT program. However, it is beyond the scope of this report to discuss each of the aspect in detail. The readers can refer the original articles given in the references for detailed information.

Clinical Outcome:

Before, proceeding with the process, a brief summary of the clinical outcome from our centre, which was recently published(15), is as follows: At median follow-up (39 months) (N=94), the local control rate (LCR) and overall progression-free survival rate were 90.1% ± 3.4% and 72.1% ± 4.8%, respectively, with grade 3 bladder toxicity in 3% of patients and rectum toxicity in 9%. The LCR at 39 months was significantly better in patients with stage IIB and IVA disease versus stage IIIB disease (100% vs 85%, P=.013). Local failures were limited to stage IIIB only and were associated with significantly larger HR-CTVs at brachytherapy (70 ± 25.7 cm^3 vs 44.3 ± 21.9 cm^3, P=.01) but not with HR-CTV D_{90} doses (which were similar for patients who had local failures vs those who did not: 86.3 ± 3.9 α/β equal to 10 Gy (Gy_{10}) vs 88.5 ± 5 α/β equal to 10 Gy, P=.987). There was a significant improvement in O-PFS in the study cohort with the use of MR IGABT and dose escalation over the historic cohort (21) using conventional radiography-based BT.

Applicators / Selection:

Lack of CT/MR compatible applicators is one of the major reasons for non implementation of IGABT in India. Conventional stainless steel applicators are the most commonly used applicators in India, as they are robust, sturdy

and economical. These applicators produce artifacts in CT imaging that do not allow the anatomy to be visualized clearly. Moreover, they are not compatible with MRI. The new applicators made of CT/MRI compatible material do not throw artifacts, and does not interfere with the MRI signal and hence tumor visualization is possible (Figure 1).

. In India, tandem/ovoid is the most commonly used BT applicator, as compared to tandem/ring applicator. Recently, many new hospitals in India have procured ring applicators,. At the moment there is no data supporting the clinical benefit of either of the applicator type. Levin et al, and Tuncell N et al evaluated the dosimetric differences in tandem and ovoid (TO) and tandem and ring (TR) applicators (17, 18). It was found that there were no significant differences between TO and TR applicators in doses to prescription points or OARs. However, there were significant differences between the applicators in treated volumes and total treatment time. TO treated larger volumes over a longer time. Within each patient, when the applicators were compared, treated volumes were found to be significantly different, which could be attributed to the fixed geometry of the TR as compared to. It is unclear if this difference is clinically important.

Conventionally, for cervix cancer BT, only intracavitary applicators were used, which produces a dose coverage of 4cm width at the level of point A. However, if the tumor is large >4cm at the level of point A at the time of brachytherapy, then, the dose coverage is inadequate if a standard intracavitary plan with prescription to point A is applied. Adaptations to larger volumes can partly be performed but are limited to the fact that prescription to a larger volume will increase the dose to the OARs. For appropriate coverage of tumours which are larger at the time of brachytherapy, a novel system of intracavitary and interstitial applicator was originally introduced by Kirisits et al (19) Fig 1b. This applicator has a facility to implant additional needles along with intracavitary component, which can treat a tumor of up to 6.5cm in width at the level of point A, while respecting the OAR tolerance. A similar applicator design was made by University Medical Center Utrecht for TO applicator type Fig 1f (20) It was reported that the use of additional needles resulted in better clinical outcome (21,22)

.Imaging:

Imaging is the most crucial component of the whole process of IGABT. In India, 2D radiographic localization is widely used for BT, however in the recent past, with the increasing number of CT scanners available in new radiotherapy centers, CT imaging is being used for both external RT and BT planning. However, access to MRI for BT planning is limited to a few centers (23).

MR images provide good soft tissue definition but may suffer from spatial distortion (24). Studies were undertaken to compare the contouring in CT and MR which showed that the tumor volume can be significantly overestimated in CT images as compared to MR. No systematic differences in the volume or in the dose to OARs were found between CT and MR images (13, 25), although MRI has in general also better visualization of OARs.

The overestimation of tumor width in CT results in reduced D90, and resultingose escalation in D90, would result in increased dose to OARs. CT image based contouring guidelines is a work under progress in our institution .

Gyn GEC ESTRO recommendations for MRI imaging has been published which describe in detail all the issues pertaining to imaging (26). A brief summary of which is as follows:

Generally, applicators used for IGABT are MRI compatible, made up of either polymer or titanium. The plastic/polymer applicators do not infere with the magnetic field and appear as black voids in the images, however titanium applicators, produces susceptibility artifacts particularly in the regions of considerable material thickness which is typically at the end of the tandem, needle, ovoid, and ring channels. In particular with 3T MRI, titanium applicators may compromise the image quality due to susceptibility artifacts. The titanium artifacts depend on image sequence and may extend beyond 5–10 mm on 3T T2-weighted sequences whereas they may be less than 3–5 mm on 3T T1-weighted MRI(27). The spatial accuracy of MR images is crucial for precise dose planning in RT (24). The impact of spatial distortions will directly translate into dose calculation uncertainties as the BT dose gradient is about 5–10% per mm. Therefore, geometric accuracy of the MR imaging system needs to be tested. However it is to be noted that the distortion is quite significant at the field edges and minimal at the center, which is the region of interest in IGABT. Yet, quantification of these distortions needs to be carried out, as the dose gradient is quite high in brachytherapy. A 1mm distortion may cause a dose variation of 5-10% in the region of point- A. These effects are small for 1.5 and 3.0 T scanners, (28, 29). Susceptibility distortions are field dependent, but it has so far been proven that these distortions are acceptable for magnetic field strengths up to 1.5 T (28) and 3 T (27). Geometric distortions are sequence dependent and this has to be taken into account when choosing MRI-sequences. Fortunately the geometric stability of standard T2-weighted spin-echo and turbo spin-echo sequences is fairly robust to susceptibility artifacts, while fast imaging techniques like gradient echo techniques and echo planar imaging (EPI) techniques as used for diffusion weighted imaging (DWI) are much more prone to induce geometrical instability.

Gyn GEC ESTRO working group IV recommendations tabulates all the sequences of pre RT and BT MRI scans required to be performed for the implementation of IGABT (26). Out of which the mandatory scans, include a minimum of T2 FSE paraxial (in the axis of the uterus), para-saggittal and para- coronal sequences that covers the entire uterine body, inferior border of symphysis pubis, entire vagina- if vagina is involved and pelvic side wall. A slice width of 3-5mm is recommended. While the Pre RT MRI optional scans include T1 FSE or 3D GRE without contrast – axial and with contrast for saggital and coronal orientation. Similarly optional BT MRI scans are axial-T2FSE, coronal 3D T2FSE isotropic and T1FSE, FLASH and T1GRE 3D. It further lists all the protocols that tabulate the sequence parameters such as time of repetition, time of echo, echo train length, slice width etc for quick

reference. These parameters as a starting point and further customization of these parameters that are machine specific produce the best image quality. Once if a site specific protocol is obtained, then the user can freeze that protocol for further imaging in their center.

For gynecologic brachytherapy, MRI is considered as the gold standard to image the soft-tissue structures of the pelvis which leads to the fusion of CT or other imaging modalities with MR. Current recommendations suggests not to use deformable image registration for clinical application, as these algorithms are not yet robust enough. Rigid registration based on the applicator has to be used , based on the assumption that in brachytyherapy the anatomy moves with the applicator(29).

Volume delineation:

In the year 2004, GYN GEC ESTRO first published its recommendations, which describes the concepts and terms used in 3D IGABT (30). Various definitions of GTV and CTV were proposed, which are now widely accepted. It is highly recommended to follow these definitions so that, the data comparison is possible among the institutions for future research. The salient features of the GYN GEC ESTRO I recommendations are as follows:

Clinical examination plays a crucial role in the evaluation of disease extent / residual tumor during IGABT (Figure 2). The height, width, and the thickness of the tumor is schematically marked both at the time of diagnosis and BT. This information is useful to evaluate the pattern for regression of the tumor and to select the applicator at the time of BT appropriately. The role of clinical examination is crucial especially, in situations of vaginal involvement, where imaging has a lesser role.

The target definition at the time of BT includes the GTV, High Risk CTV and Intermediate Risk CTV. These volumes are defined at each BT application, taking into account the changes in tumor and true pelvis topography and dimensions during treatment. Assuming a fixed relation between the applicator and the target, no safety margins are applied, and planning target volume (PTV) equals CTV (31).

GTV at the time of BT represents the macroscopic tumor as visible and palpable on clinical examination and detectable on T2-weighted MRI as high signal intensity mass. (Figure 3).

The HR CTV is assumed to carry a high density of tumor cells and is characterized by a high risk of recurrence. It includes the whole cervix, GTV and any high- to intermediate-signal intensity areas in the parametria, uterus, or vagina, indicating residual macroscopic disease and areas of low-signal intensity (gray zones) in the parametria corresponding to the topography of initial tumor spread. It is recommended that high dose, (>80 –90 Gy), appropriate for eradication of macroscopic residual disease is prescribed to the HR CTV.

The IR CTV is assumed to carry a significant microscopic tumor load. It is characterized by an intermediate

risk of local recurrence and requires delivery of a dose (>60-70 Gy) appropriate for eradicating disease which is microscopic at the time of BT

The most important OARs are urinary bladder, rectum, and sigmoid colon. However the dose to bowel, vagina and ureters are also to be documented. Recently a new proposal for documenting the vaginal doses is published (32).

The above terms and concepts regarding the target volume were tested in the multi institutional setup, which demonstrated an encouraging level of inter-observer agreement when contouring is performed by experienced observers according to GEC-ESTRO recommendations (33-36). In a recent publication Tanderup et al quantifies the contouring uncertainty, which amounts to 9% for target and 5-11% for OARs (37).

In summary, tumor volume definitions are new, and the expertise to interpret tumor volume in MRI at the time of BT is associated with a learning curve, however these volumes were proven to be reproducible in a multi institutional setup when drawn by people guided by GYN GEC ESTRO recommendations with sufficient experience (30) It must be also emphasized that large amount of uncertainties exist, which can be minimized by adapting to the guidelines and by attending teaching courses/workshops, so that the concepts can be understood well, which is very important to be consistent with the definitions. Otherwse it will make a high impact on the dose volume parameters.

