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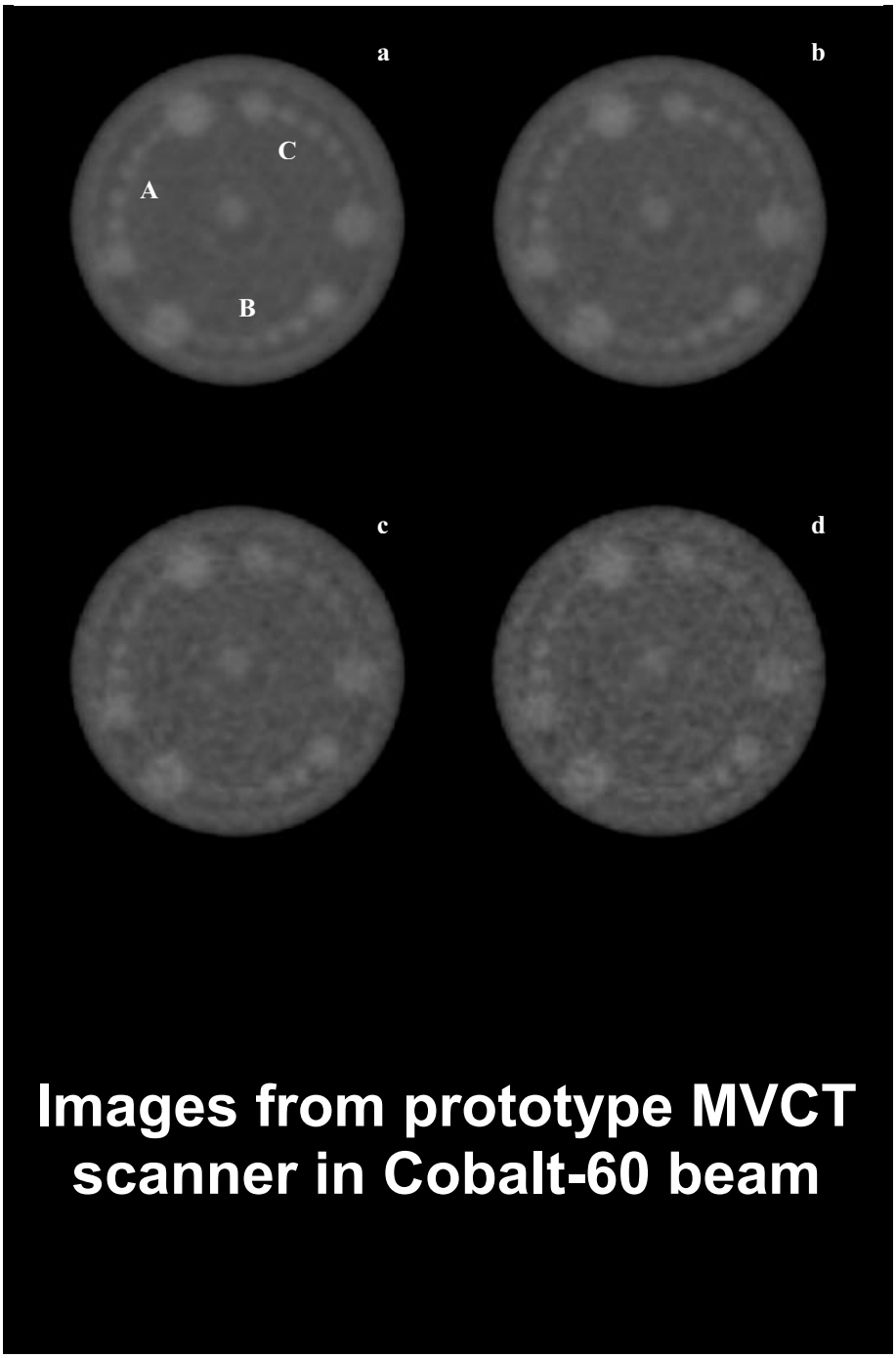
51 (2) avril/April 2005



Images from prototype MVCT scanner in Cobalt-60 beam

About our Cover

These images were obtained by a prototype, bench-top, third generation megavoltage computed tomography (MVCT) scanner in a Co^{60} beam. The system uses an 80-element detector array of $CdWO_4$ crystals and photodiodes, arranged on an arc of radius 110 cm. This phantom (module CTP612 in CATPHAN500, Phantom Labs) was especially designed for MVCT, and consists of inserts at 3%, 2.5% and 1.5% nominal contrast levels. Each contrast level has cylinders of diameters 2, 0.4, 0.5, 0.6, 0.7, 0.8 and 1.5 cm, and there is a central cylinder of 0.4 cm diameter with a contrast level of 1.5 %. The dose to the centre of the phantom was estimated to be approximately 17 cGy when all the projections were used in the reconstruction process. Images with doses of 8.5, 4.3 and 2.1 cGy were obtained by utilising only one-half, one-fourth and one-eighth of data pulses per revolution, respectively. The figure shows images of CTP612 module at four different dose levels, (a) 17 cGy, (b) 8.5 cGy, (c) 4.3 cGy and (d) 2.1 cGy. Groups A, B and C have measured contrast levels of 2.1%, 1.9% and 2.8% respectively while the cylinder in the middle has a contrast of 1.5% in Co^{60} with respect to the background material in the phantom. All the images have been windowed and levelled in the same way. The bench-top MVCT provides a contrast resolution of 1.5% at 0.6 cm diameter using a dose of 2.1 cGy.

Images provided by T. Monajemi[1], D. Tu[1], D. Rickey[2], S. Rathee[1], and G. Fallone[1]; 1. Cross Cancer Institute and University of Alberta, Edmonton, AB., 2. CancerCare Manitoba and University of Manitoba, Winnipeg, MB

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

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Corporate advertising enquiries can be made (until a new Executive Director is found) to:
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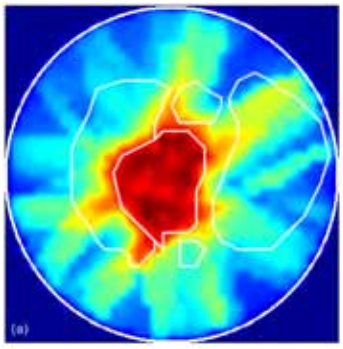

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Stewart Gaede and Eugene Wong

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Message from the COMP Chair:

We expect that this new leadership [Nancy Barrett] will add significantly to the profile of our organization and will add value for the members.

As promised in the last Interactions, we have now completed the process for hiring a new executive director for COMP and the CCPM. We were fortunate to have several good candidates for this position. **Brenda Clark** and I interviewed the finalists and after consulting with the COMP executive and the CCPM board we have agreed to a 2-year contract with **Ms**. **Nancy Barrett** and her firm, Association Management, Consulting and Evaluation Services. Nancy was introduced as the new executive director in an email sent in January to all COMP members. This contract will bring stability and continuity to this very important COMP position. Nancy will be the face of COMP, acting as the main point of contact for our commercial colleagues, for other medical physics associations and for other groups. Nancy will be at the annual meeting and is anxious to meet as many COMP and CCPM members as possible. We expect that this new leadership will add significantly to the profile of our organization and will add value for the members. However, there will be a cost. At the AGM this summer a proposal will be put forward to increase membership fees, partially in response to our new leadership model.

Plans for the COMP Gold Medal are progressing although the input from the members for the medal design has been unimpressive. At this writing I am not aware of 1 submission!. However, I am very pleased to announce that **Dave Rogers** has agreed to be the chair of the selection committee. Dave will prepare the terms of reference for the award and will present these to the executive at the annual meeting in July.

2005 is the World Year of Physics (WYP). While the World Year of Physics was so-named by the International Union of Pure and Applied Physics (IUPAP), the UN General Assembly passed a resolution in June 2004 that 2005 be the "International Year of Physics". There may be some confusion but both names refer to the same thing and WYP is the term adopted in Canada. All physics associations in Canada have been asked by the Canadian Association of Physicists to plan events to commemorate this year. The first COMP public lecture is the main event planned by COMP for the WYP. You can check out the range of events available (including the COMP public lecture and the COMP conference) on the CAP website (www.cap.ca). There are also commemorative items (mugs, t-shirts etc) available through the CAP.

Hopefully when this article is printed winter weather will be behind us. With renewed energy we can begin the last stages of planning for the annual COMP meeting in Hamilton, July 7-9. I must thank **Darcy Mason** for the time and effort that he has put into the preparation for the meeting. We have used a new AAPM sponsored abstract service this year (AMOS) and Darcy as chair of the communications committee has led the effort to adapt this to our needs. **Joe Hayward** and his local arrangements team have done an outstanding job preparing for the COMP meeting and I hope that you will support them with your attendance. I look forward to seeing everyone in Hamilton.

Mr. Peter O'Brien, COMP Chair

Message from the CCPM President:

I will start by welcoming Nancy Barrett to her new position as Executive Director of our two organisations. I am looking forward to working with Nancy and her team at AMCES.

In my last editorial, I mistakenly stated that **Margaret E. J. Young** was our first Chief Examiner. She wrote to me recently to point out that Harold E. Johns was the initial Chairman of the Examining Board and Margaret was chairman of the examiners for the oral exams. Margaret writes:

> *"Just for the record, there were slightly different examiners for the written and oral parts for each specialty. For the radiation oncology section, the examiners who set and marked the written papers were* ***Harold Johns, Doug Cormack, Jack Cunningham****, and myself with Harold being the chairman, while for the oral, the examiners were* ***Jack Cunningham, John MacDonald, Roger Mathieu*** *and myself as chairman."*

Dr. Brenda Clark, CCPM President

Thank you, Margaret, for this clarification and for sending a complete list of all the original examiners for all specialties for our archives.

As I write this message in early March, our Chief Examiner, ***Katharina Sixel***, and her team of invigilators and examiners are preparing for the written Membership examination, to be held on Saturday, 19 March. This year, 18 candidates will write this examination in centres across the country. The success of this examination each year is a result of considerable effort on the part of many Medical Physicists across Canada, most of whom remain nameless in the interests of anonymity. Clearly all the invigilators give up a Saturday for this task. Also, the work of setting questions and marking papers is time consuming and cannot be described by any criterium as exciting! We very much appreciate the dedication to our certification program shown by all these volunteers.

Elsewhere in this edition of InterACTIONS you will find the notice of this year's proposed changes to the CCPM Bylaws for voting at the AGM in Hamilton. The most important change we are proposing is to modify sections III and IV of the written Membership examination by re-publishing the question bank in the form of a larger number of shorter questions. Many of the comments/suggestions we have had over the years has been to the effect that the examination as it is currently structured with the selection of only two out of a possible 30 long questions intrinsically restricts the scope of the questions that are asked. The solution that we are proposing is to divide up the long questions where appropriate into several smaller ones such that several questions could be selected each year for the examination. In this way, a wider range of topics could be tested. This strategy would also make it easier to revise and update the questions, a task that is required each year to ensure the examination remains relevant. Clearly some effort would be required to ensure that an appropriate depth of knowledge was also addressed and that the shorter questions did not translate into a less rigorous examination.

Please write to us if you have any comments or suggestions on our proposals or other activities. We are always seeking input, whether you are a current or a potential member.

...we are proposing... to divide up the long questions where appropriate into several smaller ones such that several questions could be selected each year for the [M C C P M] examination. .

Message from the Executive Director of COMP/CCPM:

I look forward to working with members, volunteers and partners to profile the contribution and competency of medical physicists in Canada...

I am pleased to make my first submission to InterACTIONS since taking on the role of Executive Director of COMP/CCPM. Thank you for your wonderful welcome and support during this time of transition.

As I write this article, the 2005 federal budget has just been released and the Canadian Consortium for Research, of which COMP is a member, has expressed a mixed reaction. While a modest increase (less than 3%) in research-granting council budgets was announced and the Canadian Academies of Science and Genome Canada received funding, there were no new initiatives to address the challenges faced by post-secondary institutions.

As you are aware, health care and education are the top two concerns of Canadians and COMP/CCPM must work, in conjunction with other organizations, to promote the benefits of increased capacity in research, post-secondary education and scientific knowledge in Canada to address these concerns.

The United Nations has declared 2005 as the International Year of Physics. This is a tremendous opportunity to acknowledge the progress and importance of this great field of science and COMP/CCPM are doing just that by conducting their first public lecture in conjunction with the 2005 annual conference in Hamilton. This is an exciting initiative and an opportunity for the general public to learn more about medical imaging and actually get a "view from inside". Dr. Michael Bronskill of the University of Toronto will deliver this lecture.

I have been involved with the association/not-for-profit sector for the past eight years and am pleased to have an opportunity to serve COMP/CCPM. I look forward to working with members, volunteers and partners to profile the contribution and competency of medical physicists in Canada, to identify and address issues facing the profession and to facilitate the exchange of information and research.

Thank you to the many volunteers and to Barb Callaghan for making my first three weeks a most positive experience. I look forward to meeting you in Hamilton at the 2005 conference. I know that Joe Hayward and the Local Arrangements Committee are working hard on this important event!

In the meantime, please feel free to contact me in Ottawa with your ideas and suggestions or to just say hello. I can be reached at 613-599-1948 or at execdir@medphys.ca.

Ms. Nancy Barrett,
COMP/CCPM Executive Director

Report on Great Lakes AAPM Chapter Meeting

Submitted by Jake Van Dyk
London Regional Cancer Program ,
London, ON

One of the largest and most successful meetings of the Great Lakes Chapter (GLC) of the American Association of Physicists in Medicine (AAPM) was held in London, Ontario on Saturday 6 November 2004. On 17 June 2004, Jean Moran, President of the GLC AAPM e-mailed Jake Van Dyk to see whether London would be interested in hosting the fall Young Investigators' Symposium (YIS) of the GLC. She thought that the Chapter members might be interested in seeing the London tomotherapy unit. Jake responded with two questions: (1) When is the usual date? and (2) How many people usually attend? Jean's response: 23 October or 6 November 2004 and usually 5 or 6 people participate in the YIS with a total of 20-30 people participating in the meeting. Jean also suggested inviting Rock Mackie from Madison WI to speak on helical tomotherapy. Jake suggested adding David Jaffray to the program to generate a discussion on the competing modalities of cone beam CT and helical tomotherapy. The net result was a meeting that involved 16 young investigators and a symposium on Image-Guided Therapy which included Rock Mackie, David Jaffray (Princess Margaret Hospital, Toronto), Tomas Kron (London Regional Cancer Program, London, Ontario), Fang-Fang Yin (Duke University, formerly from Henry Ford Hospital in Detroit). The meeting had >140 attendees as well as 11 commercial exhibitors. People traveled from as far as Hawaii to attend. The day was rounded out with a panel discussion moderated by Colin Orton on Cone Beam CT versus Tomotherapy. The winner of the YIS was Dylan C Hunt (co-authored by John Rowlands) of Sunnybrook Health Sciences Centre/University of Toronto. The event was a tremendous success and is being talked about as one of the largest AAPM chapter meetings ever.

Tomas Kron – Tomotherapy tour guide at the GLC-AAPM meeting. Picture courtesy of Randy Ten Haken.

Students who presented at the GLC-AAPM YIS Pictured are (Back Row, from left to right): Rojano Kashani, Neelam Tyagi, Sean A Graham, Steven Babic, Bryan Kim, Bryan Schaly, Mike Oliver, and Andreas W Rau. (Front Row, from left to right): Mihaela Rosu, Jeff Small, Martha M Coselmon, Andrea McNiven, Alexandra Rink, Dylan C Hunt, and William Song. (Missing from picture is Zhouping Wei). Picture courtesy of Randy Ten Haken.

30 Years Ago: First PET Scanner in Canada

Submitted by Chris Thompson
Montreal Neurological Institute,
Montreal, QC

In April 1975 Ernst Meyer, (the late) Lucas Yamamoto, and I drove to the Brookhaven National Laboratory on Long Island and returned with the first instrument for positron emission tomography (PET) in Canada. Thirty years ago, "PET" was a domestic animal, not a medical imaging technique. To many or you reading this today, PET, and better still PET/CT, is something that your department "has" or "wants" to improve the work-up and radio-therapy treatment planning of cancer patients. This is a relatively recent phenomenon, and even though PET has been around for over 30 years, it had very little impact on the lives of most Medical Physicists until 10 years ago with the advent of whole-body PET scanning with the glucose analog commonly known as FDG.

Soon after the Montreal Neurological Institute (MNI) acquired the first CT scanner in 1973, interest in other tomographic imaging modalities was initiated. Lucas Yamamoto had worked at the Brookhaven National Lab. (BNL) of the US Department of Energy for several years before coming to the MNI. He often talked about a device, that he had worked on while at BNL known as the "head shrinker", that was now unused. He was convinced that if it was in Montreal it would work, even though it had never performed satisfactorily in Brookhaven. He, and the director of the MNI, Dr William Feindel, had perfected two techniques for investigating regional cerebral blood flow (rCBF)in the exposed brain, both in animal experiments and during human surgery for arterial-venous malformations and certain highly vascular brain tumours. They saw this instrument as being able to measure rCBF non invasively. One of these techniques involved applying small silicon diode radiation detectors and administrating Xe-133 and measuring the "washout" of this inert gas in the exposed brain. The other involved injecting fluoresceine dye into the blood and taking rapid sequences of photographs to study the passage of the dye through the blood vessels and the exposed cortex. The positron emitting isotope Kr-77, could perform the same function as the Xe-133 and the generator produced Ga-68 EDTA could measure the blood transit time and breakdown of the blood-brain barrier. Since all of the studies involved using a computer, and I had been involved in getting them to work, I was expected to get the "head shrinker" to work as well!

There had been a few trips to Brookhaven to look at the instrument, and to negotiate the "loan" of it to the MNI. During these trips, I became familiar with the detectors, amplifiers and circuits which detected coincident gamma rays from positron annihilation, as well as the program which was supposed to reconstruct the images. I was quite familiar with the way the "EMI-scanner" reconstructed images, but had no idea how the algorithm used by the Brookhaven group worked [1]. I did know that it took a long time on the Lab's main-frame computer and I was expected to get it working on a PDP-12 with 16K of memory. (That's right 16,384 12-bit words!). One day we were in the small on-site hospital negotiating the transfer. During a break, I looked at a display of occupational therapy where patients had made patterns by stringing coloured yarn over arrays of nails. Many patterns were possible and some were very pretty. It occurred to me that these nails were like the ring detectors in the scanner, and the yarn between two nails represented the lines of response of the each pair of detectors. If they were organized in the correct way, they would look like the projections in a CT scanner. Instead of the attenuation along each line we would have the number of counts acquired during the time of a study. So perhaps the same algorithm used in CT scanners would work here.

