What is the Radiosurgery Society®?
We are a mutual benefit nonprofit corporation (501c6). Membership in the Radiosurgery Society (RSS) is available to health care professionals affiliated with any stereotactic radiosurgery or stereotactic body radiation therapy treatment center.

What’s in it For You?
The RSS provides a forum for open discussion, clinical research, improving treatment techniques and increasing publications. Providing physicians, physicists, and other medical professionals the ability to push forward, at the most rapid pace possible, the discipline of full-body radiosurgery, thus providing immense benefit to the public.

How is This Society Different?
Our fundamental philosophy - that of bringing together under one umbrella - all the radiation and surgical specialties with direct collaboration from medical device and product manufacturers... thereby shattering the competitive clinical paradigms of unfettered competition that ends up hindering all.

Our Members Have Access to:

- Treatment Protocols and Opportunities to Promote Face to Face Collaboration
- Peer to Peer Discussion Boards
- Treatment Guidelines/Whitepapers
- RSResearch™ Patient Registry
- Protocol Development Committee
- Archive of Performance and Quality Improvement Cases
- Discount Registration Fees at RSS Scientific Meetings
- Online Meetings and Archived Webinars
- Archive of Abstracts from Prior Scientific Meetings
- A variety of Committees to Participate and Make a Difference

For more information, please visit us at www.therss.org

or scan the below QR code
THE RADIOSURGERY SOCIETY® (RSS) WELCOMES YOU. It’s been an exciting and interesting journey for us all. We find ourselves in a world where whole body radiosurgery indications are expanding right alongside traditional intracranial radiosurgery; a world in which every major equipment manufacturer is offering stereotactic options and academic departments are touting SRS/SBRT/SABR as a new way of reducing costs while improving both the patient experience and outcomes.

With this increasing interest in SRS/SBRT comes a need for increased knowledge, education and training of practitioners in this exciting field. Recognizing this, the RSS is putting more emphasis on training and education: Bridging the Gap: Working Together. Device manufacturers teach you how to “push the buttons” but how does the practitioner learn “how and when” to treat the patient? Together, we can bridge that gap. We are offering, “The Introduction to Thoracic SRS/SBRT Workshop” designed to increase competence in the areas of SRS/SBRT of thoracic cancers. The curriculum highlights specific areas in radiation biology, patient work-up, simulation & planning, dose calculation, and safety. This workshop received the endorsement from The Society of Thoracic Surgeons (STS).

Along with our emphasis on training and education, we are increasingly involved in activities related to reimbursement. To help those new to the discipline of whole body SRS/SBRT, we are offering the billing and coding symposium “Obstacles for Reimbursement”. After years of dedication from many, finally there is a thoracic code but the work doesn’t stop, we must to work together to proliferate this effort to other specialties.

There is more that can be done and we can use your help. The RSS has several committees you can join and make a difference in the ever expanding world of SRS/SBRT. For instance, the Physics Committee has done an outstanding job drawing those pre-eminent in the field of radiosurgery to present on topics such as QA & Patient Safety, Dosimetry and Monte Carlo. We are very pleased to have received the endorsement of the American Association of Physicists in Medicine (AAPM).

Last but not the least, without working as a team there would be little and slow progress in the development of evidence for comparative effectiveness and best practices in SRS/SBRT. We cannot in good clinical conscience sit back and wait for “others” to define what’s the future of radiosurgery- we can only efficiently do it as a team. We hope you recognize the value of this society - and if not already a member – please join the RSS today.

Thank you,

Alexander Muacevic, MD
Chairman of the BOD
the Radiosurgery Society®

Anand Mahadevan, MD
President of the BOD
the Radiosurgery Society®
CONTINUING EDUCATION INFORMATION

TARGET AUDIENCE
This meeting is designed to meet the interests of practicing physicians (surgeons, radiation and medical oncologists), residents/fellows, radiation biologists, medical physicists, radiation therapists, nurses, and all other health professionals involved in the fields of stereotactic radiosurgery and stereotactic body radiation.

PHYSICIANS AND NURSES
No CME/CE awarded sessions

PHYSICISTS
This activity is approved for credit by the Commission on Accreditation of Medical Physics Educational Programs (CAMPEP). There is a maximum of 19.82 MPCEC awarded for the sessions listed below.

The Radiosurgery Society in conjunction with the Commission on Accreditation of Medical Physics Educational Programs (CAMPEP) will be providing Medical Physics Continuing Education Credit (MPCEC) using an on-line electronic evaluation system. This will serve to provide feedback to the program directors and continuing education awards to physicists for the sessions listed below. At the completion of any of the below listed sessions, log into the evaluation system at http://questionpro.com/t/AwuLZO7PQ and follow instructions. YOU MUST SUBMIT YOUR EVALUATION BEFORE MARCH 15, 2013 TO RECEIVE MPCEC. Confirm your credential with CAMPEP after March 30, 2013.

Educational Objectives
- Investigate the latest advances in the management of cancers using stereotactic radiosurgery (SRS) and stereotactic body radiotherapy (SBRT)
- Identify current novel therapies of SRS/SBRT in the treatment of cancer and other medical disorders
- Increase awareness of evidence-based practice among their peers utilizing SRS/SBRT and surgical approaches
- Report on developments in the field of QA
- Educate on IAEA and AAPM dosimetry protocols
- Share best practices and clinical methodology for performance improvement

Attendance will be monitored during this meeting by the use badge scanners at the entrance of the General and Physics Sessions. You must scan your badge to document attendance.

Awarded Sessions

Thursday, February 21, 2013 - (6.96 CE)
- 1.82 CE Hours – Physics Session I
- 0.99 CE Hours – Physics Session II
- 0.40 CE Hours – Physics Oral Poster Session
- 1.75 CE Hours – SRS/SBRT Dosimetry Workshop
- 2.00 CE Hours – Monte Carlo Workshop

Friday, February 22, 2013 (8.86 CE)
- 1.36 CE Hours – Thoracic Oral Presentation
- 4.50 CE Hours – The Showdown Returns
- 3.00 CE Hours – QA & Safety in SRS/SBRT Symposium

Saturday, February 23, 2013
- 4.0 CE Hours – Performance and Quality Improvement Session (PQIS)
DOSIMETRISTS

This activity is approved for credit by the Medical Dosimetrist Certification Board (MDCB). There is a maximum of 17 credits awarded for the sessions listed below.

Attendance will be monitored during this meeting by the use badge scanners at the entrance of the General and Physics Sessions. You must scan your badge to document attendance during below sessions. A roster of your attendance will be submitted to the MDCB after the completion of the SRS/SBRT Scientific Meeting. Confirm your CMD credential with MDCB.

Awarded Sessions

Thursday, February 21, 2013 - (7 CE)
- 2.0 CE Hours – Physics Session I
- 1.0 CE Hours – Physics Session II
- 2.0 CE Hours – SRS/SBRT Dosimetry Workshop
- 2.0 CE Hours – Monte Carlo Workshop

Friday, February 22, 2013 - (10 CE)
- 1.5 CE Hours – CLINICAL SESSION: Thoracic Oral Presentation
- 5.0 CE Hours – The Showdown Returns
- 3.5 CE Hours – QA & Safety in SRS/SBRT Symposium

Saturday, February 23, 2013 - (0 CE)
- No CE Hours awarded for the Performance and Quality Improvement Session (PQIS)

RADIATION THERAPISTS

This activity is approved for credit by the American Society for Radiologic Technologists (ASRT). There is a maximum of 11.5 Category A CE credits awarded for the sessions listed below.

Attendance will be monitored during this meeting by the use badge scanners at the entrance of the General Session. Badges must be scanned upon entry and exit of the listed lectures below for Continuing Education credit to be granted. Badges not scanned or participants that depart sessions early will not be awarded credits. You must attend the entire session in order to receive awards. An Attendance Certificate will be emailed to you after the completion of the meeting, please allow 30 days after the completion of meeting. ASRT member technologists are responsible for submitting a copy of their documentation to the ASRT for CE tracking.

Awarded Sessions

Thursday, February 21, 2013 - (5.0 CE)
- 2.0 CE Hours – CLINICAL SESSION: Central Nervous System – Intracranial and Spine
- 1.5 CE Hours – CLINICAL SESSION: Genitourinary
- 1.5 CE Hours – CLINICAL SESSION: Extracranial-Other, Emerging Technology & Gastrointestinal

Friday, February 22, 2013 - (6.5 CE)
- 1.5 CE Hours – CLINICAL SESSION: Thoracic
- 5.0 CE Hours – The Showdown Returns

Saturday, February 23, 2013 - (0 CE)
- No CE Hours awarded for the Performance and Quality Improvement Session (PQIS)


**SCIENTIFIC PLANNING AND REVIEW COMMITTEE**

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
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<tbody>
<tr>
<td>Richard D. Bucholz, MD</td>
<td>Saint Louis University Hospital, St. Louis, Missouri</td>
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<tr>
<td>Paul Chomiak, MD</td>
<td>Frederick Memorial Hospital, Frederick, Maryland</td>
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<tr>
<td>Donald B. Fuller, MD</td>
<td>CyberKnife Centers of San Diego, a Division of Genesis Healthcare Partners,</td>
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<td>San Diego, CA</td>
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<tr>
<td>Martin Fuss, MD</td>
<td>Oregon Health &amp; Science University, Portland, Oregon</td>
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<tr>
<td>Deepak Khuntia, MD</td>
<td>Western Radiation Oncology, Mountain View, California</td>
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<tr>
<td>John J. Kresl, MD, PhD</td>
<td>Phoenix CyberKnife and Radiation Oncology Center, an Affiliate of Radiation</td>
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<td>Oncologists of Central Arizona (ROCA), Phoenix, Arizona</td>
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<tr>
<td>Anand Mahadevan, MD</td>
<td>Beth Israel Deaconess Medical Center, Boston, Massachusetts</td>
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<tr>
<td>Clinton A. Medbery, III, MD</td>
<td>St. Anthony Hospital, Oklahoma City, Oklahoma</td>
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<tr>
<td>Alexander Muacevic, MD</td>
<td>CyberKnife Zentrum München-Grosshadern, Munich, Germany</td>
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**PHYSICS PLANNING AND REVIEW COMMITTEE**

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<th>Name</th>
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<tr>
<td>Ian Cowley, PhD</td>
<td>The Harley Street Clinic, London, United Kingdom</td>
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<tr>
<td>Christian G. Drexler, MSc</td>
<td>CyberKnife Zentrum München-Grosshadern, Munich, Germany (now Varian Medical Systems)</td>
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<tr>
<td>Steve Goetsch, PhD</td>
<td>San Diego Gamma Knife Center, San Diego, California</td>
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<td>Mary Ellen Masterson-McGary, MA, MS</td>
<td>CyberKnife Centers of Tampa Bay, Tampa, Florida</td>
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<tr>
<td>Brian Wang, PhD</td>
<td>University of Utah, Salt Lake City, Utah</td>
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<tr>
<td>Jun Yang, PhD</td>
<td>Philadelphia CyberKnife Center, Havertown, Pennsylvania</td>
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</table>

We are very pleased to say that the Physics Sessions of the meeting have been endorsed by the American Association of Physicists in Medicine.

**PERFORMANCE & QUALITY IMPROVEMENT SESSION COMMITTEE**

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**INTRODUCTION TO THORACIC SRS/SBRT WORKSHOP PLANNING COMMITTEE**

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<td>Deepak Khuntia, MD</td>
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<td>Arjun Pennathur, MD, FACS</td>
<td>University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania</td>
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<td>John Suh, MD</td>
<td>Cleveland Clinic, Cleveland, Ohio</td>
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THE RADIOSURGERY SOCIETY®

OUR OBJECTIVES

- Improve results achieved in the fields of stereotactic radiosurgery (SRS)/stereotactic body radiotherapy (SBRT) by promoting scholarly exchange among the members, with a focus on defining and expanding the role of SRS/SBRT.

- Share detailed clinical information pertaining to SRS/SBRT to promote protocol development.

- Encourage and enhance the adoption of radiosurgical techniques in the worldwide medical community and among healthcare providers and patients.

- Facilitate the development of treatment methods that offer the optimum in safety and efficacy for patients.

THE RADIOSURGERY SOCIETY BOARD OF DIRECTORS

Alexander Muacevic, MD  Chairman of the Board  
Anand Mahadevan, MD  President  
Richard D. Bucholz, MD  Secretary  
Donald B. Fuller, MD  Treasurer  
Paul N. Chomiak, MD  Board Member  
Martin Fuss, MD  Board Member  
Kristine Gagliardi  Board Member  
Paul Goldfarb, MD, FACS  Board Member  
John J. Kresl, MD, PhD  Board Member  
Jun Yang, PhD  Board Member

THE RADIOSURGERY SOCIETY STAFF

Kristine H. Gagliardi  Executive Director  
Nalani Brown  Clinical Programs Manager  
Denise Hitzman  Membership & Administration Manager
SPECIAL THANKS

THE RADIOSURGERY SOCIETY® WOULD LIKE TO THANK THE FOLLOWING:

- Kristjan Gavin and his team at In Good Company Events®
- The team at InVision Communications, Inc.
- The team at ICV Digital Media

WE ARE PLEASED TO ACKNOWLEDGE OUR GENEROUS SUPPORTERS OF THIS YEAR’S MEETING – WITHOUT WHOM, THIS MEETING WOULD NOT BE POSSIBLE. WE STRONGLY ENCOURAGE ALL ATTENDEES TO SHOW YOUR SUPPORT AND VISIT THEIR EXHIBITS – AFTER ALL, YOU ARE THE REASON THEY ARE HERE – TO OFFER YOU PRODUCTS AND SERVICES THAT JUST MIGHT MAKE YOUR LIFE AND THOSE OF YOUR PATIENTS, EASIER.

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THE SHOWDOWN SESSION HAS BEEN MADE POSSIBLE IN PART BY AN UNRESTRICTED EDUCATIONAL GRANT FROM:

- The Varian Medical Systems Foundation, an advised fund of Silicon Valley Community Foundation.

IN ACKNOWLEDGEMENT OF THEIR GENEROUS SUPPORT OF THE INTRODUCTION TO THORACIC SRS/BRT WORKSHOP WE WOULD LIKE TO THANK:

- Accuray Incorporated
- Brainlab
- Elekta
- Philips
- Varian Medical Systems
<table>
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<th>Time</th>
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<td>Short Oral Presentations</td>
<td>Intro to Thoracic SRS/SBRT Workshop</td>
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## DAILY SCHEDULES AND MEETING ROOM LOCATIONS

### Wednesday, February 20th

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<tr>
<td>1:00pm – 7:00pm</td>
<td>Registration</td>
<td>Costa Del Sol Foyer</td>
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<tr>
<td>1:00pm – 7:00pm</td>
<td>Poster Set-Up</td>
<td>Costa Del Sol Foyer</td>
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<tr>
<td>1:00pm – 4:00pm</td>
<td>Varian Satellite Symposium</td>
<td>Costa Del Sol, Salon A-D</td>
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### Thursday, February 21st

<table>
<thead>
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<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>7:00am – 8:00am</td>
<td>General Session</td>
<td>Costa Del Sol, Salon A-D</td>
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<tr>
<td>8:00am – 10:00am</td>
<td>Clinical Session - CNS</td>
<td>Costa Del Sol, Salon A-D</td>
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<td>8:00am – 10:00am</td>
<td>Physics Session</td>
<td>Costa Del Sol, Salon F-H</td>
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<td>10:00am – 10:30am</td>
<td>Clinical Session - GU</td>
<td>Costa Del Sol, Salon A-D</td>
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<tr>
<td>10:30am – 12:00pm</td>
<td>Physics Session</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>12:00pm – 1:30pm</td>
<td>Lunch</td>
<td>Costa Del Sol, Foyer &amp; Salon E</td>
</tr>
<tr>
<td>1:30pm – 3:00pm</td>
<td>Clinical Session – GI and Other</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>1:30pm – 5:30pm</td>
<td>Physics Session</td>
<td>Costa Del Sol, Salon F-H</td>
</tr>
<tr>
<td>3:00pm – 4:00pm</td>
<td>Short Oral Presentations</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>3:00pm – 5:45pm</td>
<td>Intro to Thoracic SRS/SBRT Workshop – Day 1</td>
<td>Gardenia, Coastal Events Center</td>
</tr>
<tr>
<td>5:30pm – 7:30pm</td>
<td>Mix &amp; Mingle Reception</td>
<td>Costa Del Sol, Foyer &amp; Salon E</td>
</tr>
</tbody>
</table>

### Friday, February 22nd

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00am – 8:30am</td>
<td>General Session - Thoracic</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>8:30am – 10:00am</td>
<td>The Showdown Returns: Lung Cancer</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>10:00am – 10:30am</td>
<td>Break</td>
<td>Costa Del Sol, Foyer &amp; Salon E</td>
</tr>
<tr>
<td>10:30am – 12:00pm</td>
<td>The Showdown Returns: Prostate Cancer</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>12:00pm – 1:30pm</td>
<td>Lunch</td>
<td>Costa Del Sol, Foyer &amp; Salon E</td>
</tr>
<tr>
<td>1:30pm – 3:00pm</td>
<td>The Showdown Returns: Trigeminal Neuralgia</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>3:00pm – 6:00pm</td>
<td>Physics Session</td>
<td>Costa Del Sol, Salon F-H</td>
</tr>
<tr>
<td>3:00pm – 5:30pm</td>
<td>Intro to Thoracic SRS/SBRT Workshop – Day 2</td>
<td>Gardenia, Orchid &amp; Iris, Coastal Events Center</td>
</tr>
<tr>
<td>3:30pm – 5:00pm</td>
<td>Obstacles for Reimbursement</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>5:30pm – 7:30pm</td>
<td>Poster Reception</td>
<td>Costa Del Sol Foyer &amp; Salon E</td>
</tr>
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</table>

### Saturday, February 23rd

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>8:00am – 10:00am</td>
<td>Performance and Quality Improvement Session</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>10:00am – 10:30am</td>
<td>Break</td>
<td>Costa Del Sol, Foyer &amp; Salon E</td>
</tr>
<tr>
<td>10:30am – 12:30pm</td>
<td>Performance and Quality Improvement Session</td>
<td>Costa Del Sol, Salon A-D</td>
</tr>
<tr>
<td>12:30pm – 1:30pm</td>
<td>Grab and Go Lunch</td>
<td>Costa Del Sol Foyer</td>
</tr>
<tr>
<td>2:00pm – 6:00pm</td>
<td>Scramble Golf Tournament</td>
<td>South Course</td>
</tr>
<tr>
<td>6:00pm – 9:30pm</td>
<td>Dancin’ to the Beat</td>
<td>Veranda</td>
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INTRODUCTION TO THORACIC SRS/SBRT WORKSHOP

February 21-22, 2013 (5 hours total)

Workshop Description
This half-day program, endorsed by The Society of Thoracic Surgeons, is designed to increase competence through didactic lectures in the areas of stereotactic radiosurgery (SRS) and stereotactic body radiotherapy (SBRT) of thoracic cancers. The curriculum will also highlight specific areas in radiation biology, patient work-up, simulation & planning, dose calculation, and safety. This session is specially designed for the practitioners new to SRS/SBRT and will help prepare residents for their board examinations and provide basic information to practicing physician interested in the biological effects of exposure to ionizing radiation.

Target Audience
This workshop is designed to meet the interests of practicing radiation oncologists, pulmonologists, thoracic surgeons, medical oncologists, and residents involved in the field of SRS/SBRT, a multidisciplinary approach of thoracic malignancy.