Applicator reconstruction:

Systematic investigation as a part of commissioning is required when new applicators are procured. The accuracy in applicator reconstruction is crucial due to the inherent steep dose gradients present in BT. Tanderup et al have quantified, that an 8-10 % of dose variation was found per mm of applicator displacement for target and OAR doses (38). Therefore the errors due to applicator reconstruction have to be kept at minimum to minimize the dose variation. Applicator reconstruction is defined as the process, where the geometry of the applicator and the source dwell positions is delineated in the patient image which is required for the calculation of dose to anatomical structures by the treatment planning system.

Applicator reconstruction with CT images is more straightforward as compared to MRI. In CT images, source channels can be visualized by means of a dummy marker with predefined source positions. The vendor of the applicator provides this dummy marker to be used with CT images. However, such dummy markers are not commercially available with the vendors for MRI as yet. Previous experience showed that catheters containing Cuso4 (39), water (40), Glycerine and ultrasound gel (vitamin D) when inserted in the applicator produce good contrast such that the source channel could be visualized. These markers need to be checked periodically, as they

may change their characteristics over time. In the titanium applicators, these channels cannot be visualized, as titanium is known to cause susceptibility artifacts (41). In such cases, the applicator landmarks such as needle holes, cavities can be used to aid the process of reconstruction (41, 42). Hellebust at al has found that the slice thickness is an important parameter that has direct impact on the precision of reconstruction, and it was recommended that reconstruction is performed in image series obtained with a slice thickness of ≤ 5 mm (43).

GEC-ESTRO recommendations for applicator reconstruction have been published which describe in detail the complete reconstruction procedure (43). A brief summary of the report is as follows: The commissioning process includes the verification of the location of clinically relevant source positions in relation to the outer surface of the applicator and/or in relation to reference points in the applicator, which includes for example, the distance from the tip of a tandem applicator or a needle to the first dwell position, distance from the top of a ring applicator to the level of the source. Traditionally the commissioning has been performed using X-ray images (44). However, with wide availability of CT scanners now in the clinics, CT images can be used to commission the applicators. The correct method of reconstruction should be verified using auto-radiographs from which the true location of the dwell positions is found. Extra care should be taken using curved applicators, e.g. the ring applicator or ovoids. Hellebust et al. performed a comparison of marker string and true source position by imaging the ring applicator with the source inside using CT (45). They found a deviation of 2.5 mm between the dwell position and the corresponding marker in the posterior part of the ring, which is most probably due to the curvature of the applicator. For after loaders which are extending the source to the distal end of the applicator tube before starting source retraction (e.g. GammaMed, Varian), the first millimeters of cable retraction will just straighten the wire without leading to any physical retraction of the source (slack of the source cable). If no correction is applied, this will lead to a systematic misplacement of all source positions in the ring. However, applying an offset and defining the end of the source channel beyond the real end of the source channel by 2–3.5 mm can perform compensation. The offset is dependent on the type of ring and may even change slightly with source exchange. In the case of library reconstruction, the error in the library files will lead to systematic errors in the whole database of the hospital using the applicator. Hence it is crucial that special care is undertaken to perform the commissioning properly.

The following test is carried out, as a commissioning process and the purpose of this test is to validate the applicator geometry specified by the manufacturer and to verify that the applicator geometry including the source path is reconstructed accurately. The applicator is positioned on the CT table in such a way that the relevant part of the applicator can be visualized in one image, followed by autoradiography with the known dwell positions (Figure 4b,c). The dwell positions are identified in relation to reference points in the applicator or to the outer surface of the applicator which should be within the specified tolerance. The applicator geometry can be obtained from the

technical manual provided by the manufacturer during the purchase of the applicator. If the results of this test are within the tolerance, then the physicist can approve of the applicator for clinical use.

Alternatively, an In-house phantom with the fiducials/markers with the known geometry can be fabricated which can house the applicator in fixed geometry (Figure 4a). To produce good contrast of the applicators the phantom can be filled with agarose gel. Images of both CT and MRI of various sequences, which will be used clinically (TI , T2 weighted, all sequences - spin-echo, turbo spin-echo, gradient echo, echo planar imaging (EPI) techniques and diffusion weighted imaging (DWI), various strengths 1.5T, 3.0T) can be obtained. The MR images have to be compared with the corresponding CT images by means of image registration to quantify the artifacts and spatial distortion. These images can also be used to validate the image quality of MRI and fusion algorithms.

To summarize, applicator reconstruction errors are systematic and can be avoided by proper commissioning of the applicator. GEC ESTRO working group guidelines are available for applicator reconstruction (43)

Treatment planning / optimization:

Historically, Manchester/ Fletcher dosimetry systems were used, which consist of standard radium loadings in tandem, ovoid/ring that produced a classical pear shaped dose distribution. With the introduction of remote after loaders and stepping source technology, standard loading pattern were followed that resembles the traditional radium loading which produce a similar pear shape dose distribution. The dose prescription/normalization was at point A, which lies 2 cm from the tandem, and 2 cm cranial to the upper surface of the vaginal applicator. Although, various optimization algorithms are available with stepping source technology, which modifies the dwell weights/ time across the dwell positions, in Intra cavitary BT, these algorithms were used minimally. The dwell positions or the dwell weight were changed minimally 2.5mm and up to 50%, to reduce the dose to the rectum and bladder point. in our hospital The same strategy is being followed in IGABT treatment planning, where the starting point is to follow a standard loading pattern, normalization to point-A, minimal optimization to reduce the dose to OARs without compromising the target coverage. Although, the dose prescription in IGABT is on HRCTV, it is recommended to report the dose to point A.

Generally, it is advisable, that large deviation from the standard loading pattern or the pear shape dose distribution is avoided. If Interstitial + intracavitary approach is being used, it is important to maintain the loading of the interstitial needles to a maximum of 20-30% so that the major part of the dose is delivered from the intracavitary applicator and the high dose region remains inside the uterus/GTV (46). By means of optimization the prescription isodose can be expanded typically by 5mm in intracavitary applications (47). By introduction of additional interstitial needles parametrial involvement can be targeted and it is possible to provide prescription depth upto 15mm from point A without increasing the dose to OARs significantly (46) (Figure 5). Inverse planning

is not widely used in clinics, and had to be done with caution as certain algorithms are known to produce large variation among the dwell times, it is important to understand how these inverse planning algorithm works in a certain clinical situation, prior to clinical implementation (50,51).

To optimally use the resources, delivery of two fractions of treatments, one on the day of the implantation and the other on the next day morning maybe done with one application, which is practiced in few centers (47,52) The DVH parameters recommended for reporting is given in table 1 (53)

Unlike 2D orthogonal image base planning, in IGABT, we are dealing with the 3D images in both external RT and brachytherapy, and hence, it is now possible to evaluate a cumulative dose distribution for target and OARs (Figure 6). However, the radio-biological basis of combining EXRT and BT dose is too complicated. However, to keep the addition of doses simple, widely accepted LQ model is used. which assumes mono-exponential repair with repair half time of 1.5 h and the linear–quadratic model with values for a/b of 10 for tumor and 3 for organs at risk (54). By applying this model and summing the equivalent dose in 2 Gy fractions (EQD2) derived from EBRT and BT, a total dose can be calculated. A free downloadable excel spreadsheet which calculates the EQD2 for various schedules (HDR, PDR) and organs are available. For 3D conformal RT where 4 field box technique is used, the dose is homogeneous throughout the PTV, and hence the prescription dose can be considered as the dose from EXRT, however for patients where EXRT is delivered by IMRT, simultaneous integrated boost or parametrial boost, the dose distribution could be quite heterogeneous, and the dose to the critical organs may not be the same as the prescription dose, and hence more careful evaluation of dose accumulation should be done in such cases. It is important to look for hot spots in OARs that needs to be taken into account for dose accumulation.

The recent publications of dose response relationship with DVH parameter validate the prescription concept and dose levels followed by most of the institutions practicing IGABT in the last decade (55, 56, 15). D90 of at least 85 Gy (EQD2) has been recommended for prescription to HRCTV, while D100 is in the range of 70-75 Gy (EQD2). D100 is a sensitive parameter to small uncertainties in contouring and dose calculations and hence D90, which is a more robust and representative DVH parameter, is widely used for reporting the target dose. For bladder, 90 Gy (EQD2) and 70–75 Gy (EQD2) for both rectum and sigmoid as minimal doses to the most exposed D2cc of the OAR is recommended. The dose effect relationship and the clinical relevance of using the above constraints have been proven (57) for various OARs. New data will emerge in the future with larger patient cohort. It is important to document both D2cc and D0.1cc for the OARs, as these parameters are found to correlate various toxicities, for instance, in the case of rectum, D0.1cc level may be relevant for the development of ulceration, necrosis, and fistula and at the D2cc level for telangiectasia (58). Due to difficulties in defining the vagina on images and the steep dose gradients with very close proximity to BT sources, a meaningful DVH analysis and

correlation of dose to vaginal morbidity have so far been impossible (590). Recently a new method has been proposed to document the vaginal dose (32). An ongoing collaborative IntErnational study on MRI-guided brachytherapy in locally advanced cervical cancer (EMBRACE) will reveal more information on the dose effect relationship on local control/morbidity of the tumor and toxicities of OARs.

To summarize, as far as possible, deviation from the standard loading pattern and the pear shape dose distribution should be avoided. In the case of Intracavitary + Interstitial implants, the dwell weight of the needles should not exceed 20-30%. The cumulative dose is calculated in terms of EQD2. The EQD2 cumulative dose constraints are D90 HRCTV 85Gy, D2cc rectum and sigmoid 70-75 Gy, bladder 90Gy.

Dose Delivery / Inter-intra fraction/application variation:

In multi fractional brachytherapy, inter-application/fraction variations occur between different treatments/ applicator insertions, both in terms of geometric and dosimetric parameters (10,60,61). Inter-fraction variation has been defined as change between fractions without removal of the applicator, while Inter-application variation is the variation between different applications after reinserting the applicator (10). The current practice of determining the D2cm3 cumulative dose to OARs during brachytherapy is based on what has previously been called "the worst case scenario", which is the assumption that the D2cm3 regions are located in the same anatomical part of the organ in each fraction (47). This assumption implies that the cumulated brachytherapy dose can be calculated by adding D2cm3 values for each fraction. Various parameters such as bladder and/or rectal filling, movements of sigmoid colon, and variation in vaginal packing have been identified for inter-fraction/inter application variation (53).