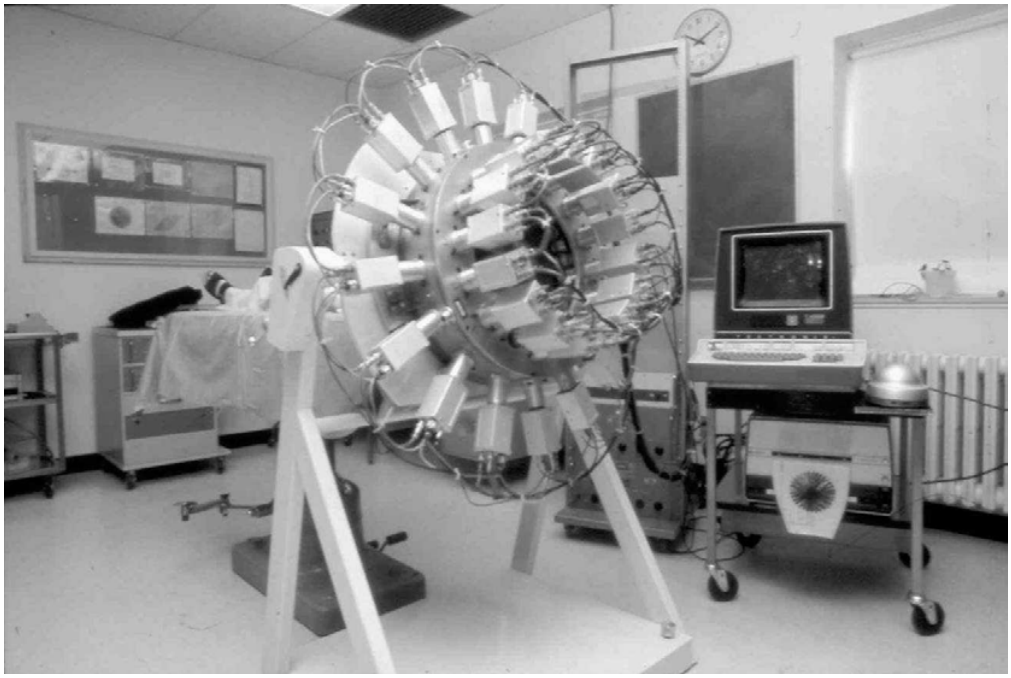


Figure 1: Original Positome configuration.

At Brookhaven, the original concept had the patient sitting in a chair and the detectors were arranged in a hemisphere and looked rather like a strange hair dryer. By the time I was involved with it, the detectors were arranged in a single ring. There were 32 1" diameter NaI crystals and PMTs, the even ones inserted radially and the odd ones axially. We decided that the patients would be scanned supine like in a CT scanner, and had a stand built for them. I did not think that patients would like being told that the device was called the "head shrinker" and decided that "Positome" would be a better name.

(Continued on page 49)

30 Years of PET in Canada…. (Continued from page 48)

The Positome was installed on the second floor of the MNI, as shown in Figure 1, and a cable was run up to the 7th floor where the computer was. The programs for acquisition of the scans, reconstruction, and display were initiated on a Tektronix graphics terminal. This had a storage screen (like a big storage oscilloscope screen) with both a character generator, and 1024 by 768 addressable points. The images were reconstructed using the Shepp and Logan algorithm, see figure 2, which was published in 1974 [2]. This simple technique was able to reconstruct 32 x 32 images in less than 30 seconds on a computer with a clock speed of 0.5 MHz. The Brookhaven algorithm (which involved inversion of the Radon transform) was run as a batch job on a main-frame computer and the images were not available until the next day.

This Positome was used for three years. One or two days a week we could get Kr-77 from the cyclotron in the Foster laboratory of the McGill Physics Department. The gas was trapped in a U-tube immersed in liquid nitrogen, then sealed. Ernst Meyer, who did all the data analysis for our studies then carried this tube in a lead pot about one block up University St from the Foster lab. to the MNI. (The half- life of Kr-77 is just over an hour, so he did not have to run!) On other days we used Ga-68 EDTA from a Ge-68/Ga-68 generator. The software allowed dynamic studies which were displayed on the terminal screen by intensifying a pseudo-random array of 7x7 sub-pixels which formed each of the 32x32 image pixels to simulate shades of grey in a similar fashion to a dot matrix printer. They were painted on the storage screen where they were stable for a few minutes or until erased. The display software allowed for multiple images to be displayed, regions of interest to be selected, and the display log-linear time-activity plots from which the washout or transit time was estimated from the down-slope of a fitted line.

One of the images included here is what Dr. Feindel believes to be the first image of a glioblastoma made with PET. This was made with Ga-68 EDTA after an initial dynamic study. The 68 minute half-life allowed "static" images through several slices through the brain.

The first paper we wrote about PET [3] was presented in August 1975 at a conference in Stanford Ca. At that time we had still not performed any patient studies. A more complete report on its performance and use in clinical studies appeared the following year[4].

In 1978 we made Positome II which was the first PET scanner to use bismuth germanate detectors. This new, high density, scintillator became the mainstay in PET for over 25 years.

1) Shepp L A, and Logan B F: The Fourier Reconstruction of a Head Section. IEEE Trans. Nucl. Sci. NS-11:21-38 (1974)

2) Marr RB, On the Reconstruction of a Function on a Circular Domain from a Sampling of its Line Integrals. J. Math. Anal. and App. 357-374 (1974)

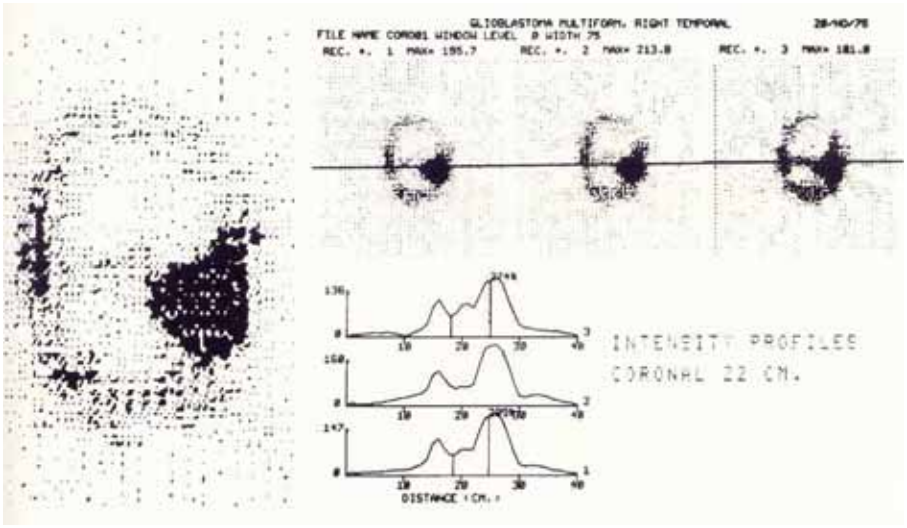
3) Thompson C J, Yamamoto Y L and Meyer E: "Positron emission tomography: reconstruction of images from a multiple coincidence detector ring". Proc. Amer. Optical Soc Meeting on Image Processing for 2D and 3D Reconstruction from Projections. pp. TuA4-1 to TuA4-4, (Aug. 1975)

4) Thompson C J, Yamamoto Y L and Meyer E: "A positron imaging system for the measurement of regional cerebral blood flow." Proc. Soc. Photo Optic Instrument Engineers: 96: Optical Instrumentation in Medicine V, 263-268 (1976)

Figure 2: Shepp-Logan reconstruction code.

```
DO 20 J=1,N
THETAJ=(J-1)*PIN
COSTHTAJ=COS(THETAJ)
SINTHTAJ=SIN(THETAJ)
COSDELOA=COSTHTAJ*DELTA/A
READ(12) (PROJ(K),K=1,M)
*****************************
DO 30 KR=1,M
CONV(KR)=0
DO 40 K=1,M
KABS=IABS(KR-K)+1
CONV(KR)=CONV(KR)+PROJ(K)*PHI(KABS)
40 CONTINUE
30 CONTINUE
************************
DO 51 IY=1,NY
Y1=-YPOS+2*YPOS*IY/NY
R=(-XPOS*COSTHTAJ+SINTHTAJ*Y1+1)/A
 -COSDELOA
DO 50 I=1,NX
R=R+COSDELOA
L=R
IF(L.LE.0.OR.L.GE.M) GO TO 50
Z(I,IY)=Z(I,IY)+(L+1-R)*CONV(L)+(R-L)
*CONV(L+1)
50 CONTINUE
51 CONTINUE
20 CONTINUE
```

Figure 3: Glioblastoma Ga-68 EDTA from 1975.



Across Canada

Toronto Sunnybrook Regional Cancer Centre, and University of Toronto, Toronto, ON
Submitted by Peter O'Brien

The Toronto Sunnybrook Regional Cancer Centre (TSRCC) is a program of the Sunnybrook and Women's College Health Science Centre (S&W), located in north Toronto. The TSRCC is organized along program lines - the Medical Physics Department is completely within the Radiation Program and includes physicists, physics technologists, mechanical and electronics technologists, secretaries and students. We now have 15 physicists in a total full-time staff of 45. The department supports radiation treatment planning and delivery for approximately 5700 new patients each year. Our equipment includes 12 linear accelerators, 1 cobalt unit, orthovoltage, 2 CT-simulators, 1 conventional simulator and 1 PET/CT simulator.

We support a wide range of clinical programs from stereotactic radiosurgery to intravascular brachytherapy. Many of the treatment techniques that we use were developed locally. A new development at the TSRCC (described in Interactions – January 2005) is partial breast irradiation using implanted Palladium seeds.

It is not possible to describe each person's role in this short article but each physicist does have several well-defined clinical responsibilities and all new developments or major programs are handled in an interdisciplinary team based way. The largest sub-unit in the physics group is the treatment planning group, led by our Senior Planning Physicist Kathy Mah.

We are now commissioning a new Pinnacle TPS with plans for implementation to be completed over the summer. This is part of a major effort to integrate much of our planning activity, now spread out over about 10 different commercial systems. We are also in the middle of a conversion to the IMPAC radiotherapy data management system. We are now filmless and hope to be paperless at the end of this process.

Academically, most physicists are appointed to the department of Radiation Oncology (University of Toronto). The DRO includes radiation oncologists, medical physicists and some radiation therapists from both the Sunnybrook Regional Cancer Centre and the Princess Margaret Hospital. Several physicists also have appointments with the department of Medical Biophysics (U of T) and graduate students are typically registered in that department.

Research activity is in several areas:

- Target definition (Mah, Sixel, Basran), including defining the role of PET/CT planning in radiation therapy planning and development of functional CT.
- Imaging for Radiation Therapy (Pang, Rowlands, Yeboah, O'Brien), including the development of

(Continued on page 51)

A picture of the physics crew is above: the physicists are scattered throughout-starting in the bottom row: Kathy Mah, Beibei Zhang (resident); second row: Raxa Sankreacha; third row: Collins Yeboah, David Beachey, Geordi Pang, John Rowlands (Head of Medical Physics Research), Alec Lightstone, Stan Szpala (resident); back row: Nelson Videla, Milton Woo, Daryl Scora, Peter O'Brien, Brian Keller, Bryan Schaly (resident) and Parminder Basran. Missing are Katharina Sixel, William Que and Stuart Burnett (resident). Many of you will have talked to the person in the red jacket, in the middle of the photograph, our secretary Rose Lisi.

ACROSS CANADA… (Continued from page 50)

systems for MVCT

- Detector Technology (Rowlands, Pang)
- Brachytherapy (Keller, Sankreacha, Que, Pignol (Rad. Onc)), including a novel partial breast irradiation technique using Palladium-103 seeds.
- Intermediate Photon Energy Tomotherapy (iPET) (Pignol, Beachy, Keller)

Research is supported by grants from NCIC, U.S Army, CBRF, CHIR, NSERC and industry.

Many physicists teach courses at the U of T, at Ryerson University and at the Michener Institute. There is also an initiative underway to completely restructure the medical physics residency program as a joint TSRCC/PMH professional diploma through the Department of Radiation Oncology at the University of Toronto.

After 2 decades of constant growth in patient numbers, the Toronto Sunnybrook Regional Cancer Centre has now reached a relatively stable position in that regard. We are now ready to embark on a different stage of our growth – with much more emphasis on grant-supported independent researchers, to create a balanced academic and clinical department.

Newfoundland Cancer Treatment and Research Foundation; Dr. H. Bliss Murphy Cancer Centre, St. John's, NL

Submitted by Maria Corsten

The Newfoundland Cancer Treatment and Research Foundation (NCTRF) was established in 1971 as a provincial health care organization. It is a province-wide organization with a mandate to meet the needs of Newfoundlanders and Labradorians in cancer prevention, treatment and support and research. The NCTRF operates the Dr. H. Bliss Murphy Cancer Centre in St. John's and regional oncology programs throughout the province. In 1999, our organization was awarded Accreditation with the Canadian Council on Health Services Accreditation.

The Dr. H. Bliss Murphy Cancer Centre provides the only Radiation Oncology Department and Services for the entire province on Newfoundland and Labrador. We treat ~1200 Radiation Therapy patients per year.

The Department of Medical Physics and Electronics has grown significantly in the past few years. The department, headed by Maria Corsten has five physicists (NY Feng, Donia MacDonald, Michael Gillard and David Goodyear), three dosimetrists and two electronic technologists.

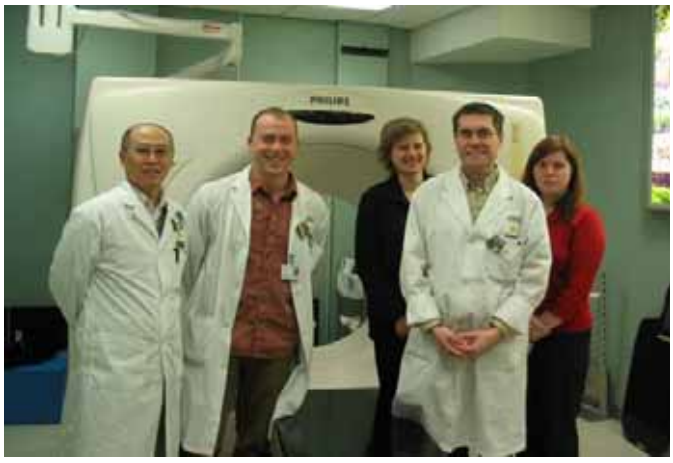
Our equipment includes two Varian dual energy linacs with 120 leaf MLC, aSi Portal Imaging, a Co-60 unit, a 250kV x-ray unit, a Nucletron LDR remote afterloading system, a Philips large-bore AcqSim CT scanner, a Ximatron conventional simulator, Eclipse Treatment Planning System and Varis/Vision Record and Verify System. We have purchased a GammaMed HDR afterloader and the BrachyVision treatment planning system with installation planned for Spring 2005.

As a small centre that had been understaffed for many years in the past, our current projects are all clinical in nature. These include the development of an HDR program, commissioning enhanced dynamic wedge and implementing the RadCalc Monitior Unit check program. We recently implemented a prostate protocol using implanted gold seeds for localization and a 6-field conformal treatment technique. We have completed an extensive review of our QA program for linacs and updated our program to include more MLC and Portal Imaging tests to meet the COMP and AAPM standards. We are now reviewing the CT Sim QA and treatment planning system QA in the same manner.

As our treatment hours are 8am-6pm and we have a waiting list for treatment, we are proposing an expansion to our facility to include two new treatment rooms – it is amazing how quickly you run out of space!

We are looking forward to the expansion of our projects as our staff remains stable and is gaining experience. We were happy to host the 2004 Atlantic Medical Physics Group Meeting last fall.

In April 2005, the NCTRF will be amalgamated into a larger health board: the Newfoundland and Labrador Eastern Regional Integrated Health Authority. It remains to be seen what impact this will have on the Provincial Cancer Program.



NCTRF Medical Physicsts, from left to right: NY Feng, Michael Gillard, Maria Corsten, David Goodyear and Donia MacDonald

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

LE COLLÈGE CANADIEN DES PHYSICIENS EN MÉDECINE

Proposed Bylaw Amendments - 2005

The Board of the CCPM hereby gives notice that we will be seeking ratification of the following Bylaw amendments at the Annual General Meeting in July 2005 in Hamilton, Ontario. The proposed changes are in bold, italic and underlined.

1 THE ADDITION OF A DEPUTY CHIEF EXAMINER

RATIONALE: The duties of the Chief Examiner have recently been substantially increased with the addition of an oral examination at the Membership level. The aim of adding a Deputy Chief Examiner is to distribute some distribution of the work involved in the whole examination process and also to ensure a smooth transition between Chief Examiners.

ARTICLE IV: OFFICERS AND GOVERNING BODIES

Add a sixth executive officer "***6) Deputy Chief Examiner"***

Also, after the section describing the "Duties of the Chief Examiner",

Add "***Duties of the Deputy Chief Examiner***

The Deputy Chief Examiner shall assist the Chief Examiner in the examination processes."

2 MODIFICATION OF THE WRITTEN MEMBERSHIP EXAMINATION STRUCTURE

RATIONALE: The current structure requires that two questions from the 30 question bank be randomly selected for Sections III and IV of the examination. We are proposing that the question banks be revised to give more than 30 shorter questions to enable a wider selection of topics to be addressed in each examination through the selection of a number of shorter questions. This change in the wording of the Bylaw Appendix would provide that flexibility.

APPENDIX III: EXAMINATIONS, Membership Written Examination

Section II and IV

Change "This portion of the examination is based on a question bank specific to the applicant's sub-specialty available to the applicant ~~***at least three months prior to the exam***~~ ***by the first of October prior to the examination***. ~~***Each sub-specialty bank contains thirty questions.***~~"

Add ***The question bank will be posted on the CCPM web site together with more specific information regarding the upcoming examination. The questions for Sections III and IV will be chosen at random from the bank.***

(Continued on page 53)

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

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(Continued from page 52)

Delete "Section III contains ~~***one question chosen at random from the twenty***~~ questions ~~***in the bank***~~ specific to the sub-specialty."

Delete "Section IV contains ~~***one question chosen at random from the remaining ten***~~ questions which cover more general areas of the sub-specialty."

3 AMENDMENT OF BYLAWS

RATIONALE: Currently the Bylaws request proposals for additions, corrections or amendments of the Bylaws to be forwarded to the Registrar. With the addition of a Secretary/Treasurer in 1994, it is now more appropriate for this person to be responsible for these proposals.

ARTICLE VIII

Replace (2) Proposals for additions, corrections or amendments to the bylaws should be forwarded to the ~~**Registrar**~~ **Secretary/Treasurer** by means of …

Replace (3) The ~~**Registrar**~~ **Secretary/Treasurer** shall submit any such proposals ...

4 DELETION OF INFORMATION ABOUT WHO DOES NOT REQUIRE CERTIFICATION

RATIONALE: It was decided at the mid-year board meeting that it was not the business of the college to give advice as to who does not require certification.

