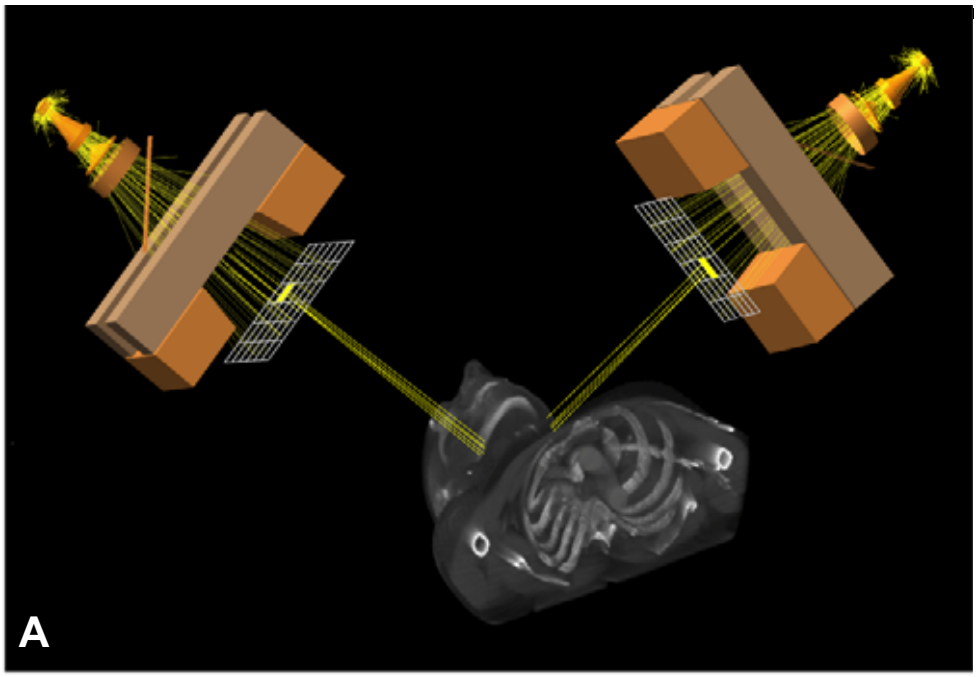
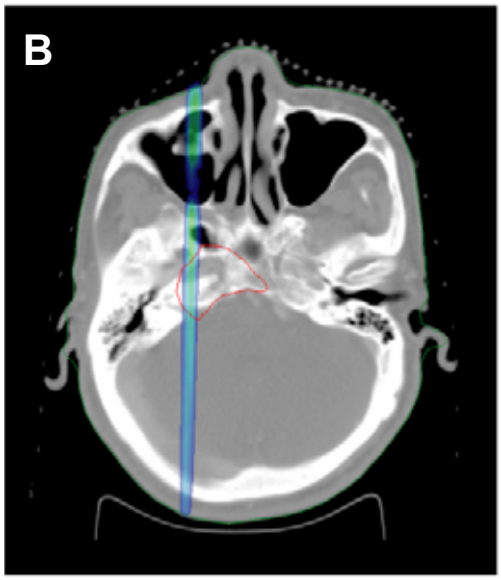
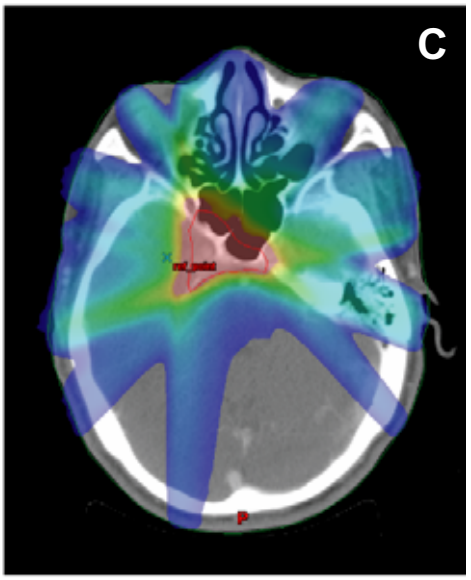
InterACTIONS

CANADIAN MEDICAL PHYSICS NEWSLETTER
Le BULLETIN CANADIEN de PHYSIQUE MÉDICALE







Monte Carlo BEAMlets for Inverse Treatment Planning by Direct Aperture Optimization

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CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE
LE COLLÈGE CANADIEN DES PHYSICIENS EN MÉDECINE

52 (2) avril/April 2006

About our Cover

A software package called *BEAMlets* has been developed at the British Columbia Cancer Agency, Vancouver Island Centre, to generate Monte Carlo beamlets using the BEAMnrc simulation system. *BEAMlets* provides a means to calculate beamlet dose distributions for IMRT treatment planning, with a level of accuracy not achievable using conventional dose calculation methods.

Particles crossing a plane defined at the level of the multi-leaf collimator are scored into a phase space file. A grid can be superimposed on this plane, breaking the phase space up into beamlets. Beamlet labels can then be written into the particle history variable located in the phase space file. All particles of a given beamlet can then be transported separately into a patient model (Figure A).

Figure B shows the dose distribution of a single beamlet passing through a sinus cavity. Looking closely, the effect of the air cavity on the dose distribution can be seen. This illustrates the unmatched ability of Monte Carlo to calculate dose in regions of charged particle disequilibrium, where conventional methods have been shown to be inaccurate.

BEAMlets has been successfully implemented into a Direct Aperture Optimization (DAO) algorithm. Figure C shows an IMRT dose distribution generated by this method. The use of *BEAMlets* in DAO results in true Monte Carlo inverse treatment planning.

Images provided by Karl Bush[1], Alanah Bergman[2], Marie-Pierre Milette[2], Tony Popescu[2], Karl Otto[2], Sergei Zavgorodni[1], and Wayne Beckham[1]

[1]BC Cancer Agency, Vancouver Island Centre, Victoria, BC.
[2]BC Cancer Agency, Vancouver Centre, Vancouver, BC.

The Canadian Medical Physics Newsletter, which is a publication of the Canadian Organization of Medical Physicists (COMP) and the Canadian College of Physicists in Medicine (CCPM) is published four times per year on 1 Jan., 1 April, 1 July, and 1 Oct. The deadline for submissions is one month before the publication date. Enquiries, story ideas, images, and article submissions can be made to:

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Pat Cadman: pcadman@scf.sk.ca
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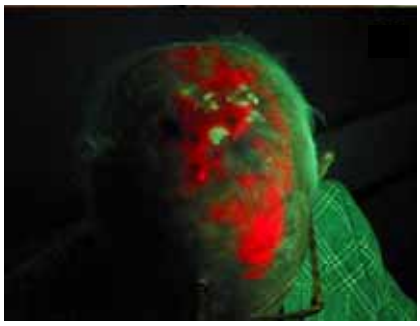
Please submit stories in Publisher 98, Word 6.0, Word 97, or ASCII text format. Hardcopy submissions will be scanned to generate an electronic document for inclusion in the Newsletter. Images in Tiff format at 300 dpi resolution are preferred.



Inside this issue:

Photodynamic therapy dosimetry: Estimating dose from fluorescence, photobleaching, and photoproduct formation.…60
Jonathon S. Dysart

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Message from the COMP Chair:

The effort to introduce a national program for quality assurance at Canadian radiation treatment centres now sits with the Standards Action Group (S-AG) of the Canadian Strategy for Cancer Control

The recent radiation treatment incident in Scotland http://www.timesonline.co.uk/article/0,,2-2031688,00.html highlights once again the importance of quality assurance in our radiation treatment programs. At the time of this writing the details of this incident are not known but the fact of the incident immediately brings focus to the efforts that we all make to minimize the risk of misadministration. Physicists who are responsible for the accuracy of dose delivery for increasingly complex treatment techniques are often faced with the conflicting pressures of expeditious patient treatment and the time and resources required for a complete quality control procedure. Also, we are often aware that the quality control procedure available may not be thoroughly testing the real physical situation. Most of us would agree that in Canada there are reasonable standards for quality control of treatment equipment and compliance with those standards is very good. However this is only a part of the story. New treatment techniques which may require heavily modulated beams and rely on precise target localization and patient positioning require patient-specific quality control procedures. These new QC techniques are in development and standards are not yet in place. Inevitably then we must make judgements about the procedures that are necessary to ensure quality and to make the necessary decisions we need to rely on available equipment QC standards, supplemented by our clinical expertise. The Radiation Safety and Technical Standards Advisory Committee (RSTSAC) of COMP has a very important role in helping to set the standards for use in Canada. **Peter Dunscombe** and his committee continue to produce quality control documents for radiation treatment equipment and I encourage all members to review these documents on the COMP website. Four of the documents appearing on the website have been endorsed by COMP but the remainder are awaiting comment and possible revision. The effort to introduce a national program for quality assurance at Canadian radiation treatment centres now sits with the Standards Action Group (S-AG) of the Canadian Strategy for Cancer Control. In 2005 the Draft Standards were submitted to this group by the Canadian Association of Provincial Cancer Agencies (CAPCA). The effort to develop and introduce standards will continue and is sure to move into the realm of patient-specific QC.

It is a pleasure to welcome **Maryse Mondat** to the COMP executive. Maryse is a medical physicist in the Department of Radiation Oncology of the Hôpital Maisonneuve-Rosemont in Montréal. On January 1, 2006 Maryse became the COMP treasurer, replacing **Horacio Patrocinio**, who has worked on our behalf in this position for the last 3 years. I would like to publicly thank Horacio for the excellent work that he has done in this position and as a valuable and thoughtful member of the executive.

Peter O'Brien, COMP Chair

Under the leadership of **Pat Cadman, Narinder Sidhu and Stephen Pistorius**, plans for COMP 2006 are now being finalized. This will be an excellent meeting and should not be missed. I hope to see you all in Saskatoon!

Message from the CCPM President:

This is a busy time for the College, with the written membership examinations scheduled for 11 March and the orals for 13 May. This year, we have 25 candidates for the written examination who will sit at 10 centres across Canada. Included in this number are 5 candidates from outside Canada who will travel to one of our centres for the examination – a reflection of the increasing demand for clinical certification and the excellent reputation and perceived value of our version. **Katharina Sixel** and **Michael Evans**, our Chief and Deputy Chief Examiners, will be relying heavily on volunteers drawn from the ranks of the College, many of them anonymous, for marking and invigilating.

Brenda Clark, CCPM President

Thanks to all of you for helping to ensure the rigour and credibility of our certification which has earned the respect of many of our colleagues worldwide.

With **Darcy Mason**'s invaluable assistance, our website has recently undergone extensive renovation designed to clarify the separate role of the College with respect to COMP. We now have a unique address, www.ccpm.ca, giving public access to information related to the College. Included on both the College and the COMP sites are links to the other organisation but the material on both sites is now more focused to respect the very different functions of each organisation. Clearly, the two organisations will remain closely linked behind the scenes as appropriate for a relatively small group, but the certification activities of the College have always been conducted at arm's length from our professional organisation and this should now be more apparent from our web sites.

In another long-anticipated move, the College web site has recently acquired a major component in Canada's other official language with the translation of some part of the material into French. We are indebted to **Clément Arsenault** and **Maryse Mondat** for technical input after a professional translator had supplied the first draft. This effort will be ongoing, we were unable to provide a translation of all items on the site and will work towards increasing the French component over the next few years.

Our representative to HARP (Healing Arts Radiation Protection), **John Schreiner**, has recently campaigned to reconstitute a medical physics committee to provide input to the HARP board and its various advisory committees. The intent was to reestablish a manageable and sustainable forum for discussion of issues requiring physics expertise. Recent feedback from HARP is that the suggestion has been well received and the College will soon be asking Ontario physicists (within and out of the College) to participate.

This is my last editorial as President of the CCPM: by the time the next edition is published, **Dick Drost** will have replaced me in the hot seat! It has been both a privilege and a pleasure to serve on the board for the last 8 years and as your president for 4 of those. During this time, there have been several major initiatives that have been proposed, discussed and implemented; mostly concerned with maintaining the credibility and ensuring clarity and transparency of our certification processes. The addition of an oral component and the revision of the structure of the written component of the Membership examination are two examples of this work. We have also published guidelines for the training of radiation therapy treatment planning professionals, promoted accreditation of medical physics educational and training programs by the sponsorship of CAMPEP and published an almost complete set of policies and procedures. Throughout this time, I have been fortunate to work with many colleagues from across the country both on the CCPM board and others, such as the very accommodating InterACTIONS editors. I have been con-

(Continued on page 74)

Thanks to all of you for helping to ensure the rigour and credibility of our certification which has earned the respect of many of our colleagues worldwide.

Message from the Executive Director of COMP/CCPM:

The [archive] records can be used to study and understand the life, ideas and thoughts of their original creators linking the past, present and future of Canadian medical physics

Time certainly flies! I have been working with COMP and CCPM for a year now and have enjoyed connecting with the many volunteers who have played an important role in making both organizations what they are today.

A particular way that I have connected with volunteers (past and present) is through my work on the Canadian Medical Physics Archives project – a project that definitely has momentum! Thank you to those who have submitted materials and to those who have shown interest in this important initiative. Materials continue to be forwarded from British Columbia, Alberta, Saskatchewan and Manitoba – a challenge to the other provinces to contribute items from their centres as well! Thank you to Doug Cormack, John MacDonald, Ellen Wilcox and Daniel Rickey for their contributions. I have enjoyed looking through photographs, back issues of the newsletter, articles published in newspapers and magazines, copies of talks/presentations etc. The archives project will ensure that records of today are preserved for future generations. The records can be used to study and understand the life, ideas and thoughts of their original creators linking the past, present and future of Canadian medical physics. Once we have received a significant amount of material, we will then assess and catalogue the information and then determine what the next steps are in terms of organizing, storing and ensuring that the materials are accessible to all who are interested. A listing of the material that has been collected to date is posted on the COMP website. Please refer to this list and if you have additional materials to contribute, they can be emailed to me at nancy@medphys.ca or forwarded to the COMP office at: P.O. Box 72024, 329 March Road, Kanata, ON K2K 2P4.

Over the past few months, many of you have connected with Maggie Hay, the COMP Administrator, through the online dues renewal process and the online conference registration process. These processes run smoothly because of countless hours put in behind the scenes by the volunteers on the Communications committee. Julian Badragan and Darcy Mason deserve special thanks for their efforts.

I would also like to take this opportunity to acknowledge the important role our corporate members play in both our annual meeting and the publishing of InterACTIONS. At this time last year, 19 suppliers were members of COMP and today we are fortunate to be supported by 25 corporate members. This support helps us produce a highly regarded newsletter and quality events which advance medical physics in Canada. I would like to welcome Fluke Biomedical, CoreHealth International and Scanditronix-Wellhofer of North America who have joined COMP since January of 2006.

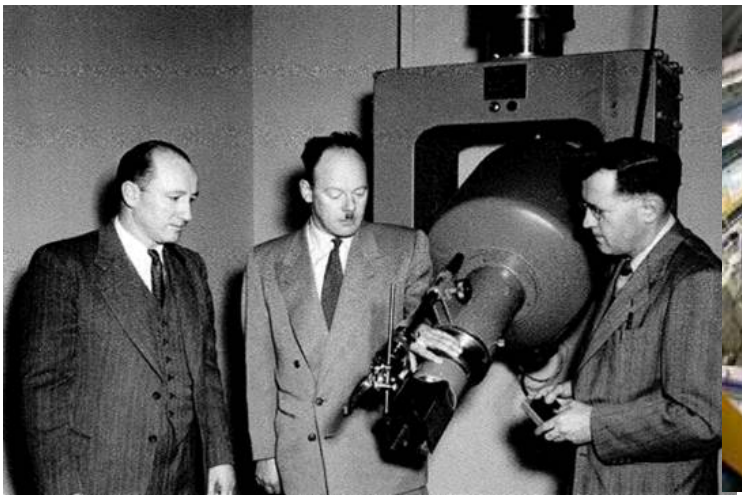
Nancy Barrett,
COMP/CCPM Executive Director

The Local Arrangements Committee continues to work hard to ensure that the 2006 Conference will exceed your expectations. I look forward to seeing you in Saskatoon!

As always, your suggestions and feedback are welcome. Please feel free to contact me (nancy@medphys.ca) or Maggie (admin@medphys.ca) at anytime.

52nd Annual Scientific Meeting of COMP and CCPM Symposium

May 31 – June 3, 2006
Saskatoon, Saskatchewan



Saskatoon Cobalt Unit

Canadian Light Source Storage Ring

Bright Past - Brilliant Future

The Canadian Organization of Medical Physicists and the Canadian College of Physicists in Medicine are pleased to invite you to Saskatoon to attend our 52nd Annual Scientific Meeting. This year's meeting will be held at the elegant Delta Bessborough Hotel, nestled on the banks of the South Saskatchewan River. –see www.medphys.ca for details.

MEETING HIGHLIGHTS:

Wednesday:	Public Lecture:	Rock Mackie and Lisa Rendall
Thursday:	CCPM Symposium:	***Biomedical Imaging and Therapy at the Canadian Light Source***
Friday:	Special Lecture /Gold Medal Presentations	
	Banquet: Wanuskewin Heritage Park, http://www.wanuskewin.com/	
Saturday:	Tour of Canadian Light Source ~ 1:30 – 3:30	

Technical Exhibitors can contact Nancy Barrett (nancy@medphys.ca) for more information

IMPORTANT – Room release date at the Delta Bessborough is April 29, 2006

!! See You In Saskatoon !!

AAPM 2005 Conference

July 24-28, 2005

Submitted by Susan Zhang,
BC Cancer Agency, Vancouver Centre,
Vancouver, BC

July 24-28, 2005, the 47th AAPM annual meeting was held in the massive Washington State Convention & Trade Center, Seattle, WA. More than 2500 medical physicists attended the meeting. Attendee's included the usual mix of medical physics professionals, students and residents who are employed in medical schools, hospitals, clinics and private practices.

The conference kicked off on Saturday July 23 with two days of Radiation Therapy Physics Review courses. Several experts presented excellent courses on radiation protection in radiotherapy; radiation generators for external beam radiotherapy; treatment planning and brachytherapy treatment planning.

On Sunday, July 24th, a memorial session in honor of Dr. John Cameron and the young investigators symposium attracted many delegates. The first place award was given to Favio Settecase, a young Canadian physicist from the University Health Network in Toronto, for his excellent work on "Factors Affecting Remote Control Endovascular Catheter Steering for IMRI".

The poster sessions started at 3:00 pm on Sunday afternoon. More than 300 posters were presented in the exhibit hall A/B and in the south lobby. Posters sessions were allocated 1.5 hours, at which time either the moderator or the authors themselves gave a brief overview of the poster, provided the conference delegates the opportunity to ask the authors questions directly, often stirring up lively discussions.

In this meeting, approximately 1152 papers were presented on various subjects classified in imaging and therapy categories. With seven parallel sessions going on at any one time there was a little bit of everything covered at the meeting. There are seven parallel sessions going on each day, often making the choice of what to attend difficult. Some of the most interesting subjects were sessions dedicated to "Flat-Panel Detectors: advanced applications", "Imaging for Target Definition" and "Optimization for IMRT" just to name a few.

In the scientific program, there were many noteworthy talks. A paper titled "Lighting up Radiation-Resistant Tumor Regions" presented by Dr. Andrei Pugachev of Memorial Sloan-Kettering Cancer Center in New York discussed the progress towards reliably finding and imaging regions of a tumor that are not destroyed by ordinary levels of radiation. Proton therapy is also gaining in popularity. Compared to conventional external beam radiation therapy using megavoltage x rays, protons offer the ability to destroy tumors just as competently while inflicting less damage to surrounding healthy tissue. An excellent paper titled "Treating lung cancer with 4D protons " presented by Martijn Engelsman discussed some of the benefits of protons.

The President's Symposium was held at 10:00 am on Monday, July 25th. It was moderated by AAPM president Dr. Howard Amols. Speaker Dr. John Rigden discussed how in 1905, the five Einstein papers helped form the bedrock of modern physics. Speaker Dr. Peter Almond gave an excellent talk about the concurrent early history of radiation physics.

Noteworthy moments for our Canadian colleagues Dr. Brenda Clark and Dr. Ian Cunningham, who were honored by the AAPM and received their fellowships this year. Congratulations to you both.

Sherry Connors of the Cross Cancer Institute organized a great Canadian luncheon on Wednesday, July 27th at the Palomino Restaurant in downtown Seattle. 85 people attended the gathering (see pictures next page, courtesy of Sherry Connors). The AAPM night out was held on Tuesday evening July 26th at Boeing exhibition center. Hundreds delegates enjoyed delicious buffet style food and took in the huge exhibition hall where all types of old and modern aircraft were on display.

The conference closed at noon on Thursday, July 28 and was fantastic.

Erratum:

In the article "Report on COMP AGM 2005", which appeared in the October 2005 issue of 'Interactions', the incorrect title was given for one of the posters (by Karl Bush and Tony Popescu) that shared the first prize. The actual title of that poster is *"Commissioning of virtual linacs for Monte Carlo simulations by optimizing photon source characteristics"*. Please note that this error also made its way into the 2005 COMP Membership Directory, on page 44 (COMP Poster Awards).

Thanks to Tony Popescu for pointing out this oversight.

Pictures from the 2005 AAPM Meeting




Pictures from the Canadian Luncheon organized by Sherry Connors.

Proposed COMP Bylaw Change

Submitted by Peter McGhee, Councillor for Professional Affairs
Thunder Bay Regional Health Sciences Centre, Thunder Bay, ON

The Executive of COMP hereby gives notice that we will be seeking ratification of the following Bylaw amendments at the Annual General Meeting in June 2006 in Saskatoon, Saskatchewan.

***JUSTIFICATION*:**

Because of the recent introduction of new patient confidentiality legislation, the Professional Affairs Committee undertook a review of the Code of Ethics. Although no changes are recommended for the Code, concern was raised that COMP Article III does not explicitly cite the Code of Ethics when addressing discipline. Reference to the Code of Ethics would clearly define what is now termed “unprofessional activities”. The amendment would also make the COMP bylaw consistent with the corresponding bylaw of the Canadian College of Physicists in Medicine (Article VII).

BYLAW AMENDMENT:

Article III: Membership

DISCIPLINE

The assembly at the General Meeting, on recommendation of the Executive, may expel, suspend, or reprimand a member engaged in *unprofessional activities* ***activities that contradict the intent of the Code of Ethics as published by COMP***.