One of the recommendations for the implementation of image based brachytherapy is the use of MR imaging for every application to adapt to the tumor shrinkage and to estimate the doses to the OARs accurately, however, this may act as a limiting factor in resource constrain settings (10,60). Imaging before every application will certainly reduce the uncertainties associated with the organ motion and applicator movements during or in between planning process and delivery. However, it is important to quantify the uncertainties to understand these factors and its possible impact on implementation in clinical practice. The recent analysis of inter application variation of the spatial location of 2cm3 volumes revealed that the applications/fractions are quite stable in topography for bladder and rectum, and hence the current practice of cumulative addition of D2cm3 dose is expected to be valid for bladder and rectum, however for sigmoid, it was reported that significant topographical changes were seen and hence the cumulative addition of doses may not be valid (62).

In a recent publication, Nesvacil et al, and Mohammed et al made a detailed investigation on using a combination of MRI for first fraction and subsequent CT based planning for the second fraction and its feasibility in

the resource constraint setting (63, 64). It was found that it is feasible and easy when automatic applicator-based image registration and target transfer are technically available. The results showed similar results to fully MRI based planning in cases of small tumours and intracavitary applications, both in terms of HR CTV coverage and respecting of OAR dose limits. For larger tumors and complex applications, as well as situations with unfavorable OAR topography, especially for the sigmoid, MRI based adaptive BT planning was recommended.

Conclusion:

An overview of various important aspects of successful implementation of MR image based Adaptive Brachytherapy has been described. The salient points can be summarized as follows:

Implementation of combined IC-IS for improved treatment of large tumours

Teaching in contouring is very essential, as inconsistent contouring may impact the DVH parameters

Applicator reconstruction quality tests to be carried out

Dose optimisation has to be performed conservatively

Dose reporting based on the ICRU 89 recommendations.

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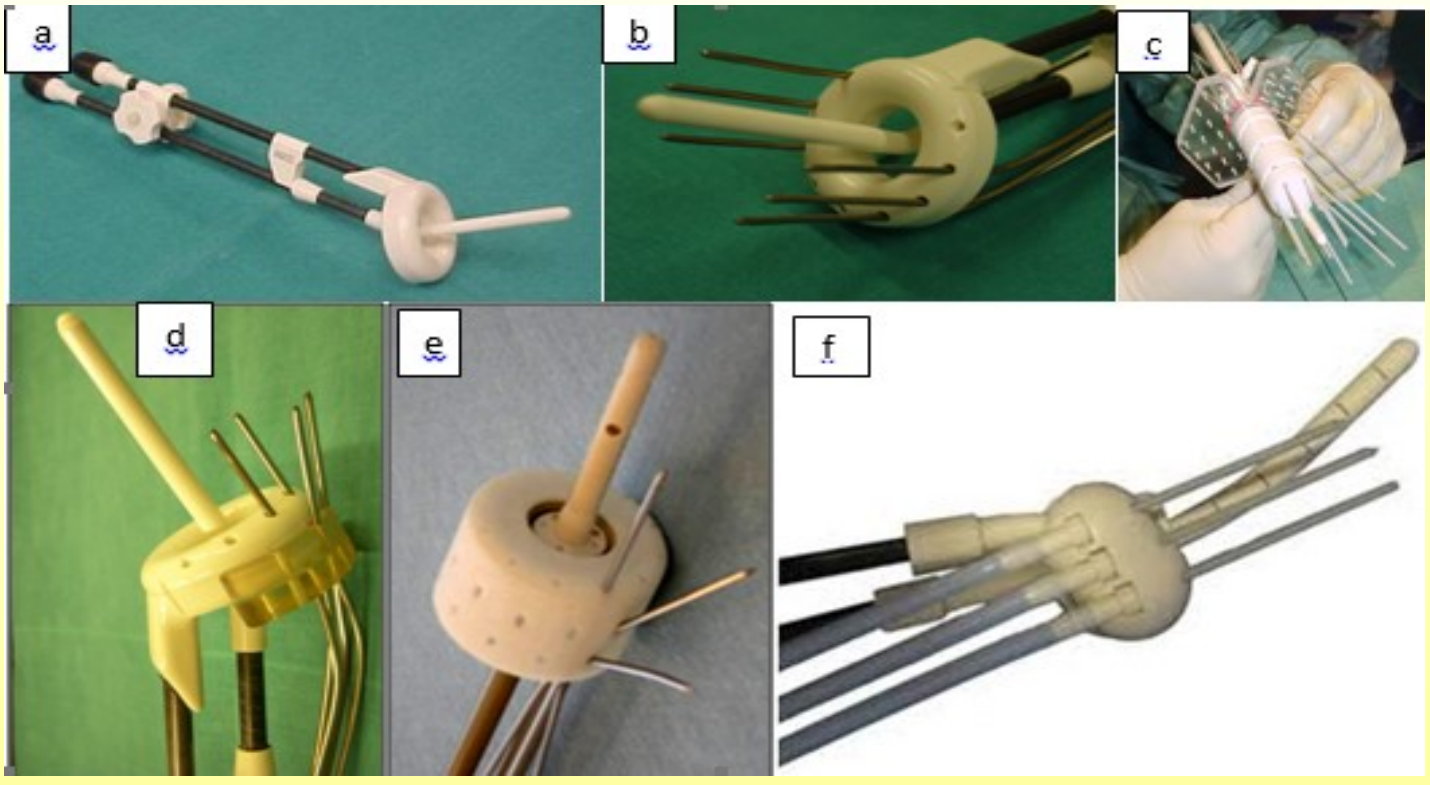
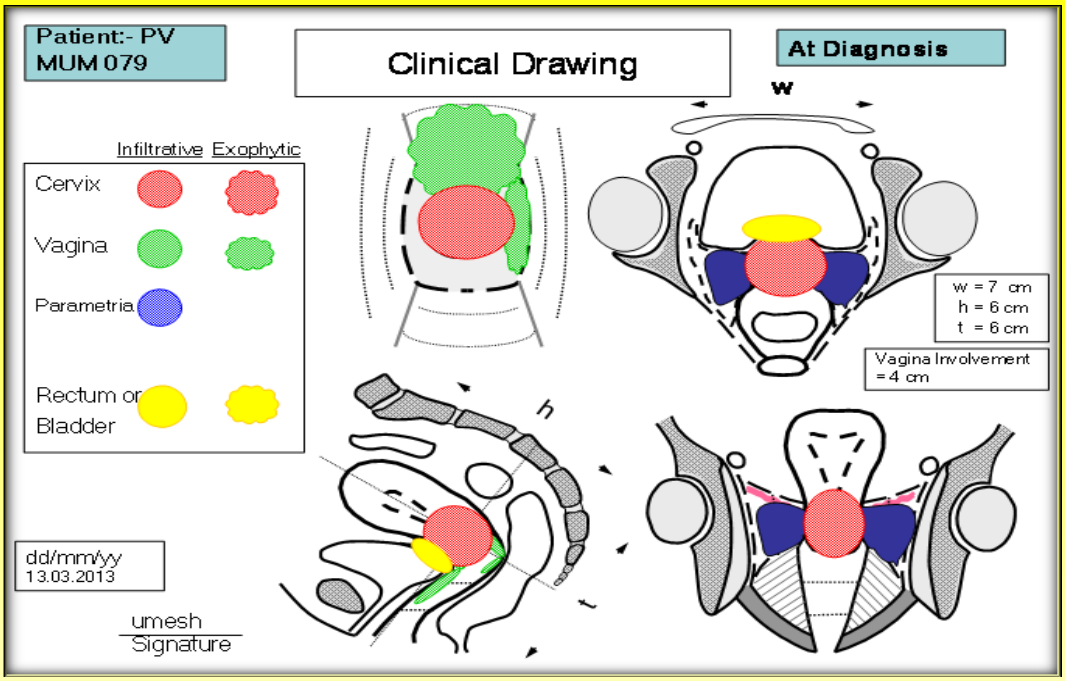
Table 1: Dose volume parameters recommended by GYN GEC ESTRO, all doses to be reported in cumulative (EXRT +BT) EQD2, there are also other level 2&3 parameters which are given in detail according to ICRU 89.

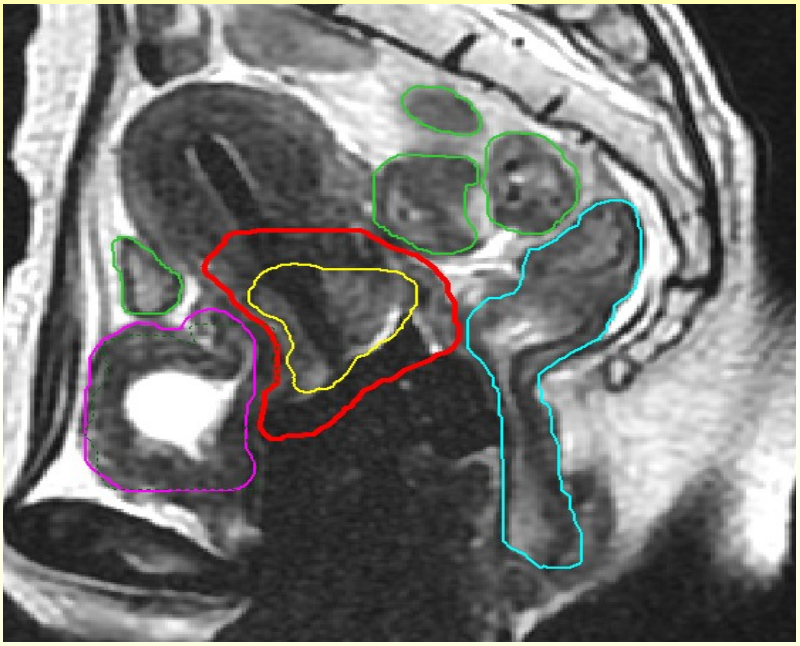
DVH parameter	*Definition*
Target	
D98	It is the dose received by 98% of the target volume, which represents the minimum target dose. This parameter is sensitive to inaccuracies in contouring and dose calculation and hence D98 is now recommended.
D90	It is the dose received by at least 90% of the target volume. This is the most used parameter to represent the target dose. Dose effect relationship of target to this parameter is established.
V100	This parameter represents the coverage of the whole target volume. V100 reaches 100% only when all portions of the target are covered by the prescribed dose. The total reference air kerma (TRAK), a value indicating the total dose delivered by a plan independent of the dose distribution. This parameter can be used for comparison and QA.
Point A, TRAK	Point A is defined as a point 2 cm from the tandem, and 2 cm cranial to the upper surface of the vaginal applicator, In case of Intracavitary and interstitial application reporting of point A may not be genuine.
OARs (Rectum, Bladder, Sigmoid) D2cc, and D0.1cc.	Minimum dose to the most irradiated 2, 1 and 0.1cc volume of each organ