Learning Objectives
The objective of this workshop is to provide attendees with the current management of lung malignancies most encountered within SBRT. At the end of this educational intervention, attendees should be able to:

- Successfully implement the information provided in daily practice applications.
- Successfully apply the information provided in preparation for target audience board examinations.
- Summarize safety issues in a radiation oncology practice in the current era of multimodal imaging and complex treatment implementation.
- Recognize indications for SRS/SBRT and appropriate patient selection for thoracic SRS/SBRT.
- Identify the roles of radiation oncologist, pulmonologist/surgeon, and physicist in SRS/SBRT procedures, staging, fiducial implantation, treatment planning contours, and a team approach.
- Be familiar with biological effects of ionizing radiation on tumor cells, patient as a whole, as well as post SBRT potential complications and minimizing risk.

Workshop Content
The workshop includes:

- Didactic session features interdisciplinary speakers addressing topics chosen for its applicability in everyday practice of thoracic SBRT.
- Interactive Practical Session includes hands on treatment planning of simple and complex lung SBRT cases on diverse treatment platforms.

Needs Statement
New and practicing physicians are expected to maintain core medical knowledge fundamental to the practice of SBRT. This workshop is designed to update physicians new and resident-in-training by reviewing specific lung SBRT topics.

Registration and Fee
$125.00 RSS and/or STS Members; $200.00 non-RSS and/or non-STS Members
All registrants who are not current members of RSS will receive complimentary RSS Membership thru June 2013.
Advance registration is strongly recommended to secure space in the practicum of your choice.
- Want to register on-site? Please inquire about availability at the registration desk.

Program Committee
Deepak Khuntia, M.D., Western Radiation Oncology
Paul Chomiak, M.D., Frederick Memorial Hospital
Clinton Medbery, III., M.D., St. Anthony Hospital
Arjun Pennathur, M.D., FACS, University of Pittsburgh Medical Center
John Suh, M.D., Cleveland Clinic Foundation

Endorsed by The Society of Thoracic Surgeons
INTRODUCTION TO THORACIC SRS/SBRT
February 21-22, 2013 (5 hours total)

Day I – The Principles (Subject to Change)
Thursday, February 21, 2013, 3:00 – 5:45 pm
Location: Gardenia Room

Didactic Session
3:00 -3:10 Introduction to Thoracic Radiosurgery Workshop
  • Deepak Khuntia, M.D., Western Radiation Oncology, CA, Dept. of Radiation Oncology
3:10 – 3:35 History, Biology, Evidence, and Fractionation of SBRT
  • Gregory M. M. Videtic, M.D., CM, Cleveland Clinic, OH, Dept. of Radiation Oncology
3:40 – 3:55 Patient Selection and Fiducial Placement
  • Robert Cerfolio, M.D., University of Alabama, AL, Dept. of Cardiothoracic Surgery
4:00 – 4:20 Pre-Treatment Workup, Evaluation, Anatomy & Contouring
  • Arjun Pennathur, M.D., FACS, University of Pittsburgh Medical Center, PA, Dept. of Cardiothoracic Surgery
4:25 – 4:45 Simulation, Immobilization, Treatment planning/dose constraints
  • Gregory M. M. Videtic, M.D., CM, Cleveland Clinic, OH, Dept. of Radiation Oncology
4:50 – 5:10 Safety/Quality
  • Brad Beck, Ph.D., Robert Boissoneault Oncology Institute, FL, Dept. of Radiation Oncology
5:15 – 5:30 Side Effects and Management
  • Paul Chomiak, M.D., Frederick Memorial Hospital, MD, Thoracic Surgery
5:30 – 5:45 Documentation/Coding/Billing
  • Wes Hodge, M.D., Robert Boissoneault Oncology Institute, FL, Dept. of Radiation Oncology

Day II – Lung Treatment Planning Practicum (Subject to Change)
Friday, February 22, 2013, 3:00 – 5:30 pm
Locations: Gardenia, Orchid, and Iris Rooms

Practicum Session
Day 2 is designed as a treatment planning practicum lead by Practicum Team, consisting of a physician and physicist for each listed planning systems. Attendees will select one of the following treatment planning systems to develop a variety of thoracic plans:

**iPlan®**  Location: Iris 2
  • Gregory Videtic, M.D. - Cleveland Clinic
  • Toufik Djemil, Ph.D. - Cleveland Clinic

**Monaco**  Location: Gardenia 2
  • James Urbanic, M.D. - Wake Forest School of Medicine
  • Quentin Diot, Ph.D. - University of Colorado

**MultiPlan®**  Location: Orchid 2
  • Paul Chomiak, M.D. - Frederick Memorial Hospital
  • Jun Yang, Ph.D. - Philadelphia CyberKnife

**Pinnacle**  Location: Orchid 1
  • Wes Hodge, M.D. - Robert Boissoneault Oncology
  • Brad Beck, Ph.D. - Robert Boissoneault Oncology

**TomoTherapy®**  Location: Orchid 2
  • Deepak Khuntia, M.D. - Western Radiation Oncology
  • David Westerly, Ph.D. - University of Colorado

**Eclipse™**  Location: Iris 1
  • Robert Cerfolio, M.D. - University of Alabama
  • Kayla Kielar, Ph.D. - Mills Peninsula Health Services
CLINICAL SESSION

the Radiosurgery Society™
### GENERAL SESSION – Costa Del Sol, Salon A-D

<table>
<thead>
<tr>
<th>Time</th>
<th>Presenter(s)</th>
<th>Title</th>
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<tbody>
<tr>
<td>7:00am – 7:10am</td>
<td>Alexander Muacevic, MD</td>
<td>Welcome to the 2013 SRS/SBRT Scientific Meeting</td>
</tr>
<tr>
<td>7:10am – 8:00am</td>
<td>Anand Mahadevan, MD and Kristine Gagliardi</td>
<td>the Radiosurgery Society® Annual Meeting and A View Behind the Curtain</td>
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### CLINICAL SESSION – Costa Del Sol, Salon A-D

#### Central Nervous System – Intracranial & Spine

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<thead>
<tr>
<th>Time</th>
<th>Presenter(s)</th>
<th>Title</th>
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<tbody>
<tr>
<td>8:10am – 8:20am</td>
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<td>Session Begins</td>
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<tr>
<td>8:20am – 8:30am</td>
<td>Scott Soltys, MD (Stanford University Medical Center, Stanford, California)</td>
<td>Risk of Leptomeningeal Disease in Patients Treated with Stereotactic Radiosurgery</td>
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<td>Targeting the Post-Operative Resection Cavity for Brain Metastases</td>
</tr>
<tr>
<td>8:30am – 8:40am</td>
<td>Maged Ghaly, MD (Hofstra North Shore-LIJ School of Medicine, Long Island, New York)</td>
<td>Adjuvant Tumor Bed Radiosurgery Following Surgical Resection of Intracranial Metastases</td>
</tr>
<tr>
<td>8:40am – 8:50am</td>
<td>Robert Taylor, MD, PhD (University of Alabama, Birmingham, Alabama)</td>
<td>Primary Radiation Therapy for Unbiopsied Presumed Meningioma: Analysis of Post-Treatment Related Seizure Toxicity with Stereotactic Radiosurgery</td>
</tr>
<tr>
<td>8:50am – 9:00am</td>
<td>Xin Wang, MD, PhD (Huashan Hospital, Fudan University, Fudan, China)</td>
<td>The Role of Stereotactic Radiosurgery in Cavernous Sinus Hemangiomas</td>
</tr>
<tr>
<td>9:00am – 9:10am</td>
<td>Harry Lomas, IV, MD (University of Virginia / Riverside Radiosurgery Center, Newport News, Virginia)</td>
<td>Reirradiation of Cervical Spine Metastases with Stereotactic Body Radiosurgery</td>
</tr>
<tr>
<td>9:10am – 9:20am</td>
<td>Maged Ghaly, MD (Hofstra North Shore-LIJ School of Medicine, Long Island, New York)</td>
<td>Salvage Single-Fraction Stereotactic Body Radiotherapy for Patients with Prior Radiation of Spinal Metastases</td>
</tr>
<tr>
<td>9:20am – 9:30am</td>
<td>Jimm Grimm, PhD (Holy Redeemer Hospital, Meadowbrook, Pennsylvania)</td>
<td>Estimated Risk Level of Unified SBRT Dose Tolerance Limits for Spinal Cord</td>
</tr>
<tr>
<td>9:30am – 9:40am</td>
<td>Fang-Fang Yin, PhD (Duke University Medical Center, Durham, North Carolina)</td>
<td>Knowledge Based Spinal Cord Sparing Models and Individualized Trade-offs in Spine SBRT Planning</td>
</tr>
<tr>
<td>9:40am – 10:00am</td>
<td>All Speakers: Central Nervous System – Intracranial &amp; Spine Q &amp; A</td>
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<tr>
<td>10:00am – 10:30am</td>
<td></td>
<td>Break</td>
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#### Genitourinary

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<thead>
<tr>
<th>Time</th>
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<th>Title</th>
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<tr>
<td>10:30am – 10:40am</td>
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<td>Session Begins</td>
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<tr>
<td>10:40am – 10:50am</td>
<td>Alan J. Katz, MD (Flushing Radiation Oncology, Flushing, New York)</td>
<td>Stereotactic Body Radiation Therapy for Low-, Intermediate- and High-Risk Prostate Cancer: Disease Control and Quality of Life at Five Years</td>
</tr>
<tr>
<td>10:50am – 11:00am</td>
<td>Debra Freeman, MD (Naples Radiation Oncology, Naples, Florida)</td>
<td>Long Term Results of Hypofractionated Radiation for Organ-Confinied Prostate Cancer</td>
</tr>
<tr>
<td>Time</td>
<td>Speaker</td>
<td>Title</td>
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<tr>
<td>11:00am – 11:10am</td>
<td>Alexander Muacevic, MD (European CyberKnife Center Munich, Munich, Germany)</td>
<td>A New and Effective Treatment Approach for Non Resectable Renal Tumors Feasibility and Early Results</td>
</tr>
<tr>
<td>11:10am – 11:20am</td>
<td>Maged Ghaly, MD (Hofstra North Shore-LIJ School of Medicine, Long Island, New York)</td>
<td>Phase I Dose-Escalation Study of Stereotactic Body Radiotherapy (SBRT) for Organ Confined Prostate Cancer</td>
</tr>
<tr>
<td>11:20am – 11:30am</td>
<td>Mark Perman, MD (South Florida Radiation Oncology, Stuart, Florida)</td>
<td>Early Outcome Results from the Multi-Institutional Registry for Prostate Cancer Radiosurgery (RPCR)</td>
</tr>
<tr>
<td>11:30am – 11:40am</td>
<td>Fang-Fang Yin, PhD (Duke University Medical Center, Durham, North Carolina)</td>
<td>Prostate SBRT in Five Fractions: 2 Year Clinical Trial Protocol Review and Analysis on Dosimetric and IGRT</td>
</tr>
<tr>
<td>11:40am – 12:00pm</td>
<td>All Speakers: Genitourinary Q &amp; A</td>
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</tr>
<tr>
<td>12:00pm – 1:30pm</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td><strong>Extracranial Other, Emerging Technology &amp; Gastrointestinal</strong></td>
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</tr>
<tr>
<td>1:30pm – 1:40pm</td>
<td>Oliver Blanck, Dipl Inf (University Clinic of Lübeck, Lübeck, Germany)</td>
<td>Radiosurgery to create Lesions in the Pulmonary Vein Antrum: Preliminary Results in a Porcine Model and Possible Implications for the Treatment of Atrial Fibrillation</td>
</tr>
<tr>
<td>1:40pm – 1:50pm</td>
<td>Jonathan A. Haas, MD (Winthrop-University Hospital, Mineola, New York)</td>
<td>CyberKnife Radiosurgery for Early Stage Breast Cancer: Updated Results and Technique from the Winthrop-University Hospital Pilot Study</td>
</tr>
<tr>
<td>1:50pm – 2:00pm</td>
<td>Markus Kufeld, MD, MS (Charité CyberKnife Center, Berlin, Germany)</td>
<td>Robotic Radiosurgery: Emulating Brachytherapy in Patients with Locally Advanced Cervical Carcinoma. Technique, Feasibility and Acute Toxicity</td>
</tr>
<tr>
<td>2:00pm – 2:10pm</td>
<td>All Speakers: Extracranial Other &amp; Emerging Technology Q &amp; A</td>
<td></td>
</tr>
<tr>
<td>2:10pm – 2:20pm</td>
<td>Martin Fuss, MD (Oregon Health &amp; Science University, Portland, Oregon)</td>
<td>Transarterial Ethiodol-based Hepatocellular Carcinoma (HCC) Embolization (TACE): Impact on Volumetric Image-Guidance for SBRT and Hypofractionated Radiation Therapy (HFxRT)</td>
</tr>
<tr>
<td>2:20pm – 2:30pm</td>
<td>Jessica Varley (Phoenix Cyberknife &amp; Radiation Oncology Center, Phoenix, Arizona)</td>
<td>SBRT is Non-Inferior to Standard Chemoradiation for Locally Advanced, Non-Metastatic Pancreas Cancer: A Meta-Analysis of Published Data</td>
</tr>
<tr>
<td>2:30pm – 2:40pm</td>
<td>Anand Mahadevan, MD (Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts)</td>
<td>Stereotactic Body Radiotherapy for Unresectable Large and/or Multiple Hepatocellular Carcinoma</td>
</tr>
<tr>
<td>2:40pm – 2:50pm</td>
<td>Malolan Rajagopalan, MD (University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania)</td>
<td>Pathologic Response after Stereotactic Body Radiotherapy for Borderline Resectable and Locally-Advanced Pancreatic Cancer</td>
</tr>
<tr>
<td>2:50pm – 3:00pm</td>
<td>All Speakers: Gastrointestinal Q &amp; A</td>
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### Short Oral Posters

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker &amp; Institution</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>3:00pm – 3:05pm</td>
<td>Zsolt Levente January, MD (Liege University Hospital, Liege, Belgium)</td>
<td>PET CT Supported Robotic SBRT for Primary and Secondary Lung Lesions: Clinical Outcome</td>
</tr>
<tr>
<td>3:05pm – 3:10pm</td>
<td>Elizabeth Ester, MD (University of Minnesota Medical Center, Minneapolis, Minnesota)</td>
<td>Lung Reirradiation with Stereotactic Body Radiotherapy (SBRT)</td>
</tr>
<tr>
<td>3:10pm – 3:15pm</td>
<td>Dominique Mathieu, B. Eng. (Centre hospitalier de l’Université de Montréal, Quebec, Montréal, Canada)</td>
<td>Accuracy of Breath-hold CT and Treatment Planning for Lung SBRT</td>
</tr>
<tr>
<td>3:15pm – 3:20pm</td>
<td>Kristina Young, MD, PhD (Oregon Health &amp; Science University, Portland, Oregon)</td>
<td>A Retrospective Review of SBRT for Larger Brain Metastases or Post-Resection Cavities</td>
</tr>
<tr>
<td>3:20pm – 3:25pm</td>
<td>Christy Goldsmith, MD, FRCR, MRCP, BSc (Harley Street Clinic, London, United Kingdom)</td>
<td>Stereotactic Ablative Body Radiotherapy (SABR) for Pancreas Cancer: Lessons to Learn from Toxicity</td>
</tr>
<tr>
<td>3:25pm – 3:30pm</td>
<td>Christy Goldsmith, MD, FRCR, MRCP, BSc (Harley Street Clinic, London, United Kingdom)</td>
<td>Stereotactic Ablative Body Radiotherapy (SABR) to Lymph Node Oligometastases - UK Experience &amp; Clinical Outcome: An Update</td>
</tr>
<tr>
<td>3:30pm – 3:35pm</td>
<td>David Clump, MD, PhD (University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania)</td>
<td>Stereotactic Body Radiotherapy for Recurrent Oropharyngeal Cancer - Influence of HPV and Smoking History</td>
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### WORKSHOP – Coastal Events Center

<table>
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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>3:00pm – 5:45pm</td>
<td>Introduction To Thoracic SRS/SBRT Workshop – this is a ticketed event</td>
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<tr>
<td></td>
<td>Day 1: The Principles</td>
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### EVENING EVENT – Costa Del Sol

<table>
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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>5:30pm – 7:30pm</td>
<td>Mix &amp; Mingle Reception</td>
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</table>
Friday, February 22, 2013

GENERAL SESSION – Costa Del Sol, Salon A-D

7:00am – 7:10am  Alexander Muacevic, MD
RSS Morning Greeting

Thoracic

7:10am – 7:20am  Ben Slotman, MD, PhD (VU University Medical Center, Amsterdam, The Netherlands)
SABR: An Alternative for Surgery in Stage I NSCLC?

7:20am – 7:30am  Peyman Kabolizadeh, MD, PhD (University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania)
Salvage Stereotactic Body Radiation Therapy (SBRT) for Medically-Inoperable Patients with NSCLC following RFA

7:30am – 7:40am  Lindsay Mathew, PhD (Juravinski Cancer Centre, Hamilton, Ontario, Canada)
Evaluation of PTV Margins for Lung SBRT on CyberKnife and Trilogy

7:40am – 7:50am  John Lamond, MD (Philadelphia CyberKnife, Philadelphia, Pennsylvania)
Comparison of Stereotactic Body Radiation Therapy Results for Clinical Stage 1 Non-Small Cell Lung Cancer Using 3 Different Tracking Modalities

7:50am – 8:00am  Nisha Patel, MD (Drexel University College of Medicine, Philadelphia, Pennsylvania)
Stereotactic Ablative Radiotherapy for Re-Irradiation of Lung Cancer Recurrence

8:00am – 8:10am  John Vargo, MD (University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania)
Stereotactic Body Radiotherapy Salvage for Locally-Recurrent Central Non-Small Cell Lung Cancers

8:10am – 8:20am  Alan Monroe, MD (Penrose Cancer Center, Colorado Springs, Colorado)
Monte Carlo Calculations Associated with Superior Clinical Outcomes Relative to Pencil Beam Calculations in Early Stage Lung Cancer

8:20am – 8:30am  All Speakers: Thoracic Q & A

THE SHOWDOWN RETURNS

8:30am – 10:00am  Robert J. Cerfolio, MD, FACS, FCCP and Gregory M.M. Videtic, MD, CM, FRCPC
(University of Alabama, Birmingham, Birmingham, Alabama and Cleveland Clinic, Cleveland, Ohio)
Early Stage Lung Cancer

10:00am – 10:30am  Break

10:30am – 12:00pm  Matthew R. Cooperberg, MD, MPH and Alan J. Katz, MD
(UC San Francisco, San Francisco, California and Flushing Radiation Oncology, Flushing, New York)
Early Stage Prostate Cancer

12:00pm – 1:30pm  Lunch

1:30pm – 3:00pm  Kim Burchiel, MD, FACS and Douglas Kondziolka, MD, MS, FRCS(C)
(Oregon Health and Science University, Portland Oregon and New York University, New York, New York)
Trigeminal Neuralgia
**WORKSHOP – Coastal Events Center**

<table>
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<tr>
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</tr>
<tr>
<td></td>
<td>Day 2: Lung Treatment Planning Practicum</td>
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<td>Gardenia, Orchid &amp; Iris</td>
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**ADMINISTRATION BREAKOUT – Costa Del Sol, Salon A-D**

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>3:30pm – 5:00pm</td>
<td><strong>Obstacles for Reimbursement</strong></td>
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**EVENING EVENT – Costa Del Sol**

<table>
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<th>Time</th>
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<tbody>
<tr>
<td>5:30pm – 7:30pm</td>
<td><strong>Poster Reception</strong></td>
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**Saturday, February 23, 2013**

**PERFORMANCE AND QUALITY IMPROVEMENT SESSION – Costa Del Sol, Salon A-D**

<table>
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<tbody>
<tr>
<td>8:00am – 8:15am</td>
<td><strong>John J. Kresl, MD, PhD</strong> <em>(Phoenix CyberKnife &amp; Radiation Oncology Center, Phoenix, Arizona)</em></td>
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<td>8:15am – 10:00am</td>
<td><strong>Case Study Presentations</strong></td>
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<td>10:00am – 10:30am</td>
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<td>10:30am – 12:15pm</td>
<td><strong>Case Study Presentations</strong></td>
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<td>12:30pm - 1:30pm</td>
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**AFTERNOON & EVENING EVENTS**

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<td>2:00pm – 6:00pm</td>
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<td>6:00pm – 9:30pm</td>
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Risk of Leptomeningeal Disease in Patients Treated with Stereotactic Radiosurgery Targeting the Post-Operative Resection Cavity for Brain Metastases

Scott G Soltys, Leslie A Modlin, Banu Atalar, Iris C Gibbs, Steven D Chang, Griffith Harsh, John R Adler, and Clara YH Choi

Presented by: Scott Soltys, MD

Objectives: We sought to determine the risk of leptomeningeal disease (LMD) in patients treated with stereotactic radiosurgery (SRS) targeting the post-operative cavity following surgical resection of a brain metastasis, deferring whole brain irradiation (WBRT) in all patients.

