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INSIDE STORIES

Prof. Dr.Arun Chougule

From the desk of editor

I am happy to bring out June 2016 issue of AFOMP newsletter for us. I take this opportunity to thank the AFOMP Excom for reassuring faith in me as editor of AFOMP newsletter. This issue of the newsletter has very good exhaustic articles on "**Stereotactic Radiosurgery and Stereotactic ablative body Radiotherapy**" by Prof. M. Saiful Haq and "**A Brief Review of Clinical Small Field Relative Dosimetry**" by Prof. Gavin Cranmer-Sargison in addition we have report of recently concluded JSMP meeting and calendar of events.

This year we have very important scientific meeting "International Conference of Medical Physics" **ICMP2016** [www.icmp2016.org] at Bangkok, Thailand during 9-12 December 2016. First time ICMP is being organised in AFOMP region and hence big role to play for AFOMP which is being handled by new officer bearers and chairs of various committees.

I appeal to all the AFOMP member organization to give wide publicity to this unique meeting with a very appropriate theme "**Propelling Health Care through Medical Physics**" so that members take advantage of the golden opportunity to actively participate in this event. Further as science committee chair of AFOMP, I appeal to all the AFOMP member country organizations to plan activity to celebrate "International Day of Medical Physics" **IDMP** on 7th November to highlight the contribution of medical physics to health care. We, at Jaipur have planned "Conference on Radiation in Health Care" **CRHC-2016** on 7th & 8th November to commemorate IDMP and world Radiography day, you all should plan some activity to make medical physics from non-visible to visible in the society.

Looking forward for your feedback.

With good wishes to all

Dr. Arun Chougule
Editor, AFOMP Newsletter
Vice President AFOMP

WELCOME

17th Asia-Oceania Congress of Medical Physics "AOCMP - 2017"
In conjunction with
38th Annual Conference of Association of Medical Physicists of India "AMPICON - 2017"

4th - 7th November 2017
Jaipur, India

Organised by
Department of Radiological Physics, SMS Medical College, Jaipur ,India

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FIRST ANNOUNCEMENT

AOCMP - 2017

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A BRIEF REVIEW OF CLINICAL SMALL FIELD RELATIVE DOSIMETRY

G Cranmer-Sargison, Adjunct Professor, University of Saskatchewan, Saskatoon, **Canada**

Introduction

Experimental small field dosimetry, as noted by Das *et al* [Ref], is a challenge given the lack of lateral charged particle equilibrium, detector choice and subsequent perturbations of the charged particle fluence. Aspradakis *et al* [Ref] highlights that most of the dosimetric tools routinely used in the clinic are inappropriate for small fields and that almost every aspect associated with radiation therapy dosimetry must be scrutinized for its appropriateness for use with small fields. Today most clinical physicists would agree that traditional Farmer type ionization chambers are not suitable for small field dosimetry, as the active volume is often wider than the field itself and this alone results in extreme beam perturbations and unavoidable problems with volume averaging. To address these types of limitations many vendors have made available small volume ionization chambers and solid -state diode detectors. The intention of this review is to provide an awareness level summary of the now well understood small field dosimetry formalism for use in clinical practice.

Small field dosimetry formalism

Alfonso *et al* [Ref] has, under the mandate of an international working group, presented a new formalism for reference dosimetry of small and non-standard fields. The authors extend clinical reference dosimetry based on absorbed dose to water to include small static fields. A number of new definitions were used in the proposed formalism and are as follows:

f_{ref} is the conventional reference field in dosimetry CoPs at which the calibration coefficient of an ionization chamber, in terms of absorbed dose to water, has been provided by a standards laboratory. f_{msr} is the machine-specific reference field, for static modalities or treatment machines that cannot establish the conventional reference field. f_{clin} is the clinical radiation field at which the absorbed dose to water needs to be determined. The absorbed dose to water for the machine specific reference field is related to the conventional CoP reference field as follows,

$$D_{w,Q_{msr}}^{f_{msr}} = M_{Q_{msr}}^{f_{msr}} \cdot N_{D,w,Q_0} \cdot k_{Q,Q_0} \cdot k_{Q_{msr},Q}^{f_{msr},f_{ref}} \quad . \qquad (1)$$

$k_{Q_{msr},Q}^{f_{msr},f_{ref}}$ accounts for the difference in ionization chamber response in the fields f_{ref} and f_{msr} and is defined as follows,

$$k_{Q_{msr},Q}^{f_{msr},f_{ref}} = \frac{D_{w,Q_{msr}}^{f_{msr}} / M_{Q_{msr}}^{f_{msr}}}{D_{w,Q}^{f_{ref}} / M_{Q}^{f_{ref}}} \quad . \qquad (2)$$

Although the definition of $k_{Q_{msr},Q}^{f_{msr},f_{ref}}$ is rigorous, and represents a natural extension from the established CoPs, it is not unreasonable to assume that for most linear accelerator based systems the change in beam quality between the conventional reference field and a well-chosen machine-specific -reference field will be small and therefore $k_{Q_{msr},Q}^{f_{msr},f_{ref}}$ will typically be set to unity.

The relative dose for f_{clin} , with respect to f_{msr} , is defined as follows,

$$D_{w,Q_{clin}}^{f_{clin}} = D_{w,Q_{msr}}^{f_{msr}} \cdot \Omega_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} , \qquad (3)$$

where $\Omega_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ is defined as a field factor that converts the absorbed dose to water from the machine-specific reference field to that of the clinical field size of interest. $\Omega_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ is by definition a ratio of absorbed doses to water and can be thought of as being equivalent to the traditional definition of an output factor. However, for small and non-standard field sizes one cannot assume that the ratio of detector readings will be equivalent to the ratio of absorbed doses and therefore, unlike traditional output factors used for standard field sizes, a correction factor must be applied to the measurement ratio. As such,

$$\Omega_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = \frac{M_{Q_{clin}}^{f_{clin}}}{M_{Q_{msr}}^{f_{msr}}} \cdot k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} \qquad (4)$$

where $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ corrects for the ratio of detector readings not being equivalent to the dose to water ratio at the point of interest. However, as Alfonso *et al* note, if $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ can be shown to be close to unity for a given detector then the ratio of readings will be sufficient in reporting the associated field factor (i.e. output factor). The authors clearly state that $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ needs to be taken into account for any detector not satisfying this condition. Using equations [3] and [4] the correction factor can be written as follows,

$$k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = \frac{D_{w,Q_{clin}}^{f_{clin}} / M_{Q_{clin}}^{f_{clin}}}{D_{w,Q_{msr}}^{f_{msr}} / M_{Q_{msr}}^{f_{msr}}} . \qquad (5)$$

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Subtleties in reporting small field relative output

Measuring and reporting relative output might not be considered overly novel but the subtlety of reporting relative output ratios (i.e. the ratio of measured values) as opposed to reporting relative output factors (i.e. the ratio of dose to water) marks a clear change in practice. Output factors are by definition the field size specific relative output ratios in water. Output factors can be considered equivalent to the ratio of ionization chamber readings measured under Bragg-Gray conditions, which implies the following would be required: (1) the field size must be large enough to ensure lateral charged particle equilibrium across the entire chamber, (2) that the ionization in the cavity can be directly related to the absorbed dose in the chamber wall and (3) the wall thickness must have a dimension great enough to ensure that all electrons that cross the cavity arise from within the wall and not the medium. This is clearly not the case for most small field relative output measurements and therefore, investigators reporting measured small field output factors for a detector with $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} \neq 1$ are in error. Only once a measured output ratio has been corrected using $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ can the data be referred to as an output factor – which by definition is $\Omega_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ in the Alfonso *et al* formalism.

Understanding the difference between measured small field output ratios and the associated small field output factors has become clear for many of the active researchers in the area of small field dosimetry. However, the subtleties are not well understood by the community as a whole, and yet are required for the accurate reporting of relative output in small field applications (i.e. SRS and/or SBRT). As the community evaluates the clinical implementation of the proposed small field dosimetry formalism the impact of publishing experimental small field relative output ratios as opposed to relative output factors will become more important and requires thoughtful interpretation.

Evaluating published detector specific $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$

Following on from the Alfonso *et al* publication there were still some points of detail regarding the methodology required to implement the proposed small field dosimetry formalism and standardizing the methods for using either Monte Carlo simulation and/or experimental techniques in determining $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$. The work of Francescon *et al* [Ref] and Cranmer-Sargison *et al* [Ref] appeared in the literature at the same time and outlined very similar Monte Carlo benchmarking processes for use in small field dosimetry. Both papers present $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ for a selection of diode detectors to be less than unity in every case. This result implies that at the smallest of field sizes the relative output measured with any of the diodes investigated will be greater than the actual dose ratio in water. The

impact of the data presented by these authors, in addition to earlier work of Scott *et al* [ref], did clarify the apparent ambiguity in diode detector response in small fields - as even the IPEM Report Number 103 stated that for diode detectors the high atomic number of silicon leads to a higher response to low energy photons compared to water and that an under-response for narrow fields is due to the reduced low energy photon contribution to the small field dose. Other very good examples of Monte Carlo derived $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ would be that of Underwood *et al* [ref], Papaconstadopoulos *et al* [ref] and Charles *et al* [ref]. Common across the fore mentioned papers was a thorough benchmarking of the combined linear accelerator and detector models against good experimental measurements.

