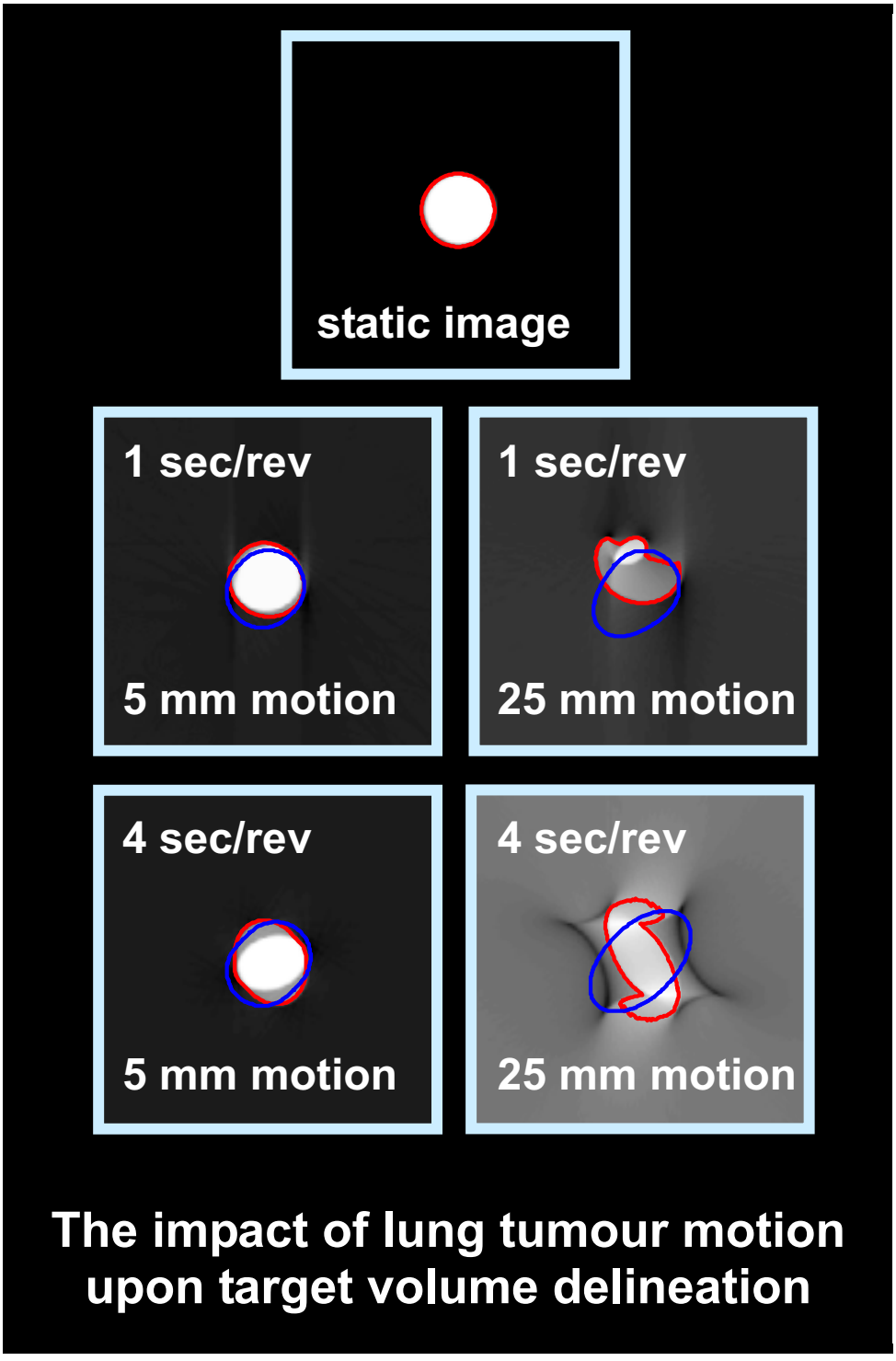
InterACTIONS

CANADIAN MEDICAL PHYSICS NEWSLETTER
Le BULLETIN CANADIEN de PHYSIQUE MÉDICALE



The impact of lung tumour motion upon target volume delineation

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

50 (2) avril/April 2004

About our Cover

Three-dimensional conformal radiotherapy (3D-CRT) planning is heavily reliant upon the anatomical information provided by computed tomography (CT) for target volume and organ localization as well as dose calculations. The reconstruction algorithm used in CT assumes the spatial invariance of objects during data acquisition. With the exception of breath-hold schemes, all current lung radiotherapy approaches acquire images while the tumor is non-stationary and, as such, are subject to the presence of motion artifacts. Since lung tumors can exhibit a high degree of mobility, the detrimental effect of these motion-induced distortions on image quality and subsequently target volume delineation can not be ignored in the pursuit of improved treatment outcomes. In an effort to understand the impact of tumor motion upon target volume delineation, simulation and experimental images were acquired for a wide range of possible tumor motions. Since acquisition times for lung radiotherapy planning differ depending on the scanning technique used, or on the CT scanner technology, various techniques were investigated. The cover page shows simulation images for a 25 mm diameter sphere undergoing an average 5 mm upper lobe and a large 25 mm lower lobe motion, respectively. Results show that the spatial extent of a mobile object is distorted from its true shape and location and thus does not accurately reflect the total volume occupied (TVO – blue contour) during image acquisition. The presence of motion also negatively impacts image intensity (CT number) integrity rendering accurate volume delineation (red contour) highly problematic and calling into question the use of such data in CT number based heterogeneity correction algorithms for dosimetric calculation.

Images provided by Isabelle Gagné and Donald Robinson , Cross Cancer Institute and University of Alberta, Edmonton, Alberta.

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, article submissions can be made to:

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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.

Corporate advertising enquiries can be made to:
Mr. Michael Henry
Email: henry@abellshenry.com
Phone: (780) 462-7974
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Job advertisements should be submitted to:
Dr. Julian Badragan
Tom Baker Cancer Centre
1331—29 Street NW
Calgary, AB, T2N 4N2
E-mail: badragan@cancerboard.ab.ca
Phone: (403) 944-4598
Fax: (403) 944-2397

Job Advertising Options

OPTION 1 ($200): Job posting on COMP/CCPM website only (updated monthly)
OPTION 2 ($300): Job posting on COMP/CCPM website AND in InterACTIONS! (single page)
OPTION 3 ($300): Job posting is immediately e-mailed to COMP/CCPM members (no website or InterACTIONS! posting)

Regular Advertising

	1/2 page	1 page	Addn. pages
Member Announcement		$100	$100
Corporate Member	$150	$200	$100
Non Profit Organisation	$225	$300	$125
Corporate Non-Member	$300	$400	$200
Color	Add $400 (when available)		

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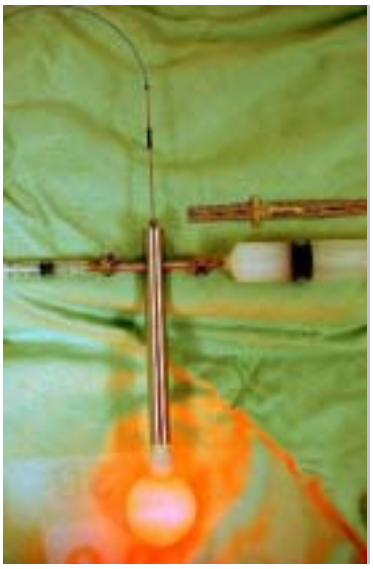

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Photodynamic Therapy: A Medical Physicists' Perspective ….. 55
Michael S. Patterson

Message from the COMP Chair:

As you are all aware, it is always difficult to recruit members for positions on the Executive…. I would like to reiterate the importance that members get involved.

Since my last message, the COMP Executive has been working mostly on the upcoming meeting and a few small changes to our Bylaws.

The abstract submission process is now complete and the Conference Committee is finalizing the program for the meeting, which is available through the CAP conference website, www.cap.ca. Information on registration and accommodations are available on the University of Manitoba website (www3.physics.umanitoba.ca/Congress2004). As you recall, we are meeting this year with several other Canadian physics societies. This will provide us with a unique opportunity to interact with physicists in many other areas of physics. This should make for interesting discussions and could provide many of us with new opportunities for collaboration.

As you are all aware, it is always difficult to recruit members for positions on the Executive. The Nominations Committee quite often receives no nominations after its Call for Nomination. At this point, the Committee tries to recruit a candidate as best as possible by contacting members directly. This often leads to a single nominee for a given position. Our present bylaws require a ballot vote for these situations even though only one name appears on the ballot. The bylaw change presented in this edition of InterACTIONS! proposes a simpler approach to elect a single nominee to office. This bylaw will be presented and voted on at the next AGM in Winnipeg.

Our Awards Committee has a new Chair! Jean-Pierre Bissonnette has agreed to take on this important task. He has served on numerous occasions as a judge for the Awards Committee. We look forward to working with him and wish him all the best.

Speaking of awards, in the last issue of InterACTIONS!, Mike Paterson made some very interesting suggestions regarding the Sylvia Fedoruk Award, which honours the best Canadian paper in Medical Physics. Since then, I have received several comments in support of changes to the present approach. I have asked our Awards Committee to review the present approach and make recommendations on what should be the appropriate changes. These will then be presented to the membership for your approval. I am certain that Jean-Pierre would be very interested in receiving your comments.

In closing, I would like to reiterate the importance that members get involved. I did a quick survey of our directory and found that approximately 35 individuals represent COMP at various levels (Executive, Committees, Representatives). Most of these are 3-year terms so, over a typical career of 30 years, approximately 350 individuals would be required to keep COMP going. Since COMP has only 350 Full Members, this means that EVERY MEMBER of COMP should, throughout their career, hold a position within COMP. Please keep this in mind when the Call for Nominations comes out in January of every year.

Dr. Clément Arsenault, COMP Chair

Message from the CCPM President:

As I write this column in early March, the preparations for this year's membership examinations are well in hand. Our Registrar, ***Wayne Beckham,*** received and processed a total of 33 applications, 29 for membership and 4 for fellowship, and all but 2 were approved after review by our Credentials Committee. Our Chief Examiner, ***Katharina Sixel***, and her group of volunteer invigilators have arranged for the written examination to be held in 10 centres across Canada so that most of the candidates will not have to travel far to write the examination. As always, this endeavour relies heavily on volunteers: our thanks go to all the members and fellows who either give up a Saturday to invigilate or devote other time slots to help with setting and marking of the completed papers. That our organisation continues to grow at a rate of approximately 10% per year is a testament to the high regard that our examination process is held, not only in Canada but worldwide.

Dr. Brenda Clark, CCPM President

This year for the first time our membership examination process will require an oral examination. This is an extra workload for our volunteers. We will be reporting more on this topic at the Annual General Meeting in Winnipeg in June.

On the topic of the annual meeting in Winnipeg, the COMP/CCPM representatives on the organising committee have made every attempt to ensure a topical and relevant content for our members. In particular, I would like to recognise the efforts of ***John Schreiner*** in the selection and coordination of speakers in the plenary session entitled **Scientific Images in the Public Sphere** which will take the place the CCPM symposium of our stand-alone meetings. This meeting is a great opportunity for us to showcase the efforts of medical physicists in the wider environment of the whole physics community.

Also at the AGM in Winnipeg, we will yet again be proposing several Bylaw changes. Please review the details when you receive them and be prepared to discuss the issues raised, either by email prior to the AGM or at the AGM itself. Of the four changes proposed, three are relatively minor. The fourth is to remove the membership category of emeritus. The reason for this is that, when the board discussed criteria for this category which have not previously been set, it became clear that the rationale for this category is questionable. COMP has an existing emeritus category designed to recognise and honour physicists who have made a significant contribution to the field during their career and it would be inappropriate for the College to duplicate this. Clearly if the CCPM defines a category to recognise significant contributions only to the College, it may appear to be self-congratulatory and inappropriate. Please let us know what your views are on this, preferably before the Winnipeg meeting.

Peter Dunscombe and I have also been busy on your behalf with ***CAMPEP*** activity. As your representatives on the Board, Peter and I have a mandate to ensure that CAMPEP is responsive to Canadian needs. We are working with the other members of the board and the committee chairs to review CAMPEP activities and formulate a strategy for the next few critical years. CAMPEP was incorporated in 1995 and to date has worked to establish minimum standards for medical physics educational programs, evaluate compliance with these standards and, where appropriate and requested, formally accredit such programs. Although there are currently 11 accredited graduate and 9 accredited residency programs in medical physics in North America, there are clearly many excellent programs that have either not sought accreditation or not been successful. We are now at the stage where we need to find out how we can better serve the community by increasing the participation in accreditation. As part of

(Continued on page 63)

This meeting [Joint COMP/ CASCA/CAP] is a great opportunity for us to showcase the efforts of medical physicists in the wider environment of the whole physics community.

Message from the Executive Director of COMP/CCPM

Some medical physicists, while recognizing the value of cross-professional meetings, also recognize the importance of medical physicists to come together as a distinct professional group.

I expect that many reading InterACTIONS! this month have June 13-16th booked for the annual general meeting in Winnipeg.

This year's meeting promises to be especially interesting as we partner with the Canadian Association of Physicists, the Canadian Astronomical Society, and the Biophysical Society of Canada. Medical physicists share much in common with the professionals from other physics related professions and our 2004 meeting gives us the chance to share perspectives, trends, and conversation with our 'physics cousins'.

Some medical physicists, while recognizing the value of cross-professional meetings, also recognize the importance of medical physicists to come together as a distinct professional group.

Your executive has been involved in several discussions on the merits of stand-alone meetings and the benefits gained from joint meetings with other related disciplines in physics, health, or cross-boarder meetings. While discussions have been wide ranging, there appears to be a growing agreement that medical physicists want the best of both meeting patterns and that perhaps alternating stand-alone and joint meetings would serve this purpose.

There is no plan to develop a hard and fast rule about alternating meetings, but there has been considerable discussion about having a general pattern of alternating meetings.

Your thoughts on this are important and I encourage you to share your thoughts with your executive about joint and stand alone meetings. I also encourage you to plan to attend the AGM in Winnipeg!

Our new website is still on track, with Darcy Mason and his team of volunteers working closely with AAPM in designing, constructing, and preparing to launch our new website. Many thanks to Darcy and his committee for their continued hard work!

Another issue that has presented itself to your executive is the increasing number of requests to use the COMP membership list to distribute announcements, advertisements, position advertisements, etc. To date, most of the requests have been dealt with by insertion into InterACTIONS! and posting on our website. There have been an increasing number of requests to distribute information in a more timely fashion (rather than the quarterly publication of InterACTIONS!) and the most obvious vehicle is through broadcast email to the entire membership.

Is this an effective mechanism for passing on professional related material to COMP members? Is there a point at which the

Mr. Michael Henry, Executive Director

volume of such distributions would be seen as intrusive or 'spam-like' by our members? These are the questions being considered by your executive and communications committee. If you have any thoughts on this matter, it is important that we hear from you. Feel free to email me, or any member of the executive or communications committee with your thoughts. Only your input will guarantee a process that works for you, COMP and our supporters.

I look forward to seeing you in Winnipeg!

50th Annual Scientific Meeting of COMP and CCPM Symposium

June 13-16, 2004
Delta Winnipeg Hotel
Winnipeg, Manitoba

The Canadian Organization of Medical Physicists and the Canadian College of Physicists in Medicine are pleased to invite you to Winnipeg, Manitoba for our **50th Annual Scientific Meeting**. This anniversary year is also a return to our roots. We are meeting with the Canadian Association of Physicists which, before COMP, was the national organization for medical physicists in Canada through its Division of Medical and Biological Physics (DMBP). Also meeting with us will be the Canadian Astronomical Society and the Biophysical Society of Canada. This is a unique opportunity to hear the latest from our colleagues in these disciplines.

Registration:
The Early-registration is now open and will end on May 1, 2003. Information and instructions on how to register are posted on the University of Manitoba website (www3.physics.umanitoba.ca/Congress2004). Registration fees are 320$ for Full COMP Members and 100$ for Student Members. Note that, contrary to COMP meetings, the cost of the banquet is not included in the registration fees. Those willing to attend must purchase banquet tickets separately at 65$ per ticket.

Accomodations:
The Meeting will take place at the Delta Winnipeg Hotel. Information and instructions on how to book rooms are posted on the University of Manitoba website. Room rates are 109$ per night and must be reserved before May 12, 2004. Student rooms at the University of Manitoba are also available at the rate of $38.76 per night for single occupancy and $28.50 per person per night for double occupancy. A shuttle service will be available from the University to the Delta Hotel. To book rooms at the University, please e-mail Sandi Gibson at sgibson@ms.umanitoba.ca.