Methods: We retrospectively reviewed 175 brain metastasis resection cavities in 165 patients with evaluable follow-up imaging treated with post-operative SRS from 1998 to 2011. No patient had WBRT. LMD was defined through radiologic and/or pathologic findings. The local cavity, distant parenchymal brain, and leptomeningeal brain failure rates were calculated using the competing risk analyses, with death as a competing risk. Control rates were censored at the time of last follow-up or at the time of salvage WBRT. Factors associated with LMD were determined through univariate analysis. The overall survival rate was calculated using the Kaplan-Meier estimates.

Results: Median follow-up duration was 12 months (range, 1 - 156 months). Median overall survival was 18 months. The cumulative incidence rates of local cavity failure at 1- and 2- years were 10% and 14%, respectively. Twenty-one patients (13% crude rate) developed LMD at a median of 5 months (range, 2 – 33 months) following SRS. The 1- and 2- year cumulative incidence rates of LMD were 11% and 13%, respectively. Posterior fossa (p=0.5) or pial (p=0.2) location was not associated with LMD. The factors predictive for LMD on univariate analysis were new parenchymal metastases (p=0.009) and breast cancer histology (p=0.004). Both continued to be significant on multivariate analysis (p=0.03 and 0.007, respectively). The 1 year rate of LMD was 24% for breast (n=26 patients) vs. 9% for non-breast (n=139) histology. The receptor status of breast cancer patients did not correlate with risk of LMD. All LMD patients were subsequently treated with WBRT. Median survival following the diagnosis of LMD was 7 months (range, 1 - 37 months).

Conclusions: Patients treated with SRS targeting the post-operative cavity following resection of breast cancer metastases have a higher risk of LMD in this series. Whether the inclusion of WBRT would decrease the rate of LMD or if the biology of breast cancer brain metastases places patients at higher risk irrespective of the treatment choice is unknown. We encourage all future reports on SRS cavity boost to include the risk of LMD.
Adjuvant Tumor Bed Radiosurgery Following Surgical Resection of Intracranial Metastases

Joel S. Katz, Marina Kushnirsky, Jonathan P.S. Knisely, Maged Ghaly, Michael Schulder

Presented by: Maged Ghaly, MD

Objectives: Post-resection adjuvant radiosurgery (SRS) of metastases avoids the use of whole brain radiation therapy (WBRT). There have been few previous studies analyzing outcomes of this approach. We evaluated LC of metastatic tumors in patients undergoing resection followed by adjuvant SRS.

Methods: We reviewed all patients from our institution who were treated with adjuvant SRS following resection of intracranial metastases between 01/2010 and 09/2012. We abstracted diagnosis, tumor location, treatment date, SRS target volume, and other SRS parameters. Serial MRI scans between 0.8–23.2 months after SRS provided LC data. Imaging responses after adjuvant multiple or single fraction SRS were compared using chi-square.

Results: 53 patients with 54 lesions were identified. 34 lesions (62.9%) were > 3 cc. 28 lesions underwent single session SRS and 26 received 3 sessions. The median prescription dose and the median target volume for single session lesions were 20 Gy (16–21 Gy) and 2.1cc (0.13-1.73 cc). Corresponding values for multiple session lesions were 24 Gy (19.5-27 Gy) and 8.9 cc (11.3-44.8 cc). 46 tumors (85%) had post-SRS LC. 7 of 8 lesions without LC had single session SRS. LC was better for lesions treated with 3 SRS fractions than for lesions treated in a single session (P = 0.01).

Conclusions: Following surgical resection of intracranial metastatic lesions, 3-session SRS yielded improved LC relative to single-fraction SRS, despite the larger tumor and SRS volumes in the fractionated group. Our results support consideration of fractionating postoperative adjuvant SRS for patients with metastatic brain tumors.
Primary Radiation Therapy for Unbiopsied Presumed Meningioma: 
Analysis of Post-Treatment Related Seizure Toxicity 
with Stereotactic Radiosurgery

Robert B Taylor MD, PhD, Philip E Schaner MD, Aleksandar F Dragovic MD, James M Markert MD, Barton L Guthrie MD, Michael C Dobelbower MD, PhD, Sharon A Spencer MD, Christopher D Willey MD, PhD, John B Fiveash MD

Presented by: Robert B. Taylor, MD, PhD

Objectives: Radiation therapy has come to play an increasing role in the primary treatment of meningiomas. Both conventional fractionation and stereotactic radiosurgery (SRS) have been used. One of the toxicities associated with radiation treatment has been the development of post-treatment seizures. Here we compare the development of post-treatment seizures between those patients treated with SRS and conventional fractionated radiotherapy as well as identify factors predictive of seizure toxicity in patients that have never undergone surgery. 

Methods: The records of patients treated at the University of Alabama at Birmingham between 1988 and 2009 who were treated with radiation therapy for meningioma were reviewed. After excluding patients who had undergone surgery or had tissue diagnoses as well as those with pre-treatment seizures, 152 patients were available for analysis. Seizure toxicity was assessed with clinical follow up and defined as those with evidence of seizure and requiring anti-epileptics (RTOG grade 2 toxicity or higher). 

Results: Fifty-four patients were treated with conventional fractionated radiotherapy with a median dose of 5220 cGy in 29 fractions (range 5040cGy to 5760cGy) and 98 patients were treated with SRS with a median dose of 1200 cGy in a single fraction (range 1200 cGy to 1600 cGy). No patients developed post-treatment seizures in the conventional therapy group while 7 (7.1%) developed post treatment seizure in the SRS group (p=0.044 on univariate analysis). However, the post-treatment seizures were confined to the parasagittal and supratentorial convexity and no conventionally treated patients had parasagittal tumor location and only one supratentorial convexity tumor was treated conventionally. When stratified by tumor location there was no statistically significant difference between the conventional and SRS groups. Within the SRS treated group, tumors located in the parasagittal region were statistically more likely to develop post-treatment seizures (17.2%) than those treated elsewhere (2.9%) p=0.012. Those SRS patients that received dose of 1300 cGy or higher had a trend toward the development of post treatment seizures compared to those with dose of 1200 cGy (p=0.057). Patient sex, age and steroidal requirements during treatment were not statistically related to post-treatment seizures. None of those with post-treatment seizures developed recurrence. There was no statistical difference in 5 year actuarial local control (96.7% for conventional radiotherapy and 95.5% for SRS; LogRank(Mantel-Cox) p=0.684). 

Conclusions: In unbiopsied patients with suspected WHO grade I meningioma treated with definitive radiation therapy, those treated with SRS to the parasagittal region may be at higher risk of developing grade 2 or higher post-treatment seizures than patients treated elsewhere. Doses of 1300 cGy or higher may also increase this risk. Future studies comparing the effect of tumor size, specific performance of conventional versus SRS in the parasagittal region as well as the risk of developing other post-treatment toxicities are needed.
The Role of Stereotactic Radiosurgery in Cavernous Sinus Hemangiomas

Xin Wang, M.D., Xiaoxia Liu, M.D., Guanghai Mei, M.D., Huaguang Zhu, M.D., Jiazhong Dai, M.D., Li Pan, M.D., and Enmin Wang, M.D.

Presented by: Xin Wang, MD, PhD

Objectives: Cavernous sinus hemangioma is a rare vascular tumor. The direct microsurgical approach usually results in massive hemorrhage. The purpose of this study was to assess the efficacy of Stereotactic radiosurgery with the CyberKnife in patients with cavernous sinus hemangiomas.

Methods: 34 patients with cavernous sinus hemangiomas were treated in our center between December 2007 and December 2011. The volume of the tumors ranged from 0.84 cm³ to 102 cm³. The Doses ranged from 1300 cGy to 2100 cGy in one to 4 sessions.

Results: After a mean follow-up of 20 months (range, 6-48 months), the magnetic resonance images showed a mean of 81.6% tumor volume reduction. Among the 21 patients with cranial nerve impairments before treatment, 3 achieved symptomatic complete resolution and 13 had improvement. No radiotherapy-related complications were observed during follow-up.

Conclusions: Our current experience, though preliminary, substantiates the role of Stereotactic radiosurgery with the CyberKnife for cavernous sinus hemangiomas. Although a longer and more extensive follow-up is needed, Stereotactic radiosurgery with the CyberKnife is effective in reducing the tumor volume without causing any new deficits and can be considered as a treatment modality for large cavernous sinus hemangiomas.
Reirradiation of Cervical Spine Metastases with Stereotactic Body Radiosurgery

Lomas, Harry; Bennion, Nate; Richardson, Martin; Spencer, Kelly; McAllister, William; Sheehan, Jason; Kersh, Ronald

Presented by: Harry Lomas, IV, MD

Objectives: Stereotactic body radiotherapy for progressive spinal metastases previously irradiated is a viable option in well selected patients. The authors examine a series of spinal metastasis patients reirradiated with stereotactic body radiosurgery (SBRT).

Methods: Using our institutional database we collected data from 253 cases of spinal radiation for metastasis. There were 37 cases of cervical spine radiation for metastasis treated between 2007 and 2011. We further identified 11 cases of reirradiation of the cervical spine region with complete data available, including dose per fraction, total dose of both treatment courses, and appropriate follow-up. Spinal magnetic resonance imaging was performed before treatment initiation and either CT or MRI at regular follow-up intervals to evaluate for disease progression. The National Cancer Institute Common Toxicity Criteria version 3.0 was used to evaluate toxicity.

Results: The median and mean interval between initial radiotherapy and SBRT re-irradiation was 15 months (range 1 to 49 months), and 18.3 months respectively. Mean and median follow-up periods were 18.4 months (range 4-60 months) and 15 months respectively. No patients experienced myelitis, progression of fracture or a new fracture. Radiographic local control was 100%. Toxicity was limited to grade 1 dysphasia in 3 patients and 1 patient had grade 1 dermatitis. The cumulative doses for the SBRT ranged from 15 to 24 Gy with a mean dose of 20.45 Gy given in 3 treatment fractions with one treatment per week.

The patients were immobilized in typical supine full supported fashion with a vacuum bag system. The planning and treatment component was conducted with the majority of the plans categorized as Forward Planned, static field, static aperture with reserved comparison to IMRT and VMAT when necessary. A small field biased Superposition / Convolution algorithm was used for planning and delivery was executed with a 6MV beam with a 4mm MLC. A robotic couch was used for daily repositioning and stereotactic treatment alignment.

Conclusions: Reirradiation for progressive cervical spinal metastases with stereotactic body radiosurgery results in excellent local control and with minimal toxicity.

However, it is prudent to propose the collection of prospective data from a greater number of patients receiving BED doses in the range of 136-150 Gy to assess the safety of higher retreatment doses for those patients in whom lower doses might convey a reduced rate of tumor control.
Salvage Single-Fraction Stereotactic Body Radiotherapy
for Patients with Prior Radiation of Spinal Metastases

M. Ghaly, M. Kushnirsky, E. Montchal, F. Diaz-Molina, M. Marrero, L. Vijeh, M. Schulder, A. Latefi, J. Knisely

Presented by: Maged Ghaly, MD

Objectives: As spinal cord tolerance often precludes reirradiation with conventional techniques, local recurrence of spinal bony metastases within a previously irradiated field presents a treatment challenge.

Methods: We reviewed the treatment plans of 10 patients with spine metastases (24 spinal segments) who initially received conventional external beam radiation (EBRT). All were reirradiated with single-fraction SBRT (16 Gy) at or above the L2 vertebral body with the spinal cord itself verified and contoured by MRI or post operative CT myelogram imaging at the treatment level. Gross tumor was contoured as the planning target volume; no additional margins were used. Spinal cord dose–volume histogram (DVH) endpoints were constructed, keeping D0.35 (dose to 0.35cc of spinal cord volume) < 10 Gy, D1.2 < 8 Gy and any cord point max dose (Pmax) <12 Gy. The biologically effective doses (BED) using a/ß = 2 Gy for late spinal cord toxicity were calculated and normalized to a 2-Gy equivalent dose (nBED = Gy2/2).

Results: SBRT was given at median 7 months (range, 2-36) after conventional palliative radiotherapy. Median distance from the tumor to spinal cord surface was 3.4 mm (range, 1.3-9.0). Tumor encased = 180° of the spinal canal circumference in 42 % of lesions. The median prescription isodose was 86% (range 65-90%) and targeted a median tumor volume of 7.3 cc (range, 3—74-cc). The initial conventional radiotherapy nBED ranged from 30 to 45 Gy2/2 (median 37.5 Gy 2/2). The SBRT reirradiation cord point dose (mean P max) in BED was 33.9 Gy2/2. The mean total (Pmax) nBED was approximately 71.5 Gy2/2.

The average percentage of the total (Pmax) nBED accounted for by the SBRT (Pmax) nBED was 47%. After a median post-SBRT follow-up of 10 months, no radiation-induced myelopathy or radiculopathy has occurred.

Conclusions: SBRT given at least 7 months after conventional palliative radiotherapy with a reirradiation spinal cord (Pmax) nBED = 34 Gy 2/2 appears to be safe provided the total (P max) nBED does not exceed approximately 72 Gy 2/2, and the SBRT cord (P max) nBED comprises no more than approximately 50% of the total nBED.
Estimated Risk Level of Unified SBRT Dose Tolerance Limits for Spinal Cord

Jimm Grimm, PhD, Gary Luxton, PhD, Arjun Sahgal, MD, Scott Soltys, MD, Ashish Patel, MD, Scott Herbert, MD, Jinyu Xue, PhD, Lijun Ma, PhD, John R. Adler, MD, Iris C. Gibbs, MD

Presented by: Jimm Grimm, PhD

Objectives: A variety of guidelines have been reported to estimate spinal cord dose tolerance for patients treated with stereotactic body radiation therapy (SBRT). The purpose of this work is to comprehensively analyze dose-volume data of a cohort of patients treated by SBRT in order to estimate the complication probability and compare these probabilities to dose tolerance limits currently in clinical use.

Methods: An extensive literature review of English-language publications identified 59 spinal cord dose tolerance limits suggested for clinical use. These guidelines were partitioned into a unified format of high-risk and low-risk dose tolerance limits. A dataset of spinal cord dose-volume points were interpolated from a previously published cohort of 74 patients with 102 spinal metastases in whom 3 patients developed treatment-related severe myelopathy. Seventy-four percent (50/68) of previously treated patients had prior radiation. Dose-volume data was digitized into the DVH Evaluator software tool where the rest of the DVH was approximated and parameters of the probit dose response model were fitted to the data using the maximum likelihood approach. We estimated risk levels for spinal cord dose-volume parameters including maximum dose, D1cc, and D0.1cc, and compared the corresponding risk level with the published suggested guidelines for spinal cord tolerance.

Results: Based on the risk model generated from this limited dataset, the Accuray STARS 20Gy to 1cc limit and the RTOG 0813 30Gy maximum limit had the highest risk levels, at about 5%, and most of the other unified dose tolerance limits had 1-3% risk. Only one of the unified low-risk limits had higher than 3% risk. Two thirds of patients in this study had prior irradiation so it is likely that in other patient populations the risk level of these limits will be lower.

Conclusions: While severe myelopathy is an unacceptable complication, no clinical procedure is without risk. Guidelines, therefore, should aim to minimize the risk of injury to 1-3% or less. No single dose-volume parameter can be relied on to predict this complication, however, it is likely that the use of multiple dose-volume-based guidelines may improve safety. Based on the findings of this study, the current guidelines for D0.1cc as well as the low-risk guidelines for maximum dose (Dmax) may be useful to establish the lower limits of tolerance. Longer follow-up with more patients from more institutions is required to improve the risk estimates.
Knowledge Based Spinal Cord Sparing Models and Individualized Trade-offs in Spine SBRT Planning

Q. Jackie Wu, Lulin Yuan, Taoran Li, John Kirkpatrick, Fang-Fang Yin, Yaorong Ge

Presented by: Fang-Fang Yin, PhD

Objectives: This project focuses on the modeling and distribution of human expert knowledge in designing high quality IMRT/VMAT plans for Spine SBRT treatment.

Methods: A major source of expert’s clinical knowledge is embedded in the prior treatment plans that have been developed by expert physicians and planners and proven to be effective and optimal for that patient. This project proposes a novel approach to learning from existing databases of high-quality Spine SBRT plans and developing models to predict optimal dose coverage that are specific to an individual patient. Further, the knowledge models are trained to quantify the dose sparing trade-offs between OAR dose sparing and target dose coverage.

IMRT/VMAT plans of 21 spine SBRT plans were used to build the knowledge models. The final models were tested by the leave-one-out method.

Results: For Spine SBRT planning, the most significant patient anatomical feature that affects cord sparing is the tightness of the geometric enclosure of PTV surrounding the cord and the homogeneity of PTV dose coverage.

The most significant OAR dose sparing trade-off is the interaction between cord dose sparing and PTV dose coverage in spine SBRT plans.

The dosimetric parameters predicted for the test patient cases using the knowledge models were in agreement with those from the clinical plans in more than 75% of the cases.

Conclusions: The knowledge models are capable of predicting OAR dose sparing based on expert experiences and their prior IMRT/VMAT plans. These knowledge models will help physicians and planners to design high quality of treatment plans customized to individual patient’s anatomy, and obtain better cord dose sparing by exploring different trade-off options in Spine SBRT treatment.
Stereotactic Body Radiation Therapy for Low-, Intermediate- and High-Risk Prostate Cancer: Disease Control and Quality of Life at Five Years

Alan J. Katz, MD

Objectives: Stereotactic body radiation therapy (SBRT) takes advantage of the prostate’s low a/ß ratio to deliver a large radiation dose in few fractions. Initial studies on small groups of low-risk patients support SBRT’s potential for clinical efficacy while limiting treatment-related morbidity and maintained quality of life (QOL). This prospective study expands upon prior studies to further evaluate SBRT efficacy and QOL for a large patient population that includes low-, intermediate- and high-risk prostate cancer patients.

Methods: 515 patients with organ-confined prostate cancer (471 T1c and 44 T2a, all N0M0) received CyberKnife SBRT. The mean age was 69 years and the mean PSA was 6.48 ng/ml. 343 patients were low-risk (PSA = 10 ng/ml and Gleason < 7), 134 were intermediate-risk (PSA 10-20 ng/ml or Gleason = 7), and 38 were high-risk (PSA > 20 ng/ml or Gleason > 7). Androgen deprivation therapy was administered to 70 patients for up to one year. 158 patients received 35 Gy delivered in 5 daily fractions. These patients were either low risk or low-intermediate risk. The remaining patients, from all risk groups, received a total dose of 36.25 Gy in 5 daily fractions. The dose was prescribed to a planning target volume (PTV) created by a 5 mm expansion of the prostate gross tumor volume (GTV), with a 3 mm posterior expansion. The proximal seminal vesicles were included for intermediate- and high-risk patients. The PTV was covered by the 83-87% isodose line; real-time intrafractional motion tracking was used. Biochemical failure was assessed using the Phoenix criterion.