A number of investigators have explored experimental methods alone for deriving $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$; the work of Ralston *et al* [ref], Cranmer-Sargison *et al* [ref] and Azangwe *et al* [ref] all being good examples. One notable aspect to each of these works is the use of either Gafchromic film and/or a scintillator based detector system as a "correction-free" dosimeter for use in small field applications. The claim of "correction-free" for scintillator systems is a well-argued based on the experimental and theoretical work of Ralston *et al* [ref] and Fenwick *et al* [ref] respectively. However, there is an inconsistency across all authors as to the choice of f_{msr} in calculating $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$. Examples of f_{msr} for conventional linac based systems range from 10.0 cm x 10.0 cm down to 3.0 cm x 3.0 cm which, for the end user, can make the clinical implementation more complicated than necessary. An end user can renormalize the reported $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ to a common f_{msr} but care must be taken not to incur a systematic error. In addition, the end user must be careful not to apply "volume average corrected" $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ values as presented by some authors – that is unless the local experimental data has also been "volume average corrected".

Applying published detector specific $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$

The formalism presented by Alfonso *et al* is simple yet one may well concede there is little direction given regarding the clinical implementation. This is not necessarily a surprise as the intent of the original paper was to outline a new dosimetry framework, which in essence extended the recommendations given in conventional CoPs for clinical reference dosimetry. Liu *et al* [ref] presents the first real summary of published diode detector $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ data and clearly represents a first at-

tempt to solidify the application of published $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ for clinical use. However, even the Liu *et al* data must be applied using an unambiguous definition of field size.

As noted by Cranmer-Sargison *et al* [ref], the viability of applying $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ requires that measured data be presented as a function of a clearly defined field size metric, which can be used to appropriately correlate the measured output to the dosimetric field size (i.e. the actual measure field size). The authors highlight that for small fields collimated with jaws and/or MLCs one cannot expect the geometric field size to be the same as the nominal field size set at the console. This difference can be the result of jaw and/or MLC calibration as well as the inherent positional accuracy of the system itself. Add to this the fact that for small field sizes the dosimetric field size will always be greater than the geometric field as projected by the light field (see Das *el at* [ref]) and the requirements for a simple field size metric becomes obvious.

Given the magnitude of the field size and scatter component changes which need to be taken into account Cranmer-Sargison *et al* define an effective small field size as follows,

$$FS_{eff} = \sqrt{A \cdot B}, \qquad (6)$$

where A and B correspond to the in-plane and cross-plane dosimetric field widths defined as the FWHM at the 50% isodose level.

Following on from this Liu *et al* present their summary data for diode detectors as a function of the equivalent square based on the measured FWHM; an example being the PTW electron diode over-response, averaged across three different linear accelerator platforms, presented as a function of FS_{eff}. The authors show that regardless of linac platform the PTW electron diode over-response relative to water can be calculated as a percentage ($r_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$) using the following relationship,

$$r_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}} = 0.163e^{-0.208x} \qquad (7)$$

where x is the FS_{eff} as defined in Equation 6. It is important to note that Equation (7) provides the over-response of the raw detector signal (i.e. what is actually measured) and not the detector "volume average corrected" signal, which is also present in the published work. Again, care must

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be taken regarding the clinical interpretation of the published $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ values.

Conclusion

The proposed formalism does move towards traceability but an unambiguous small field CoP would require specific procedures regarding detector selection, experimental methods and the application of detector specific $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$. Many of the details regarding detector selection and experimental set-up have been addressed in the literature and should be distilled down into procedural recommendations and/or clinical requirements. The intention here was to provide an overview level summary of the various aspects associated with small field dosimetry. The hope is that this will help raise the clinical awareness. For a more in-depth understanding the reader is encouraged to source the "essential reading" as listed below. In light of the recent developments in small field dosimetry it is only fitting that the warning to of Aspradakis *et al* clinical physicists be repeated and that "every aspect associated with small field dosimetry must be scrutinized for its appropriateness".

Essential Reading

Alfonso R *et al.* (2008) "A new formalism for reference dosimetry of small and nonstandard fields" *Med. Phys.* **35**, 5179-86

Francescon P *et al.* (2011) "Calculation of $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ for several small detectors and for two linear accelerators using Monte Carlo simulations" *Med. Phys.* **38**, 6513-27

Cranmer-Sargison G *et al.* (2013) "A methodological approach to reporting corrected small field relative outputs" *Radiother. Oncol.* **109**, 350-355

Charles P H *et al.* (2014) "A practical and theoretical definition of very small field size for radiotherapy output factor measurements" *Med. Phys.* **41**(4), 041707-(8)

Liu P Z Y *et al.* (2014) "Can small field diode detectors be applied universally?" *Radiother. Oncol.* **112**, 442-446

References

1. Alfonso R *et al.* (2008) "A new formalism for reference dosimetry of small and nonstandard fields" *Med. Phys.* **35**, 5179-86
2. Aspradakis *et al.* (2010) IPEM Report Number 103: Small Field MV Photon Dosimetry." Published by the Institute of Physics and Engineering in Medicine.

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3. Charles P H *et al.* (2013) "Monte Carlo-based diode design for correction-less small field dosimetry" *Phys. Med. Biol.* **58**, 4501-12
4. Charles P H *et al.* (2014) "A practical and theoretical definition of very small field size for radiotherapy output factor measurements" *Med. Phys.* **41**, 041707-(8)
5. Cranmer-Sargison G *et al.* (2013) "Small field dosimetric characterization of a new 160-leaf MLC" *Phys. Med. Biol.* **58**, 7343-54
6. Cranmer-Sargison G *et al.* (2013) "A methodological approach to reporting corrected small field relative outputs" *Radiother. Oncol.* **109**, 350-355
7. Das *et al***.** (2008). "Small fields: Nonequilibrium radiation dosimetry" *Med. Phys.* **35**, 206-15.
8. Fenwich *et al.* (2013) "Using cavity theory to describe the dependence on detector density of dosimeter response in non-equilibrium small fields" *Med. Biol.* **58**, 2901-23
9. Francescon P *et al.* (2011) "Calculation of $k^{f_{clin},f_{msr}}_{Q_{clin},Q_{msr}}$ for several small detectors and for two linear accelerators using Monte Carlo simulations" *Med. Phys.* **38**, 6513-27
10. Liu P Z Y *et al.* (2014) "Can small field diode detectors be applied universally?" *Radiother. Oncol.* **112**, 442-446
11. Papaconstadopoulos *et al.* (2014) "On the correction, perturbation and modification of small field detectors in relative dosimetry" *Phys. Med. Biol.* **59**, 5937-52
12. Ralston *et al.* (2012) "Small field diode correction factors derived using an air core fibre optic scintillation dosimeter and EBT2 film" *Phys. Med. Biol.* **57**, 2587-2602
13. Scott *et al.* (2009) "Monte Carlo modeling of small photon fields: quantifying the impact of focal spot size on source occlusion and output factors, and exploring miniphantom design for small-field measurements" *Med. Phys.* **36**, 3132-44
14. Underwood *et al.* (2013) "Mass-density compensation can improve the performance of a range of different detectors under non-equilibrium conditions" *Phys. Med. Biol.* **58**, 8295-8310

REPORT OF THE 111TH INTERNATIONAL SCIENTIFIC MEETING OF JSMP

Shinji Kawamura, Ph.D., Chairperson of executive committee

The 111th scientific meeting of Japan society of medical physics (JSMP) was held in the Pacifico Yokohama Convention Center in Yokohama city, Japan, from April 14 to 17, 2016 in conjunction with the 75th Annual Meeting of the Japan Radiological Society (JRS), the 72nd Scientific Congress of the Japanese Society of Radiological Technology (JSRT), and the International Technical Exhibition of Medical Imaging (ITEM) 2016. The main theme of this joint congress (JRC2016) was "Instructive, Innovative, and Integrative Radiology," focusing on recent advances in medical physics and predictions for future progress in medical physics. There were future events such as joint symposiums, plenary lectures, educational lectures and several exchange sessions of international and intermeeting. Additionally, over 170 research presentations were published in this meeting. According to a report of organizing committee, over twelve thousand participants that include from abroad came together at this meeting.

At the first day (April 14th) of the meeting, it started from viewing CyPos presentation slides at the viewing area, and there were several workshops in the afternoon. After these program, the welcome reception was held in"Rainbow", 70th Floor, Yokohama Royal Park Hotel. Several invited speakers, committee members of the Asia-Oceania Federation of Organizations for Medical Physics (AFOMP) and organizing committee members of JSMP attended the welcome reception and deepened exchange each other.