NEWS FROM THE NRC: DIRECT CALIBRATION OF ION CHAMBERS IN LINAC PHOTON BEAMS

Submitted by Malcolm McEwen, Carl Ross
Ionizing Radiation Standards, National Research Council of Canada, Ottawa, Canada

INTRODUCTION

In 1999 the AAPM introduced a new absorbed dose protocol, TG-51. This is based on the calibration of an ionization chamber in a ^{60}Co beam and to determine dose in a linac megavoltage X-ray beam one must use calculated conversion factors. An alternative approach is to obtain absorbed dose calibration coefficients in linac photon beams. In this case there is no need for the calculated conversion factors.

Several national laboratories have developed primary standards for high-energy photon beams and determined calibration coefficients for a range of chamber types. However, a major limitation to date is that standards laboratories, in general, operate research machines rather than clinical linacs. This has generated much controversy in recent years over the validity of using calibration coefficients obtained in such beams in the clinical situation.

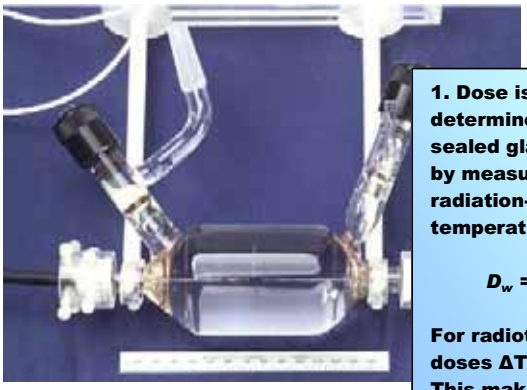
INSTALLATION OF CLINICAL LINAC

The Ionizing Radiation Standards Group at the NRC has addressed this concern by installing a clinical linear accelerator (Elekta *Precise*).

This is a standard "off-the-shelf" linac with X-ray energies of 6, 10, & 25 MV and electron energies of 4, 8, 12, 18 & 22 MeV. The absorbed dose calibration coefficients determined using this accelerator will be directly applicable to the clinical situation.

Although initially there was some concern as to the suitability of such a machine for primary standards measurements, an in-depth investigation showed that the performance of the linac was more than satisfactory.

THE PRIMARY STANDARD WATER CALORIMETER

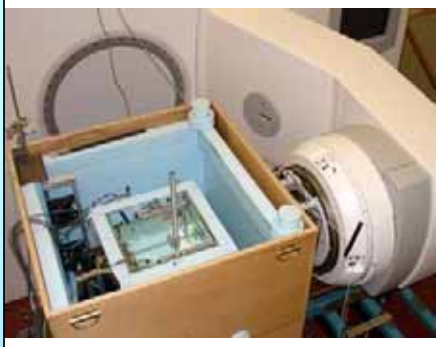


1. Dose is determined in a sealed glass vessel by measuring the radiation-induced temperature rise:

$$D_w = c_w \cdot \Delta T$$

For radiotherapy doses ΔT ~ few mK. This makes calorimetry a very challenging endeavour.

2. The calorimeter vessel is placed in a water phantom, which is temperature controlled at 4 °C to minimise convection.



3. The ion chamber to be calibrated is placed in the same water phantom at the same measurement depth:

$$N_{D,w} = D_w / M_w$$

RESULTS

Measurements were carried out in 6, 10 and 25 MV photon beams. By measuring in ^{60}Co as well we can test the calculated conversion factors given in TG-51.

(Continued on page 70)

Results of a Canadian IMRT Survey

Submitted by Boyd McCurdy,
CancerCare Manitoba,
Winnipeg, MB

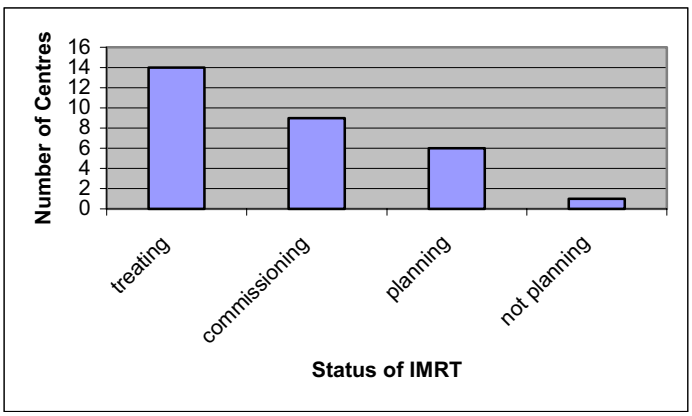
In early January 2006, an informal survey was sent out to all cancer treatment facilities across Canada. This survey asked questions pertaining to the use, implementation, and ongoing support of IMRT (Intensity Modulated Radiation Therapy) programs. The response was extremely good, with 30 out of 33 contacted centres returning the survey at least mostly completed. I would like to thank those who participated in this survey. I view this high level of response as a sign of the strength of the Medical Physics community in Canada. I have recently received information that I missed one or two centres from the initial survey distribution and I apologize for this, but I do not feel that it will grossly affect the results presented here.

The survey was developed by the author in a very short period of time, with input from a few medical physicists at centres that are actively delivering IMRT (and my thanks to them!). I make no claim that all questions in the survey are useful to everyone, but perhaps some portions of it will be useful or at least interesting to most COMP members. The short time period allowed for response (responses were required by Feb. 1 2006) ensures that the survey results are a true 'snapshot' of the developing clinical implementation of IMRT in Canada.

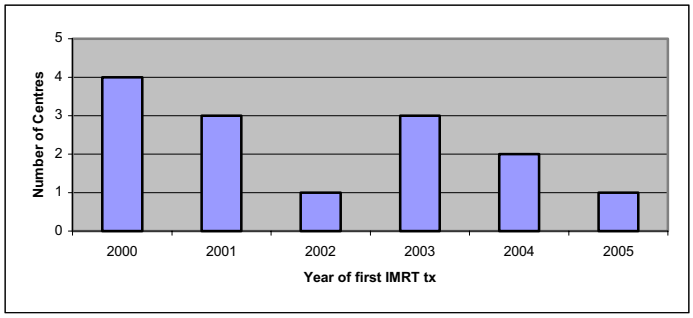
NOTES: (1) Helical, dynamically delivered IMRT treatments (ie. those delivered by Tomotherapy units) are *not* included in these results. I have received completed surveys from the three (to date) Canadian centres currently using dynamic helical equipment, and I will attempt to assemble those specific results for the July newsletter issue. **(2)** Several vendor names appear in the responses to some of the survey questions. Their appearance in the survey results DO NOT indicate an endorsement by the author or this newsletter in any way. **(3)** Questions that were not answered are labeled 'n/a'. **(4)** Questions 3-6 only include responses from centres delivering IMRT clinically.

Question 1— Current status of IMRT in your clinic

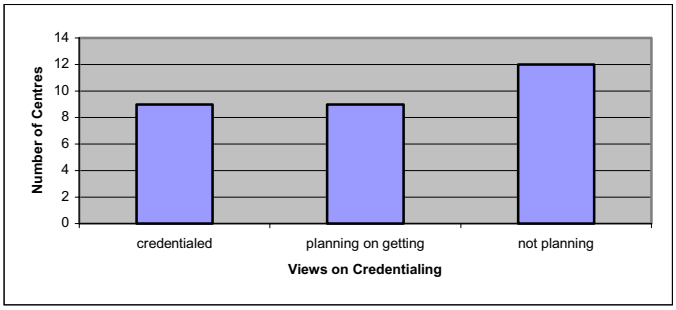
Question 1(a) - Is your centre treating patients, commissioning IMRT, or planning to commission IMRT?



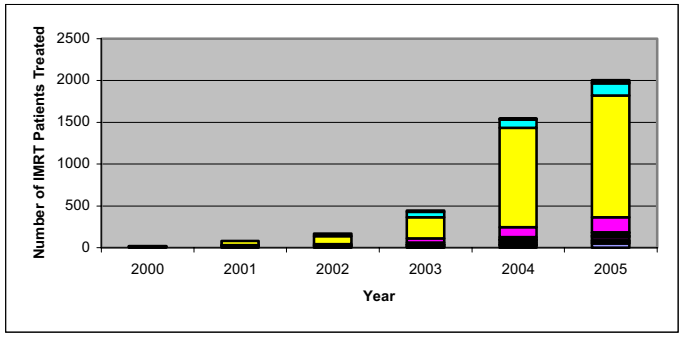
Question 1(b) - If treating, what was the approximate date of the first IMRT treatment delivered to a patient?



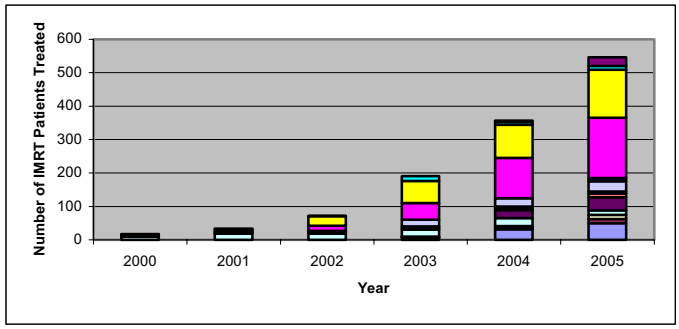
Question 1(c) - Are you credentialed by the RPC, or in progress, or planning to get credentialed?



Question 1(d) - How many IMRT patients did your clinic treat in the years since program startup?



One of the centres treated over 1000 patients in 2005. This centre masks the results of the smaller centres in the graph above. To provide a more detailed picture of the treatment numbers at smaller centres, the graph below excludes the numbers from the single large centre:



(Continued on page 52)

IMRT Survey Results… (Continued from page 51)

Summary of results from Question 1:

Fourteen out of thirty centres have already implemented IMRT while nine more centres are in the commissioning phase, and eight centres are in the planning phase. The single centre that responded that they were not planning on IMRT implementation cited financial restrictions as the main reason why they were not planning for IMRT. This clearly indicates that IMRT is quickly evolving as a *de facto* standard of care at Canadian Cancer treatment facilities.

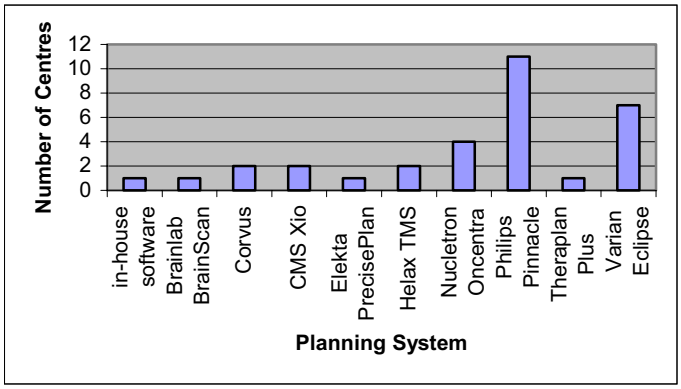
Of those centres that are treating IMRT, many of them began in 2000 and 2001. A second wave of centres began treatments in 2003 and 2004. Judging by the number of centres that are in the commissioning phase, I would estimate that 2006 and 2007 will see another increase in centres beginning to offer IMRT treatments.

Many (9) centres delivering IMRT have been credentialed by the RPC (Radiological Physics Center,), while nine more are planning on obtaining this credentialling. Twelve centres indicate that at this time they do not intend to pursue RPC credentialling.

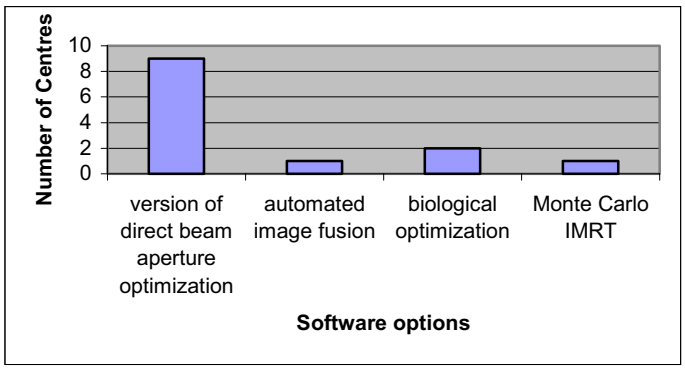
The growth in the number of patients being treated with IMRT in Canada has demonstrated nearly exponential growth since the first centres began treating in 2000 and 2001. Even when treatments at the single large centre are removed, this exponential growth pattern is evident. About 2000 patients were treated with IMRT in Canada in the year 2005, while about 550 of these IMRT patient treatments were delivered outside the largest centre.

Question 2 — Software/hardware involved in IMRT delivery

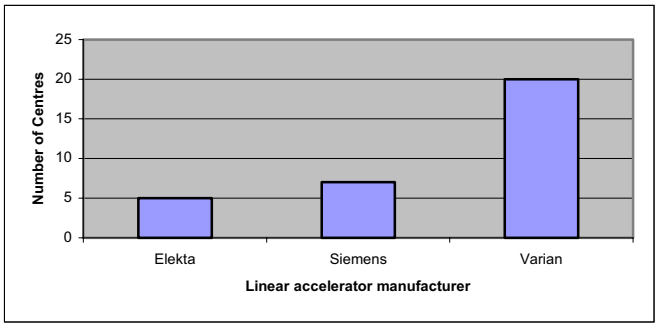
Question 2(a) - Treatment Planning System manufacturer?



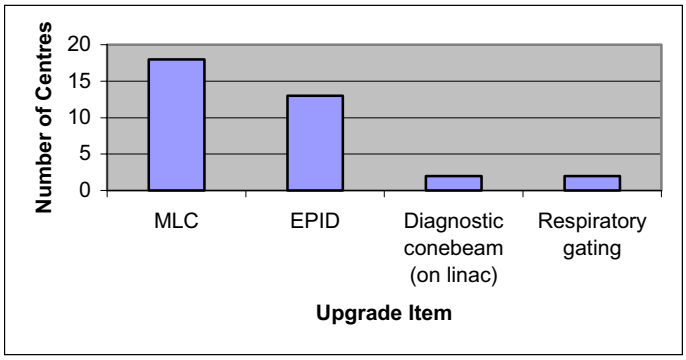
Question 2(b) - Treatment planning software options (if any)?



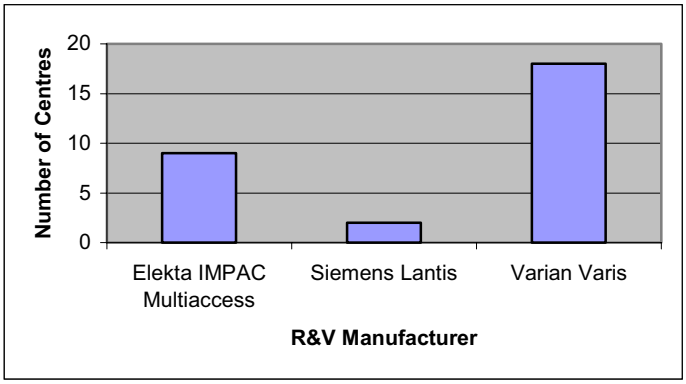
Question 2(c) - Linear accelerator manufacturer?



Question 2(d) - Linear accelerator upgrades for IMRT?



Question 2(e) - Record and Verify manufacturer?



Summary of results from Question 2:

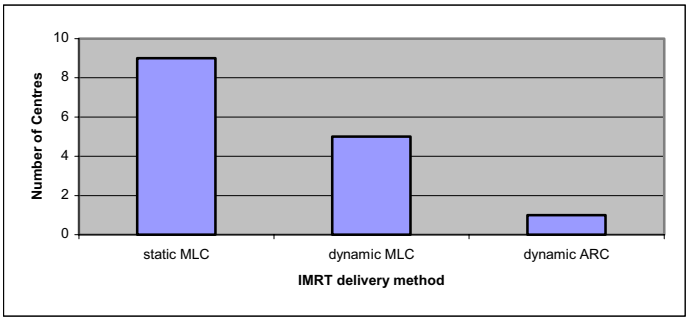
There appears to be a very wide range of software used to (or being commissioned or contemplated to) plan IMRT treatments. The most popular versions of Philips Pinnacle were v7.# (10), v6.# (2) and of Varian Eclipse were v7.# (7). The most popular software option is the implementation of 'direct aperture optimization', as proposed by Shepard [Sh02]. Delivery will occur primarily on Varian linacs, followed by Siemens and Elekta. Primary linac upgrades include MLC (multileaf collimator), followed closely by the EPID (electronic portal imaging device) The most popular R&V system for intended delivery is Varis, followed by IMPAC and Lantis.

(Continued on page 53)

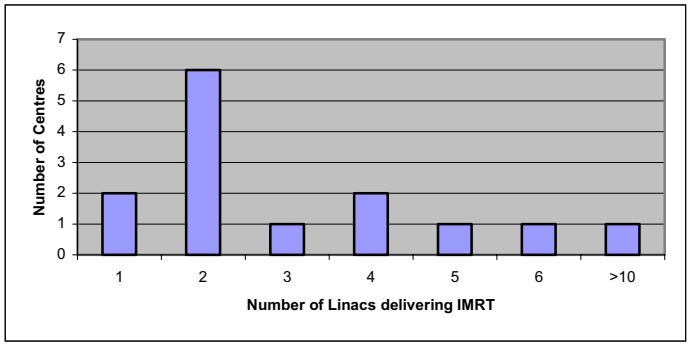
IMRT Survey Results… (Continued from page 52)

Question 3— Current IMRT application

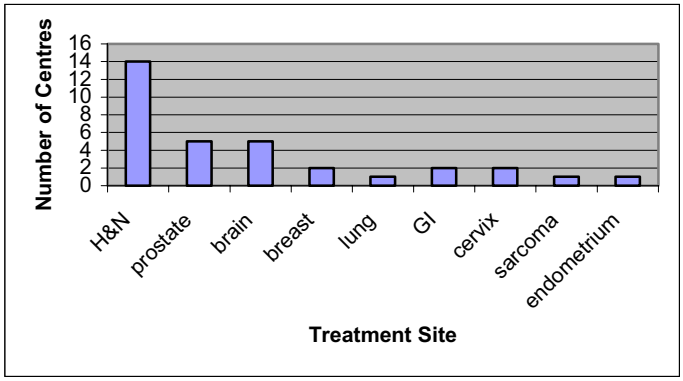
Question 3(a) - What methods of delivery are using?



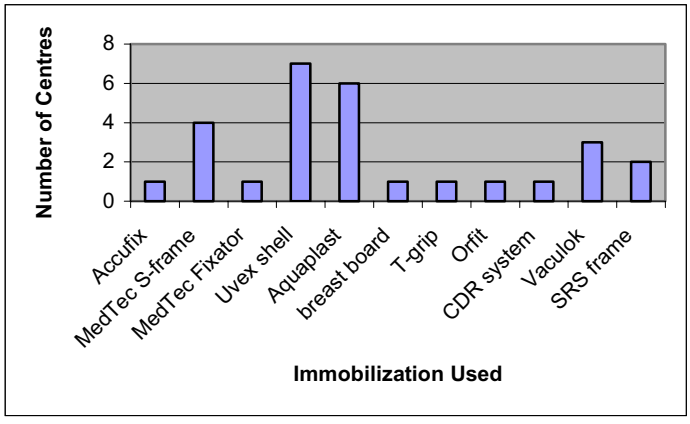
Question 3(b) - How many treatment units are delivering IMRT?



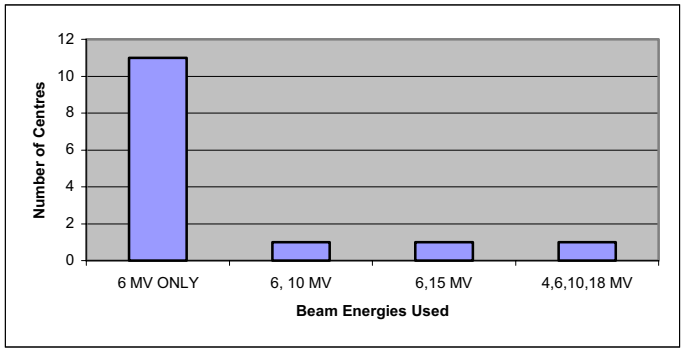
Question 3(c) - Main patient treatment sites?



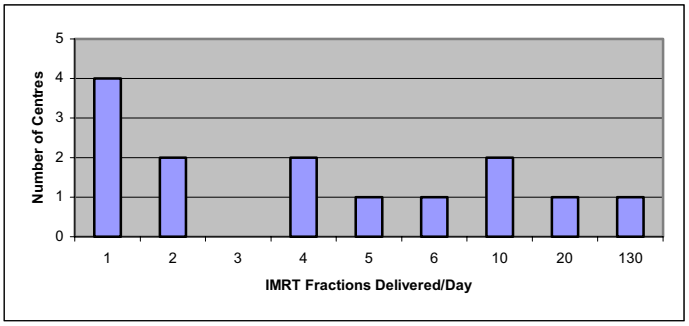
Question 3(d) - What types of immobilization are being used?



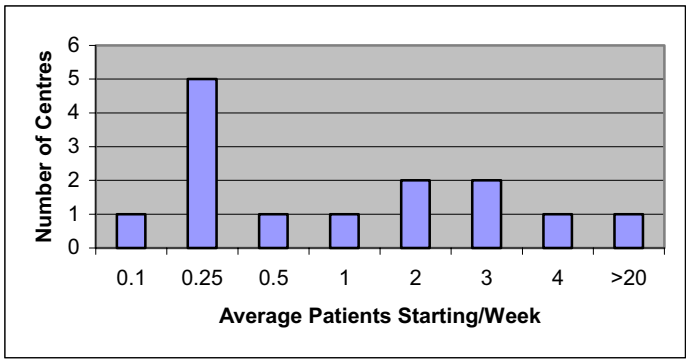
Question 3(e) - What beam energies are being used?



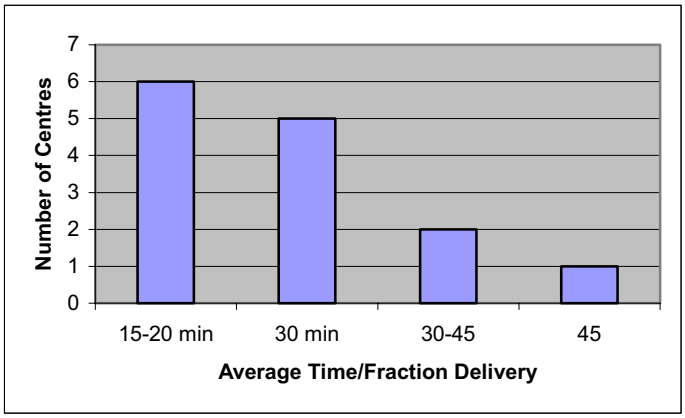
Question 3(f) - Average number of IMRT fractions being delivered per day?