Please visit the CAP website for further details on the meeting (www.cap.ca). A link to the CAP website can also be found on the COMP website (www.medphys.ca).

Proposed COMP Bylaw Change

**Submitted by Clément Arsenault,
Dr. Leon Richard Oncology Centre, Moncton, NB**

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 2004 in Winnipeg, Manitoba.

JUSTIFICATION:

Quite often, the nominating committee receives no candidates after a Call for Nominations appears in InterACTIONS. The nominating committee then tries to recruit a candidate by contacting members directly. This method leads to a single nominee for the given position. The present bylaws require a mail ballot to elect the individual even though the nominee is unopposed. These proposed changes would allow the nominating committee to present the nominee at the AGM where the nominee would be acclaimed into office if no new candidates step forward. This simpler process is consistent with *Robert's Rules of Order* under *Viva-Voce Elections* and would eliminate the necessity of elections with only one nominee.

BYLAW AMENDMENT:

Article IV: Officers

B) ELECTION OF OFFICERS

6. ***If more than one nomination is received by the nominating committee,*** election of officers will be made by mail ballot according to article X. Ballots will be counted ....

7. ***If only one nomination is received by the nominating committee, the Chair of the nominating committee will present the nominee at the Annual General Meeting. The COMP Chair will then call for nominations from the floor. If there are no further nominations, the nominee will be appointed to the office by acclamation. If nominations are received from the floor, election of officers will be made by show of hands.***

~~7.~~***8.*** The Executive thus elected ....

~~8.~~***9.*** In the event that a resignation ....

COMP/CCPM/CRPA Liaison

**Submitted by Peter Dunscombe,
Tom Baker Cancer Centre, Calgary, AB**

Preamble

The activities of the Canadian Organization of Medical Physicists (COMP)/Canadian College of Physicists in Medicine (CCPM) and the Canadian Radiation Protection Association (CRPA) encompass several areas of common interest. These include, but are not limited to, the certification of 'Radiation Safety Officers' and the development and collation of educational materials for radiation safety training. At their annual general meetings in the summer of 2003 these organizations recognized the value in working collaboratively in areas of common interest and proposed the establishment of a liaison mechanism.

The Liaison Mechanism

1. The CRPA and the COMP/CCPM will both appoint an appropriate individual to act as a liaison.
2. The liaisons may be Board (CRPA)/Joint Executive (COMP/CCPM) members or may be drawn from an appropriate standing committee that reports to the Board or Joint Executive.
3. The liaisons shall keep each other informed of all relevant projects, actions and decisions of their respective organizations. Communication may be through extracts from minutes of meetings, verbal or any other means as appropriate.
4. The liaisons may propose to their organizations the establishment of joint ad hoc committees to deal with common issues.
5. The liaisons shall prepare jointly a written report on their activities for presentation to the Board/Joint Executive at their annual meeting.

Peter Dunscombe
for COMP/CCPM

Michèle Légaré-Vézina
for CRPA

Report on WESCAN 2004

Submitted by Chris Newcombe
Tom Baker Cancer Centre, Calgary, AB

This year, the annual WESCAN conference was hosted by the British Columbia Cancer Agency at the Vancouver Island Centre.

25 years ago several carloads of dedicated pioneers braved the elements to visit their western neighbours in Saskatoon. This year continued that fine tradition as 100+ Medical Physicists, Electronics Staff, Radiation Therapists, students, and support staff descended on Victoria. WESCAN has an informal friendly atmosphere, provides a great venue for making new acquaintances and for learning what the Canadian Radiation Therapy community at large is doing. The presentations tend to be practical and down-to-earth and in one case included an innovative choreograph much to the amusement of all concerned.

This year the organization committee under the guidance of Dr Wayne Beckham offered two student travel awards. The awards went to Isabelle Gagné of the Cross Cancer Institute and Christina McLaughlin of the Northwestern Ontario Regional Cancer Centre.

The conference was divided into three major sections. The first day featured presentations on a wide variety of subjects with competition for the best presentations in three categories: technical, radiation therapy and student.

In the technical competition the day's winners were:
* 1st place Jason Figueredo of the British Columbia Cancer Agency, Vancouver Island Centre with a presentation titled "Quantitative Methods for Picket Fence Analysis"
* 2nd place Chad Harris of CancerCare Manitoba, and
* 3rd place Kurt Knibutat of the Tom Baker Cancer Centre, Alberta

In the radiation therapy competition the day's winners were:
* 1st place Kevin Gillund of the British Columbia Cancer Agency - Centre for the Southern Interior with a presentation titled "Treating Head and Neck Volumes that Extend Deep into the Mediastinum"
* 2nd place Calvin Merritt and Leo Moriarity of the Tom Baker Cancer Centre, Alberta, and
* 3rd place Ming Fong of British Columbia Cancer Agency - Vancouver Centre

In the student competition the day's winners were:
* 1st place Isabelle Gagné of the Cross Cancer Institute with a presentation titled "The Impact of Lung Tumour Motion on Target Volume Delineation"
* 2nd place Gavin Cranmer-Sargison of the University of Victoria
* 3rd place Christina McLaughlin of the Northwestern Ontario Regional Cancer Centre

The first day of sessions was concluded with a fine banquet hosted at the Laurel Point Inn. Featuring a local seafood cuisine theme the finishing touch of class was provided by Dr. Isabella Uzaraga playing the harp.

The second day of the conference was 'Theme Day', with a focus on Breast Cancer. The day's talks opened with remarks by Dr Ivo Olivotto, British Columbia Cancer Agency, and ranged from the basics of the disease, physics of mammography, 3-d planning through the future of advanced imaging techniques.

More talks were scheduled for the morning of the third and final day which concluded with a tour of the Vancouver Island Centre with many "oohs" and "aahs" at the swank surroundings of the Vancouver Island Centre.

A big thanks to the organizers, Wayne and his crew in Victoria for putting on a first-rate meeting. Well done guys!

Next year WESCAN will be in Calgary. While the weather may be uncertain we can guarantee that the traditions associated with WESCAN will continue. So put it on your calendar, and check out http://www.wescan.org over the next few months for more details.

Report on AMP 2003

Submitted by John Andrew,
PEI Cancer Treatment Centre, Charlottetown, PEI

The 5th annual Atlantic Medical Physics Meeting was held at the Prince Edward Island Cancer Treatment Centre in Charlottetown on November 7th and 8th, 2003. AMP 2003 was attended by therapy physicists from the four Atlantic Provinces and our guest speaker, Dr. Peter Raaphorst from Ottawa. The conference opened with a social gathering at the PEI Culinary Institute followed by a banquet. Our scientific session was held the next day at the PEI CTC. Peter Raaphorst made an excellent, thought provoking presentation on the "Biological Aspects of Treatment and Treatment Planning". His talk was followed by presentations by many of the physicists in attendance. Delegates also had a chance to tour the newly expanded PEI CTC and to see their new Varian 2100 EX accelerator. We enjoyed an excellent lunch, but the epicureal highlight of the day was the wide variety of toppings for the "make your own" ice cream Sundays we made for our afternoon break. We ended the day with a business meeting where we discussed physics issues of common interest and selected St. John's, Newfoundland and Labrador, as the location for the 2004 meeting.

Thank you to the meeting sponsors, Varian Medical Systems, Nucletron Inc. and Harpell Associates. Thank you also to the PEI CTC for their hospitality.

Back row (left to right): John Andrew, Peter Raaphorst, John Grant, Clément Arsenault, Maria Corsten, Donia MacDonald, Judy Hale, Amjad Waheed, Grant MacNevin, and Jim Meng.

Front Row (left to right): Narayan Kulkarni, James Robar, Jason Schella, and Larry Gates.

In Brief

NS/PEI Medical Physics Agreement
Submitted by John Andrew
PEI Cancer Treatment Centre, Charlottetown, PEI

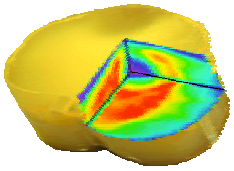
A formal affiliation agreement covering the provision of oncology medical physics services has been implemented by the Prince Edward Island Cancer Treatment Centre (PEI CTC) and the Queen Elizabeth II Health Sciences Centre (QEII) in Halifax. The agreement lays the framework for a working partnership between the medical physicists of the PEI CTC and the QEII. A similar agreement has existed between the QEII and the Cape Breton Cancer Centre in Sydney, Nova Scotia since it opened in 1998. The NS/PEI agreement has already provided for coverage during Judy Hale's recent maternity leave from the PEI CTC and for assistance in the commissioning of the new linear accelerator that was installed in the expanded PEI CTC in 2003.

The expansion of the PEI CTC has required an increase in the number of physics staff. After fifteen years as head of oncology medical physics in Halifax, I have resigned from that position and have taken the opportunity, under the provisions of the agreement, to return to my native province. Any physicists planning a trip to "Come Play on our Island" are welcome to pay us a visit at our new clinic.

PEI Swells in Numbers!
Submitted by Judy Hale
PEI Cancer Treatment Centre, Charlottetown, PEI

Medical Physics presence in Prince Edward Island swells in numbers: Welcome to John Andrew, Michelle Cottreau, and Bill Whelan.

DOSEGEL 2004 ANNOUNCEMENT!!
Submitted by John Schreiner
Kingston Regional Cancer Centre
Kingston, ON



Everyone is invited to attend the DoseGel 2004 meeting in Gent, Belgium, Sept. 13-16. The meeting will have a heavy Canadian contingent in the planning and organization! Check out www.dosgel.org for more details.

Launch of the NEW www.medphys.ca

Submitted by Darcy Mason,
Centre for the Southern Interior, Kelowna, BC

As I write this, we are in the final stages of testing the new website (www.medphys.ca), and depending on when you read this, it is either now running or will be shortly. COMP members will receive an email announcing the launch and how to get set up. An important note: not all member database info could be transferred – we ask that you all go and enter your missing/ incorrect information. Instructions were in the email announcement, and also at the website itself (click the "Welcome to the new web site" news item in the side-bar).

The Communications Committee has put in a lot of work on the new web site - my thanks to the committee members for their work. Our first priority was to transfer the existing information from the old site, bringing it up to date at the same time. New features will continue to be added.

The new site is hosted through an arrangement with AAPM. They provide the server, web content authoring tools, backup, and some programming such as for the member directory and conferences. The hope was that with these new tools we could more easily keep the content up to date, and provide more information to our members. There are also administrative tools accessible to a few key people, used to update database information and to send group emails.

It is important that you consider your email options, which you can update at the site. You cannot opt-out of receiving emails for official COMP business (e.g. dues reminders, etc), but you may choose not to receive some other kinds of email. One is for a monthly update of the current job listings, which will be a list with a line for job title and location. The email will contain a link to the web site for more details. The other opt-out is for advertising. We offer as a paid service to send a group email (for e.g. a full job ad). The volume (fluence?) of these will probably be quite low; we suggest you don't opt out so we can tell advertisers that they are reaching a large number of people, but ultimately it is up to you. Note that your contact information itself will not be given to any outside company or organization – COMP will send the emails on behalf of the paying customer.

We hope you enjoy the new site, and keep coming back – we will try to keep the content "fresh"!

Darcy Mason, Chair, Communications Committee

From the Editor (+erratum):

Boyd McCurdy, CancerCare Manitoba, Winnipeg, MB

I would like to apologize to Alistair Baillie for mangling the spelling of his name on page 9 of the January 2004 issue of InterACTIONS! I guess I won't be applying to any job openings in the Kelowna centre anytime soon!

Next, I would like to draw everyone's attention to the new options and fee schedule for advertising jobs through the COMP/CCPM. Options include a web site posting only, as well as a combined website and InterACTIONS! Posting. A completely new option consists of an immediate e-mail burst to all COMP/CCPM members (but no website or InterACTIONS! Posting). Fees will be $200, $300, and $300 respectively. The advertising fee schedule is inside the front cover of InterACTIONS!, and is also posted on the new website. We hope that these options will be able to better serve the needs of the COMP/CCPM membership.

Furthermore, the Communications Committee has decided to dedicate a single contact person for all job advertising inquiries. This will remove confusion as to whom to contact, and ensure more timely service to our advertising customers.

I would like to extend a warm welcome to our newest Communications Committee volunteer, Dr. Julian Badragan, for coordinating all job advertising for COMP/CCPM. His contact information is:

Dr. Julian Badragan
Tom Baker Cancer Centre
1331—29 Street NW
Calgary, AB, T2N 4N2
E-mail: badragan@cancerboard.ab.ca
Phone:(403) 944-4598
Fax: (403) 944-2397

This contact information is also available on the inside front cover of InterACTIONS!, as well as on the new website.

Note that all other advertising is to be directed to Mr. Mike Henry (henry@abellshenry.com and 780-462-7974), as usual.

FEDERAL-PROVINCIAL TERRITORIAL RADIATION PROTECTION COMMITTEE

Submitted by P.J. Wall,
Senior Radiation Health Officer,
NS Department of Environment and Labour,
Halifax, NS

Normally comprising three and one half days the meetings of the Federal Provincial Territorial Radiation Committee (FPTRPC) have, for the past three years, been preceded by a full training day. This year Health Canada (HC) was host for that day which began with "An Introduction to Epidemiology," an excellent presentation by epidemiologist Rachel Lane from the Canadian Nuclear Safety Commission (CNSC). The afternoon was filled by Christian Lavoie, chief of the X-ray and Mammography Division of the Consumer and Clinical Radiation Protection Bureau (CCRPB). Christian, and his staff, provided an informative overview of mammography equipment that included how equipment testing is performed for compliance with the Radiation Emitting Devices Regulations.

Wednesday, the first official day of proceedings, was hosted by the provinces and opened by committee co-chairman Wayne Tiefenbach who had Kevin Bundy introduce the CNSC's president, Linda Keen. She spoke of the importance of the FPTRPC in helping the CNSC achieve its strategic goal of becoming the best regulatory agency in the world and vowed continued support for the committee. President Keen indicated that the International Atomic Energy Agency (IAEA) and the International Commission on Radiation Protection (ICRP) were developing benchmarks on risks to non-human biota and that the CNSC would devote resources in this area as necessary.

In his response to the president's remarks provincial co-chairman Wayne Tiefenbach , on behalf of the provinces and territories, reiterated his concerns regarding the lack of resources and the need for support from the federal level as mentioned by President Keen. Wayne made particular reference to the committee's concern about the future of federal/provincial joint documents. Following the official opening Wayne proceeded to guide the day's agenda which began with a presentation by Mr. Phil Webster in which he outlined the status of the CNSC's regulatory documents. On completion of his presentation Mr. Webster was asked by the chairman to clarify the status of joint federal/provincial documents. His response was that there were many difficulties with joint document publication and that CNSC lawyers were insisting the documents be legally defensible by referencing CNSC regulations. A discussion on the issue concluded with a proposal to appoint a provincial representative to participate in a discussion with CNSC lawyers regarding the issuing of joint documents.

The remainder of the day's proceedings involved following up with action items placed on members from the previous year's meeting and reports from the various working groups and sub-committees, interspersed with speakers who made presentations on various topics. Several members of the committee felt there were inconsistencies across the country on when workers should wear dosimeters, however, it was noted that CNSC's R-91 document titled: "Ascertaining and Recording Radiation Doses to Individuals" addressed this concern. The provincial radiation dosimetry review committee, chaired by Wayne Tiefenbach, informed the group that the National Dosimetry Service (NDS) was investigating the feasibility of longer wearing periods for dosimeters. It had discussions with the CNSC and some provinces, because of queries to that effect, however, the committee felt there were technical and administrative issues that needed to be addressed before approval could be given on extending the wearing period.

Brian Phillips of British Columbia, chairman of both the ELF and Business Plan Working Groups, informed those present that HC's electromagnetic radiation regulatory program, led by Dr. Art Thansandote, is currently updating information on health effects from ELF. Also, a number of research topics are being reviewed by members of the working group with a target deadline of December 2003 to complete a final report. He informed the group that the World Health Organization (WHO) is expected to complete a large multi-national study titled "The EMF Project" by 2005. Brian noted that the business plan will be updated at each yearly meeting of the committee and, now that it has the committee's approval, the plan will be translated and posted to the FPTRPC website.