APPENDIX I: CERTIFICATION

Delete ~~Who does not need to be "certified"~~

1. ~~Medical Physicists who work in industry and do not provide any medical physics consultation services to medical institutions.~~
2. ~~Medical Physicists who work at universities and are involved in teaching and research, and whose work is not related to patient care.~~
3. ~~Medical Physicists who work for regulatory agencies and whose work is not related to patient care.~~

Report on WesCan 2005

Submitted by Matt Schmid
Allan Blair Cancer Centre, Regina, SK

The 2005 version of the Western Canada Medical Physics Meeting (WESCAN) was held March 16 -19 in Calgary. WESCAN has always been a relatively informal venue for physicists, therapists, dosimetrists, mould room and electronics staff, students, and other cancer care specialists to meet with their colleagues in western Canada to strengthen both professional and social ties. This year, the conference drew a larger attendance than ever before. As has been happening over the past few years, there were even attendees from east of Thunder Bay!

The format of the conference this year was somewhat different than it had been in previous years. Each session was opened by guest speakers and this allowed the conference to follow a somewhat programmed format. The guest speakers gave presentations on selected topics followed by presentations of relevant works in progress. There were also a large number of poster presentations for viewing and a commercial exhibit area. Representatives of some of the commercial vendors hosted workshops highlighting some of their products. Since the abstracts for the works in progress are being published elsewhere in this newsletter, the following comments deal mostly with the invited talks.

The conference opened with a session on "Cancer care – Where are we now?". This session gave three speakers the opportunity to present us with a patient perspective, a provider perspective, and a provincial perspective on this subject. The same three individuals spoke at the final session dealing with "Cancer Care – The Future". Having the same three speakers both open and close the conference was an interesting way of wrapping everything up. The talks were informative and thought provoking.

To my knowledge, there has never before been a presentation by a patient at the WESCAN meeting. Listening to a patient's perspective at such an event is always a good reminder of why we do what we do. The particular patient in question was also a retired medical oncologist so it was interesting to hear her comments on what it is like to be on the receiving end of medical treatment.

The provider's perspective was given by Dr. Stephan Larsson and the provincial perspective was given by Dr. Tony Fields who is the VP of Medical Affairs and Community Oncology for the Alberta Cancer Board.

After hearing Dr. Fields speak, it is evident that the Alberta Cancer Board not only has a vision, but also has the resources and the will to bring it about. He spoke of setting firm goals for minimizing the time between diagnosis and treatment, the need to ensure that surgeons are properly trained and follow proper protocols, and the existence of a "patient navigator" to guide patients through the sometimes confusing path of their treatments. He certainly left the impression that real progress was being made along these lines to make cancer care more effective. When speaking about the future, he stated that taking an aggressive role in applying what we know about the causes of cancer followed by a more effective system of treating the cancers that can't be prevented would greatly reduce the impact of cancer on the population. He openly stated that reducing the impact of cancer on the population would be one of the legacies of the substantial revenues generated by the oil industry in Alberta.

Among other topics, Dr. Larsson addressed the challenges related to the escalating costs of cancer treatment. The increase in costs is largely (but not entirely) due to the stunning increase in drug costs in recent years. He pointed out that although drugs account for a large proportion of the total budget, they are responsible for only about 5% of the cures.

Other sessions dealt with Assessment and Consultations, Planning and Simulation, Immobilization and Delivery, Verification, Clinical Trials, Information Management, and Risk Management. The abundance of invited talks in each of these sessions provided a great learning opportunity on many topics, such as risk management, that normally wouldn't surface at a WESCAN meeting.

As always, there was much spirited discussion taking place during the sessions. The relatively small, friendly, and informal atmosphere of the WESCAN conference is particularly suited to promoting this type of interchange of ideas. The discussions spilled over into a number of excellent social events, including a special St. Patrick's day event. [note: pictures on p. 74]

For the die-hards, a tour of the Tom Baker Cancer Centre was offered on Saturday morning. This was a great opportunity for outsiders to get a look at two new technologies that Calgary has to offer. The first was their new Novalis stereotactic unit. This is basically a dedicated high precision 6 MV accelerator with an integrated multileaf collimator system. A dedicated planning system is used to plan the treatments and special imaging hardware is mounted in the room for position verification. This is the only Novalis unit in Canada. One of the presented talks at the meeting dealt with the challenges of funding this unit.

The other highlight of the tour was the Nucletron intraoperative seed implant system for permanent seed implants of the prostate. Dose distributions are calculated based on a 3D volume acquired from an integrated ultrasound system. Onboard optimization software can calculate needle locations and seed loadings in real time. Needles are inserted using the standard grid template approach under ultrasound guidance. After the needles are in place, the machine forms the designed seed train and then loads the seeds into the needles automatically. If desired, the dose distribution can be updated on the fly. During one of the scientific sessions, the group performing prostate implants with this system presented very impressive dose-volume statistics for the implants they have carried out so far. For those centers considering starting a prostate implant program, this sophisticated system and the intraoperative planning approach as opposed to the preplanned approach should be given a great deal of consideration.

In summary, the 2005 edition of WESCAN was a great success.

(Continued on page 73)

WesCan 2005 Conference Abstracts

Editors note: For the first time ever (to my knowledge), we are publishing conference abstracts in InterACTIONS. This will provide broader Canadian Medical Physics community exposure for research and clinical work being presented at small, local conferences. This can only benefit us as a whole, and I look forward to further submissions of this nature from local conferences. In this particular entry, the abstracts are from the Western Canadian Radiotherapy Conference ('WesCan'), a multidisciplinary conference including Medical Physicists, Radiation Therapists, Electronics Technicians, Mould Room, Machine Shop staff, and even the occasional Radiation Oncologist. This year the conference was hosted by the Tom Baker Cancer Centre, March 17-19 in Calgary, AB.

WesCan 2005 Abstracts:

Genetic Algorithm in Respiratory Motion Prediction for Four–Dimensional Radiotherapy

G. Badragan[1], A. Chan[2], I. Kay[1], P. Dunscombe[1]; [1]Medical Physics, Tom Baker Cancer Center, Dep. of Physics and Astronomy, U of C, [2] Dep. of Oncology, Tom Baker Cancer Center, U of C, Calgary,AB

Four-dimensional or gated radiotherapy for lung tumors is currently the subject of considerable research. The successful application of this technique requires accurate prediction and /or monitoring of organ motion. The purpose of this study is to assess the performance of Genetic Algorithm (GA) in predicting the parameters which characterize respiratory motion from a limited number of samples. The Genetic Algorithm is a stochastic global search and optimization method that mimics the metaphor of natural biological evolution. The Algorithm is an iterative process in which new populations are created by elitism, crossover and mutation at each step. Over successive generations, the population "evolves" toward an optimal solution. For the objective function in the GA, a least mean squares approach was used and the prediction is based on fitting a periodic curve to some past history of the respiratory motion signal. Discrete data was synthesized at sampling intervals of: 0.25s, 0.5s, 0.75s, 1s. The mean value and the standard deviation for each parameter which characterizes respiratory motion were computed using discrete data and the Genetic Algorithm.

The Genetic Algorithm outperformed other algorithms based on gradient search minimization. The improved performance is ascribed to the ability of the Genetic Algorithm to avoid local minima and find the global minimum.

A Monte Carlo Approach for TBI Dosimetry

J. Badragan[1], G. Badragan[1], P. Dunscombe[1]; [1]Dep. Medical Physics, Tom Baker Cancer Centre, Calgary, AB

Background: TBI dosimetry has been always associated with difficulties, which arise from the special conditions of large fields at high SSDs. Previous studies have shown that the knowledge acquired for more conventional SSDs does not extend properly for the TBI conditions. Monte Carlo has been successfully employed so far in many radiation oncology applications.

Objective: Explore the potential of Monte Carlo methods to provide a better dosimetry for TBI.

Method: Monte Carlo methods attempt to accurately model the physical processes, which occur while radiation interacts with matter. Therefore, is always essential to have a proper model of the radiation source to start with. We tried two methods both Monte Carlo based. The next step was to run simulations for the TBI conditions and compare the results obtained to available measurements.

Results: We obtained a good model for the radiation source and the comparisons against measurements have shown that Monte Carlo can be employed as an alternative method to providing better TBI dosimetry.

Future Work: The clinical implementation of a Monte Carlo method requires dealing with many details. A friendly software interface between the clinician and the Monte Carlo engine has to be built. Extensive documentation and further testing is also required.

This method is certainly of academic value. But it is still to be evaluated whether the patients will benefit more as a consequence of implementing it clinically.

Correction of Geometric Distortion in MR Images

LN Baldwin, K Wachowicz, BG Fallone - Cross Cancer Institute, Edmonton, AB

Magnetic Resonance Imaging (MRI) is an extremely powerful diagnostic tool. Because of the excellent soft tissue information provided by magnetic resonance (MR) images, and the flexibility to explore various physical properties of tissue that this modality allows, MRI has revolutionized the field of oncologic imaging. Despite these strengths, the applicability of MR to radiotherapy treatment planning is limited by the geometric inaccuracies in MR images due to inhomogeneities and non-linearities that are inherent in the static and gradient magnetic fields used to form the MR image. Although the soft tissue detail provided by the MR image may be excellent, the spatial information may not be ideal for treatment planning. While magnetic field inhomogeneities can be reduced, they cannot be entirely eliminated. Therefore, this research seeks to develop post-processing techniques to correct for the residual geometric inaccuracies in MR images. The magnetic field inhomogeneities and non-linearities inherent in the new Philips 3 Tesla clinical magnet recently acquired at the Cross Cancer Institute will be characterized and the geometric distortion in images will be measured via phantom experiments. The in-house developed phantom contains a 3D distribution of approximately 10,000 points that can be used to quantify the amount of distortion throughout the magnet's bore. The locations of the points are measured using Matlab software, and the MR distortion is calculated with respect to a standard CT image. This information will be used to correct images so that the soft tissue (tumor) information provided by MR images can be accurately used for radiotherapy treatment planning purposes in the future.

Development and integration of a post-reconstructive CT de-streaking algorithm in the radiation therapy treatment planning environment

P.S. Basran(1,2), I. Kay(3,4); 1) Dept. of Medical Physics, Toronto-Sunnybrook Regional Cancer Centre, Toronto, ON 2) Dept. of Radiation Oncology, U. Toronto, Toronto, ON 3) 4) Depts. Oncology and Physics, U. Calgary, Calgary AB

Streak artifacts from high-density substances degrade x-ray computed tomography (CT) image quality and may introduce errors in identifying tissues of interest and the subsequent radiation therapy dose calculation. The objective of this work is to develop a post-reconstruction CT de-streaking algorithm for radiation treatment planning CTs and integrate this algorithm in the clinical environment. The post-reconstructive algorithm consists of 1) two fanbeam re-projection of the original CT image and a segmented image containing only the high-density object; 2) re-scaling the segmented high-density fanbeam projections; 3) merging of the two re-projections; and finally 5) back-projection of the modified fanbeam projections. This simple method significantly reduces the masking effects of the high-density artifacts and allows for more accurate delineation of normal and diseased tissues. The reconstructed images are then introduced into the treatment planning system as a secondary image data set which can be fused with the original CT data for contouring purposes. Some examples of the de-

(Continued on page 56)

streaking algorithm will be presented.

A Time and Motion Analysis of Treatment Planning and Delivery Comparing 3D Conformal Radiation Therapy Versus Permanent Seed Implantation for Prostate Cancer

S. Bernard, G. Graham, S. Iftody, D. Radford Evans, L. Traptow; Dept. Medical Physics, Tom Baker Cancer Centre, Calgary, AB

At the present time there are several options for treating early stage prostate cancer; including surgical prostate resection, external beam radiation therapy, brachytherapy or a combination of two or more of these modalities.

Over the past several years, permanent seed implantation using dine 125 has become a very popular and viable option for early stage prostate cancer. Due to the convenience and a decrease in side effects, many patients are opting for this type of therapy. Over the past 24 months the Tom Baker Cancer Centre has instituted a permanent seed implantation program.

Pinnacle Version 7.4 Physics Improvements – All's Well That Ends Well

P.Cadman[1], T. McNutt, K. Bzdusek[2]; 1. Medical Physics Dep., Saskatoon Cancer Centre, SK, 2. Philips Medical Systems

A new Pinnacle 3D treatment planning system software release has recently become available (version 7.4, Philips Radiation Oncology Systems, Milpitas, CA) which supports modeling of rounded MLC leaf ends plus a number of other software enhancements intended to improve the overall dose calculation accuracy. In this report, we have provided a general discussion of the dose calculation algorithm and new beam modeling parameters. The requirement for a dosimeter with good spatial resolution and appropriate energy response is established through comparisons of ion chamber, film and diode measurements. The dose calculation algorithm and modeling parameters chosen were validated through various test field calculations and measurements including a bar pattern, a strip pattern and a clinical head and neck IMRT field.

A Comparative Study of Mucosal Dose Distribution for Head & Neck Cancer Patients using IMRT and Conventional Treatment Planning

F. Cao, D. Wells; Vancouver Island Centre, BC Cancer Agency, Victoria, BC

Purpose: Head and neck (H&N) cancer patients often suffer from mucosal toxicities when treated with conventional external beam radiation therapy techniques (lateral pair, anterior supraclavicular). A recent H&N study conducted at BCCA showed that mucosal complications were significantly reduced using a seven field IMRT technique. Only two of 20 patients had transient grade 3 mucosal toxicity and no grade 4 toxicities were observed. The purpose of this study was to quantify dosimetric differences to mucosa between conventional and IMRT H&N techniques.

Methods: The inner edge of the "mucosa" structure was auto-contoured (HU = -500) and was defined to be 2mm thick. Dose distributions were calculated using Cadplan/Helios v6.27. For IMRT plans, no constraints were placed on the mucosa during the optimization process. Dose distributions were also calculated using NRC EGS4 Monte Carlo software and an additional module to simulate multi-leaf collimator sequences. Dose volume histograms and surface dose areas (based on a cylindrical model) were estimated for all plans.

Results and Discussion: No significant differences were noted between dose distributions derived from Cadplan versus Monte Carlo. Significant regional reductions in mucosal dose were achieved with IMRT plans as compared to conventional plans. It may be possible to correlate these dose reductions with patient mucosal toxicity. IMRT optimization constraints for mucosa may be warranted to further reduce toxicity.

Does Sufficient Evidence Exist To Support Hypofractionation For Prostate Cancer?

M. Carlone, D. Wilkins, P. Raaphorst; Ottawa Hospital Regional Cancer Center, Ottawa, ON *Presently at Cross Cancer Institute, Edmonton, AB*

A publication by Brenner and Hall in 1999 regarding the use of hypofractionation for prostate cancer has generated much discussion in the literature about fraction size dependence for prostate cancer radiotherapy. It is becoming more and more accepted that prostate cancer has a low alpha/beta ratio, which suggests that hypofractionation may be used to effectively treat this disease. The purpose of this presentation is to review the clinical evidence for this conclusion. Two methods have been used to estimate the alpha/beta ratio for prostate cancer from clinical data: dose escalation analysis and isoeffect analysis. The conclusions of our investigations are that these two methods are consistent with a low alpha/beta ratio for prostate cancer; however, including population heterogeneity results in a considerable increase in the confidence interval of the alpha/beta estimate. The increase in confidence limits is so large that the estimate becomes statistically insignificant. Our analysis can be used to understand why prohibitively large confidence intervals result when using a heterogeneous model, and suggest that clinical data from a much larger survival range is needed to reduce confidence intervals. The presentation will conclude by showing that the method of dose escalation analysis of tumour control is fundamentally limited since the presence of linearly correlated parameters is in fact an estimate of the dose of 50% tumour control.

Hepatic Radiation and Concurrent 5FuDR Infusion for colorectal Liver Metastases: Efficacy and Toxicity

A. Chan, A. Wong+, E. Yan*; Deps. Radiation Oncology* and Medical Oncology+, Tom Baker Cancer Center, Calgary, AB*

Purpose: A review of the results of a phase I/II study of concurrent radiation and 5FuDR infusion to evaluate the efficacy and toxicity of whole hepatic radiation in liver metastases from colorectal cancer.

Materials and Methods: Between January 1985 and October 1990, 75 patients were treated with whole hepatic radiation and 5FuDR infusion. 2600 cGy was administered with AP-PA parallel portals to cover the entire liver. 2-cm superior and inferior margins were added to account for respiratory motion. 17 patients received additional 600 to 1000 cGy boost with smaller portals for localized disease. Continuous 5FuDR (0.11-0.16 mg/kg/day) was given concurrently with the hepatic radiation. There were 44 males and 31 females. After hepatic radiation, 46 patients (61%) received additional chemotherapy.

Results: There were 5 CR's and 18 PR's by CT evaluation. 46 patients had stable disease and 6 patients had disease progression. The response rate (CR+PR) was 30%. The median survival after hepatic RT was 10.5 months. The 1- and 2-year survival was 40% and 11% respectively. For CR+PR group, the median survival was 16.7 months, compared a median survival of 9.2 months for those with stable disease or progression, p = 0.00016 (log-rank). 7 patient developed grade 3 thrombocytopenia ($<50 \times 10^9$/L). There was transient elevation of serum ALT (up to 2x normal) during the first 3 months after RT in 21 patients. Most patients with disease progression developed jaundice or hepatic insufficiency before death. However, 3 patients developed jaundice without evidence of disease progression. Two patients recovered uneventfully and one patient died of progressive jaundice.

Conclusion: Whole hepatic radiation of 2600 cGy is fairly well tolerated. When given concurrently with 5FuDR infusion, it had resulted in partial response and survival benefit in selected patients. The limitation of whole hepatic radiation has been the liver tolerance. Further research should focus on partial hepatic radiation with dose escalation, given in conjunction with newer effective chemotherapy for colorectal cancers.

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Optimization in Intensity Modulated Radiation Therapy

By Stewart Gaede and Eugene Wong, London Regional Cancer Program and University of Western Ontario, London, Ontario

1. INVERSE TREATMENT PLANNING OPTIMIZATION

Intensity Modulated Radiation Therapy (IMRT) has led to a practical means of planning and delivering 3-D conformal radiotherapy to complex cases. IMRT can be characterized by beams that have individually defined intensity profiles formed using dynamic multileaf collimators (DMLC). In other words, each beam can be thought of consisting of many smaller *beamlets* of radiation, each with its own intensity that can be optimized to produce the most favourable dose distribution.

IMRT requires a method of designing optimal non-uniform beam intensity profiles given a prescribed dose distribution. The use of optimization methods for an IMRT plan is called *inverse treatment planning*. Because of the large number of degrees of freedom, conventional trial-and-error methods are often impractical. The goal is to find the best plan within the physical limits of IMRT. Clinically meaningful objectives and constraints of the treatment must be defined.