The second day (April 15th) of meeting, joint opening ceremony and joint special lecture were held in main hall. A former Japanese astronaut Naoko Yamazaki talked special lecture 'Universe, Human, and Dream 'which got applause from audience. In the JSMP program, two plenary lectures were held in this day. Firstly, Dr. John M Boone who is Professor of the UC Davis cancer center and chairman of the board, the American Association of Physicists in Medicine (AAPM) talked with the title 'New Concepts in CT Dosimetry'. Secondly, Dr. Paul Keall who is Professor of University of Sydney lectured about 'Integrated MRI-LINACS: A new weapon in the battle against cancer'. In addition, in the educational lecture, Dr. Tae Suk Suh who is Professor of the Catholic University of Korea and President of AFOMP lectured with title 'Image Guided Application in Radiation Therapy'. Many young researchers attended each lectures.

In the third day (April 16th), a joint symposium was held in the National convention hall at Pacifico-Yokohama, the title of this symposium was 'Dose evaluation and control for medical radiation exposure'. First Dr. John M Boone gave a keynote lecture and then experts at each field in Japan talked and discusses about how to manage problems on exposure dose in radiological fields. In additions, the JSMP-JSRT joint symposium which is titled as 'Current status of real-time tumor tracking therapy' was held on the afternoon. Dr. Paul Keall gave a key-note lecture of 'Real-time radiotherapy: motion management from bench to bedside'. Several researcher of motion management for radiation therapy talked and discussed about effective management and problems to be solved for

tumor tracking.

The last day (April 17th), a commendation ceremony (Doi award) of Radiological Physics and Technology (RPT) which is the official English journal of JSMP and JSRT performed, three researchers from each field of 'diagnostic Imaging', 'MRI, Nuclear medicine and informatics', and 'Radiation therapy physics' were awarded and presented relevant to their papers. From this year (2016), the RPT journal has been recognized officially by AFOMP. We will expect that the RPT journal develops globally and contributes to activate of medical physics and technology fields in Asia-Oceania. At the end of the joint congress (JRC2016), closing ceremony and award ceremony were performed in main hall. JSMP made official commendations of the CyPos Award and Excellent Presentation Award. List of recipients of award are as follow:

A JSMP plan to this meeting will be Internationalize and Globalize, therefore, we promote many AFOMP members attending to this meeting. We appreciate all the support we receive from participants to this meeting. The 113th scientific meeting of JSMP will be held on April 13 to 16, 2017 in the same venue in Yokohama. We hope many AFOMP members will come to Japan and deepen exchange each other.

At the end of this report, I express deep condolences for victims of big earthquake which occurred in Kumamoto regions at the first day (April 14th) of this meeting. Dr. Fujio Araki who is the president of this meeting and Professor of Kumamoto University, despite his family and house suffered from a disaster, remained in Yokohama till end of the meeting and made it a success. It was really inspiring to all of us.

111th JSMP Glimpses

AFOMP official journal ceremony

Stereotactic radiosurgery and stereotactic ablative body radiotherapy

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I. Introduction:

Stereotactic radiosurgery (SRS) is a non-surgical specialized type of external beam radiation treatment in which large doses of highly accurate, precise, and conformal ionizing radiation are delivered to a well-defined target volume in a single procedure using image guidance. The term "stereotactic" refers to a procedure in which a targeted mass is localized with respect to a fixed three -dimensional reference system such as a rigid head frame. The "radiosurgery" is accomplished by directing beams of radiation along any trajectory in this 3-D space toward the localized targeted mass of known 3-D coordinates. Lars Leksell, a Swedish neurosurgeon, developed the term stereotactic radiosurgery in 1951 as a novel concept of a non-invasive method to treat lesions that were not accessible by open surgery techniques. Patients with Trigeminal neuralgia (a nerve disorder that causes pain in the face) were the first to be treated using an orthovoltage x-ray machine mounted to a stereotactic frame. In 1968, Leksell developed the first commercially available dedicated radiosurgical device called the "Gamma Knife." In an era before the emergence of computed tomography (CT), treatments were initially limited to patients with acoustic neuromas and arteriovenous malformation (AVM), which are tangles of expanded blood vessels that disrupt normal blood flow in the brain which bleed sometimes [1-2]. The Gamma Knife technology made it possible to precisely deliver a single, large dose of highly conformal radiation to any number of intracranial targets using 201 fixed cobalt-60 sources aimed at a focal point while delivering very low doses to the surrounding normal tissue. This provided an alternative treatment to certain neurosurgical procedures, which were then associated with significant morbidity [2-3]. Conditions thought to be appropriate for radiosurgery included acoustic schwannomas, intracranial arteriovenous malformations, pituitary adenomas, metastatic tumors, skull base meningiomas, as well as functional disorders such as trigeminal neuralgia and essential tremor.

For decades, SRS treatment has been successfully used in the treatment of brain metastases and many intracranial neoplasms and functional disorders. Radiosurgery can halt tumor cell division, destroy neoplastic blood vessels, induce apoptosis or necrosis, and when used intracranially, modify the blood-brain barrier around the tumor [4-10]. Since the introduction of SRS, thousands of publications have appeared in the literature reporting the benefits of the use of this non-invasive procedure as an efficient and effective means of achieving a high rate of local control and, in some settings, improved survival [11]. SRS is now routinely used for the management of single and multiple metastatic, primary, malignant, intracranial, and central nervous system (CNS) tumors as well as benign tumors such as pituitary adenomas, acoustic neuromas, and meningiomas. SRS is also used for the management of arteriovenous malformations and other neurological conditions such as trigeminal neuralgia, tremor, etc.

The success of SRS in the management of intracranial and CNS tumors has led to the development of fractionated stereotactic radiosurgery, also called stereotactic body radiation therapy

(SBRT) or stereotactic ablative body radiotherapy (SABR), with unique technological and clinical considerations. SABR employs the advantages of stereotactic guidance to deliver hypofractionated, highly conformal, high doses of radiation to extra-cranial tumors using image guidance in two to five sessions. Biologically equivalent doses greater than 100 Gy can be delivered to various extra-cranial tumors using this technique.

As in intra-cranial stereotactic radiosurgery, SABR also requires a high level of precision and accuracy at every step in the treatment process. Therefore, successful clinical implementation of SABR requires careful consideration of details of every step in the treatment process and integration of several technologies that provide solutions to challenges posed by the unique characteristics of various extra-cranial tumors. Important considerations for SABR treatments include, but are not limited to:

3-D imaging and localization techniques that determine the exact 3-D coordinates of the target within the body

Integration of modern imaging systems (CT, MRI, PET-CT, etc.) in order to precisely delineate the target volume and critical structures

For moving targets such as lung and liver tumors, technologies such as 4-D CT for quantification of motion of tumor(s) as well as that of the critical structures that lay close to the tumor

Technologies and techniques to manage tumor motion during SABR treatment to more effectively spare irradiation of healthy tissue; examples of such techniques are gated treatment delivery or tumor tracking

An immobilization system that ensures accurate and reproducible patient positioning throughout the duration of treatment

Treatment planning systems with the capability of integrating information from various imaging modalities for delineating target and critical structure volumes and calculating accurate highly conformal dose distributions with a sharp dose gradient using different techniques such as intensity modulated radiation therapy (IMRT), volumetric modulated arc therapy (VMAT) etc

Availability of dose calculation algorithms that can account for the effects of tissue heterogeneities

Linear accelerators and/or other machines that are designed for the delivery of SABR treatments

Sophisticated image guidance technologies and techniques such as cone beam CT imaging,

stereoscopic x-ray imaging, fluoroscopic verification of tumor motion, gating, tracking, etc to confirm the location of a tumor immediately before and during the delivery of radiation

One of the key challenges of SABR is motion assessment and motion management for tumors and critical structures close to the tumor that move during treatment. Special considerations must be made to account for the effect of internal organ motion (primarily breathing-associated motion but also bowel peristalsis motion) on target positioning and reproducibility. As a first step, it is necessary to quantify the specific motion of a target or critical structure close to the target. Options for motion assessment include real time fluoroscopy or 4-D CT scanning. The gross target volume (GTV) to planning target volume (PTV) expansion should be no greater than 0.5 cm in the axial plane and 0.7 cm to 1.0 cm in the cranio-caudal plane. If tumor motion combined with setup error causes any PTV to be greater than the GTV beyond these limits, then a motion management strategy (or plan to reduce setup error) must be employed with validation of success. The patient should be instructed to breathe normally at the time of initial tumor motion assessment. Deep inspiration- or expiration breath hold is not recommended for the initial tumor motion assessment, as such assessment generally overestimates free breathing tumor motion.