Naturally Occurring Radioactive Material (NORM) was covered from two different aspects. First, Gary Hughes of Alberta, a member of the NORM "Working Group" brought everyone up-to-date on his work in guiding the harmonization of the Western NORM guidelines with the current Canadian guidelines. Gary indicated that the goal is to achieve amalgamation of the two documents to eliminate duplication and confusion. After Gary, Health Canada's Dr. Bliss Tracy provided a presentation on Radon wherein he asked the question "Should the Canadian radon guideline of 800 Bq/m^3 be revisited?" Part of his message was that radon has been included in a list of 10 environmental factors for the causation of cancer in a monograph published by the Population and Public Health Branch of Health Canada. He implied that a radon workshop is likely in early 2004 to further address guideline changes.

A round of open discussion on activities in each jurisdiction ended this first day of meetings. During this period Chris Thorp, the Department of National Defense (DND) representative, informed the committee that DND was moving towards their own Risk Based Regulatory and Compliance Program and are working, in conjunction with the Canadian Radiation Protection Association (CRPA), towards a Radiation Safety Officer (RSO) certification program.

Day two of proceedings was hosted by the CNSC with Kevin Bundy, acting director of the Radiation Protection and Environmental Compliance Division, in the chairman's role. Kevin began with an overview on the activities of the United

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Radiation Protection Committee… (Continued from page 52)
Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and on the International Atomic Energy Agency's (IAEA) Radiation Safety Standards Committee. Kevin's efforts in providing updates and various documents from these international organizations to the FPTRPC for comments is appreciated, as it provides an opportunity for all Canadian jurisdictions to state their position. An update on amendments to the CNSC Act and Regulations followed, including the most recent changes to the Cost Recovery Fees Regulation that came into effect on July 1, 2003. These new changes can be found on the CNSC website at: www.nuclearsafety.gc.ca under "For Licensees."

Of particular interest to committee members was information provided by CNSC staff on a new radiation protection program that will be required by transport carriers under CNSC's amended Packaging and Transport of Nuclear Substance Regulations and international regulation TS-R-1. This new risk based radiation protection program will come into effect in June 2004. To alleviate disruption to businesses CNSC staff have had discussions with affected carriers. Discussion on this program initiated further comments by members on radiation doses received by drivers crossing the Canada/US border. Some jurisdictions had been informed that drivers were required to stay in their vehicles while their cargo was being scanned by a gamma source. Following the discussion it was suggested that an information document be produced by either CNSC and or HC to educate affected parties and health and safety organizations on the associated risks. The only information currently available on these devices is provided by the manufacturer. On completion of this item several presentations covering: licensing, inspections, inspection grades and an update to the risk-based regulatory program were presented by CNSC staff. The latter program provided by Robert Chamberlain demonstrated the new electronic inspection worksheets used by inspectors in the field. Mr. Chamberlain explained the integrated compliance approach whereby: low risk licensees only have to complete annual compliance reports (ACR); moderate risk licensees submit an ACR and will be subject to a Type II inspection (conventional) and high risk licensees will undergo a Type I inspection (audit). This new system, currently being phased in, will be fully operational by mid 2004.

Since the last meeting of the FPTRPC the CNSC's Directorate of Nuclear Substance Regulation(DNSR) has formed a task force to improve the effectiveness and efficiency of radiography within the oil and gas industry. Because of the potential for lost sources, high exposures and equipment failures, this sector is considered high risk. The task force found there were major deficiencies in the industry that included: uncertified sealed sources and holders ; limited training for supervisors and operators; no RSO training and generally, a lack of worker familiarity with licensee procedures and regulations. As a result of these findings the task force has recommended that a new risk-based regulatory process be developed to strengthen licensing and compliance in this area CNSC management is currently considering the establishment of a working group to address this recommendation. In a related presentation on the security of radioactive sources it was noted that, at present, there isn't a National Registry in place to track the inventory of sources in Canada. The DNSR has implemented an external notification procedure for the loss or theft of radioactive substances and devices. Copies of the appropriate forms that are now in use were provided to the audience. A lengthy discussion followed on the detection of radioactive waste at landfills and scrap metal yards. Staff at the CNSC have noticed an increase in the number of "what to do"queries, from operators of these establishments when alarms occur. Committee members suggested that the reason for this increase is twofold: more facilities are installing these highly sensitive portal alarms, and, alarm thresholds are being set too low. As a result of discussions with portal monitor suppliers, and following site visits, CNSC staff have developed forms that outline procedures to be followed by workers in the event of an alarm. Several committee members felt the forms were mostly directed towards landfills. CNSC staff agreed and will review them to insure they also apply to scrap yards.

The last item of the day involved a discussion on dose limits to first responders in emergency situations. In general, this is a provincial area where several dose limits currently apply. Because the item needed more discussion than time allowed it was tabled until Saturday's meeting.

Health Canada hosted the third day of meetings with Dr. Jack Cornett chairing the morning sessions and Robert Bradley directing proceedings in the afternoon. Following Dr. Cornett's welcoming remarks Tony Mattioli, chief of the Occupational Radiation Hazards Division at HC gave on overview of software changes taking place at the National Dose Registry. These new changes were made to upgrade a 20 year old system and will be more user friendly than the old one and allow better access for regulatory authorities. He noted that training will be provided to users sometime early in the new year. Tony emphasized that the dosimetry formatting requirements will stay the same for service providers.

Our next presenter was Dr. Dorothy Meyerhof, chief of the Environmental Radiation Hazards Division at HC, who brought everyone up-to-date on the Intervention Guidelines following nuclear emergencies. Dr. Meyerhof indicated that following extensive consultations with the provinces the document, which stresses intervention based on the most sensitive part of the population, was complete. She mentioned that some additional work needs to be done on transportation through evacuated areas, protection of workers and links to operational levels. These areas will be addressed sometime in 2004/05. Dr. Cornett added to the information by providing members with the names of two companies, Purity Life and Burditt-Coutts, that now provide 65 mg. potassium iodide (KI) tablets in Canada. He also suggested that issues related to tablet size have been addressed and the dosage for neonates is consistent with the World Health Organization's (WHO) guidelines that have been adopted in the HC document.

Prior to the morning break this scribe gave an overview of Nova Scotia's naturally occurring radioactivity in drinking water issue. In the province, 2 radionuclides are of significance: Uranium and Lead-210. To date 184 school; 82 municipal and 98 "other" water supplies are involved in the testing protocol. Because of environmental variability the protocol, requires 4

(Continued on page 54)

Radiation Protection Committee… (Continued from page 53)
samples over a period of one year to determine the average level of lead-210 and 2 samples for uranium. Results for the 18 schools that have had 4 tests completed show that 14 exceed guidelines for Lead-210 and 3 for Uranium. The remainder of the involved water supplies are in various stages of sampling. It is important to note that all but 8 of these supplies are from drilled wells. Discussion on this item moved easily into the next one on the morning's agenda: changes to the Canadian radioactivity in drinking water guidelines. Dr. Bliss Tracy, section head of the Radiological Impacts Section at HC, pointed out in his presentation that changes in Maximum Acceptable Concentrations, for natural radionuclides, calculated from recent dose coefficients, have caused some limits to increase while others have decreased. The limits for most artificial radionuclides have remained unchanged. He also indicated that the new draft guidelines and supporting documentation will better outline the alpa/beta screening criteria and would likely not include a specific number. A working group of the FPTRPC has reviewed the proposed amendments, made some changes, and a new draft has been sent to all committee members requesting comments . The comment period ends on December 15, 2003.

Updates by HC staff on various topics of interest to members including: environmental monitoring; renewal of federal health legislation; safety code and regulatory updates; and the medical devices review process continued throughout the morning.

The afternoon sessions, guided by Bob Bradley, director of the Consumer and Clinical Radiation Protection Bureau CCRPB, began with Wayne Tiefenbach summarizing the results of a poll he conducted with respect to the frequency of provincial X-ray equipment inspections. It was noted during this summary that the frequency in most regions has decreased in recent years. Reference levels for various diagnostic x-ray procedures were discussed at length since the ICRP is recommending them and the European Union is actively working in this area. Manitoba's radiation protection personnel are now utilizing their own reference levels that are based on exposures measured during the previous year's inspections. The committee's medical utilization working group has been asked to examine this issue before the next meeting. A related topic: digital radiography guidelines were debated, particularly since many jurisdictions are finding doses to patients increasing with the introduction of this modality. It was felt, because of rapid advances in this area, new standards need to be developed. Further review of this item will be undertaken by the medical utilization group.

Two topics in the non-ionizing radiation area closed out the day's agenda . Dr. Stephen Bly, head of the Acoustics Section of the CCRPB, informed the group that HC has prepared an "It's Your Health" information document explaining the issues associated with entertainment ultrasound. He noted that many facilities are beginning to perform this procedure and although there are no documented negative health affects he emphasized ultrasound does produce local heating and other biological effects to tissue. In the other non-ionizing area Dr. Art Thansandote and staff demonstrated a system they have developed to measure cellular emissions. This easy to use device, containing a Global Positioning System (GPS) with a computer interface, can be mounted on the roof of a vehicle and, while it is been driven, perform real-time displays. His staff have used this device extensively with success and offered it to any jurisdiction who wishes to carry out similar measurements.

Wayne Tiefenbach had everyone on deck early for Saturday's meeting which began with a review of the work completed since last year's meeting and the assignment of new work to the various working groups and sub-committees. The following is a synopsis.

Radiation Standards Working Group.

Mr. Chris Thorp of the DND, chairman of this group, reported that there were three items delegated to the group: activities related to the harmonization of pregnant worker dose limits; industrial radiography regulation harmonization and what workers should be monitored (badged).
On the pregnancy dose limits item, a communique outlining the workshop conclusions has been signed by the co-chairmen of the FPTRPC. A similar communique for release to the general public is not yet complete. An action plan is being developed to promote the conclusions of the workshop and the responsibility for this promotion will be assigned to the federal members of the committee.

Committee members are to comment by January 30, 2004 on an Industrial Radiography Harmonization document that was distributed by the chair of the group during Wednesday's proceedings. With respect to the monitoring of workers, it was suggested by the group that the conditions of CNSC's R91 be applied.

Provincial Radiation Dosimetry Review Sub-Committee.

This sub-committee will continue to monitor CNSC's dosimetry application process and draft an extended wearing criteria document for the committee's approval.

Survey Instrument Working Group.

All committee members will receive another internal/external instrument calibration survey form from this group to be completed and returned by December 31, 2003.

Canadian Naturally Occurring Radioactive Material Working Group.

Members of this group will: review their terms of reference; review their respective sections of the Western Canadian Guidelines and propose a new title for the Western guidelines. Amendments to the transportation section of the guidelines will be completed pending the finalization of amendments to CNSC's Packaging and Transport of Nuclear Substances Regulations.

Medical X-ray Utilization Working Group.

Representatives of all jurisdictions were asked to submit to this group any data or studies they may have on computerized (CR) and digital radiography (DR). Richard Tremblay and Bob

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Photodynamic Therapy – A Medical Physics Perspective

By Michael S. Patterson

Juravinski Cancer Centre and
McMaster University
Hamilton, Ontario

Introduction

Although the adjective "photodynamic" sounds like the creation of a Madison Avenue brainstorming session, it was actually coined a hundred years ago by the German photobiologist Hermann von Tappeiner. He used the term "photodynamic action" to describe the oxygen-dependent photochemical reactions by which certain dyes such as eosin were able to kill micro-organisms. It has taken a century for these original observations to evolve into a mature medical technology (i.e. one that makes money for somebody), but if you enter "photodynamic therapy" into PubMed, you will now find over 9,000 references. The odds are increasing that someone will approach you in the hall one day and ask you (as the repository of esoteric scientific knowledge in your hospital), what this PDT stuff is all about. This article is an attempt to provide you with enough information to make intelligent noises in response. It is not a review article – several have recently been published and are listed below. Instead I want to introduce basic concepts from the perspective of the medical physicist and describe some of our recent research on PDT dosimetry.

What is PDT and how does it work?

Figure 1 illustrates the essential ingredients and steps in PDT. Nothing happens until a photosensitizer molecule in the ground state, S_o , absorbs a photon. While there are naturally occuring sensitizers present in our bodies in low concentration, exogenous sensitizers are usually supplied, either systemically or topically. Depending on the drug, this phase of the treatment occurs a few hours or days before irradiation. Absorption of a photon raises the sensitizer molecule to an excited electronic state with a lifetime of a few nanoseconds (S_1 in Fig. 1). Return to the ground state can occur by fluorescence or a non-radiative process, but efficient sensitizers undergo an electron spin rearrangement (intersystem crossing or ISC) to produce a triplet excited state, T_1 . This triplet state is relatively long-lived (tens of microseconds in tissue) because radiative transition to the ground state is forbidden although it does occur with low probability (indicated as phosphorescence in Fig. 1). The most likely fate for the triplet is an interaction with molecular oxygen that results in an excited electronic state. This singlet state is highly reactive and is thought to be the mediator of most PDT effects, although it is only recently that definitive evidence of this has been obtained. Note that this so-called "singlet oxygen", $^1O_2$, can return to its triplet ground state by emission of phosphorescence but that this is a rare event. The lifetime of singlet oxygen in tissue is tens of nanoseconds, so that it diffuses less than 100 nm before reacting. Damage from PDT is thus "local" even on a cellular scale and occurs very close to the site of light absorption by the photosensitizer molecule. This description shows that there are three essential ingredients to PDT: sensitizer, light, and oxygen – all three must be present if photodynamic damage is to occur. Oxygen is even more critical than in radiation therapy where hypoxic cells are two or three times less sensitive. For PDT it has been demonstrated *in vitro* and *in vivo* that hypoxia provides complete protection.

The sequence of events following the generation of singlet oxygen is complex and depends on many variables such as the particular photosensitizer and its cellular localization, the time interval between sensitizer administration and light delivery, and the temporal dependence (e.g. fluence rate, fractionation) of irradiation. Mitochondria and lysosomes are common sites of sensitizer localization and damage to these organelles can lead to cell death by necrosis or apoptosis (programmed cell death). While DNA damage is possible, it is believed to be relatively unimportant and the mutagenic potential of PDT is low. In addition to this direct cell killing, PDT can also target the vasculature if the sensitizer is retained by endothelial cells or if there is sensitizer in circulation. The resulting vascular shutdown can cause ischemic cell death and this is known to be a significant factor in tumor response for some sensitizers. Finally, PDT can elicit an inflammatory response and these systemic immune effects may be important in successful treatments.

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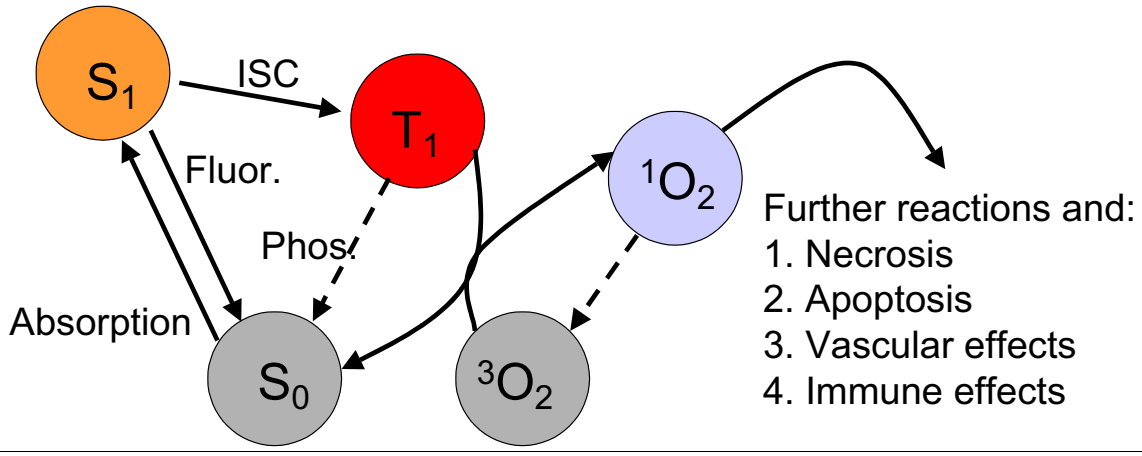

Figure 1: Basic elements of PDT. Light absorption by the ground state of the photosensitizer molecule leads to production of its triplet state and energy transfer to molecular oxygen. Singlet oxygen is highly reactive and is believed to be the principal mediator of biological effects.

Photodynamic Therapy... (Continued from page 55)

What does PDT have to offer?

To help answer this question I have listed the characteristics and potential advantages of PDT below:

1. The extent of tissue damage is limited by light penetration.
2. Except for the manageable cutaneous photosensitivity associated with some sensitizers, the toxicity of PDT is relatively low.
3. The healing response of normal tissue is good.
4. Blood vessels can be selectively targeted.
5. The treatment can be repeated if necessary and does not preclude other interventions such as surgery or ionizing radiation.
6. The treatment can be delivered in a single session.
7. Equipment and drug costs are relatively modest.