Gradient search and other iterative techniques are common deterministic approaches to solving radiotherapy problems (1–9). The most well-known example of a physical objective function that can be solved with a gradient search method is the mean square deviation between the calculated dose distribution and the ideal dose prescription in the entire volume (Equation 1).

$$F = \sum_i r_i (D_i - D_i^p)^2 \qquad (1)$$

where $D_i = \sum_j d_{ij} w_j$ is the total dose delivered to pixel *i*, d_{ij} is the contribution of the dose delivered to pixel *i* by beamlet *j*, w_j is the intensity of beamlet *j*, r_i is the relative importance parameter of the structure containing pixel *i*, and D_i^p is the prescribed dose to pixel *i*. (e.g. using relative dose, ideally, D_i^p =1 for PTV pixels and D_i^p =0 for critical organ and normal tissue pixels).

Importance Parameters, r_i, are introduced to differentiate between different critical organs' mean square dose deviation and between the target's and critical organs'. Often referred to as a weighted least squares objective function, the attractiveness of this formulation is that it contains a quadratic objective function subject to simple bounds, such as the non-negativity in the intensities. For a fixed set of gantry angles and predefined relative importance parameters, such an optimization problem is convex (10). That is, any local solution found by a gradient or other downhill techniques is also the global solution (11).

However, selecting beam directions to achieve a desired dose distribution can be time consuming and unintuitive. Moreover, beam directions, when added as free variables, excessively enlarge the search space due to their interdependence with beamlet intensities. Bortfeld *et al.* (12) showed an example of multiple local minima in beam direction problems.

Dose-volume constraints are often used in inverse treatment optimization. These constraints are of the form "no more than x% of this critical organ can exceed a dose of y." However, Deasy (10) showed that the inclusion of dose-volume constraints could lead to multiple local minima. Simulated annealing (13-19) and genetic algorithms (20-22) are common stochastic algorithms in radiotherapy optimization that allow for an escape from local minima. These methods are often desired because the choice of objective function and constraints are not as limited as its deterministic counterpart. However, even with stochastic algorithms, they can converge to a local minimum that is still not guaranteed to be the global minimum.

In this report, we describe methods to incorporate beam directions and dose-volume constraints into the inverse treatment planning optimization problem in order to overcome some of the disadvantages of current methods.

2. AN ALGORITHM FOR SYSTEMATIC SELECTION OF BEAM DIRECTIONS FOR IMRT

Since IMRT usually involves a large number of beams, frequently 7-11 beams, the impression is that there are enough degrees of freedom in the intensity-modulation so that the choice of beam directions is of secondary importance. However, in complex cases where the PTV surrounds a critical organ or is surrounded by multiple critical organs, the selection of beam directions becomes important, even in IMRT (23). Not only can better target dose uniformity and better critical organ sparing be achieved, but it is also possible to achieve these goals with a fewer number of beams than standard IMRT plans which are typically composed of an odd number of equally spaced beams (24). A fewer number of beams simplifies quality assurance of beam setups, faster treatment times, and a lower probability of patient movement.

However, optimization of beam directions is complicated due to the dependence of one beam direction on its corresponding beamlet intensities and the beamlet intensities of all other beam directions. The result is an excessively enlarged search space, even when the number of beams is small (2-3). Compared to fixed beam IMRT, much less research focuses on beam direction optimization (12,17,18,22,23,25-27). Furthermore, the optimal number of beams to employ is only considered in equally-spaced fixed beam IMRT (18) and not together with the selection of beam directions.

We report a non-brute force systematic algorithm

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Optimization in IMRT... (Continued from page 57)

which determines a suitable set of beam directions with *the fewest number of beams possible*.

2.1 General Description

Our approach is similar to that of Soderstrom and Brahme (28) in that we retain beam directions for a plan composed of N beams as beam direction candidates for a plan composed of $N+1$ beams. We start by searching for the best "one-beam" plan. This is accomplished by exhaustively searching the beam direction space in 10^o steps, optimizing the set of beamlet intensities for each beam direction sampled, and simply choosing the beam direction with corresponding optimal beamlet intensities that minimizes the objective function, ie. best matches the desired dose distribution. This beam is then fixed in direction only, and the search for the second beam is performed. The beamlet intensities for each beam pair are then optimized and the set that minimizes the objective function is selected as the best two-beam plan. Adding beam directions in this manner guarantees that the objective function describing the treatment plan quality will always improve.

For every beam orientation sampled by the algorithm, we optimize the beamlet intensities by minimizing the weighted least squares objective function, as in Equation 1. A quasi-newton method was used to solve each fixed beam formulation. Although the objective function is simplistic, it is well known and is an obvious fit for our algorithm, since it involves many fixed beam optimizations. For the final set of beam directions, one could use a more sophisticated objective function that includes dose-volume constraints to generate the beamlet intensities.

2.1.1 Beam Significance Criteria

At this stage, the selection of beam directions via the above approach may not constitute the optimal set of beam directions. For example, the first beam direction that is selected primarily for its ability to minimize our objective function may be a suitable beam direction for a "two-beam" plan, but it may no longer be suitable for, say, a "seven-beam" plan. By unsuitable, we mean a beam that does not make a significant contribution to the multi-field dose distribution. If such a beam exists in a set currently selected by the algorithm, then it is eliminated and the iteration restarts *dropping the current eliminated beam direction*. We require that one of the following must hold:

1. At least one beamlet of an incident beam must have a relative intensity of at least 0.15 (plans are normalized to 1 at the isocentre).

2. At least two beamlets of an incident beam must have a relative intensity of at least 0.10.

If beams with more segments were used, then it makes sense to relax this beam significance criteria to account for the increase. It is up to the user to define beam significance in this situation, realizing that an increase in optimization time is expected. We also realize that as the number of beams increase, the beamlet intensities will decrease. Therefore, this criteria helps control the number of beams necessary for an adequate treatment plan.

2.1.2 Stopping Criteria.

The beam selection process continues until one of three stopping criteria is met:

1. If the most recent best beam selection is one in which its beamlet intensities fail the beam significance criteria, then this addition is rejected and the algorithm stops.

2. If a beam direction is eliminated from the plan, then the beam direction that ultimately replaces the eliminated beam direction must improve the objective function. If it doesn't, then the algorithm stops.

3. When searching for the (N+1)-st beam, if the N-th beam selection (the one most recently selected) fails our beam significance criteria for any (N+1)-beam orientation, then the algorithm terminates and accepts the N-beam plan most recently selected by the algorithm. We add this criteria to avoid an infinite loop.

2.2 Prostate Phantom

We considered a "prostate-like" phantom in which the prostate gland and seminal vesicles were encompassed by the planning target volume (PTV) which wraps around the rectum. We prescribed 78 Gy to the PTV and ensured that 40% of the rectal volume does not exceed 83% of the dose, 30% does not exceed 90% of the dose, and 5% does not exceed 96% of the dose (29).

FIGURE 1 shows the progression of the algorithm at the point where either a beam direction is selected or eliminated. Relative importance parameters were chosen to be the same as those that satisfy the dose-volume constraints for a standard IMRT plan composed of seven equally spaced beams. Corresponding objective function values and term by term contributions to the objective function by the PTV, rectum, and normal tissue are shown in TABLE 1.

Notice that an intermediate six-beam plan selected by the algorithm (270^o,170^o,220^o,130^o,190^o,70^o) has a lower objective function value (F=326.6) than the standard seven-beam IMRT plan (F=328.4). The algorithm continues until the addition of the eighth beam at 90^o caused its parallel-opposed beam at 270^o to become insignificant. This suggests that lateral parallel opposed pairs are not useful, at least with the current set of employed beams. Therefore, the 270^o beam is eliminated and a search is performed to replace this beam. It may not be surprising that a beam at 90^o was the beam ultimately chosen. However, as TABLE 1 shows, this addition provided no gain to the quality of the treatment plan. According to the second stopping criterion, the algorithm stops and the seven-beam plan at angles (270^o,170^o,220^o,130^o,190^o,70^o,290^o) is accepted. The corresponding dose-volume histograms, shown in FIGURE 2 with all plans normalized to D_{90}, compares the optimal plan generated by the algorithm, the standard IMRT plan, and the

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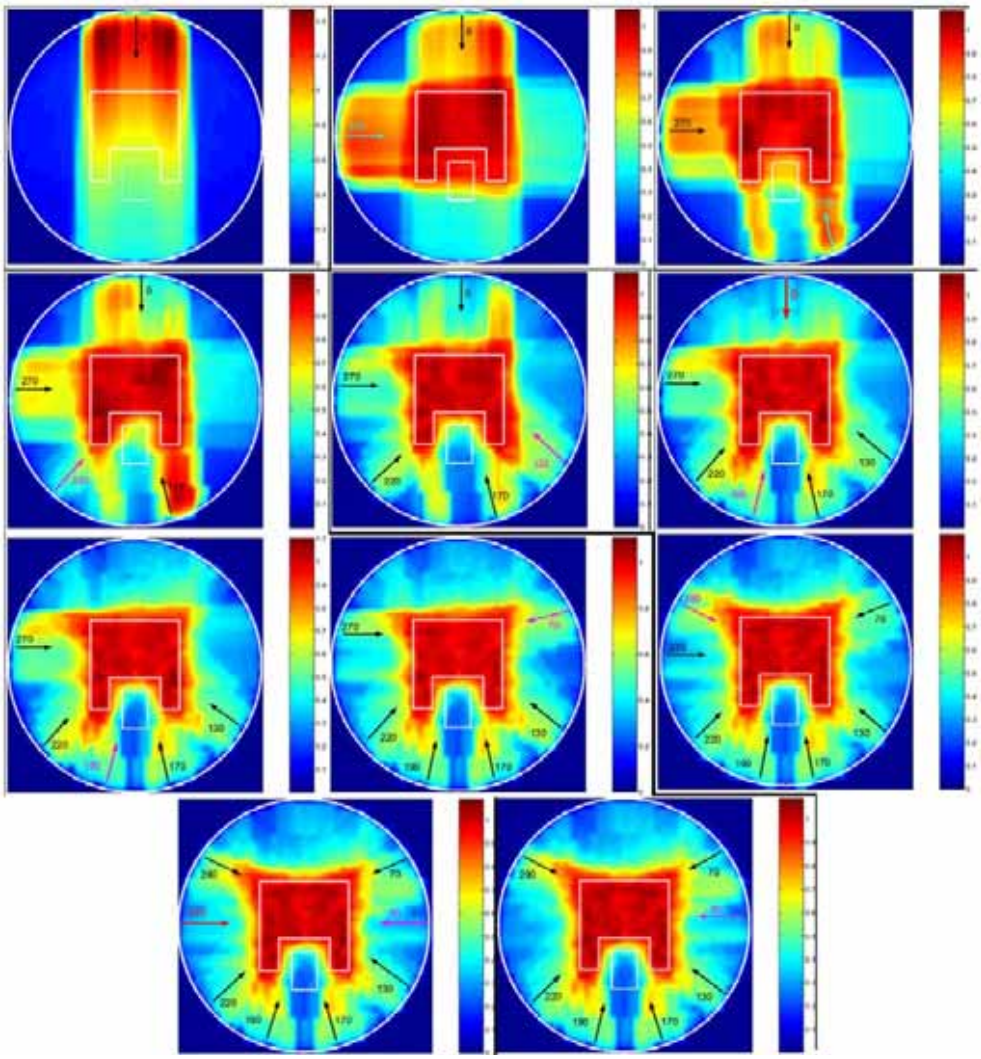

FIGURE 1: Dose Distributions corresponding to plans generated by the beam direction selection algorithm for the prostate phantom. The algorithm proceeds left to right, then top to bottom.

*TABLE 1: Beam direction selection algorithm for the "prostate-like" case. *- denotes an insignificant beam. Results of the seven equally spaced beam plan are shown in the last row.*

Direction	F_{min}	PTV	Critical Organ	Normal Tissue
(0^o)	755.3	228.8	92.4	434.0
(0^o,270^o)	489.8	48.7	104.9	336.2
(0^o,270^o,170^o)	441.1	49.7	70.0	321.4
(0^o,270^o,170^o,220^o)	398.6	46.7	52.0	299.9
(0^o,270^o,170^o,220^o,130^o)	353.5	51.8	32.3	269.4
(0^{o*},270^o,170^o,220^o,130^o,190^o)	333.2	46.9	25.9	260.4
(270^o,170^o,220^o,130^o,190^o)	336.2	48.1	26.8	261.3
(270^o,170^o,220^o,130^o,190^o,70^o)	326.6	49.0	23.3	254.3
(270^o,170^o,220^o,130^o,190^o,70^o,290^o)	**318.8**	**50.5**	**22.7**	**245.7**
(270^{o*},170^o,220^o,130^o,190^o,70^o,290^o,90^o)	317.8	50.2	22.4	245.7
(170^o,220^o,130^o,190^o,70^o,290^o,90^o)	319.3	50.9	22.5	245.9
7 Equally Spaced Beams	328.4	50.7	18.7	258.9

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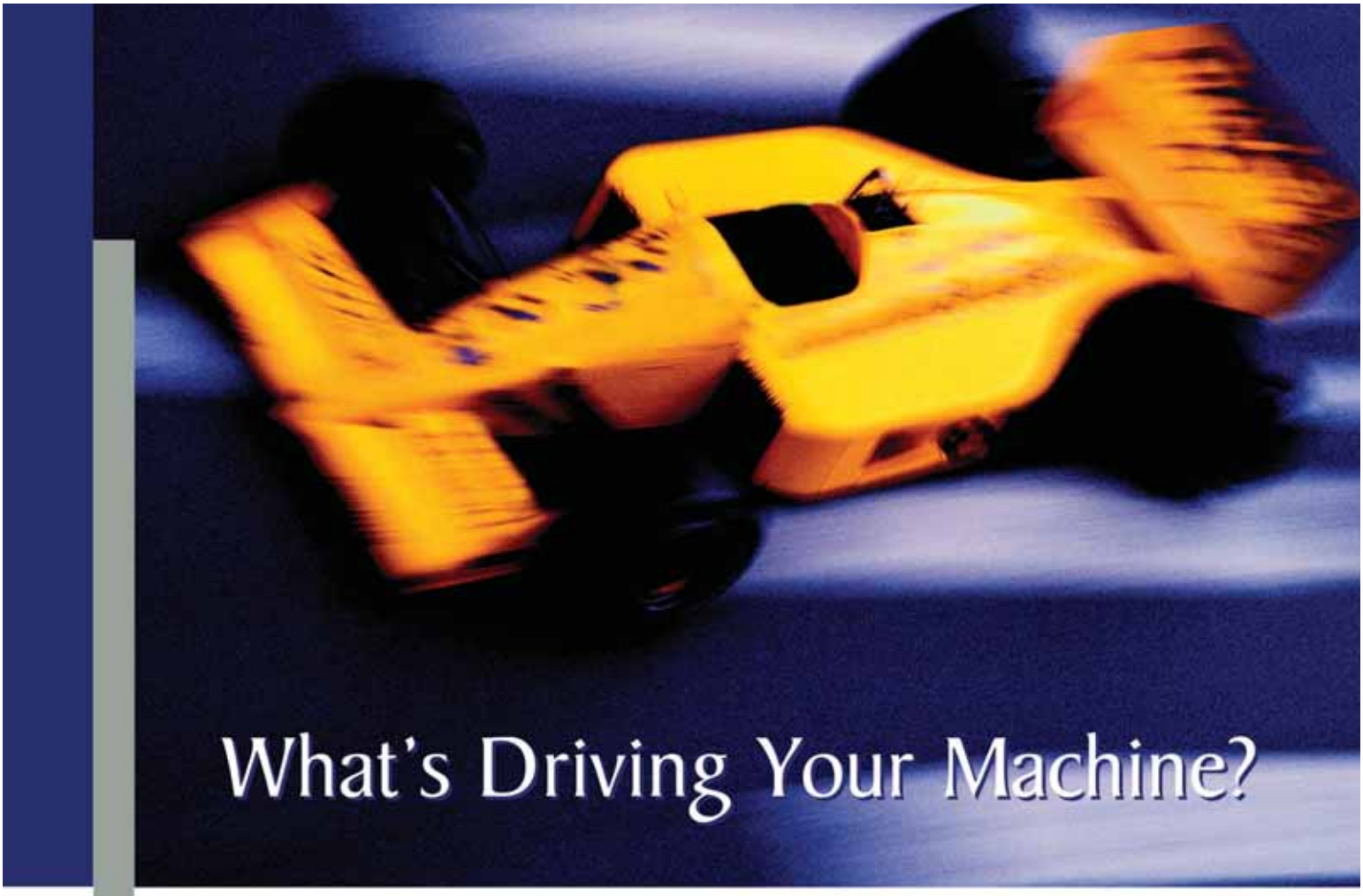

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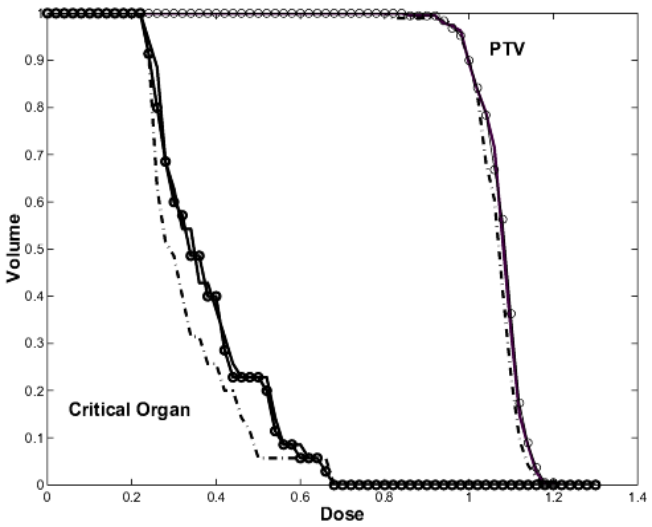

FIGURE 2: Relative Dose-Volume Histogram normalized to D90 for the "Prostate-Like" phantom. Solid lines represent the six-beam plan generated by the beam direction selection algorithm. A minimum dose of 84% to the PTV and objective function value of 326.6 resulted. Circled lines represent the seven-beam plan generated by the algorithm. A minimum dose of 84% to the PTV and objective function value of 318.8 resulted. Dash-dotted lines represent the standard seven equally spaced plan. This has a minimum dose of 80% to the PTV and objective function value of 328.4.

intermediate six beam plan generated by the algorithm.

This algorithm has the benefit of providing the user with choices. Some planners may choose the intermediate six-beam plan because it is already an improvement to the standard plan with fewer employed beams.

3. GLOBAL OPTIMIZATION OF DOSE-VOLUME BASED INVERSE TREATMENT PLANNING

The simplest class of inverse planning formulation uses weighted least squares objective functions, with importance parameters, designed to match the dose prescribed to both the PTV and critical organs, but does not directly use dose-volume constraints. Such objective functions are convex for fixed beam directions and guarantee a global solution, but don't always intuitively result in a desired dose-volume histogram (DVH).