Picture1. *CT-MR compatible applicators a) ring CT/MR compatible applicator b) Vienna applicator, c , d and e) Vienna with additional needles. F) Utretcht applicator*

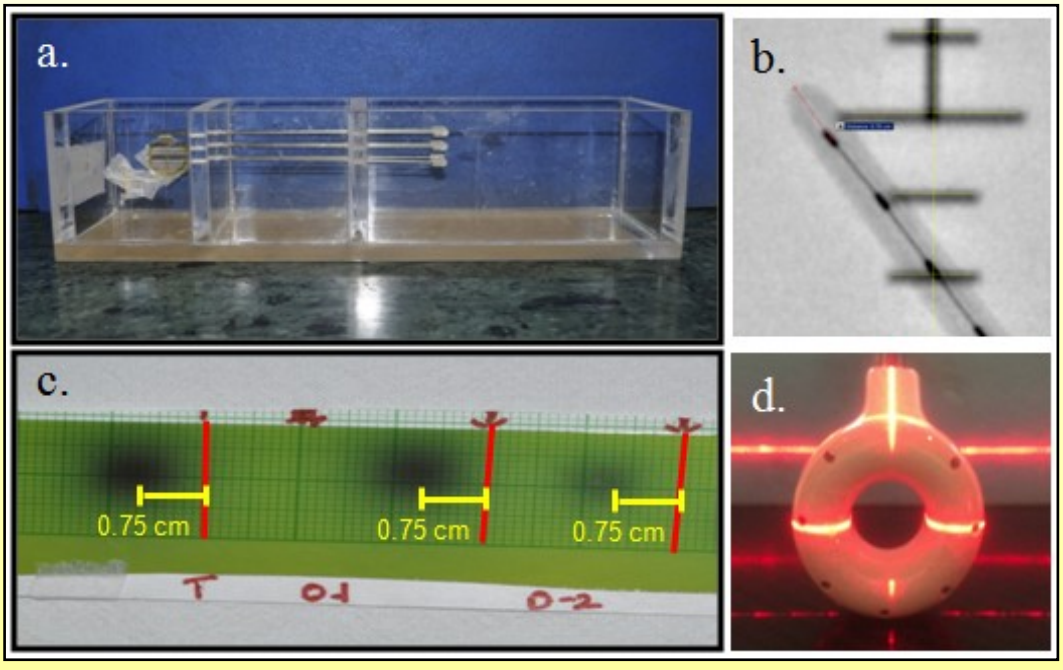




Picture 2: Documentation of Clincal findings

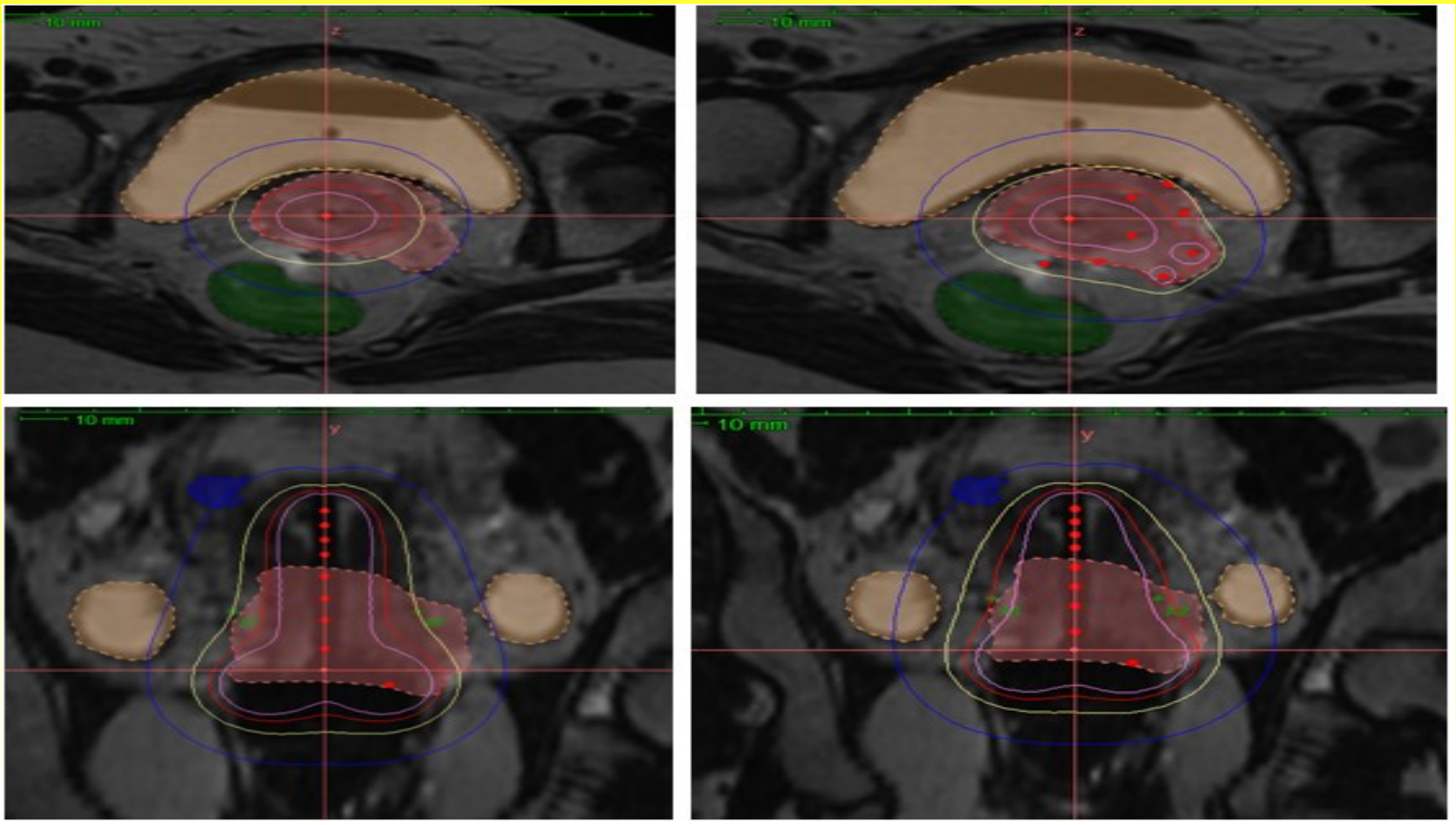


Picture 3. Figure illustrates the target volumes drawn as per GYN GEC ESTRO recommendations. GTV (yellow), HR CTV (red) and OARs rectum (blue), bladder (magenta) and green (sigmoid).

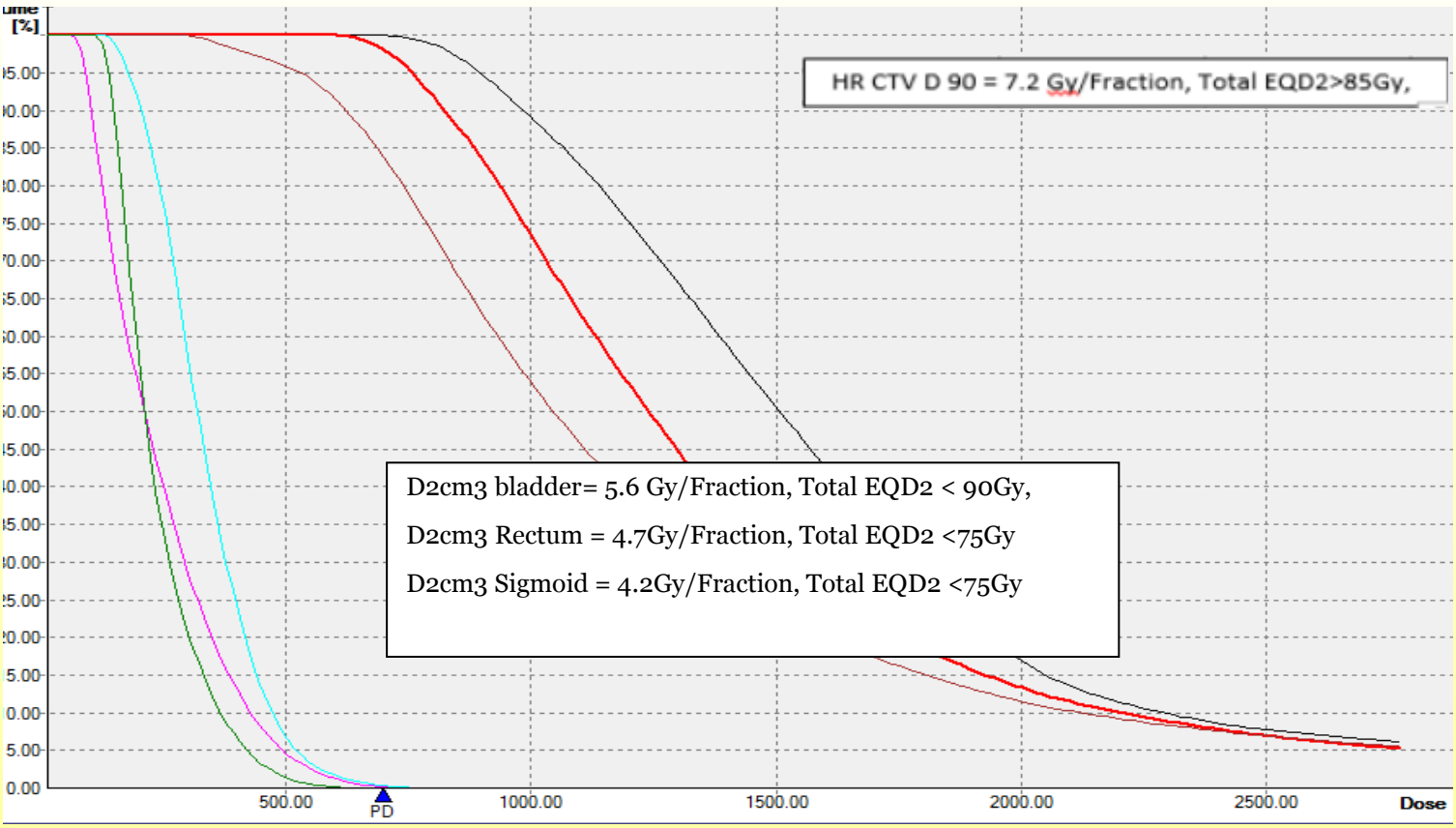


Picture 4: Figure showing various processes of the quality assurance procedures for applicator commissioning a: In house made phantom b & c : Auto radiograph and the radiograph to determine the offset for first dwell position. d: Ring applicator positioned during the CT scan.