We might speculate that PDT would be ideal for treating diseases characterized by the chronic local proliferation of new blood vessels. This occurs in one form of age-related macular degeneration (AMD) – the leading cause of vision loss in Western society. PDT is now approved for treatment of AMD in 72 countries and this is far-and-away its greatest success. Sales of Visudyne, the sensitizer used in the treatment (and developed in Canada by QLT), were $357 M (US) in 2003. Cancer could also be included in this category and, in fact, most of the first 90 years of PDT development were focused on cancer – ophthalmology is a relatively new application. Although PDT has been used as a "last resort" in treating advanced disease, the list above suggests that it would be most suitable as frontline therapy for early, even precancerous, lesions. Of course, securing regulatory approval for such applications is more difficult, especially if other accepted (even if ultimately inferior) treatments exist. Nonetheless, we are seeing a trend in this direction as PDT has received approval for treatment of actinic keratoses and high grade dysplasia in Barrett's esophagus – a precursor of esophageal cancer. PDT might also have a role in treating local recurrences after other modalities have failed. For example, a clinical trial is now under way of PDT for local recurrence of prostate cancer following radiation therapy. Palliative applications of PDT have taken advantage of its low toxicity and single fraction delivery. Outside of oncology and ophthalmology, PDT is being investigated for prevention of restenosis following angioplasty and for local treatment of autoimmune diseases. The review papers listed at the end of this article provide a complete listing of clinical applications to date.

The Nuts and Bolts of PDT

This article is not intended as a how-to manual for PDT but some specific examples should help illustrate what is involved in a typical treatment. The first step is sensitizer administration and, as mentioned above, this is usually systemic by intravenous injection. If the vasculature is the target, irradiation will take place within a few hours. Otherwise, several days might pass to allow the sensitizer to clear from the circulation and distribute in the target tissue. For skin cancer, topical application of the PDT agent may be possible. An elegant treatment pioneered by Jim Kennedy at the Kingston Regional Cancer Centre is to apply aminolevulinic acid (ALA) to the skin. ALA is not a sensitizer, but it is taken up by cells and used by the heme synthesis pathway to produce protoporphyrin IX, an effective generator of singlet oxygen. There are hundreds, if not thousands, of compounds capable of photodynamic action, but only about a dozen of these are in human use. Even fewer (four at last count) have received regulatory approval for various indications.

The second step of the treatment, light irradiation, poses problems familiar to the radiation oncology medical physicist. The target volume should receive a uniform light fluence (typically 100 J cm^{-2} is required at the peak absorption wavelength of the sensitizer). For surface lesions, a number of light sources are viable candidates. Filtered broadband lamps have been used in the past but an attractive option now available is a LED array. Figure 2 shows the PDT treatment room at the London Regional Cancer Centre equipped with a number of these arrays for treating several patients simultaneously. Figure 3 shows a squamous cell carcinoma prior to and one year after PDT with ALA. The excellent cosmesis is typical of these treatments and makes them attractive for lesions on the face. Also shown in Fig.3 is an image of the fluorescence emitted by the PpIX synthesized within the cells. The fluorescence emitted by the sensitizer may be useful in demarcating the lesion and deciding on the treatment volume.

Treatment of internal lesions is more challenging and, as in brachytherapy, the light source can be either intralumenal or interstitial. The light is delivered using an optical fiber that is modified to act as a line or point source of light. Lasers are the only sources capable of coupling adequate power into an optical fiber. In the last few years high power diode lasers have become available at the wavelengths necessary for sensitizer excitation (630 – 800 nm). These lasers are cheaper, more reliable, and more efficient than the dye and metal vapor lasers that were utilized in the past. Their only drawback is a lack of tunability, so that different lasers may be required to excite different

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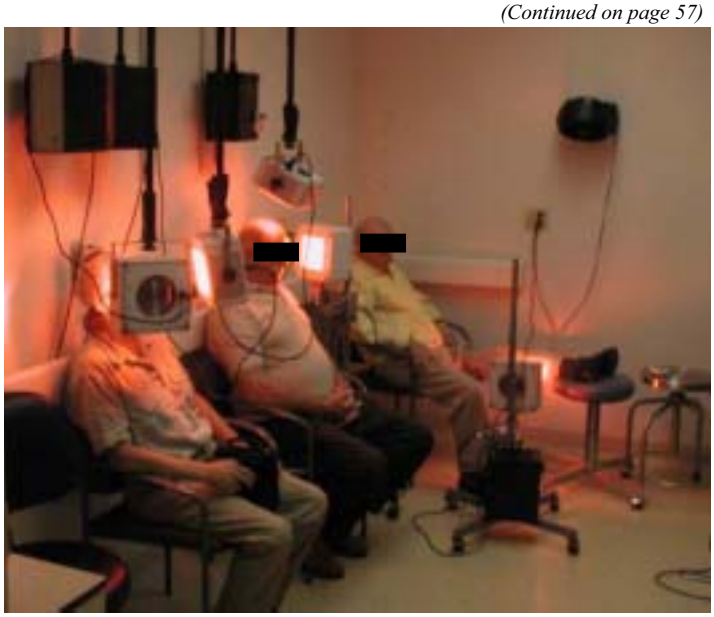
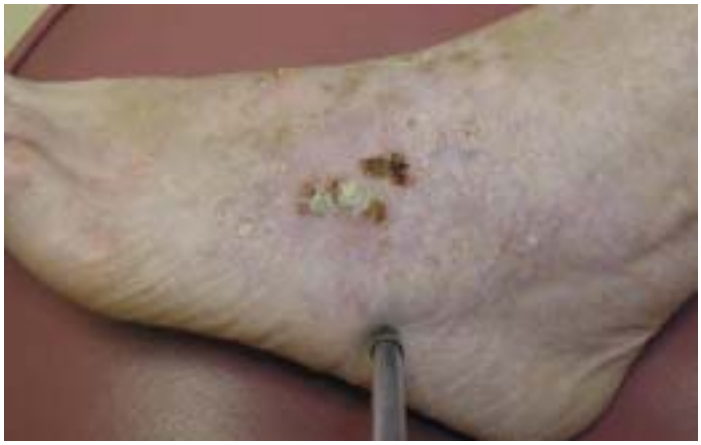
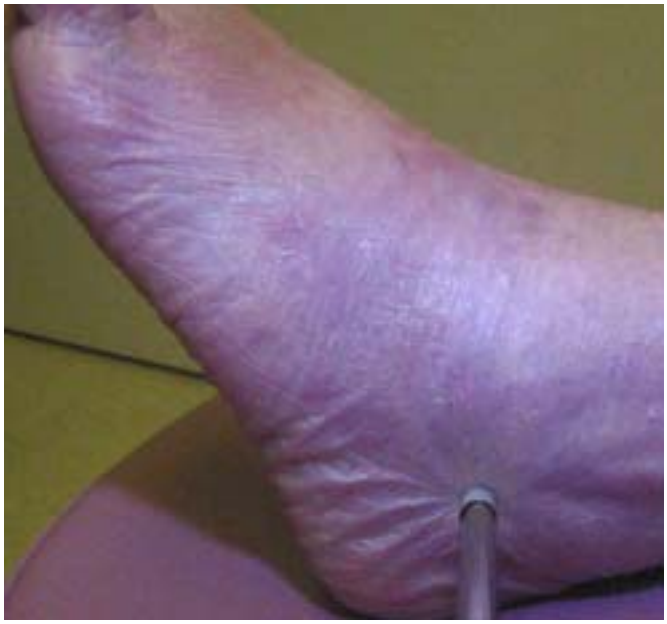


Figure 2: PDT treatment room at the London Regional Cancer Centre. Three patients are receiving treatment simultaneously using LED arrays for surface irradiation. Photo courtesy of Kevin Jordan, London Regional Cancer Centre.





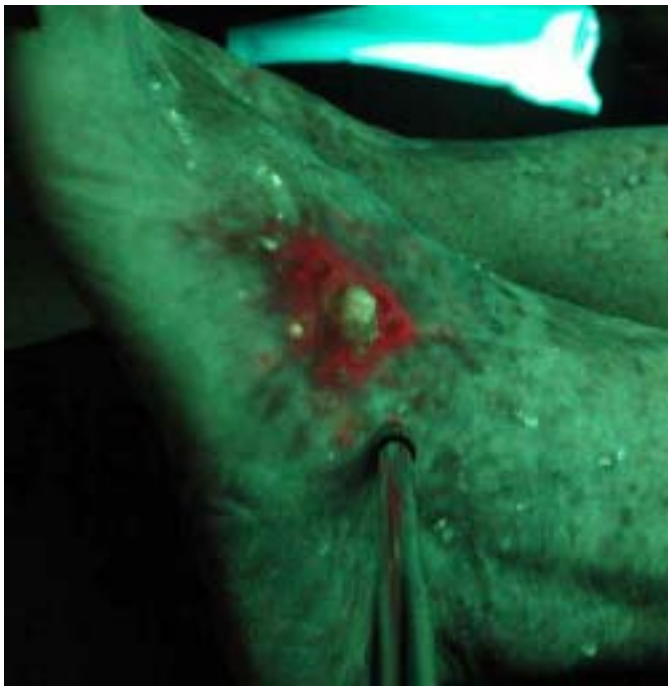


Figure 3 (clockwise from upper left): Squamous cell carcinoma prior to PDT, PpIX fluorescence during PDT, excellent response one year after PDT. Photos courtesy of Kevin Jordan, London Regional Cancer Centre.

sensitizers. A clinical diode laser with an output of several watts costs $50 to $100K Canadian. For intralumenal delivery, a bare point or line source fiber may be used, but a specialized applicator that holds the fiber in a fixed geometry is advantageous. An example of a specialized applicator is shown in Fig. 4. This was designed by Brian Wilson (now at the Ontario Cancer Institute) for PDT of the resection cavity following surgical removal of brain tumors. The applicator consists of a disposable balloon that can be filled with a light scattering liquid until it fits snugly in the cavity. A point source optical fiber inside the balloon delivers light from the laser, and scattering within the balloon ensures uniform irradiance at the tissue surface. Similar designs have been used for cylindrical applicators for the esophagus, lung, and rectum.

Interstitial techniques are necessary when treating volumes more than 5 – 10 mm thick. Optical fiber line sources are implanted using techniques very similar to those employed in brachytherapy. Beam-splitting optics can be used to couple the output of the treatment laser into multiple interstitial fibers. Figure 5 is a contrast-enhanced MRI taken seven days after PDT was delivered via two optical fibers implanted trans-peritoneally in the prostate. This patient had suffered a recurrence following radiation therapy and was participating in a Phase 1 trial of PDT using TOOKAD, a new sensitizer excited at 760 nm. This wavelength offers maximum light penetration in tissue and, as seen in Fig. 5, a large volume of necrosis can be achieved around each treatment fiber. In Phase 2 trials soon to begin, complete prostate ablation will be attempted using additional implanted fibers.

In conclusion, clinical PDT requires a sensitizer, a light source, and for internal applications, single-use optical fiber applicators. The cost of drug (for systemic use) and applicators is the same order of magnitude as a course of radiation therapy. I will address the issue of dosimetry in the next section.

PDT dosimetry – not quite TG51!

In ionizing radiation therapy the term “dose” has a precise definition (energy absorbed per unit mass) and many decades of clinical experience have established a reliable relationship between radiation dose and clinical response. Clinical physicists strive to measure and calculate absolute dose to within a few percent using national and international protocols. In comparison, PDT dosimetry is, at best, crude. It is not even clear what the definition of PDT dose should be. One candidate would be the total amount of singlet oxygen generated per unit mass (or volume) of tissue, but this quantity is difficult to measure or calculate. Fifteen years ago, we suggested that a proxy could be the number of photons absorbed by the sensitizer per unit volume of tissue. This quantity is the time integral of the product of the light fluence rate and the sensitizer concentration – two

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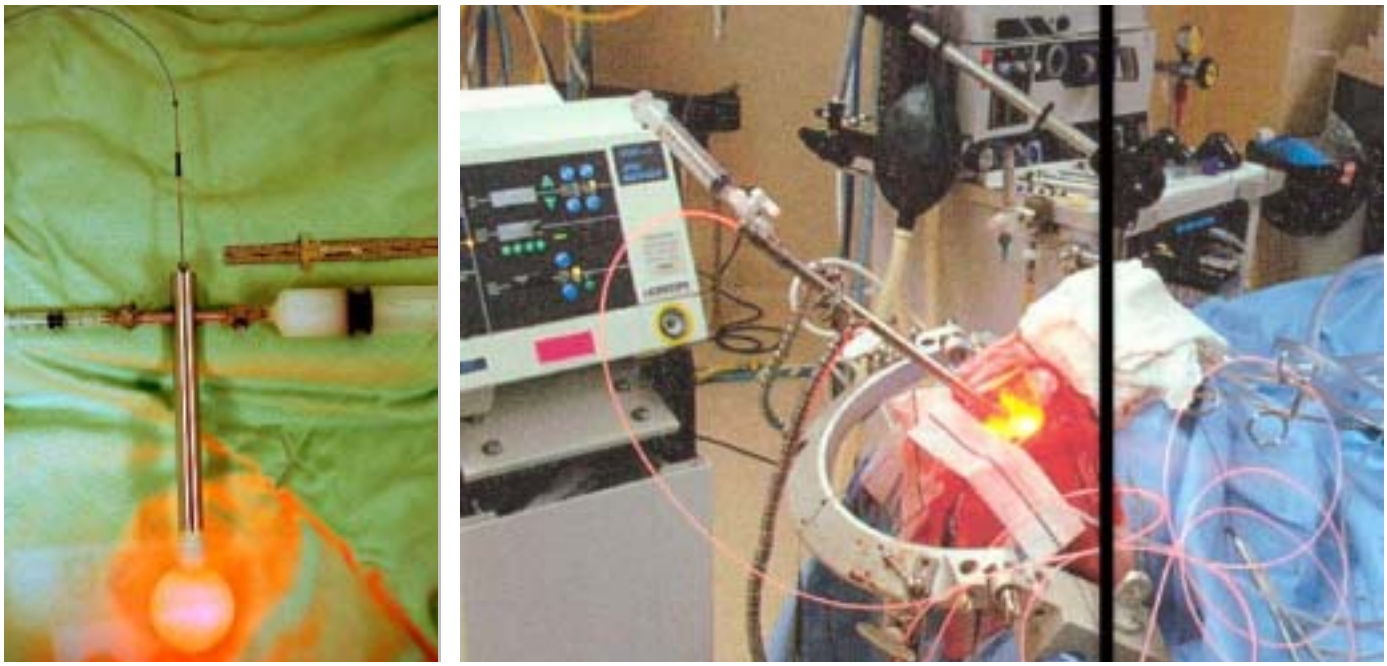

Figure 4: (left) Applicator for PDT of the resection cavity following surgical removal of brain tumors. (right) The applicator in use in the OR at St. Michael's Hospital, Toronto. The device at the far left is a dye laser pumped by a solid-state laser. The optical fiber that couples light from the laser to the applicator can be identified by the red light that "leaks" through the fiber cladding. Photos courtesy of Brian Wilson, Ontario Cancer Institute.

parameters more amenable to routine measurement. As long as the singlet oxygen quantum yield is constant, this integral is proportional to the singlet oxygen dose defined above. Since that suggestion was made, evidence has mounted that this assumption is not always true. The problem is that PDT can consume oxygen faster than it can be supplied by the microvasculature. If the local pO_2 gets too low, the sensitizer triplet molecules will de-excite by competing pathways and the singlet oxygen yield will drop. This has been shown in experiments where PDT treatments performed at high fluence rates were less effective than those at low fluence rates even though the total fluence was identical. Clearly, PDT dosimetry is a tough problem! We are pursuing three parallel strategies to address it and each is described briefly below. For historical reasons I will refer to these strategies as explicit, implicit, and direct dosimetry.