Results: At a median follow-up of 50 months (range, 9-76 months), 38 patients died of other unrelated causes and 28 were lost to follow-up. The median PSA at 60 months was 0.11 ng/ml. Biochemical failures occurred for 7 low-risk patients (none locally), 8 intermediate-risk patients (one locally), and 9 high-risk patients (2 proven local failure). The 5-year freedom from biochemical failure was 97%, 93%, and 74%, for the low-, intermediate- and high-risk groups (p < 0.001). For low and low-intermediate risk patients, there was no difference in terms of median nadir or biochemical control between doses of 35 and 36.25 Gy. Late RTOG toxicity was mild with 4% Grade 2 rectal, 7.8% Grade 2 urinary, and 1.4% Grade 3 urinary (all with 36.25Gy). Late Grade 2 urinary toxicity for 35Gy was 5.1% vs 9.9% for 36.25 Gy(p=.01). Mean EPIC urinary and bowel QOL declined at 1 month post-treatment and returned to baseline by 2 years where it remains. EPIC sexual QOL declined by 23% at 6-12 months where it remains. 76 percent of the patients potent at baseline remain potent.

Conclusions: CyberKnife SBRT produces excellent biochemical control rates at up to 6 years with mild toxicity and minimal impact on quality of life. Median PSA levels compare favorably with other radiation modalities and strongly suggests durability of response. Further follow-up is needed to determine if these results are durable in the long term. These results also strongly suggest that 35 Gy is as effective as 36.25 Gy for low and low-intermediate risk patients with less urinary toxicity.
**Long Term Results of Hypofractionated Radiation for Organ-Confined Prostate Cancer**

Debra Freeman, MD; Jay Friedland, MD; Mary Ellen Masterson-McGary, MA, MS; David Spellberg, MD

Presented by: Debra Freeman, MD

**Objectives:** To review outcomes of SBRT treatment for prostate cancer at >5 years follow up.

**Methods:** Between February 2005 and June 2007, 155 men with low-intermediate risk prostate cancer (stage T1c-T2b; Gleason <7) were treated in Naples, FL with stereotactic, hypofractionated radiation using a CyberKnife system. All received 35 Gy in 5 fractions, delivered in a homogeneous dose distribution. One hundred thirty-six were treated with radiation alone; 19 received short-course hormonal therapy prior to radiation. Mean age was 70 years (range 53-87). Mean initial PSA was 5.5 ng/ml (range 1.1-17.2). Median follow up for the entire cohort was 4.5 years; 65 men had more than 5 years follow up.

**Results:** Biochemical progression-free survival (nadir +2 definition) at 5 years was 92%. Six patients developed biopsy-confirmed local recurrence, 30-60 months following treatment. One developed distant metastases at 12 months, with no evidence of residual local disease.

One patient experienced rectal bleeding at 18 months post-treatment, controlled conservatively. Two required TURP following treatment for urinary obstructive symptoms. No other significant late GU or GI toxicity has been reported. Comparing SHIM scores at baseline and 5 years following treatment, 60% of patients reported "erections sufficient for intercourse" prior to treatment; 44% reported the same at 5 years.

**Conclusions:** At 5+ years of follow up, outcome results for hypofractionated SBRT for low-intermediate risk prostate cancer remain favorable, with no evidence of delayed toxicity.
A New and Effective Treatment Approach for Non Resectable Renal Tumors: Feasibility and Early Results

Alexander Muacevic, Markus Bader, Boris Schlenker, Jozefina Casuscelli, Alexander Karl, Christian G. Stief, Berndt Wowra, Michael Staehler

Presented by: Alexander Muacevic, MD

Objectives: To evaluate safety and efficacy of single fraction high dose radiosurgery in patients with renal tumors.

Methods: Thirty-three eligible patients with surgically untreatable renal tumors seen at the Klinikum Großhadern hospital in Munich were entered into a prospective study, between December 2007 and May 2011. Twenty patients were male; median age was 64 years. Only patients with an eastern cooperative oncology group (ECOG) status of 0 or 1 and a live expectancy of more than 1 year were treated with SRS. Patients with surgically removable renal lesions were not included. Tumor histology was confirmed in all patients prior to study entry. In twelve patients histology of renal tumors was transitional cell cancer (TCC) and twenty-one patients had primary renal cell cancer mainly of clear cell origin. Prior to SRS gold fiducials were planted into the renal parenchyma under ultrasonographic guidance. Follow up was done every three months using computer tomography scanning and laboratory test for renal function. Tumor response in follow up imaging, local tumor control rate, renal function, progression-free survival, overall survival, and adverse events.

Results: Thirty-eight lesions were treated. Median follow-up was 11.2 months (2.7 - 31.8 months). Local tumor control nine months after SRS was 98% (95% CI: 89-99%). 31 lesions showed a measurable tumor size reduction and eighteen complete remissions. In eight patients the tumor-size stabilized. There were no treatment related deaths, and no late complications after SRS noted so far. Renal function remained stable with a median serum creatinine at baseline of 1.30 mg/dl and 1.35 mg/dl at six months follow-up. In one patient grade I erythromdermia was seen, three patients suffered from grade I fatigue and two patient had grade I nausea.

Conclusions: Our initial results of this completely new approach for selected patients with renal tumors proof SRS being safe and effective. Single-fraction delivery as an outpatient procedure can avoid nephrectomy and hemodialysis. Oncological results with a short follow-up are similar to those of other ablative techniques in renal tumors. Functional results are so far excellent. Further studies are needed to determine the limits of SRS in this setting and long term oncological and functional results.
**Phase I Dose-Escalation Study of Stereotactic Body Radiotherapy (SBRT) for Organ Confined Prostate Cancer**

M. Ghaly, M. Marrero, L. Vijeh, E. Montchal, L. Lee, L. Potters

Presented by: Maged Ghaly, MD

**Objectives:** To evaluate patient’s tolerability of the initial dose levels in a dose-escalation study for localized prostate cancer, using linear accelerator–delivered SBRT.

**Methods:** Eligible patients included those with Gleason score < 7 with prostate-specific antigen (PSA) = 10, Gleason score 7 with PSA = 15, T2b, prostate size = 60 cm3, and American Urological Association (AUA) score = 15. Patients were enrolled in a prospective single-institution, institutional review board-approved study. Pretreatment preparation required intraprostatic fiducial marker placement and thin cut MRI of 1.5 mm thickness acquired and fused with the simulation CT of each patient. Starting at 40 Gy in 5 fractions (delivered twice a week), the dose was safely escalated to 45 Gy in 5 fractions. All treatments were prescribed to the 90% isodose surface and were given with a dedicated 6 MV linac-integrated stereotactic delivery system (Novalis, BrainLAB, Munich). An X-ray verification accuracy threshold of 1.0 mm and intra-fraction verification was performed every 60 seconds during treatment to ensure accurate targeting and accommodating intrafractional prostate motion without treatment interruption*. Dose-limiting toxicity (DLT) was defined as grade 3 or worse GI/GU toxicity by CTCAEv3. Patients completed Expanded Prostate Cancer Index Composite (EPIC) prostate quality of life questionnaires starting at 3 weeks post treatment and every three-months thereafter.


**Results:** Twelve patients with organ confined prostate cancer completed the initial dose level (40 Gy in five fractions over two weeks) and ten were treated in the second dose level of 45 Gy in 5 fractions biweekly. Mean baseline AUA score was 5.5. The worst GU toxicity reported during treatments was grade 1 in 67% in both dose levels, and grade 2 in 42% and 50% respectively; with a single grade 3 toxicity (X%). Two patients experienced grade 1 rectal bleeding. After a median follow-up of 12 months (range 11-20 month) for patients in dose level one and 7 months in dose level two (range, 3 -12 months) no delayed GI toxicity was reported. Six patients reported grade 1 erectile dysfunction with a decreased libido in 3. Transient grade 1 increased urinary frequency was noticed in 4 patients, two in each level. Rectal quality-of-life scores remained at the baseline levels at both dose levels. In all patients, PSA control is 100% by the nadir + 2 ng/mL failure definition.

**Conclusions:** Linear accelerator–delivered SBRT to organ-confined prostate cancer using our approach and with dose level of 45 Gy in 5 fractions is well tolerated. Longer follow up is warranted to assess long-term toxicity and tumor control rates. The results of this study allow for treating patients to 50 Gy in five fractions to further evaluate this investigational therapy.
Early Outcome Results from the Multi-Institutional Registry for Prostate Cancer Radiosurgery (RPCR)

Mark Perman, MD; Debra Freeman, MD; Gregg Dickerson, MD

Presented by: Mark Perman, MD

Objectives: The RPCR was developed to track and collect clinical outcome data for prostate cancer patients across the U.S. treated with stereotactic radiosurgery.

Methods: Retrospective data was collected from 35 centers currently treating localized prostate cancer with stereotactic radiosurgery. From July 2010 to July 2012, 1100 patients were entered in the Registry database. Baseline and post-treatment outcome measures recorded included PSA level, International Prostate Symptom Score (IPSS), Bowel Health Inventory (BHI), International Index for Erectile Function (IIEF) and Quality of Life score.

Results: Median PSA decreased from a baseline level of 5.7 ng/ml to 0.5 ng/ml at 24 months. IPSS and BHI scores remained stable at 24-30 months post-treatment. Mean IIEF score was 15 prior to treatment, decreasing slightly to 12 at 24-30 months post-treatment.

Conclusions: Registries like the RPCR are an effective way to track clinical outcomes from new or innovative therapies such as prostate radiosurgery, reducing evidentiary gaps that can impede patient access to care.
Prostate SBRT in Five Fractions: 2 Year Clinical Trial Protocol Review and Analysis on Dosimetric and IGRT

Q. Jackie Wu, Taoran Li, Lulin Yuan, Fang-Fang Yin and W. Robert Lee

Presented by: Fang-Fang Yin, PhD

Objectives: This mid-way protocol review and analysis summarizes our first 2 year experiences on a 37Gy/5-fraction prostate SBRT protocol from a dosimetry and IGRT prospective.

Methods: The IRB approved clinical trial has treated 28 patients (total accrual target of 60 patients) with stage T1-T2c prostate cancer over past 2 years, with a regimen of 37Gy in 5 fractions using IMRT and IGRT protocols. Precise patient and prostate positioning and dynamic tracking of prostate motion were performed with electromagnetic localization device (Calypso) and on-board imaging (OBI) system.

Planning: The prostate is delineated on co-registered CT/MRI image set; planning target volume (PTV) is defined as the prostate plus a margin of 3mm in posterior direction and 5mm elsewhere. Primary organs-at-risks (OARs) include the bladder, the rectum, and the femoral heads.

Treatment & Dynamic Tracking: Patient and target alignment is performed based on fiducials with OBI imaging system and Calypso system. Prior to treatment, cone-beam CT (CBCT) is performed for soft tissue alignment verification. During treatment, per-beam corrections for target motion using translational couch movements is performed before irradiating each field, based on electromagnetic localization or on-board imaging localization.

Analysis: Dosimetric analysis on target coverage and OAR sparing is performed based on key DVH parameters corresponding to protocol guidance. Treatment delivery analysis is focused on the average frequency and magnitude of corrections during treatment, and overall intra-fractional target drift. A margin value is derived using actual target motion data and the margin recipe from Van Herk et al, and is compared to the current one in practice. In addition, cumulative doses with and without per-beam IGRT corrections are compared to assess the benefit of online IGRT.

Results: 1. No deviation has been found in 10 of 14 dosimetric constraints, with minor deviations in the other 4 constraints.
2. Online IGRT techniques including Calypso, OBI and CBCT supplement each other to create an effective and reliable system on tracking target motion and correcting intra-fractional motion.
3. On average ½ corrections have been performed per fraction, with magnitude of (0.22±0.11) cm. Average target drift magnitude is (0.7±1.3) mm in one direction during each fraction.
4. Benefit from per-beam correction in overall review is small: most differences from no correction are < 0.1 Gy for PTV D1cc/Dmean and < 1%/1.5 cc for OAR parameters. Up to 1.5 Gy reduction was seen in PTV D99% without online correction. Largest differences for OARs are -4.1cc and +1.6cc in the V50% for the bladder and the rectum, respectively.
5. Margin derived from actual target motion is 2.5 mm isotropic, consist with current practice.

Conclusions: Initial experience in a 37Gy/5-fraction prostate SBRT protocol is reported. Dosimetric analysis demonstrated excellent target coverage and OAR sparing for our first 28 patients in this trial. Online IGRT techniques implemented are both effective and reliable. Per-beam correction in general provides a small benefit in dosimetry. Target motion measured by online localization devices confirms that current margin selection is adequate.
Radiosurgery to Create Lesions in the Pulmonary Vein Antrum: Preliminary Results in a Porcine Model and Possible Implications for the Treatment of Atrial Fibrillation

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Presented by: Oliver Blanck, Dipl. Inf.

Objectives: Radiosurgery has found its way into clinical routine practice for a variety of selected benign indications. Radiosurgery of the heart for potential treatment of cardiac arrhythmias has recently been under investigation, exploring the feasibility of atrial flutter ablation in animals. The most common arrhythmia in humans is atrial fibrillation, where electrical isolation of the pulmonary veins has been established in clinical routine as a curative treatment. While invasive catheter ablation carries significant risks, radiosurgery might be able to non-invasively induce lesions at the pulmonary vein ostia comparable to catheter ablation to block the electrical veno-atrial connections. We present first results of a porcine feasibility and dose escalation study to create lesions in the left atrial-pulmonary vein junction using radiosurgery.

Methods: The study was conducted in 10 adult Göttingen-Mini-Pigs (weight 40-60 kg). Two animals were used for baseline evaluation without radiation exposure and 8 were treated with single fraction radiosurgery. The animals underwent general anesthesia and ventilation and were fixated in a tight vacuum bag during treatment. Cardiac MRI was performed before radiosurgery to assess heart function, pulmonary vein anatomy and myocardial scarring. Electrophysiological voltage mapping was performed in the left atrium and the target vein using the NavX Ensite System. A homogeneous dose ranging from 17.5 Gy to 35 Gy was applied circumferentially to the upper right pulmonary vein antrum. For compensation of cardiac and respiratory motion during treatment we used margins derived from 4D cardiac CT during inspiration and expiration. Radiation was delivered with a conventional linear accelerator (Varian DHX 2100) using a stereotactic frame and ConeBeam CT for setup. Six months after radiosurgery, MRI and electrophysiological mapping were repeated and results were compared to pretreatment findings. Animals were sacrificed and a histological examination was performed to assess radiation related lesions at the target vein antrum and potential collateral damage to adjacent structures such as the bronchus or the aorta.

Results: At baseline all animals had normal heart function assessed by MRI. Voltage mapping consistently showed electrical potentials in the upper right pulmonary vein. Pacing the target vein prompted atrial excitation, thus proving veno-atrial electrical conduction in this model. 6 months after treatment MRI assessment demonstrated no adverse effects on general heart function. A dose-dependent decrease of potential amplitude in the target area was noted at doses above 30Gy though without complete electrical block. Histology revealed a dose-response-relationship of the targeted area with fat tissue necrosis at doses above 20Gy and partial transmural scarring in the muscle tissue at doses above 30Gy. With the highest doses, small damages to the adjacent bronchial tree were noted as well as stenosis of a smaller sub branch of the targeted pulmonary vein.

Conclusions: This proof-of-principle-study demonstrates for the first time that radiosurgery with a conventional linear accelerator is able to induce focal lesions in anatomically defined areas of the pulmonary vein antrum with a subsequent reduction in electrophysiological signals and the creation of scar. The preliminary results indicate that doses above 30 Gy may be necessary to achieve an electrical conduction block at the pulmonary vein antrum in normal pig hearts at 6 months after treatment. Further studies are needed to prove complete pulmonary vein isolation with optimized radiation parameters.
CyberKnife Radiosurgery for Early Stage Breast Cancer: Updated Results and Technique from the Winthrop-University Hospital Pilot Study

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Diane Accordino, R.N., Matthew R. Witten, Ph.D.

Presented by: Jonathan Haas, MD

Objectives: Standard radiation therapy for patients with breast cancer desiring breast conservation typically consists of lumpectomy followed by radiation. Radiation can either be delivered to the whole breast or to part of the breast. Whole breast radiation is given daily for 3-6 weeks depending on the dose/fractionation scheme. When partial breast irradiation is given, often an implanted catheter is used to deliver a conformal dose of radiation to the lumpectomy cavity in an accelerated manner over one week. In properly selected patients, the results for partial breast irradiation appear comparable to results for conventional whole breast radiation. We examined the safety and efficacy of using Cyberknife for selected patients with early stage breast cancer after lumpectomy and report on our technique and updated results.

Methods: 15 consecutive patients with Stage 1 breast cancer were enrolled on the Winthrop-University Hospital IRB approved CyberKnife breast protocol. Eligibility included Stage I/II (< 3 cm) Age >45, margins negative. 1 patient had fiducial markers placed by the surgeon. The other 14 patients had fiducial markers placed by the treating radiation oncologist using image guidance on a CT simulator with coordinate placement determined by the physics/dosimetry staff for optimal location. Patients were immobilized either using a thermoplastic cast with a hole removed around the areola to allow for reproducibility daily or with an alpha cradle to allow the breast to remain in its natural position. All patients received a dose of 3000cGy in 5 fractions of 600 cGy each given on five consecutive days. The median number of beams was 86. The median prescription isodose line was 71%. This isodose was chosen to allow for a more rapid fall of dose beyond the target volume to more accurately emulate HDR treatment.

Results: With a median follow-up of 1 year, (range 4-24 months) all 15 patients (100%) remain locally controlled with no evidence of disease following treatment. RTOG Grade 1 dry skin desquamation occurred in 1 of 15 patients. The cosmesis was good-excellent in all twelve patients using the Harvard cosmesis scale.

Conclusions: With updated term follow-up, Cyberknife radiosurgery for early stage breast cancer is very well tolerated and efficacious for selected patients desiring breast conservation after lumpectomy. More accrual and further follow-up will be required to see if these results remain durable.
Robotic Radiosurgery: Emulating Brachytherapy in Patients with Locally Advanced Cervical Carcinoma. Technique, Feasibility and Acute Toxicity

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Presented by: Markus Kufeld, MD, MS

Objectives: The aim of this study was to evaluate the technique, dosimetry and acute toxicity of a CyberKnife boost irradiation replacing the standard intra-cervical brachytherapy in patients with cervical cancer.

Methods: Eleven patients (32–69 years) with histologically proven FIGO stage IIB–IIB cervical cancer underwent primary chemoradiation. During the third week, after fiducial implantation, a T2 contrast-enhanced planning MRI and a new CT scan were conducted in provisioned treatment position. On Multiplan workstations the clinical target volume was defined as cervix plus macroscopic residual tumour on MRI. Rectal wall, bladder wall and sigmoidal wall were contoured as organs at risk. Five fractions of 6 Gy each were prescribed to the target volume. In order to allow dose inhomogeneity within the tumour comparable to intra-cervical brachytherapy, the surrounding isodose was defined between 60–70%. Dose-volume parameters (DVH) were evaluated for the target and organs at risk. Three months after treatment, a curettage could be performed in 10 of the 11 patients to confirm complete response, one patient underwent clinical follow up. Acute toxicity was documented once a week according to CTCAE version 4.03.

Results: Median planning target volume (PTV) was 48.9 cc. Median dose to the PTV (DmeanPTV) was 36.7 Gy with a median coverage of 97.7%. For the complete treatment, a median EQD2 to 1 cc and 2 cc of the bladder wall was 98.8 Gy and 87.1 Gy, respectively. Median EQD2 to 1 cc and 2 cc of the rectal wall was 72.3 Gy and 64 Gy, respectively, correlating with a risk far below 10% for Grade 2-4 late toxicity. Gastrointestinal (GI) and genitourinary (GU) toxicity was mild: grade 1 in 9 patients, grade 2 in two patients. There was no grade 3 or higher GI and GU toxicity. After 6 months of follow up there were no local recurrences.