Question 3(g) - Average number of new IMRT patients beginning a treatment course, per week?



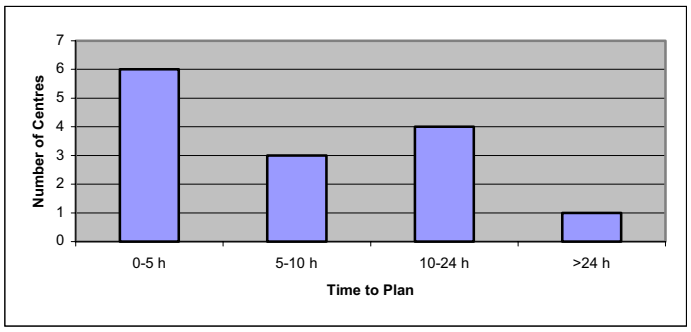
Question 3(h) - Average treatment timeslot for one IMRT fraction delivery?



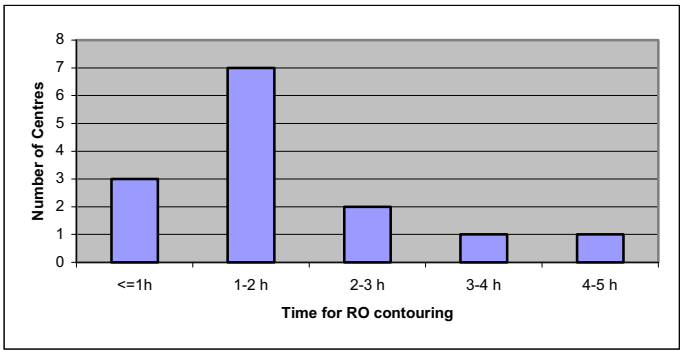
(Continued on page 54)

IMRT Survey Results… (Continued from page 53)

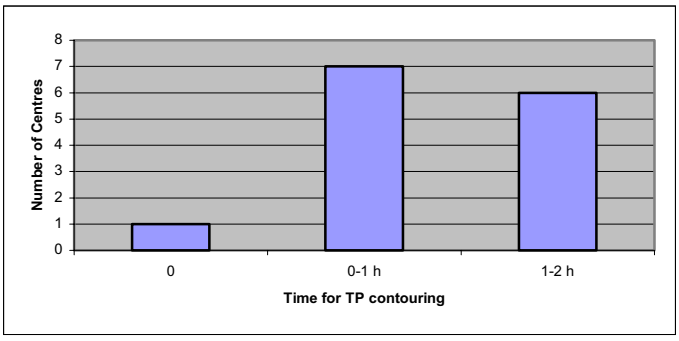
Question 3(i) - Average time to plan a treatment (not including contouring time)?



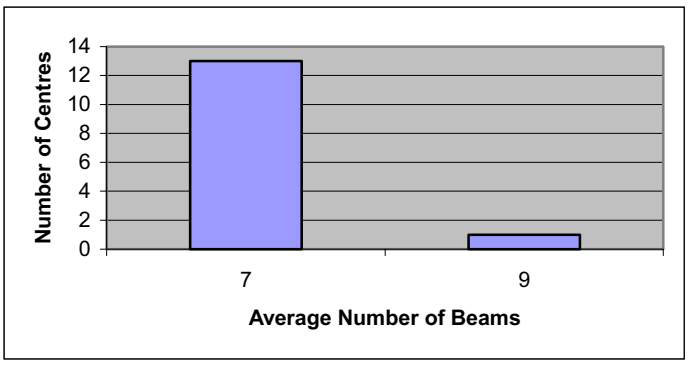
Question 3(j) - Average time for Radiation Oncologist to perform contouring per patient?



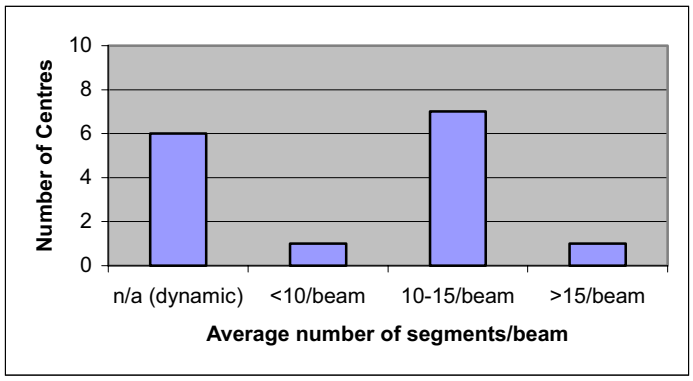
Question 3(k) - Average time for Treatment Planner to perform contouring per patient?



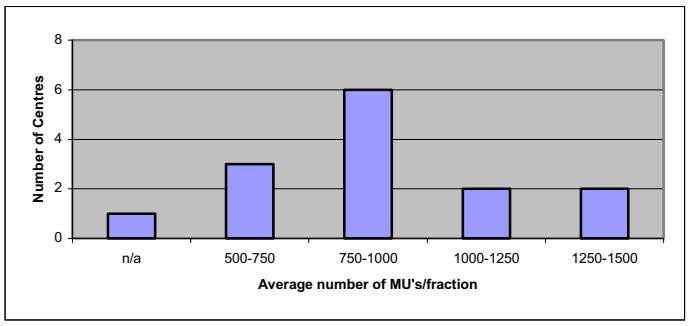
Question 3(l) - Average number of beams applied per patient per fraction?



Question 3(m) - Average number of segments per beam (if static delivery used)?



Question 3(n) - Average number of monitor units delivered per fraction?



Summary of results from Question 3:

Most (9) centres are delivering IMRT using static MLC techniques, with the remainder (5) using dynamic MLC. One centre is using both dynamic ARC MLC and static IMRT delivery.

The majority of centres (6) are using two linear accelerators ('linacs') for IMRT delivery, while the remaining centres show an even spread in the number of linacs being used to deliver IMRT treatments (ranging from 1 to above 10).

The most dominate treatment site is 'head and neck' a.k.a. H&N (14), with prostate (5) and brain (5) the next most common, followed by a variety of other treatment sites.

Many centres are using multiple types of immobilization, with specific choices obviously depending on treatment site. Due to the dominance of the head and neck treatment site, one observes a corresponding large use of head and neck specific immobilization (ie. Aquaplast, Uvex shell, Orfit, etc.).

The predominant beam energy used for IMRT treatments is 6 MV, with most centres delivering only with this beam energy. Three centres deliver with two or more beam energies.

The average number of IMRT fractions delivered per day ranges from above five for some of the more experienced centres, with some of the centres who have recently begun IMRT programs delivering one or two fractions per day. The average number of new IMRT patients beginning treatment per week is also divided between relatively experienced centres and centres with more recently implemented IMRT programs. Most centres are starting approximately 1 IMRT patient per month (ie. 0.25/ week) , with several centres ranging upwards from that level from one to four patient starts per week. One large centre is currently delivering nearly 20% of their radiation treatments via

(Continued on page 55)

IMRT Survey Results… (Continued from page 54)

IMRT.

Many centres (6) are delivering IMRT in 15-20 minute time slots, while several are using 30 minute time slots (on average). A few centres require longer delivery times (>30 minutes). The delivery time is dependent on the combination of software/ hardware being used. There will also be a time dependence based on the complexity of the treatment delivered. For example, head and neck IMRT deliveries will typically take longer than prostate IMRT deliveries, due to the increased complexity and modulation usually required for the head and neck cases.

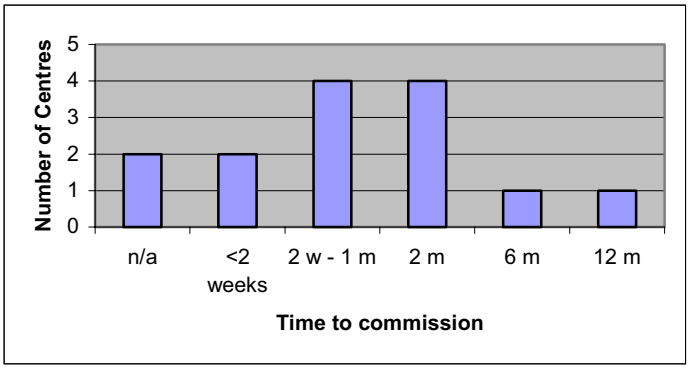
Several centres (6) reported that average planning times (not including contouring) were below five hours. A few centres (3) reported times in the 5-10 hour range, and four centres reported times in the 10-24 hour range. The range of times centres reported were as low as two hours and as high as 80 hours. These times will be dependent on the specific software and hardware used, as well as on the experience of the Treatment Planners and Physicists.

Most centres (10) reported that the average time required for Radiation Oncologist contouring is two hours or less. The remaining centres reported Radiation Oncologist contouring times ranging from two to five hours. Treatment Planner contouring was typically under one hour (8), or between one and two hours (6).

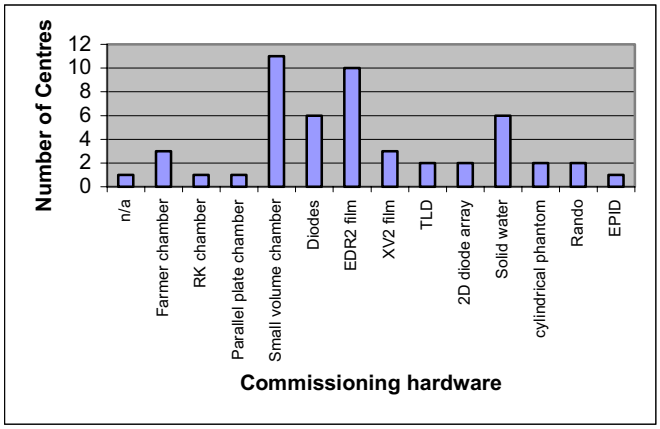
The average number of beams used per IMRT treatment was nearly a unanimous seven (13), with one centre favouring nine beam arrangements. The range of responses varied from a low of two to a high of eleven beams. Of the nine centres using static beam delivery, most of them (7) reported average number of segments per beam in the range of 10-15. The full range reported by centres was 2-32 segments per beam. The average number of monitor units reported per IMRT fraction delivery was most commonly in the range of 750-1000 (6), with some centres (3) typically delivering less than 750 and some centres (4) typically delivering more than 1000.

Question 4— Commissioning and Quality Assurance (QA)

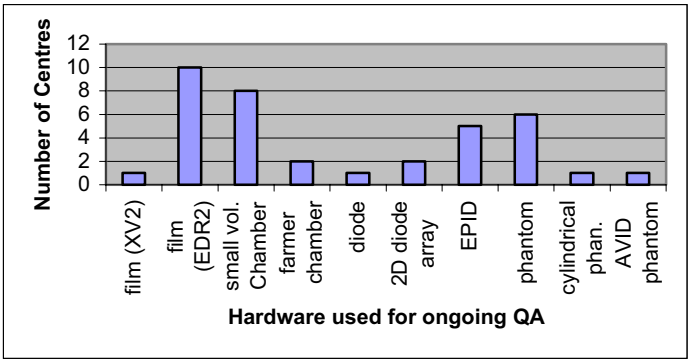
Question 4(a) - What was the time required for 1 EFT (equivalent full-time) physicist to commission the IMRT program?



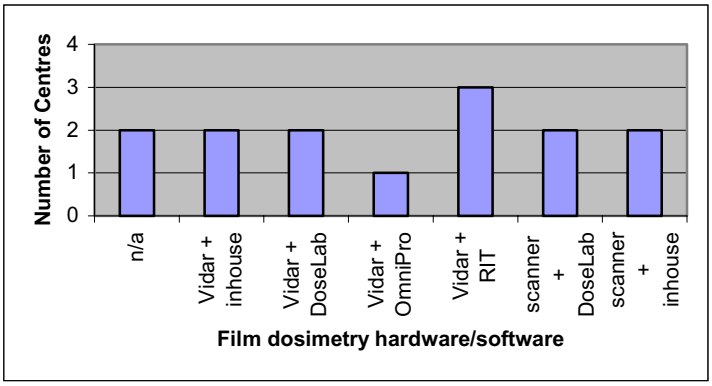
Question 4(b) - What hardware was used for commissioning (ie. phantoms, micro-chambers, film, etc.)?



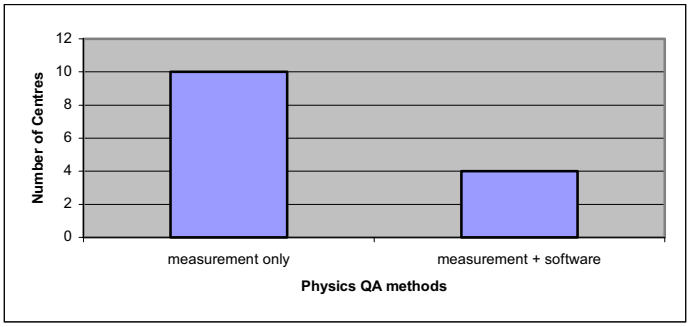
Question 4(c) - What hardware is used for ongoing QA?



Question 4(d) - What hardware/software combination is used for film dosimetry program (if used)?



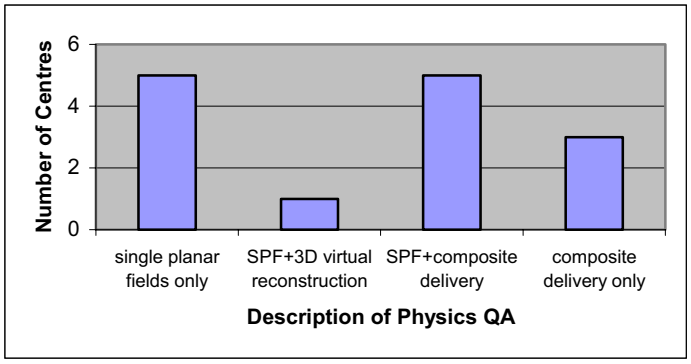
Question 4(e) - What method of physics QA per patient is used (measurement based, software based, both)?



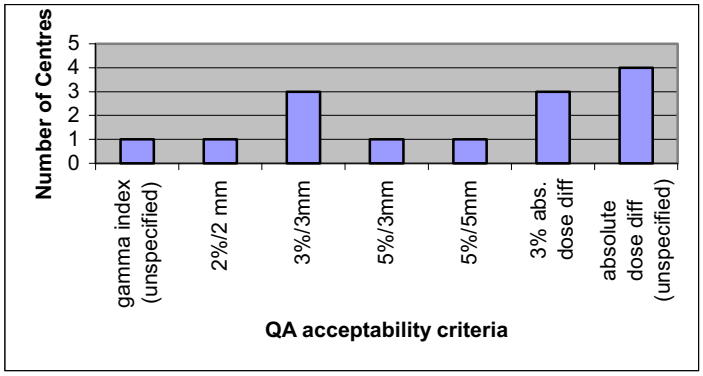
(Continued on page 56)

IMRT Survey Results… (Continued from page 55)

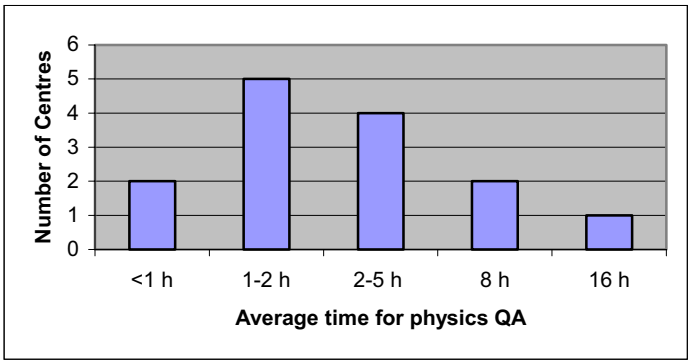
Question 4(f) - Provide a brief description of the physics QA per patient (note: SPF = single planar field).



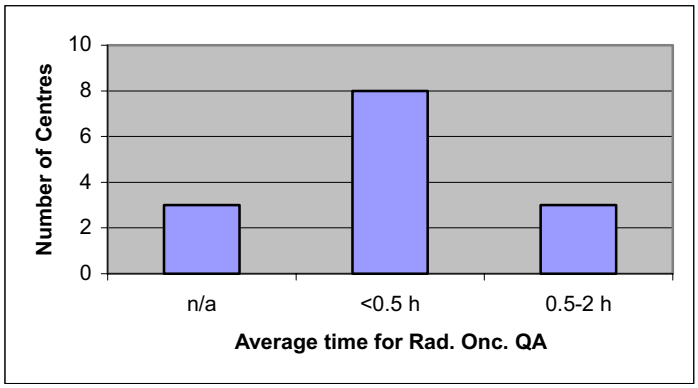
Question 4(g) - What is your QA acceptability criteria?



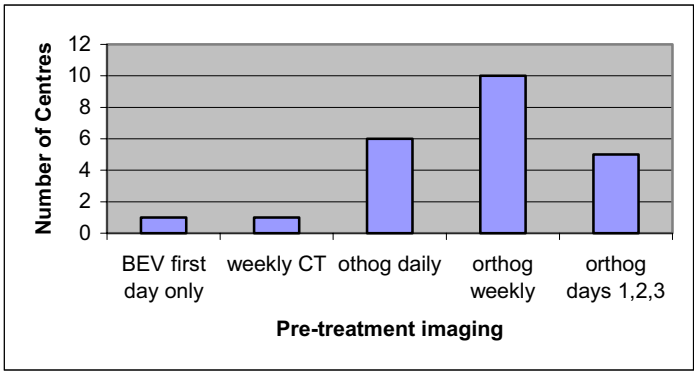
Question 4(h) - What is the average time required for physics QA per patient?



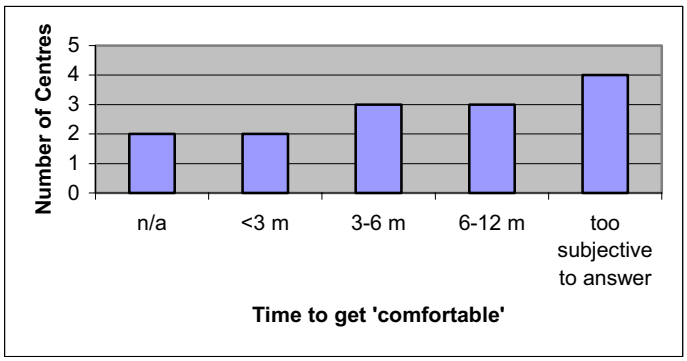
Question 4(i) - What is the average time for Radiation Oncologist QA per patient (ie. contouring QA or rounds review)?



Question 4(j) - What pre-treatment imaging is performed for IMRT patients (orthogonal images, diagnostic cone-beam imaging, etc.)?



Question 4(k) - What is the approximate time between end of commissioning and being 'comfortable' with IMRT?



Summary of results from Question 4:

Several (6) centres required less than one month to commission their IMRT program, while many required 2 months (4), or more (2). A large variety of hardware was used for commissioning, primarily small volume ionization chambers (11) and film (13). Many centres also used diodes (6).

Similarly to the above results, for ongoing QA most centres used small volume ionization chambers (8) and film (11). The use of EPID's for ongoing QA was reported by five centres.

Film dosimetry programs seemed to primarily involve the use of a Vidar film scanner combined with a variety of analysis software.

Most centres (10) use a measurement-only QA prgoram, while remaining centres (4) use a combination of measurement and verification software. For the QA measurements, five centres verify single planar field delivery only, while five centres perform both single planar field delivery and composite beam delivery. Three centres perform composite beam delivery, while one centre performs single planar field delivery combined with a virtual 3D dose reconstruction (in-house software). For acceptability criteria, half the centres (7) are using an absolute dose difference (many specified at 3%), while the remainder are using some form of the 'gamma index' [Lo98] with a variety of percent differences (low gradient regions), and distance-to-agreement (high gradient regions).

The average time for physics QA per patient is about 1-2 hours (5) with 2-5 hours (4) also being common. Two centres indicated less than two hours is required, while three centres

(Continued on page 57)

IMRT Survey Results… (Continued from page 56)

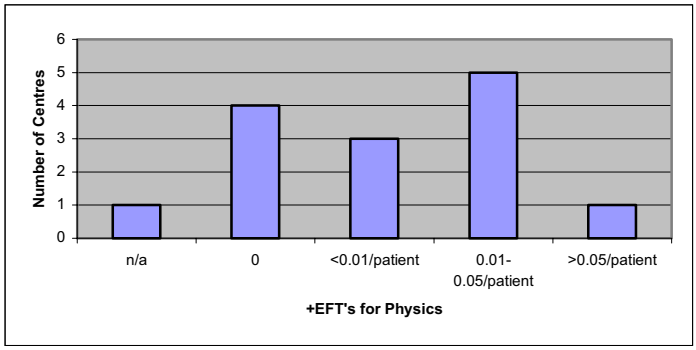
indicated 8 hours or more is required. In terms of Radiation Oncologist QA, most centres responded that under 0.5 hours was used. A few centres indicated that Radiation Oncology QA was performed during the contouring session.

Regarding treatment imaging, many centres (6) indicated they performed daily orthogonal imaging, while 5 centres indicated orthogonal imaging was performed on treatment days 1, 2 and 3. Often these centres then switched to weekly orthogonals for the remainder of the treatment. Ten centres responded that orthogonals were performed weekly.

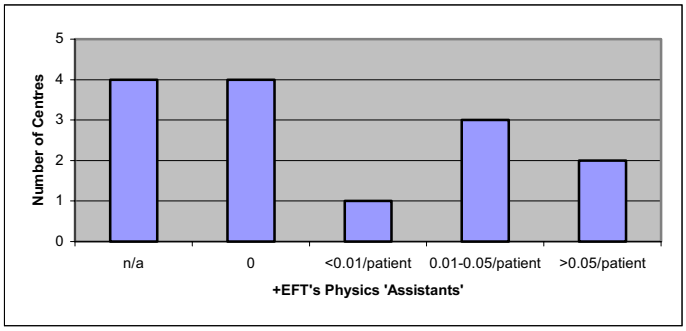
As far as the approximate time between commissioning IMRT and that warm fuzzy feeling of comfort, many people felt that was too philosophical to answer (or didn't answer at all)! Those that did answer gave a wide variety of times (<3 m to 1 year).