A second class of formulation of the optimization problem includes dose-volume constraints that minimize a mean-squared deviation between the prescribed and actual doses to the PTV subject to user defined dose-volume constraints to the critical organs and normal tissues (10,30). This formulation improves on the simplest formulation, but has an inherent weakness. To achieve the best PTV uniformity, the optimization process will push the critical organ dose as close as possible to the specified tolerance. This is not always necessary or desirable. Simply tightening the dose-volume constraints may reduce the critical organ dose, but may come at the cost of PTV uniformity. Iterative optimization cycles are needed to determine the degree of critical organ sparing and PTV coverage trade-off.

Therefore, we propose a new class of formulation of the optimization problem to overcome the iterative nature of the former classes. The result is a formulation that directly maps the minimum objective function value to the corresponding critical organ DVHs. As we pointed out earlier, such DVH constraints will create multiple local minima, and we investigated a new stochastic optimization procedure to solve this optimization problem. The basic goal of this formulation is to minimize the dose to specified fractional volumes in the DVH constraints, while respecting specified dose-volume tolerances and maintaining PTV dose uniformity. In other words, the objective function is designed for critical organ sparing and the constraints are user defined or protocol-based PTV requirements such as the minimum and maximum dose.

3.1 Formulation of the Optimization Problem

The objective function, $F_{\text{Critical Organs}}$, is a sum of critical organ dose-volume based objective functions, f_{kj} , where j indexes the constraint of critical organ, k. By design, a hard constraint is used to satisfy user defined or protocol-based PTV requirements. The following formulation of the optimization problem is devised:

$$\min \; F_{CriticalOrgans} = \sum_{k=1}^{N_s} \sum_{j=1}^{N_c} f_{kj}$$

where

$$f_{kj} = \begin{cases} -\sum_{i \in C_k} \left[D_i\left(V_{C_k}^{TOL_j}\right) - D_{C_k}^{TOL_j}\left(V_{C_k}^{TOL_j}\right) \right]^2 : \; D_i\left(V_{C_k}^{TOL_j}\right) \le D_{C_k}^{TOL_j}\left(V_{C_k}^{TOL_j}\right) \\ 100 \sum_{i \in C_k} \left[D_i\left(V_{C_k}^{TOL_j}\right) - D_{C_k}^{TOL_j}\left(V_{C_k}^{TOL_j}\right) \right]^2 : \; D_i\left(V_{C_k}^{TOL_j}\right) > D_{C_k}^{TOL_j}\left(V_{C_k}^{TOL_j}\right) \end{cases}$$

subject to

$$D_{\min} \le D_i \le D_{\max}, \forall i \in \text{PTV}$$

$$(V_{95})_{PTV} \ge (V_{95}^{p})_{PTV}$$

$$D_i = \sum_{p=1}^{N_{bl}} D_{ip} w_p, \quad \forall i$$

$$w_p \ge 0$$

In this mathematical expression, N_S is the number of critical structures, N_{C_k} is the number of dose-volume constraints of critical structures, k, $D_{C_k}^{TOL_j}\left(V_{C_k}^{TOL_j}\right)$ is the specified dose that a fractional volume $V_{C_k}^{TOL_j}$ of critical structure k can tolerate without complication, $D_i\left(V_{C_k}^{TOL_j}\right)$ is the actual dose received by this tolerance volume, $D_{\min}$ and $D_{\max}$ are, respectively, the specified minimum and maximum dose to the PTV, and is $(V_{95}^{p})_{\text{PTV}}$ the corresponding prescribed volume at 95% of the dose, D_i is the total dose to pixel i, D_{ip} is the dose contribution to pixel i by beamlet p, w_p is the intensity of beamlet p, and N_{bl} is the total number of beamlets.

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Optimization in IMRT... (Continued from page 62)

One feature of this objective function is that any critical organ dose-volume constraint can potentially be exceeded in order to better spare other critical organs. Although we wish to avoid using unintuitive importance parameters, we did invoke a penalty factor (set to 100 in this study) in an attempt to force any exceeding dose to a particular critical organ to be at least close to tolerance. This factor is not invoked unless the situation arises where one of the dose-volume points has been exceeded.

3.2 Modified Luus-Jaakola Algorithm

In order to explore the full potential of our proposed formulation, we developed a new stochastic optimization procedure to inverse treatment planning that includes dose-volume constraints. It is based on the Luus-Jaakola (LJ) optimization procedure (31), which is a direct search optimization method with a systematic search region reduction that has been used to solve a variety of chemical engineering problems.[32–35]. It essentially involves three steps:

1. Given some initial n-dimensional vector $\mathbf{w}^*$, a predefined number of random points in the n-dimensional space are chosen around this point via the equation

$$\mathbf{w}=\mathbf{w}^*+M\mathbf{r} \qquad (2)$$

where M is an n-dimensional diagonal matrix with randomly chosen diagonal elements in the interval [-1,1], and $\mathbf{r}$ is defined as the region size vector with elements, r_i describing the absolute range of w_i. In radiotherapy problems, the components of $\mathbf{w}$ are the beamlet intensities.

2. The feasibility of each set of random intensities is investigated, and if all constraints are satisfied, then the objective function is evaluated. If any set of random intensities violates any one of the constraints, it is not considered further. To satisfy the non-negativity constraints, any negative component of the set of intensities is set to zero. Only beamlets that pass through the PTV are used in the optimization. The remaining beamlet weights are set to 0. The best feasible $\mathbf{w}$-value is stored. Steps 1 and 2 define an iteration.

3. At the end of each iteration, the initial set of intensities $\mathbf{w}_*$ is replaced by the best feasible $\mathbf{w}$-value obtained in Step 2 and the region size vector $\mathbf{r}$ is reduced by γ via the equation

$$\mathbf{r}^{j+1}=\gamma^j\mathbf{r}_o \qquad (3)$$

where γ is a region contraction factor, j is the iteration number, and $\mathbf{r}_o$ is the initial region size.

This sequence is repeated for a predefined number of iterations. Optimization with Non-linear Score functions and Constraints algorithm (RONSC) proposed by Niemierko (36) can be viewed as a subset of this procedure.

To increase the efficiency of this procedure and make it applicable to high-dimensional optimization problems, Luus *et al.* modified the algorithm to include a "multi-pass" procedure (37). Here, the procedure is repeated for a given number of iterations, where the initial region size of the random search space, $\mathbf{r}_0$, is reduced after each pass. The main attraction of this approach is that only a small number of random points is sufficient for each iteration.

For our problem, we modified the "multi-pass" procedure by reducing the initial region size vector for each pass using the equation

$$\mathbf{r}_{p+1}^{(0)}=\beta\mathbf{r}_p^{(0)} \qquad (4)$$

where $\mathbf{r}_p^{(0)}$ is the initial region size for the pth pass and β is an initial region size contraction factor. This controls the CPU time of the algorithm. The algorithm stops when the initial region size vector reaches some predefined tolerance, ε, which is related to the minimum change in beamlet intensities.

This procedure is compared to a fast simulated annealing approach which uses a generating function given by the Lorentzian probability density function. Details of this procedure are given by Magaras and Mohan (17). Other probability distributions, such as the Cauchy or Gaussian distributions could be used, but we choose the Lorentzian distribution because of its computational ease.

Although stochastic optimization approaches could eventually converge to a global solution if enough time was granted, our intent was to focus on shorter optimization runs. Because of the random nature of such algorithms, we investigate the variability of the different solutions by repeating the optimization ten times each with a re-initialized seed of the random number generator.

3.3 Lung Phantom

We considered a lung case in which the PTV was surrounded by both lungs, heart, and spinal cord with dose-volume constraints derived by Emami *et al.* (38). To control hot spots in the normal tissue, we also enforced that no more than 5% of the normal tissue can receive more than 70 Gy. Seven equally spaced beams were employed. We prescribed a dose of 71 Gy to the PTV. To maintain suitable coverage of the PTV, we restrict the isodose curve representing 93% of the prescription dose to the isocentre must encompass the entire PTV (ie. the minimum dose to the PTV) and specified a maximum dose to the PTV to be 110% of the prescription dose. Another PTV dose requirement was that $V_{95} \geq 96\%$.

FIGURE 3 shows the dose distributions for the best and worst plans based on the minimum objective function value generated by each optimization procedure. The corresponding DVH is shown in FIGURE 4. For this particular case, the lowest objective function value was obtained using the modified LJ procedure. TABLE 2 breaks down the contribution of each term to the objective function value for this plan emphasizing the direct correspondence to its DVH shown in FIGURE 4.

The spinal cord and heart received less dose than the fast simulated annealing procedure as shown in FIGURE 4. The

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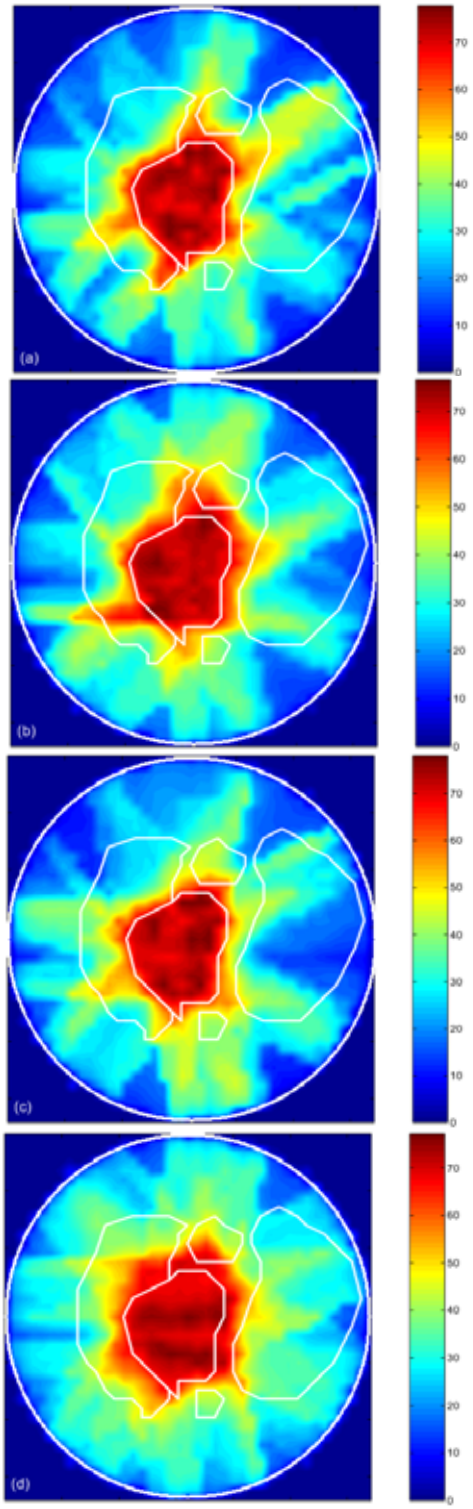
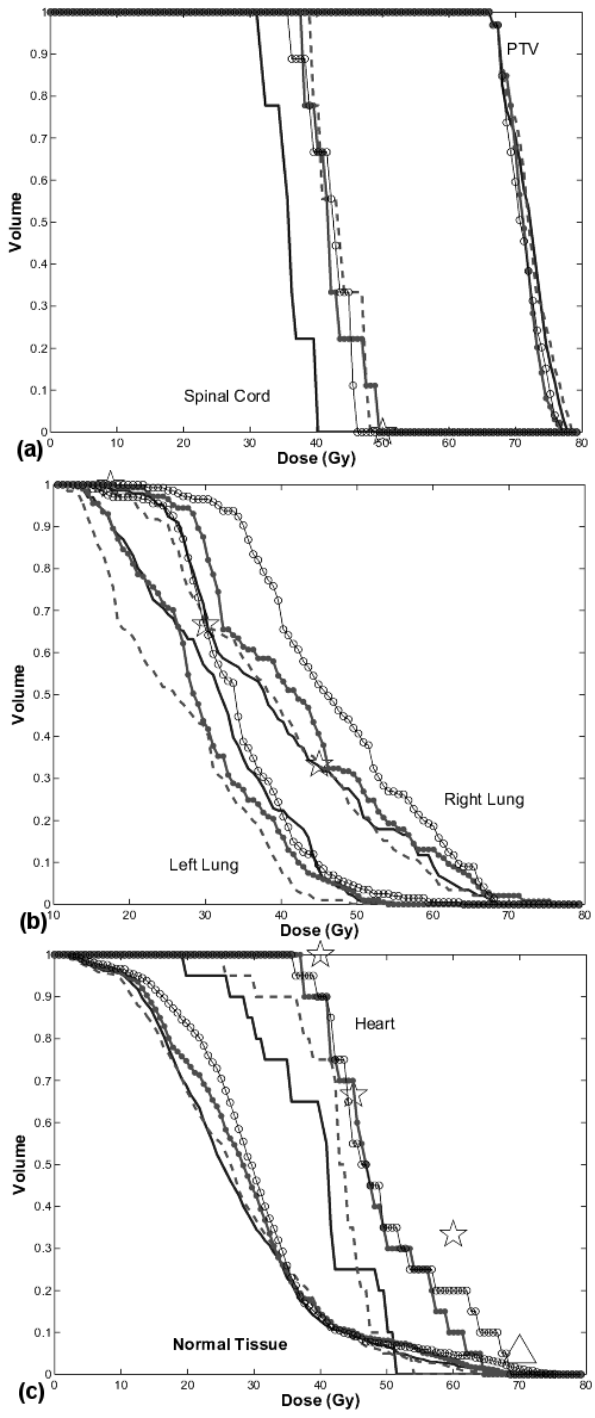


FIGURE 3: Dose Distributions for lung plans generated to demonstrate variability of each optimization procedure due to a change in the seed of the random number generator: (a) Best plan generated by the modified LJ procedure (F=-1322.8); (b) Worst plan generated by the modified LJ procedure (F=226.8); (c) Best plan generated by the FSA procedure (F=-1211.1); d) Worst plan generated by the FSA procedure (F=16,144.0).

FIGURE 4: Dose-Volume Histogram for lung plans to demonstrate variability of each optimization procedure due to a change in the seed of the random number generator. Solid lines and dotted solid lines represent the best and worst plans, respectively, generated by the LJ procedure. Dashed lines and circled lines represent the best and worst plans, respectively, generated by the FSA procedure: (a) The star represents the maximum dose to the spinal cord; (b) The stars represent the dose-volume constraints for both lungs; (c) The stars represent dose-volume constraints for the heart. The triangle represents the dose-volume constraint for the normal tissue.



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Organ	Fractional Volume	Obtained Dose (Gy)	Specified Dose (Gy)	f_{organ}
L. Lung	1/3	35.2	45	-96.3
	2/3	26.3	30	-13.6
	3/3	12.5	17.5	-24.8
R. Lung	1/3	45.04	45	0.16
	2/3	30.14	30	2.08
	3/3	17.0	17.5	-0.3
Heart	1/3	41.9	60	-327.2
	2/3	40.1	45	-24.4
	3/3	19.8	40	-408.0
Cord	3/3	40.2	50	-96.4
N. Tissue	0.05	51.7	70	-334.0
$F_{\text{Critical Organs}}$	-	-	-	-1322.8

TABLE 2: Contribution of each dose-volume point for each critical structure to the total objective function values for the best plan generated by the modified LJ procedure.

fast simulated annealing procedure had an advantage in sparing the left lung better than the modified LJ procedure. There existed less variability in the minimum objective function values generated by the modified LJ procedure.

Notice that the worst plans generated by both procedures correspond to positive values of the minimum objective function value. The DVH shows that the ipsilateral lung was the main contributing factor. For the LJ procedure, the largest term contributing to the objective function was the 2/3 right lung volume term (F=354.2). This translated into a $\sqrt{(354.2/100)}$=1.9 Gy violation of the corresponding dose-volume point. For the fast simulated annealing procedure, the largest term contributing to the objective function was again the 2/3 right lung volume term (F = 9636.2). This translated to a $\sqrt{(9636.2/100)}$=9.8 Gy violation of the corresponding dose volume pair. Clearly, the latter procedure produced an unacceptable result. There may be some debate whether or not the worst plan generated by the LJ procedure is acceptable. The DVH for the other critical organs were satisfied and the specified PTV coverage was obtained.

Although only one example is shown here, it should be noted that the modified LJ procedure does not always produce a better plan than the fast simulated annealing procedure. The benefit of the fast simulated annealing algorithm is that, given enough time, the algorithm will converge to an acceptable result. However, it is unpredictable how much time is needed. This explains why the modified LJ procedure always had less variability in solutions over the 10 runs.

4. CONCLUSIONS

Intensity modulated radiation therapy (IMRT) has the potential to deliver a more conformal dose distribution to complex geometries than conventional non-IMRT techniques that involve simple, modulated beams (39). However, much of the effectiveness of IMRT depends on the inverse treatment planning, in which the intensity distribution is calculated to optimize prescribed dose distributions.

In principle, it is clear that the higher the number of beams, the higher the dose conformation potential (24). However, the degree of improvement for adding an additional beam to a plan diminishes as the number of beams increase. Research indicates that it is not necessary to use more than 11 intensity-modulated beams to achieve more than feasible results (18). Also, the mentality is that there are enough degrees of freedom in the intensity modulation so that beam directions are less important. We developed an algorithm (40) which systematically selected proper beam directions in the fewest number of beams possible. Fewer employed beams would mean easier quality assurance, faster treatment times, and less probability of patient movement.

An ideal treatment planning system that includes dose and/or dose-volume based inverse treatment planning optimization would allow the user to predefine desirable goals, such as points on a dose-volume histogram, and allow the user to choose the optimization routine whose objective is to, at the very worst, satisfy all these predefined goals. We have investigated a new formulation of the inverse treatment planning optimization problem that consists of an objective function which attempts to minimize the dose to critical organ volumes that produce a risk of complications if a certain tolerance dose to those volumes were exceeded (41). This critical organ based objective function was constrained by the desired dose distribution to the PTV. The advantage of this new formulation is that we have developed a direct correspondence between the objective function value and the dose-volume histogram. However, this formulation gave rise to multiple local minima. A new stochastic approach based on the Luus-Jaakola optimization procedure (31) was introduced and was applied to the new formulation for a 2D lung phantom. The advantages of the modified LJ procedure include the obvious mode of escaping local minimum traps, its fast convergence to a solution when short runs are desired, and a smaller variability in solutions when multiple runs are employed compared to fast simulated annealing.

The algorithms presented here will not change when generalizing the approach to 3-D, which is a future focus. The only consequence will be the increase in time due to the initial 3-D dose calculation, as well as the increase in beamlet intensities to be optimized. We have provided two approaches in this report to improve upon inverse treatment planning optimization which have the benefits of achieving optimal radiotherapy plans that are both physically and clinically relevant.