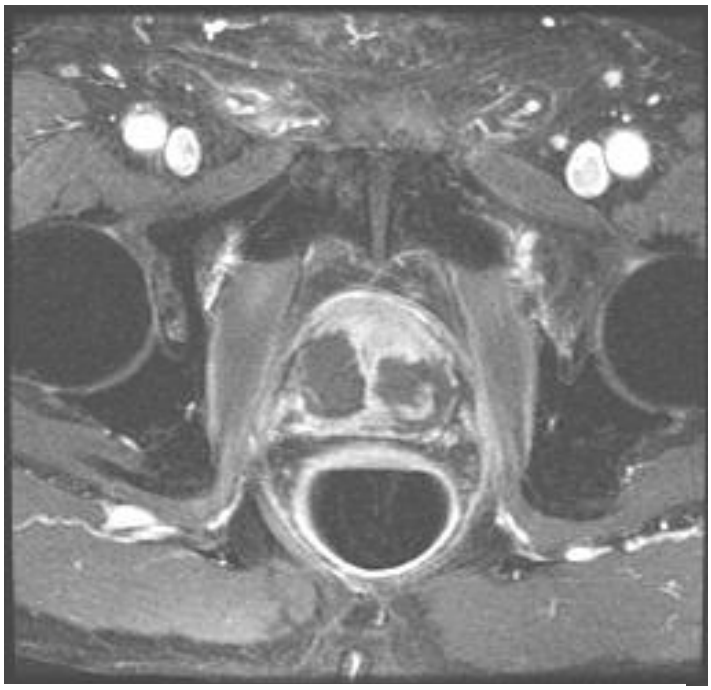

Figure 5: Contrast-enhanced MRI seven days after PDT of the prostate. Note the two necrotic regions produced around each of the implanted optical fibers. Photo courtesy of Robert Weersink, Ontario Cancer Institute.

Explicit dosimetry

We know that photosensitzer concentration, light fluence rate, and oxygen concentration drive the photodynamic effect. We also know that these can vary from patient-to-patient due to differences in pharmacokinetics, tissue optical properties, and tumor physiology. Furthermore, all of these can change dynamically during a PDT treatment. The goal of this dosimetry approach is to make "explicit" measurements of these quantities in real time and to use that information to calculate an effective singlet oxygen dose. Much of our effort has been focused on developing the tools to make such measurements and that has required us to learn a lot about light propagation in tissue. Figure 6 is an example of this work. It shows a schematic diagram of an optical fiber probe that can be placed on the tissue surface or implanted. Excitation light from a diode laser is coupled into the fiber and causes the sensitizer to fluoresce. This emission is collected by the same fiber and is reflected into a miniature spectrometer by a dichroic mirror. Because the excitation is delivered and the fluorescence collected by the same 200 micron fiber, the probe is very compact. An additional advantage is that

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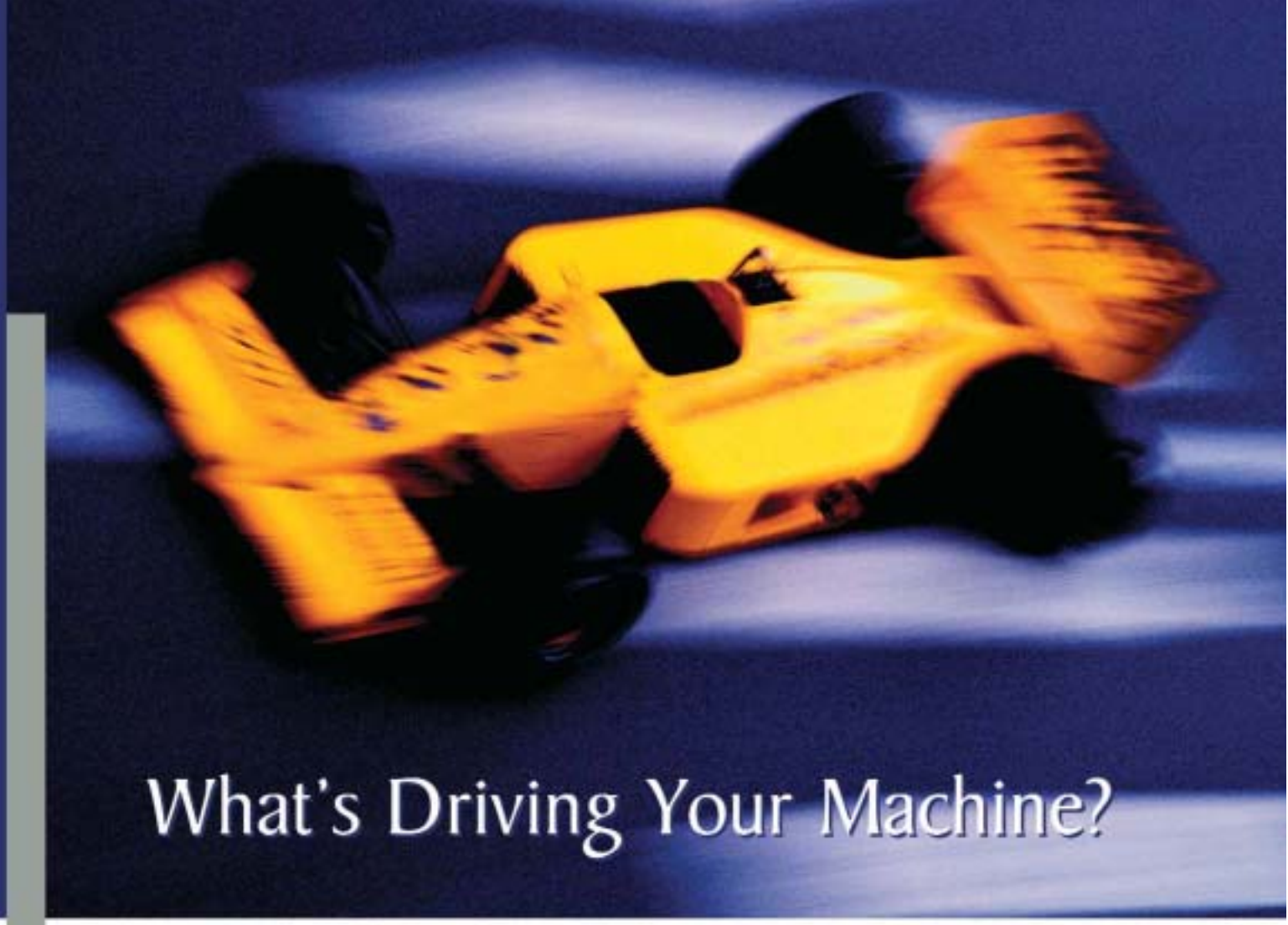

What's Driving Your Machine?

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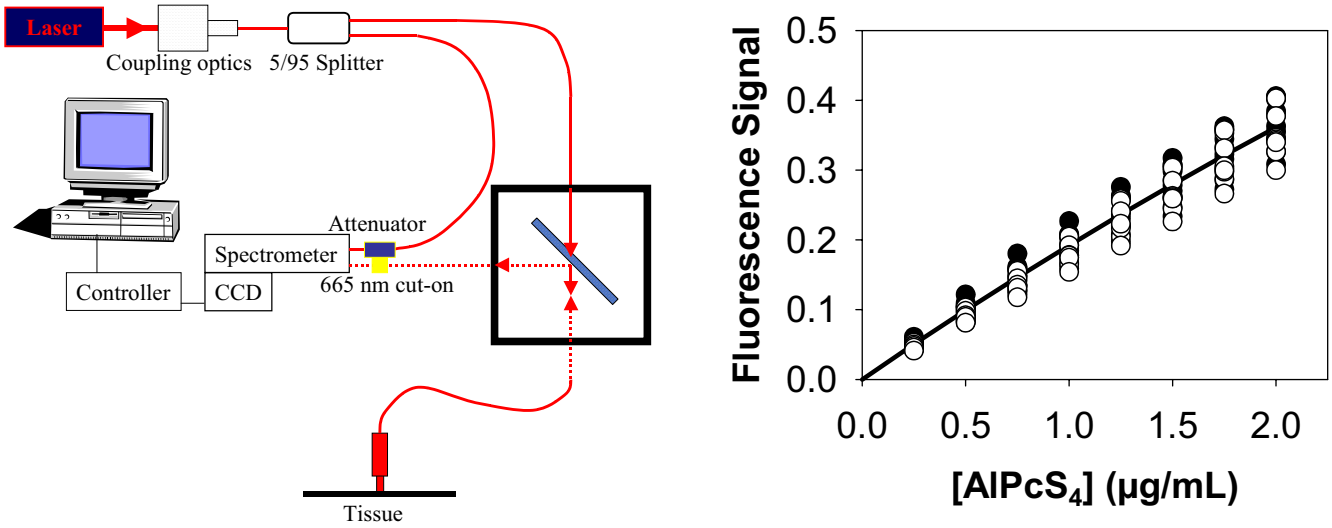

Figure 6: On the left is a schematic diagram of a system designed to measure sensitizer concentration *in vivo* by fluorescence spectroscopy. Excitation light is transmitted through the dichroic mirror and into the optical fiber. Fluorescence collected by the same fiber is reflected by the mirror into the miniature CCD spectrometer. The graph on the right plots the fluorescence signal versus sensitizer concentration for tissue-simulating phantoms with a wide range of optical properties. The solid symbols represent measurements made with the probe on the phantom surface while the hollow symbols correspond to interstitial placement. The smooth calibration curve yields rms errors of 10% in concentration.

this geometry responds to the sensitizer in a small volume at the fiber tip so that the signal depends mainly on the sensitizer concentration and only weakly on the optical properties of the tissue. This is illustrated in Figure 6 where the signal is plotted versus photosensitizer concentration for several tissue-simulating phantoms with a wide range of scattering and absorption coefficients.

Implicit Dosimetry

While we have made considerable progress with the explicit approach, the simultaneous measurement of light, drug, and oxygen is complex. Our second approach seeks a surrogate for biological damage that is "implicitly" related to the dose. This might be some physical property of the tissue that changes in response to PDT (e.g. MR relaxation times or ultrasound backscatter) but another promising candidate is the photochemical destruction of the sensitizer itself. The simple picture in Fig. 1 implies that the photosensitizer molecule acts as a sort of catalyst , but the singlet oxygen can also react with the sensitizer and convert it to an inactive form. This form is usually non-fluorescent as well, so we can monitor this process (referred to as fluorescence photobleaching) in real time using an instrument like that shown in Fig. 6. As a first step in exploring this approach we are using a simpler model – cell suspensions where all the conditions during PDT including oxygen concentration can be carefully controlled and monitored. The apparatus in Fig. 7 allows us to acquire fluorescence spectra from the sensitizer as PDT is delivered. Small aliquots of the suspension are removed at various time points for colony forming assay. If fluorescence photobleaching is to be useful as an implicit dosimetry technique, there should be a universal relationship between bleaching and cell survival that does not

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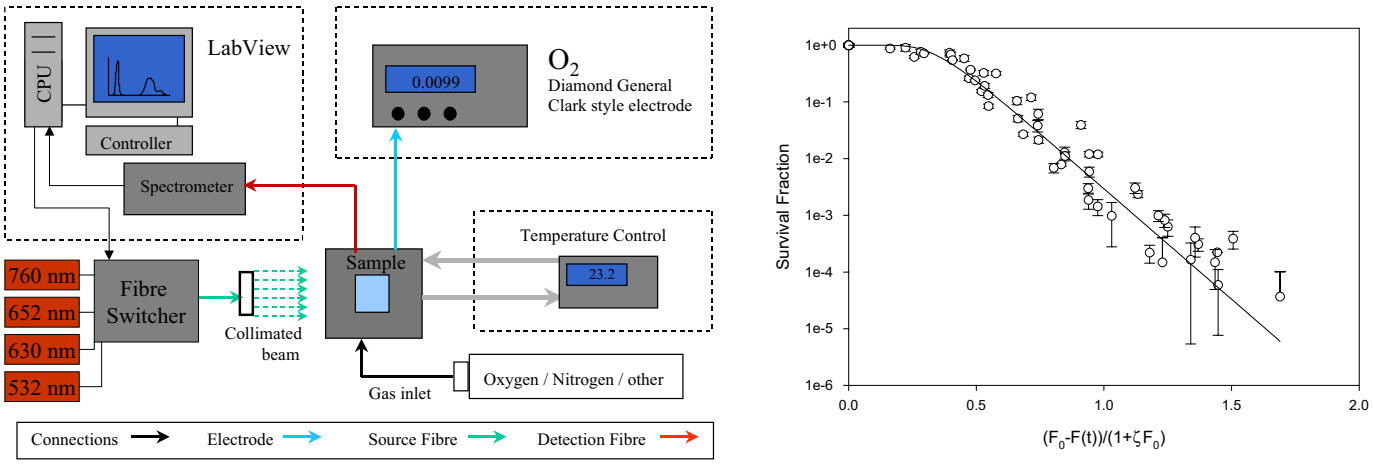

Figure 7: (left) Schematic of the apparatus used to study the relationship between cell survival and sensitizer fluorescence photobleaching. (right) Plot of cell survival versus an implicit dose based on photobleaching and described in the text.

depend on (or can be easily corrected for) treatment variables such as fluence rate, sensitizer concentration, and oxygenation. For the sensitizer mTHPC we have proposed that an implicit dose is given by $(F_0 - F)/(1 + \zeta F_0)$ where F_0 is the initial fluorescence, F is the fluorescence after treatment and ζ is a parameter that accounts for the fact that singlet oxygen can react with the sensitizer molecule that generated it or it can diffuse a short distance to react with a different molecule. In Fig. 7 cell survival is plotted against this implicit dose for a wide range of treatment conditions including hypoxia and a single curve can indeed be used to fit all of the data. We are currently investigating the validity of this approach for different sensitizers and cell types.

Direct dosimetry

Earlier (see Fig. 1) I mentioned that singlet oxygen emits weak phosphorescence in the near infrared (1270 nm). Detection of this emission would provide a direct measure of singlet oxygen and would be the ultimate measure of PDT dose. There was a flurry of activity in this area around 1990 when several groups (including us) attempted to detect singlet oxygen *in vivo.* At that time we concluded that available detectors did not have the required sensitivity. Recent development of a new photomultiplier tube with enhanced infrared sensitivity prompted us to try again and in 2002 Mark Niedre, a PhD student at the Ontario Cancer Institute, published the first convincing demonstration of singlet oxygen detection in cells and animals during PDT. The apparatus currently used for *in vivo* work is shown in Fig. 8. Because the phosphorescence is so weak and it must be separated from a huge background of fluorescence and scattered light, both spectral and temporal discrimination are employed. A short pulse of light is used to initiate the PDT reactions, and the emission is collected through a system of optical filters designed for optimal transmission at 1270 nm after the fluorescence has decayed.

Mark's latest experiments have examined the relationship between the time-integrated singlet oxygen signal and treatment effect. PDT was performed on the normal skin of mice and the response was graded by a blinded observer on a scale ranging from no effect to necrosis. Figure 8 shows a plot of this score integrated over two weeks for individual animals versus the total singlet oxygen phosphorescence. The latter is an excellent predictor of treatment response, but these measurements will be challenging to perform in the clinical environment. Direct dosimetry may be most valuable as a means of calibrating and standardizing the other methods described above.

Final words

The long term goal of our research on dosimetry is to understand what physical measurements are necessary to predict the response of individual patients to PDT and to optimize their treatment. We do not yet know how accurate dosimetry must be for PDT because we are only now figuring out what dose is and how to measure it. We anticipate that better dosimetry will foster the development and utilization of PDT. As for the therapy itself, interest continues to grow at a slow pace except in ophthalmology where PDT is the best treatment available for some indications. As clinicians learn more about the concept, and as better sensitizers and devices become available, PDT will likely assume a larger role in oncology and other fields of medicine as well.