Question 5 — Human resources (post commissioning) compared to 'pre-IMRT'

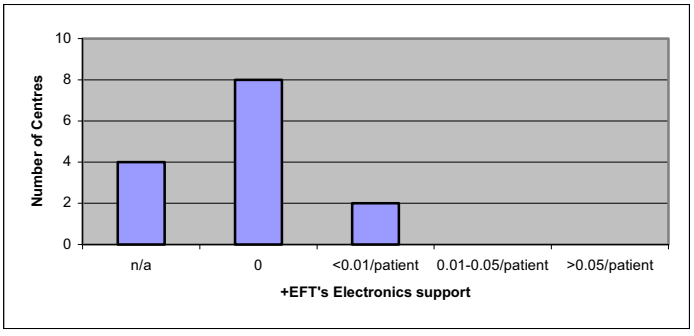
Question 5(a) - Additional EFT's (equivalent full-time) required for physics?



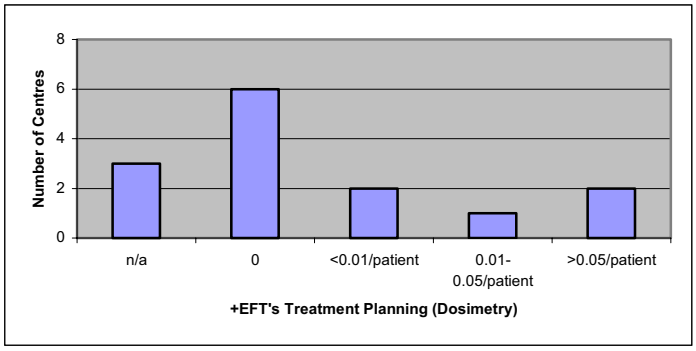
Question 5(b) - Additional EFT's (equivalent full-time) required for physics 'assistants'?



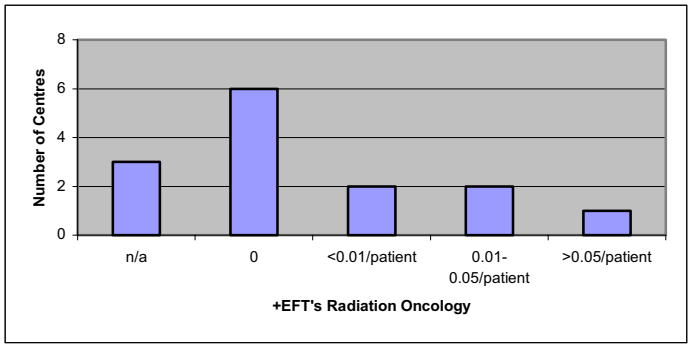
Question 5(c) - Additional EFT's (equivalent full-time) required for electronics support?



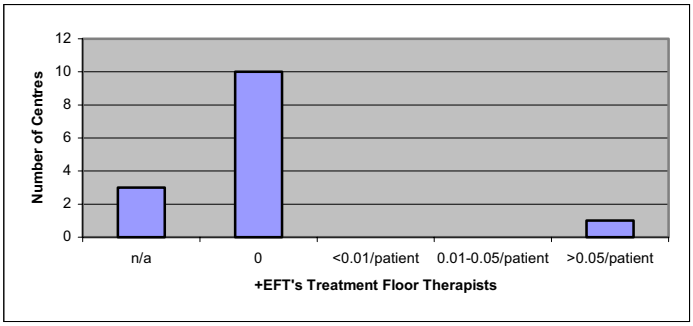
Question 5(d) - Additional EFT's (equivalent full-time) required for treatment planning ('dosimetrists')?



Question 5(e) - Additional EFT's (equivalent full-time) required for radiation oncology?



Question 5(f) - Additional EFT's (equivalent full-time) required for treatment floor therapists?



Summary of results from Question 5:

This series of questions is very difficult to answer with any degree of accuracy. It is difficult to track or estimate time requirements for the various disciplines. Furthermore, some centres indicated that they consider IMRT a standard of care, that should be striven for by existing staff (ie. without hiring of additional staff). Please interpret cautiously with large grains (boulders) of salt!

Possibly along this line of thought (that IMRT is a standard of care), several centres indicated that no extra physics positions were required for their IMRT program implementation. However, many (5) indicated somewhere in the range of 0.01-0.05 physicists per patient were needed. Several (4) centres indicated that they did not need additional physics assistants, while many (4) centres did not respond to this question. However, some centres in Canada do not use physics

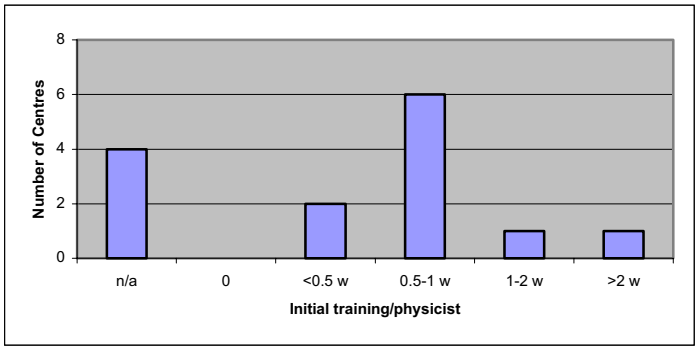
(Continued on page 58)

IMRT Survey Results… (Continued from page 57)

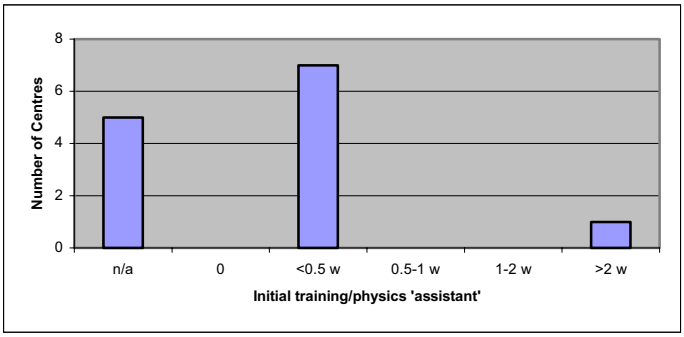
'assistants' at all, so this could be a factor in the responses. Other centres did indicate additional physics assistants on the order of 0.01-0.05/patient (3) or even >0.05/patient (2). Most centres (8) indicated there was no need for an increase in electronics support for IMRT program implementation, or did not answer (4). Similar results were obtained for additional treatment planners, where 6 centres indicated there was no need and 3 centres declined to answer. The remaining centres gave a broad range of responses. Nearly identical results were obtained for the radiation oncology staffing. Regarding treatment floor therapists, most (10) centres indicated there was no need for additional human resources, while 3 centres did not answer.

Question 6 — IMRT training typically required (not including primary physicist setting up program)

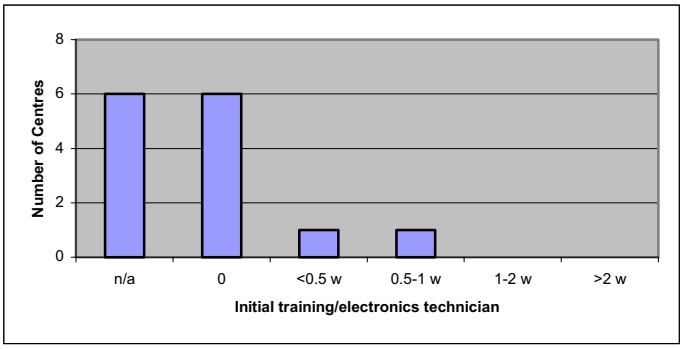
Question 6(a) - Initial IMRT specific training required per physicist?



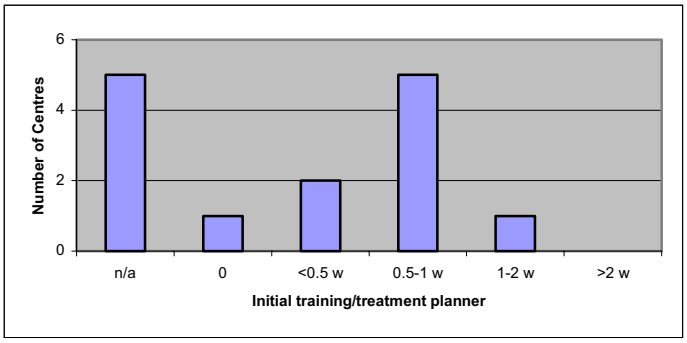
Question 6(b) - Initial IMRT specific training required per physics 'assistant'?



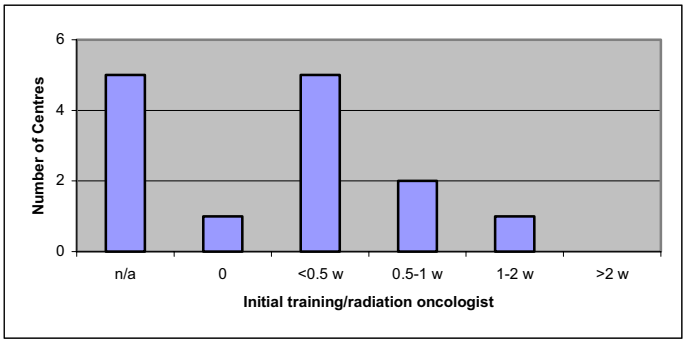
Question 6(c) - Initial IMRT specific training required per electronic support technician?



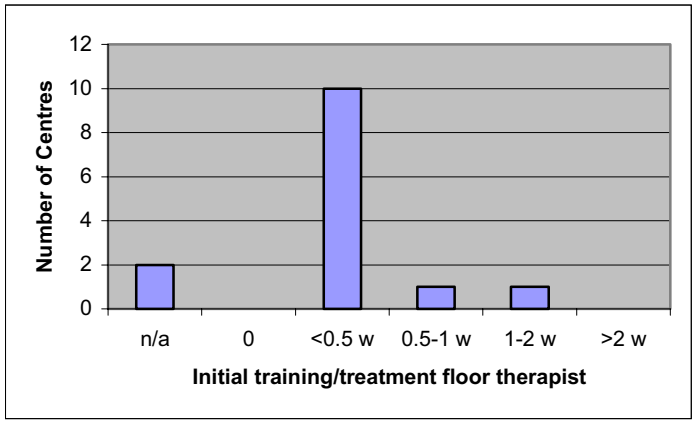
Question 6(d) - Initial IMRT specific training required per treatment planner (dosimetrist)?



Question 6(e) - Initial IMRT specific training required per radiation oncologist?



Question 6(f) - Initial IMRT specific training required per treatment floor therapist?



Summary of results from Question 6:

This question had a large number of 'no answers' (n/a). This may be due to respondents exhaustion at this point, or perhaps due to the difficulty in estimating some of these requirements. For example, how much training is 'adequate' for a particular position will likely vary somewhat between centres.

Most centres (6) indicated that initial physics training of approximately 0.5-1 week was used. Physics 'assistant' training was primarily set at less than 0.5 weeks. Electronics support training was deemed by most centres as unnecessary (6), corresponding to results from question 5(c). Treatment Planner training was mostly (5) indicated to be 0.5-1 week. Radiation oncology training was mostly (5) less than 0.5 weeks. Finally, Treatment Floor Therapist training was mostly (10)

(Continued on page 80)

Report on the Forum of Physics Education

Submitted by Gino Fallone
Cross Cancer Institute,
Edmonton, AB

On the initiative of Dr. William Hendee, a three day Forum of Physics Education was organized by Drs. Hendee and Herbert Mower under the auspices of the American Association of Physicists in Medicine was held in Atlanta on January 20-22, 2006. It involved discussion of Physics education to Radiologists, Medical Physicists and Radiation Oncologists, with the participation of all the major educational, professional and scientific organizations representing these three disciplines. Organizations that send representatives to the Forum were expected to cover the travel and lodging expenses of participants; the AAPM would pay the costs of hosting the Forum, breakfasts, lunches and refreshments. Participating organizations included the AAPM, ASTRO, CAMPEP, CCPM, COMP, a3CR2, AUR, ABMP, ABR, ACGME, ACMP, ACR, APCR, APDR, APDR,, ARRO, ARRS, CAMPEP, ICTP, and RSNA. Canadian participants included Brenda Clark (CAMPEP), Gino Fallone (CCPM,COMP) and Ervin Podgorsak (AAPM facilitator).

The purpose of the Forum was to develop a strategy to improve the physics and engineering education of specialists in each of these disciplines. The science and technology employed by these disciplines is rapidly becoming more complex and more integrated, and there is every reason to believe that this trend will continue well into the future. For several reasons, the education of residents and physics students may not be keeping pace with this trend. In addition, some practicing radiologists, medical physicists and radiation oncologists are struggling to keep pace with the evolving technology and complexity of their disciplines. It is felt that a new strategy may be required to educate residents and practitioners in the physics and engineering (or 'technology') of their disciplines. The purpose of the Forum was to develop this strategy, including its conceptualization and the details of its deployment.

The three days of the Forum were divided up in the following manner: the first day was devoted to the physics education of radiologists, the second day devoted to the physics education of medical physicists, and the third day devoted to the physics education of radiation oncologists. Each organizational representative could have participated in all three days or only that day of the Forum that addressed their particular interests. Each day was divided up into four sessions that were each introduced by an invited speaker on a particular topic. For each session, each representative was assigned to one of five groups. Each group was given the task of discussing a different aspect of the particular topic. Each group was lead by an AAPM supported physics facilitator who then gave a detailed report to the general audience at the end of each session. Each day ended with a summary and conclusions resulting from discussions of that day.

Particular topics for each of the days are summarized below with the name of the speaker:

Physics Education of Radiologists

- Appraisal of Physics Education of Radiologists (Hendee)
- AAPM Proposed Program for Physics Education of Radiologists (Massoth)
- Expectations of Physics Knowledge for Certification (Bednarek)
- Challenges to Implementing the AAPM Proposed Program (Mower)
- Discussion on the Strategies to Meet the Challenges

It was obvious from the discussions that this was now an opportune time for medical physicists to help radiologists learn the basic physics essential for radiologists to practice their discipline safely in a cost-effective manner. The challenges include the identification of what should be the breadth and depth of physics training with an emphasis on the clinical relevance. To meet this challenge, the physicist and radiologist are to work together to develop a standard curriculum by tying together the ABR certification syllabus with the AAPM curriculum of training physics to radiologist. This work is to continue to reflect the activities of ABR's process of Maintenance of Certification (MOC).

The radiologists of the group felt that improvements can be made to the way physics knowledge is assessed in the certification process. Some ideas included having a radiology resident on the committees, increase the communication to the resident directors on what is required for the examination, make the physics questions more clinically relevant and perhaps consider adding physics-type questions in the written and /or oral clinical part of the examination. The actual style of teaching physics to radiologists was also discussed. The introduction of teaching modules, either paper-based, computer-based or web-based, would be a welcomed addition for radiology residents who may need review of basic physics principles at their own pace. A major challenge for physics instructors involves the quality of their teaching: in some cases, there may be a need for significant improvement. Many felt that the approach to teaching physics where the image is the starting point, not the end point, may have significant positive effect on the understanding of physics by residents. However, it was also recognized that physics instructors are often not given sufficient time to teach, nor are they sufficiently recognized in the promotion process for their teaching to radiology residents. It was also indicated that there must be demonstrated support from the Radiology Chair and Radiology Resident Coordinator of the teaching and importance of physics to the radiology resident. It was felt that the lack of support presently existing in many centers from senior radiology staff towards the teaching of physics to radiology residents is a major hindrance to the proper education of physics to the radiology resident.

Physics Education of Medical Physicists

- Appraisal of Physics Education of Medical Physicists (Hendee)
- CAMPEP Program for Physics Education of Medical Physicists (Clark)

(Continued on page 75)

Photodynamic therapy dosimetry:

Estimating dose from fluorescence, photobleaching, and photoproduct formation.

By Jonathan S. Dysart
Juravinski Cancer Centre,
Hamilton, ON

PROLOGUE

This article is not intended to give a detailed review of PDT or current PDT dosimetry techniques. Several excellent review articles on the subject have recently been published and are included in the references below.[1,2] As well, the reader can refer to the April 2004 issue of InterACTIONS for a general review of PDT written by Dr. Michael Patterson.

INTRODUCTION

Photodynamic therapy (PDT) was first approved for clinical use in Canada in 1993. Despite a significant amount of research and clinical trials world wide, PDT remains a somewhat novel approach to treating cancer. One factor which has impeded its acceptance has been a lack of sufficient dosimetry. PDT works by the generation of singlet oxygen in tissue as a result of the excitation of a photosensitizer by light. Determining the 'dose' during PDT is challenging because the amount of singlet oxygen generated depends on multiple factors, including the amount and distribution of sensitizer, light, and oxygen in the tissue. All of these parameters can change during treatment and can be highly variable among patients and within the treatment volume. Some of these modifying factors are listed in figure 2.

Standard clinical PDT protocol does not attempt to estimate the amount of singlet oxygen generated, but relies only on the amount of administered photosensitizer and fluence of incident light (figure 1). This approach does not account for variations in tumor sensitizer concentration, tissue oxygenation, or tissue optical properties. As a result, the amount of singlet oxygen generated during treatment may be insufficient to achieve a tumor response.

There is a wide body of evidence that suggests individualized dosimetry can greatly improve the predicted therapeutic outcome. Measurements of *in situ* photosensitizer concentration in the treatment tissue can improve the estimate of PDT dose by correcting for patient to patient variations, but this alone cannot fully characterize PDT dose. The variation in optical properties of the tissue can have a significant impact on the light fluence where, for example, tissue fluences have been found to vary by more than a factor of four for the same incident light fluences in cancers of the head and neck.[3] Tumor response also depends on tissue oxygenation, where high sensitizer concentrations and/or high fluence rates have been shown to consume oxygen at such a high rate that PDT efficacy is limited by the resulting hypoxia.[4] It is apparent that true 'explicit' dosimetry is challenging because of the requirement to measure all three of these parameters during treatment.

An alternative strategy to estimate PDT dose has been proposed and termed 'implicit dosimetry'.[5] Implicit dosimetry relies on the assumption that a single parameter can be correlated to therapeutic outcome, thereby eliminating the need to measure sensitizer concentration, light fluence, and oxygenation

(Continued on page 61)

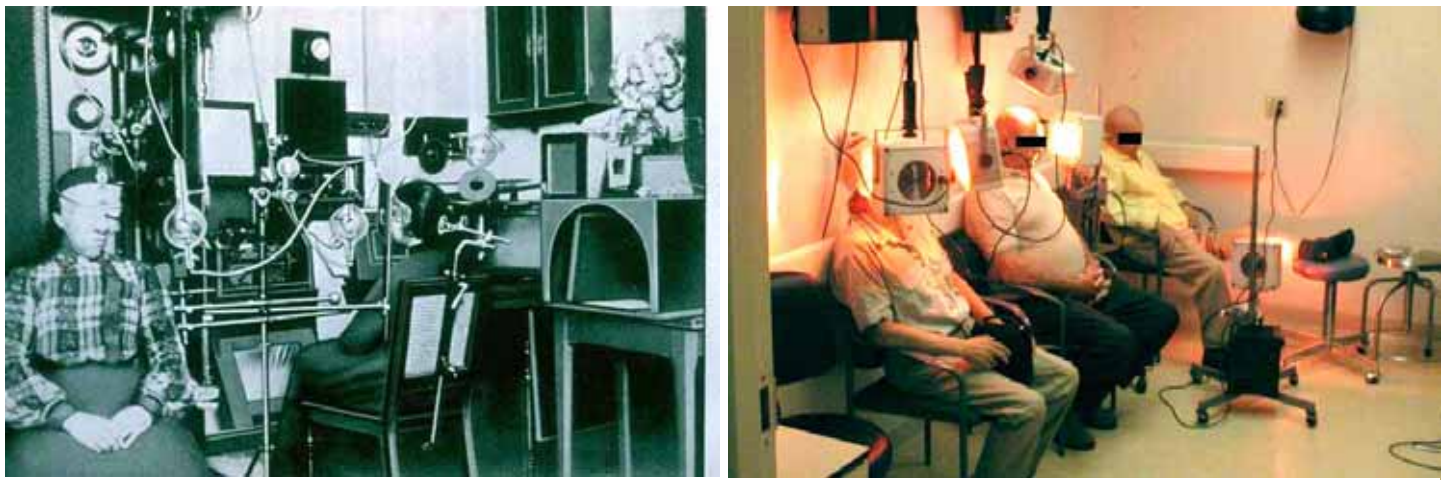


Figure 1: The striking similarity between a radiation treatment suite circa 1910 and a modern PDT treatment suite in 2001. The therapeutic effects of ionizing radiation and PDT were both realized at the beginning of the 20th century. Radiation therapy dosimetry has advanced considerably, but PDT dosimetry has remained virtually unchanged since its discovery. Left: A radiation treatment suite in Munich in 1910, complete with primitive shielding (© Radiology Centennial, Inc.). Right: A PDT treatment suite at the London Regional Cancer Centre in 2001, photo courtesy of Kevin Jordan, LRCC.

independently. The aim of this study has been to assess PDT induced damage to the photosensitizer, known as photobleaching, as a potential implicit dose metric (figure 3). Photobleaching can be measured through changes in absorption or fluorescence. Our work has been based on changes in fluorescence, since this is an easier measurement to make clinically. Fluroescence detection is used clinically for photodynamic diagnosis (PDD) where high tumor selectivity and strong photosensitizer fluorescence are used to differentiate tumor margins (figure 4). Fluorescence photobleaching can be readily mesaured *in vivo* and clinical implemnetation is technically feasible. It is reasonable to assume that a correlation between photobleaching and biological damage exists since both may depend on the generation of singlet oxygen. Additional dosimetry information may be obtained when the reaction of singlet oxygen with the sensitizer results in a fluorescent photoproduct. Photoproducts may be appropriate for dosimetry provided that their generation depends on the production of singlet oxygen and that they are stable.

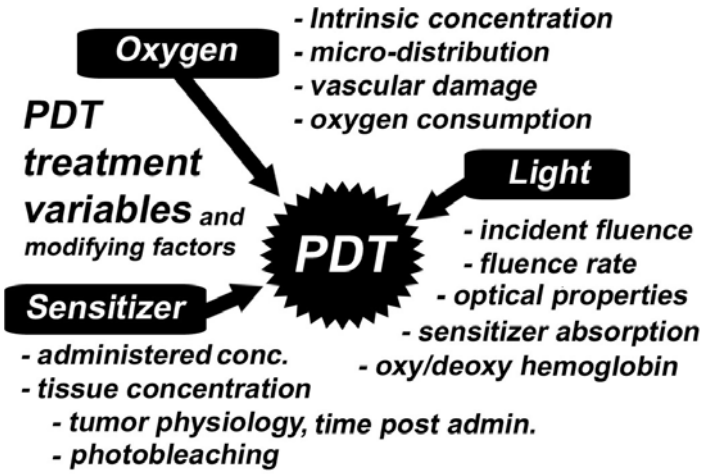


Figure 2: PDT relies on the availability of sensitizer, light, and oxygen. These parameters are dynamic during treatment and can be modified by an array of treatment and tissue dependent factors.