Picture 5 : *Dose distribution of Intracavitary where the target is not adequately covered(left), the addition of interstitial needles helps to extend the dose coverage by 8mm, while sparing the OARs (right) . Dotted red line- HRCTV, Dotted Yellow line-GTV, Dotted Majenta-Bladder continuous blue line – 7Gy, continuous red line – 9 Gy.*



Picture 6 : A typical DVH of a Brachytherpy application. The dose volume parameters quoted here refers for one BT application



Increasing access to radiotherapy with affordable cancer technologies

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The need for simplified radiotherapy technology to increase access to care

If you have cancer will you receive treatment? The answer to that question, in many countries and regions, is "no". Many millions of people around the globe suffer from cancer and many of these have few or no options for effective treatment. This problem is only expected to grow in the coming years and decades as the burden of disease shifts and the disparity between countries and regions becomes larger. By 2030 it is estimated that 70% of all cancers will occur in LMICs[1]. Faced with these challenges, the goal in the coming years is to improve access to high-quality cancer care for more patients around the world.

Of the various possible treatment options, radiotherapy (RT) plays a key role. It is estimated that more than half of all cancer patients should receive RT [2,3] and this is often delivered with curative intent. This proportion is even higher in regions where disease presents at a later stage. In India, for example, approximately 80% of patients present with Stage III or IV disease.

RT also benefits not only individual patients, but also the economy and healthcare system as a whole. It is non-invasive and has relatively few toxicities if administered well. Therefore it exerts relatively little burden on the healthcare system. It is estimated that making RT widely available would results in a net economic benefit of US$11 to $280 billion per country over the next 20 years[3]. Still, in many places RT is not widely available. India currently has 650 RT units (in 438 centers)but it is estimated that the nation needs 1300 units[4].As another example, in Africa as of 2010, there were 29 countries that offered no radiotherapy services and 7 countries with only one machine[5].

What limits the availability of RT? There are many factors, but one of the major issues is the cost and complexity of technologies that are currently available.Linear accelerators from major vendors has evolved over the last twenty years to suit the North American and European market. The result is a highly complex technology that is not only costly to purchase, but also difficult to maintain once it is installed. In a typical US clinic, for example, a specialized engineer is needed approximately 2-3 times per month for each linear accelerator to fix problems. In addition, spare parts are needed on demand. In many regions this is not sustainable and the result is that machine become unavailable for use for long periods of time. This has lead recent authors to ask: "Is Africa a 'graveyard' for linear accelerators?"[6]. The answer, in many cases, is yes. Units are being installed but often cannot be maintained. In addition,there are concernsabout patient throughput in a busy clinic and it can be affected by technology and infrastructure. A recent modeling study indicates that patient throughput can be reduced by half if there are daily power outages of >4 hours and also that advanced techniques like intensity modulated radiotherapy (IMRT) are affected more by these problems[7].

In summary, because of the growing burden of cancer globally more access is needed tohigh-quality care. Radiotherapy is an important part of that.Technologies like IMRT are needed to treat patients and reduce toxicity. However, the current RT technology make this difficult to achieve in many countries and regions. New solutions are needed.

Simplified IMRT: an NCI-funded project in Affordable Cancer Technology

In an effort to address this major problem, we have undertaken an initiative to develop simplified technologies for delivering advanced radiotherapy. This project is supported by funding from the National Cancer Institute (NCI) in the US under the Affordable Cancer Technologies program. The goal of our project is to develop a new generation of device to enable intensity modulated radiotherapy (IMRT) with reduced cost and complexity.

A key component of the project is to use compensators to deliver the intensity modulated beams, i.e. a metal device placed in the beam to attenuate. In most modern therapy units, multileaf collimators (MLC) are used to deliver the beam, with the leaves moving to create the modulated intensity fluence. However, there are many potential advantages of compensators over MLCs. 1) Fewer mechanical failures. One of the key failure points in modern RT units is the MLC. MLC motors can fail, needingand engineer to repair as well as spare parts. 2) Eliminate problems of MLCmiscalibration, thereby streamlining QA. The calibration of the MLC has a large effect on the quality of treatment delivery and tight tolerances must be maintained (e.g. 1 mm per AAPM Task Group Report #42). This requires extensive quality assurance (QA) program to monitor and maintain, including physics effort and equipment. By eliminating the MLC, these calibration and QA demands are reduced. 3) More efficient use of dose. With an MLC most of the field is "closed" in any given segment. Only a small region is irradiated as the MLCs move. The radiation that is seen by the closed part of the MLC never enters the patient and is "wasted". With a compensator this is not true. The treatment field is always "on". This more efficient use of dose means substantially reduced treatment times (more on this below). 4) Fewer problems with patient motion. An example of this is respiratory motion. As the patient breathes, the tumor and other anatomy move sometimes by more than a centimeter. This movement interplays with the moving MLC and can cause underdosing of the tumor and other effect. With a compensator design there is no such interplay.

Given these many advantages of compensators, why are compensators not more widely used? Why are MLCs the de facto standard in modern RT delivery systems?First, compensators are sometimes thought of as an "old" technology. They were extensively explored in the 1990s in clinical use and in investigational studies (e.g. [8]). However, there were several technical problems with compensators that were never solved before MLCs emerged to dominate the market. Although none of these problems were fundamental physical limitations, they limited the widespread adoption of compensators. These included: 1) The need for large, complex milling machines to create metallic compensator usually out of brass. The requirements for this meant that compensators were typically created by a mail-order system and even with high-efficiency postal system this required days and was costly. 2) Material for patient specific compensators was not reusable. 3) The need to change compensator blocks for each field. This

greatly reduced the potential efficiency gains of the compensator because a radiographer or therapist was required to enter the vault and physically change the compensator between each beam.

These potential limitations of compensators are not fundamental in nature. Each can be addressed and solved, and we are engaging in this through the NCI project. First, it is possible to manufacture compensators on-site without expensive milling equipment. This eliminates the need for a mail-order system. It is also possible to employ reusable materials by using a negative cast system (i.e. a shape or mold created out of Styrofoam or some other material which is then filled with metal). This approach has been explored before (e.g. [8]) but never fully developing into a widespread solution.The third limitation listed above is arguably the most important to address, i.e. the need to change compensator blocks for each field which greatly reduces the efficiency for beam delivery. Our approach is to use a fixed compensator system, e.g. compensators placed in a fixed ring around the patient. With such a design, the compensators are all put in place before the treatment starts. The gantry then rotates around the compensator ring and delivers beams through each compensator plate. In this way there is no need to exchange blocks between fields and the efficiency is greatly enhanced. Other solutions are also possible allow for automatic compensator placement without the need to enter the treatment vault.

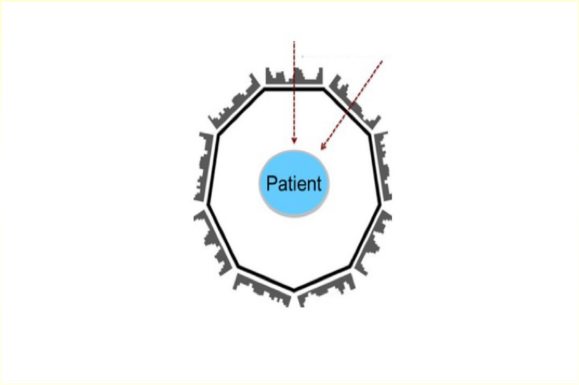

Figure 1: A ring design for compensator-based IMRT. The compensator plates are placed around the patient before treatment begins. The gantry is rotated around and each treatment beam (red) is treated. This eliminates the need for block changes during treatment which greatly enhances efficiency.

Our recent simulation study[9] indicates that this approach is highly efficient. With compensators the overall treatment times are reduced by more than a factor of two compared to MLC-based delivery. Also treatment plan simulations of head-and-neck and gynecological cancer patient show that plan quality of compensator plans is similar to clinical MLC systems and Monte Carlo simulations indicate that calculations of dose through these devices can be accurately calculated.

Further promise: Cobalt-60 IMRT

Because of the high efficiency of the compensator IMRT system discussed above, we have been exploring the possibility of delivering IMRT with Cobalt-60 teletherapy units. Many such units are in use and will continue to be in use. However, to date no Cobalt-60 devices have successfully accomplished IMRT in the clinical setting. There is one exception: the MR-guided delivery device from ViewRay Inc., a state-of-the art MR-guided unit first installed four years ago at Washington University in St. Louis. Cobalt-60 was used in the design instead of a linac in order to reduce the electromagnetic interference with the MRI imaging system. This system has an MLC. However, to

achieve efficient delivery it was necessary to employ *three* Cobalt-60 treatment heads in the device. Standard Cobalt-60 teletherapy units can be fitted with an MLC and several of the major manufacturers offer this solution now. However, it likely will not be possible to deliver IMRT with these devices given the low dose rates of Cobalt-60 units and the inefficient use of dose of the MLC (c.f. ViewRay MLC-based system which requires three delivery heads). However, compensator-based IMRT offers the exciting possibility of delivering IMRT with a Cobalt-60 teletherapy unit.

Is this feasible? Our simulation and planning studies indicate that it is[9]. The first thing to note is that the plan quality of Cobalt-60 IMRT is not substantially different that from a 6MV linear accelerator. While this might be surprising at first, given the large source size and poor penumbra, it must be noted that with IMRT it is possible to modulate out these effects in a large part. Our studies indicate that Cobalt-60 IMRT is essentially equivalent to 6MV linac IMRT in terms of dosimetric coverage of the target structures and organ-at-risk sparing[9]. This also reflects the experience with the ViewRay Inc. MR system where Cobalt-60 has been used to deliver IMRT in one of the most state-of-the-art systems now available in the world. A second concern is relatively long treatment time due to the lower dose rate of Cobalt-60 teletherapy units. Our simulations indicate that with compensators this is not a problem. In fact, the average delivery time is shorter with Cobalt-60 compensator IMRT than with linac-MLC IMRT: 3.9 ± 0.9 min vs. 7.6 ± 2.0 min in head-and-neck plans[9]. These times will be even shorter with an 80 SAD system. The short times are a reflection of the fact that compensators use dose much more efficiently than MLCs.