Conclusions: CyberKnife robotic radiosurgery emulating a brachytherapy boost in patients with cervical cancer is feasible and safe. The technique delivers excellent target coverage with steep dose gradients toward normal tissues and provides safe DVH parameters for bladder, rectum and sigmoid. Acute toxicity was mild. Longer follow-up is needed to evaluate the oncological benefit.
Transarterial Ethiodol-based Hepatocellular Carcinoma (HCC) Embolization (TACE): Impact on Volumetric Image-Guidance for SBRT and Hypofractionated Radiation Therapy (HFxRT)

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Presented by: Martin Fuss, MD

Objectives: Image-guidance for HCC suffers from a lack of contrast between tumor and liver parenchyma. IGRT strategies have employed liver or diaphragm contour and spine alignment or metallic fiducials as surrogates. Transarterial chemoembolization (TACE) is a level 3 evidence treatment for HCC. If iodine-rich Ethiodol is used as embolizing agent, the treated HCC is stained by this radio-opaque oil. We assessed the quality and durability of Ethiodol tumor stains and their suitability for daily volumetric image-guidance.

Methods: 51 patients underwent staged TACE prior to SBRT (50 Gy/5 fx; n=37) or HFxRT (45 Gy/18 fx; n=14). These multi-modality treatments were administered under an institutional protocol. We assessed quality of HCC Ethiodol stains in simulation CT and in cone-beam CT acquired for daily image-guidance. Quality in simulation CT were graded as excellent (dense stain with mean HU of >350 and diameter >10 mm), good (mean HU of 200-350 or dense stain with diameter <9 mm), fair (mean HU <200 without dense focal retention), and poor (faint or no stain). All CBCT (n=437) were reviewed and suitability of the tumor stain for image-guidance was graded. A stain excellently suited for image-guidance was readily visible on CBCT and did not change in shape during the course of radiation delivery. Good stains provided sufficient information for image-guidance, but required careful windowing of the CBCT scan. Poor quality was assessed when only punctuate densities were seen, or stains barely provided any imaging-information or were not seen.

Results: Simulation scans showed excellent and good tumor stains in 29, and 11 cases (78%). Fair stains were recorded in 5 CTs, and no Ethiodol was retained in 6 tumors. Mean lesion size was 23 mm (range 6 to 56 mm), and corresponding mean tumor stain was 23 mm (range 4 to 56 mm). Mean HU in excellent tumor stains was 698, with densities up to 1276 HU. Suitability of the stain for CBCT image-guidance was graded as excellent and good in 26 and 13 cases (76%). Poor quality was assessed in the remaining cases. Four cases showed some loss in Ethiodol stain during the course of treatment; their score changed from excellent in simulation CT to good on CBCT (change was observed from the first day, with no further loss of stain). One case each was graded as good, fair and poor in simulation CT and upgraded to excellent (n=1) and good (n=2) in CBCT review. There was no variability between treatment days in the grading of the CBCT.

Conclusions: TACE or TAE-based Ethiodol tumor stain facilitates volumetric image-guidance for SBRT and HFxRT of HCC. All tumors that showed staining in simulation CT retained that stain for the course of radiation therapy; a minor change in stain density was observed in less than 10% of cases, but was still serviceable for image-guidance. TACE and TAE stains persisted for up to 43 months, the longest imaging follow-up available in the studied population.
Objectives: Image-guided body stereotactic radiosurgery (SBRT) is an emerging treatment option for definitive therapy of locally advanced pancreatic cancer. The objective of this study was to assess the efficacy of this treatment by combining data from the available small, single institution published series.

Methods: The MEDLINE database was searched to identify publications reporting on the outcomes of cohorts of at least 20 patients without imaging evidence of metastatic disease treated with body radiosurgery. The actuarial overall survival plots from these studies were digitized. Individual patient survival data were reconstructed as per the method of Guyot et al. (BMC Medical Research Methodology 2012, 12:9). The accuracy of the data reconstruction process was verified by comparing the calculated Kaplan-Meier survival probabilities from the reconstructed data with the published results. The individual patient survival data was then aggregated to create the combined actuarial survival data. Similar methodology was used to reconstruct aggregate survival data from five Phase I/II prospective trials of gemcitabine-based, standardly fractionated chemoradiation each with cohorts of 20 patients with locally advanced, non-metastatic disease.

Results: Seven studies of pancreatic radiosurgery were identified meeting the inclusion criteria, which included a total of 274 patients. The aggregate, actuarial median survival after radiosurgery was 12.6 months with 6 month, 1 year, and 2 year survival probabilities of 85%, 52%, and 22%, respectively. The aggregate, actuarial median survival of 199 patients treated on the prospective ECOG, Hoosier Oncology Group, Israeli, and CALGB chemoradiation therapy trials was 10.8 months with 6 month, 1 year and 2 year survival probabilities of 74%, 44%, and 15 %, respectively. This represented a non-significant trend towards better survival with SBRT as compared to chemoradiation with a HR for death of 0.89 (95% CI 0.73 – 1.08, p = 0.24).

For patients treated with SBRT, overall survival was statistically improved with neoadjuvant versus adjuvant chemotherapy with a HR for death of 0.71 (95% CI 0.55 – 0.92, p = 0.01). The median survival was 13.7 months in the three studies in which more than 90% of patients received induction chemotherapy prior to SBRT (n = 114 patients) versus 11.1 months in the four studies (n = 160 patients) in which chemotherapy was given after radiosurgery. The delivered BED varied across studies from 47.2 Gy10 - 87.5 Gy10. When treated as a continuous variable, no radiotherapy dose response was identified (HR 1.01, 95% CI 0.997 – 1.013, p = 0.17).

Conclusions: Meta-analysis of published reports of SBRT for locally advanced, non-metastatic pancreatic adenocarcinoma using reconstructed individual patient survival data suggests this therapy is not inferior to standard chemoradiation therapy. The apparently equivalent outcomes indicate that future randomized trials comparing SBRT to conventional chemoradiation may need to be conducted using a non-inferiority design. Patients receiving induction chemotherapy prior to SBRT appear to have more favorable outcomes than those treated with up-front radiosurgery. It is unclear if this is due to selection of favorable prognosis patients with chemosensitive disease or due to chemosensitization or another biologic interaction between the timing of systemic therapy and SBRT. There was no clear radiation dose response, although this may be confounded by the stronger effect of chemotherapy timing. These data support the development of prospective randomized trials comparing induction chemotherapy followed by SBRT versus standard chemoradiation.
Stereotactic Body Radiotherapy for Unresectable Large and/or Multiple Hepatocellular Carcinoma

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Presented by: Anand Mahadevan, MD

Objectives: Hepatocellular carcinoma (HCC) is a significant problem in Asia and its incidence is rising in the USA. Surgical resection and transplantation remain the curative treatment options. Liver directed therapies including RFA (Radio Frequency Ablation) and TACE (Trans Arterial Chemo Embolization) have been successfully used but may have limitations due to size, location and background liver function. Stereotactic Body Radiotherapy (SBRT) has been used in Liver tumors. We explored the use of SBRT in unresectable large and multiple HCC when other liver directed therapies were not appropriate.

Methods: 57 Patients presented Between September 2005 and March 2012, in a Multidisciplinary Liver Tumor Clinic, with unresectable large and/or multiple HCC, who were otherwise deemed unsuitable for RFA or TACE were included in this study. Patients needed to have at least 750ccs of uninvolved Liver. There were 9 women and 48 men. 68 Lesions were treated with SBRT using the Cyberknife system. All patients had fiducial gold seeds and contrast enhanced CT for treatment planning. In 3 fractions, the tolerance doses for the liver was set to be V15<50% and V21<21%, the tolerance to the Kidneys was V12<30% and the Tolerance to the Bowel was <8Gy to <30% of circumference with point dose not> 10Gy per fraction.

Results: 68 lesions in 57 patients were included in this study. There were 9 women and 48 men with a mean age of 62 (range 23-88yrs). 35 patients had Child’s A disease, 18 had Child’s B and 4 had Child’s C disease. Based on tolerance to residual liver, patients were treated with 3 fractions of 8-15Gy each with a mean total dose of 32Gy and a mean maximum dose of 41.53Gy. The mean conformity and homogeneity indices were 1.44 and 1.3 respectively. 13 patients progressed in the treated area, giving a local control rate of 77%. There were 5 complete responses (9%) and the remaining (69%) was stable or smaller. Most patients tolerated the treatment with mild fatigue being the major immediate effect. However all patients in Child’s C and 8 Patients in Child’s B worsened in their Child score with an overall 23% decline in Liver function.

Conclusions: Patients with unresectable large and multiple HCC have a dismal prognosis and other established liver directed therapies may often not be appropriate. SBRT offers an effective treatment modality for these patients. Caution should be exercised in treating patients with poor background liver function, which could further deteriorate.
**Pathologic Response after Stereotactic Body Radiotherapy for Borderline Resectable and Locally-Advanced Pancreatic Cancer**

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Presented by: Malolan Rajagopalan, MD

**Objectives:** Neoadjuvant stereotactic body radiotherapy (SBRT) is being increasingly explored in the management of borderline resectable and locally-advanced pancreatic adenocarcinoma. In this report, we present the pathologic outcomes in the subset of patients who underwent surgery after completion of neoadjuvant SBRT.

**Methods:** Patients with biopsy-proven borderline resectable or locally-advanced pancreatic adenocarcinoma who were treated with SBRT followed by surgical resection were included in this study. Patients were treated between 2008 and 2011. SBRT was prescribed as either 24 Gy in a single fraction or 36 Gy in three fractions. Chemotherapy was to the discretion of the medical oncologist and was delivered prior to SBRT for most patients. All surgeries were performed by experienced pancreatico-billiary surgical oncologists.

**Results:** Twelve patients met inclusion criteria and all were available for analysis. Average age was 65.6 (range: 48.2 – 82.2) and 42% were male. Most patients (92%) received neoadjuvant systemic therapy with gemcitabine/capecitabine as the most frequently used (n=7), followed by FOLFIRINOX (n=2), gemcitabine/erlotinib (n=1), gemcitabine alone (n=1). Most patients were treated with fractionated SBRT to a dose of 36 Gy in 3 fractions (58%) and the remainder with single fraction to 24 Gy. The mean target volume was 16.6 cm³ (range: 5.1 – 44.6 cm³). No grade 3 or higher toxicities attributable to SBRT were found. The mean time to surgery after SBRT was 3.3 months (range: 1.5 – 6.6 months). A complete resection with negative margins was performed in 92% of patients (n=11/12). In 25% (n=3/12) of patients, a complete pathologic response to neoadjuvant treatment with no viable neoplasm was achieved. An additional 25% (n=3/12) demonstrated extensive response to treatment as demonstrated by significant fibrosis with tumor necrosis and/or <10% viable tumor cells. Post-operatively, two patients had bleeding complications and one died secondary to this. Median survival was 17.1 months for entire cohort and 22.6 months for those with a complete or extensive pathologic response.

**Conclusions:** This is the first study to report the pathologic response in patients who completed neoadjuvant chemotherapy and SBRT for borderline resectable and locally-advanced pancreatic cancer. In our experience to date, 92% achieved an R0 resection and 50% of patients demonstrated either complete or extensive pathologic response to treatment. Three patients achieved a complete pathologic response. The results of a phase II study of this novel approach will be forthcoming.
PET CT Supported Robotic SBRT for Primary and Secondary Lung Lesions: Clinical Outcome

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Presented by: Zsolt Levente Janvary, MD

Objectives: To report the clinical outcome of treatment using robotic Stereotactic Body Radiotherapy (SBRT) for patients with primary or secondary lung lesions ineligible for surgery, or refusing surgical intervention. The target volume determination was predominantly supported by fused treatment planning PET CT, and metabolic imaging was also widely applied in evaluation of clinical outcome.

Methods: Between April 2010 and March 2012, one hundred and nineteen patients with a total of 130 lung lesions were treated with 40 to 60 Gy in 3 to 5 fractions using Cyberknife (Accuray, Sunnyvale, US). Median age at treatment was 71 years (range 40-93). Primary NSCLC represented 59% of the lesions and 24% were oligometastases. 17% were a mixed group consisting of local relapse or intrapulmonary metastases of a former lung cancer, or solitary lymph node recurrence. Large or centrally located lesions were not excluded. Risk adapted fractionation schemes were applied in order to reduce toxicity. For this analysis, treatments were classified in high dose (H, 67%) and low dose (L, 33%) groups in function of BED higher or lower than 120 Gy10. In 95% of the cases PET CT images acquired in treatment position were applied to help delineation. For all patients a GTV to PTV margin of at least 5 mm was taken. Histological confirmation was available in 65% of the lesions. Lesion tracking (with or without fiducials) was done were possible (44%). The mean and median follow up time (FUP) were 13 and 14 months, respectively. Inclusion criteria for the present analysis were a minimum of 6 months of FUP or the availability of at least one control PET CT examination. Toxicity was prospectively evaluated using CTCAE ver4.

Results: The actuarial 1-, and 2 year Kaplan–Meier local control rates for lesions treated with high doses were 94 and 76%, compared to 74 and 68% for the low-dose group (p=0.011). Overall survival for the whole study population at 1 and 2 years was 84 and 67%, respectively. During the follow up 85% (n=107) of the lesions were evaluated using PET CT, in addition to a contrast enhanced CT. In a total of 52 (49%) cases out of this 107 we observed a complete metabolic response. 41 out of these 52 lesions were treated in the "high dose range", representing 47 % of lesions treated with a BED higher than 120 Gy10. Severe acute toxicity was observed in 2 patients, one with a Grade 3 radiation pneumonitis, requiring hospitalisation, and one with a possibly treatment-related pulmonary haemorrhage causing death (Grade 5 toxicity). Severe late toxicity was observed in 1 patient presenting a Grade 3 sick sinus syndrome, requiring a pacemaker implantation. Rib fracture was observed in 3 patients (< Grade 2). One patient developed Grade 2 recurrent laryngeal nerve palsy. Grade 2 late radiation pneumonitis was observed in 11 patients. Grade 2 pneumothorax after transthoracic marker placement occurred in 6 cases.

Conclusions: In our mixed study population of primary and secondary, central and peripheral lung lesions, robotic SBRT showed 1-, and 2 year local control rates comparable to published data, especially in the high dose group. An important proportion of this latter group developed a documented complete metabolic response. The rate of severe toxicity was low.
Lung Reirradiation with Stereotactic Body Radiotherapy (SBRT)

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Presented by: Elizabeth Ester, MD

Objectives: There is limited available data on the use of SBRT in reirradiation of lung tumors.[1,2,3] We reviewed the survival, recurrence pattern and toxicity following SBRT after previous thoracic radiotherapy at the University of Minnesota Medical Center.

Methods: From August 2006 through October 2012, fourteen tumors in thirteen patients with either biopsy confirmed Non-Small Cell Lung Cancer or patients with presumed NSCLC who were medically unable to undergo biopsy, were retreated with SBRT. Four tumors were centrally located. Patients were treated with 9 or 10 Gy per fraction for a total of five fractions, delivered every other day. Eligible patient charts were retrospectively reviewed to evaluate survival, recurrence pattern and toxicity following reirradiation. NCI-Common Terminology Criteria for Adverse Events (CTCAE) v4.0 was used to evaluate toxicity.

Results: The median age of patients at the time of SBRT was 67.9 years (Range 45.9-86.7 years). One patient did not complete the prescribed course of SBRT and was therefore excluded from analysis. The median duration of follow-up for remaining patients was 11.4 months (Range 0.9-38.3 months). Ten patients had received prior conventional thoracic radiation with a median dose of 6120 cGy. Two patients received previous SBRT with curative intent. The median time to reirradiation with SBRT was 19.7 months (Range 4.7-84.7 months). Following reirradiation with SBRT, eight patients (67%) had progressive disease. There were five distant recurrences, two regional recurrences and only one patient developed an isolated local recurrence. Local control of the retreated tumors was 92%. There have been six deaths, all of which were in patients with progressive disease, at a median of 17.6 months from completion of SBRT. Four patients (33%) are alive and disease free, a median of 14.0 months from completion of SBRT. There was one grade 2 toxicity, described as lobar atelectasis occurring six months following SBRT. There was one grade 3 toxicity occurring in a patient who developed oxygen dependence four months following SBRT. There were no grade 4 or 5 toxicities.

Conclusions: SBRT is a reasonable salvage therapy for lung tumor recurrence in patients previously treated with thoracic radiotherapy, offering good local control and resulting in acceptable toxicity. However, controlling regional and systemic progression of disease remains a challenge. Further evaluation of this treatment option is warranted.
Accuracy of Breath-hold CT and Treatment Planning for Lung SBRT

Dominique Mathieu, Charles Martel, Marie-Pierre Campeau, Édith Filion, Toni Vu, Jean-François Carrier

Presented by: Dominique Mathieu, B.Eng.

Objectives: At Centre hospitalier de l’Université de Montréal (CHUM), lung stereotactic body radiotherapy treatments (SBRT) can be delivered with several machines including a Cyberknife unit. Treatment planning includes a four-dimensional computed tomography (4DCT) scan during free breathing (FB) to evaluate tumor range of motion and a breath-hold (BH) CT scan, preferably at end-expiration (EE), used for dose calculation. The aim of this study is to measure conformity of tumor position on BH CT scans relative to natural tumor path during FB and to evaluate the benefits of Abches (Apex Medical, Inc). Abches is a breathing monitoring device that allows the patient to self-control the respiratory motion of the chest and abdomen.

Methods: In 53 lung cancer patients (17 inferior lobes), 4DCT and BH CT images were obtained. For 12 patients, BH CT scan was acquired using Abches device. Natural tumor motion was assessed by using local rigid registration of region of interest on the end-inspiration (EI) and EE phases of the 4DCT scan. Tumor motion was modeled as a linear movement since no patient showed significant hysteresis trajectory on 4D analysis. Absolute differences between BH and EE 4DCT phase were also measured.

Results: The average natural movement amplitude of gross tumor volume (GTV) was (1.2±1.2) mm, (2.2±1.9) mm, and (5.6±6.4) mm in medio-lateral, anterior-posterior, and cranio-caudal (CC) directions, respectively. The CC motion of GTV in lower lobe was larger than in upper lobe (10.7±8.9) mm vs (3.3±3.0) mm. Among the 41 patients scanned without Abches, 26 (63%) presented tumor position on BH CT scan closer to EE than to EI 4DCT phase. Among the 12 patients scanned with Abches, the proportion was 75%. For the 53 BH scans, 40 (75%) showed a GTV standing within a 3 mm radius of tumor trajectory observed on 4DCT. For marginal BH, GTV displacements perpendicular to natural tumor path were as great as 6.3 mm, 6.4 mm and 10.5 mm and couldn’t systematically be avoided using Abches.

Conclusions: Tumor position during BH CT may not accurately correspond to positions observed on FB 4DCT, cases done with Abches monitoring device included. Hence, accurate and custom 4D analysis for each individual patient is recommended for treatment planning. The benefits of using Abches would need further evaluation in a larger cohort of patients. For real-time respiratory tracking treatment on Cyberknife (Fiducial, Xsight lung), using marginal BH CT for dose calculation could result in an underestimation of the effective dose to organ at risk. For patients treated with an internal target volume technique on Cyberknife (Xsight spine), treatment planning based on a marginal BH may result in significant increase in treatment volume.
A Retrospective Review of SBRT for Larger Brain Metastases or Post-Resection Cavities

Kristina Young, MD, PhD, Faisal Siddiqui MD, PhD, James Tanyi, PhD, Carol Marquez, MD, Charlotte Kubicky, MD, PhD, Martin Fuss, MD, PhD

Presented by: Kristina Young, MD, PhD

Objectives: Radiation treatment for brain metastases is typically delivered by whole brain radiation (WBRT), stereotactic radiosurgery (SRS), or a combination of these modalities. However, there are patients with solitary tumors or post-resection tumor cavities that are not candidates for SRS owing to a maximum target diameter larger than 3 cm, for which an avoidance of WBRT may provide a quality of life benefit. Here we summarize treatment data and outcomes of patients who underwent stereotactic hypofractionated radiation therapy for brain metastases or resection cavities ranging from 3 to 6 cm in maximum diameter (SBRT brain).