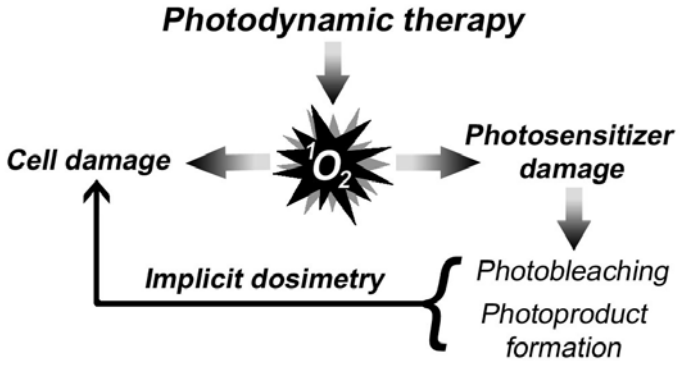


Figure 3: Photobleaching and photoproduct formation should yield information about cell damage since they all depend on singlet oxygen generation.

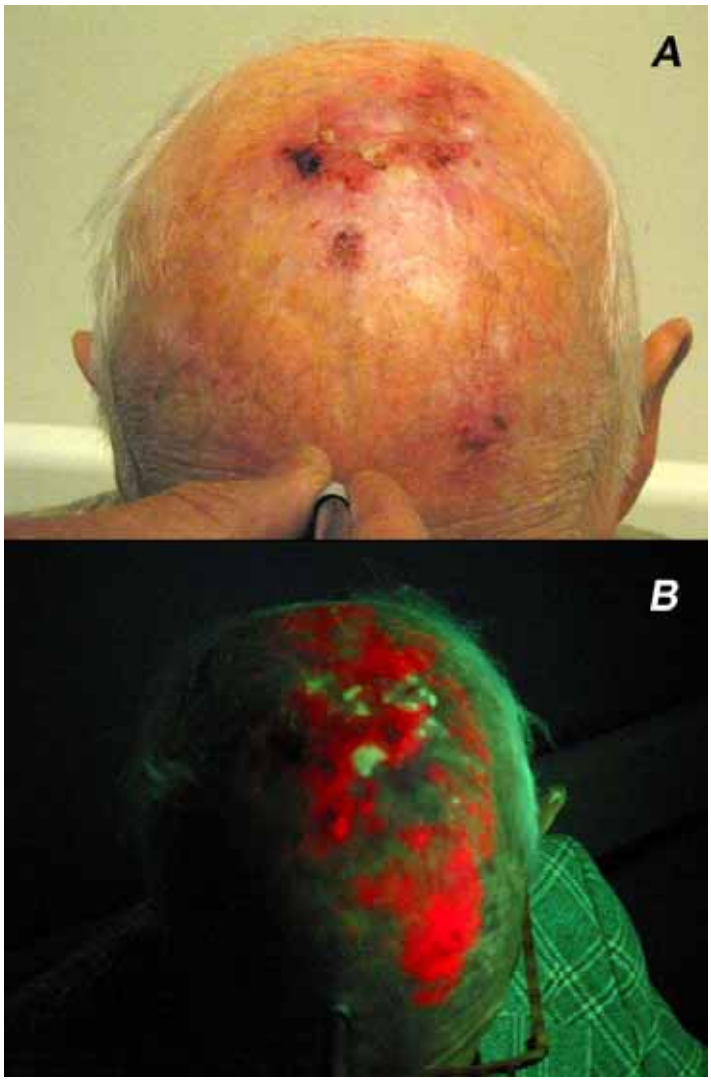


Figure 4: **(A)** A white light and **(B)** fluorescence image of a BCC on the scalp after topical application of ALA. The picture illustrates that photosensitizer fluorescence is easily detectable. Photos courtesy of Kevin Jordan, LRCC.

This paper will highlight our work investigating fluorescence photobleaching of three photosensitizers: meta-tetra (hydroxylphenyl)chlorin (mTHPC, Temoporfin or Foscan), Porfimer sodium (Photofrin), and δ-aminolevulinic acid (ALA, Levulan).[6-8] The latter is itself not an exogenous photosensitizer, but is converted to the photosensitizer protoporphyrin IX (PpIX) in the mitochondria via the heme biosynthetic pathway when present in excess in the cell. These sensitizers were chosen because they are the three most commonly used sensitizers for clinical PDT. The specific aims of these studies are twofold: first, to characterize the photobleaching of these sensitizers for a wide variety of treatment conditions so that an appropriate dose model relating photobleaching and singlet oxygen generation can be developed, and second, to confirm the validity of the dose metric(s) in a biological system. In addition, the photoproducts of Photofrin and ALA-PpIX PDT have been assessed as potential dose metrics.

(Continued on page 65)

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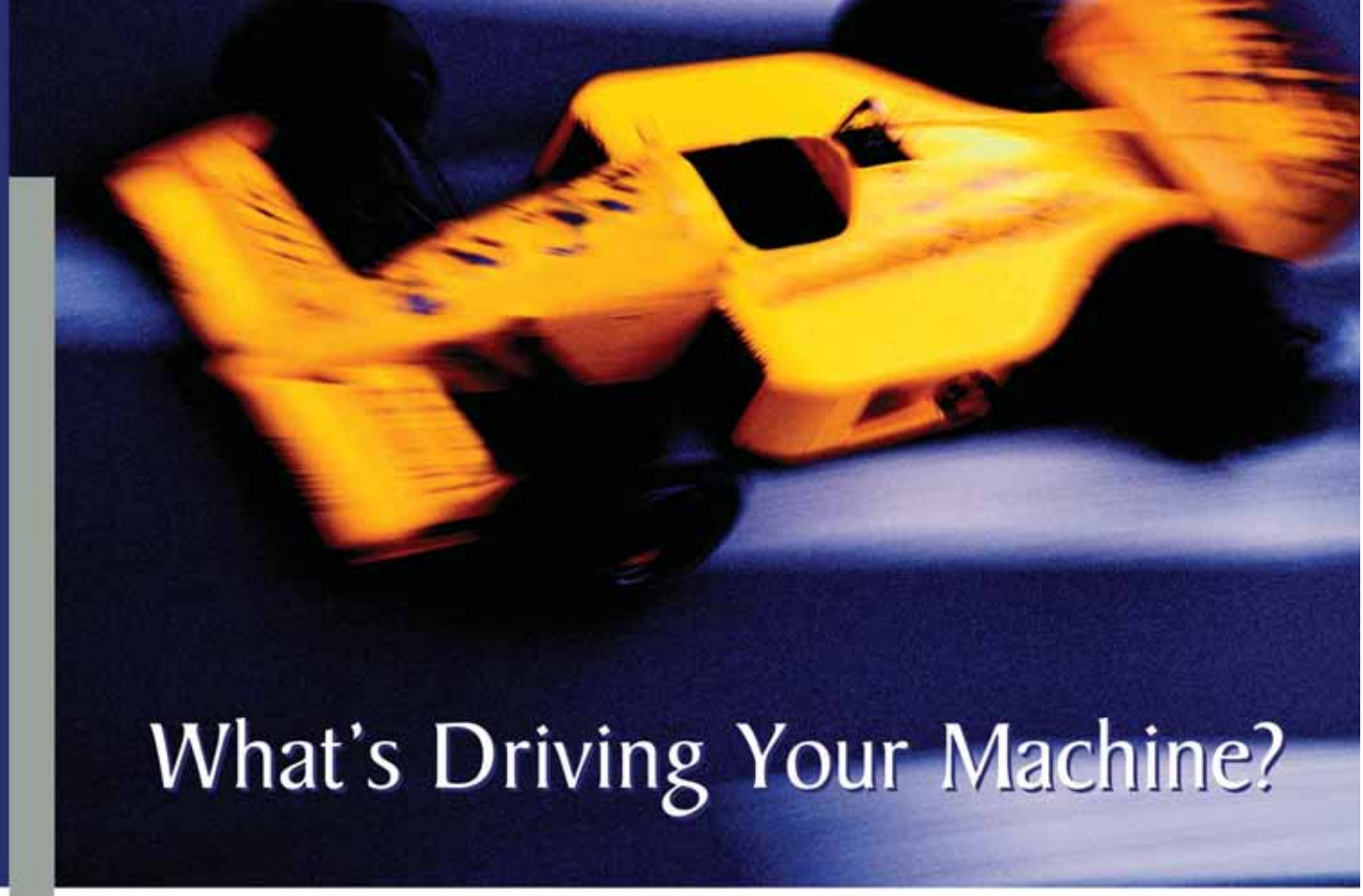

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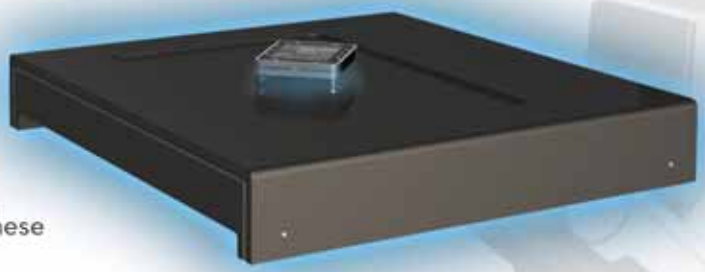

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Photodynamic Therapy Dosimetry... (Continued from page 61)

THEORY

Developing a fluorescence based singlet oxygen dose metric relies on choosing the proper expression that relates fluorescence, or changes in fluorescence, to singlet oxygen generation. Since photosensitizer photobleaching is, at least in part, a result of singlet oxygen interactions, photobleaching kinetics should form an appropriate basis for the metric. Some photosensitizers can photobleach via mechanisms other than singlet oxygen reactions. I will discuss later how the extent of non-singlet oxygen mediated bleaching can profoundly complicate the proposed dose metric. For mTHPC, the bleaching is exclusively mediated by singlet oxygen, so I will develop the dose model for this simplest case first, and later extend the result to the more complex case of Photofrin.

It can be shown experimentally that the photobleaching of mTHPC can be described by the following kinetic equation:[6]

$$\frac{d[S_0]}{dt} = -k_{os}\left([S_0]+\delta\right)\cdot[{}^1O_2] \qquad (1)$$

where $[S_0]$ and $[{}^1O_2]$ are the concentrations of ground state photosensitizer and singlet oxygen, and k_{os} is the rate constant for their reaction. The constant δ is equal to the concentration of S_0 where the average intermolecular spacing between sensitizer molecules is equal to the diffusion distance of singlet oxygen. This constant is required because of the co-localization of S_0 and ${}^1O_2$, since ${}^1O_2$ is always generated in close proximity to a sensitizer molecule as a result of an energy transfer reaction between an excited state (triplet) sensitizer molecule and ground state oxygen. The co-localization requires the bleaching kinetics to depend on sensitizer concentration. At very low sensitizer concentrations singlet oxygen can only react with the sensitizer molecule with which it was generated, and the resulting kinetics are first order. At high sensitizer concentrations singlet oxygen can diffuse to and react with other adjacent sensitizer molecules and the kinetics are second order. Interestingly, the dependence of bleaching rate on sensitizer concentration can be used to determine δ, and therefore obtain an estimate of singlet oxygen diffusion distance and lifetime.

Since PDT dose is a result of the generation of singlet oxygen, the dose can be defined as the total amount of singlet oxygen produced during treatment:

$$Dose = \frac{1}{\tau_\Delta}\int_0^T [{}^1O_2](t)\,dt \qquad (2)$$

where $[{}^1O_2]$ is the instantaneous concentration of singlet oxygen and τ_Δ is the singlet oxygen lifetime and T is the total treatment time. If equation 1 is arranged in terms of $[{}^1O_2]dt$ and substituted into equation 2, solving the integral for singlet oxygen dose gives:

$$Dose = \frac{1}{\tau_\Delta k_{os}}\ln\left[\frac{[S_0](0)+\delta}{[S_0](T)+\delta}\right] \qquad (3)$$

where the *relative* dose can be estimated from knowing only the initial and final concentrations of sensitizer and the constant δ. The dose estimate can be further simplified by making the assumption that the fluorescence quantum yield remains constant during treatment. In this case $[S_0]$ is proportional to the measured fluorescence, $F(t)$, and the expression for dose can be written as:

$$Dose \propto \ln\left[\frac{F(0)+\delta^*}{F(T)+\delta^*}\right] \qquad (4)$$

where δ^* is the fluorescence corresponding to the concentration δ. The constant δ^* can easily be determined during treatment by measuring the rate of fluorescence photobleaching at two photosensitizer concentrations (i.e. by measuring the photobleaching in at least two locations where the concentration varies).

Equation 4 is valid only if the bleaching is mediated exclusively by singlet oxygen. This is not the case for Photofrin and ALA-PpIX, where these sensitizers have been shown to photobleach in the absence of oxygen (i.e. no singlet oxygen generated). It is believed that this non-singlet oxygen mediated bleaching is a result of reactions of the triplet excited state sensitizer molecule, and is referred to as triplet mediated bleaching. Fluorescence photobleaching can still be used to calculate singlet oxygen dose

(Continued on page 66)

Table 1: A summary of results of the studies investigating mTHPC, Photofrin, and ALA-PpIX.

Sensitizer	Range of [PS]	λ_{trt} / λ_{ex}	Summary of photobleaching kinetics	Reference
mTHPC	0.05 - 1.0 µg/mL	652 nm / 532 nm	Simple – oxygen required for bleaching. No fluorescent photoproducts.	J. S. Dysart, G. Singh, and M. S. Patterson, *Photochem. Photobiol.*, 2005, 81, 196-205.
Photofrin	1 - 25 µg/mL	532 nm / 532 nm	Complex – oxygen not required for bleaching (photosensitizer triplet mediated). Fluorescent photoproduct is photochemically stable.	J. S. Dysart and M. S. Patterson, *Phys. Med. Biol.,* 2005, 50, 2597-2616.
ALA-PpIX	0.1 - 1.0 mM	532 nm 635 nm / 532 nm	Complex – oxygen not required for bleaching. At least two fractions of PS, each with different bleaching kinetics. Several fluorescent photoproducts, at least one is also a photosensitizer. One photoproduct is stable and may be used for dosimetry.	J. S. Dysart and M. S. Patterson, *Photochem. Photobiol. Sci*., 2006, 5, 73-81.

Photodynamic Therapy Dosimetry... (Continued from page 65)
in these cases, but the expression for dose becomes more complex than that given in equation 4. The modified dose expression requires a correction to account for the loss of fluorescence not attributed to singlet oxygen. Unfortunately, this correction requires a time dependent measure of oxygen concentration, and therefore the implicit dosimetry approach does not represent a significant advantage over explicitly monitoring the treatment parameters. For full details of this dose metric, please refer to reference 7.

MATERIALS AND METHODS

The following section gives brief details of the materials and methods used in three separate studies of the sensitizers mTHPC, Photofrin, and ALA-PpIX. For complete details please refer to the references in table 1.

Chemicals
mTHPC (Scotia Pharmaceuticals, Surrey, UK): A 2 mg/mL stock solution was made by dissolving the sensitizer in a solution of 20% ethanol, 30% polyethylene glycol, and 50% water. Further dilutions were made with cell medium supplemented with 10% fetal bovine serum (FBS). Photofrin (Axcan Pharma Inc., Quebec): A 2.5 mg/mL stock solution was prepared in phosphate buffered saline (PBS). Further dilutions were made in cell medium supplemented with 10% FBS. ALA (Sigma-Aldrich, St. Louis, USA): A 10 mg/mL stock solution was made in PBS. Further dilutions were made in cell medium supplemented with 20 mM Hepes buffer and without FBS.

Cell culture
Photodynamic therapy was done *in vitro* so that the treatment parameters could be individually controlled and monitored. This allowed us to explicitly test the dependence of the proposed dose metrics on each treatment parameter. MatLyLu (MLL) rat prostate adenocarcinoma cells were grown in cell media containing either mTHPC (0.05 to 1.0 µg/mL), Photofrin (1 to 25 µg/mL), or ALA (0.1 or 1.0 mM). Cells were incubated in the dark for either 18 hours (mTHPC and Photofrin) or four hours (ALA). After this time, the medium was removed, the cells were washed with PBS, and removed from the plate using trypsin. The resulting suspension was centrifuged, and the cell pellet was re-suspended in PBS to a concentration of 2 $x10^6$ mL^{-1}.

Irradiation apparatus and procedure
The PDT irradiation apparatus is shown in figure 5. Two milliliters of cell suspension were put in a 4 mL cuvette. The cells were kept in suspension using a miniature magnetic stir bar. Treatment and fluorescence excitation light were delivered to the cuvette via fiber optics terminated with collimating lenses. Fluorescence was collected with a lens coupled fiber perpendicular to the excitation light. At selected times during treatment, 50 µL cell samples were withdrawn from the cuvette and diluted in 10 mL of cell medium. A volume was plated in triplicate in six well tissue culture dishes so that the total number of surviving colonies would not exceed 400. After 4 days of dark incubation, the colonies were fixed and stained with methylene blue dye. Colonies were counted with a light microscope.

Light sources
The treatment light source for mTHPC was a 652 nm fiber coupled diode laser (Photonics Research Ontario, Toronto), capable of a maximum output power of 200 mW. For fluorescence measurements, the excitation source was a 532 nm diode pumped frequency doubled single mode laser (Alphalas GmbH, Germany) with an output of ~60 mW. For Photofrin and ALA PDT, this laser was used for both treatment and fluorescence excitation. Light fluence rates were measured using a handheld optical power meter at the incident face of the cuvette.

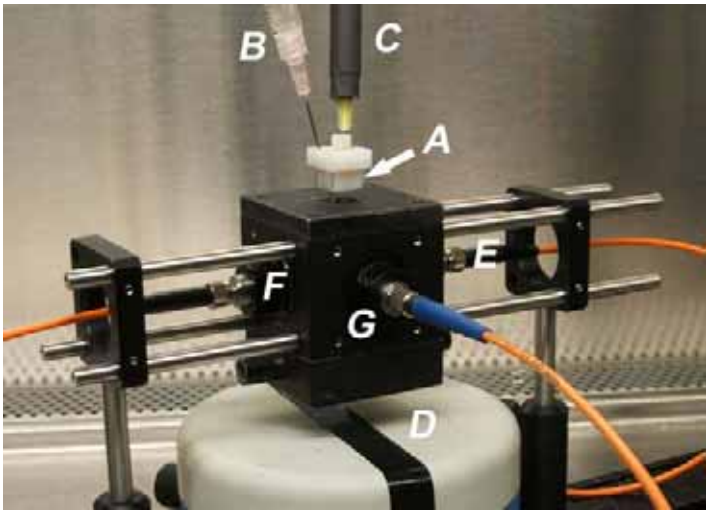

Figure 5: Experimental apparatus. The cell suspension was contained in a 4 mL cuvette (A) with a specially designed stopper to hold a nitrogen gas supply (B) and an oxygen electrode (C). The cells were kept in suspension with a miniature stir bar and a magnetic stirrer (D). Treatment and fluorescence excitation light were delivered via lens coupled fibre optics (E,F) and fluorescence was collected with a lens coupled fibre (G). Experiments were done in a sterile laminar flow hood.

Oxygen depletion and measurement
Oxygen pressure was reduced by flowing 100% nitrogen gas into the cuvette. Oxygen concentration was determined with a Clark style oxygen electrode (Diamond general corp., MI). Complete oxygen depletion typically occurred within 30 minutes of nitrogen flow.

Analysis of fluorescence and photobleaching
Fluorescence spectra from the sample were collected via a lens coupled fibre to a USB2000 Ocean Optics spectrometer (Ocean Optics Inc., Dunedin, USA) with a spectral range of 600 – 890 nm. Typically, spectra were acquired every 30 seconds and acquisition time was less than one second. For mTHPC, photobleaching was uniform over the entire fluorescence spectrum and no changes in spectral shape were observed during treatment. Fluorescence was quantified by the integral of the fluorescence spectra between 630 and 680 nm after correcting for autofluorescence. The complex photobleaching of Photofrin and PpIX required a more rigorous analysis of fluorescence photobleaching. For these sensitizers, basis spectra were obtained for each contributor to the overall fluorescence spectrum. The basis spectra included the spectra from the sensitizer, fluorescent photoproduct(s), and cell/instrument autofluorescence. The basis spectra were fit to the acquired spectra using a singular value decomposition (SVD) fitting

(Continued on page 67)

Photodynamic Therapy Dosimetry... (Continued from page 66)
routine implemented in MatLab (The Mathworks, Mass., USA). Fluorescence of the photosensitizer and photoproducts were quantified by the weights of the respective basis spectra in the fit.

RESULTS

A brief summary of the findings of this work are given in table 1. The results presented in this article represent a highlight of the important findings of this work. For complete results please refer to references 6-8.

Cell survival

Figure 6 shows typical MLL cell survival curves obtained during PDT with mTHPC. Similar curves have been generated for PDT with Photofrin and ALA-PpIX. Under well oxygenated conditions, higher incubation concentrations exhibited increased cell kill. Limited cell killing was observed under conditions of hypoxia, and varying the fluence rate had no effect on survival for the range of fluence rates tested (squares).

Fluorescence and photobleaching

The fluorescence spectra of mTHPC, Photofrin, and PpIX are shown in figure 7. Typical fluorescence photobleaching curves for mTHPC are shown in figure 8. Photobleaching was independent of treatment fluence rate, but higher rates of bleaching were found for higher sensitizer concentrations, as predicted by equation 1. Photobleaching was significantly reduced for experiments done under hypoxic conditions, demonstrating the requirement of singlet oxygen for photobleaching. For Photofrin and ALA-PpIX, significant photobleaching was observed in the absence of oxygen, as illustrated in figure 9 with Photofrin. Under hypoxic conditions, Photofrin photobleaching was independent of concentration. Under well oxygenated conditions, the bleaching rate increased with increasing concentration. ALA-PpIX photobleaching exhibited complex kinetics that could not be described using equation 1. It is likely that the photosensitizer localized in different compartments within the cell and the unique kinetics for each compartment confounded the fluorescence measurement.