Acknowledgements

I am grateful to the National Cancer Institute of Canada, the National Institutes of Health (US), Photonics Research Ontario, and the Canadian Institute for Photonic Innovations for financial support of PDT research. I also appreciate the contributions of

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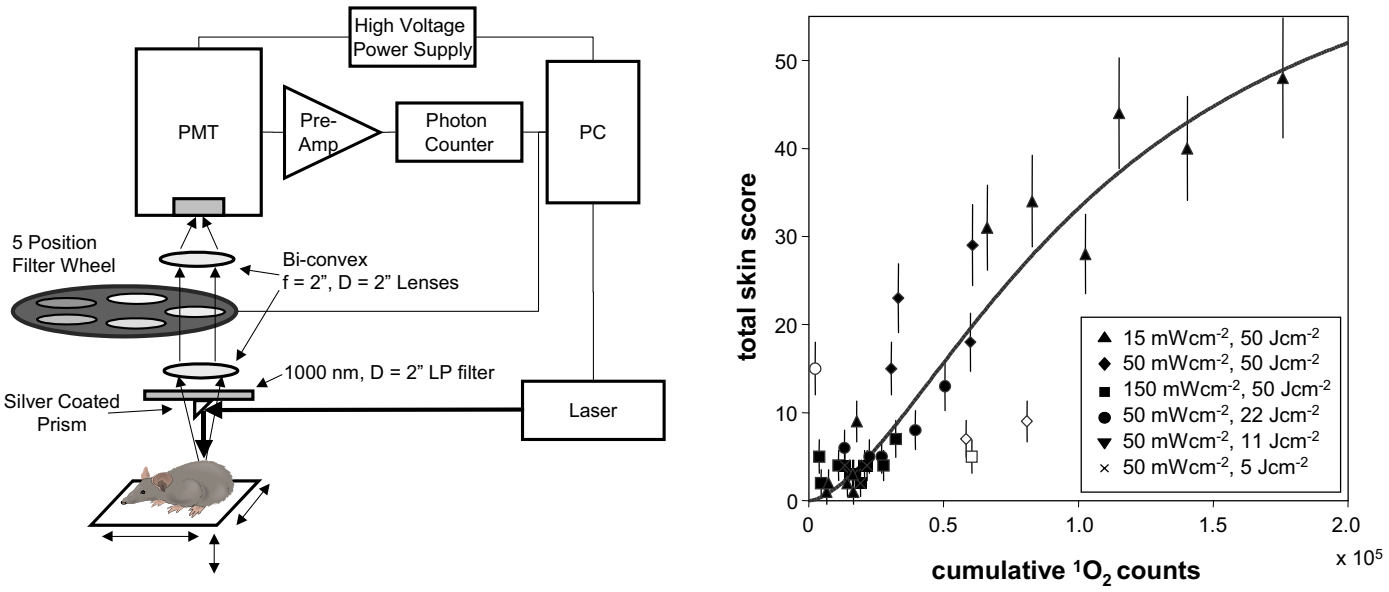

Figure 8: (left) Apparatus for the detection of singlet oxygen phosphorescence *in vivo.* (right) Visually scored response of normal mouse skin to PDT versus the total singlet oxygen signal measured during treatment. The symbols refer to different light fluence rates and total fluence.

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

many colleagues and students, in particular Brian Wilson, Tom Farrell, Joe Hayward, Gurmit Singh, Lothar Lilge, Robert Weersink, Paul Muller, Fred Hetzel, Kevin Jordan, Kevin Diamond, Jon Dysart and Mark Niedre.

Further reading (reviews of PDT)

D. Dolmans, D. Fukumura and R.K. Jain, Photodynamic therapy for cancer, *Nature Reviews/Cancer* 3:380 – 387 (2003).

M.V. Vrouenraets, G.W.M. Visser, G.B. Snow and G.A.M. van Dongen, Basic principles, applications in oncology and improved selectivity of photodynamic therapy, *Anticancer Research* 23: 505 – 522 (2003).

J. Moan and Q. Peng, An outline of the hundred-year history of PDT, *Anticancer Research* 23: 3591 – 3600 (2003).

Further reading (some of our recent dosimetry papers)

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 Research* 63: 7986-7994 (2003)

J.S. Dysart, M.S. Patterson, T.J. Farrell and G. Singh, Relationship between mTHPC fluorescence photobleaching and cell viability during photodynamic treatment of DP16 cells, *Photochemistry and Photobiology* 75: 289-295 (2002).

K.R. Diamond, M.S. Patterson and T.J. Farrell. Quantification of fluorophore concentration in tissue simulating media by fluorescence measurements with a single optical fiber. *Applied Optics*, 42: 2436-2442 (2003).

Dave Rogers on the move!

Submitted by Paul Johns,
Ottawa Regional Cancer Centre, Ottawa, ON

Congratulations to David W.O. Rogers on being named CRC Tier 1 Chair in Medical Physics!

David Rogers was approved by the Canada Research Chairs Program this past October for a Tier 1 Chair in Medical Physics at Carleton University in the Department of Physics. In December 2003 Dave moved from being Leader of the National Research Council's Ionizing Radiation Standards group to Carleton University where he heads a new laboratory in numerical radiation transport modelling for radiotherapy. Since the 1980's Dave has been a strength of the medical physics academic program in Ottawa. He was appointed an Adjunct Professor to Carleton Physics in 1986 and served as the Secretary of the Ottawa Medical Physics Institute (OMPI) for its first two years from its founding in 1989. Under his supervision, 4 PhD + 1 MSc theses have been completed, and currently 1 PhD + 2 MSc students are in progress. The awarding of this Chair will expand the Cancer Therapy stream in Carleton's medical physics program substantially. Dave's research will build on collaborative work done with scientists at the NRC and elsewhere on Monte Carlo methods of simulating radiation transport, both for calculating radiation doses in cancer radiotherapy patients and for improving clinical dose measurement. Application of the EGS code to radiotherapy has largely been the work of the NRC group headed by David Rogers over the last 18 years. The current version, EGSnrc, is considered the gold standard for such calculations. There will be important linkages between Dave's research program in Monte Carlo applications to radiotherapy, situated on the Carleton campus, radiation standards research at the NRC, and clinical research at the Ottawa Regional Cancer Centre. To our knowledge, this is the first CRC awarded in the area of radiotherapy physics.

For more details:
(i). Carleton University announcement:
http://www.carleton.ca/duc/newsreleases/jul_dec_2003/crc-oct03.html
(ii). CRC profile on Dave Rogers:
http://www.chairs.gc.ca/web/chairholders/index_e.asp > search for Rogers
(iii). Medical physics in Canada's capital:
http://www.physics.carleton.ca/ompi

New contact information:
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Web: www.physics.carleton.ca/~drogers

Radiation Protection Committee… (Continued from page 54)
Bradley will investigate the availability of information on the calibration of monitors for CR/DR.

Joint Documents Working Group.

A lengthy discussion on the future of joint document publication ensued with the possibility that the committee may have to unilaterally publish documents. Health Canada offered to provide translation services if this became a reality. Kevin Bundy from the CNSC will discuss options for joint publications with CNSC's legal and regulatory departments. In the meantime the joint publication of C-260 will await legal opinion.

Business Plan Working Group.

Comments on the FPTRPC's business plan, developed by this group, are to be submitted to the group chairman by December 31, 2003. Following incorporation of the comments the plan will be complete, posted to the committee's website and updated at each yearly meeting.

Communications Working Group.

The usual summary of the Committee's meetings will be prepared by the working group chairman, yours truly, and published in both the Canadian Radiation Protection Association's (CRPA) and Canadian Organization of Medical Physicists publications. Health Canada representatives indicated that they would provide translation for this summary. The chairman was also requested to investigate the cost of developing and maintaining a stand-alone committee website. The results are to be submitted to the co-chairs prior to next year's meeting. Representatives from both Health Canada and the CNSC implied that funding maybe available.

ELF Working Group.

Due to on-going international research, and projects like the WHO initiative, there will be no updates to the current position statement, however, an update to the background supporting document is well underway.

Mammography Working Group.

There was no action for this group since the last meeting.

Health Canada Drinking Water (radionuclide) Working Group.

The chairman of this group requested that committee members send their comments on the draft guideline revisions, along with any provincial data on radionuclides in their jurisdictions, to either Dr. Anar Baweja or Dr. Bliss Tracy by December 15, 2003.

New Business:

During a discussion on 1st responder training and dose limits, Dr. Jack Cornett indicated he would provide members with CRBN's 1st responder training curriculum and cross country training schedules. The provinces were asked to provide the chairman of the Radiation Standards Working Group with any relevant regulatory information on 1st responder dose limits they may have in their jurisdictions. Once this information is received the working group will develop a position statement regarding those limits.

Earlier in the week HC representatives proposed a radon workshop on Radon levels which the committee accepted. It will be held either in early March 2004 or in conjunction with the CRPA annual conference.

Concern was raised by members regarding the non-participation of some provinces on the FPTRPC. It was concluded that the co-chairs would write to the Deputy Ministers of those provinces to solicit their participation. A new letter to the participating province's deputies will be sent to thank them for their continued support.

This concluded the 2003 meetings and October 26-30 was set as the dates for the 2004 gathering in Ottawa.

CCPM President... (Continued from page 45)

the review of current activities and forward planning, you will shortly be receiving a questionnaire offering you the opportunity to give input to CAMPEP to help shape it's future directions. I urge you all to take the opportunity to give your views on what CAMPEP should be doing to enhance and build on the activity that has been done in the past. With the current shortage of medical physicists, maintaining the standard of medical physics education and training will continue to be a priority for some years to come.

During the last year, a third Canadian graduate program (University of British Columbia) applied and was successful in gaining accreditation and McGill was also successful once again in their application for re-accreditation. I would like to personally congratulate the program directors, ***Ervin Podgorsak*** and ***Alex Mackay*** and their teams at McGill and UBC respectively. I have now been involved with CAMPEP for many years, initially as a minor faculty member at McGill when they first applied for accreditation 10 years ago and now as a member not only of the board of directors but also of several site review teams and recently as a member of the UBC faculty. So I have been through the accreditation process on both sides and have found it to be valuable in each case. From the perspective of the recent UBC application, I can say that although there was a certain amount of work involved in gathering and formatting the documentation, there has been a tremendous benefit. The program has been strengthened substantially as a result both of the work that we did before we filed the application and from the recommendations of the site review team. The net result for us is a more focused and coordinated program and a considerably higher profile in the UBC Physics and Astronomy Department but clearly the students are the big winners. My understanding is that prospective students are voting with their feet and preferentially applying to accredited programs, both here and south of the border.

Announcement

Advanced Workshop: Current Topics in Monte Carlo Treatment Planning

http://mctp.medphys.mcgill.ca

May 3-5, 2004
McGill University Health Centre
Medical Physics Department
Montréal, Québec, Canada

Background

During the 90's and this early millennium, a vast amount of work has been carried out on the development and implementation of Monte Carlo-based patient-specific treatment planning systems in research labs and academic hospitals. Most of the work has been done for external-beam radiotherapy; to a smaller extent brachytherapy has also been addressed. Recently, commercial versions of fast Monte Carlo algorithms for external-beam radiotherapy are being implemented in clinics. However, there are significant clinical issues that these new systems introduce and their potential to accuracy can be compromised by a lack of proper implementation. Furthermore, so far, only a small amount of data is available on the true clinical impact of Monte Carlo treatment planning for specific treatment sites or treatment techniques. Hence, the extent to which differences in doses and dose distributions link to predictive biological models for complication and control and how they will affect clinical treatment planning remains largely to be investigated. To address the current status of algorithm development, clinical implementation and clinical evaluation of Monte Carlo treatment planning, this Workshop will bring together developers, people involved in implementation as well as potential users of this technology. The workshop is designed to allow for plenty of in-depth discussion time and is organized in cooperation with IAEA (Vienna), NCI (Canada), IOP (UK), etc.

General Topics

A. Monte Carlo algorithms and virtual beams

1. Algorithms, cross sections and variance reduction techniques
2. Beam modeling
3. Parameterized source models
4. Brachytherapy Monte Carlo modeling
5. Monte Carlo-based inverse treatment planning

B. Clinical implementation and verification issues

1. Beam / source commissioning
2. Experimental verification in phantoms
3. Hardware / User interfaces / Automated MC planning systems
4. Evaluation software
5. Smoothing

C. Clinical evaluation issues

1. Monte Carlo issues in treatment sites and treatment techniques
2. Monte Carlo issues in IMRT
3. Dose to water - dose to tissue
4. Patient digitization issues (CT – density conversion, CT artifacts)

Invited speakers

A. Bielajew (USA)
B. Curran (USA)
B. Faddegon (USA)
M. Fippel (Germany)
R. Jeraj (USA)
I. Kawrakow (Canada)
T. Knoos (Sweden)
A. Lomax (Switzerland)
A. Lomax (Switzerland)
C.-M. Ma (USA)
J. Antolak (USA)
D.W.O. Rogers (Canada)
J. Sempau (Spain)
L. Souhami (Canada)
E. Spezi (UK)
J. Williamson (USA)

Publication of the proceedings of this international workshop will be in *Phys. Med. Biol.* For more information regarding registration and detailed program, see:

http://mctp.medphys.mcgill.ca

or contact the organizers:

Jan Seuntjens (jseuntjens@medphys.mcgill.ca) or Frank Verhaegen (fverhaegen@medphys.mcgill.ca).

Canada's First Gamma Knife⊇: Commissioning Report

Submitted by Anita Berndt and James Beck, CancerCare Manitoba, The University of Manitoba, and The Winnipeg Centre for Gamma Knife Surgery, Winnipeg, MB

A. Gamma Knife® Fundamentals

The Gamma Knife® provides patients with a minimally invasive alternative for treatment of benign and malignant lesions, venous malformations, and various functional conditions. Doses ranging from ~8 to 140 Gy are delivered with sub-millimeter accuracy. Complete agreement between the imaging and treatment coordinate system is achieved by attaching a rigid head frame to the skull.

The dose is delivered by means of 201 ^{60}Co beams (Figure 1) with a common focus point (radiation isocenter) to produce an approximately spherical treatment volume. "Spheres" of different size, generated using one of the four collimator helmets (4, 8, 14 or 18 mm single beam profile FWHM) are combined to achieve conformal coverage of the lesion. If necessary, critical structure doses can be reduced by replacing selected collimator openings with solid plugs.

During treatment the patient is positioned using the manual or automatic positioning system, which is in turn fixed to the helmet (Figure 1). The shielding doors open and the helmet docks with the primary collimation assembly for the duration of the treatment. Once the treatment time has elapsed, the patient is retracted and their head is moved to the next treatment position. This procedure is repeated until the treatment is complete.

B. Gamma Knife® Acceptance Testing and Commissioning Measurements

It is essential to recognize that commissioning a GK® involves more than just ensuring that the GK® itself works properly. The whole treatment chain, including the imaging modalities, treatment planning system and the GK® must be tested. This report briefly summarizes some basic imaging tests, equipment functionality measurements, and describes the dosimetric measurements in some detail. The tests described are a combination of those recommended by the Elekta acceptance testing procedure, Leksell Gamma Knife® user manual, scientific literature and good physics practice.

Gamma Knife® commissioning measurements are very different from those performed for a linear accelerator for two reasons: first, the geometry of the system is such that a large number of beams are coming in from many angles to generate an approximately spherical dose distribution. Measurements with a conventional rectangular dosimetry phantom are therefore not possible. Second, the GK® has no moving collimator jaws, wedges, blocks or other beam modifiers. All components are precisely machined so that the dose profiles for all GK®s are virtually identical, which allows a standard set of profiles and helmet (output) factors to be hard coded into the treatment planning computer. Profile and helmet factor measurements are performed solely for verification purposes.

1. Imaging Quality Assurance

The importance of imaging quality assurance can not be overemphasized. Large doses are delivered in the vicinity of

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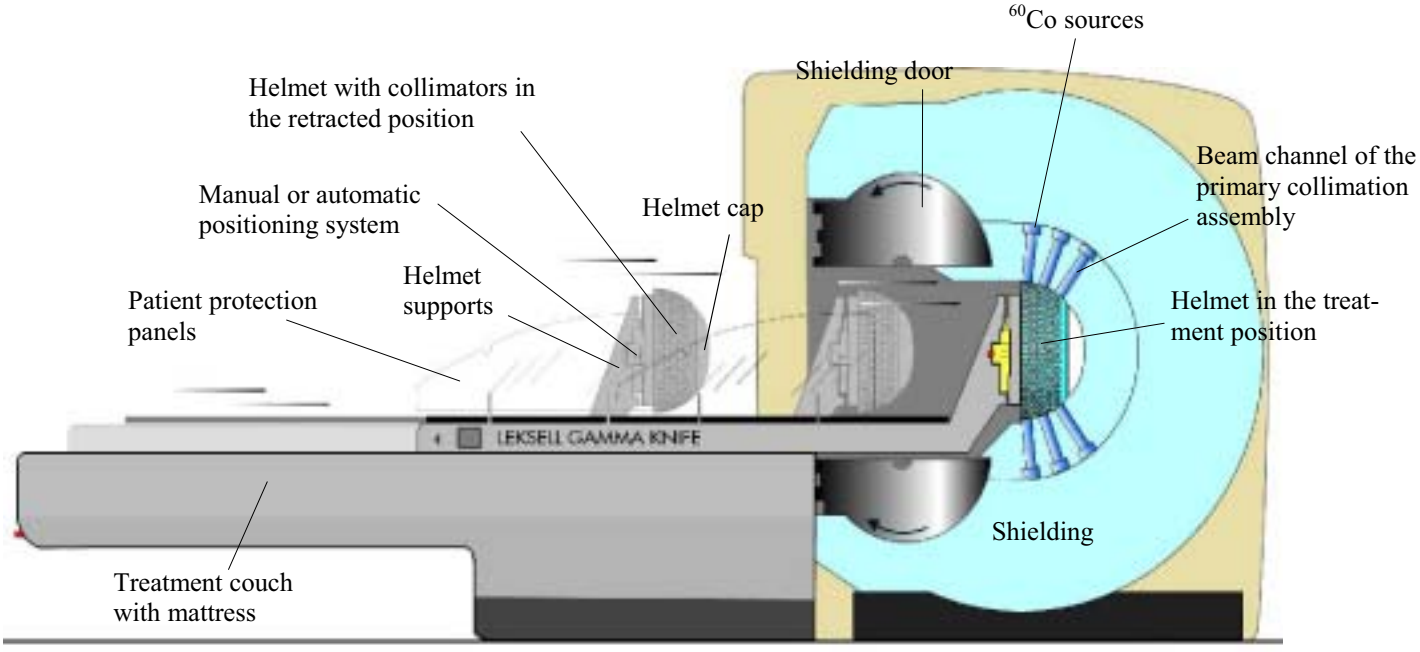

Figure 1: Schematic of the GK® with the couch and helmet retracted, and in the treatment position. Diagram courtesy of Elekta Corporation.