Motion assessment involves a query to appreciate the nature of both tumor target and normal tissue displacement that may occur during a typical SABR treatment session. Dynamic imaging is typically required for such an assessment such as fluoroscopy, ultrasound, 4-D CT, etc. It is not enough to understand how surrogates for targets move (e.g., the diaphragm for a lung tumor). Instead, the actual motion of the target must be reasonably understood. In turn, this assessment may either allow appropriate expansions of targets to encompass this movement (if the expansion would only be minimal) or to trigger the use of motion control. Motion management is a logical reaction to excessive motion appreciated from the motion assessment where either the natural physiological motion is modified (e.g., dampened) or countered with an active process (e.g., gating or tracking).

Motion management is highly recommended for SABR. In instances in which motion management is not possible, larger expansion volumes will be used to adequately cover the motion-related uncertainties. Typical motion management strategies include 4-D CT, active breath-hold, gated treatment, and abdominal compression.

Image-guided radiation therapy (IGRT) is radiation therapy using imaging to facilitate accuracy and precision throughout its entire process from target and normal tissue delineation to radiation delivery to adaptation of therapy to anatomic and biological changes over time in individual patients. Here, the terminology IGRT is used to focus on image-guidance at the time of radiation delivery to ensure its adherence to the planned treatment. Sophisticated image guidance reduces uncertainties and allows smaller treatment margins for SABR treatments. Confidently identifying the

stereotactic fiducials (e.g., implanted markers, close body tissue surrogates, or even the tumor itself) before and during treatment mostly eliminates inter-fraction error and reduces intra-fraction error allowing the smaller margins critical to the overall SABR approach.

II. Technologies for SRS and SABR:

While the vast majority of clinical experience and biological understanding of radiosurgery is the result of the body of work generated by the Gamma Knife™ (Elekta Medical Systems, Stockholm, Sweden) delivery system, more recently, linear accelerators (linacs) have been extensively used for the treatment of both intra-cranial and extra-cranial targets. Using both frame-based and frameless approaches, the linear accelerators allow for accurate, efficient, precise, and reliable delivery of single fraction regimens of ionizing radiation to the brain, while also facilitating fractionation when necessary. An alternative to frame-based approach to radiosurgery, the CyberKnife® (Accuray Inc., Sunnyvale, CA), system, does not rely on a surgically placed frame and allows for treatment of other areas outside the skull.

Many different technologies are currently available for the delivery of SRS and SABR treatments. Given below are brief descriptions of the Leksell GammaKnife® Perfexion™ unit by Elekta Instrument AB, Edge™ Radiosurgery systems by Varian Medical Systems and CyberKnife ® M6 ™ system by Accuray Inc.

II.1. Leksell Gamma Knife® Perfexion ™ by Elekta Instrument AB:

Fig. 1 shows a detailed illustration of the Leksell GammaKnife® Perfexion ™ (LGK PFX) collimator system (Elekta Instrument AB, Stockholm, Sweden). The LGK PFX is a fully-integrated automated system for stereotactic radiosurgery for brain lesions. Several limitations of the earlier models of LGK, e.g., LGK U, LGK B, and LGK C are eliminated in the design of LGK PFX. A total of 192 sealed Co-60 sources are arranged on eight movable sectors in the Perfexion unit. Each sector of the collimator has 24 collimators for a 16 mm beam, 24 collimators for an 8 mm beam and 24 collimators for a 4 mm beam resulting in a total of 192 collimators for each of 4, 8 and 16 mm collimator size. During treatment, the sectors with sources move over the tungsten collimator ring to various exposure positions to provide either a 4, 8, or 16 mm beam size or a combination of these beam sizes with some of the sectors being in the "off" position if required. This new design feature for Perfexion enabled the replacement of the multiple helmets that were used with LGK U, LGK B, and LGK C models with a single robotic system with three collimator sizes. Because the collimator size automatically changes, according to the treatment plan, treatment times are significantly reduced. The details of the design of LGK PFX and comparison of LGK PFX can be found in references 12-17.

II.2. Edge™ Radiosurgery System by Varian Medical Systems

Fig. 2 shows an image of the Edge ™ Radiosurgery System manufactured by Varian Medical Systems. The Edge radiosurgery system is a fully-integrated system that provides various capabilities. These include, but are not limited to:

A solution to deliver highly conformal dose distribution to tumors of the lung, brain, spine, and other areas of the body

Tracking of certain extra-cranial tumors in real time, precise calculation of patient movement in all six degrees of freedom, and monitoring of respiratory motion

iii) Real-time kilovoltage image guidance for target localization and other advanced imaging techniques such as respiration-synchronized fluoroscopy and cine MV

iv) Flattening filter free beams with a maximum dose rate of 2400 MU/min for 10 MV beam and 1400 MU/min for 6 MV beam

v) Capabilities for gated and non-gated volumetric modulated arc therapy (branded as Rapid Arc® radiotherapy)

vi) Synchronization between imaging, patient positioning, motion management, beam shaping and dose delivery technologies

Elekta has manufactured a radiosurgery linac, Versa HD, which is also equipped with sophisticated conformal beam-shaping technology and high-dose rate mode delivery. Both the Edge Radiosurgery linac and the Versa HD linac offer many features that are similar to each other.

II.3. CyberKnife ® M6 ™ system by Accuray Inc.

Fig. 3 shows an image of the CyberKnife® M6 ™ system manufactured by Accuray Inc. The system is designed such that a lightweight compact 6 MV linear accelerator, mounted on a robotic manipulator, can deliver beams from thousands of non-coplanar, isocentric, or non-isocentric angles by using either any one of 12 fixed collimators, an Iris ™ variable aperture collimator, or a multileaf collimator. Depending on the type of tumors being treated, the CyberKnife system uses six different targeting and tracking features to track the tumor in real time. Changes in tumor position and orientation are calculated from digitally reconstructed radiographs reconstructed from live kV images acquired throughout treatment at user-defined intervals. The relevant data is then sent to the robotic manipulator for immediate and automatic motion compensation by adjusting the beam position and orientation rather than by moving the patient. This is different from the other radiosurgical systems, which require the physical movement of the pa-

tient or couch during treatment. Additionally, unlike the gating and breath-holding techniques commonly used in other delivery systems, the CyberKnife robotic radiosurgery system is capable of tracking respiratory motion in real-time and automatically correcting for any changes in the tumor's position as well as adapting to any changes in the patient's breathing pattern, without user intervention.

III. Clinical Applications of SABR

SABR is now routinely used for the treatment of various extracranial disease sites such as lung, liver, abdomen, spine, prostate and head and neck. Representative examples are given below of the clinical applications of SABR treatment for non-small cell lung cancer (NSCLC) and liver tumors.

III.1. SABR for NSCLC

Surgical resection of stage I NSCLC results in 5-year survival rates of 65-80%; thus, the gold standard therapy is lobectomy and mediastinal lymph node removal for "standard-risk operable" patients [18-20]. However, some patients ("high-risk operable" or "medically inoperable" patients) are unable to tolerate the surgical procedures because of pre-existing medical comorbidities. High-risk operable patients are treated with less extensive surgeries such as wedge or sub-lobar resection with potentially suboptimal outcomes [18,21]. For medically inoperable patients with stage I NSCLC, conventionally fractionated radiotherapy (CRT) has been the treatment of choice [22]. However, poor rate of primary tumor control (30%-40%) and a high rate of mortality (5-year survival, 10%-30%) have led to declining use of this approach [23-27].

Over the last decade, several prospective studies have reported treatment outcomes using SABR for medically inoperable stage I NSCLC patients. All results have demonstrated significant improvement in local control and survival rates with SABR compared to historical data using CRT [28-34]. The results of the RTOG phase II study performed in 59 biopsy-proven peripheral T1T2N0M0 tumors treated with 54 Gy in three fractions show that the 3-year primary tumor control rate was 98%, and a 3-year local control rate was 91%. The 3-year disease-free and overall survival rates were 48 and 56%, respectively [34]. Thus, SABR has become the first line of treatment for this patient population [35,36]. Solda et al [37] performed a systematic review of the efficacy of SABR for the treatment of primary non-small cell stage I lung cancer and compared these results to controls treated with surgery. The authors reviewed forty-five reports containing 3771 patients treated with SABR for NSCLC and met the selection criteria that they developed. They concluded that "Systematic review of a large cohort of patients with stage I NSCLC treated

with SABR suggests that survival outcome in the short term is equivalent to surgery for this population of patients regardless of co-morbidity. As selection bias cannot be assessed from the published reports and treatment related morbidities are limited, a direct comparison between the two treatment approaches should be a priority. In the meantime, SABR can be offered to stage I patients with NSCLC as an alternative to surgery".