ACKNOWLEDGEMENTS

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REFERENCES

(1) Q. Wu and R. Mohan. Algorithms and functionality of an intensity modulated radiotherapy optimization system. *Med. Phys.*, 27(4):701–711, 2000.
(2) J. Seco, P. M. Evans, and S.Webb. An optimization algorithm that incorporates IMRT delivery constraints. *Phys. Med. Biol.*, 47(6):899–915, 2002.
(3) S. V. Spirou and C. S. Chui. A gradient inverse planning algorithm with dose-volume constraints. *Med. Phys.*, 25(3):321–333, 1998.
(4) D. H. Hristov and B. G. Fallone. A continuous penalty function method for inverse treatment planning. *Med. Phys.*, 25(2):208–223, 1998.
(5) L. Jones and P. Hoban. A method for physically based radiotherapy optimization with intelligent tissue weight determination. *Med. Phys.*, 29(1):26–37, 2002.
(6) D. M. Shepard, G. H. Olivera, P. J. Reckwerdt, and T. R. Mackie. Iterative approaches to dose optimization in tomotherapy. *Phys. Med. Biol.*, 45(1):69–90, 2000.
(7) Y. Chen, D. Michalski, C. Houser, and J. M. Galvin. A deterministic iterative least-squares algorithm for beam weight optimization in conformal radiotherapy. *Phys. Med. Biol.*, 47 (10):1647–1658, 2002.
(8) L. Xing, J. G. Li, S. Donaldson, Q. T. Le, and A. L. Boyer. Optimization of importance factors in inverse planning. *Phys. Med. Biol.*, 44(10):2525–2536, 1999.
(9) J. Llacer. Inverse radiation treatment planning using the dynamically penalized likelihood method. *Med. Phys.*, 24(11):1751–1764, 1997.
(10) J. O. Deasy. Multiple local minima in radiotherapy optimization problems with dose- volume constraints. *Med. Phys.*, 24(7):1157–1161, 1997.
(11) M. S. Bazaraa, Hanif D. Sherali, and C. M. Shetty. *Nonlinear Programming: Theory and Algorithms*. Wiley-Interscience series in discrete mathematics and optimization. Wiley, New York, 2nd ed edition, 1993.
(12) T. Bortfeld and W. Schlegel. Optimization of beam orientations in radiation therapy: some theoretical considerations. *Phys. Med. Biol.*, 38:291–304, 1993.
(13) S. Webb. Optimization of conformal radiotherapy dose distributions by simulated annealing. *Phys. Med. Biol.*, 34:1349–1370, 1989.
(14) S.Webb. Optimization by simulated annealing of three-dimensional conformal treatment planning for radiation fields defined by a multileaf collimator. *Phys. Med. Biol.*, 36:1201–1226, 1991.
(15) P. S. Cho, S. Lee, R. J. Marks, S. Oh, S. G. Sutlief, and M. H. Phillips. Optimization of intensity modulated beams with volume constraints using two methods: cost function minimization and projections onto convex sets. *Med. Phys.*, 25(4):435–443, 1998.
(16) I. I. Rosen, K. S. Lam, R. G. Lane, M. Langer, and S. M. Morrill. Comparison of simulated annealing algorithms for conformal therapy treatment planning. *Int. J. Radiat. Oncol. Biol. Phys.*, 33(5):1091–1099, 1995.
(17) G. S. Mageras and R. Mohan. Application of fast simulated annealing to optimization of conformal radiation treatments. *Med. Phys.*, 20(3):639–647, 1993.
(18) J. Stein, R. Mohan, X. H. Wang, T. Bortfeld, Q. Wu, K. Preiser, C. C. Ling, and W. Schlegel. Number and orientations of beams in intensity-modulated radiation treatments. *Med. Phys.*, 24(2):149–160, 1997.
(19) A. Pugachev and L. Xing. Incorporating prior knowledge into beam orientation optimization in IMRT. *Int. J. Radiat. Oncol. Biol. Phys.*, 54(5):1565–1574, 2002.
(20) M. Langer, R. Brown, and S. Morrill. A generic genetic algorithm for generating beam weights. *Med. Phys.*, 23:965–971, 1996.
(21) G. Ezzell. Genetic and geometric optimizaiton of three-dimensional radiation therapy treatment planning. *Med. Phys.*, 23:293–305, 1996.
(22) X. Wu and Y. Zhu. A mixed-encoding genetic algorithm with beam constraint for conformal radiotherapy treatment planning. *Med. Phys.*, 27(11):2508–2516, 2000.
(23) A. B. Pugachev, A. L. Boyer, and L. Xing. Beam orientation optimization in intensity-modulated radiation treatment planning. *Med. Phys.*, 27(6):1238–1245, 2000.
(24) T. Bortfeld. Optimized planning using physical objectives and constraints. *Semin. Radiat. Oncol.*, 9(1):20–34, 1999.
(25) S. Soderstrom and A. Brahme. A selection of suitable beam orientations in radiation therapy using entropy nd fourier transform measures. *Phys. Med. Biol.*, 37:911–924, 1992.
(26) A. Pugachev and L. Xing. Computer-assisted selection of coplanar beam orientations in intensity- modulated radiation therapy. *Phys. Med. Biol.*, 46(9):2467–2476, 2001.
(27) M. Braunstein and R. Levine. Optimum beam configurations in tomographic intensity modulated radiation therapy. *Phys. Med. Biol.*, 45:305–328, 2000.
(28) S. Sodertrom and A. Brahme. Optimization of the dose delivery in a few field techniques using radiobiological objective functions. *Med. Phys.*, 20(4):1201–1210, 1993.
(29) L. Boersma, M. van den Brink, A. Bruce, T. Shouman, L. Gras, A. Velde, and J. Lebesque. Estimation of the incidence of late bladder and rectum complications after high-dose (70-78 gy) conformal radiotherapy for prostate cancer, using dose-volume histograms. *Int. J. Radiat. Oncol. Biol. Phys.*, 41(1):83–92, 1998.
(30) D.M. Shepard, M.C. Ferris, G.H. Olivera, and T.Rockwell Mackie. Optimizing the delivery of radiation therapy to cancer patients. *SIAM Review*, 41(4):721–744, 1999.
(31) Rein Luus. *Iterative dynamic programming*. CRC Press LLC, Boca Raton, 2000.
(32) R. Luus. Optimization of multistage recycle systems by direct search. *Can. J. Chem. Eng.*, 53:217–220, 1975.
(33) R. Luus. Optimization in model reduction. *Int. J. Contr.*, 32:741–747, 1980.
(34) R. Luus. Optimization of heat exchanger networks. *Ind. Eng. Chem. Res.*, 32:2633–2635, 1993.
(35) R. Luus and D. Hennessy. Optimization of fed-batch reactors by the luus-jaakola optimization procedure. *Ind. Eng. Chem. Res.*, 38:1948–1955, 1999.
(36) A. Niemierko. Random search algorithm (RONSC) for optimization of radiation therapy with both physical and biological end points and constraints. *Int. J. Radiat. Oncol. Biol. Phys.*, 23(1):89–98, 1992.
(37) R. Luus, F. Hartig, and F. Keil. Optimal drug scheduling of cancer chemotherapy by direct search optimization. *Hung. J. Ind. Chem.*, 23:55–58, 1995.
(38) B. Emami, J. Lyman, A. Brown, L. Coia, M. Goitein, J. E. Munzenrider, B. Shank, L. J. Solin, and M. Wesson. Tolerance of normal tissue to therapeutic irradiation. *Int. J. Radiat. Oncol. Biol. Phys.*, 21(1):109–122, 1991.
(39) Faiz M. Khan and Roger A. Potish. *Treatment Planning in Radiation Oncology*. Williams and Wilkins, Baltimore, 1998.
(40) S. Gaede, E. Wong, and H. Rasmussen. An algorithm for systematic selection of beam directions for IMRT. *Med. Phys.*, 31 (2):376–388, 2004.
(41) S. Gaede, E.Wong, and H. Rasmussen. Global optimization of dose-volume based inverse treatment planning. Abstract published in *Med. Phys.*, 30(6):1486, 2003.

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Does Intensity Modulation Improve Healthy Tissue Sparing in Stereotactic Radiosurgery of Arteriovenous Malformation?

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The aim of this study is to investigate conformal stereotactic radiosurgery (SRS) techniques and quantify potential advantages of intensity modulation for stereotactic radiosurgery of arteriovenous malformation (AVM).

Twenty patients treated with SRS for AVM between 1998 and 2001 were replanned with each of four techniques: circular non-coplanar arcs, dynamic arcs, static conformal fields and intensity modulated fields (IMRS). Patients were selected for size and irregular target shape; with a maximum AVM dimension at least 20mm or volume greater than $10cm^3$. Target volumes ranged from $2.12cm^3$ to $13.87cm^3$ with a median of $6.03cm^3$. Resulting dose distributions were analysed to determine conformality to AVM, target dose homogeneity and healthy tissue dose at 3, 6, 12, 18 and 24 Gy.

The results show an improvement in conformality index with differences statistically significant ($p \leq 0.01$) between circular arcs and either conformal or IMRS, conformal and dynamic arcs and IMRS and conformal. The paired differences between dose homogeneity index are significant for improvement in moving from circular arcs to either conformal or IMRS, conformal to IMRS ($p \leq 0.001$) with no difference between conformal and dynamic arcs.

The normal tissue analysis data shows a substantial reduction in dose at 24 Gy for all other techniques and an increase in dose at 3 Gy for the static field techniques when compared to the arc techniques. Overall, no advantage was seen for intensity modulation and the dynamic arc technique offers the greatest potential for minimization of normal tissue dose at all dose levels.

Extending the application of EUD to account for stochastic processes

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As a method for reporting and analyzing dose heterogeneity, the concept of *equivalent uniform dose* (EUD) asserts that dose distributions are equivalent if they produce the same biological effect. In addition to dose heterogeneity, we considered the case, where the total dose to a volume element has an associated uncertainty.

To account for the dose uncertainty, we calculate the mean survival fraction (SF) for a stochastic process. Mathematically, the expression for this mean survival fraction is identical to that used by Niemierko (1997) in defining EUD. To distinguish between spatial and probabilistic dose variations, we define *equivalent stochastic dose* (ESD) as the dose that results in a mean survival fraction given a set of random events depositing a dose D in a volume. If D follows a probability density function (pdf), SF(ESD) can be calculated using the convolution technique. In the case where the pdf follows a Gaussian distribution, an analytic expression was derived for SF(ESD). The derived expression was verified using the Monte Carlo method for treatments of 60 and 70 Gy with the fractional dose fixed at 2 Gy. The expression was then extended to account for multiple stochastic and spatial dose heterogeneities.

The results show that the derived expression allows evaluation of the reduction in *equivalent uniform dose* for a combination of stochastic and spatial dose variations.

Automatic methods of PET target volume delineation

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Current radiation therapy techniques, such as IMRT and 3D-CRT, rely on the precise delivery of high doses of radiation to well defined volumes. CT, the imaging modality that is most commonly used to determine the treatment volumes cannot, however, easily distinguish between cancerous tissue and normal tissue. Since positron emission tomography (PET) can more readily differentiate between cancerous and normal tissues there is great interest in using PET images to delineate target volumes for radiation treatment planning. The drawback of using PET is that tumors appear as ill-defined amorphous regions of higher activity density, which renders manual delineation highly problematic. As the manual delineation of target volumes in PET images is difficult, an automatic tool to delineate target volumes is being sought. Three methods of automatic target volume delineation are being examined: thresholding, edge detection and the marker based watershed technique. The accuracy and usefulness of each method will be investigated using a phantom study with well-defined target volumes and activity distributions.

The Evolving Role of Radiation Therapists in Basic Medical Research - How Evolved Are We?

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At the 2002 CARO annual meeting in Toronto, Radiation Therapists presented their experiences in a multi-centre research initiative investigating the effects of cytoprotective agent demonstrating the value of Radiation Therapists in clinical research. They argued their specialized knowledge of technical limitations, clinical workflow, dosimetry, radiobiology and basic science make them valuable resources to the clinical research team.

Since October 2002, strides have been made preparing Radiation Therapists for key roles in research. In 2001, the Ontario School of Radiation Therapy moved from a diploma granting program to one granting Bachelor of Science degrees from the Michener Institute of Applied Health Sciences and the University of Toronto's undergraduate department. Additionally, the evolution of an Advanced Integrated Practice Model at Princess Margaret Hospital has included the creation of six Research Radiation Therapist positions. Each Therapist works part-time clinically and part-time on a research project or team. Key to these roles is the translation of research to clinical practice. These initiatives include the development of new planning, scanning and treatment techniques, the development, improvement and implementation of new technologies, as well as data collection, management, analysis, and presentation. Specifically these roles provide an environment in which the view to publication for therapists as co-authors and authors is the norm.

The authors of this paper intend to build on their previous work highlighting the evolution of the role of the Research Radiation Therapist at their centre, and drawing upon the U.S. and U.K. experiences as support.

Probabilistic Risk Analysis of Patient Safety in Radiation Oncology

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The process of treating cancer with ionizing radiation (radiotherapy) is complex and subject to errors in the treatment preparation and delivery process. The potential for morbidity and mortality to multiple patients compels a systematic approach to assessment and management of risk.

In high consequence, low probability hazardous systems such as the nuclear power industry and the chemical manufacturing industry, probabilistic risk analysis (PRA) has evolved as a safety analysis tool. More recently, there have been attempts to adopt a more quantitative and systematic approach to risk analysis in health care delivery systems using PRA as a tool. PRA is a quantitative and proactive approach to risk analysis that examines all factors contributing to an adverse event including infrastructure failure, operating errors and protocol errors and their interactions. PRA identifies their probability of occurrence, and consequences. It complements tools already used in patient safety such as the Health Care Failure Mode and Effect Analysis (HFMEA), a

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semi-quantitative proactive approach, and Root Cause Analysis (RCA), a qualitative and reactive approach to patient safety. Common modeling techniques employed in the current PRA project include event tree analysis task analysis and fault tree analysis. This project will also examine the potential of Bayesian Networks as a modeling technique within PRA.

The results of this PRA of patient safety will inform quality control groups and improve incident reporting systems.

An improved derivation of the Joiner expressions for determining a simple α/β-independent method to derive a fully isoeffective schedules following a change in dose per fraction.

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In the paper written by Joiner (*IJROBP* 2004; 58(3): 871-875), entitled *A simple α/β-independent method to derive fully isoeffective effective schedules following a change in dose per fraction*, the author derived two mathematical expressions by which dosimetric errors in delivering the prescribed dose per fraction in a treatment can be corrected for. In doing so, the author made an invalid assumption in which he assumed α/β is zero for both early and late effects. Even though this assumption is wrong, the author arrived "mistakenly" at the right solution. In this presentation, we use first principles to derive these two expressions and the limits at which they cannot be applied, both from radiobiological and mathematical point of views. We also explain the inherent α/β-independence of the expressions.

Innovative Immobilization for Conformal Radiation Treatment of Extremity Soft Tissue Sarcoma

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Conformal radiation planning techniques permit escalated tumour doses with decreased tumour margins and decreased dose to normal tissues. Efficient immobilization is imperative to accurately deliver the radiation as prescribed.

Present immobilization obstacles in treating sarcomas include an inability to fix the mould to a variety of planning and treatment couches. Fixation provides setup reproducibility from CT simulator to treatment couches as well as MRI and PET. Studies have indicated that increased skin dose may result if immobilization devices are used in the pre-operative treatment area, potentially leading to wound healing complications. Currently available devices are either limited to the distal region of the limb, or are too large to avoid the treatment region.

The sarcoma group at Princess Margaret Hospital has developed an immobilization device that addresses these obstacles. It consists of a modified uniframe and a vac lok with a versatile fixation device that can be attached to an assortment of planning and treatment couches. The modified uniframe and vac lok provide comfortable and stable immobilization resulting in less patient movement during treatment.

We anticipate that routine use of this device will minimize patient setup times and adjustments after daily image matching, and potentially reduce the incidence of radiotherapy related wound healing complications. This new device is vital for highly conformal and IMRT sarcoma treatment plans.

Current work is examining the effectiveness and accuracy of this device using portal and cone beam CT image matching protocols.

Information Infrastructure Requirements for Radiation Therapy

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The radiation therapy process is becoming increasingly complex. The use of 4D and multi-modality imaging for virtual simulation, along with increasingly complex delivery techniques is rapidly escalating the amount of information generated before, during, and after a treatment procedure. The institutional requirements for a stable & robust infrastructure (hardware, software, personnel, and processes) to support the demands of radiotherapy will be provided. To 'close the loop' for radiotherapy, some form of outcome analysis is required. In-house protocols and multi-institutional clinical trials are one way of standardizing the collection of data to perform this analysis. These clinical trials require additional infrastructure support, for both the accruing institution and for the clinical trials data warehouse. A brief overview of the infrastructure used by the Advanced Technology Consortium and its organizations (QARC, RPC, ET, RTOG), along with some recent advances for radiotherapy trials supported by the National Cancer Institute of Canada Clinical Trials Group will be described. The presentation will conclude by providing a few discussion topics.

Radiation therapists' verification of isocentric placement and error correction during prostate radiotherapy: Do we still need radiation oncologists to review check films?

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Background: Conventionally, verification portal images on first day of treatment are reviewed by radiation oncologists. A written guideline and process was instituted to train radiation therapists (RTTs) to perform the task independently.

Objective: To compare isocentric set up errors measured by RTTs to those measured by a reference radiation oncologist (RO).

Methods: Isocentre set up errors with respect to bony landmarks were determined on electronic portal images (EPIs) using Varian™/Vision anatomy matching software. Any systematic isocentre error over 3 mm (by averaging 3 days of EPIs) would be corrected by adjusting the table position. Three systematic errors (right-left, ant-post, sup-inf) were determined for each patient. Over a one-year period, 100 patients, whose EPIs were reviewed by RTTs, were randomly selected to have their EPIs independently evaluated by a reference RO. The goal was to achieve ≤1.5 mm (within 2 standard deviations) difference between the RTTs and reference RO.

Results: Each of the 297 anatomy matches were evaluated in the three directions: right-left, ant-post, sup-inf. The data was analyzed using Pearson Correlation Coefficient. All three directions demonstrated statistical significance and high correlation but only the right-left direction met the original criteria of ≤1.5 mm. However, further investigations demonstrated the 'Law of Averages' worked to an advantage. The measured offset difference between the RTTs and reference RO, averaged over three days, validated the objective of ≤1.5 mm (within 2 standard deviations)

Conclusion: With guidelines and averaging over three days, radiation therapists are able to determine systematic set up errors comparable to the radiation oncologist. The high correlation between the RTT and RO measurements support the validity of the process.

Evolution of Breast Irradiation

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Standard breast irradiation involving the use of opposing tangential fields with hard or dynamic wedging has limitations. 1. Frequent hotspots are recognized in axilla and infra mammary folds. 2. Scatter dose to contralateral breast from hard wedges.

Technology has provided us with the capability to improve dose homogeneity by using 3D planning, which enables us to introduce novel techniques. One such technique that has been developed is MLC Compensation, which dispenses with hard and dynamic wedges and in principle produces a more homogeneous dose.

This paper will review how breast planning is evolving from traditional wedge tangents to compensation using MLC shaping, and to assess effectiveness. At present, the VIC is involved in a study comparing conventional wedge planning to MLC compensation planning.