Summary

There is an acute need for more widespread access to radiotherapy around the world. The advanced technology that now exists works well in certain regions of the world where the resources exist to support it, but in other regions it is very difficult to maintain. New solutions are needed like those discussed here and others. Albert Einstein once said that "The measure of intelligence is the ability to change." By being open to this change and pursuing it we may be able to positively impact the lives of many people who suffer from cancer.

Conflict of interest statement: The authors have no financial interest in the technologies discussed here. They receive no funding from commercial entities.

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Congratulations

IOMP Awards and Honours

- **Prof. Kwan Ng (Malaysia) – IOMP Marie Sklodowska-Curie Award**
- **Prof. Anchali Krisanachinda (Thailand) – IOMP Harold Johns Medal**
- **Prof. Eliseo Vano (Spain) - IUPESM Award of Merit**
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- **Dr Melissa Martin (USA) – Fellow IOMP**
- **Mrs Sally Hawking (UK) - Honorary Member IOMP**

Proposal for a common forum of medical physicists in South Asian countries

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Cancer affects people in all countries regardless of their age, gender or socio-economic conditions. Radiotherapy and other advanced forms of cancer treatment are accessible to mass people in developed countries; however, the scenario is different in developing countries. According to WHO [1], it is estimated that the global cancer burden will increase from 12.7 million new cases per year in 2008 to 21.4 million per year by 2030, with nearly two-thirds of all cancer diagnoses occurring in low- and middle-income countries. The South Asia region with its eight countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka) has approximately one-fourth of the world's and 40% of Asia's population [2]. This region is presently experiencing a shift in infectious disease to an increasing incidence of non-communicable diseases like cardiovascular and cancer. South Asian countries face a big challenge in all four key components of cancer control such as prevention, early detection, diagnosis and treatment [3]. According to the Directory of Radiotherapy Centres (DIRAC) of International Atomic Energy Commission (IAEA) database, there are approximately 712 Megavoltage (MV) units in South Asia region; 309 linear accelerators and 403Cobalt-60 representing 1.2 MV units per million populations. Based on the estimation of new cancer cases by 2030, South Asia will require 2338 MV units 4676 radiation oncologists and 2924 medical physicists (in 2012: 1415 radiation oncologists and 922 medical physicists) [4,5].

Although overall cancer incidence rates in the developing countries are half those seen in the developed world in both sexes, the overall cancer mortality rates are generally similar. Cancer survival trends to be poorer in developing world, this is most likely due to a combination of a late screening and limited access to the standard treatment at the right time. Through the application of existing cancer control knowledge and by implementing programs for tobacco control, vaccination, early detection and treatment, as well as public health campaigns promoting physical activity and a healthier dietary intake a considerable proportion of the global mass ofcancer could be prevented. Clinicians, public health professionals, and policymakers can play an active role in accelerating the application of such interventions globally [6]. With respect to the global context, about 24.59% populations are present in South Asia area wherethe incidence of new cases is 10.23 % and the burden of cancer death is 68.85%. This well-known fact indicates that this region of the world requires to improve its strategies in cancer management [7].

The infrastructure and human resources for oncologic care in countries are steadily improving. Each country is purchasing the updated technologies for radiological diagnosis and treatment. In order to provide quality treatment to the patients, radiologists, oncologists, medical physicists, technologists need to be appointed, as well as

they should be well trained and qualified. In some countries of this region, medical physicists are not mandatory personnel in the government hospital, which will lead to inaccurate diagnosis and treatment. Therefore, a combined force is necessary for the awareness of the importance of medical physicists in cancer treatment in this region. However, being professional in medical physics discipline in South Asian region we have a long way to go compared to developed countries. Through the formation of a common forum sharing clinical observations, educational materials, research findings and organizing scientific events, this goal could be achieved. That was the vision of Prof. Golam Abu Zakaria since long time, who is the initiator of medical physics education in Bangladesh and also one of the excellentpromoters of medical physics in theSouth Asia region.

We believe that the South Asian forum will provide an impetus to accelerate advances in cancer care for South Asia and ultimately help us to provide the best possible cancer care to the quarter of the world's population that has made this region their home.

Meeting regarding common forum for medical physicists in South Asian countries

An initiative has been taken from Bangladesh in order to form a common platform in medical physics discipline for the South Asian region, which has successively been discussed in all three international conferences (ICMPROI), organized by Bangladesh Medical Physics Society (BMPS) in the year of 2011, 2014 and 2018. Bangladesh Medical Physics Society (BMPS) had also approached medical physics community and discussed in a separate meeting regarding the role and formation of a forum during the annual conference organized by the Association of Medical Physicists in India (AMPI) in Vellore, India in 2011.

1st International Conference on Medical Physics in Radiation Oncology and Imaging (ICMPROI-2011), Dhaka, Bangladesh in2011

During the 1st International Conference on Medical Physics in Radiation Oncology and Imaging (ICMPRO-2011) [8], 11-13 March 2011 organized by Bangladesh Medical Physics Society (BMPS), where more than 200 participants including 36 foreign experts from 10 countries were present. In that conference, an issue was raised to set up a forum of medical physicists in the South Asia region, which was supported by Bangladesh, India, Nepal and Pakistan. The representatives (Figure-1) from South Asian region are from four countries (Prof. Dr. HasinAnupamaAzhari, President (BMPS); Prof. Dr. ArunChougule, (AMPI); Mr. P. P. Chaurasia, President, Nepalese Association of Medical Physicist (NAMP); Dr. MonsoorNaqvi,President,Pakistan Organization of Medical Physicists (POMP). All the representatives have shown their strong support in the formation of a common forum for medical physicists in the South Asian countries. It was the first approach for a common platform of medical physicists in this region. The positive expression of the representatives during the closing ceremony of the ICMPROI-2011 has helped us for the further approach (8).

Picture-1: (a) Inaugural session of ICMPROI-2011; (b) Closing ceremony of ICMPROI-2011 (From left, Dr. HasinAnupamaAzhari/Bangladesh, P. P. Chaurasia/Nepal, Prof. Dr. Arun-Chougule/India, Prof. Dr. Golam Abu Zakaria/Germany and Dr. Syed MansoorNaqvi/Pakistan); (c) Discussion between BMPS and AMPI delegates; (d) Main organizers with foreign delegates

32rd Annual Conference of Association of Medical Physicists in India (AMPICON- 2011),Vellore, Indiain2011

The second meeting regarding this issue was held during AMPICON-2011 in Vellore, India. The discussants were AMPI president Dr. Kanta Chopra, Dr. D. D. Deshpande, Mr. VijoyChoube, Dr. S. D. Sharma, Dr. Pratik Kumar, Dr. KamleshPassi, etc. from India; and from Bangladesh Prof. Dr. G. A. Zakaria and Dr. HasinAnupamaAzhari (Figure-2). Among the South Asian countries, medical physicist is well recognized in both public and private hospitals only in India. In Bangladesh, medical physics education has already been established and through the BMPS activities, both public and private sectors already know the importance of medical physicists in cancer management. The recruitment policy is in process for the government hospitals. Therefore, participants from other countries like Bhutan, Myanmar, Nepal, Pakistan including Bangladesh also emphasize that medical physics situation need to be developed and can be improved by making a common forum called South Asian Forum. It was also discussed with Dr. Paul Ravindran, Chairman of the Organizing Committee, AMPICON-2011.

Picture-2: (a) Participants of the second meeting during AMPICON-2011 (First row-from left: Dr.D.D. Deshpande, Prof. Azhari, Dr. Chopra, and Dr. Passi ;Second Row-from right Dr. Kumar,Dr. Choube,Dr. Sharma, Prof. Zakaria, others.); (b) From left- Prof. Zakaria. Prof. Ravindran, Prof. Azhari, Dr.Viswanathan)

2nd International Conference on Medical Physics in Radiation Oncology and Imaging (ICMPROI-2014), Dhaka, Bangladeshin2014

In 2014, the second ICMPROI-2014 was again organized by BMPS with presence of more than 300 participants including 40 foreign experts from 24 countries[9,10]. During the conference,there was a follow-up meeting at the Milton Hall of the Bangabandhu Sheikh Mujib Medical University (BSMMU) with the presence of delegates from Bangladesh, India, and Nepal to foster the cooperation among these countries for the development of medical physics activities (Figure-3).As a consequence of the above meetings, the Association of Medical Physicists in India (AMPI) offers BMPS members to sit for College of Medical Physics in India (CMPI) to become a qualified medical physicist (QMP). There were a lot of discussions and conversations including going on between Bangladesh and India for the formation of a forum for medical physicists in the South Asian region.

Picture-3: (a) Inaugural session of ICMPROI-2014; (b) The meeting on 22/08/2014 during ICMPROI-2014 at the Milton Hall of BSMMU. (From left- Dr. AK Rath/India, Dr. SrinivasChallapalli/India, Mr. Anwarul Islam/Bangladesh, Prof. HasinAnupamaAzhari/Bangladesh, Prof. Golam Abu Zakaria/Bangladesh-Germany/Dr. Kumaresh Chandra Paul/Bangladesh and Mr. P.P. Chaurasia/Nepal; (c) Closing ceremony of ICMPROI-2014 with presidents of Medical Physics Societies of South Asia countries and Poland, China and the MEFOMP; (d) Part of the participants

3rd international conference on Medical Physics in Radiation Oncology and Imaging (ICMPROI-2018), Dhaka, Bangladeshin2018

Recently, during third ICMPROI-2018of BMPS (more than 300 participants from 22 countries) on 10-12 March 2018at Krishibid Institution, Dhaka(Figure-4), the delegates from South Asia region particularly the young medical physicists of these countries showed their strong interest to make a common forum for building a bridge for the development of medical physicist in research, education and treatment of these countries as the problems

are almost similar in this region. This time delegates from Sri Lanka also joined the conference for the first time. ICMPROI-2018 gained significant attention to the international medical physics community to be one of the main platforms around the globe. BMPS is getting support from many reputed national and international societies, vendors and organizations for its relentless activities to develop the medical physics situation in Bangladesh.