III.2. SABR for liver tumors

Historically, radiotherapy had a limited role in the treatment of liver metastases. This is because of the challenges associated with the management of respiration-induced tumor motion as well as the radiosensitivity of the organ itself. However, SABR has emerged as a favorable treatment option for the treatment of unresectable liver metastases or hepatocellular carcinoma (HCC) because in contrast to conventional radiotherapy, which delivers low dose fractions to a larger volume for a higher number of daily fractions, SABR delivers high doses of radiation precisely in a single or a few fractions (1-6 fractions), with tumor ablation and maximum normal tissue sparing. Hypofractionated SABR has been found to provide excellent local control with minimal side effects in selected patients with limited hepatic metastases [38]. Scorsetti et al [39] performed an analysis of the toxicity profile and outcome in terms of local control and overall survival from various prospective studies [40-46] that investigated the efficacy of SABR in the treatment of liver metastases from various primary tumors. They found that for lesion sizes less than 3 cm in size [42] and higher prescription doses [40], the local control rate varied from 70% to 100% at 1 year and 60% to 90% at 2 years. Two-year overall survival rate was 30-83%, with a median overall survival rate ranging from 10-34 months. Another study by Ada law and her colleagues [47] on 33 patients with hepatocellular carcinoma show that after a median follow-up of 16.5 months (range: 3.5 – 40.7), all but 2 patients demonstrated radiological tumor progression. Eight patients achieved complete remission. All these studies show that SABR offers a safe adjuvant treatment option for this patient population.

IV. Safety considerations for SABR

The literature is filled with reports of harmful incidents related to radiosurgery treatments as well as to technologies that are used to deliver radiosurgery treatments. These include, but are not limited to, the following: errors in the measurement of small field output factors affecting 145 patients in Toulouse, France in 2006-2007; calibration error on a SRS linac affecting 77 patients in Florida in 2004-2005 [48-50]; error in setting up backup jaws behind cones for SRS treatment affecting 3 patients in Evanston, IL in 2008 [51] and 1 patient in France [49], and many more. All these reported errors could have been avoided if proper procedures were put in place. Since in

the SRS and SABR treatments, a high dose of radiation is delivered in a single or a few fractions, the margin of error for these treatments is significantly smaller than those of the conventional treatments. An error in one single fraction can cause significant harm to patients. It is therefore imperative that the entire SRS/SABR team pays special attention and diligence to all aspects of SRS and SABR delivery. A comprehensive quality assurance and quality management program, such as that recommended by the American Association of Physicists in Medicine Task Group no. 100 [52], should be in place to ensure that patients receive the prescribed treatment correctly.

V. Summary

SABR is a cutting edge, non-invasive, well-tolerated, and effective treatment technique for various cancerous conditions. Use of SABR for primary, metastatic, benign, and malignant cancers has shown increases in survival rates with minimal negative side effects. Future applications of SABR will depend on further developments of tumor imaging and other imaging technologies, as the planning and delivery of SABR requires a high degree of accuracy and precision.

References

[1] Chin LS, Regine WF, editors. *Principles and practice of stereotactic radiosurgery*. Springer, 2008

[2] Leksell L. The stereotaxic method and radiosurgery of the brain. *Acta Chir Scand*. 102:316–319, 1951.

[3] Leksell L. Stereotactic radiosurgery. *J Neurol Neurosurg Psychiatry*. 46: 797-803, 1983.

[4] Kondziolka D, Lunsford LD, Claassen D, Maitz AH, Flickinger JC: Radiobiology of radiosurgery: Part I. The normal rat brain model. *Neurosurgery*. 31:271-279, 1992.

[5] Kondziolka D, Lunsford LD, Claassen D, Pandalai S, Maitz AH, Flickinger JC: Radiobiology of radiosurgery: Part II. The rat C6 glioma model. *Neurosurgery*. 31:280-287; discussion 287-288, 1992.

[6] Kondziolka D, Lunsford LD, Flickinger JC: The radiobiology of radiosurgery. *Neurosurg Clin N Am*. 10:157-166, 1999.

[7] Kondziolka D, Lunsford LD, Witt TC, Flickinger JC: The future of radiosurgery: radiobiology, technology, and applications. *Surg Neurol* 54:406-414, 2000.

[8] Niranjan A, Gobbel GT, Kondziolka D, Flickinger JC, Lunsford LD: Experimental radiobiological investigations into radiosurgery: present understanding and future directions. *Neurosurgery* 55:495-504; discussion 504-495, 2004.

[9] Witham TF, Okada H, Fellows W, Hamilton RL, Flickinger JC, Chambers WH, Pollack IF, Watkins SC, Kondziolka D: The characterization of tumor apoptosis after experimental radiosurgery. *Stereotact Funct Neurosurg* 83:17-24, 2005.

[10] Santacroce A, Kamp MA, Budach W, Hänggi. Biomed Res Int. Biomed Res Int. 2013; 2013: 362761. Published online 2013 Dec 29. doi: 10.1155/2013/362761 PMCID: PMC3891621

[11] Andrews, DW, Scott, CB, Sperduto, PW: Whole brain radiation therapy with or without stereotactic radio-

surgery boost for patients with one to three brain metastases: phase III results of the RTOG 9508 randomized trial. *Lancet* 363:1665–1672, 2004.

[12] Bhatnagar JP, Novotny J, Niranjan A, Kondziolka D, Flickinger JC, Lunsford D, Huq MS: First year experience with newly developed Leksell Gamma Knife Perfexion. J. Med. Phys. 34:141-148, 2009.

[13] Lindquist C, Paddick I: The Leksell Gamma Knife Perfexion and comparisons with its predecessors. Neurosurgery. 61:130-140, 2007.

[14] Niranjan A, Novotny J, Jr., Bhatnagar J, Flickinger JC, Kondziolka D, Lunsford LD: Efficiency and dose planning comparisons between the Perfexion and 4C Leksell Gamma Knife units. Stereotact Funct. Neurosurg 87:191-198, 2009.

[15] Novotny J, Bhatnagar JP, Niranjan A, Quader MA, Huq, MS, Bednarz G et al: Dosimetric comparison of the Leksell Gamma Knife Perfexion and 4C. J Neurosurg 109 Suppl: 8-14, 2008.

[16] Petti P, Larson D, Kunwar S: Comparison of treatment planning and delivery parameters for the Model C and Perfexion Gamma Knife units, in Proceedings of the 14th International Meeting of the Society of Leksell Gamma Knife, Quebec, Canada, 2008.

[17] Regis J, Tamura M, Guillot C, Yomo S, Muraciolle X, Nagaje M: Radiosurgery with the world's first fully robotized Leksell Gamma Knife Perfexion in clinical use: a 200-patient prospective, randomized, controlled comparison with the Gamma Knife 4C. Neurosurgery 64:346-355, 2009.

[18] Ginsberg RJ, and Rubinstein LV: Randomized trial of lobectomy versus limited resection for T1 N0 non-small cell lung cancer. Lung Cancer Study Group. *Ann Thorac Surg* 60:615-22, 1995.

[19] Kato H, Ichinose Y, Ohta M, et al: A randomized trial of adjuvant chemotherapy with uracil-tegafur for adenocarcinoma of the lung. *N Engl J Med* 350: 1713-21, 2004.

[20] Whitson BA, Groth SS, Andrade RS, et al: Survival after lobectomy versus segmentectomy for stage I non-small cell lung cancer: a population-based analysis. *Ann Thorac Surg* 92:1943-50, 2011.

[21] Landreneau RJ, Sugarbaker D, Mack M, et al: Wedge resection versus lobectomy for stage I (T1 N0 M0) non-small-cell lung cancer. *J Thorac Cardiovasc Surg* 113(4): 691-8; 1997.

[22] Rowell NP, Williams CJ: Radical radiotherapy for stage I/II non-small cell lung cancer in patients not sufficiently fit for or declining surgery (medically inoperable): a systematic review. *Thorax* 56:628-38, 2001.

[23] Coy P, Kennelly GM: The role of curative radiotherapy in the treatment of lung cancer. *Cancer* 45: 698-702, 1980.

[24] Armstrong JG, Minsky BD: Radiation therapy for medically inoperable stage and 11 non-small cell lung cancer. *Cancer Treat Rev* 16:247-255, 1989.

[25] Haffty B, Goldberg NB, Gerstley J, et al: Results of radical radiation therapy in clinical stage I, technically operable non-small cell lung cancer. *Int J Radiat Oncol Biol Phys* 15:69-73, 1988.

[26] Kaskowitz L, Graham MV, Emami B, et al. Radiation therapy alone for stage I non-small cell lung cancer. *Int J Radiat Oncol Biol Phys* 27:517-523, 1993.

[27] Dosoretz D, Katin MJ, Blitzer PH, et al: Radiation therapy in the management of medically inoperable carcinoma of the lung: Results and implications for future treatment strategies. *Int J Radiat Oncol Biol Phys* 24: 3-9, 1992.

-: CONTD :-

[28] Benedict SH, Yenice KM, Followill D, et al: Stereotactic body radiation therapy: the report of AAPM Task Group 101.*Med Phys* 37:4078-101, 2010.

[29] Nagata Y, Takayama K, Matsuo Y, et al: Clinical outcomes of a phase I/II study of 48 Gy of stereotactic body radiotherapy in 4 fractions for primary lung cancer using a stereotactic body frame. *Int J Radiat Oncol Biol Phys* 63:1427-31, 2005.