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MLC compensation is formulated by a manual forward planning method, using individual sub fields. With the recent installation of the Eclipse Planning System at the VIC, there are tools available to allow us to automate a new "Field in Field (FIF) planning procedure. It also makes treatment delivery more efficient by performing automated dynamic step and shoot MLC.

We will compare the two previously mentioned techniques (Conventional and MLC Compensation) to the newer FIF technique. Factors that will be considered are: homogeneity of dose distributions, resource implications for Treatment planning, delivery and staff training. This is in anticipation of using the FIF technique for Breast Radiation Therapy as a Standard.

Alternatives to anesthesia for pediatric immobilization in Radiotherapy

C. Harris; CancerCare Manitoba, Winnipeg, MB

Traditionally treating pediatric patients using any of a variety of Radiotherapy techniques has always had a common concern, immobilization. The challenge of holding still for the required time can be a problem for many patients and is exacerbated by the young age of some, even when shells or other devises are employed. During the past year a conversation about the quasi-hypnotic effect a cartoon has on a small child prompted a more serious discussion regarding the merits of providing entertainment to distract the patient during setup and treatment. At the time a small child was having difficulty holding still for her treatment and was struggling against her shell creating difficulties in delivering treatment, examining the options, we decided to try a distractive method to secure her co-operation.

Using a commercially available portable DVD player with built in TFT screen; we developed a lead shielded multi-positional stand so that the child can have a clear, unobstructed view of their favorite character without compromise to comfort or optimal treatment. This initial patient immediately became compliant once Spongebob Squarepants was deployed, and went on to complete her course of therapy without problem. Subsequent pediatric patients have had similar results and we have actually cancelled anesthesia where it was thought to be required.

This presentation will look at the cases this technique has been used for, describe the methods for building the device and use an algorithm to explain the histogram on the finer points of Spongebob and his undersea cohorts.

Do CT streak artifacts affect dose calculations, or are they just unsightly?

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Streak artifacts from high-density substances certainly interfere with visualization of patient anatomy in CT images, but do they really affect the dose calculations. Some planners, under the impression that it matters, painstakingly contour the streaks and override their density before doing the dose calculation. While some literature exists suggesting that the streaks themselves are negligible the demonstration was based on purely synthetic, numerical simulations.

We have acquired CT images of metal rods in a water tank. Dose distributions were calculated assuming a homogeneous medium (density 1g/cc), and using heterogeneity corrections, but with the metal object contoured and its density over-ridden to be 1g/cc. The difference between dose maps is due to three effects: high densities around the metal rod which are artifacts of the CT imaging process that were missed in the contouring; differences remote from the rod which were due to the presence of the streak artifacts and differences near the surface of the water due to waves excited by the couch motion. The last problem was removed by adding a contour at the surface and overriding the density.

The results show almost no evidence of the streak artifacts in the dose map. Work will continue with patient images to see if streaks are still negligible in cases of bi-lateral hip prostheses.

Improving the spectral dose-response of an a-Si EPID

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Amorphous silicon electronic portal imaging devices (a-Si EPIDs) demonstrate great promise as tools for dose measurement, offering an efficient alternative to other two-dimensional dosimeters such as film. To date they have been applied for pre-treatment field verification and compensator measurement, and show promise to eventually provide a means to online dose verification during treatment.

Recently, it has been reported that the generally linear response of an a-Si EPID to dose displays some variation when comparing open fields to those attenuated by compensators. We have demonstrated that this variation can be greater than 4 % of the open field measurement at 6 MV. It has also been established that EPIDs employing high Z scintillation screens such as Gd_2O_2S:Tb, have an increased sensitivity to low energy (< 1 MeV) photons, which we demonstrate is the cause of this discrepancy. Using Monte Carlo techniques, we modeled both the energy specific dose-response of a commercial EPID (Varian aS500) as well as the spectral shifts of a generic 6 MV Varian Clinac photon beam arising from transmission through steel shot compensators up to 4.5 cm thick. These results were combined to simulate the scenario-specific detector response. Subsequently, we were able to determine that by using an external copper plate suspended above the EPID, the beam could be effectively "pre-hardened" to reduce the observed discrepancy to ~1%. Experimental measurements confirm this finding.

Assessment Of Patient Positioning And Patient Motion Using Daily MVCT Imaging

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Helical tomotherapy is a highly conformal external beam modality that represents a convergence of three dimensional imaging and intensity modulated radiation therapy (IMRT). It is only with the aid of daily MVCT imaging that a truly image guided adaptive radiotherapy (IGAR) means of delivering IMRT can be realised. Accurate delivery of the planned dose distribution is, however, still highly contingent not only on accurate patient positioning, but on sufficient patient immobilisation as well.

An analysis of initial patient positioning and patient shifts required for patients treated to date is presented. This analysis looks at the results using the different rigid body fusion options available (translations vs. translations and rotations), the need for manual intervention in both translations and rotations, and the reproducibility for daily patient position.

MVCT data was also acquired for a number of patients both before and after treatment. Based on these pre and post delivery scans, an analysis is made of both the intra-fraction motion on this subset of patients.

Direct calibration of ion chambers in linac photon beams

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Currently, the starting point for dosimetry in the radiotherapy clinic is an ion chamber calibrated at the standards laboratory in a 60Co beam. Conversion factors obtained from a protocol such as TG-51 are then required to derive the dose in a linac beam. The installation of a clinical linac at the Institute of National Measurement Standards in Ottawa in 2002 offered the possibility of directly measured calibration factors for ion chambers in megavoltage photon and electron beams.

The first stage of this work on photon beams has been completed. The NRC primary standard water calorimeter was used to calibrate a

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set of NE2571 Farmer-type ion chambers in 6, 10 & 25 MV photon beams from an Elekta Precise linac. The standard uncertainty in the calibration of a chamber is estimated to be 0.4% and the results are in good agreement with previous measurements using the NRC Vickers research linac reported by Seuntjens et al in 2000. As a further check, intercomparisons are currently underway with other national standards laboratories and initial results are encouraging.

The experimental set-up of the new clinical linac at INMS means that it is relatively simple to calibrate user ionisation chambers directly in megavoltage photon beams using the NRC transfer standards. This approach provides a direct test of each chamber in the beams in which it will be used and removes the need for calculated conversion factors, resulting in a lower overall uncertainty. It is hoped to offer a calibration service some time in 2005.

Dosimetry Measurements of a Novalis Stereotactic Unit

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Novalis® Shaped Beam SurgeryTM, is a state-of-the-art stereotactic system for radiosurgery and radiotherapy delivery from BrainLAB built on a Varian linac. Novalis treats irregularly shaped tumors non-invasively with very high accuracy to the prescribed plan by shaping the 6 MV photon beam to match the contour accurately using built-in micro-multileaf collimators (mMLCs) or circular cones. Hence systematic measurements must be performed by acquiring dosimetric data before employing the machine for precision treatment. For ascertaining the dose characteristics, measurements of percent depth dose, relative scatter factors, and beam profiles were carried out, for both MLCs and cones to be input into the BrainScan treatment planning system for dose calculation. The dose characteristics were measured using an ion chamber and diodes of superior spatial resolution suitable for stereotactic measurements of small fields ranging from 6 x 6 mm2 to 100 x 100 mm2 and for cone size openings as small as 4 mm. The results of the measurements confirm the stability and the high precision of the machine for providing dose distributions with small fields suitable for stereotactic treatments.

Imaging with a Bench-top Megavoltage CT Scanner with Cadmium Tungstate-Photodiode Detectors

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Megavoltage computed tomography (MVCT) is a potential tool for positioning and dose delivery verification during image guided radiotherapy. The problem with most MVCT systems, however, is their low detective quantum efficiency (DQE) which leads to poor low contrast resolution and high noise. This makes separating the tumors from their soft tissue background difficult. In an earlier study, we investigated the DQE of eight $CdWO_4$ crystals and photodiodes in our system design and found it to be 26% and 19% in Co^{60} and 6MV beams, respectively. Once we found these reasonably high DQEs, we expanded the eight element detector to an eighty element detector, and added a rotary stage to create a CT scanner. In the study presented here, the focus is the difficulties encountered in getting the images from this system as well as the imaging characteristics of the system, mainly in a 1.25 MeV beam. We found the biggest problem to be ring artifacts in the images. The methods which were employed to eliminate the ring artifacts are presented along with some sample images in 6 MV and 1.25 MeV beams. Some of the important imaging characteristics of this CT system, such as the linearity of the CT numbers, low contrast resolution, image resolution, and image signal to noise ratio are quantified.

Intranets – An Expanding Role in Information Management.

C. Newcomb; Dep. of Medical Physics, Tom Baker Cancer Centre, U. Calgary, Calgary, AB

Intranets can provide a vital infrastructure for managing information flows within any department. Although creating and maintaining an intranet can be a daunting task and to be useful an intranet must be able to respond quickly to the users changing needs.

We present an intranet which allows a modular design for rapid development and customization through the use of extended markup language (XML) templates and configuration files.

In operation for just over 6 months, the system developed at the TBCC currently manages many functions in the department including; strategic goals and objectives, notice board, vacation and duty calendars, patient workflow, machine QA and reporting. Providing a basic infrastructure and incorporating best business practices the system is being continually expanded to meet information management needs of the department.

Prostate Brachytherapy Program at the Tom Baker Cancer Center.

J. Parsons, Tom Baker Cancer Centre, Calgary, AB

Patient eligibility criteria for this procedure are outlined followed with a summary of the contraindications and advantages of the transperineal template ultrasound guided technique. The acute and chronic side effects of prostate brachytherapy are discussed. Provincial and national radiation protection requirements and guidelines that are distributed to the patients following the treatment procedure are summarized. The issues associated and encountered when planning treatment procedures are examined. Survival benefits comparing patients treated with surgery and those patients treated with external beam radiotherapy are presented.

Victoria's Latest Trends

P. Picco; BC Cancer Agency, Vancouver Island Centre, Victoria, BC

Modern radiotherapy treatment equipment produces a wide variety of data that can be used to monitor its health. Two applications of time trend data used at the BC Cancer Agency's Vancouver Island Centre (VIC) are presented.

1. Is the linac monitor chamber sealed to atmosphere?

In weekly QA tests, linac radiation output is recorded and plotted against time along with data for normalised inverse of atmospheric pressure. If the ion chamber is sealed then the two sets of data will be correlated, but if the chamber is open to atmosphere they will not. We have had two occasions to change monitor chambers in 4 years. Correlation coefficients derived from the plots referred to above show obvious differences (before & after) ion chamber change for chamber 1 (0.6389, 0.2279) and chamber 2 (0.9321, 0.0275). We intend to use these correlation coefficients to monitor future health of the ion chambers.

2. Does image quality of electronic portal imaging devices degrade with time?

Several image quality parameters (signal/noise ratio, spatial resolution & response consistency) were monitored monthly over a four year period on four treatment machines using PIPS QC phantom and software. Preliminary analysis over 1 year has showed that one EPI system exhibited significant degradation of signal/noise ($p= 0.004$). This particular unit operates at 18 MV predominantly, so we speculate that photoneutrons may be the cause.

We believe that the two examples of time trend data presented have some practical significance in our clinic.

Sensitivity Of Objectives And Constraints Of An IMRT Plan To Patient Set-Up Uncertainty

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Objectives: The goal of this study was to assess the impact of set-up uncertainty on compliance with the objectives and constraints of an intensity modulated radiation therapy (IMRT) protocol for head and

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neck cancer.
Method: A seven-field head-and-neck IMRT plan was generated on the Pinnacle Treatment Planning Systems®. Numerical simulations were then performed, in the three orthogonal directions, to examine the effect of set-up uncertainty on the approved static dose distribution on eight structures: CTV54, CTV66, Brainstem, Glottic Larynx, Mandible, Spinal Cord and Left and Right Parotid Glands. In a population based approach, both Dose Volume Histograms (DVH) and Equivalent Uniform Doses (EUD) were used to summarize the information contained in the dose distribution achieved by the plan.
Results: With 5mm margins around the Clinical Target Volumes (CTV), coverage of the CTV54 and CTV66 remained broadly adequate on the bases of the DVHs and EUDs up to 4mm systematic and 2mm random set-up uncertainty in all three directions. The five organs at risk of interest in this plan continued to meet the criteria established up to 4mm systematic and 2mm random error except for the contralateral parotid gland, which the protocol is specifically designed to protect.
Conclusion: We have shown that our IMRT plan is robust up to 4mm systematic and 2mm random set-up uncertainties in the three orthogonal directions. This study provides a quantitative link between the CTV to PTV expansion and clinical set-up uncertainty.

Inverse Planning Dynamic Multibeam IMRT - a Promising Treatment Technique in Improving Outcomes in Left Breast Cancer Patients - a Case Study
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The importance of post-operative radiotherapy in women with node-positive breast cancer in achieving locoregional control and improving overall survival was shown in several trials. Published analyses confirm that the risk of death due to cardiovascular disease for left-breast cancer patients, 10-15 years after RT, is associated with the volume of heart irradiated.

We have developed a method based on inverse planning dynamic multiple intensity modulated beams -"Victoria Conformal IMRT" -for breast and IMN (CTV) that improves sparing of heart and ipsilateral lung compared with conventional techniques. In this work we present our IMRT method and compare with DIM (Direct Internal Mammary) for a left-sided breast cancer patient that was recently treated in our clinic. Both techniques used the monoisocentric setup for treating the supraclavicular nodes with anterior-posterior fields. Metrics for plan comparison included homogeneity and conformity index for CTV (HI= percentage of CTV with dose>95%and <105%; CI=volume of CTV with dose >95%/body volume >95%), V30% for heart and V20% for ipsilateral lung (volume receiving > 30 Gy and > 20 Gy).

IMRT resulted in more uniform PTV coverage than did DIM (HI= 0.87 vs. 0.81 ; CI =0.70 vs. 0.50). V30% for heart was reduces from 11.6% to 2.5% with IMRT compared to DIM. V20% for ipsilateral lung was reduced from 30.3% to 11.6%. Victoria Conformal IMRT technique is superior to conventional treatment methods because of the reduction in high doses to heart and lung when regional lymph nodes are included in the target volume.

Dosimetry guidelines for intra-operative treatment planning
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Introduction: In 2003, the Tom Baker Cancer Centre implemented a real-time live-planning prostate brachytherapy program using low dose-rate I-125 seeds to treat low risk prostate cancer. Live planning is in its infancy in the brachytherapy community, and pre-planning techniques are more commonly used throughout North America. The goal of this study is to determine if the dosimetric criteria used with the pre-planning technique apply to the intra-operative (live) treatment planning setting.
Methods: Pre-plans were generated using data from volume study ultrasound scans acquired from 30 patients receiving intra-operative prostate brachytherapy. Standard pre-planning guidelines for prostate position and dose distribution were used to generate pre-plans and intra-operative plans for each patient. Pre-plans were then overlaid on the intra-operative volume (only the intra-operative plan was delivered to the patient). Dosimetric parameters were compared for each of the pre, overlay, intra-operative plans. D90 and V100 for post-plans were compared with literature values for pre-planning techniques.
Results: Comparison between live and overlay plans showed that the live-plan provided superior prostate coverage and was better at limiting the dose to the urethra. Using a pre-plan on the intra-operative volume resulted in D90s that were on average 28% lower than those of the intra-operative plans. The average volume of urethra receiving greater than 150% of the dose was above the acceptable tolerance. Post-plans for these thirty patients resulted in an average D90 of 177.7Gy with V100 coverage of 94.4%. These values are well above ABS early guidelines for intra-op brachytherapy of D90 between 120.5 – 136.5Gy, and V100 of 76.2 – 84.9%.
Conclusion: Using pre-planning guidelines in an intra-operative setting results in superior prostate coverage with increased dose to the prostate and reduced dose to the urethra at the time of post-planning.

A Quantified Assessment of the Use of Non-Linear Image Registration in Image Guided Adaptive Radiotherapy
R.C. Rivest,[1,2,3] T.A. Riauka,[2,3] A.D. Murtha,[2,4] and B.G. Fallone[1,2,3]; [1]Dep. Physics, U. Alberta, [2]Dep. Oncology, U. Alberta, [3]Dep. Medical Physics, Cross Cancer Institute, [4]Dep. Radiation Oncology, Cross Cancer Institute, Edmonton, AB

An important step in the image guided adaptive radiotherapy process is the registration of medical images. Image registration has been used in clinical radiotherapy for a number of years; however registration systems have been restricted to linear or rigid registration, meaning that they cannot take into account soft tissue or organ motion with respect to rigid bony structures. Among its many applications, non-linear or deformable registration will allow for more accurate delineation of tumours and critical structures by correcting for organ motion and patient miss-alignment from image study to study. Since deformable registration is still in its infancy, a standard protocol for the validation of these systems does not exist. A comprehensive protocol to assess the accuracy of deformable registration systems over a wide range of clinical and research applications has been developed. The protocol has been applied to the Reveal-MVS Fusion Workstation from Mirada Solutions Ltd. The protocol consists of a preliminary phantom study designed to assess the registration of images with well-defined objects that have known positions, sizes, and shapes. In addition, a collection of novel and established metrics are used to determine image registration accuracy for both, real and simulated images. Emphasis will be placed on non-linear registration applications that are directly related to radiation therapy. Results will be used to further refine and improve upon existing non-linear image registration algorithms.

Interobserver Variability in Electronic Portal Imaging (EPI) Registration in the Treatment of Prostate Cancer
.J. Runkel, B. Bendorffe, D. Sayers, S. Zavgorodni, P. Truong, E. Berthelet; Radiation Oncology, BC Cancer Agency, Vancouver Island Centre, U. Victoria, Victoria, BC
Introduction: A protocol of EPI registration for the verification of treatment fields has been implemented at our institution. A template is generated using the reference images which is then registered with the EPI for verification. This study examines the impact of interobserver variability on the registration process.
Materials & Methods: 20 patients were selected for the study. The EPIs from the initial 10 fractions were registered independently by 6 observers. For each fraction, an anterior-posterior (AP) and right lateral (LAT) EPIs were generated. These were registered with the reference images. Two values of displacement for the AP EPI in the superior-
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inferior (SI) and right left (RL) directions and 2 values for the LAT EPI in the AP and SI directions were established. A total of 2400 images and 4800 variables were analyzed. The relationships between the measurements and the patients, observers, and fraction number were examined using linear regression analysis. The proportion of measurements within –3mm to +3mm, was evaluated using the χ^2 test. Multivariate analyses were conducted to examine sources of variation and potential interactions.

Results: Linear regression analysis showed no statistically significant observer effect for the 4 measurements analysed. A statistically significant time trend was observed only for measurement AP LR. The proportion of measurements within -/+ 3mm were: 73.8% for AP LR, 81.3% for AP SI, 66.8% for LAT AP and 78.2% for LAT SI. There was significant variation of this proportion between observers in the AP SI ($p \leq 0.001$) LAT AP ($p=0.002$) and LAT SI ($p \leq 0.001$) measurements. On multivariate analysis an observer effect was seen for measurement LAT SI only. Time trends however, were not apparent.