Picture-4: (a) ICTP travel awardees with organizers of ICMPROI-2018; (b) Prof. Dr. Golam Abu Zakaria was speaking in a special meeting on the 11th Match 2018 with the delegates of Bangladesh, India, Nepal and Sri Lanka; (c) Posters evaluation leading by Prof. Tomas Kron (Australia); (d) Cultural programme

Therefore, another formal meeting was conducted during the (ICMPROI-2018) on 11th March 2018 (Figure -4b). The main objective of this meeting was to make a forum for the medical physicists of the South Asian countries to improve the educational and professional cooperation. Professor Dr. Golam Abu Zakaria, thePatron of ICMPROI-2018 discussed about the present situation of medical physics, radiation oncology and diagnostic radiology of this sub-continent. According to his dream, there are possibilities to make strong cooperation among the medical physicists of this region because of their geographical position, similar languages, cultures and commonheritage. They also share similar oncology profiles. If a single forum of medical physicists is possible to form, then this type of international conference can be arranged easily in any of these countries alternatively. Sri Lanka, India and Nepal have supported this idea and haveshown their interest to form a forum of medical Physicists.

Accordingly, a proposal for the name of the forum were also discussed. The proposed names were as follows:

SAFOMP (South Asian Federation of Organizations for Medical Physics)

SAFMP (South Asian Federation of Medical Physicists)

ASAMP (Association of South Asian Medical Physicists)

FSAMP (Federation of South Asian Medical Physicists)

SAAMP (South Asian Association of Medical Physicists)

The above-mentioned meetings already have initiated the process of making the common forum and all of us need to inform the other members of our own organizations about the necessity of this forum. Therefore, it was decided that discussion would further be continued through e-meeting or any other social media as if everyone can take part in the discussion and share their individual invaluable ideas to make an effective forum for the medical physicists of South Asian countries. This forum could be with the similar objectives like South East Asian Federation of Organizations for Medical Physics (SEAFOMP). The combined demand and voice from the same profession of other countries will be effective for maintaining the equal quality standard. It would be highly appreciated to receive any recommendations that could really help us to build a bridge among the scientists in medical physics profession for the improvement of the patient's healthcare having cancer.

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WORKSHOP REPORT

ACOMP Workshop on Radiation Dosimetry II

6 December 2017, Kuala Lumpur, Malaysia

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ACOMP Workshop on Radiation Dosimetry II was hosted by the Department of Biomedical Imaging, University of Malaya and the Division of Medical Physics, Institute of Physics Malaysia in association with the ACOMP (ASEAN College of Medical Physics).

This workshop aims to:

Provide a basic understanding of physics of semiconductor and OSL dosimetry.

Discuss the dosimetric considerations of using semiconductor dosimeters in brachytherapy and kV photo beams.

Introduce advance semiconductor detectors for different radiation detection applications.

Provide hands-on demonstration of selected solid state detectors.

This workshop was the second in the series of Radiation Dosimetry workshops, organized by our group, with the theme Solid State and Optically Stimulated Luminescence (OSL) Dosimetry: Physics and Applications.

The local organizing committee was headed by Dr. Jeannie Hsiu Ding Wong and Dr. Chai Hong Yeong with the support of the Medical Physics Unit, University of Malaya Medical Centre. A total of 38 participants from 6 countries joined the workshop. Amongst which, 25 participants attended the hands-on sessions in the afternoon.

The one-day workshop comprises of lectures in the morning and hands-on demonstration and practical sessions in the afternoon. The lectures were delivered by prominent speakers with wide experience in solid state and OSL dosimetry: Prof. Dr. Kwan Hoong Ng (University of Malaya, Malaysia), Dr. Marco Petasecca (University of Wollongong, Australia), Dr. Ikuo Kobayashi (Nagase Landauer Ltd., Japan), Dr. Jeannie Hsiu Ding Wong (University of Malaya, Malaysia) and Ms. Zulaikha Jamaluddin (University of Malaya Medical Centre, Malaysia). Dr. Marco Petasecca delivered two lectures on semiconductor dosimetry and advanced dosimetry techniques. Professor Ng gave a lecture on a primer on radiation dosimetry while Dr. Wong and Miss Zulaikha each gave a lecture on the dosimetric considerations in kV beams and brachytherapy.

The highlights of the workshop the demonstration of the Magic Plate 512 (MP512), developed and prototyped by the Centre for Medical Radiation Physics (CMRP), University of Wollongong by Dr. Marco Petasecca. The MP512 was used to measure the dwell position of the Co-60 high dose rate (HDR) brachytherapy source in real time. This is followed by two parallel hands-on sessions of diode dosimetry and OSL dosimetry. The diode dosimetry session was led by Ms. Zulaikha Jamaluddin and Dr. Marco Petasecca while the OSL dosimetry session was led by Dr. Jean-

nie Wong and Dr. Ikuo Kobayashi. Figure 1 shows the group photo of the speakers and participants and Figure 2 shows the photos taken during the hands-on sessions.

The organizers have uploaded the workshop materials and group photos on following Google drive:

https://drive.google.com/open?id=1IWckNOoKXF8nAhCSdlcd5TFKacPMUtFf

Group Photo:

Picture 1: Group photo of the speakers and participants of the workshop.

Practical Session:

Picture 2: Photos taken during the hands-on sessions.

Report on "3rd International Conference on Medical Physics in Radiation Oncology and Imaging-2018"

Bangladesh Medical Physics Society (BMPS)

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The Bangladesh Medical Physics Society (BMPS) is a professional organization primarily engaged in professional, educational and research activities throughout Bangladesh in the field of medical physics including biomedical engineering. It represents the interests of medical physicists globally and creates education and training possibilities for the rising scientific generation. As lie in the previous years in 2018 BMPS has organized the **"3rd International Conference on Medical Physics in Radiation Oncology and Imaging, 2018 (ICMPROI 2018)"** on 10-12 March at **Krishibid Institution of Bangladesh** in Dhaka, Bangladesh (Fig: 1).

The co-organizers were

Bangladesh Cancer Society **(BCS)**

Bangladesh Society of Radiation Oncology **(BSRO)**

Bangladesh Society of radiology and Imaging **(BSRI)**

Department of Medical Physics and Biomedical Engineering **(MPBME)**

Nepalese Association of Medical Physicists **(NAMP)**

The endorsers are

"Asia-Oceania Congress of Medical Physics **(AFOMP)**

International Organization for Medical Physics **(IOMP)**

American Association of Medical Physics **(AAPM)**,

Middle East Federations of Medical Physics **(MEFOMP)**

Deutsche Gesellschaft fur Medizinische Physik **(DGMP)**

European Federations of organizations for Medical Physics **(EFOMP)**,

International Center of Theoretical physics **(ICTP)**.

Fig-1 Krishibid Institution of Bangladesh

At a Glance: ICMPROI-2018

Day-1	Inaugural Programme	Vendor Presentation (3)	Plenary & Scientific Session (13)
Day-2	Plenary & Scientific Session (31)	Poster Session (31)	Cultural Programme
Day-3	Scientific Session (32)	Poster Award Ceremony	Valedictory Session

Special Attraction of ICMPROI-2018:

IMPCB Examination: For the first time in Asia IMPCB (INTERNATIONAL MEDICAL PHYSICS CERTIFICATION BOARD) examinations (Part I &II) was held in Bangladesh (Fig: 2) after the conference ICMPROI 2018 (13 - 14 March) organized by Bangladesh Medical Physics Society (BMPS).

Meeting with participants of South Asian countries: One of the key issues has been discussed to form a **South Asian Federation of Organizations for Medical Physics (SAFOMP)** by Prof. Dr. Golam Abu Zakaria to enhance the cooperation and work together for the improvement of cancer situation in these areas (Fig:3).

ICTP award: For the first time ICTP has given the travel award for ICMPROI-2018 which is successfully distributed within 11 participants (Fig: 4) from different OEA countries.

Participants: Total 400 participants were present from 22 different countries from Asia, Europe, Middle East and

USA in this conference. For the first time participants (Fig: 5) from Srilanka, Vietnam were participated and from Nepal total 22 participants were present in ICMPROI-2018.

Fig: 2 IMPCB 2018 13 March, Dhaka Bangladesh

Fig: 3 Meeting with participants SA regions

Fig: 4 ICTP Travel Awardees: ICMPROI 2018

Inaugural Ceremony: ***Chief Guest:*** **Mr. Zahid Malek MP,** Honorable state Minister, Ministry of health and family welfare. ***Special Guest:*** **Md. Habibur Rahman Khan** Additional Secretary, and Ministry of health and Family Welfare; ***Guest of Honors:*** Prof. Dr. Chop Lal Bhusal, Ambassador of Nepal to People's Republic of Bangladesh; Prof. Dr. Kamrul Hasan Khan, Vice Chancellor, Bangabandhu Sheikh Mujib Medical University **(BSMMU),** ***International Advisory Member:*** Prof. Dr. Tomas Kron, Director of Physical Sciences, Peter MacCallum Cancer Centre, Melbourne, Australia; ***National Advisory Member*** **Dr. A. K Azad**, ***Patron*** Prof. Dr. G. A. Zakaria, University of Cologne, Germany; ***Organizing chairperson:*** Prof. Dr. H. Anupama Azhari as well as the co-organizers **(Fig:6)**