[30] Baumann P, Nyman J, Hoyer M, et al. Outcome in a prospective phase II trial of medically inoperable stage I non-small-cell lung cancer patients treated with stereotactic body radiotherapy. *J Clin Oncol* 2009; 27:3290-6.

[31] Fakiris AJ, McGarry RC, Yiannoutsos CT, et al: Stereotactic body radiation therapy for early-stage non-small -cell lung carcinoma: four-year results of a prospective phase II study. *Int J Radiat Oncol Biol Phys* 75:677-82, 2009.

[32] Ricardi U, Filippi AR, Guarneri A, et al. Stereotactic body radiation therapy for early stage non-small cell lung cancer: results of a prospective trial. *Lung Cancer* 2010; 68:72-7.

[33] Pennathur A, Luketich JD, Heron DE, et al: Stereotactic radiosurgery for the treatment of stage I non-small cell lung cancer in high-risk patients. *J Thorac Cardiovasc Surg* 137:597-604, 2009.

[34] Timmerman R, Paulus R, Galvin J, et al: Stereotactic body radiation therapy for inoperable early stage lung cancer. *JAMA*. 303:1070-6, 2010,

[35] NCCN Clinical Practice Guidelines in Oncology: Non-small cell lung cancer Version 1.2013 [Internet]. Available online: http://www.nccn.org/

[36] Vansteenkiste J, De Ruysscher D, Eberhardt WE, et al: Early and locally advanced non-small-cell lung cancer (NSCLC): ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Ann Oncol.* 24 Suppl 6: vi89-98, 2013.

[37] Solda F, Lodge M, Ashley S, Whitington A, Goldstraw P, Brada M: Stereotactic radiotherapy (SABR) for the treatment of primary non-small cell cancer, Systematic review and comparison with a surgical cohort: Radiotherapy Oncology. 109:1-7, 2013.

[38] Kruis MF, van de Kamer JB, Snoke JJ, Jansen EP, van Herk M: Registration accuracy and image quality of time averaged mid-position CT scans for liver SABR. Radiother Oncol. 109: 404-408, 2013.

[39] Scorsetti M, Clerici E, Comito T: Stereotactic body radiation therapy for liver metastases. Journal of Gastrointestinal Oncology. 5:1-7, 2014.

[40] Lee MT, Kim JJ, Dinniwell R, et al: Phase I study of individualized stereotactic body radiotherapy of liver metastases. J Clin Oncol. 27:1585-91, 2009 [PubMed].

[41] Goodman KA, Wiegner EA, Maturen KE, et al: Dose-escalation study of single-fraction stereotactic body radiotherapy for liver malignancies. Int J Radiat Oncol Biol Phys. 78:486-93, 2010 [PubMed].

[42] Rusthoven KE, Kavanagh BD, Cardenes H, et al: Multi-institutional phase I/II trial of stereotactic body radiation therapy for liver metastases. J Clin Oncol 27:1572-8, 2009 [PubMed].

[43] Ambrosino G, Polistina F, Costantin G, et al: Image-guided robotic stereotactic radiosurgery for unresectable liver metastases: Preliminary results. Anticancer Res 29:3381-4, 2009 [PubMed].

[44] Méndez Romero A, Wunderink W, van Os RM, et al: Quality of life after stereotactic body radiation therapy for primary and metastatic liver tumors. Int J Radiat Oncol Biol Phys. 70:1447-52, 2008 [PubMed].

-: CONTD :-

[45] Hoyer M, Roed H, Traberg HA, et al: Phase II study on stereotactic body radiotherapy of colorectal metastases. Acta Oncol. 45:823-30, 2006 [PubMed].

[46] Scorsetti M, Arcangeli S, Tozzi A, et al: Is stereotactic body radiation therapy an attractive option for unresectable liver metastases? A preliminary report from a phase 2 trial. Int J Radiat Oncol Biol Phys. 86:336-42, 2013; [PubMed].

[47] Law AL, Ng WT, Lee MC, Chan AT, Fung KH, et al: Treatment of primary liver cancer using highly0conformal radiotherapy with kV image guidance and respiratory control. Radiother Oncol. 102: 56-61, 2012.

[48] Borius PY, Debono B, Latorzeff I: Dosimetric stereotactic radiosurgical accident: Study of 33 patients treated for brain metastases. Neurochirurgie. 56:368-373, 2010. [Article in French] [PubMed].

[49] Derreumaux S, Etard C, Huet IC: Lessons from recent accidents in radiation therapy in France. Rad Prot Dosim. 131:130-135, 2010 [PubMed].

[50] Gourmelon P, Bey E, De Revel T: The French radiation accident experience: emerging concepts in radiation burn and ARS therapies and in brain radiopathology. Radioprotection. 43:23-26, 2008.

[51] Bogdanich W, Rebelo K: The radiation boom: A pinpoint beam strays invisibly harming instead of healing. The New York Times (New York Edition). December 28, 2010; Section A:1.

[52] Huq MS, Fraass BA, Dunscombe PB, Gibbons JP Jr, Ibbott GS, Medin PM, Mundt A, Mutic S, Palta JR, Thomadsen BR, Williamson JF, Yorke ED. The report of Task Group 100 of the AAPM: Application of Risk Analysis Methods to Radiation Therapy Quality Management; Approved by AAPM; Conditionally accepted in the journal of Medical Physics, 2016.

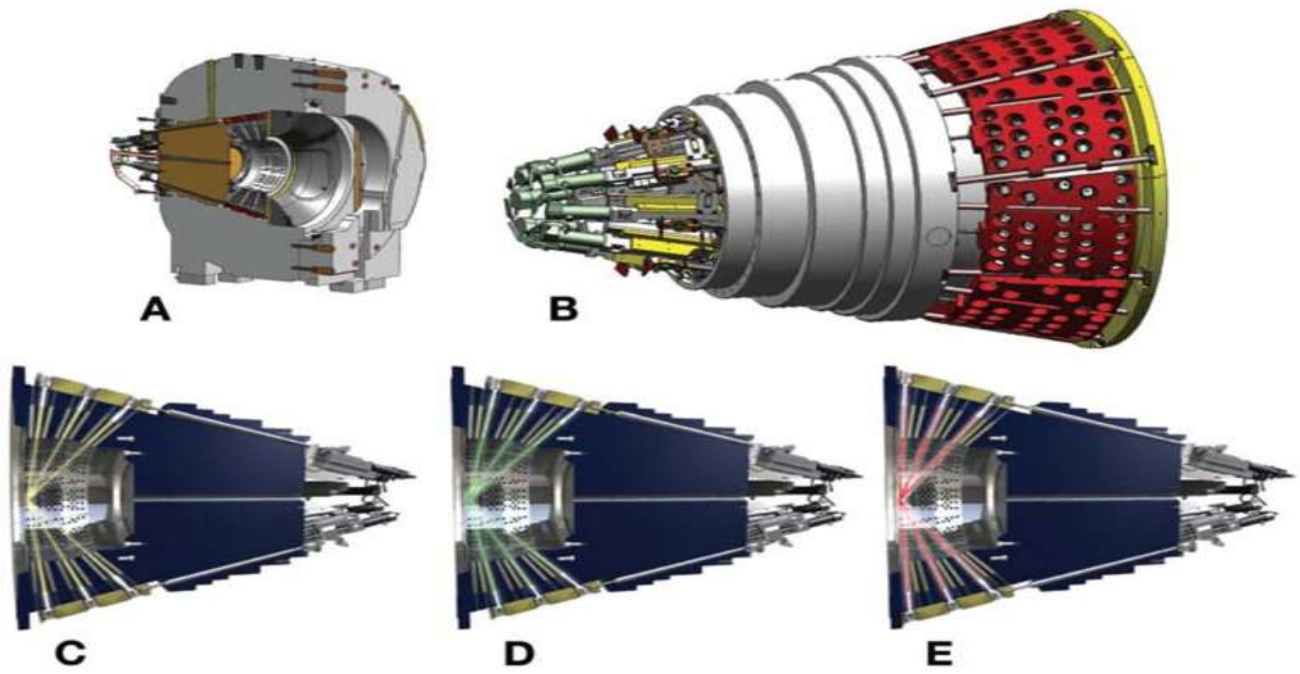

Figure 1. Leksell Gamma Knife Perfexion unit and collimator system. A: Cross-section of the Perfexion unit. B: Detailed view of the sectors. Each sector holds 24 Co-60 sources and can be moved independently of other sectors in desired position to define a collimator size or block beams. C: Sector position that defines a 4-mm collimator. D: Sector position that defines an 8

Figure 2. An image of a Varian Medical System's Edge Radiosurgery Systems

Figure 3. The CyberKnife® M6 ™ robotic radiosurgery system displaying the robotic manipulator, robotic couch, and the InCise multileaf collimator.