Methods: We performed a single-institution retrospective analysis of treatment parameters and outcomes of 46 patients treated by SBRT brain between July 2007 and February 2012. The most common fractionation was 30 Gy in 5 fractions (n=21), followed by 35 Gy in 5 fractions (n=16), and 25 Gy in 5 fractions (n=4). Treatments were delivered using a BrainLab/Varian NovalisTx linear accelerator over 5 consecutive days on 30 patients, and every other day in 16 patients, respectively. Image-guidance employed daily stereotactic x-rays for 6D setup correction (ExacTrac, Brainlab), and subsequent cone-beam CT (OBI, Varian) for volumetric validation. Clinical and dosimetric data was obtained from the electronic charts. We analyzed for local tumor control, normal tissue complications, and survival.

Results: Mean follow-up was 8.3 months (range 0 to 41 months). Forty-three percent of treated metastases were non-small cell lung cancer, 15% melanoma, and 7% renal cell carcinoma. Eighty-three percent of patients underwent resection prior to radiation, 13% of tumors were intact. Twenty-six percent had tumor recur locally, with median local recurrence free survival of 3.6 months in intact tumors versus 10.1 months in resected tumors. Rate of local recurrence did not correlate with dose or histology. Thirty percent of patients had non-local in-brain failure, with median non-local brain recurrence free survival of 7.4 months. Fifty-eight percent of patients with local failure also failed elsewhere in the brain. Median overall survival was 6.3 months, 5.0 months in intact tumors versus 9.9 months in resected tumors.

Acute treatment related side effects were mild and included fatigue and focal hair loss. The incidence of radiologically evident radionecrosis was 8.7%, with average onset of 23 months. However, none of these cases showed clinical symptoms, or warranted a therapeutic intervention. Fifteen percent of patients underwent additional radiation therapy procedures, including whole brain radiation (6.5%) and additional focal radiation therapy (SRS or SBRT brain) for new brain lesions (8.7%).

Conclusions: SBRT brain for larger brain metastases and post-resection cavities can be administered with a favorable side effect profile. Outcomes after SBRT for brain metastases compare favorably to historical data for WBRT. While longer-term survival was observed, in-brain failure and/or systemic disease progression are limiting overall survival. The observed local recurrence rate warrants a prospective study of dose escalation.
Stereotactic Ablative Body Radiotherapy (SABR) for Pancreas Cancer: Lessons to Learn from Toxicity

Dr. Christy Goldsmith, Prof. Pat Price, Dr. Nicholas Plowman
Presented by: Christy Goldsmith, MD, FRCR, MRCP, BSc

Objectives: To examine the influence of patient specific factors, treatment planning variables, and treatment delivery parameters on toxicity and treatment outcome.

Methods: 48 patients with unresectable pancreatic tumours were studied. All were treated with CyberKnife at Harley Street Clinic, London, between 2009 and 2012. Patient specific factors, including tumor site, stage and previous treatment, were retrieved from patient records. A majority of patients (n=45, 94%) had fiducials sited. Three patients (6%) were tracked with XSight Spine. Following planning scans, 45 patients (93%) received 18–36Gy in 3 fractions (BED 29-79, a/β ratio of 10 for tumour control). A single patient received 10Gy in 1 fraction, and 2 patients (4%) received 25Gy/5# (BED 38Gy10). Dose was prescribed to the Median 66% isodose, (Range = 52-78%). The Synchrony system was used for tumor tracking in all who had fiducials sited. Treatment planning and delivery variables, including dose/fractionation, biologically equivalent dose (BED), and planning target volume (PTV), were prospectively collected. Acute and late toxicity was scored using EORTC Common Toxicity Criteria Adverse Events version 3 (CTCAEv3).

Results: 79% of patients had pancreatic head tumors, 17% body tumors and 4% tail tumors. The majority (90%) had T3 or T4 unresectable primary pancreatic cancer. A majority of patients (77%) had received prior chemotherapy, 21% had undergone previous surgery, and 23% had received prior radiotherapy. Most patients (65%) had 3 or more fiducials sited for tracking purposes. Median PTV size was 69cc (Range 16cc-259cc), Median BED was 51 Gy10 and Median treatment time was 67 minutes per fraction.

Acute toxicity rate was low: 34% showed no acute toxicity and 52% showed toxicity = grade 2. The most common all grade acute toxicities were fatigue(26%), nausea(22%) and abdominal pain(20%). Only 3 (7%) patients had grade 3 acute toxicity (obstructive jaundice, fatigue and pain, respectively).

To date, median follow-up is 208 days (7 months).

Late toxicity (= grade 2) has been experienced by four patients. One patient had Grade 2 late toxicity (nausea and abdominal pain) a year after CyberKnife, the patient had been too frail to receive prior chemotherapy. A further patient had Grade 3 duodenal haemorrhage 4 months after CyberKnife treatment, with stable disease on imaging at this time, although endoscopy reported “tumour erosion of the duodenum”. There were two cases of duodenal stricture possibly related to CyberKnife treatment. Investigation into the aetiology of the strictures in these cases is ongoing.

One patient has importantly converted to resectable (and therefore potentially curable) status.

After full statistical analysis of patient factors, treatment planning, and treatment delivery parameters and outcome (toxicity) data, there did not appear to be any statistically significant relationships, but this may be because toxicity incidence was low. This is likely to reflect good patient selection, highly conformal treatment planning (Median nCI=1.18), and accurate treatment delivery. Ongoing data collection and analysis, including inter-fraction shifts of the Target/Organ At Risk interface due to duodenal filling changes, may reveal additional information.

Conclusions: Toxicity was low, below that of contemporary studies. Patient, planning and delivery factors did not appear to be related to toxicity, suggesting that dose escalation may be less risky to duodenum/small bowel than previously thought. However, the low incidence of serious duodenal late toxicity experienced highlights the need for caution and further study to investigate contributory factors.
Stereotactic Ablative Body Radiotherapy (SABR) to Lymph Node Oligometastases - UK Experience & Clinical Outcome: An Update

Dr. Christy Goldsmith, Dr. Alex Martin, Dr. Nicholas Plowman, Dr. Andrew Gaya

Presented by: Christy Goldsmith, MD, FRCR, MRCP, BSc

Objectives: We report the acute toxicity and clinical outcome of SABR delivered to lymph node oligometastases.

Methods: Between February 2009 and July 2012, 37 consecutive patients with unresectable nodal metastases were treated with SABR delivered via the CyberKnife system. The median age was 61 (range 42-86 years). Of these patients, 29 (78%) had node-only metastases, while 8 patients (22%) had dominant nodal lesions as part of oligometastatic disease, defined as up to five metastases. A PET scan confirmed disease extent in 31 patients (84%).

14 (38%) had received prior conventional radiotherapy to the target nodal site. Patients had been pre-treated with a median of 2 lines of systemic therapy (Range 0-7). Disease Free Interval prior to SABR was recorded. A total of 41 lymph node sites were treated, anatomical location of sites treated: Neck (n=3), Thorax (n=14), Abdomen (n=14), and Pelvis (n=10). Histopathology of Primary: Colorectal (n=12), Breast (n=8), Urological (n=6), Lung (n=4), Gynae (n=3), and Other/Unknown primary (n=4).

Median CTV to PTV margin was 2 mm (range 0-5mm). PET or MR fusion were used if appropriate to aid target delineation in addition to the Contrast-enhanced CT planning scan.

The dose/fractionation regimes used were 18Gy single, 24-36Gy in 3 fractions (BED 43 - 79 Gy10 assuming a/B=10) and 35-47Gy in 5 fractions (BED 60- 91Gy10). The most commonly used regime was 24Gy in 3 fractions (14 patients, 38%). Dose was prescribed to the median 66% isodose (range 48-78%). 23 patients had fiducials inserted (14 of these tracked with Synchrony), and 18 sites were tracked using X-Sight Spine.

Primary endpoint was radiological progression at the treatment site.

Secondary end-points included Progression Free Survival (PFS) and Overall Survival (OS). PFS was defined as the time to progression, or death, whichever came first. All endpoints were calculated from the date of the first radiation treatment.

Results: Acute toxicity data was available for 28 patients (76%). 61% had no acute toxicity. Grade 1-2 toxicity was experienced by 34%, most commonly Grade 1 fatigue. There was one case of grade 2 to grade 3 pain escalation in a disease progressor following SABR to a pelvic lymph node metastasis.

There have been 2 cases of Grade 3 late treatment-related toxicity. Both patients had received prior conventional radiotherapy.

Follow up information was available for 34 patients (92%), with a total of 36 treatment sites, at median follow up 14 months. There was evidence of in-field disease progression in 5 sites (14%) giving a crude local control rate of 86%. All that progressed locally were treated with the lowest BED regimes (of 43Gy10). Local Control was 100% in those treated to a BED of at least 50Gy10.

Distant disease progression was documented in 18 patients (53%), translating to a Freedom from Distant Disease Progression rate of 47%.

Three patients have died, giving a crude Overall Survival rate of 88%. The cause of death was disease progression in all patients.

An analysis by histopathology of the primary showed a particularly favourable response in Colorectal Cancer patients with a Median progression-free survival of 22 months.

Conclusions: SABR is a feasible and well-tolerated treatment for patients with lymph node oligometastases. Local control rates in this series are very good, with a Local Control rate of 100% when SABR is prescribed to a threshold BED of 50Gy10 i.e., single fraction>18Gy, >27Gy in 3 fractions, or >35Gy in 5 fractions. Colorectal histology is associated with a more favourable outcome versus other histology (Median Progression Free Survival of 22 months).
Stereotactic Body Radiotherapy for Recurrent Oropharyngeal Cancer -
Influence of HPV and Smoking History

Clump DA, Vargo JA, Rwigema JC, Davis K, Ferris R, Heron DE, Quinn A, Burton S

Presented by: David Clump, MD, PhD

Objectives: Prospective clinical data has identified 3 distinct risk groups of head-and-neck cancer patients based on HPV status and smoking history. The low-risk group has considerably better outcomes in local-control (LC) and overall survival (OS). Despite this, local recurrences are still common across all the sub-groups. SBRT ± cetuximab has emerged as a promising salvage strategy for locally-recurrent, previously-irradiated head-and-neck cancer (rHNC) relative to conventional re-irradiation ± chemotherapy. However the influence of HPV and smoking status remains unknown in the setting of salvage strategies.

Methods: All patients (n=29) with rHNC of the oropharynx salvaged with SBRT ± cetuximab from February 2005 through January 2010 were retrospectively reviewed. SBRT consisted of primarily 40-50Gy in 5 fractions delivered on alternating days over 1.5-2 weeks. Concurrent cetuximab was administered at a dose of 400mg/m2 of day -7 followed by 250mg/m2 of day 0 and +7 in n=19 patients (68%) including patients on our prospective institutional protocol UPCI 06-093 (results not yet reported).

Results: The 6-month actuarial LC for the entire cohort was 50%. Patients with HPV positive disease (n=6) had 6-month LC of 60% vs 46% for (n=22) HPV negative/not-recorded (p=0.524). The 6-month LC for never smokers was 83% vs 25% for smokers with <40 year pack history vs 29% for heavy smokers with =40 year pack history (p=0.013). The 6-month OS for the entire cohort was 74%. The 6-month OS for HPV positive patients was 83% vs 71% for HPV negative/not-recorded (p=0.195) with no significant difference in OS by smoking status (p=0.612).

Conclusions: Never smokers and patients with HPV positive rHNC cancers have a trend towards superior LC and OS following salvage SBRT ± cetuximab comparable to the definitive setting which may permit differentially aggressive salvage strategies by risk-group stratification as data continues to emerge supporting salvage SBRT ± cetuximab for rHNC.
**SABR: An Alternative for Surgery in Stage I NSCLC?**

Ben Slotman, Frank Lagerwaard, Niels Haasbeek, Naomi Verstegen, Max Dahele, Suresh Senan

Presented by: Ben Slotman, MD, PhD

**Objectives:** Stereotactic ablative radiotherapy (SABR) is now standard treatment for medically inoperable patients with stage I NSCLC. In recent years, an increasing number of patients who are operable elects to undergo SABR. In this study, we report on the outcomes of these fit patients treated with SABR.

**Methods:** Close to 1,000 Stage I NSCLC patients have been treated and have been prospectively entered in the institutional database since 2003. About 25% of patients with sufficiently long follow-up were found to be operable. These 177 patients were selected based on absence of one or more of the following characteristics: (1) synchronous lung tumors or other malignancy, (2) prior high-dose radiotherapy/pneumonectomy, (3) chronic obstructive pulmonary disease with a severity score of 3-4 according to the Global initiative for Obstructive Lung Disease classification, (4) a performance score of =3, and (5) other co-morbidity precluding surgery.

The median age was 76 years and there were 101 males and 76 females. Sixty per cent were staged as cT1N0 and 40% a cT2N0. As published before, a dose of 60 Gy was delivered using a risk-adapted protocol in either 3, 5, or 8 fractions, depending on tumor size and location. Follow-up chest CT-scans were performed at 3, 6, and 12 months and yearly thereafter.

A matched pair analysis with patients who underwent video-assisted thoracoscopic lobectomy was performed. Patients were matched using propensity scores based on cTNM, age, gender, Charlson-comorbidity score, lung function and performance score. Matching was blinded to all outcomes, and a total of 86 VATS and 527 SABR patients were eligible (1:1-ratio, caliper distance 0.025). Loco-regional failure was defined as recurrence in or adjacent to the PTV or surgical margins, ipsilateral hilum or mediastinum. The cohort consisted of 64 SABR and 64 VATS-lobectomy patients.

**Results:** The median follow-up was 32 months. Median overall survival was 62 months, with 1- and 3-year survival rates of 95% and 85%, respectively. Post-SABR 30-day mortality was 0%, while predicted 30-day mortality for a lobectomy, derived using the Thoracoscore predictive model (Falcoz PE et al. J Thorac Cardiovasc Surg 2007;133:325-332), would have been 2.6%. Local control rates at 1 and 3 years were 98% and 93%, respectively. Regional and distant failure rates at 3 years were each 10%. Toxicity was mild, with grade 3 or higher radiation pneumonitis and rib fractures in 2% and 3%, respectively.

For the matched-pair analysis, median follow-up was 30 and 16 months, respectively. SABR patients had better loco-regional control rates at 3-years (93% vs 83%, p=.03). There was no significant difference in freedom from progression (FFP) and overall survival between the two groups.

**Conclusions:** These results show that SABR is a curative option for operable Stage I patients as well and support ongoing randomized trials comparing surgery and SABR in these patients. Updated results will be presented during the conference.
Salvage Stereotactic Body Radiation Therapy (SBRT) for Medically-Inoperable Patients with NSCLC following RFA


*Department of Radiation Oncology, University of Pittsburgh Cancer Institute and **Department of Cardiothoracic Surgery, University of Pittsburgh Medical Center

Presented by: Peyman Kabolizadeh, MD, PhD

Objectives: CT-guided radiofrequency ablation (RFA) is an alternative therapy for patients with inoperable early-stage lung cancer. Despite a comparable median survival to other nonsurgical modalities, site-specific progression remains as high as 30% with RFA. Stereotactic body radiation therapy (SBRT) is another safe and effective treatment option for the non-surgical treatment of patients with early stage lung cancer. Herein, we report the results of salvage SBRT for persistent or recurrent disease following RFA in medically-inoperable non-small cell lung cancer (NSCLC) patients.

Methods: Thirty patients (median age of 74 years; range 58-91 years) with Stage I NSCLC were treated with RFA followed by salvage radiosurgery for isolated tumor recurrence from 2004-2011. The median duration between RFA and SBRT in patients with staged therapy was 9 months (range, 1-54 months). Treatment dose and fractionation was based on tumor location and size with the median SBRT dose of 60.0 Gy in 3 fractions and an average treatment volume of 30 cc (range, 6 to 126 cc). Radiation-induced toxicities were graded and recorded. Tumor control and survival were estimated using Kaplan-Meier method.

Results: Thirty (30) patients with 31 lesions had recurrent NSCLC following RFA and were salvaged with SBRT to a median dose of 60 Gy in 3 fractions. The 6-month and 1-year local control (LC) were 88% and 79%, respectively. Regional control (RC) were 81% and 73% at 6-months and 1-year respectively with the distant metastases control (DC) of 92% and 81%, respectively. The 6-months and 1-year overall survival (OS) were 93% and 76%, respectively. Two patients had acute grade 2 chest wall pain, 3 patients had grade 1 shortness of breath, and 1 patient had grade 2 dysphagia. Two patients experienced late toxicities with 1 grade 3 skin toxicity and 1 grade 1 dry cough.

Conclusions: SBRT is a safe and effective treatment option for salvage therapy in non-surgical patients with recurrent early stage lung cancer following RFA. The toxicity profile is favorable with no grade 4 or higher due to treatment.
Evaluation of PTV Margins for Lung SBRT on CyberKnife and Trilogy

Lindsay Mathew, Dickson Wong, Bill Edwards, Raimond Wong, Anand Swaminath, Marcin Wierzbicki, Tom Chow

Presented by: Lindsay Mathew, PhD

Objectives: The purpose of this study was to retrospectively evaluate the impact of planning target volume (PTV) margins used on CyberKnife and Trilogy for Lung SBRT at this center.

The CyberKnife RS system uses an active tracking system (Synchrony) that models the motion of the target based on orthogonal images encompassing different phases of breathing. The linac then tracks the target based on this model when the beam is on. Deviations of the target motion from the motion model can be analyzed at the time of interval imaging. For these treatments, internal target volume (ITV) = gross target volume (GTV).

On the Varian Trilogy Linac, we examine ITV as localized on pre- and post-SBRT cone-beam computed tomography (CBCT) images.

Methods: The CyberKnife image tracking logs of all lung SBRT treatments using X-Sight Lung (soft tissue tracking system) & Synchrony were examined. For each image log, the x,y,z translation corrections of the target relative to the model position at that time were evaluated to quantify potential targeting error during treatment.

SBRT plans for the Varian Trilogy were created using free-breathing and four-dimensional CT scans from which maximum intensity projection images were computed and ITV’s were contoured. Pre and post CBCTs were acquired. Registration of the treatment planning image to each CBCT was performed using deformable image registration. The resultant transformations were applied to the planning ITV to obtain the ITV for each CBCT. The fraction of the CBCT ITV within a given PTV was determined using Boolean logic. ITV to PTV margin expansions of 0 to 10 mm were evaluated at 1mm intervals.

Results: Analysis of all image tracking logs on the CyberKnife for 35 patients (2589 correlations) showed that target was within 5mm of the previous tracking reference 96.3% of the time. Increasing the PTV margin to 6mm would cover the target 98.6% of the time.

141 CBCT images were evaluated from 13 patients across 47 treatment fractions from the Varian Trilogy. The 3 and 5 mm PTV margins covered 97.9 ± 4.0% and 99.6 ± 1.4% of the pre and post treatment CBCT ITV respectively (mean ± standard deviation). Histogram analysis of the data showed that a 4 mm margin covered at least 95% of the CBCT ITV’s for 95% of the fractions evaluated. CBCT ITV coverage was not related to ITV (cm3) or tumour location (upper vs. middle/lower), nor was the post-treatment CBCT-ITV coverage related to the time to post-treatment CBCT.