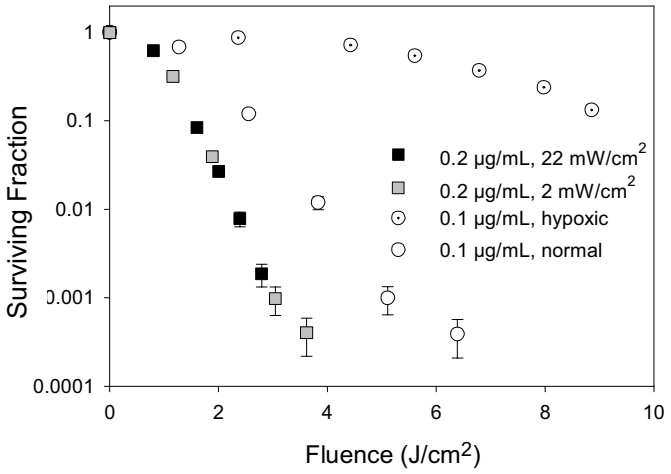

***Figure 6**:* MLL cell survival determined by colony formation assay versus light dose for mTHPC PDT. Cells were incubated in mTHPC for 18 hrs and treated with 652 nm light.

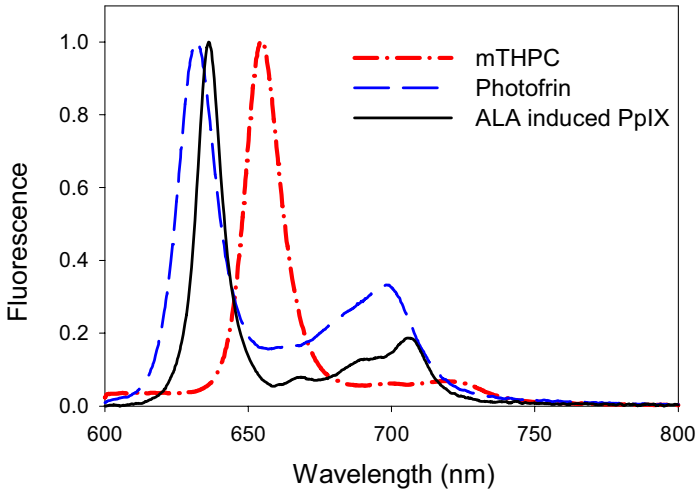

Figure 7: Fluorescence spectra of photosensitizers used in this study. Fluorescence was excited with 532 nm light. Spectra are not corrected for instrument response.

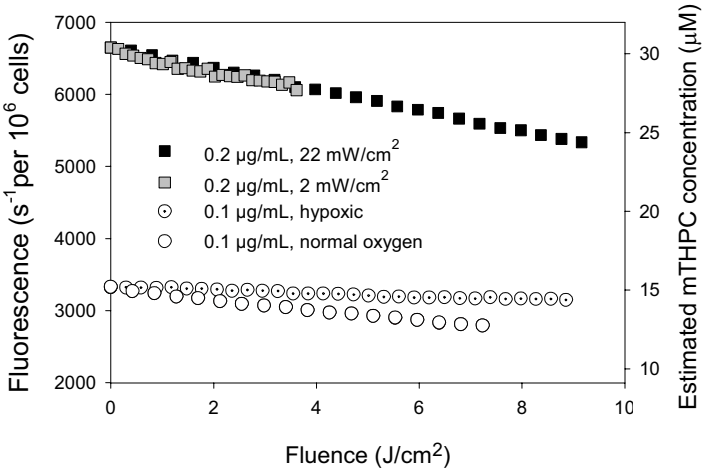

Figure 8: Fluorescence photobleaching of mTHPC during PDT. Right axis gives the estimated intracellular concentration.

Estimating PDT dose

Figure 10 shows MLL cell survival versus PDT dose calculated explicitly as the product of photosensitizer concentration and light fluence. A single curve can be fit to the data relating survival to dose, independent of sensitizer concentration and light fluence rate, but dose is significantly overestimated for experiments done under hypoxia. This illustrates the requirement to measure oxygen for explicit dosimetry to fully characterize PDT dose. If the implicit dose metric is used to calculate dose, survival is accurately predicted even under conditions of hypoxia (figure 11). All variations in the treatment parameters are incorported in the calculated dose by using only the initial and final sensitizer fuorescence and the constant δ.

Absolute singlet oxygen dosimetry

Although unpractical and unnecessary for clinical dosimetry, one of the most interesting developments of this work is the ability to estimate the absolute amount of singlet oxygen generated during treatment (equation 3). Experiments were done to calibrate measured fluorescence to intracellular photosensitizer concentration, as seen on the right axis of

(Continued on page 68)

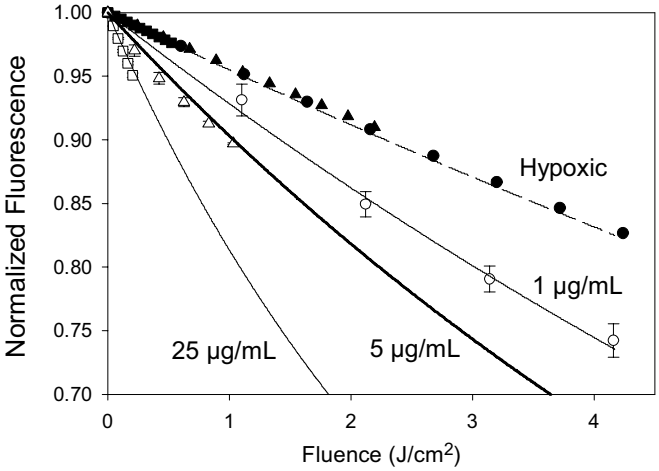

Figure 9: Fluorescence photobleaching of Photofrin during PDT. PDT was performed under well oxygenated (open circles) or hypoxic (closed symbols) conditions.

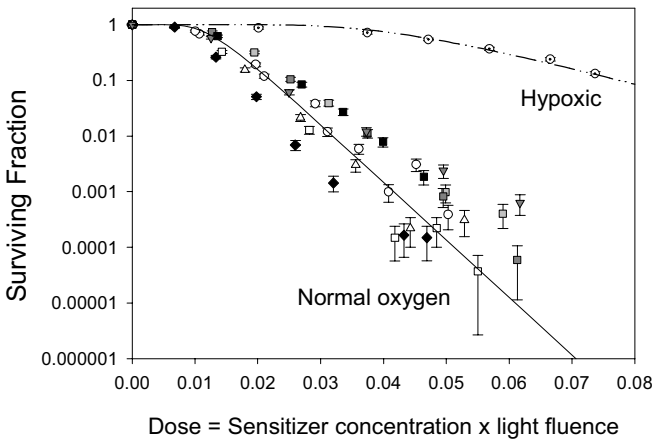

Figure 10: MLL surviving fraction versus an 'explicit' estimation of PDT dose (sensitizer concentration x light fluence) for mTHPC PDT. PDT was done for a wide range of treatment conditions. A single curve could be fit to all the data, except the experiments done under hypoxic conditions.

figure 8. The absolute sensitizer concentrations and photobleaching rates were used to give an estimate of δ of ~33 µM for mTHPC and 390 µM for Photofrin. This translates into an estimated singlet oxygen lifetime of 0.10 ± 0.05 µs, consistent with other estimates of singlet oxygen lifetime in the literature. The constant ($\tau_\Delta k_{os}$) can be estimated by making some assumptions about the photochemistry and available photochemical data (the full details can be found in reference 1). Using these numbers, the absolute amount of singlet oxygen generated during treatment has been calculated for mTHPC and Photofrin as shown in figure 12. The data have been acquired for a large range of treatment conditions. A survival curve fit to this data gives a singlet oxygen dose required to reduce the survival fraction by 1/e of 1.6 ± 0.3 and 0.3 ± 0.2 mM for mTHPC and Photofrin respectively. The differences in these numbers are not necessarily unexpected since mTHPC and Photofrin localize in different parts of the cell and therefore the cellular targets may be different. The calculated singlet oxygen doses are consistent with estimates of singlet oxygen dose derived from oxygen consumption measurements in the cell

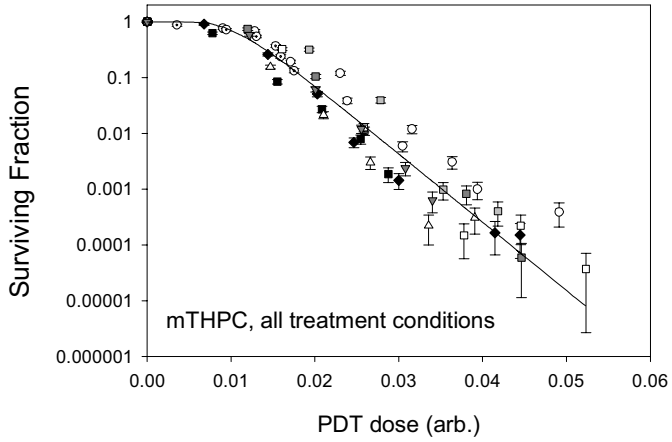

Figure 11: MLL surviving fraction versus PDT dose calculated using equation 4. Cell survival correlated well to calculated dose independent of all treatment conditions.

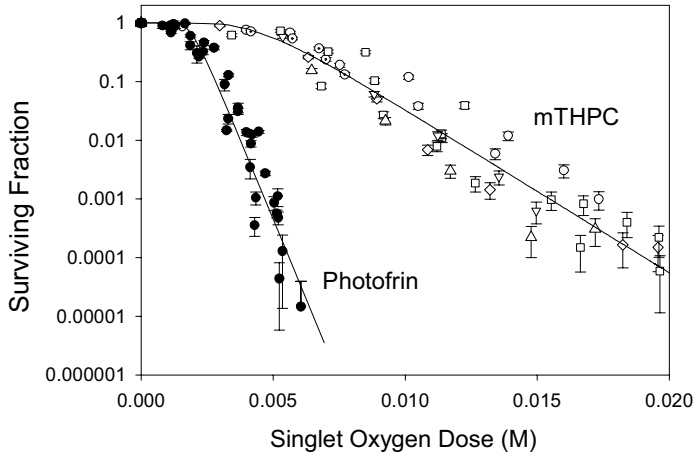

Figure 12: MLL cell survival versus singlet oxygen dose calculated using equation 5 (mTHPC) and a modified version of equation 5 for Photofrin (equation not shown, see reference 2). The data are fit by a single hit multiple target cell survival model.

medium. As well, these estimates of singlet oxygen dose are remarkably close to other published studies, especially considering that different sensitizers, cell lines, and biological assays have been used.

Photoproducts

Figure 13 shows the fluorescence spectra of several photoproducts generated during Photofrin and ALA-PpIX PDT. For Photofrin, the photoproduct (curve C) correlated well to cell survival for PDT under well oxygenated conditions. However, it was also generated during hypoxic treatments, indicating that the photoproduct is not exclusive to singlet oxygen mediated reactions, and is therefore unreliable as a singlet oxygen dose metric. For ALA-PpIX PDT three photoproducts were identified. The main photoproduct (curve h) was identified as photoprotoporphyrin (Ppp), a photosensitizer which undergoes singlet oxygen mediated photobleaching. A second photoproduct (curve g) appeared only during well oxygenated treatments and correlated well to cell survival (figure 14).

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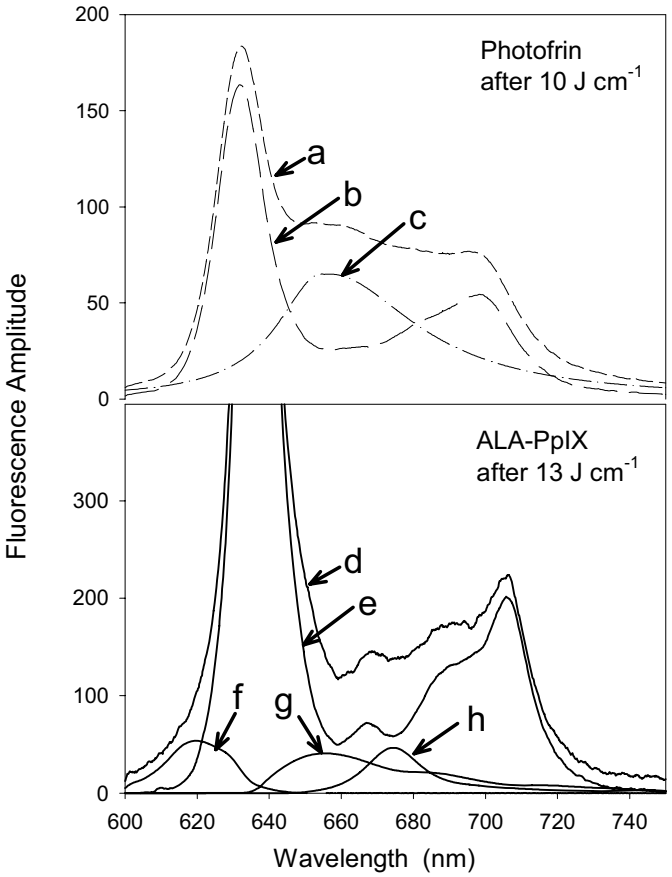

Figure 13: Fluorescent photoproducts of Photofrin (top) and ALA-PpIX (bottom) after PDT performed under well oxygenated conditions. Curves are (a, d) the acquired fluorescence spectrum and the fit fluorescence spectra of the photosensitizer (b, e) and photoproducts (c, f-h).

DISCUSSION AND CONCLUSIONS

The interdependence of photosensitizer concentration, treatment light, and oxygen on singlet oxygen generation makes determining a true clinical PDT dose challenging. Monitoring fluorescence and photobleaching during treatment may potentially be useful as a dose metric. The work presented in this paper used a simplified *in vitro* PDT model to investigate the relationship between photosensitizer photobleaching, singlet oxygen generation, and biological response. The results for each sensitizer varied. For mTHPC, the photobleaching kinetics were straightforward and the dose could be calculated using a relatively simple metric. The kinetics were more complex for Photofrin, and the resulting dose metric required a measurement of oxygen to estimate dose. ALA-PpIX exhibited the most complex photobleaching kinetics and PpIX photobleaching could not be used to estimate cell survival, however a photoproduct of PpIX correlated well to survival and may provide a measure of PDT efficacy.

Despite the simplicity of our biological model, this work suggests that monitoring fluorescence, photobleaching, and photoproduct formation during clinical PDT treatments may be adequate for individualized dosimetry. Of course, extending this work *in vivo* presents additional challenges, including how to

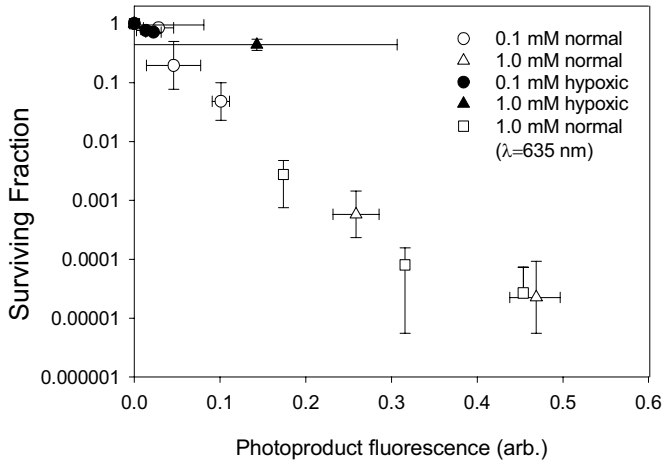

Figure 14: MLL cell survival versus photoproduct fluorescence (identified as curve g in figure 12) for ALA-PpIX PDT. The correlation between survival and photoproduct fluorescence is independent of ALA incubation, oxygenation, and treatment light wavelength.

account for the inhomogeneity of the treatment parameters in tissue and how to correctly interpret the measured fluorescence.[9] One of the biggest challenges *in vivo* will be determining the spatial resolution required to predict local response. These issues may be resolved by testing the dose metric in a pre-clinical animal model where local photobleaching can be compared to local response.

Our current research involves investigating another promising pre-clinical photosensitizer, HPPH (Photochlor), using an *in vitro* model. We will also be developing a system to measure singlet oxygen production directly via singlet oxygen luminescence,[10] which will aid in validating our proposed metrics. In the near future we will be incorporating Photofrin fluorescence measurements during clinical PDT of recurrent non small cell lung cancer in a recently initiated clinical trial at our centre, and it will be particularly interesting to compare the results of this clinical study to those obtained *in vitro*.

ACKNOWLEDGEMENTS

I would like to thank Dr. Mike Patterson, without whose supervision this work could not have been accomplished. This work has been supported by the National Institutes of Health.

SELECTED REFERENCES AND FURTHER READING

1 Z. Huang, A review of progress in clinical photodynamic therapy, *Technol. Cancer Res. Treat.,* 2005, 4, 283-294.

2 J. Moan and Q. Peng, An outline of the hundred-year history of PDT, *Anticancer Res.,* 2003, 23, 3591-3600.

3 I. B. Tan, H. Oppelaar, M. C. Ruevekamp, R. B. Veenhuizen, A. Timmers, and F. A. Stewart, The importance of in situ light dosimetry for photodynamic therapy of oral cavity tumors, *Head. Neck,* 1999, 21, 434-441.

4 D. J. Robinson, H. S. de Bruijn, N. van der Veen, M. R. Stringer, S. B. Brown, and W. M. Star, Fluorescence photobleaching of ALA-induced protoporphyrin IX

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Photodynamic Therapy Dosimetry...(Continued from page 69)

during photodynamic therapy of normal hairless mouse skin: the effect of light dose and irradiance and the resulting biological effect, *Photochem. Photobiol.,* 1998, 67, 140-9.

5 B. C. Wilson, M. S. Patterson, and L. Lilge, Implicit and explicit dosimetry in photodynamic therapy: a new paradigm, *Lasers in Med. Sci.,* 1997, 12, 182-199.

6 J. S. Dysart, G. Singh, and M. S. Patterson, Calculation of Singlet Oxygen Dose from Photosensitizer Fluorescence and Photobleaching During mTHPC Photodynamic Therapy of MLL Cells, *Photochem. Photobiol.,* 2005, 81, 196-205.

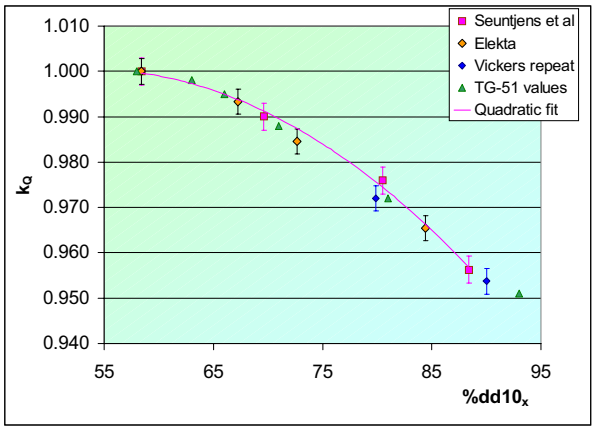
7 J. S. Dysart and M. S. Patterson, Characterization of Photofrin photobleaching for singlet oxygen dose estimation during photodynamic therapy of MLL cells in vitro, *Phys. Med. Biol.,* 2005, 50, 2597-2616.

8 J. S. Dysart and M. S. Patterson, Photobleaching kinetics, photoproduct formation, and dose estimation during ALA induced PpIX PDT of MLL cells under well oxygenated and hypoxic conditions, *Photochem. Photobiol. Sci.,* 2006, 5, 73-81.

9 K. R. Diamond, P. P. Malysz, J. E. Hayward, and M. S. Patterson, Quantification of fluorophore concentration in vivo using two simple fluorescence-based measurement techniques, *J. Biomed. Opt.,* 2005, 10, 024007.

10 M. J. Niedre, A. J. Secord, M. S. Patterson, and B. C. Wilson, In vitro tests of the validity of singlet oxygen luminescence measurements as a dose metric in photodynamic therapy, *Cancer Res.,* 2003, 63, 7986-7994.

Update from the NRC...(Continued from page 50)



k_Q factors determined for a single NE2571 chamber

Seuntjens *et al* (2000) used the NRC Vickers research accelerator; therefore as part of this new work we repeated some of those measurements.

Findings

1. High stability of long-term response of the primary standard water calorimeter - repeated Vickers data points agree well with those obtained previously by Seuntjens et al (2000).
2. Agreement between the results obtained on the Elekta and Vickers linacs confirms the validity of using the beam quality specifier $\%dd(10)_x$ to transfer measurements between accelerators of very different designs.
3. The standard uncertainty in the calibration of an ion chamber in terms of absorbed dose to water is ± 0.35%. This is as good as claimed by any other standards laboratory in the world.
4. For this particular ion chamber the calculated values for k_Q, as given in TG-51, agree with the measured values.

USER CALIBRATION SERVICE

Once we have a set of calibrated NRC "reference" chambers it is a straightforward procedure to calibrate other chambers. $N_{D,w}$ factors for user chambers are obtained by comparison with these reference chambers in a water phantom. The advantages of this approach over using the calculated values of TG-51 are:

- Lower overall uncertainty in absorbed dose
- Direct test of each chamber in the beams in which it will be used
- No assumptions about response
- Chambers not included in protocols can be calibrated

Work on this procedure has continued in recent months and the calibration service is now operational. Accreditation of the service to ISO17025 is anticipated in the coming year. Meanwhile, any clinic interested in obtaining megavoltage calibrations is invited to contact the authors.

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REFERENCES

AAPM (American Association of Physicists in Medicine), "AAPM's TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams," Med. Phys. 26, 1847-1870 (1999)

Seuntjens J P, Ross C K, Shortt K R, and Rogers D W O Absorbed-dose beam quality conversion factors for cylindrical chambers in high energy photon beams Med. Phys. 27, 2763-2779, 2000

Across Canada

Windsor Regional Cancer Centre
Windsor, ON
Submitted by Siobhan Ozard and Jeff Richer

Greetings from The Rose City!

At the Windsor Regional Cancer Centre (WRCC) we currently have two dedicated medical physicists: Jeff Richer (who is the departmental Clinical Lead and also the Radiation Safety Officer) and Siobhan Ozard. The other members of the core medical physics department include John Agapito (Physics Associate), Jeff George (Physics Associate), and Igor Shishkov (Resident). The department also has 3 dosimetrists, 2 electronics engineers and shares a secretary with other departments within Radiation Therapy.