A REPORT ON THE CONFERENCES

"Emerging trends in Radiotherapy Techniques- CETRTT-2016" &

"Stereotactic Radio Surgery& Stereotactic Body Radiation Therapy SRS & SBRT-2016"

A roundup from the **Conference on Emerging Trends in Radiotherapy Techniques 2016** hosted by **Department of Radiological Physics, SMS Medical College and Hospitals, Jaipur** under the auspices of Association of Radiotherapy Technologists of India- Northern Chapter (**ARTTI-NC**) on 2nd April 2016 and **Stereotactic Radio Surgery &Stereotactic Body Radiation Therapy - Clinical, Physical and Dosimetric aspects** under the auspices of Association of Radiation Oncologists of India – Rajasthan Chapter (**AROI-RC**) and Association of Medical Physicists of India- Northern Chapter (**AMPI-NC**) on 3rd April 2016.

It was indeed a true scientific vaganza, where eminent speakers shared their knowledge and wisdom in the diverse field of radiotherapy. Dr. Raja Babu Panwar, Vice Chancellor, Rajasthan University of Health Sciences, Jaipur, Dr. U S Agarwal, Principal and Controller, SMS Medical College and Hospitals, Jaipur, Dr. Gavin Cranmer, Adjunct Professor, University of Saskatchewan, Saskatoon, Canada were guests of honor for the inauguration of CETRTT-2016. In his chief guest address, Dr. Raja Babu Panwar stated, if the field of Medicine and Physics works together, the emerging trends in radiotherapy techniques can be better used for the quality treatment of patients. Dr. U S Agarwal and Dr. Gavin Cranmer also shared their valuable views on how the emerging trends in radiotherapy technology are a boon to modern healthcare. The organizing chairman Dr. Arun Chougule briefed about the conference and the need to have conferences like this to strengthen the knowledge of professionals in new technologies. The e-Souvenir of the conference was released at this function by Dr. Raja Babu Panwar.

The key topics discussed in the conference were:

- Small field dosimetry
- Charged particles in Imaging and Therapy
- Radiobiology of Radiotherapy
- Adapted 4D Radio surgery
- Gating
- Gamma Knife SRS
- Nuclear Medicine in Oncology
- Occupational Health and Safety
- Commissioning, QA and Audits

There were 4 scientific sessions which included 15 talks and a best paper session where 9

young investigators contested. Ms. Soniya Hooda (Measurement of contralateral breast nipple dose during radiotherapy treatment of breast cancer), Mr. Ajay Prajapathi (Measurement of corneal dose during external beam radiotherapy of head and neck malignancies) and Mrs. Priti Gupta (Dosimetric characterization of OSLD in diagnostic and therapeutic energy use) won the 1st, 2nd and 3rd awards respectively. Dr. R Charry was the guest of honor for the valedictory function. A great cultural event performed by students followed and that marked the end of day's programme.

350 participants including Medical Physicists, Radiotherapy and Radiology technologists and students, Radiation Oncologists and Radiologists from in and around Jaipur, invited international speakers and guest faculty from across the country made this one day conference scientifically as well as culturally ever memorable.

On 4th April, the conference on **Stereotactic Radio Surgery & Stereotactic Body Radiation Therapy - Clinical, Physical and Dosimetric aspects** was inaugurated by Dr. D P Punia, Vice Chancellor, Mahatma Gandhi University of Medical Sciences and Technology, Jaipur. Dr. P L Nawalkha and Dr. U S Agarwal graced the inaugural function with their esteemed presence and shared their valuable experience.

There were 3 scientific sessions with 14 talks. All the talks were highly informative and educational.

The topics of discussion included:

- Linear Accelerator based SRS and SBRT
- SRS&SRT with Gamma Knife
- Clinical aspect of PET-CT, PER-MR in oncology practice
- Harnessing FFF mode
- Concepts of biological models
- Clinical radiobiological considerations in SRS, SRT & SBRT
- Radiotherapy techniques in management of brain malignancies.

About 150 Medical Physicists and Radiation Oncologists actively participated in the scientific deliberations. It not only brought notice to the clinical, physical and dosimetric aspects of SRS&SBRT, but also discussed thoroughly on the advantages and drawbacks of SRS&SBRT in the present era of modern healthcare. The events of the day were concluded with the valedictory function.

CETRTT & SRS/SBRT-2016
Glimpses

Welcome Massage from Thai Medical Physicist Society

On the behalf of Thai Medical Physicist Society and the local organizing committee, I am pleased to extend our warm welcome to the 22nd International Conference on Medical Physics 2016 held on December 9-12, 2016 at the Shangri-La Hotel, Bangkok, Thailand.

The Theme of the Conference is

"Medical physics propelling global health"

The Conference is hosted by the cooperation of:

- International Organization of Medical Physics (IOMP)
- Asia- Oceania Federation of Organizations for Medical Physics (AFOMP)
- European Federation of Organizations for Medical Physics (EFOMP)
- Middle East Federation of Organizations for Medical Physics (MEFOMP)
- South-East Asian Federation of Organizations for Medical Physics (SEAFOMP)
- Japanese Society of Radiological Technology (JSRT)
- Thai Medical Physicist Society of Medical Physics (TMPS)
- Thailand Convention & Exhibition Bureau (TCEB)

It is the first time that Thailand hosts the International Conference on Medical Physics(ICMP) in Bangkok, the 'City of Angels' and the 'Venice of the East' which you can enjoy the Asian culture of the gorgeous temples and Grand Palace along the Chao Phya River with the fantastic world famous Thai food.

The Scientific and Commercial Exhibition Committee are preparing for the highest scientific and educational quality through lectures, symposium, workshop, proffered papers, e-posters together with the radiological products of advanced technology from every corners of the world.

I wish you participate the coming conference arranged with the Welcome Reception, Lunch Symposium, Scientific and Exhibition sessions with several social programs in December 9-12, 2016 Bangkok, Thailand.

Thank you,

Anchali Krisanachinda, Ph.D.
President, TMPS
November 12, 2015

www.icmp2016.org

Calendar of Events 2016

JUNE 2016	27 – 30 Jun 2016 **18th Int'l Conference on the Use of Computers in Radiation Therapy - London, UK** London, UK , http://www.iccr2016.org/ *27-29 June, 2016* **6TH WORLD CONGRESS OF BRACHYTHERAPY**, ***San Francisco, USA***
JULY 2016	July 11-13, 2016 **10th Global Annual Oncologists Meeting**, Cologne, Germany July 14-15, 2016 Global Summit on **Melanoma and Carcinoma,** Brisbane, Australia
AUGUST 2016	Jul 31 – Aug 4, 2016 **AAPM 58th Annual Meeting & Exhibition - Washington, DC** Washington, DC, USA, www.aapm.org
SEPTEMBER 2016	1 – 4 Sep 2016 **1st European Congress of Medical Physics ,** Athens, Greece http://www.ecmp2016.org/ 7 – 10 Sept 2016 **47th Annual Meeting of the German Society of Medical Physics (DGMP),** Würzburg, Germany, 10th Sep 2016 **Radiation Oncology-The Upcoming Decade**, FMRI, Gurgaon,Haryana September 15-17, 2016 **7th International Conference and Expo on Molecular & Cancer Biomarkers,** Berlin, Germany September 26-28, 2016 **12th Euro Global Summit on Cancer Therapy,** London, UK
OCTOBER 2016	October 17-19, 2016 **11th Asia-Pacific Oncologists Annual Meeting,** Kualalumpur, Malaysia October 24-26, 2016 **8th International Conference on Biomarkers & Clinical Research,** Chicago, USA
NOVEMBER 2016	**November 03-05, 2016** International Conference on **Leukemia and Bone Marrow Transplantation,** Istanbul, Turkey **November 7, 2016** CRHC-2016 Conference on Radiation in Healthcare Department of Radiological Physics, SMS Medical College, Jaipur crhc2016@gmail.com **November 7, 2016** **2nd Vietnam Conference for Medical Physics,** VAMP, Vietman **9-11 November , 2016** International Conference on Radiation Biology (ICRB 2016) and the 13th Biennial meeting of the Indian Society for Radiation Biology (ISRB) Centre for Environmental Nuclear Research, SRM University, Chennai, www.srmuniv.ac.in/icrb2016