Conclusions: Current protocols using a 5mm PTV expansion achieve satisfactory ITV coverage on the Trilogy where mean geometric coverage is >95% with margins of = 3mm. On the other hand, image tracking logs from the CyberKnife indicate that a 5mm margin may not be sufficient when motion tracking is used.
Comparison of Stereotactic Body Radiation Therapy Results for Clinical Stage 1 Non-Small Cell Lung Cancer Using 3 Different Tracking Modalities

John Lamond, Joseph Weiner, Caspian Oliai, Rachelle Lanciano, Jun Yang, Luther Brady

Philadelphia CyberKnife & Drexel University College of Medicine

Presented by: John Lamond, MD

Objectives: To determine if there is a local control or survival difference in our patients treated with 3 different Cyberknife (fiducial, Xsight-lung, and Xsight-spine) tracking modalities.

Methods: A total of 82 patients with clinically staged T1 or T2a (5 cm or less) NoMo non-small cell lung cancer were treated with Cyberknife radiosurgery. All were treated to a total dose of 100Gy10 or greater in 3-5 fractions. All patients were evaluated by at least one physician and physicist before deciding on the tracking modality. Patients eligible for Xsight-lung tracking had peripheral lung cancers well seen on orthogonal imaging (both images 45 degrees lateral to anterior). Patients eligible for Xsight-spine tracking were in the upper portion of the lung, typically with 0.5 cm or less movement on normal inspiration and expiration CT scans, 5 cm or less away from the tracked vertebral body. These patients required a somewhat larger volume of lung treated, given that the tumor movement during treatment could not be tracked, an ITV was treated.

Results: Median follow-up was 20 months. There were 44% fiducial, 28% Xsight-lung, and 28% Xsight-spine. There were a total of 3 local failures: 1 with fiducials, 1 with Xsight-lung, and 1 with Xsight spine. 2 of the local failures (the fiducial and Xsight-spine case) retrospectively were associated with significant underdosing (less than 100Gy10) from using a ray-tracing algorithm. Actuarial 3 year local control was 96% and 3 year actuarial survival was 55%. 66% of our patients were still alive at their last follow-up. There were no statistically significant differences in local control or survival based on the tracking modality.

Conclusions: Excellent results were obtained with all 3 tracking modalities. In our experience, treatment planning was more complex in Xsight-spine and Xsight-lung cases, and treatment was more complex in Xsight-lung cases. Less morbid techniques of fiducial placement are becoming more readily available to our patients, allowing us to consider fiducial tracking in a greater percentage of curative cases. For Cyberknife users, we recommend routine dosimetry review using the Monte Carlo algorithm.
Stereotactic Ablative Radiotherapy for Re-Irradiation of Lung Cancer Recurrence

Nisha Patel MD, Rachelle Lanciano MD, Karna Sura BA, Jun Yang PhD, John Lamond MD, Jing Feng MS, Michael Good BSN, Lydia Komarnicky MD, Luther Brady MD

Presented by: Nisha Patel, MD

Objectives: To evaluate local control, survival, acute and long-term toxicities of stereotactic ablative radiotherapy (SABR) for re-irradiation of recurrent tumors of the lung.

Methods: Retrospective review of clinical records from January 2008 to December 2011 demonstrated 278 lung cancer patients treated with SABR in a single institution. Of those, 26 patients with 29 tumors were retreated with SABR after receiving previous irradiation. 90% (26/29) of retreated tumors received prior external beam irradiation and 10% (3/29) received prior SABR. Previous median radiation dose was 61.2 Gy (range 30~74 Gy) with a median 8 month interval from previous treatment. 93% (27/29) of retreated tumors were in field recurrences considered to be high dose recurrences and received at least 30 Gy previously to the current SABR target. The median prescribed dose was 30Gy to a median isodose of 69.5% with a median 5 fractions with a median 5mm margin. A tumor was considered to have received a low SABR dose if it received less than BED of 48Gy10 (6Gy x 5 fx equivalent) and high dose if it received = 48 Gy10. The median number of radiation beams used was 122. Patients were tracked with fiducial (n=9), x-site lung (n=3), and x-site spine (n=17) tracking. All but one plan used Ray-Tracing dosimetry calculation. 25/29 tumors were evaluable for local control with a minimum of 3 month follow up.

Results: Median follow up after SABR retreatment was 11 months with a median survival of 11 months. 20 of 25 tumors were locally controlled. The median time to progression was 9 months. 10 tumors received low SABR dose with median previous dose of 68.3 Gy and 15 tumors received high SABR dose with median previous dose of 59.4 Gy. The median follow up for the low dose group was 10.5 months and 13 months for the high dose group. The local control was 70% (7/10) for low dose and 87% (13/15) for high dose groups. Only grade 1 and 2 acute toxicities were reported, with a higher proportion of patients experiencing symptoms in the high dose treatment group (12/15) than the low dose group (4/10). Acute toxicities included fatigue (n=5), esophagitis (n=4), dyspnea (n=2), cough (n=2), dermatitis (n=1), subacute pneumonitis (n=1) and nausea (n=1). No late toxicity was identified in high dose group. There were two patients in the low dose group that experienced late toxicity with grade 3 dyspnea and grade 3 tracheoesophageal fistula requiring surgery. However, malignant cells were present within the fistula to suggest disease progression. Of note, the 3 patients that received BED of 100 Gy10 or higher remained locally controlled without late toxicity.

Conclusions: SABR re-irradiation for patients with recurrent lung cancer provides good local control with relatively low toxicity. A higher BED dose for retreatment provides a better rate of local control with a tolerable level of acute toxicity. Clinical trials should include SABR for patients with previously irradiated localized recurrent lung cancer.
Stereotactic Body Radiotherapy Salvage for Locally-Recurrent Central Non-Small Cell Lung Cancers

Vargo JA, Leeman JE, Clump DA, Christie A, Schuchert M, Christie N, Quinn A, Burton S, Heron DE

Presented by: John Vargo, MD

Objectives: Despite advances in multimodality management, locoregional recurrence remains a significant clinical dilemma in non-small cell lung cancer (NSCLC). Salvage options remain challenging in these patients. SBRT has emerged as a promising definitive therapy for inoperable early-stage NSCLC with excellent local control and minimal toxicity; however data for SBRT salvage for patient receiving prior chest radiotherapy is limited.

Methods: Patients (n=55) with central located locally-recurrent NSCLC receiving salvage SBRT to 48Gy in 4 fractions from June 2007 through June 2012 were retrospectively reviewed. Thirty patients (55%) received prior external beam radiation therapy (median dose of 68.4Gy; range: 30-118Gy) with a median re-irradiation interval of 24 months (range: 3-120 months). Tumor control and survival were estimated using Kaplan-Meier method with comparison between groups made using log-rank t-test.

Results: At a median follow-up of 7 months (range: 0-42 months), the 6-month local- (LC), regional- (RC), distant-control (DC) and overall-survival (OS) for the entire cohort was 86%, 75%, 66%, 87%, respectively. There was no significant difference in LC (p=0.291), RC (p=0.433), DC (p=0.548), and OS (p=0.706) by prior irradiation. The crude rate of acute toxicity was 4.6% (2/55 patients experienced chest wall pain), neither of which received prior RT. Similarly the crude rate of late toxicity was low at 5.4% (1.8% esophageal stricture requiring dilation, 1.8% pneumonitis, 1.8% persistent chest wall pain), two of which received prior RT.

Conclusions: SBRT represents a promising salvage therapy for patients with locally-recurrent NSCLC with excellent tumor control and minimal toxicity even in the setting of prior thoracic irradiation.
Monte Carlo Calculations Associated with Superior Clinical Outcomes Relative to Pencil Beam Calculations in Early Stage Lung Cancer

Alan Monroe, MD; Gyongyver Bulz, MS; Andrew Tanner, MD; Gerald White, MS; Anuj Peddada, MD

Presented by: Alan Monroe, MD

Objectives: CyberKnife dose calculations were initially performed using a pencil beam (PB) algorithm. Recent studies have demonstrated underdosing of lung targets with pencil beam relative to Monte Carlo (MC) calculations. We investigate whether this associated dosimetric inaccuracy has clinical implications in a series of consecutively treated early-stage lung cancer patients.

Methods: A prospective database was maintained for two cohorts of patients treated with Cyberknife radiosurgery for lung cancer: an early cohort planned with pencil beam (n=14) and a later cohort planned with Monte Carlo (n=19). All patients had T1 or T2 N0 lung cancer and were either medically inoperable or borderline resection candidates for wedge resection. The median age was 74.8 years. The median prescription dose to peripheral lesions was 5400 cGy in 3 fractions; nine central tumors were prescribed 5000 cGy in 5 fractions. Plans were normalized to 95% PTV coverage. Those patients planned and treated with PB had repeat MC plans performed for dosimetric comparison. Kaplan-Meier statistics were performed to compare survival curves between the two techniques. Median follow up was 20 months (range 2-36 months).

Results: Patients whose plans were calculated with the PB algorithm demonstrated underdosing of the PTV by an average of 17% compared to MC (range: 6%-32%). Smaller volume tumors demonstrated a greater degree of underdosing. The anticipated prescription dose only covered 49% of the PTV on average when PB was performed; whereas, patients planned with MC achieved a median of 95% PTV coverage. For the entire cohort, local control at two years was 92% and overall survival was 81%. Actuarial 2-year local control favored those treated with MC calculations compared with PB calculations (100% vs. 83%; p=0.12). PTV margin expansion of 5 mm was associated with superior local control when compared with margins < 5 mm (p=0.04).

Conclusions: Pencil beam calculations consistently overestimate the amount of dose received by lung tumors with smaller lesions surrounded by air density showing the greatest degree of underdosing. We have observed a statistical trend to inferior local control using PB calculations. Monte Carlo should replace PB as the gold standard for Cyberknife treatment planning.
THE SHOWDOWN RETURNS
Early Stage Lung Cancer

Presented by Robert J. Cerfolio, MD, FACS, FCCP and Gregory M.M. Videtic, MD, CM, FRCPC

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Early Stage Prostate Cancer

Presented by Matthew R. Cooperberg, MD, MPH and Alan J. Katz, MD

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Trigeminal Neuralgia

Presented by Kim Burchiel, MD, FACS and Douglas Kondziolka, MD, MS, FRCS(C)
PHYSICS SESSION

the Radiosurgery Society™
**Thursday, February 21, 2013**

**GENERAL SESSION – Costa Del Sol, Salon A-D**

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<td>7:00am – 7:10am</td>
<td>Alexander Muacevic, MD</td>
<td>Welcome to the 2013 SRS/SBRT Scientific Meeting</td>
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<tr>
<td>7:10am – 8:00am</td>
<td>Anand Mahadevan, MD and Kristine Gagliardi</td>
<td>the Radiosurgery Society® Annual Meeting and A View Behind the Curtain</td>
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**PHYSICS SESSION – Costa Del Sol, Salon F-H**

**Physics Session I – Moderated by Jeffrey Garrett, MS & Per Halvorsen, MS, DABR, FACR**

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<td>8:10am – 8:30am</td>
<td>Joseph Barbiere, MS (Hackensack University Medical Center, Hackensack, New Jersey)</td>
<td>DVH based VMAT Patient Specific QA for Lung SBRT</td>
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<td>8:30am – 8:50am</td>
<td>Evan Thomas, MS (University of Alabama School of Medicine, Birmingham, Alabama)</td>
<td>Comparison of Plan Quality and Delivery Time between Volumetric Arc Therapy (VMAT) and Gamma Knife Radiosurgery for Multiple Cranial Metastases</td>
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<td>8:50am – 9:10am</td>
<td>Yu Yuan, PhD (University of Alabama at Birmingham, Birmingham, Alabama)</td>
<td>Collimator Angle Selection for Single-Isocenter Multi-Target Radiosurgery</td>
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<tr>
<td>9:10am – 9:30am</td>
<td>Christoph Fürweger, PhD (European CyberKnife Center Munich, Munich, Germany)</td>
<td>CyberKnife Robotic Spinal Radiosurgery in Prone Position: Dosimetric Advantage due to Posterior Radiation Access?</td>
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<tr>
<td>9:30am – 9:50am</td>
<td>James A. Tanyi, PhD (Oregon Health &amp; Science University, Portland, Oregon)</td>
<td>Changes in Respiratory-Induced Motion Patterns of Primary Liver Tumors using an Abdominal Compression Device</td>
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<tr>
<td>9:50am – 10:00am</td>
<td>All Speakers</td>
<td>Physics Session I Q &amp; A</td>
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<tr>
<td>10:00am – 10:30am</td>
<td>All Speakers</td>
<td>Break</td>
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**Physics Session II – Moderated by Christoph Fürweger, PhD & Brian Wang, PhD**

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<tr>
<th>Time</th>
<th>Speaker(s)</th>
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<tbody>
<tr>
<td>10:35am – 10:55am</td>
<td>Stephen Sorensen, PhD, MS (St. Joseph’s Hospital and Medical Center, Phoenix, Arizona)</td>
<td>Dose Impact on Targets and Organs at Risk (Oars) from Sub Millimeter Collimator Size Differences</td>
</tr>
<tr>
<td>10:55am – 11:15am</td>
<td>Veronique Baart, MS (Liège University Hospital, Liège, Belgium)</td>
<td>Validation and Use of the “Iris Quality Assurance Tool”</td>
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<tr>
<td>11:15am – 11:35am</td>
<td>Nathan Childress, PhD, DABR (Mobius Medical Systems, LP, Houston, Texas)</td>
<td>Design and Development of a Novel SBRT Plan Verification System</td>
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**Physics Oral Poster Session – Moderated by Christoph Fürweger, PhD & Brian Wang, PhD**

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<thead>
<tr>
<th>Time</th>
<th>Speaker(s)</th>
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<tbody>
<tr>
<td>11:35am – 11:40am</td>
<td>Oliver Blanck, Dipl Inf (University Clinic of Lübeck, Lübeck, Germany)</td>
<td>Imaging Dose Measurements for the CyberKnife X-Ray Cameras and Potentials for Dose Reduction</td>
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<tr>
<td>11:40am – 11:45am</td>
<td>James A. Tanyi, PhD (Oregon Health &amp; Science University, Portland, Oregon)</td>
<td>Circumferential or Sectored Beam Arrangements for Stereotactic Body Radiation Therapy (SBRT): Impact on Target and Normal-Structure Dose-Volume Metrics</td>
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</table>
11:45am – 11:50am  Ronald Lalonde  *(D3 Oncology Solutions, Pittsburgh, Pennsylvania)*
Validation of the Use of Commercial MU Second Check Programs in Radiosurgery

11:50am – 11:55am  James A. Tanyi, PhD *(Oregon Health & Science University, Portland, Oregon)*
Geometric Evaluation of Intrafraction Motion during Frameless Intracranial Stereotactic Radiosurgery (SRS)

11:55am – 12:00pm  Oliver Blanck, Dipl Inf *(University Clinic of Lübeck, Lübeck, Germany)*
Properties of Gafchromic EBT3 and MDV3 Film and Application for Quality Assurance in Robotic Radiosurgery

12:00pm – 1:30pm  Lunch

SRS/SBRT Dosimetry Workshop – Moderated by Ian Cowley, PhD & Charlie Ma, PhD

1:30pm – 2:00pm  Jun Yang, PhD *(Philadelphia CyberKnife Center, Havertown, Pennsylvania)*
CyberKnife Dosimetry

2:00pm – 2:30pm  Brian Wang, PhD *(University of Utah, Salt Lake City, Utah)*
Planning Techniques for Linac SRS/SBRT

2:30pm – 3:00pm  Steven Goetsch, PhD *(San Diego Gamma Knife Center, San Diego, California)*
Gamma Knife Dosimetry

3:00pm – 3:15pm  Stephen Kry, PhD *(MD Anderson Cancer Center, Houston, Texas)*
The Radiological Physics Center’s Standard Dataset for Small Field Size Output Factors

3:15pm – 3:30pm  Break

Monte Carlo Symposium – Moderated by Mary Ellen Masterson-McGary, MS, MA & Fang-Fang Yin, PhD

3:30pm – 4:15pm  Charlie Ma, PhD *(Fox Chase Cancer Center, Philadelphia, Pennsylvania)*
General Concepts and Methods of Monte Carlo in Clinical Treatment Planning

4:15pm – 4:45pm  Stephen Kry, PhD *(MD Anderson Cancer Center, Houston, Texas)*
Verification of Monte Carlo Dose Calculations by the Radiological Physics Center (RPC)

4:45pm – 5:30pm  Ian Cowley, PhD *(Harley Street Clinic, London, United Kingdom)*
Stephen Kry, PhD *(MD Anderson Cancer Center, Houston, Texas)*
Charlie Ma, PhD *(Fox Chase Cancer Center, Philadelphia, Pennsylvania)*
Jun Yang, PhD *(Philadelphia CyberKnife Center, Havertown, Pennsylvania)*
Panel Discussion: Clinical Implementation of Monte Carlo

EVENING EVENT – Costa Del Sol

5:30pm – 7:30pm  Mix & Mingle Reception
## GENERAL SESSION – Costa Del Sol, Salon A-D

**Friday, February 22, 2013**

### 7:00am – 7:10am

**Alexander Muacevic, MD**  
RSS Morning Greeting

### 7:10am – 7:20am

**Ben Slotman, MD, PhD** *(VU University Medical Center, Amsterdam, The Netherlands)*  
SABR: An Alternative for Surgery in Stage I NSCLC?