WRCC is physically located within the Anthony P. Toldo building adjacent to the Windsor Regional Hospital Metropolitan Campus near Windsor's historic "Old Walkerville" area. Completed in 2001, the Anthony P. Toldo building has received a "Citation of Merit" for its outstanding architectural design from HealthCare Design Magazine. The ground floor of the WRCC houses three Siemens Primus linear accelerators, a Gulmay orthovoltage machine, and a Nucletron-Odelft simulator. Each Primus unit is equipped with Virtual Wedge and portal imaging. Two of the Primus units are matched. Construction has just begun for the installation of a diagnostic GE MRI Suite located within the Department of Radiation Oncology dedicated specifically for cancer patients. Plans are also in place for the addition of a GE CT-Sim (LightSpeed RT) with installation scheduled concurrently with the MR unit. A Kodak computed radiography system has just been received to replace the Kodak film processor for portal imaging. Multi-Access was installed for record/verify/imaging in October of 2005 and the radiation oncology program is rapidly moving towards a fully electronic treatment record.

In January of 2004 Varian's BrachyVision high-dose rate (HDR) planning software was commissioned along with the GammaMed+ HDR remote afterloader. This equipment was a replacement for our Nucletron microSelectron Classic HDR and PLATO software. HDR treatments are used for prostate and gynecological cancers as well as the occasional lung case. Over 150 prostate cancer patients have been treated using HDR brachytherapy since the program started in 2000; the majority of these patients have been treated with a combined HDR-external beam regimen while a few have received HDR brachytherapy as monotherapy. Prostate cancer treatment is also carried out using

The Medical Physics department at the Windsor Regional Cancer Centre (from left to right) – Siobhan Ozard, Jeff Richer, Igor Shishkov, John Agapito, and Jeff George.

^{125}I permanent seed implants. Over 300 patients have received a permanent seed implant since the program started in June 1999.

The Pinnacle^3 treatment planning system was commissioned during early 2004 and the first patient was planned with this new system in September 2004. Eight Pinnacle^3 workstations are available: two have AcQSim for CT-Sim, all eight are dose-calculation capable, and four are licensed for intensity modulated radiotherapy (IMRT). Four Pinnacle P3MD stations are distributed in the clinic areas for contouring and dose review by the physicians. Pinnacle's IMRT module is currently being commissioned and work is underway for utilizing physical compensators for missing tissue and dose compensation. RadCalc is used for photon monitor unit checks and is being commissioned for electron monitor unit calculation.

Research in the department has focused on electron planning and collaboration with the radiation oncologists. This research has employed several co-operative education students and M.Sc. students over the last few years. An investigation of the Siemens Virtual Wedge operation has also been part of our research initiatives. Teaching activities have focused on training radiation oncology physics residents and therapists as well as teaching courses at the University of Windsor and within the CAMPEP accredited medical physics programs at Wayne State University.

(Continued on page 72)

ACROSS CANADA… (Continued from page 71)

The 2006 AAPM Summer School, "Integrating New Technologies into the Clinic: Monte Carlo and Image Guided Radiation Therapy", will be held at the University of Windsor on June 18-22. COMP members of the local arrangements committee (LAC) include Sherry Connors (Windsor native!) and Will Parker with Jeff Richer as the LAC Chair. The LAC is hard at work making preparations for the school, which is well on its way to being one of the best yet! Please see http://www.aapm.org/meetings/06SS/ for registration and other important Summer School information. Looking forward to seeing you there!

Grand River Regional Cancer Centre
Kitchener, ON
Submitted by Rob Barnett

The Grand River Regional Cancer Centre (GRRCC) began serving patients in 2001 and became the 9th Integrated Cancer Program (ICP) within Cancer Care Ontario (CCO). At that time, the new building was under construction, and a temporary combined outpatient clinic was run from Grand River Hospital (GRH). For the Radiation Program, patients were assessed in Kitchener but CT-simulated and treated at LRCP in London, and this service continued until building occupancy in the fall of 2003.

GRRCC was planned in partnership with CCO and GRH and was built to serve the Waterloo-Wellington region (Kitchener-Waterloo, Cambridge, Guelph) of Southern Ontario. The cancer centre was operationally integrated with GRH from the onset, and strongly guided by CCO via the Regional Planning Office in London until 2004. The architect, Vermeulen-Hind, received a design award for GRRCC from Healthcare Design Magazine in September, 2005 and there are several good images of the centre on the web site (http://www.healthcaredesignmagazine.com/Past_Issues.htm).

The Radiation Program at GRRCC was constructed with six treatment bunkers and initially outfitted with four Varian 2100 EX accelerators and one wide-bore CT simulator. Two of the accelerators were installed and accepted in early summer and put into clinical service in November of 2003. The remaining two accelerators were put into service in late spring of 2004. GRRCC would like to acknowledge the radiation protection support of Senior Physicists, Dr. Don Dawson and Alan Rawlinson from the Regional Planning Office. The doorless bunkers at GRRCC were designed by Dr. Dawson while working at LRCC, and have been incorporated into several other new and expanded cancer centres in the province. Project Manager Alan Rawlinson has been carefully analyzing the radiation survey results from new treatment facilities in Ontario as part of an ongoing process to improve "standard" bunker design.

Due to a protracted construction phase, GRRCC Medical Physics did not experience rapid growth until the fall of 2003.

Medical Physics Department staff at the GRRCC.

At that time we grew from two physicists to a 15 member department and were finally able to occupy permanent offices in the new building. We were very fortunate to be able to hire a team of highly qualified individuals and we were able to accomplish a great deal in a relatively short period of time. In 2004, we recruited an additional physicist, two PhD graduate students, and one physics resident.

Our physicists include Dr. Paule Charland, Dr. Ernest Osei, and myself. Dr. James Chow, who was a physicist at GRRCC from 2002 – 2005, recently joined UHN/PMH. James was a huge part of our initial commissioning effort. Our physics resident is Andre Fleck and our physics assistants are Ron Snelgrove and Grigor Grigorov. Walter Bawa is our IT/IS analyst, Denis Brochu is our machinist, and John Ukos and Mariusz Ogrodowczyk are providing electronics support. You can see some of our smiling faces in the departmental picture included with the article.

One of the more exciting aspects of our development has been our involvement with the University of Waterloo. In 2003 we established a new undergraduate medical physics course (Physics 480) and all of our physicists are currently involved with teaching. It is rewarding that in the three years we have provided this course, two of our students (3%) have gone on to pursue graduate work in medical physics. Currently, we have two U of Waterloo graduate students working at GRRCC; Runqing Jiang, a PhD Physics student who is working on incorporating internal organ motion into treatment planning and Jiazhi Ma, an PhD Engineering student who is using carbon nanotube technology to investigate ionization collection efficiency. GRRCC Physics also worked with Kathleen Wilkie, a U of Waterloo Applied Math student (MSc), who successfully defended her thesis in 2005 on ROI-based image co-registration (Prof Ed Vrscay, supervisor).

Since the beginning of our treatment unit commissioning in 2003, we have been hiring senior undergraduate students from COOP programs (McMaster, Carleton, and U of Waterloo) who have played an important role in our development. In addition to performing regular quality assurance measurements, the COOP students have assisted in a number of important departmental projects which have served us very well. The COOP students

(Continued on page 73)

ACROSS CANADA… (Continued from page 72)
were particularly helpful during our initial commissioning.

The Radiation Program at GRRCC was one of the first facilities in Ontario to go forward with paperless and film-less operation. The Medical Physics Department at GRRCC has played a major role in this accomplishment (respecting our partnership with Radiation Therapy and Radiation Oncology), including co-establishment of the network infrastructure, co-establishment of an electronic patient record (interfacing Pinnacle, Varis, Hermes, and other software with the host hospital IS), and assisting Decision Support with wait time and workload analysis. More recently we have been using Hermes to extend the capability of the hospital PACS facility, and are working to provide physicians with a custom "portal" to access patient images and other data from one screen.

In addition to providing regular support for four linear accelerators, our clinical physics group has been working hard towards implementation of IMRT and adaptive radiation therapy. We have recently published some of our IMRT QA work and hope to be clinical with IMRT for GU patients in early summer. We installed a superficial x-ray unit in December, 2005 and will be commissioning HDR brachytherapy upon completion of a shielded OR (GRH) in 2007. The balance between clinical service and research and development is uniquely challenging for smaller medical physics departments.

Although GRRCC Medical Physics has worked very hard internally, we would like to acknowledge several facilities who have helped us. We would like to thank UHN/PMH, CCSO (Kingston), and JRCC (Hamilton) for independent dose and equipment calibrations that were an essential part of our QA process. We would especially like to thank Jake VanDyk, Jerry Battista, and the Clinical Physics group at LRCP for ongoing technical support, extensive physics consultation., and physics residency support.

The Carlo Fidani Peel Regional Cancer Centre (Credit Valley Hospital, Mississauga), which opened in June 2005, is currently the newest ICP in Ontario. Having received all the help that we did as part of our development, GRRCC was pleased to provide assistance to PRCC and to establish a collaborative working arrangement with Dr. Ramani Ramaseshan and the Clinical Physics group. Although the initial emphasis has been on supporting physics residency, we have been working on several other projects including IGRT, portal imaging dosimetry, and Monte Carlo based dose calculation.

We appreciate this opportunity to tell you about GRRCC and look forward to seeing you at the COMP/CCPM meeting later this year in Saskatoon.

Nova Scotia Cancer Centre
Halifax, NS
Submitted by Jason Schella

While radiation therapy has been performed in Halifax for more than 80 years, hospital based therapy really began in 1925 with the establishment of the first radon emanation plant (that's right folks, radon) at the Victoria General (VG) Hospital in Halifax. Some time after this, departments of radiation therapy were formed at both the VG Hospital and the Halifax Infirmary (HI). As was the norm for the day, these existed as separate entities providing service for the Protestants and the Catholics respectively. The first cobalt-60 unit was installed at the VG around 1963 and then at the HI a few years later. In 1980, the Cancer Treatment and Research Foundation of Nova Scotia was established as a crown corporation in order to manage the provision of cancer care and to coordinate research into the causes of cancer and development of treatments for it. In 1996 the foundation was merged in the Queen Elizabeth II Health Sciences Centre. In 1998 it was re-created as Cancer Care Nova Scotia, a program of the Department of Health. This program is comprised of the Halifax clinic, now called the Nova Scotia Cancer Centre (NSCC), and the newly built Cape Breton Cancer Centre in Sydney both offering radiation therapy services. The NSCC serves a population of approximately 700,000. The Medical Physics Department of the NSCC has affiliations with the CBCC as well as the Prince Edward Island Cancer Treatment Centre. This arrangement allows for support of the smaller centres though they do operate autonomously.

The Medical Physics Department provides clinical and research support for the NSCC. Most staff physicists also have appointments with the Departments of Radiation Oncology and Physics & Atmospherics at Dalhousie University. The department consists of seven physicists (Mike Hale, Jim Meng, Mammo Yewondwossen, James Robar, Robin Kelly, and Jason Schella with one position unfilled), one junior physicist/ resident, two physics assistants, three electronics technologist, and one mechanical technologist. On the equipment front, our centre has five linacs (Varian 2100C, 2100CD, 600C 6MV, 600C 4MV, and a newly installed 21EX) , a new Varian Acuity Simulator-CT, a Picker AcqSim CT simulator, a Siemens Stabilipan orthovoltage unit, a microSelectron HDR, a Selectron LDR, and three treatment planning systems (Conventional, SRS/IMRT and Brachytherapy). In 2004, our last cobalt-60 unit (a T1000) was removed in order to make room for the Varian 21EX.

Clinical programs include: head and neck IMRT, stereotactic radiosurgery/radiotherapy, image-guided conformal prostate, a linac-based TBI program (this replaced the cobalt-60 based program when the T1000 was decommissioned), in addition to conventional therapies. Under development are respiratory gated therapy and extra-cranial IMRT. An expansion of our HDR program to include those patients currently targeted for

(Continued on page 74)

ACROSS CANADA… (Continued from page 73)

LDR is pending approval. This is intended to address the impending end-of-life for these units worldwide. The use of cone-beam CT, which came with our Acuity simulator, is also being studied with regard to its efficacy. A large part of our time, however, will be spent expanding our research and academic programs. The medical physicists play a major role in the Physics education of the radiation oncology and medical physics residents at the NSCC. In addition, the department has committed to running a graduate program in Medical Physics through the Physics and Atmospheric Science department at Dalhousie University. This program will begin in September 2006.

Our group is presently involved in the following research areas:
(1) Tumour dose enhancement using high-Z contrast media, in which we are conducting a proof-of-concept study on the use of high-Z contrast media (CM), including iodine and gadolinium, which are taken up preferentially by brain tumours due to blood-brain-barrier damage, for dose enhancement of dose during radiation therapy. The main focus of this work is on tailoring the photon spectrum created by the linear accelerator to increase the cross-section for photoelectric absorption within the CM-containing tumour. Distributed Monte Carlo calculation has been employed to identify required modifications to the linear accelerator target and beam-flattening for optimization of the dose-enhancement effect. Four experimental linac-generated x-ray beams have been generated in our centre, with beryllium and aluminum targets, in order to examine the feasibility of this approach. Increased absorption in iodinated contrast medium relative to water has been quantified experimentally as a function of concentration. Future work will involve Monte Carlo –based treatment planning with CM-containing tumours, and investigation of new materials including gold nanoparticles.
(2) Off-line image guidance in head and neck IMRT. Clinically-oriented physics research in this area focuses on quantifying the spatial and dosimetric effects of anatomical change (including tumour shrinkage, weight-loss, for example) in the head and neck. We use periodic, off-line, CT-based image guidance to monitor tumour coverage and organ-at-risk sparing throughout the course of IMRT treatment. In addition to providing useful quality assurance during treatment, this approach has provided a population data set that has allowed reliable planning risk volumes to be defined, and realistic estimates of the degree to which dosimetric goals are satisfied throughout the treatment course.
(3) Novel applications of polymer gel dosimetry. We are applying polymer gels to the measurement of the absorbed dose distribution from the beta-emitting radioisotope, Y-90/P-32, which is used in our centre during craniopharyngioma radiation therapy and radionuclide synovectomy in the knee. We have developed phantoms that model the relevant geometry and that allow insertion of the Y-90/P-32 source inside the volume of the gel dosimeter. Results are compared to those obtained using Monte Carlo modeling. Accurately determining this dose distribution should facilitate improved treatment outcome.

Our research has been supported by funding from Varian Medical Incorporated and the NSCC Medical Physics Trust Fund. Funding for upcoming graduate students is being provided by Cancer Care Nova Scotia. The NSCC is continuing to grow and we look forward to the challenges facing us. Halifax is a great city and you're always welcome to stop by if you're in the area.

Back Row (L to R): Dave Burgess (E), Scott Purcell (E), Mammo Yewondwossen (P), James Robar (P), Jim Meng (P), Jim Allan (PA), Ian Porter (M). Front Row: Tanner Connell (PA), Carl Murphy (E), Jason Schella (P), and Larry Gates (JP). Missing are Mike Hale (P) and Robin Kelly (P).
(P) Physicist, (PA) Physics Assistant, (E) Electronics, (M) Mechanical, (JP) Junior Physicist

CCPM President's Message… (Continued from page 45)

stantly impressed by the enthusiasm and dedication shown by all these individuals towards furthering College initiatives. I very much appreciate the support they have given me over the last 8 years and wish Dick success in his term of office.

Report on Forum of Physics Education… (Continued from page 59)

- Expectations of Physics Knowledge for Certification (Thomas)
- Challenges to Implementing the CAMPEP Program
- Discussion on the Strategies to Meet the Challenges

It is quite surprising to realize that there is not a common educational process for the training of medical physicists. A major concern was the need for the organizations in education in medical physics (AAPM, ABR, ABMP, ACMP, CCPM, etc), groups within the AAPM, as well as regulatory agencies and licensing boards to work towards a common focus. The AAPM should have the main responsibility in leading this program to achieve shared objectives.

It was recognized that CAMPEP has the huge responsibility of clarifying the educational standards with the AAPM (the CCPM and/or COMP should also be included) and granting accreditation to the appropriate programs. CAMPEP should also recommend the appropriate pathway to the training (graduate, residency) of a certified medical physicist, and provide any possible alternate pathway that may be considered acceptable for the profession. The issue of granting some kind of affiliated accreditation status to those smaller programs that are not able to achieve full accreditation on their own was also raised. These smaller programs would rely on, or somehow become a satellite to, a fully accredited program. This issue was raised because of the urgent need of developing a sufficient number accredited training programs to satisfy the somewhat "vague deadline of 2010" of having all candidates for the ABR examination come from accredited programs. There are, presently, simply not enough programs to even approach the possibility of having all candidates for the ABR examination come only from accredited programs by this deadline.

There was some discussion as to whether CAMPEP should investigate any distinctions between clinical and/or research for the accreditation and certification processes. One item that everyone agreed upon is that the premise of partial accreditation (eg, therapy physics without any imaging physics) of a graduate program should be avoided at all costs. In fact, it is the residency experience that best defines the specialty and is the most meaningful for certification. Graduates from medical physics graduate programs should not go directly to unsupervised clinical positions.

Additional discussion introduced the notion of a (clinical) doctorate in medial physics as a possible pathway to certification, in a similar way that physicians are trained. The idea would be to add the 2 year residency training to the master's program and grant the degree after the 4 years. This suggestion would clearly need considerable discussion.. Some issues include: universities are not easily persuaded to developing new types of degrees, especially doctorates; universities rarely adhere to curriculum developed by an outside organization; even if these hurdles would be resolved, it would be an impossible task to create this degree across a sufficiently large number of universities to have the degree recognized across North America.

Administrative issues of ABR certification of medical physicists were also discussed. It was suggested that the ABR review the demarcation of medical physics specialties, and consider adding more physicists and physician specialists in the examination panels for both the written and oral examination. The ABR presently requires a candidate taking its examination to have been supervised by an ABR-certified physicist only. It was recommended that the ABR amend this to also accept mentorship by a CCPM-certified physicist. This policy has implications for Canadians candidates being trained in Canada as most of the mentors would be certified by the CCPM rather than the ABR.

<u>Physics Education of Radiation Oncologists</u>

- Appraisal of Physics Education of Radiation Oncologists (Hendee)
- AAPM Proposed Program for the Physics Education of Radiation Oncologists (Massoth)
- Expectations of Physics Knowledge for Certification (Paliwal)
- Challenges to the Implementing the AAPM Proposed Program (Mower)
- Discussion on the Strategies to Meet the Challenges

It was felt that the education of physics to Radiation Oncology Residents is proceeding quite well, with the candidates performing satisfactorily in the physics section of the ABR Radiation Oncology examinations. Clinical commitments and the increased demand for research of radiation oncology residents would inevitably result in a decrease of time available for medical physics instruction. As compensation for this trend, the interactions between physicist and radiation oncology resident should increase to offer the best continuous physics training. As was the case with the physics training of radiology residents, ancillary on-demand teaching aids (paper-, electronic- or web-based) would also be an asset for the self-training of the radiation-oncology residents.

The main challenge is to identify the depth to which physics underlying the technology instrumentation should be taught to the resident. Some method should be devised to evaluate the effectiveness of teaching physics to the resident. It was quite clear that the physics instruction should be tailored to the residents, with the concept of physics rotation encouraged as much as possible. Improvement in communication between all examiners and learners should also be encouraged. Some recommendation for improving communication included the creation of an AAPM website for sharing teaching physics teaching techniques, as well as, a list server with representatives from at least, the AAPM, ASTRO, ARRS, ACR Residents section, ACROP, APCR, SCAROB, and SCARD. Finally, opinions from candidates/diplomats who have recently taken the ABR physics examinations should be sought actively in an effort to better develop the examination process.

In conclusion, the three days of the Forum were quite intense under the expert directorship of Bill Hendee. It was, in fact, quite exciting to be part of these brain-storming sessions. It is hoped that, at least, two white papers concerned with physics teaching to radiologists and to medical physicists, would "come out" of this Forum as these two areas were deemed to require the most immediate attention.

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

LE COLLÈGE CANADIEN DES PHYSICIENS EN MÉDECINE

Proposed Bylaw Amendments - 2006

The Board of the CCPM hereby gives notice that we will be seeking ratification of the following Bylaw amendments at the Annual General Meeting in June 2006 in Saskatoon, Saskatchewan. The proposed changes are in bold, italic and underlined.

1. THE RELOCATION OF THE HEAD OFFICE FROM EDMONTON TO OTTAWA

RATIONALE: with the appointment of an Executive Director located in Ottawa, this office will handle all correspondence.

ARTICLE I: NAME

Head Office

Change: The head office of the College shall be in the City of Edmonton, in the Province of Alberta.

To: The head office of the College shall be in the City of ***Ottawa***, in the Province of ***Ontario***.

2. ADDITION OF REFERENCE TO MAMMOGRAPHY ACCREDITATION

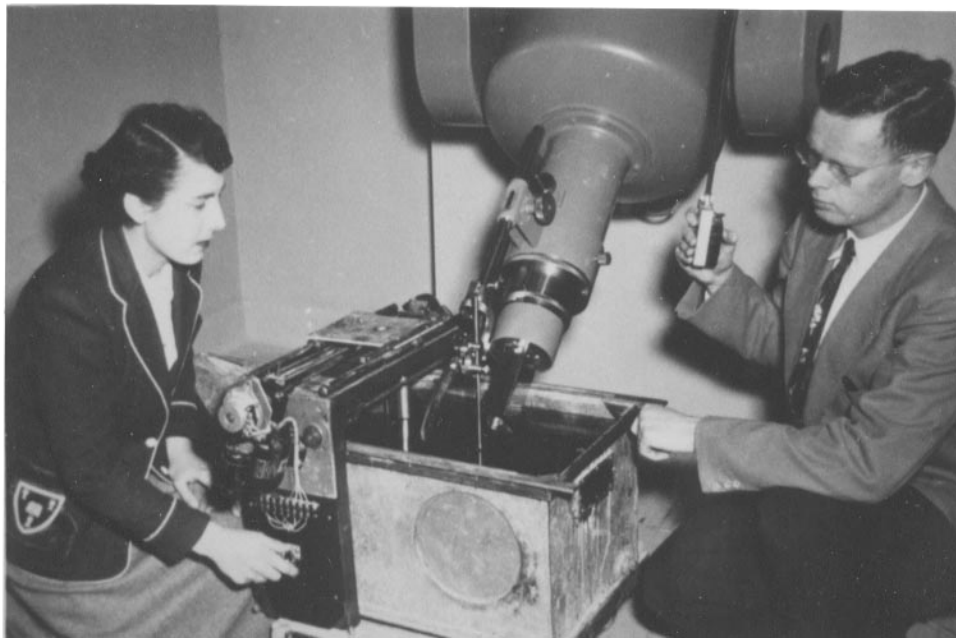
RATIONALE: Since 1997, the College has taken on a special mandate to identify individuals competent in the application of medical physics to mammography. This activity should be stated in the By-laws.