Conclusion: There is no significant systematic observer effect in the registration of EPI. Furthermore, no systematic time trends were identified. This provides, in our view, a measure of Quality Assurance, in that the process in place for the registration of EPI is reliable and consistent.

The Clinical Implications of Dynamic Therapies

S. Sidhu[1,2], N. Sidhu[1,2], C. Lapointe[2], G. Gryschuk[2]; [1]Deps Physics and Engineering Physics, U. Saskatchewan, [2] Saskatoon Cancer Centre, Saskatoon, SK

Intrafraction motion has long been suspected of causing inaccuracies in the dose delivered to patients. The Saskatoon Cancer Centre recently purchased a Varian RPM Gating System, which one hopes will improve dose homogeneity when intrafraction organ motion is present during treatment. This study attempts to determine how breathing affects dose distributions in breast patients and evaluates the potential for Gating Therapy in improving patient care. Three different treatment techniques commonly used in the clinic were investigated: physical wedge compensators (PWs), enhanced dynamic wedges (EDWs), and step-and-shoot intensity modulated radiation therapy (ssIMRT).

Equipment has been designed to simulate respiratory motion to a first order approximation. A breast phantom has also been designed to represent patient tissue and shape. Film was used as a dosimeter and static dosimetry data was used as a control for comparison. Three velocities of the breast phantom were studied and Gating Therapy was introduced for each data set. Dose area histograms were calculated for a breast and lung planning target area (PTA) and Normalized Agreement Test (NAT) Indexes were calculated in reference to the static case.

Our study shows that the results are dependent on both the respiratory rate and the wedge angle and that deviation from the static case is highest if the collimator speed is of the same magnitude as the speed of the target. Generally, there is a large overdosage to the lung PTA and an underdosage to the breast PTA. However, with the implementation of Gating Therapy, these dose discrepancies are dramatically reduced.

The Optical Wand Navigational System: An Aid in Daily Pre-treatment Patient Positioning within A Radiotherapy Department

F. Sie, G. Bootsma, D. Jaffray, J. Siewerdsen, D. Moseley, G. Wilson, T. Rosewall, E. White, C. Chiarot; Princess Margaret Hospital, Toronto, ON (Funded in-part by Elekta Oncology Systems)

Current efforts to escalate tumor doses while reducing normal tissue toxicity heighten the need for precision and accuracy during radiation field placement. This has created a clear demand for novel devices that bring improvements in precision without sacrificing efficiency. A model for achieving this objective, through the enhancement of current skin mark positioning, has been pursued through the integration of a dedicated infrared optical navigation system into a radiotherapy treatment room for routine patient positioning and 3D verification.

A multidisciplinary team has designed the operational characteristics and layout of a system to support in-room localization and correction of patient position based upon external landmarks or fiducials. PC-based software applications, in concert with the NDI Polaris Infrared localization system, have been constructed for testing and clinical evaluation. Using passive and active infrared detectors, 3D positional data is relayed continuously to a PC with a precision of +/- 0.35mm. Hardware and software elements designed specifically for radiotherapy applications take the form of graphic interfaces that display: offset measurements; depth and target-to-surface distances, couch shift verification; external contour delineation; and volume rendering tools to aid in isocenter alignment and patient positioning. Additional clinical applications also allow real-time patient position monitoring during beam delivery.

The results presented here include a pilot study comparing the accuracy and reproducibility of conventional skin mark setups to those recommended by the infrared navigation system. Comparisons were also made of the target-to-surface distances measured by a linear accelerator optical distance indicator and the navigation system. This ongoing study aims to fully examine the feasibility of integrating the infrared navigation system into routine radiotherapy planning and delivery and will continue to quantify its accuracy, precision, and efficiency in various clinical scenarios.

Assembling the Electronic Patient Record

G. Stoesz; CancerCare Manitoba, Winnipeg, MB

Information management and technology in Oncology is changing rapidly. Many cancer centers are facing challenging situations in availability of healthcare professionals, increased waiting list and growing demands to increase efficiency while maintaining cost and quality of service. Reacting to these challenges cancer centers increasingly rely on IT solutions for help. Historically, these systems have been designed and developed by different communities and are typically implemented and installed by different companies creating a fragmented IT infrastructure.

System integration can have a profound effect on the efficiency of clinical workflow activities carried out within the medical physics department and Oncology as a whole. Any medical application on its own can claim high to moderate success in improving a single clinical process. The creation of information exchange among disparate clinical applications and induced workflow management can further streamline activities both vertically in a section and horizontally across functional boundaries, resulting in a previously unanticipated return on investment of existing IT infrastructure. Therefore system integration has become an urgent requirement and the object of increasing attention. In the past this would have been troublesome to implement without the development of an intermediate application. The development of DICOM, HL7 and XML standards have helped to overcome this difficulty. This presentation provides an overview how IT underpins an organisation's effort to improve processes and quality of care while simultaneously assembling the electronic patient record.

Patient Specific Quality Assurance for Helical Tomotherapy

S. Thomas, M. MacKenzie, C. Field, B.G. Fallone; Dep. Medical Physics, Cross Cancer Institute, Edmonton, AB

Helical tomotherapy (HT) is a platform for delivering inverse planned Intensity Modulated Radiation Therapy (IMRT), which also enables a highly integrated approach to image guided adaptive radiotherapy in the clinic. This integrated approach in the TomoTherapy system to delivering highly conformal external beam IMRT is not only due to an on board megavoltage CT (MVCT) capability, but as well to the integrated image fusion, moveable lasers, and highly accurate couch. Great care must be taken, however, in order to assure that the highly conformal dose distributions that are planned are, in fact, delivered as prescribed by this high precision device.

In this presentation, we shall describe the patient specific quality assurance, which employs several software tools, some developed and

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provided by the manufacturer (TomoTherapy Inc.), and some developed in house. The most important feature of the QA process is the integrated ability of the system to export patient delivery sinograms onto for calculation in a phantom, and the analysis tools for comparing the measured results from this delivery to the calculations. We will discuss results from the film dosimetry system, ion chamber point measurements, as well as the use of the gamma function to assess the resulting measured vs. calculated distribution. An in house computer code has been developed which allow the gamma analysis to be constrained to region of interest. Results for a sample of patients on in house research protocol are presented, as well as for phantom studies for some up coming in house research protocols.

CT-MR Image Registration for Permanent Prostate Implant Post-Dosimetry

S. Vidakovic[1], R.S. Sloboda[2]; (1) Dep. Physics, U. Alberta, (2) Cross Cancer Institute, Edmonton, AB

An effective treatment for early stage prostate cancer is brachytherapy, where radioactive sources are implanted directly into the treatment volume. Radiation dose coverage, as assessed using post-implant dosimetry, is a good indicator of treatment outcome and hence, it is of great importance that the dose distribution is assessed accurately. In most cases the quality of the treatment is evaluated by a dosimetric study performed using CT slices one month after the implant. However, due to poor visibility of the prostate contours on the CT images the evaluation can be difficult and is only approximate. MRI allows a better appreciation of prostate contours but the visibility of the ensemble of the seeds is insufficient to allow its use as the only means of evaluating the treatment. Image registration of CT and MR scans can combine the benefits of both imaging modalities.

In our study we investigate using a mutual information registration algorithm for fusing CT and MR images. We have obtained CT and MR images of a prostate phantom (CIRS model 53-I, Norfolk, VA) implanted with inactive ^{125}I seeds (model MED3631-A/M, NASI, Chatsworth, CA). Both CT and MR volumes consist of 15 slices, each 3.0 mm thick with no inter-slice gap. The CT volume was acquired with a Picker PQ-500 CT-scanner performing a conventional scan. The MR volume was obtained using a Philips Gyroscan Intera 1.5T MRI system with pelvic coil, employing Turbo Spin Echo (TSE) sequence with parameters TE/TR= 105/4401 ms. We investigated the ability of a 3D rigid body transformation algorithm, based on maximization of mutual information, to perform automatic registration in a volume of interest surrounding the prostate. For this work we utilized Analyze 5.0 (AnalyzeDirect Lenexa, KS), a software package for image analysis (Mayo Foundation, Rochester, Minn.).

The results obtained so far are encouraging and suggest that mutual information-based registration could enable automatic fusion of clinical CT and MR images for prostate implant post-dosimetry.

Target Visualization and the Role of the Radiation Therapist

E. White, D.A Jaffray; Princess Margaret Hospital, Toronto, ON

The development of on-line image guidance technologies is having a significant impact on the practice of radiation therapy. It is common to acquire images for assessment off-line to establish systematic errors in the placement of radiation fields. With conformal techniques and IMRT becoming more conventional, the need for on-line guidance to correct for random deviations is inevitable.

Novel sources of guidance data will continue to challenge the traditional roles of the Radiation Therapist. The form and quantity of this data may have unpredictable influence on the ever-evolving role the therapist. Cone-beam CT technology is being brought into clinical use. The wealth of additional information about the patient's anatomy at the time of treatment raises interesting issues surrounding therapist-based interventions.

An examination of the information provided through the cone-beam CT process will assist in determining appropriate interventions at the time of treatment. Lack of ambiguity in interpretation of the volumetric data will provide a wealth of new information that has not previously been available. Reaction to this data requires contemplation of the impact on the relative roles of the radiation medicine disciplines. At the limit, over response to this information could paralyze the workflow, or alternatively, offer a unique opportunity for integrated quality assurance. These issues will be explored through experience from the first clinical cases at Princess Margaret Hospital.

Clinical Trial Progress Report – A Phase I/II Tricentre study of 4D Hypofractionated Radiotherapy (55 Gy/16 fractions) for Localized Prostate Cancer

J. Wu[1], D. Skarsgard[2], R. Pearcey[3]; 1.Tom Baker Cancer Centre, Calgary, AB 2. Saskatoon Cancer Centre, Saskatoon, SK 3. Cross Cancer Institute, Edmonton, AB

Objective: To determine acute/late toxicity and tumor control outcome of 55 Gy/16# - 4 fractions-per-week/4 wks in low and intermediate risk prostate cancer.

Method: A multi-centre study of prostate patients with T1-2, Gleason score </= 6 and PSA </=20 or Gleason score 7 and PSA </= 15 was initiated in Sep 2004. After TRUS-guided insertion of three gold markers into the prostate, 3D planning is done using 4-field or 6-field arrangement to PTV encompassing prostate +/- 1 cm of seminal vesicles with 10mm margin (5mm only for rectum). If dose constraints to bladder and rectum (D50=37 Gy, D35=45 Gy, D25=51 Gy, D15=55 Gy) are not met, IMRT planning is used. Daily orthogonal aSi EPIs are taken for matching of target (gold markers) to reference images, and isocentre adjustments are made to within 3mm (2mm anterior-posterior) discrepancy. EPIs are repeated during treatment where possible. Sample size is 72 patients and stopping rule is based on the likelihood of grade 3 acute toxicity > 10%.

Results: To date, 6 patients have completed protocol treatment, one of whom required IMRT. Overall, isocentre adjustments for target (gold markers) alignment are required in > 50% of the fractions given. Comparing EPIs before and during treatment, intra-fraction target movement is discernable for some patients. The average fraction time is ~20 minutes. No grade 3 toxicity is observed within first 3 months of treatment.

Conclusion: The early experience with a new dose-fractionation schedule (55 Gy/16#) incorporating real-time target imaging and realignment has been satisfactory. Study accrual will continue.

Report on WesCan 2005… (Continued from page 54)

The many attendees were treated to a number of talks on subjects outside the normal range for such meetings. The open discussions were fruitful, many old friends had the chance to renew acquaintances, and many new friends were made. The medical physics community in western Canada is well served by these meetings that promote a true sense of cooperation and friendship.

As is usual, a number of speakers from Victoria and Vancouver took great delight in showing pictures of flowers in bloom taken "last week". Patients visiting these centres must be truly amazed by the number of physicists they see outside taking such an interest in the local flora. Be that as it may, the weather in Calgary wasn't really great (can I put that any more diplomatically?) but the warm hospitality more than made up for the cold wind. A big thanks goes out to Dr. Chris Newcomb and all the other hard workers that made the conference such a success.

Next year, WESCAN will be held in Regina. Make plans now to attend this friendly, informative, fun, and very worthwhile meeting. The meeting will be great. The last time WESCAN was in Regina, the weather was great too!

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Pictures from WesCan 2005

Dr. Tony Fields kicking off the opening session.

A captive audience.

The benefits of attending a conference during St. Patrick's Day…. green hats and green beer, not necessarily in that order.

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The Ottawa Hospital Regional Cancer Centre (TOHRCC) is recruiting to fill the vacancy of:

Head, Medical Physics

The Ottawa Hospital is one of the largest academic hospitals in Canada with over 10,000 health care professionals staff. The Ottawa Hospital Regional Cancer Centre (TOHRCC) serves a population of approximately 1.2 million people, and treats 4000 patients with radiation therapy per year. The Regional Cancer Centre resides on two campuses, and has 7 linear accelerators, one cobalt unit, 1 orthovoltage unit, 1 HDR brachytherapy unit, 2 CT simulators, 1 PET CT scanner, one conventional simulator, and is in the process of installing a Tomotherapy unit for image guided IMRT.

The Physics Department within the radiation program of the TOHRCC has 11 Ph.D. Physicists with expertise in radiation therapy and imaging physics. The Physics Department is active in a program of treatment support as well as teaching and research. Ottawa has a residency program in Medical Physics, Radiation Oncology, and takes radiotherapy students for their clinical training. The Physicists hold academic appointments in the Department of Radiology at the University of Ottawa and in the Physics Department at Carleton University. A joint program between the two Universities supports up to 20 graduate students in Medical Physics.

The Head of Medical Physics will lead the department in clinical support and provide direction in new clinical therapeutic development, will provide a leadership role in the academic mission and activity of the department, will foster strong bonds with both universities, will set standards and provide a leadership role in research, education, and will participate in the management of the Regional Cancer Centre Radiation Program.

Qualifications:

- Member of the Canadian College of Physicists in Medicine or equivalent;
- A proven track record in research;
- Ph.D. in Medical Physics or directly related field;
- Experience and background that will support at the minimum an appointment at the associate professor level in the University of Ottawa Department of Radiology, Division of Radiation Oncology;
- Contribute to research, graduate and post-graduate student and resident training in Medical Physics and Radiation Oncology;
- Excellent interpersonal skills;
- Sound judgement and problem-solving;
- Superior organization skills.

If you are interested in helping shape the future of radiotherapy physics in North America, please send your curriculum vitae, **quoting competition #OH-17447 by May 27, 2005** to: The Ottawa Hospital, Human Resources, 1053 Carling Avenue, Ottawa, ON, K1Y 4E9, or fax: (613) 761-5374, or email: jobs@ottawahospital.on.ca

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RYERSON UNIVERSITY

CHAIR
Department of Physics

The Department of Physics invites applications or nominations for the position of Chair for an initial term of up to five years, beginning on July 1, 2005. The Department is composed currently of ten full-time faculty and three staff supporting programs primarily in Engineering and Applied Science at Ryerson. The Department has significant research activity in the field of Medical Physics / Biomedical Engineering and new faculty appointments have been targeted in this area. The faculty have a core group of biomedical physicists who have secured external peer-reviewed research funding to establish advanced research laboratories at Ryerson and have extensive collaborations with the surrounding biomedical community in what the City of Toronto has designated as the Discovery District, home to seven world-renowned hospitals and more than thirty specialized medical and related sciences research centers.

The candidate must possess an earned doctorate in Physics or a related field with a strong commitment to high-quality education and research and must be eligible for appointment at the Associate Professor or Professor level. The candidate should also have a strong track record in research, administration, and professional activities. The successful applicant will be an effective communicator with faculty, students, and upper administration and maintain scholarly activity in his/her area of expertise.

The Chair will be expected to provide leadership in developing and maintaining research programs, curriculum development, establishing strong university relationships with external organizations, effectively administering resources and be committed to undergraduate and graduate teaching. The Chair should exhibit academic and administrative leadership towards the achievement and maintenance of high-quality degree programs and research. Under the Chair's leadership, a collegial and vibrant learning environment is expected. The Chair will assist the Department in the development and implementation of an undergraduate and graduate program in the area of Biomedical Physics during his/her term. The Chair will be expected to contribute to the overall aim of this initiative and enhance science education and research in contemporary areas that will ensure the University's ability to recruit and retain excellent faculty and students.

Applications and nominations should be sent to: Dr. S.A. Boctor, Dean, Faculty of Engineering and Applied Science, Ryerson University, 350 Victoria Street, Toronto, Ontario. M5B 2K3 or e-mail at: sboctor@ee.ryerson.ca. Applications should include a curriculum vitae, a statement of interest addressing the candidate's role as administrator, educator, and researcher, and names of three references. The deadline for applications/nominations to be received at the Dean's Office is 4:00pm, April 22, 2005.

Ryerson University has an employment equity program and encourages applications from all qualified applicants, including women, Aboriginal peoples, persons with disabilities and visible minorities. Members of designated groups are encouraged to self-identify. In accordance with Canadian Immigration requirements, this advertisement is directed to Canadian citizens and permanent residents of Canada.

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Medical Physicist

• Cancer Centre of Southeastern Ontario

Kingston General Hospital, Kingston, Ontario

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The Radiation Oncology Programme operates four Varian linear accelerators (a Clinac 2100EX, two 2100C/D's, and a 600EX), a superficial x-ray unit, an LDR remote afterloader, a Theraplan Plus treatment planning system, an AqSim CT simulator, and is acquiring a Varian Clinac 2100IX this summer. Application is being made to acquire HDR afterloading and a new treatment planning system in the coming fiscal year.

The successful candidate will be expected to participate in all clinical, educational and research activities of the Medical Physics Department. Clinical activities include acceptance testing and commissioning of new equipment, calibrations, dosimetry data maintenance, quality assurance, and treatment planning support. All Medical Physicists are expected to be active leaders in the development of technical improvements in the radiation planning and treatment program. CCSEO Medical Physicists support training programs for Medical Physics residents, Radiation Oncology residents, and Radiation Therapists. There are also opportunities to supervise Medical Physics graduate students in the Department of Physics at Queen's University.

Candidates for this position must be fully trained Medical Physicists, with a postgraduate degree (Ph.D. preferred) and a minimum of 5 years' post-training experience in clinical radiation therapy physics. Membership in the Canadian College of Physicists in Medicine or equivalent is preferred. Experience with dynamic wedge, multileaf collimation, portal imaging, CT simulation, and Monte Carlo computer simulation plus expertise in networking and administering computer systems would be assets. Applicants must have good evidence of research and/or development activity with credentials and experience that could lead to an academic appointment at Queen's University.

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We thank all applicants; however, only those individuals to be interviewed will be contacted.

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