Fig: 5 Participants

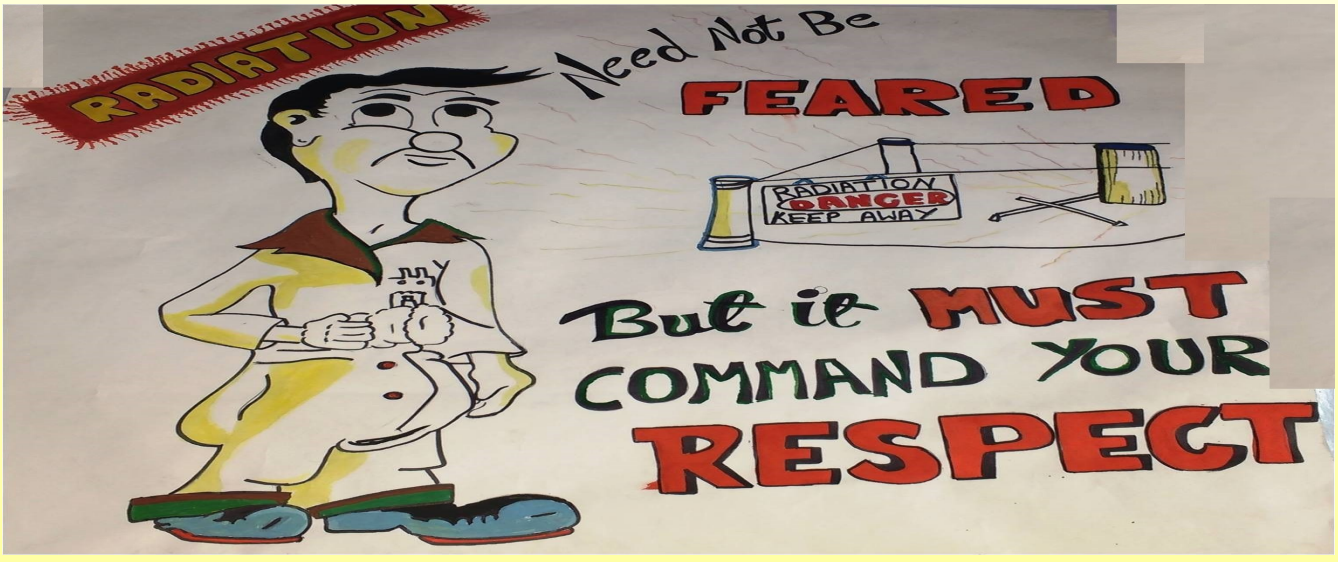
Fig: 6: Inaugural Ceremony:ICMPROI-2018

Fig:7 Registration: ICMPROI-2018

Scientific Sessions & Cultural Function: Total 112 scientific papers were presented (Fig: 8). Sessions are organized on different topics like brachytherapy, radiology and imaging, radiation oncology and Treatment planning, dosimetry, radiation protection and Biomedical Engineering, nuclear medicine and molecular Imaging. Sessions were very interactive and stimulating. The students are encouraged for poster presentation. A group comprises of three members (Prof. Dr. T. Kron, Mr. A Islam, Ms. F. Ferdous, Mr. A. Kausar & Mr. J.Jeyasugiththan) was act as a judge (Fig: 9) and selected three posters based on the evaluation criteria out of thirty one posters. On the 2nd day an amazing cultural function **(Fig:10)**was arranged.

Closing Ceremony: *Award Distribution: 1st Awardee: Ms.M Mumu; 2nd Awardee: Nazrul Islam, 3rd Awardee: Niranjan Thapa*, Nepal.

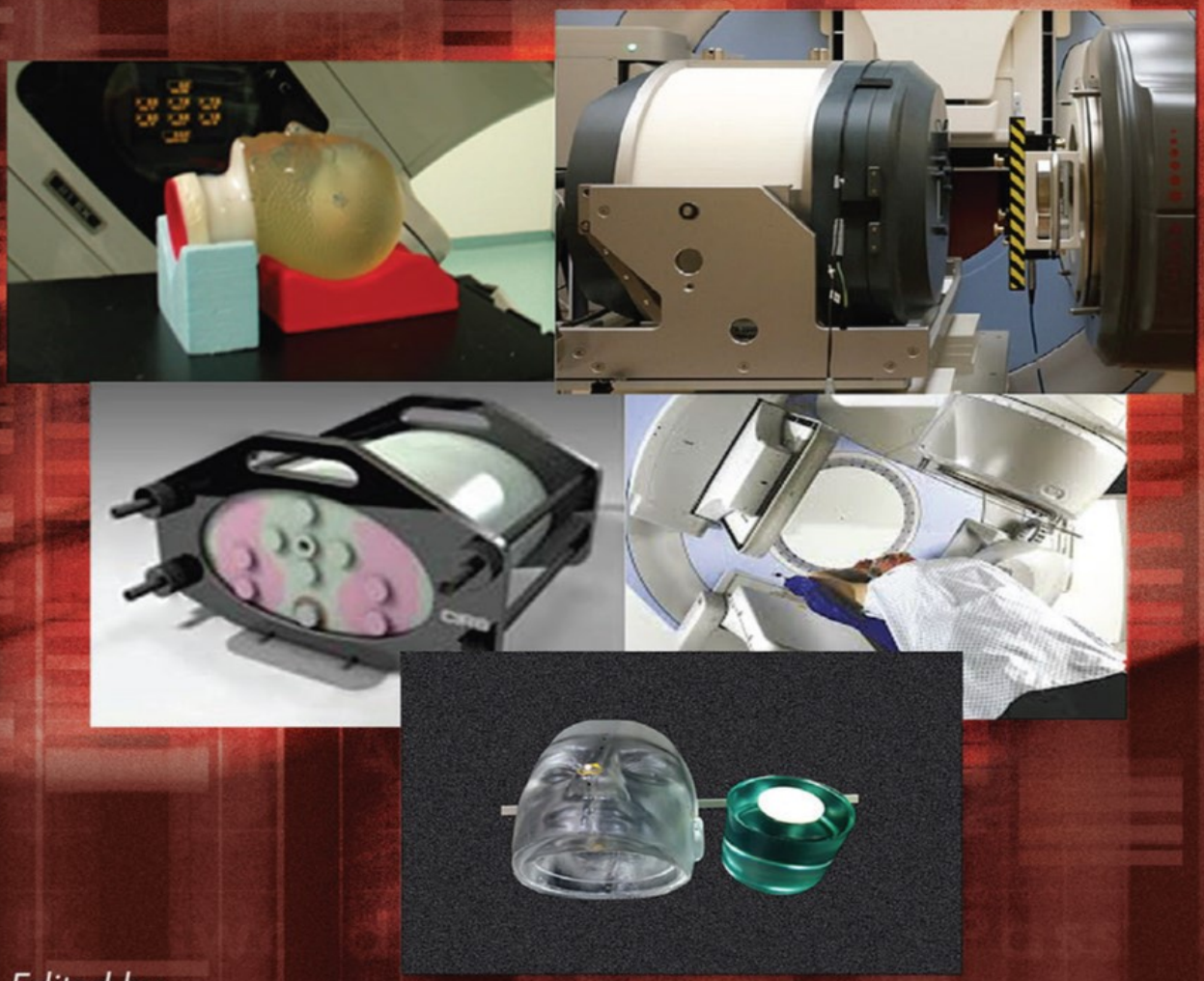
Prof. Azhari, presided the closing ceremony where each participant addresses their opinion regarding the outcome of the conference. Mementos to the foreign participants as well as poster award was (Fig. 11&12) distributed. Lastly OC, ICMPROI 2018 declared the ***"4th International Conference on Medical Physics in Radiation Oncology and Imaging (ICMPROI)-2021"***, Bangladesh from **26-28 February 2021**.



IMAGING IN MEDICAL DIAGNOSIS AND THERAPY

Andrew Karellas and Bruce R. Thomadsen, Series Editors

Clinical 3D Dosimetry in Modern Radiation Therapy



Edited by

Ben Mijnheer

CRC Press
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Calendar of Events 2018-19

3-7 July 2018	**Challenges in Modern Radiation Therapy Physics** **Ljubljana, Slovenia** http://www.aapm-isep.si/
18- 20 July 2018	**Hands-On Medical Health Physics: Emerging Technologies and Challenges** *Cleveland, Ohio* http://hps.org/meetings/pds.html
01-03 August, 2018	**2nd International Conference on Head and Neck Cancer** TEHRAN, IRAN HTTP://IHNCC.IR/EN/
09-10 August, 2018	**5th International Conference on Medical Physics and Biophysics** Madrid, Spain https://medicalphysics.conferenceseries.com/
21 – 22, August 2018	**EDMP and EACMPE Examinations** Copenhagen, Denmark https://www.efomp.org/index.php?r=news&id=2
23 – 25 August 2018	**2nd European Congress for Medical Physics** Denmark http://ecmp2018.org/
16 – 19 September, 2018	**10th International Conference on 3D Dosimetry (IC3DDose)** Kunshan (near Shanghai), China http://people.duke.edu/~twr13/oldhamWeb/home.html
17 – 28, September, 2018	**Joint ICTP-IAEA Advanced School on Quality Assurance and Dose Management in Hybrid Imaging (SPECT/CT and PET/CT)** Trieste, Italy http://indico.ictp.it/event/8336/
20-21 September, 2018	**Arab African International Cancer Congress (AAICC)** Cairo, Egypt http://aaicc.net/
26 – 28, September, 2018	**Perspectives of Advanced Radiotherapy in Middle Income Countries** Tehran, Iran http://parimics.isco.ir/
15 – 18 October. 2018	**Int'l Conference on Monte Carlo Techniques for Medical Applications (MCMA2017)** Metropolitan City of Naples, Italy https://agenda.infn.it/conferenceDisplay.py?confId=12594
26-27 October. 2018	2nd ESTRO Physics Workshop Science In Development
29 – 31, October. 2018	**Engineers and Physical Scientists in Medicine (EPSM) conference in Medical Physics** Adelaide SA 5000, Australia http://epsm.org.au/
2-4 November 2018	AMPICON 2018 Chennai http://www.ampicon2018.com
29-30 November 2018	**6th GEC -ESTRO Workshop** Brussels, Belgium
29 Nov– 2Dec 2018	AROICON Thiruvananthapuram, Kerala http://www.ampi.org.in/?p=3397
07-09 December 2018	ESTRO MEETS ASIA 2018 Singapore
26-30 April, 2019	**ESTRO 38** Milan, Italy
27 – 31, May 2019	**3rd International Conference on Dosimetry and Applications (ICDA-3)** Lisbon, Portugal http://www.ctn.tecnico.ulisboa.pt/icda-3/

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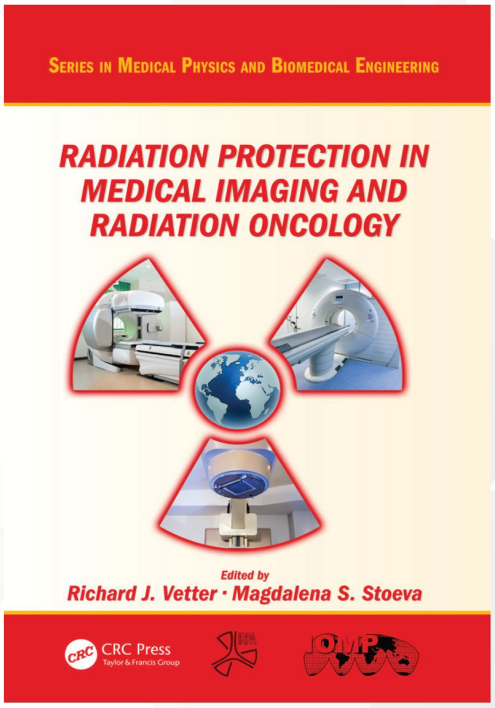

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