Gamma Knife® Commissioning… (Continued from page 65)

eloquent structures. Great care must be taken, especially in the case of MRI images, to ensure that the information in the images is geometrically accurate. To this end, the Medical Devices Service of CancerCare Manitoba constructed a phantom [YPA2001] with precisely located rods directed in all three dimensions. The phantom was imaged with both CT (GE Lightspeed 16) and MRI (GE Echospeed). For the CT images the distance between the rods was found to agree with their actual spacing, as expected. However, distortions as large as 1.5 mm were found in some of the MR images. The scanner has been adjusted so that the distortion is now less than 1.0 mm, which is considered to be acceptable. Nevertheless, nearly all patients presently receive both an MRI and a CT scan; planning is performed on the basis of the MRI images, while the CT images are used to confirm the geometric accuracy of the MRI scans. Daily MRI quality assurance is being implemented so that the CT scans would no longer have to be performed. The angiography images (Siemens Axiom) are corrected for distortion using a plastic distortion correction grid with equidistant rows of metal markers. Patient images are corrected using distortion correction grid images, collected with the same technique. The effectiveness of the distortion correction is checked for every patient by correcting the distortion correction grid images with themselves and verifying that the metal markers rows are completely straight.

2. Equipment Functionality

A large number of measurements were performed to ensure that the various features of the Gamma Knife® function correctly. This included testing the safety interlocks, radiation protection interlocks and the manual and automatic positioning system (APS) accuracy.

The following safety systems and radiation protection interlocks were all found to be operational:

- The helmet cap (Figure 1) must be in place before the treatment commences to ensure that no hair or other debris can fall into the primary collimators.
- The patient protection panels (Figure 1) must be in place to ensure that sheets, intravenous lines, etc., do not interfere with the shielding doors during couch transit.
- The emergency release handle on the couch disengages the couch motors.
- The squeeze protection on mattress downward motion is operational.
- Various interlocks related to the helmet changer ensure that it is not dropped during a helmet change.
- Radiation safety interlocks consist of standard features such as the last-man-out button, door interlock and a pause button.

The positional accuracy of the APS was verified by the Elekta service representative during acceptance testing using a precision tool which allowed the absolute position of the APS to be assessed with respect to the helmet. A similar, but more basic tool is used to test the APS during daily quality assurance. The manual positioning system is checked weekly using a device which is mounted to the helmet. In all instances, results were found to be well within the tolerance of ±0.5 mm.

One of the few adjustable components of the GK® is the helmet docking mechanism. The latter consists of two screws on each of the four helmets which must be set to make contact with microswitches adjacent to the primary collimator when the helmet is in the treatment (docked) position. The screws are correctly positioned when the helmet docks under normal conditions, but fails to dock when a 0.1 mm shim is fixed to each of the four docking pads. It can therefore be stated that the helmet docking position is reproducible to within 0.1 mm.

3. Dosimetry

This section examines the dosimetric aspects of Gamma Knife® commissioning including absolute calibration, profile measurements, geometric accuracy, helmet factor verification, timer linearity and constancy measurements.

Ion Chamber Holder and Phantom

All GK® dosimetry is performed using a plastic 8 cm radius sphere (Figures 2a and 2b), henceforth referred to as the dosimetry phantom, with interchangeable cassettes that can accommodate an ion chamber, TLDs or film. The removable cassette can be aligned in the axial, sagittal or coronal direction by changing the position of the phantom supports.

Calibration

Gamma Knife® calibration is performed using the TG21 protocol [TG21] to determine the dose rate at the center of the dosimetry phantom for the 18 mm collimator helmet. This value is the only parameter entered into the treatment planning computer; other quantities used for dose calculations are fixed by the manufacturer. Application of TG21 to the GK® differs from linear accelerators in the following aspects:

- Because of the unique geometry of the GK® beams, dose is measured at the center of a plastic phantom rather than in a water phantom. Although the manufacturer states that the phantom material is water equivalent to within 1%, most GK® centers ignore this discrepancy.
- An ion chamber with an active region less than 7 mm in length must be used to ensure that the entire active volume of the ion chamber falls within the plateau region of the 18 mm collimator helmet [GK® User Manual].
- P_{repl} defined as being the correction factor to account for the fluence gradient at depths not equal to d_{max} is taken to equal 1.0, even though measurements are made at a depth of 8 cm. This was done because there is no gradient at the measurement point; the ion chamber is located within the plateau of the dose profile.
- The treatment planning software uses the dose rate at a depth of 8 cm rather than d_{max}; no depth dose correction is therefore required.

Dose profiles

The Gamma Knife® helmets and collimators are precisely machined to produce in dose profiles which are practically identical for all machines. The treatment planning computer performs a weighted sum of the attenuated single beam dose profiles to calculate the dose distribution within the brain. Unlike external beam treatment planning systems, there are no fitting parameters which can be adjusted by the user. This

(Continued on page 67)

Gamma Knife® Commissioning… (Continued from page 66)

approach is feasible because of the tight manufacturing tolerances in the GK® collimator construction.

It is recommended to measure the sum of the beam profiles [GK® User Manual]. The narrow beam profile and complex geometry precludes use of an ion chamber for these measurements; instead, the dosimetry phantom and film cassette are utilized (Figure 2c). Films profiles were collected and analyzed by Elekta personnel using GafChromic film. The criteria for acceptance was 1 mm agreement between the measured and calculated profile FWHM. Although the individual discrepancies were not stated, it was clear from the plots provided by Elekta that all values were well within tolerance.

These measurements were repeated using EDR-2 film and the irradiations listed in Table 1. All of the films were digitized using a film scanner (Microtek ScanMaker 9600XL). The films were analyzed to find the dose profile over a region of interest 4 cm in length and 0.05 cm in width. Table 2 lists the discrepancy between the measured (averaged over two films) and calculated profile widths in the æ*x* (left-right), æ*y* (anterior-posterior) and æ*z* (head-foot) direction. As can be seen, all of the values are well within the Elekta tolerance.

Relative helmet factors

The dose rate for the 4, 8 and 14 mm helmets is calculated by multiplying the 18 mm collimator dose rate by the appropriate helmet factor (helmet factor for the 18 mm collimator = 1.0). As was the case for the dose profiles, the helmet factors are incorporated into the treatment planning software by the manufacturer. Unlike the profiles, they can be adjusted if needed.

The helmet factors were measured using individually calibrated TLDs. A batch of 1x1x1 mm^3 TLDs (Harshaw, Inc.) was exposed to a dose of 2 Gy using a ^{60}Co teletherapy unit. The TLDs were annealed (PTW-TLD O, Model 1321 TLD oven) and read (Harshaw QS, Model 3500 TLD reader) using standard CancerCare Manitoba procedures. The TLDs were analyzed on the basis of their average output for three irradiations; chips with a standard deviation of larger than 5% were not used for

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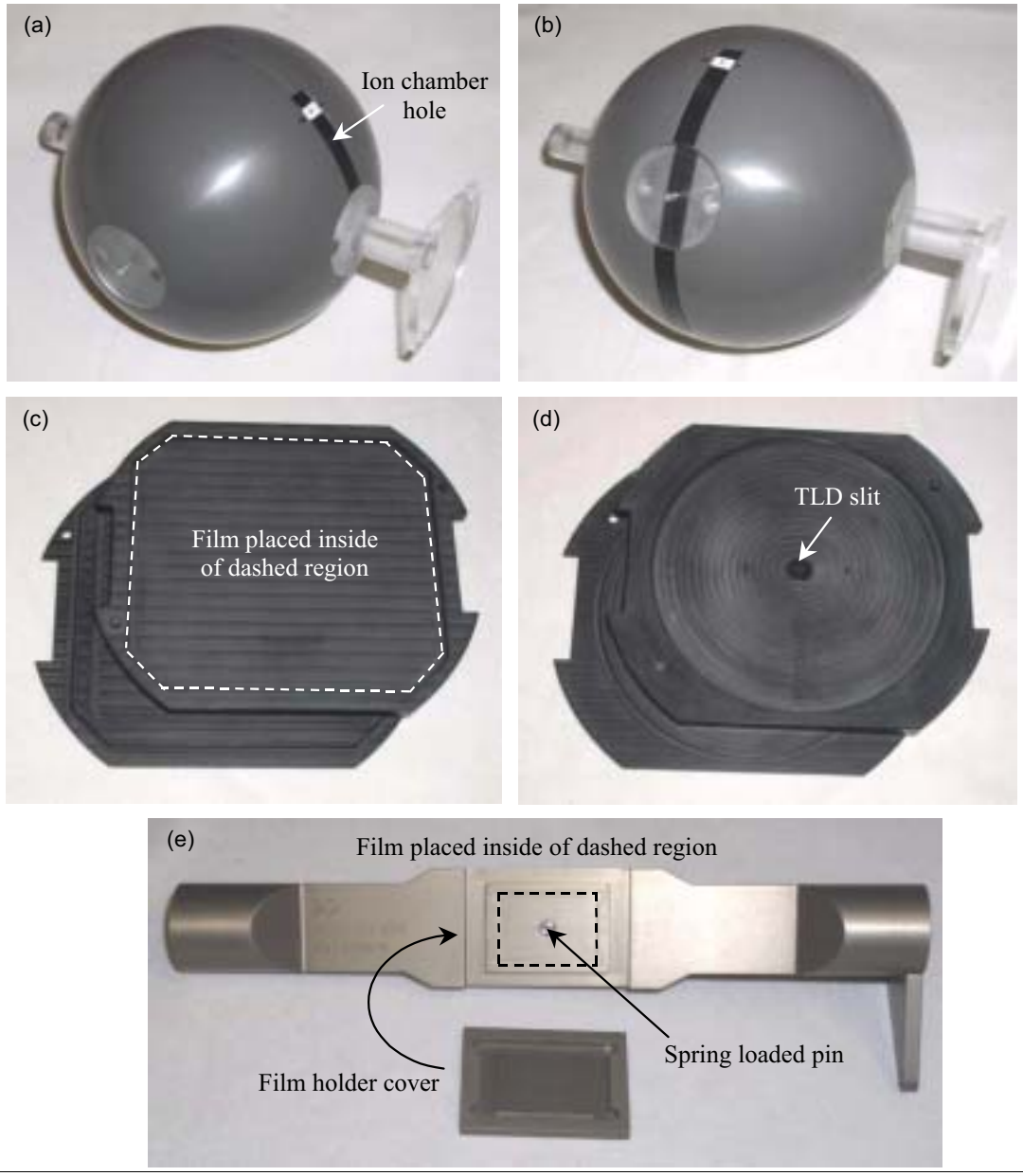

Figure 2 (a) and (b) Photographs of the dosimetry phantom showing the outer spherical portion and supports, which are attached to the GK® along the left-right axis. The supports can be arranged to align the ion chamber cassette in the (a) axial or coronal direction and (b) sagittal direction. The ion chamber cassette can be replaced by the (c) film cassette or (d) TLD cassette. (e) Aluminum center point device shown with the film holder cover removed.

Measurement	Setup	Dose (cGy)
H & D Calibration Films	18 mm helmet Film in the *xy* plane	400, 0, 50, 100, . . ., 500, 650, 400
Profile Films	4, 8, 14, 18 mm helmets Film in the *xy*, *xz* and *yz* planes	400

Table 1: Profile measurement irradiations.

Isodose	4 mm helmet			8 mm helmet			14 mm helmet			18 mm helmet		
	æx*	æy	æz	æx	æy	æz	æx	æy	æz	æx	æy	æz
20 %	0.00	0.18	0.13	0.18	0.02	-0.01	-0.33	0.32	0.03	0.15	0.04	0.47
30 %	-0.03	0.10	0.16	0.06	0.14	0.03	-0.27	0.20	0.07	0.32	-0.07	0.21
40 %	0.09	0.20	0.16	0.07	0.23	0.10	-0.16	0.19	0.05	0.09	0.11	0.19
50 %	**0.03**	**0.08**	**0.16**	**0.02**	**0.13**	**0.14**	**-0.06**	**0.27**	**0.15**	**0.07**	**0.17**	**0.36**
60 %	-0.06	-0.02	0.10	0.20	0.07	0.09	0.02	0.00	0.11	0.52	0.19	0.15
70 %	-0.04	-0.02	0.08	0.28	0.21	0.23	0.03	0.25	0.10	0.28	0.31	0.41
80 %	-0.10	-0.07	0.03	0.37	0.31	0.39	-0.02	0.25	0.12	0.59	0.37	0.45
90 %	0.03	0.07	-0.01	0.44	0.45	0.48	0.17	0.18	0.23	0.29	0.29	0.24

Table 2: Profile measurement results (*all results in mm).

any of the helmet factor measurements.

For the helmet factor measurements, the TLDs were irradiated using the dosimetry phantom and the TLD cassette. The latter contains a 6 × 1 mm^2 slit. The number of TLDs irradiated at once for a particular collimator helmet was adjusted such that the TLDs always fell within the flat portion of the dose profile for that collimator. Plastic spacers were used to ensure that the TLDs were centered within the slit. The TLDs used to measure the helmet factors were irradiated for 0.5 min, receiving a dose of about 2 Gy. A second set of chips was used to measure the transit dose. In this case, and exposure was initiated, but the pause button was pressed as soon as the helmet docked. The initiate treatment, pause routine was repeated ten times for each set of transit dose chips [YL1999], resulting in a total irradiation time of about 0.1 min because the pause was not instantaneous. The total dose accumulated by the transit dose TLDs was equal to (Transit dose) × 10 + (Irradiation time) × (Dose rate). The helmet factor TLDs received a dose of (Transit dose) × 1 + (0.5 min) × (Dose rate). After reading and annealing the chips, the TLDs were exposed to a dose of 2 Gy using a ^{60}Co teletherapy unit for the fourth time. The calibration factor for each chip was set equal to the average of the third and fourth ^{60}Co teletherapy values. The helmet factors were calculated by dividing the TLD readings from the 14, 8 and 4 mm collimator helmets by the 18 mm collimator TLD reading, after correcting for transit dose. Agreement with the manufacturer's values was found to be $æ_{14\ helmet}$ = -0.8%, $æ_{8\ helmet}$ = 1.5%, $æ_{4\ helmet}$ = -2.1%. Elekta does not recommend a tolerance value for these measurements; TG42 [TG42] suggests a value of ±3%. Many centers do not even measure the helmet factors, but simply accept the manufacturer's values. Although good results were obtained, this was an extremely time consuming process. Other approaches will be explored for future annual quality assurance measurements.

Radiation/mechanical isocenter coincidence

Radiation isocenter is the center of the region of maximum dose rate in the "non-attenuated" radiation field. This corresponds to a sphere with a 0.1 mm radius in which all of the beam axes converge [GK® User Manual]. Mechanical isocenter is the physical center of the unit as found using the center point device (Figure 2e) and the manual patient positioning system. Coincidence between the radiation and mechanical isocenter is absolutely necessary to ensure that the planned volume is equivalent to the treated volume.