ARTICLE III: Membership Categories and Conditions for Admission

Add after paragraph 5:

As part of the mandate described in Article II, (1a), the College has a separate procedure to identify individuals competent in the application of medical physics to mammography. The operation and maintenance of these activities, including accreditation, renewal and revocation, shall be carried out by the Accreditation Committee on the Physics of Mammography (ACMP) as described in the College Policies and Procedures.

The Canadian Medical Physics Archives
Linking the Past, Present and Future



Sylvia Fedoruk and Ed Epp making isodose measurements for conical rotation therapy. Saskatoon, November 1951

As a member of the medical physics community, you may have some materials to contribute. Our goal is to collect, assess, preserve and make available materials that document the history of medical physics in Canada. Examples include:

- Information pertaining to awards.
- Photos (including names and dates) of individuals or groups
- Biographical sketches of leaders in the medical physics community who have made significant contributions in medical physics
- Informal accounts of meetings, pointing out highlights
- Historical summaries of medical physics in Canada.
- Meeting Minutes
- Past newsletters and other formal communications
- Conference proceedings
- Links to Websites and other sources

A listing of the material that has been collected to date is posted on the COMP website. Please refer to this list and if you have additional materials to contribute, they can be emailed to nancy@medphys.ca or forwarded to the COMP office: P.O. Box 72024, 329 March Road, Kanata, ON K2K 2P4

Answer to the Archive Contest in the January 2006 issue of InterACTIONS:
Jake Van Dyk and Peter O'Brien were the candidates who survived the very first round of CCPM examinations and who appear in the photo found on page 13 of the January issue!

Shania in Good Company as Ontario Celebrates the Order of Canada

Submitted by Jerry Battista,
The University of Western Ontario,
London, ON

The Order of Canada recognizes "a lifetime of achievement and merit of a high degree, especially in service to Canada or to humanity at large." Dr. "Jack" Cunningham was appointed as Officer of the Order of Canada during an investiture ceremony held in Ottawa on November 18. The official citation read as follows:

"One of Canada's most distinguished medical physicists, John Cunningham has made substantive contributions to medical radiation physics. A former chief clinical physicist at the Ontario Cancer Institute and professor of Medical Biophysics at the University of Toronto, he developed innovative concepts and methods for radiation dose calculations used to treat cancer patients around the world. He is the co-author of the seminal textbook The Physics of Radiology, and is one of the founders of the Canadian College of Physicists in Medicine. Throughout his career, he has generously shared his expertise with students and colleagues and has served as a member of numerous national and international committees."

Jack's accomplishments are well known to many of you, and these were summarized in a previous issue of this newsletter. From my perspective, Jack's innovation triggered a significant paradigm shift - from qualitative "geometric treatment planning" based on beam geometry to quantitative "physical treatment planning" based on dose deposition. This is analogous to the progression made when the fundamental limitations of geometric optics were overcome by considering the electromagnetic theory of Maxwell's equations.

The Right Honourable Michaëlle Jean, Governor General of Canada, presided over the investiture ceremony at Rideau Hall and members from two generations of Jack's proud family were present (Ian and Susan were able to attend, along with two grandchildren). So was pop singer Shania Twain, also a recipient of the Order of Canada who shared the stage and spotlight with Jack (only) on that important day (photo, courtesy of Ian Cunningham)

On the weekend following the Governor General's event, a surprise party was organized and hosted at the beautiful home of Drs. Ian Cunningham and Grace Parraga in London, Ontario. Medical physicists from the London Regional Cancer Program and London's imaging research institutes were in attendance. The invitations were also broadcast to other Ontario institutions using web technology, and Jack's former Toronto colleagues (many now retired) were tracked down. Many made the car trip to London on a beautiful autumn afternoon. Jack's young grandchildren capably welcomed the guests at the front door, asking permission for taking a photo, prompting for a signature in the guest book, not to mention running an efficient "coat check" service. The entrance foyer featured a big video screen of cycling digital photographs, taken just a few days earlier. With a fine selection of food, wine, and champagne, spontaneous cheers and laughter could be heard throughout the lovely home. Glasses were raised to toast Jack and Sheila, the country of Canada, and the Queen of England. Jack was clearly in good spirits, surrounded by family and by many former Toronto colleagues and their spouses - Bob Bruce, John Hunt, Peter Ottensmeyer, Ed Martel, Peter O'Brien, Jake Van Dyk, Aaron Fenster, Frank Prato, Mary Gospodarowicz Cyril Danjoux, Alan Rawlinson, Barb Jap, Allen Mosseri, Hamideh Alasti, John Jezioranski, Gord Whitmore, Dick Hill, Mike Rauth, Terry West, Milton Woo, Stuart Rose and Jim Till, to mention a few. Some younger faces also joined the celebration – Mike Sharpe, David Holdsworth, Maria Drangova, Giles Santyr, Ravi Menon, Crystal Angers (formerly Plume), to mention a few, and David Jaffray – the present Head of Physics at PMH, who is indeed filling some mighty big shoes.

This is likely one of many more parties to come, in a wave of celebration that will spread across Canada. Photographs can be found at the following website: http://www.imaging.robarts.ca/~icunning/orderofcanadaparty.

I personally wish to take this opportunity to congratulate Jack, Sheila, and the entire Cunningham family, extending a special thanks to our hosts (Ian and Grace) for creating a day to remember. It's certainly not every day that a medical physicist is so honoured by the government and people of Canada, and surrounded by such good company.

From the viewpoint of reducing mass (ie. 'on the lighter side'): Eschewing hideousness – in search of the Apparel Index

Malcolm McEwen and Sean Kelly
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Protocols and good practice guides of all kinds have proliferated in the past decade and this is as true for the medical physicist as for any profession. Guidelines govern almost every aspect of a medical physicist's activities and the rise in esteem of medical physics professionals can, to some extent, be attributed to this increased rigour. However, it has become apparent to the authors over recent years that the medical physics community has exhibited acute myopia in one significant area – that of conference attire.

If one follows the discussions in professional newsletters and on bulletin boards it is clear that medical physicists wish to be viewed in the same light as such licensed professions as engineers, doctors and accountants. Yet at the same time it would appear that discussing major scientific advances or the future direction of the profession requires no more thought to clothing than "underwear before pants". At a time when the phrase "casual Fridays" is disappearing from the corporate vocabulary medical physicists are driving in the opposite direction. A 5-minute review of any coffee break at an international conference such as the annual AAPM or COMP meetings will reveal bizarre, imaginative, and all together too broad interpretations of the simple phrase "business casual". As with any identified large-scale non-compliance one must ask the question, "Does the fault lie with those issuing the guidelines or is it a lack of training on the participant's part?"

In analysing the issue we have concluded that the brief guidelines provided by most conference organisers are insufficient for the average medical physicist. One could consider a detailed code of practice but it is likely that international agreement on such a protocol would be difficult, if not impossible, to achieve. Local variations would evolve which would lead to as much confusion as presently exhibited. In its place we propose a much simpler method – that of the Apparel Index (AI).

The concept for this project was simple – to develop a mathematical equivalent of "What Not To Wear" (TLC– The Learning Channel—Discovery Communications Inc.). In this model every piece of clothing is assigned a value between 0 and 1 and the total apparel index (AI) is the product of all these factors:

$$AI_{tot} = AI_{pants} * AI_{shirt} * AI_{tie} * AI_{shoes} * AI_{jacket} \ldots\ldots * AI_{n}$$

For each piece of clothing the AI value in the equation above is based on a discreet quantization of the style spectrum.

All items not present on the person are assigned a value of 0 or 1 depending on whether the said item is optional or mandatory (thus differentiating between an open-necked shirt and indecent exposure).

For each individual item the AI value is further broken down into the following components:

Number of colours – $AI_{n(col)}$
Colour – AI_{col}
Luminosity- AI_{lum}
Size - $AI_{sculpture}$[1]

To keep the calculation simple it is not possible to include a full specification of every item of clothing therefore we introduce a correction factor, k_{acc}, to cover any accessorization. If any of the following are present - embroidery, Don Cherry-esque collars, patches (elbow, knee, *etc*), glitter and/or sequins, large items of jewellery[2] then $k_{acc} = 0.5$; else $k_{acc} = 1$

As we developed this model it became apparent that the simple approach outlined so far does not take account of the undesirable effect of certain combinations. For example, a small-scale plaid shirt with a black or grey pair of pants should score highly on the index but the same plaid shirt combined with a plaid or striped pair of pants is unacceptable (except for special golf-course meetings). It is therefore necessary to introduce two matrix functions that covers such unfortunate combinations. The first, M_{style}, covers accidents of style while M_{col} is designed to prevent fuschia and lime green ever being seen within 3 feet of each other.

In addition, we also propose a presentation index, PI, to cover such aspects as crumpled shirts, foodstains, holes in the crotch, frayed cuffs (shirts or pants) and yellow areas which should not be yellow (collars, armpits, *etc*). The requirement for PI is further sad confirmation of the sartorial challenges facing some members of the community. One might ask why it is not introduced as a correction factor similar to k_{acc} and the reason is that in keeping it separate the user can determine what their outfit would score if it was clean/new/mended.

From the theory expounded here it can be seen that the Apparel Index is entirely determined by the clothing – there is no external subjective component. For example, a single-breasted, dark business suit (with plain tie and properly-matched shirt) would always have a score of 1.0. For each conference the organisers would simply state a minimum and maximum qualifying value of the apparel index, which could be dependent on such factors as climate, the type of meeting, size of rooms, *etc*. Organising committees often strive to produce an atmosphere where delegates are free to think outside the normal bounds of the workplace and many studies have shown that

(Continued on page 80)

[1] baggy clothing is not the issue here; of greatest concern is the type of men's pants that could be best described as "Body Sculpting"
[2] large being defined as the total area > 10 cm^2

(Continued from page 79)
loose clothing (within limits) is an aid to clear thinking. The inclusion of a maximum value is designed to ensure that no participant is over-dressed (and also for health and safety since insufficient air conditioning can make the best business suit feel like the armour of a medieval knight).

This approach also means that creativity and personal choice are preserved, whereas, written guidelines, by contrast, tend to lead to garment uniformity reminiscent of a 1950s classroom. The use of the Index also means that there is no requirement to actively discourage any specific item (e.g. tie and jacket). Such attempts tend to be both arbitrary, unfairly discriminatory and, from the authors' experience, a recipe for disaster. A suitably set Apparel Index band will remove unwanted outfits while allowing the individual to show something of their own personality in what they wear.

Training for conference staff, already responsible for checking badges and ensuring the security of exhibition equipment, would be quick and the enforcement of the standard straightforward. However, it is likely that in the early stages there will need to be an element of policing by the professional organisations to ensure the rapid adoption of the standard as well as dealing with the more belligerent delegates who fail to meet the minimum requirements. Workshops, one-on-one counselling may prove necessary…..

It is not possible to cover all possibilities in this initial study. The biggest issue to address is that of female attire. Female dress options tend to be much wider than for males, both in terms of style, colour and luminosity but perhaps counter-intuitively, empirical data acquired to date imply that female dress tends to more often conform to acceptable standards. It is therefore recommended that a working group be formed to review the implementation of the male Apparel Index and develop the formalism for AI(w).

In addition there are clearly a number of opportunities for commercialisation and we are eager to collaborate with interested parties. For that reason the full details of the AI algorithm, AI values and Matrix functions cannot be revealed in this paper. One commercial direction we have identified is the development of a complete conference service, which would construct a meeting wardrobe that satisfies the specified AI band and would fit within the constraints of carry-on luggage. Already in development is an inverse optimisation algorithm making use of simulated annealing and convolution superposition. The user simply enters the relevant parameters – apparel index band for the conference and clothing required - and the algorithm constructs a suitable outfit using a database of the user's wardrobe. Standard bar-scanning technology will be used to simplify the digitization of the wardrobe details. It is anticipated that such a system could be fully operational towards the end of 2009.

The authors

Malcolm McEwen is a Research Officer within the Ionizing Radiation Standards group at NRC. Sean Kelly is a teacher and husband of a clinical medical physicist.

Disclaimer

The views in this article are those of the authors alone and do not represent any policy of either's employer!

IMRT Survey Results…. (Continued from page 58)
indicated to be under 0.5 weeks.

Final comments:

It appears that IMRT is rapidly becoming a standard of care in Canada. The number of patients treated per year via IMRT is experiencing close to exponential growth. However, only slightly less than half of Canadian centres are actually delivering IMRT to patients. This lags behind the widespread implementation of IMRT in the USA, where a 2004 report indicated that IMRT was being delivered by 87% of 587 responding clinics (responses given by "Chief Physicists") [AA04]. Another 2004, US based study indicated a rapid adoption of IMRT technology over the previous few years [Me04].

Most Canadian centres are using static MLC delivery, and involving a small number of linacs. The main treatment site for application is 'head and neck', using 6 MV photons, and 7 beams. Treatment delivery times are typically 30 minutes or lower. Average time to plan a patient is quite variable (2–24 h), while contouring time seems to be <2 h for Radiation Oncologists and <2 h for Treatment Planners. Physics commissioning time is typically under 2 months (EFT), and ongoing QA programs comprise primarily measurement only approaches. The average time for physics QA ranged between 1 h and 16 h (mostly <5 h). Many centres had a rigorous daily portal imaging program, with most of the remaining centres incorporating initial daily imaging for three days followed by weekly imaging. The responses to questions regarding human resources for ongoing QA were quite variable. Most centres indicated requirements for increases in Physicists and to a lesser extent, Physics 'Assistants'. Some increase was also indicated for increased Treatment Planners and Radiation Oncologists. Most centres indicated that no increases were required for Electronics support or Treatment Floor staff. The responses regarding IMRT training were reasonably consistent across respondents, typically indicating less than one week of training required for most involved disciplines.

Thanks again to all centres that took time to respond to the survey.

References:

[AA04] AAPM "Profile of Radiation Oncology Departments - Calendar Year 2004", www.aapm.org/pubs.

[Lo98] D. A. Low, W. B. Harms, S. Mutic, and J. A. Purdy, "A technique for the quantitative evaluation of dose distributions," Med. Phys. **25**, 656 (1998)

[Me04] L.K. Mell, A.K. Mehrotra, A.J. Mundt, "Intensity-modulated radiation therapy use in the U.S., 2004." Cancer **104** (6), 1296 (2005).

[Sh02] D. M. Shepard, M. A. Earl, X. A. Li, S. Naqvi, and C. Yu, "Direct aperture optimization: A turnkey solution for step-and-shoot IMRT,", Med. Phys. **29**, 1007 (2002).

Information on

Participation
Submission of papers
Grants

can be obtained from
www.iaea.org/meetings

REGISTRATION

There is no registration fee.

LANGUAGE

The conference will be held in English.

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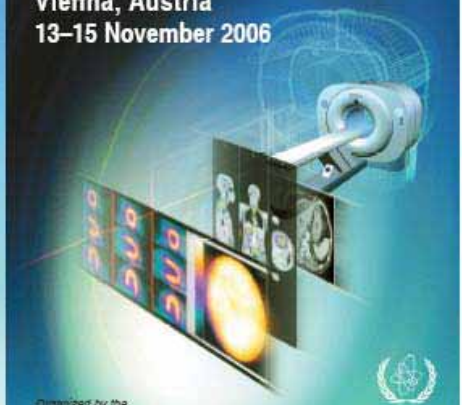
Please include reference number CN-146 in your written contacts.

International Conference on Quality Assurance and New Techniques in Radiation Medicine

Vienna, Austria
13–15 November 2006



Organized by the
International Atomic Energy Agency

IAEA

Co-sponsored by the
American Association of Physicists in Medicine (AAPM)
American Society for Therapeutic Radiology and Oncology (ASTRO)
European Association of Nuclear Medicine (EANM)
International Organization for Medical Physics (IOMP)

In cooperation with the
Asia-Oceania Federation of Organizations for Medical Physics (AFOMP)
European Federation of Organizations for Medical Physics (EFOMP)
European Society for Therapeutic Radiology and Oncology (ESTRO)
International Commission on Radiation Units and Measurements (ICRU)
International Radiology Quality Network (IRQN)
Pan American Health Organization (PAHO)
United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
World Federation of Nuclear Medicine and Biology (WFNMB)

Objective:
"QUALITY ASSURANCE FOR QUALITY CARE"

The conference will provide an opportunity to discuss the importance of quality assurance (QA) in applications involving the use of ionizing radiation in medicine in order to maximize the benefits and minimize the risks. The programme will focus on the QA systems and quality control (QC) procedures used in diagnostic radiology, nuclear medicine and radiotherapy, with a special focus on new and emerging technologies. Multidisciplinary issues such as education, training and accreditation, telemedicine, data management and storage will also be discussed.

Audience

This conference will be of interest to individuals concerned with the application of QA/QC programmes in radiation medicine. This includes hospital executives, physicians, medical physicists, biologists, biomedical engineers, technologists, QA experts and regulators. The conference seeks to bring professionals in these areas together to share experiences and expertise in order to promote and expand the implementation of QA programmes in medical procedures involving radiation.

List of Topics

- Improving quality, optimizing practice and reducing risk in diagnostic radiology through the implementation of QA programmes and QC procedures in:
  - mammography
  - X ray computed tomography
  - interventional radiology
  - digital imaging
  - bone densitometry (DEXA)
- Applications of QA in nuclear medicine to improve the quality of diagnostic imaging and therapeutic treatments with the minimum amount of administered radiation needed to ensure desired diagnostic/therapeutic results, including:
  - modern dose assessment methodologies, including patient specific approaches
  - QC of radiopharmaceuticals
  - QC of SPECT and PET scanners
- QA contributions to radiotherapy to improve treatment outcomes and quality of life through better local tumour control and fewer complications. This includes radiation oncology and medical physics aspects in:
  - dosimetry
  - treatment planning and delivery
  - conformal therapy
  - intensity modulated radiotherapy (IMRT)
  - stereotactic radiotherapy
  - brachytherapy
  - hadron therapy

Papers and Posters

Papers are invited from participants on any of the topics to be covered at the conference. In order to provide ample time for discussion, the number of papers that can be accepted will be limited. Papers are to be presented either orally or as posters, at the discretion of the scientific programme committee.

Key deadline

17 March 2006

- Submission of extended synopses (electronic version)
- Paper Submission Form (Form B)
- Grant Application Form (Form C)

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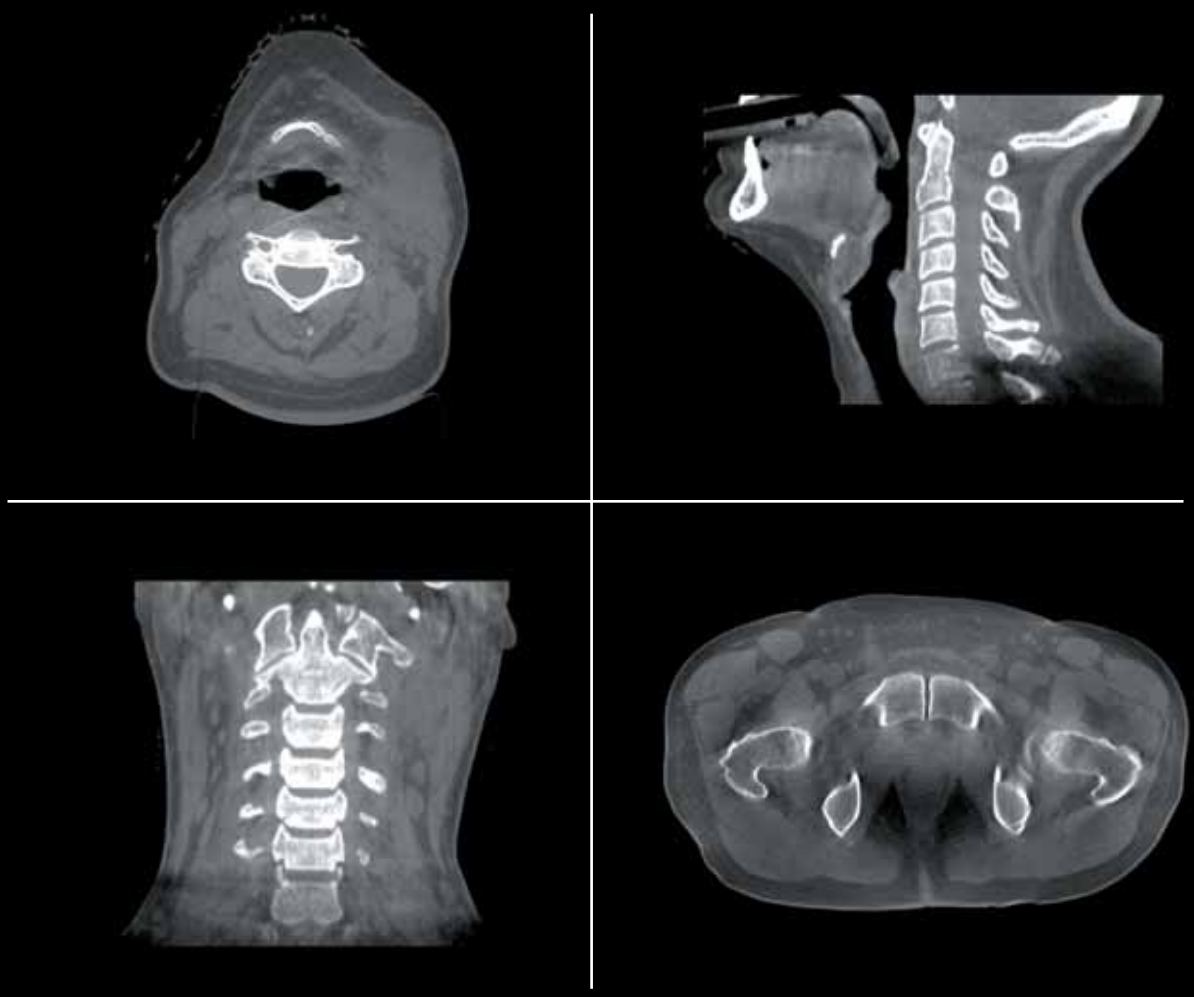

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