Calendar of Events 2016-17

NOVEMBER 2016	November , 2016 **The Annual Scientific Meeting, EPSM 2016** ACPSEM members in Australia and New Zealand for medical physicists, biomedical engineers and radiopharmaceutical scientists, Sydney, Australia, http://epsm.org.au/ 18-20 November , 2016 **AMPICON- 2016** 37th Annual Conference of Association of Medical Physicist of India "AMPICON- 2016" Hyderabad www.ampi.org.in November 17-19, 2016 **13th Global Summit on Cancer Therapy** Dubai, UAE 22nd-23rd November 2016 **5th Annual Conference of Bangladesh Medical Physics Society (ACBMPS-2016)** Bangladesh Medical Physics Society (BMPS) Dhaka, Bangladesh, www.bmps-bd.org
DECEMBER 2016	December 08-10, 2016 **14th World Congress on Cancer Therapy**, Baltimore, USA 6 – 9 Dec 2016 **22nd Int'l Conference on Medical Physics (ICMP 2016)** – Bangkok, Thailand http://www.icmp2016.org/
JANUARY 2017	13-14 Jan 2017 **ICMPRPR 2017** Zurich,Switzerland, www.waset.org
MARCH 2017	1-5 MARCH 2017 **European Congress of Radiology** – Vienna,Austria http://www.myesr.org
APRIL 2017	22 – 28 Apr 2017 **ISMRM Annual Meeting** - International Society for Magnetic Resonance in Medicine Honolulu, HI, USA http://www.ismrm.org/
OCTOBER 2017	21 – 28 Oct 2017 **IEEE Nuclear Science Symposium and Medical Imaging Conference 2017** Atlanta, GA, USA (map) http://www.nss-mic.org/2017 , email: nssmiccip@gmail.com
NOVEMBER 2017	4 – 7 Nov 2017 **AOCMP – 2017 & AMPICON- 2017** 17th Asia-Oceania Congress of Medical Physics "AOCMP – 2017 & 38th Annual Conference of Association of Medical Physicist of India "AMPICON- 2017" SMS Medical College, Jaipur, Rajasthan, India http://aocmp-ampicon2017.org/

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AOCMP — 2017

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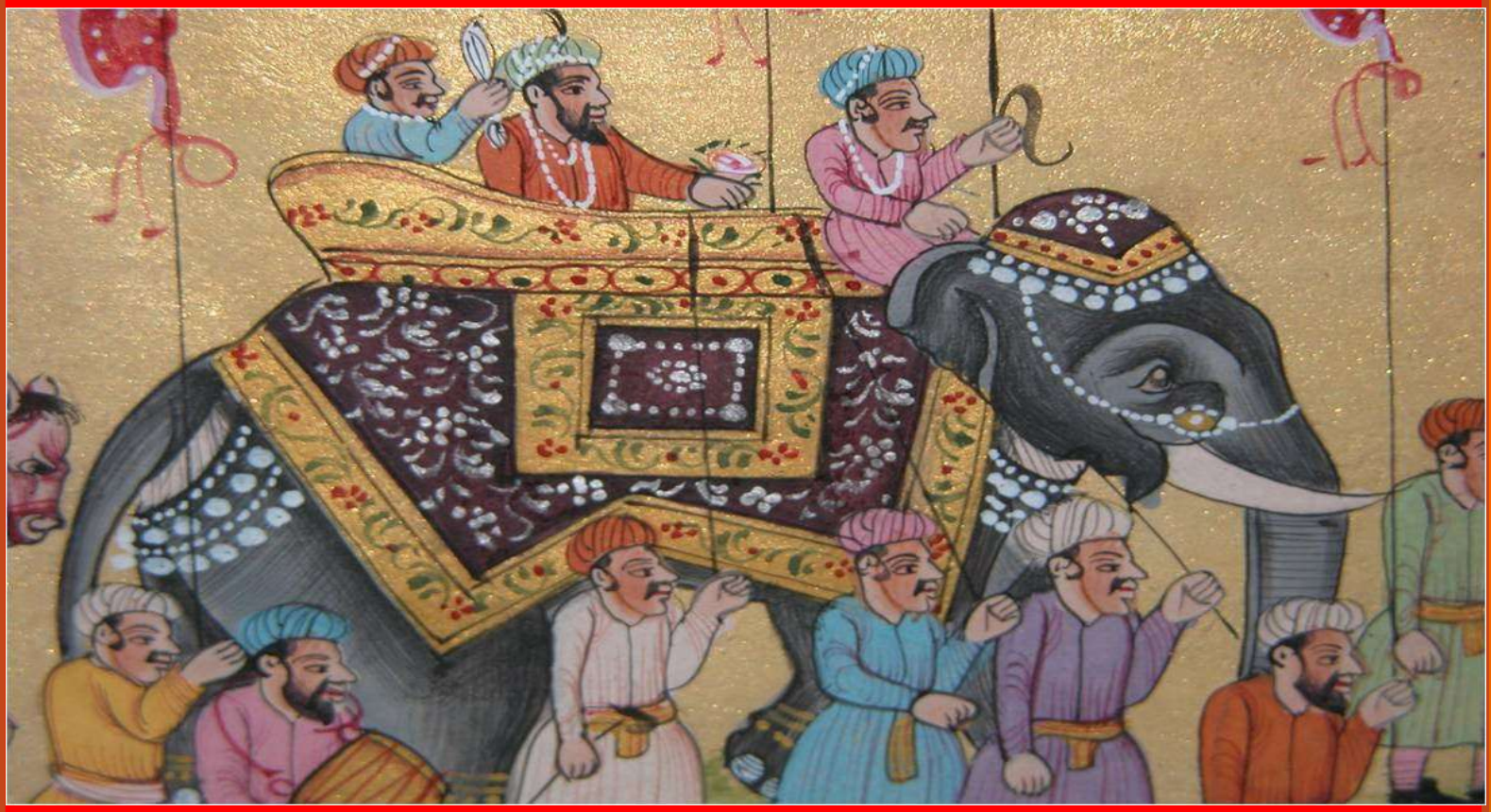

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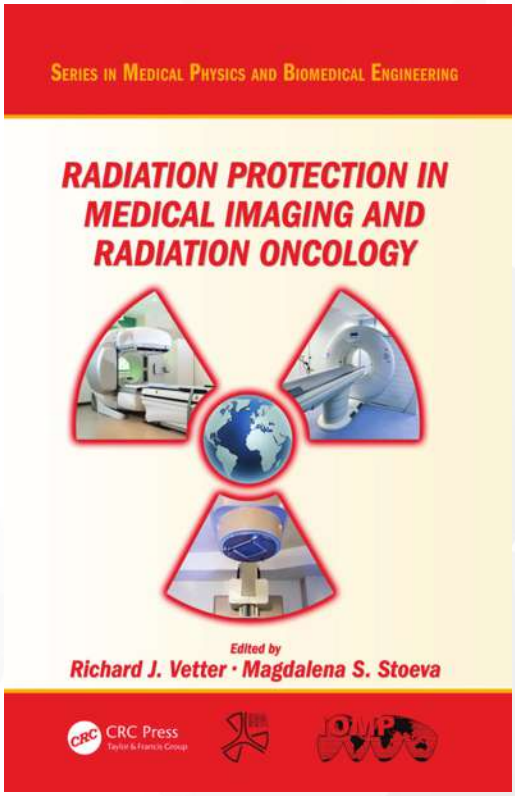

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ELEKTA TRAVEL AWARD

ELEKTA

ASIA PACIFIC SPECIAL INTEREST GROUP

The Australasian College of Physical and Engineering Scientists in Medicine's (ACPSEM) Asia-Pacific Special Interest Group (APSIG) would like to announce the 2016 Elekta Travel Award. This annual award enables one Medical Physicist from the Asia-Pacific region to travel to Australia for educational purposes.

The winner will attend the Engineering and Physical Sciences in Medicine (EPSM) conference in Sydney, 6th – 10th November 2016, present a research paper, visit Medical Physics departments and universities and submit a report to APSIG upon his/her return.

To be considered for the Award, all application materials must be received by the ACPSEM no later than 5:00 pm Australian Eastern Standard Time, 15th June 2016. The name of the successful applicant will be announced by 19th June.

Go to http://www.acpsem.org.au/documents/item/109 for selection criteria, conditions and details of the application process or email apsig@acpsem.org.au for more information.

APPLICATION FORM: Elekta Travel Award, 2016

Application and supporting material must reach APSIG by 5:00pm AEST 15th June, 2016, either by:

Mail: APSIG Chair,
ACPSEM, Suite 3.13 Aero,
247 Coward St, Mascot,
NSW 2020, AUSTRALIA

OR

email: apsig@acpsem.org.au,

1. APPLICANT:

Name:

Address:

Country:

Telephone:

Fax:

Email:

Current place of work:

Present Job Position & Main Duties:

Areas of interest/expertise in Medical Physics:

Title of paper to be presented at EPSM 2016:

(A copy of the abstract must be attached to this form)

Motivation for attending EPSM 2016:

List of conferences you have attended in the last 5 years:

Signature of Applicant: ……..……

Date: ……..……

ELEKTA Travel Award: Checklist for supporting documentation

☐ 2-page maximum typed cover letter describing your career plans and goals and how this award will assist your career, institution or country

☐ 2-page maximum Curriculum Vitae which must include your scientific publications and presentations, clinical training undertaken, positions held and any other relevant information;

☐ 1-page maximum letter of recommendation and support from your supervisor/manager;

☐ Scientific abstract of the work which you intend to present at EPSM 2015 during your visit should your application be successful.