The center point device used to perform this test is made of precisely machined aluminum into which a small (2.3 x 2.5 cm^2) film can be secured. The device can be positioned such that the film is in either the axial or the coronal plane. The cassette contains a spring loaded pin which pricks the film at mechanical isocenter when the manual positioning device is set to the isocenter location. Films are irradiated in both the axial and coronal direction using the 4 mm collimator helmet. Profiles are generated along the *x*, *y* and *z* axes to compare the pin prick location with the profile center. The sum of the squares of the discrepancies is equal to the distance *d* between the radiation and mechanical isocenter. The criteria for acceptance is $d \le 0.5$ mm. This measurement was performed by Elekta personnel during acceptance testing using GafChromic film to find a value of d = 0.11 mm, and was repeated again during commissioning using EDR-2 film to find d = 0.11 mm. Both of these values are well within tolerance.

Timer Measurements

The treatment time along with the dose rate and target depth determines the dose delivered at a particular treatment position. The timer linearity and constancy were assessed along with the timer shutter correction which accounts for the dose received by the patient while in transit to and from the treatment position. The treatment timer starts counting down once the helmet

(Continued on page 69)

Gamma Knife® Commissioning… (Continued from page 68)
microswitch is engaged, indicating that the helmet has reached the treatment position. The couch is withdrawn and the shutter doors close after the treatment time has elapsed.

The timer linearity was evaluated for the 18 mm collimator helmet by establishing the relationship between ion chamber reading and treatment time over the range of times expected clinically, i.e., ~0.5 to 60 minutes. The linearity of the other collimators was assessed for times ranging from 0.5 to 5.0 minutes. All measurements were corrected for background. The timer linearity was calculated using

$$T_{lin} = \left| \frac{Q_{av} - \langle Q_{av} \rangle}{\langle Q_{av} \rangle} \right| \times 100\%$$

where T_{lin} is the timer linearity, Q_{av} is the average charge collected per unit time for a particular irradiation, and $\langle Q_{av} \rangle$ is the average of all Q_{av} values. Timer linearity data for the 18, 14, 8 and 4 mm collimator helmets are given in Table 3. As can be seen the linearity of the GK® timer is well within the tolerance of 1%.

The timer constancy was set to equal the maximum deviation in several consecutive 2.0 minute irradiations. As can be seen (Table 3) the constancy of the GK® timer is well within the tolerance of 1%.

The timer shutter correction (on-off error) is equal to the time-axis intercept of a charge versus time plot and corresponds to the time for which zero dose is delivered. A shutter correction tolerance value of 0.01 minutes was chosen to ensure that the shutter does not produce an error of more than 1% for a 1.0 minute irradiation (most irradiations are longer than a minute). The treatment planning computer assumes that the shutter correction is negligible.

Helmet	Linearity	Constancy	Shutter Correction
18	0.23%	0.16% [1]	-0.006 s
14	0.34%	0.05% [2]	-0.005 s
8	0.17%	0.12% [2]	-0.0004 s
4	0.11%	0.0% [2]	-0.003 s

Table 3: Linearity Measurement results ([1]Five consecutive measurements; [2]Three consecutive measurements.

C. Conclusion

All acceptance testing and commissioning measurements were well within tolerance. Daily, weekly and monthly tests performed to this point have passed without any difficulties. To date, the Gamma Knife® has proven to be a reliable piece of equipment.

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Funding of Medical Physics Research in Ontario: Final Round

Submitted by Jerry Battista, Chairman Nucletron & Cancer Care Ontario Grants Panel

An "R&D" fund was established originally by Theratronics International as a result of a research agreement with Cancer Care Ontario (CCO). Theratronics was a major supplier of computer workstations, ushering in the era of 3D radiation treatment planning for Ontarions. The first commercial installation took place in the Fall of 1996 at the London Regional Cancer Centre. Theratronics computer systems were subsequently installed in Toronto, Windsor, Thunder Bay, Kingston, and Ottawa.

In a research partnership with Cancer Care Ontario's medical physics community, MDS-Nordion's software products division (now known as Nucletron Oncentra) agreed to provide medical physics research grant funding of $250,000 over a multi-year period. The goal was to seed new projects of excellent scientific merit in the area of clinical radiation oncology. Projects are peer-reviewed by a panel of Ontario physicists and a Nucletron representative. Judgement of project quality is based on criteria such as innovation, scientific merit, impact on the field, ease of technology transfer across cancer centres, researchers' track record, and the potential to attract new external funding. The following Table lists the projects recently approved by the Grants Panel in this *final* round of competition.

Congratulations to these awardees !

Nucletron - CCO Grants (2003-2004 Round)

Applicants	Location	Project Title	Amount Approved
P. Basran, M. Woo, and P. Cheung	Toronto-Sunnybrook	Dose Functional Volume Histograms in Forward and Inverse Planning	$14,000
M. MacPherson and L. Gerig	Ottawa	Investigations of Patient Surface Measurements for Gated Radiotherapy	$ 8,500
L.J. Schreiner, G. Salomons, and G. Santyr	Kingston	Gel Dosimetry: from Lab to Clinic	$13,500

Capital Health

Chief of Medical Physics - Capital Health - Halifax

Let's build a healthier world

Capital Health, Atlantic Canada's largest academic health care organization, is recruiting a **Chief Medical Physicist** for the Radiation Therapy Program at the QEII Health Sciences Centre site, Halifax, Nova Scotia. As Head of the Department of Medical Physics, you will lead a department of eleven medical physicists and eight support staff in three treatment centres, and play a key role in cancer care. Academically, you will have a faculty appointment in the Dalhousie University Department of Radiation Oncology and contribute to research, graduate student training and our radiation oncology residency program. We offer a salary competitive with any in Canada.

Capital Health is one of Canada's major tertiary care facilities and is closely integrated with the Dalhousie University Medical School. Cancer research at Dalhousie is undergoing significant growth due to a recent $12 million donation.

The Medical Physics Department provides medical physics services at the QEII, the Cape Breton Cancer Centre in Sydney, Nova Scotia and at the Prince Edward Island Cancer Treatment Centre in Charlottetown. The Chief Physicist is based in Halifax.

The QEII is equipped with four Varian accelerators with MLC, Portal Vision and Varis. Selectron LDR and HDR units are in use as well as a superficial x-ray machine. There are active stereotactic radiosurgery, intravascular brachytherapy and total body radiation programs. Implementation of IMRT is underway using both micro-multileaf and conventional multileaf collimation. Simulation is carried out on a Picker AcQsim CT system. We are in the process of replacing a cobalt unit and a conventional simulator with an additional Varian 2100 EX accelerator and a Varian Acuity Simulator. Planning systems include Theraplan Plus, Nucletron and BrainLAB BrainSCAN. Fully equipped electronics and machine shops provide clinical and research support. The Sydney facility is equipped with two Varian accelerators, a Varian simulator, a Theraplan Plus planning system and a GE Advantage Sim workstation. The PEI facility has a Varian 2100 EX accelerator, a cobalt unit, a GE CT-Simulator and a Helax-TMS Planning system.

To be considered, you hold a Ph.D. in Physics or Medical Physics and are certified in radiation oncology physics as a Fellow of the Canadian College of Physicist in Medicine or equivalent. You have a minimum of five years experience as a Medical Physicist in radiation oncology and an additional three years as a Senior Physicist with supervisory responsibilities. Previous research experience would be an asset. In accordance with Canadian Immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada.

We invite you visit the following links to learn more about Capital Health, the QEII, Halifax and surrounding areas: www.cdha.nshealth.ca/facilities/qe2hsc , www.cdha.nshealth.ca, www.medicine.dal.ca, www.region.halifax.ns.ca

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Human Resources, 1278 Tower Road, Halifax, Nova Scotia, B3H 2Y9 Phone: 902-473-5757 or Fax: 902-473-8499
E-mail: jobs@cdha.nshealth.ca (Please quote requisition # **6745**)
The deadline for the receipt of applications is May 7, 2004.

For further information please contact Dr. Andrew Padmos, Head, Cancer Care Program, VP Research and Academic Affairs, Capital Health. E-mail: andrew.padmos@ccns.nshealth.ca. Phone: (902) 473-4645.

The University of Western Ontario
NSERC University Faculty Awards

Department of Physics and Astronomy

The Department of Physics and Astronomy at The University of Western Ontario invites applications from women and aboriginal peoples for a probationary (tenure-track) position at the rank of Assistant Professor in the area of **medical physics** to begin on July 1, 2005. The successful candidate will be nominated for an NSERC University Faculty Award (www.nserc.ca/guide/sf/3g_e.htm) and must meet NSERC's eligibility criteria for this award. In particular, candidates must be Canadian citizens or permanent residents, and must not have held a tenured or tenure-track position at a Canadian university.

The medical physics research community at Western is extremely large and diverse, with established research strengths in areas that include MRI, Ultrasound, PET, SPECT, bioelectromagnetics, biomaterials, and radiation therapy. Researchers are based in the Faculties of Science, Engineering, Medicine and Dentistry, as well as the Robarts Research Institute, the London Health Sciences Centre, and the London Regional Cancer Centre. The Department of Physics and Astronomy has recently appointed a Tier 2 Canada Research Chair in Medical Physics and introduced a new undergraduate program in Honors Medical Physics.

Candidates must have a Ph.D. and a proven research record. The successful candidate will be expected to establish an independent and innovative externally funded research program involving the training of graduate students. She or he will be expected to participate effectively in teaching at the undergraduate and graduate levels. We seek applicants with research and teaching strengths in any areas of medical physics.

Interested candidates should submit a curriculum vitae, a list of publications, a research plan, and the names and addresses of three referees, and arrange for three letters of reference to be sent directly to:

Prof. James Moorhead, Acting Chair
Department of Physics and Astronomy
The University of Western Ontario
London, ON N6A 3K7
Canada.

The closing date for applications is April 30, 2004.

This position is contingent on receiving the NSERC UFA award and is subject to budget approval. Applicants should have fluent writing and verbal communication skills in English. The University of Western Ontario is committed to employment equity and welcomes applications from all qualified women and men, including visible minorities, aboriginal people, and persons with disabilities.

McMaster University

Medical Physics & Applied Radiation Sciences - Tenure-Track Faculty Position

McMaster University invites applications for a tenure-track appointment at the assistant, associate or full professor level in the Unit for Medical Physics and Applied Radiation Sciences in the Faculty of Science. The position is targeted to begin on September 1, 2004. Candidates should possess a PhD and have demonstrated an excellent research record and aptitude to teach. The ideal candidate will be able to teach in the area of the fundamentals of radiation physics, with particular emphasis on radiation transport and radiation dosimetry. She/he would be expected to contribute to graduate and undergraduate programmes in Medical Physics, Health Physics and Medical Radiation Sciences through teaching, attracting research funding and mentoring research students.

McMaster University offers a unique radiation research environment, supported by the McMaster Institute of Applied Radiation Sciences. Facilities at McMaster include a research reactor and an accelerator laboratory. In addition, the Juravinski Cancer Centre has recently undergone a major expansion. Existing research fields within the Unit include nuclear and atomic techniques used for body composition studies; the role of DNA damage and DNA repair processes in carcinogenesis and in the response of tumour cells to radiotherapy and chemotherapy; understanding risks of low doses and low dose rates of ionizing radiation in human and non-human biota using a combination of molecular cytogenetics and microbeams; the cellular and molecular basis of photodynamic therapy; laser and light propagation in tissue for photodynamic therapy and tissue characterization; radiation geochronology; novel methods of imaging bone architecture and joint structure non-invasively; and structural and functional imaging, particularly for neurological, cardiac and neuroscience studies.

Applicants should describe how they would expect their research to prosper at McMaster, taking into account existing research strengths and opportunities. Collaboration with Unit faculty is encouraged; there is a strong history of collaboration between the University, Hamilton Health Sciences Corporation and the Juravinski Cancer Centre.

All qualified candidates are encouraged to apply; however, Canadian citizens and permanent residents will be considered first for this position. McMaster University is strongly committed to employment equity within its community and to recruiting a diverse faculty and staff. The University encourages applications from all qualified
candidates, including women, members of visible minorities, Aboriginal persons, members of sexual minorities and persons with disabilities.

Applications, including a statement of research interests and teaching philosophy, together with letters from three referees should be sent by May 14, 2004 to Dr Fiona McNeill, Chair, The Unit for Medical Physics and Applied Radiation Sciences, NRB-122, McMaster University, Hamilton, Ontario, L8S 4K1, Canada. Telephone (1) 905
525 9140 ext 24182, FAX (1) 905 522 5982, contact e-mail: malarek@mcmaster.ca. Further information can be found at: http://www.science.mcmaster.ca/medphys.

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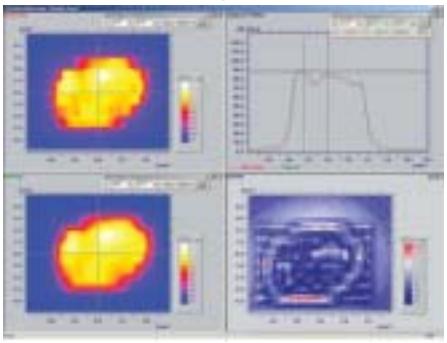

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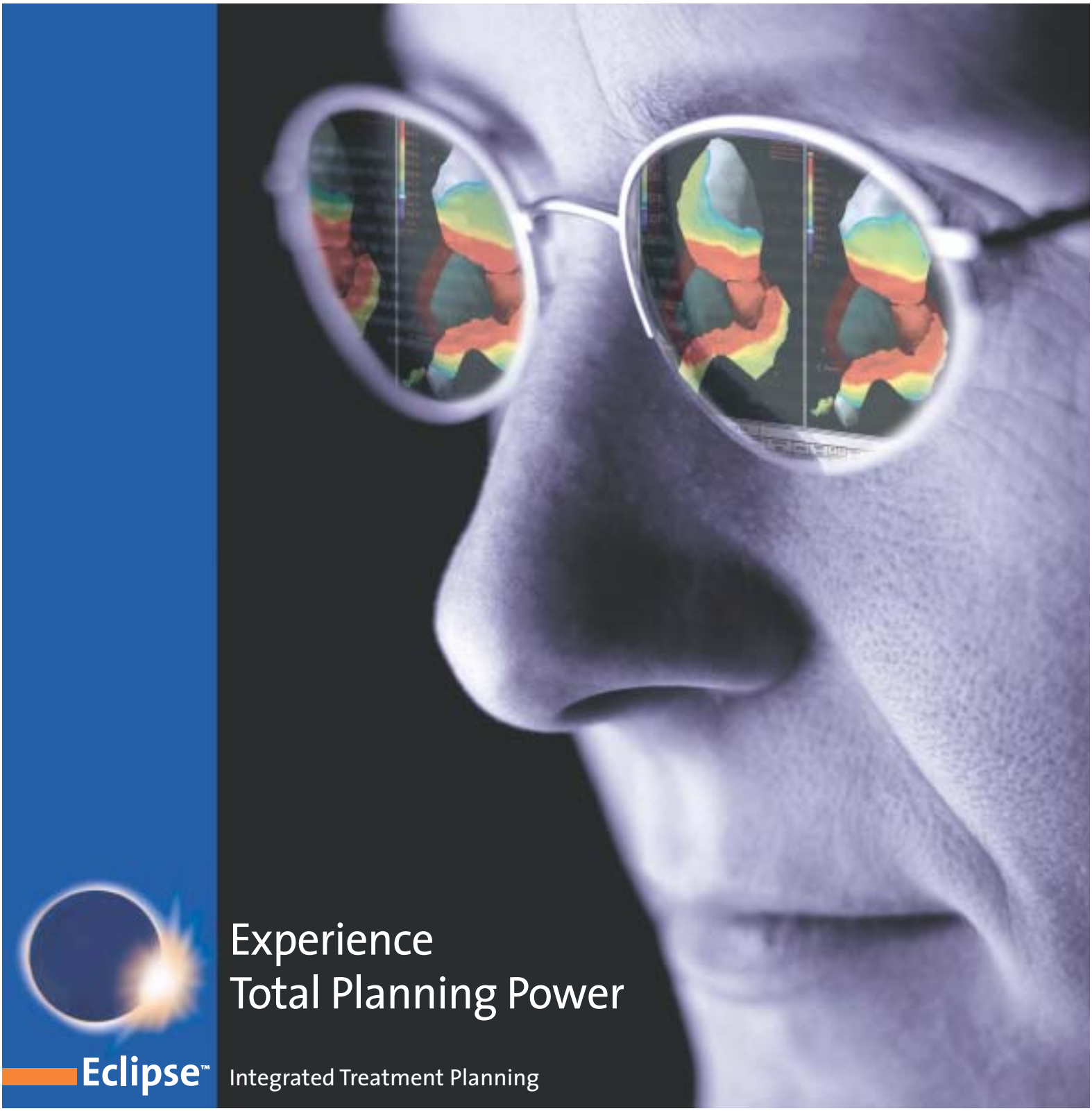

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