### 7:20am – 7:30am

**Peyman Kabolizadeh, MD, PhD** *(University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania)*  
Salvage Stereotactic Body Radiation Therapy (SBRT) for Medically-Inoperable Patients with NSCLC following RFA

### 7:30am – 7:40am

**Lindsay Mathew, PhD** *(Juravinski Cancer Centre, Hamilton, Ontario, Canada)*  
Evaluation of PTV Margins for Lung SBRT on CyberKnife and Trilogy

### 7:40am – 7:50am

**John Lamond, MD** *(Philadelphia CyberKnife, Philadelphia, Pennsylvania)*  
Comparison of Stereotactic Body Radiation Therapy Results for Clinical Stage 1 Non-Small Cell Lung Cancer Using 3 Different Tracking Modalities

### 7:50am – 8:00am

**Nisha Patel, MD** *(Drexel University College of Medicine, Philadelphia, Pennsylvania)*  
Stereotactic Ablative Radiotherapy for Re-Irradiation of Lung Cancer Recurrence

### 8:00am – 8:10am

**John Vargo, MD** *(University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania)*  
Stereotactic Body Radiotherapy Salvage for Locally-Recurrent Central Non-Small Cell Lung Cancers

### 8:10am – 8:20am

**Alan Monroe, MD** *(Penrose Cancer Center, Colorado Springs, Colorado)*  
Monte Carlo Calculations Associated with Superior Clinical Outcomes Relative to Pencil Beam Calculations in Early Stage Lung Cancer

### 8:20am – 8:30am

All Speakers: Thoracic Q & A

## THE SHOWDOWN RETURNS – Costa Del Sol, Salon A-D

### 8:30am – 10:00am

**Robert J. Cerfolio, MD, FACS, FCCP and Gregory M.M. Videtic, MD, CM, FRCPC** *(University of Alabama, Birmingham, Birmingham, Alabama and Cleveland Clinic, Cleveland, Ohio)*  
Early Stage Lung Cancer

### 10:00am – 10:30am

**Break**

### 10:30am – 12:00pm

**Matthew R. Cooperberg, MD, MPH and Alan J. Katz, MD** *(UC San Francisco, San Francisco, California and Flushing Radiation Oncology, Flushing, New York)*  
Early Stage Prostate Cancer

### 12:00pm – 1:30pm

**Lunch**

### 1:30pm – 3:00pm

**Kim Burchiel, MD, FACS and Douglas Kondziolka, MD, MS, FRCS(C)** *(Oregon Health and Science University, Portland Oregon and New York University, New York, New York)*  
Trigeminal Neuralgia
### PHYSICS SESSION - Costa Del Sol, Salon F-H

#### QA & Safety in SRS/SBRT Symposium – Moderated by Steven Goetsch, PhD & Dave Taylor, MS

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<th>Speaker</th>
<th>Affiliation</th>
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<tr>
<td>3:00pm – 3:45pm</td>
<td><strong>Steven Goetsch, PhD</strong></td>
<td><em>San Diego Gamma Knife Center, San Diego, California</em></td>
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<td>Recent Accidents in Radiation Therapy</td>
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<td>3:45pm – 4:30pm</td>
<td><strong>Todd Pawlicki, PhD</strong></td>
<td><em>University of California at San Diego, San Diego, California</em></td>
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<td></td>
<td>QA &amp; Patient Safety for SRS and SBRT</td>
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<td>4:40pm – 5:00pm</td>
<td><strong>Per Halvorsen, MS, DABR, FACKR</strong></td>
<td><em>Lahey Health, Burlington, Massachusetts</em></td>
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<td></td>
<td>Safety is No Accident - Staffing Report</td>
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<td>5:00pm – 6:00pm</td>
<td><strong>All</strong></td>
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<td>Making High-Tech Radiation Therapy Safer through Medical Physics Training and Credentialing - &quot;We Need More Educated Drivers&quot;</td>
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#### EVENING EVENT – Costa Del Sol

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<tr>
<td>5:30pm – 7:30pm</td>
<td>Poster Reception</td>
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### Saturday, February 23, 2013

#### PERFORMANCE AND QUALITY IMPROVEMENT SESSION – Costa Del Sol, Salon A-D

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<tr>
<td>8:00am – 8:15am</td>
<td><strong>John J. Kresl, MD, PhD</strong></td>
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<td>Opening Remarks</td>
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<tr>
<td>8:15am – 10:00am</td>
<td><strong>Case Study Presentations</strong></td>
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<tr>
<td>10:00am – 10:30am</td>
<td><strong>Break</strong></td>
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<tr>
<td>10:30am – 12:15pm</td>
<td><strong>Case Study Presentations</strong></td>
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<td>12:15pm – 12:30pm</td>
<td><strong>Closing of Meeting</strong></td>
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<tr>
<td>12:30pm – 1:30pm</td>
<td><strong>Grab and Go Lunch</strong></td>
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#### AFTERNOON & EVENING EVENTS

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<tr>
<td>2:00pm – 6:00pm</td>
<td><strong>Golf Scramble</strong></td>
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<tr>
<td>6:00pm – 9:30pm</td>
<td><strong>Dancin’ to the Beat</strong></td>
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**DVH based VMAT Patient Specific QA for Lung SBRT**

J. Barbiere and A. Ndlovu

Presented by: Joseph Barbiere, MS

**Objectives:** Traditional patient specific quality assurance (QA) analysis is based on calculated gamma values. Current developments indicate that gamma may not be able to detect small but clinically significant variations between the plan and actually delivered dose. For certain applications which operate near the limits of machine capabilities and tolerance doses, such as Stereotactic Body Radiation Therapy (SBRT) with modulated arc therapy (VMAT) for lung per RTOG 0915, dose volume histogram (DVH) based analysis is preferred. However, the available techniques have not been thoroughly tested and are not fully described due to the use of proprietary software and hardware. Another major drawback of commercial systems is that they often require an independent dose calculation and therefore any observed dose difference may be due to difference in the calculation algorithms.

The purpose of this project is to present the principles of a DVH based QA system using radiochromic film (ISP EBT3) in a cylindrical and a commercial treatment planning system (Eclipse) for patient planning, creation of a phantom verification plan, and DVH analysis of a modified plan based on measurements. Software using MATLAB with the imaging toolbox is described to perform some calculations not commercially available. Procedures are included to verify the accuracy of the calculations.

The use of Flattening Filter Free (FFF) beams is desirable to minimize the treatment time for SBRT with a large number of monitor units. Unlike digital systems, EBT3 film is dose rate independent, accurate up to a large accumulated dose, and has a high spatial resolution.

**Methods:**

1. A VMAT patient plan was created using an anthropomorphic chest phantom. Commonly such plans consist of a clockwise and a counterclockwise 360 degree arc. Using the proposed technique requires that each field consist of two 180 degree arcs so that we can acquire the entrance and exit doses simultaneously. For purposes of clarity, our patient plan is one simple 30 degree arc. Note that the plan is self contained and not easily manipulated. The vendor has noted that perhaps modifications could be introduced by altering the dicom treatment files but the procedure is not documented or proven.

2. Standard Eclipse software is capable of creating a Verification Plans (VP) both on the existing patient image data set or a phantom image data set. Note that the VP on the patient data set has the ability to modify several plan parameters, such as Monitor Units (MU) and Micro Leaf Collimator positions. This capability has not presented or exploited in any previous work.

3. A standard Verification Plan was created on the cylindrical phantom corresponding to perfected delivery of the patient plan and the MUs for one control point modified to represent possible delivery error.

4. Comparison of the planned phantom dose (PPD) and the actual measured phantom dose (MPD) in is performed in MATLAB. Algorithms will be described that compute the gantry angle, field size, and the ratio of the measured to plan dose of any modified control points. The calculations are facilitated by using only the difference between the two doses (i.e. PPD – MPD).

5. The measured control point modifications can easily be incorporated into the patient verification plan, updated dose distribution computed, and DVH analysis performed ALL using the commercial treatment planning system.

**Results:** We have described a technique for DVH comparison of a computed patient plan with the actual delivered plan. Simulated studies show that changes in a single control point can lead to significant clinical changes, such a maximum dose to a critical organ.

The DVH technique was able to discern critical variations affecting plan parameters that were not seen using standard gamma analysis.

The high doses commonly used in SBRT enhanced the delectability of small differences between the plan and actual delivery.

**Conclusions:** SBRT protocols are often characterized by stringent planning objectives and dose constraints which are documented by DVH analysis. The work presented describes a quality assurance technique which directly documents that the actual delivered plan also meets those objectives.
Comparison of Plan Quality and Delivery Time between Volumetric Arc Therapy (VMAT) and Gamma Knife Radiosurgery for Multiple Cranial Metastases

Evan M Thomas, M.S.; Richard A Popple, Ph.D.; Xingen Wu, Ph.D.; Grant M Clark, M.D.;
James M Markert, M.D.; Barton L Guthrie, M.D.; Michael C Dobelbower, M.D., Ph.D;
Sharon A Spencer, M.D.; John B Fiveash, M.D.

1 Department of Radiation Oncology, University of Alabama at Birmingham Comprehensive Cancer Center, Birmingham, AL
2 Department of Neurosurgery, University of Alabama at Birmingham, Birmingham, AL

Presented by: Evan Thomas, MS

Objectives: Volumetric modulated arc therapy (VMAT), has been shown clinically feasible for radiosurgical treatment of multiple cranial lesions even with a single isocenter. In this study, we investigated whether equivalent radiosurgical plan quality and reduced delivery time could be achieved for patients with multiple cranial targets in VMAT plans who had been previously treated at our institution with Gamma Knife (GK) radiosurgery.

Methods: 28 clinical Gamma Knife sessions with multiple cranial targets (metastases) were re-planned for multi-arc (MA) and single-arc (SA), single-isocenter VMAT (RapidArc) in Eclipse. Multi-arc plans utilized one 360° axial arc in concert with a 180° vertex arc, and two 45° off-axis transverse arcs. Single-arc plans solely used a 360° axial arc. The prescription for all targets was standardized to 18 Gy. Each plan was normalized for 100% prescription dose to 99-100% of target volume. Plan quality was analyzed by target conformity (RTOG CI) for all targets greater than 0.025 cm³ in volume (n = 97) as well as plan gradient index and 12 Gy isodose volume (V12Gy). The volume cutoff was chosen to balance the relevance of small target conformity and our desired target number for the study. Delivery times were also compared for each modality. Average GK source age at time of treatment was approximately 3 years.

Results: Compared to Gamma Knife, multi-arc VMAT improved average target conformity (CIGK=2.27, CIMA=1.89; p = 1E-5) and markedly reduced beam-on time per target (tGK = 15.22 min, tMA = 0.97 min; p <1E-5) without increasing 12 Gy isodose volume (V12GyGK=14.82 cm³, V12GyMA = 14.65 cm³; p = 0.86). The gradient index for GK was lower than for multi-arc VMAT (GIGK=3.01, GIMA = 6.05; p = 4E-4) but this was chiefly because multi-arc VMAT improved conformity without a corresponding improvement in the 50% prescription isodose volume (p = 0.42). Single-arc VMAT plans were more quickly delivered and achieved similar performance for some cases, but for many patients with complicated plans or co-planar target distributions, was inferior at duplicating GK or multi-arc VMAT plan quality (CISA = 2.96, GISA = 7.46, V12GySA = 22.03 cm³, tSA=0.31 min).

Conclusions: For multiple target CNS radiosurgery, 4-arc VMAT produced both equivalent conformity and moderate isodose spill compared to Gamma Knife, and also significantly reduced beam-on time. Single isocenter VMAT radiosurgery is likely to replace other forms of linac radiosurgery due to its high plan quality and delivery efficiency.
Collimator Angle Selection for Single-Isocenter Multi-Target Radiosurgery

Yu Yuan, Ph.D.; Evan M Thomas, M.S.; Grant M Clark, M.D.; John B Fiveash, M.D.; Richard A Popple, Ph.D.

Department of Radiation Oncology, University of Alabama at Birmingham
Comprehensive Cancer Center, Birmingham, AL

Presented by: Yu Yuan, PhD

Objectives: We describe a technique for determining the optimal collimator angle for radiosurgical treatment of multiple cranial targets with single-isocenter VMAT (volumetric modulated arc therapy). We hypothesized that our method would reduce low-dose spill at no detriment to other aspects of plan quality.

Methods: 6 patients treated for multiple cranial metastases (target number: 3 to 5, mean 3.5; target volume: 0.23 to 29.1 cm³, mean 6.1 cm³) at our institution were retrospectively planned for single-isocenter VMAT (RapidArc, Varian Medical Systems). For each case, a two-arc (one 360° axial arc in concert with a 180° vertex arc) and a four-arc (two such arcs with additional two 45° off-axis transverse arcs) configuration were used. For each configuration, one plan was run with all collimator angles set to 45° (STD) and one plan was run with the “optimized” collimator angle (OPT) for each arc.

The collimator angle optimization was designed to minimize “island blocking”, i.e. MLC leaf pair sharing between lesions. We achieved this by computing the total MLC leaf-opening area for every viable collimator angle of each arc and selecting the angle whose leaf-opening area was minimized.

Plans were optimized using a standardized objective function and were normalized such that 99% of the total target volume received 18 Gy.

Low-dose spill was assessed with both the absolute volume (cc) receiving 1.8 Gy (V10%) and 4.5 Gy (V25%) as well as the area under the dose volume histogram curve (AUC-DVH) for the intervals [0, 3Gy] and [0,9Gy]. Plan quality was evaluated by conformity index (CI), plan gradient index (GI), and 12 Gy isodose volume (V12Gy). One-tailed, pairwise t-tests were used for comparison.

Results: The optimized collimator setting reduced low-dose spill in both metrics we assessed. Mean V10% and V25% were improved for both 4-arc (V10%OPT=1488.2, V10%STD =1691.3; p=0.002 | V25%OPT=387.0, V25%STD =476.9; p=0.004) and 2-arc (V10%OPT=1613.2, V10%STD =1413.5; p=0.006 | V25%OPT=395.7, V25%STD =489.0; p=0.005) configurations.

Mean AUC-DVH on the [0, 3Gy] and [0,9Gy] intervals (denoted as AUC3Gy and AUC9Gy respectively) was also improved for both 4-arc (AUC3GyOPT= 5964.8, AUC3GySTD=6423.2; p=0.005 | AUC9GyOPT= 7525.2, AUC9GySTD= 8296.7; p=0.003) and 2-arc (AUC3GyOPT= 5751.0, AUC3GySTD=6202.2; p=0.007 | AUC9GyOPT= 7348.1, AUC9GySTD= 8135.1; p=0.004) configurations.

Compared to the 45° collimator setting, the optimized collimator setting either improved or did not significantly affect plan quality, i.e. the conformity or gradient indices or V12Gy. Mean GI was reduced for both the four-arc (GIOPT =3.507, GISTD =3.658; p=0.03) and two-arc (GIOPT =3.507, GISTD =3.722; p=0.006) configurations. Mean target CI was also reduced or not significantly affected for both 4 arc (CIOPT =1.075, CISTD =1.080; p=0.090) and 2 arc (CIOPT =1.085, CISTD =1.103; p=0.017) configurations. Mean V12Gy was also reduced or not significantly affected for both 4-arc (V12GyOPT=21.6, V12GySTD=22.2; p=0.056) and 2-arc (V12GyOPT=21.4, V12GySTD=22.7; p=0.019) configurations.

Conclusions: We found that an optimized collimator angle setting for VMAT treatments reduced low-dose spill in comparison to a standard 45° collimator angle setting at no expense to the conformity or gradient indices or V12Gy. In this work, the normal tissue volume receiving a low dose was not included in the objective function. Work is ongoing to determine if penalizing the volume of brain receiving a low dose has a similar effect as selecting the collimator angle.
CyberKnife Robotic Spinal Radiosurgery in Prone Position: Dosimetric Advantage due to Posterior Radiation Access?

Fürweger C, Drexler C, Muacevic A, Wowra B, De Klerck E, Hoogeman M

Presented by: Christoph Fürweger, PhD

Objectives: Cyberknife spinal radiosurgery suffers from a lack of posterior beams due to workspace limitations. This is remedied by a newly-available tracking modality for fiducial-free, respiration-compensated spine tracking in prone patient position. We analyzed the potential dosimetric benefit in a planning study.

Methods: 14 exemplary cases were compared in 3 scenarios: Supine (PTV=CTV), prone (PTV=CTV), and prone position with an additional margin (PTV=CTV+2mm), to incorporate reduced accuracy of respiration-compensated tracking. Target and spinal cord constraints were chosen according to RTOG 0631 protocol for spinal metastases. Plan quality was scored based on 4 predefined parameters: Dose to cord (D0.1cc and D1cc), high dose (V10Gy) and low dose (V4Gy) volume of healthy tissue. Prescription dose was 16 Gy to the highest isodose line encompassing 90% of the target. Results were referenced with target size and position.

Results: All plans fulfilled RTOG 0631 constraints for coverage and dose to cord. When no additional margin was applied, a majority of 8 cases benefitted from prone position, mainly due to a reduction of V4Gy by 23.2±26.4%. In the 2 mm prone scenario, the benefit was nullified by an average increase of V10Gy by 43 ± 23.8%, and an increase of D1cc to cord (4 cases). Spinal cord D0.1cc was unchanged (<±1Gy) in all but 2 cases for both prone scenarios. Conformity and number of beams were equivalent in all scenarios, but supine plans used a significantly higher number of monitor units (+16%) than prone.

Conclusions: Posterior beam access can reduce dose to healthy tissue in Cyberknife spinal radiosurgery when no additional margin is applied. Relative anterior-posterior position and size of the target are crucial factors to select patients that benefit from prone treatment.
Changes in Respiratory-Induced Motion Patterns of Primary Liver Tumors using an Abdominal Compression Device

Kyle Barton, Shreya Sekaran, Haixin Lu, James A. Tanyi, Martin Fuss

Presented by: James A. Tanyi, PhD

Objectives: This study presents a comparison of tumor motion suppression afforded by an abdominal compression plate added to a whole-body immobilization system (BodyFix) in patients undergoing respiratory-correlated computed tomography (4DCT) simulation for stereotactic body radiation therapy (SBRT) of hepatocellular carcinoma (HCC).

Methods: Twenty-three HCC patients underwent SBRT simulation 4DCTs with and without abdominal compression. All patients had previously undergone Ethiodol-based transarterial chemoembolization (TACE), which resulted in a radio-opaque stain of the HCC. Target volumes were automatically delineated using a threshold based segmentation routine (Mirada Medical Ltd.; threshold 150 HU) on all 10 respiratory phases of the respective 4DCT data sets. The range of tumor motion, GTV volumes in all 10 4DCT phases, and resulting ITV volumes were compared.

Results: Motion patterns were patient-specific (mostly approximating a plane) with overall average (maximum range) of the GTV center of mass measuring 7.8±3.6 mm (range 1.8–17.9 mm) and 10.3±5.0 mm (range 2.6–24.8 mm) with and without abdominal compression (p=0.001). As expected tumor respiratory motion was predominantly observed in the craniocaudal direction (with and without abdominal compression: 6.9±3.1 mm vs. 8.8±3.6 mm; p=0.002). However, respiratory motion also significantly varied for anterior/posterior direction (with and without abdominal compression: 2.8±2.1 mm vs. 4.3±3.9 mm; p=0.002). Furthermore, ITV's derived from 4DCTs using abdominal compression were generally smaller (average reduction 11.4%±17.0%; p=0.001). With abdominal compression, a paradoxical increase in motion amplitude and ITV was observed in 4 out of 26 (15.4%) cases.

Conclusions: While abdominal compression resulted in smaller motion amplitude and ITV reduction in the majority of patients, the induction of a paradox effect is a possibility in up to 15% of cases, and should prompt systematic evaluation on an individual basis.
Dose Impact on Targets and Organs at Risk (Oars) from Sub Millimeter Collimator Size Differences

Stephen Sorensen Ph.D., Patricia Rojas-Castillo MSc

Presented by: Stephen Sorensen, PhD, MS

Objectives: To determine the dosimetric impact on patient treatment plans, from collimator size changes of the Cyberknife Iris™ variable aperture compared to commissioned data.

Methods: Six sets of output factors (OFs), tissue phantom ratios (TPRs), and off center ratios (OCRs) were created simulating changes of ±0.5mm, ±0.25mm, ±0.1mm, at 800 mm SAD, for the following collimator sizes (mm): 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 50. The new beam data was created by interpolating between the original data; changes to the 5 mm and 60 mm field sizes were not calculated. A number of clinical treatment plans were selected and anonymized. Plans selected for evaluation had critical structures in the immediate vicinity of the targets. Types of plans included: vestibular schwannoma, pituitary adenoma, meningioma, chordoma, hemangioma, and prostate. Plans were initially re-calculated with all six sets of data. After reviewing these results a decision was made to re-calculate with only the ±0.25mm and ±0.1mm data. All the calculations were done using a research work station provided by Accuray, eliminating the need to manipulate approved institution beam data. No changes were made to the contours, number of beams, number of MUs, prescription dose, beam orientation, alignment, fractionation, etc. The ray-tracing algorithm was used for all calculations. None of the plans evaluated in this study used the 5 mm or 60 mm field sizes. The changes in mean and max doses to individual organs at risk (OARs) and targets were compared to the original plan. All structures (targets and OARs) were combined to get an average dose difference for a given plan and collimator change.

Results: The average percent dose differences ranged from -13.1 % to -4.9 % for -0.5mm, 4.9 % to 11.4 % for +0.5mm, -7.3 % to -1.3 % for -0.25mm, 1.4 % to 5.8% for +0.25mm, -3.1 % to -0.5 % for -0.1mm, and 0.6% to 2.2% for +0.1mm. Plans using primarily smaller Iris™ collimator sizes (7.5mm & 10mm) resulted in larger dose differences, and by eliminating these plans the average percent dose difference changes to a range of -3.5 % to -1.3% for -0.25 mm and 1.4% to 3.2% for 0.25 mm. Percent changes in dose to OARs were greater than changes to targets. Decrease in collimator size results in larger percent dose changes compared to a comparable increase in collimator size.

Conclusions: Accurate commissioning and routine spot checks of the Cyberknife Iris™ variable aperture collimator are necessary to reduce differences between treatment plans and the actual delivered treatment. Maintaining changes = 0.1 mm would assure dose differences of less than 3.1 % for the plans evaluated in this study. However, the field size reproducibility limitation of the Iris™ is =0.2 mm at 800 mm SAD. In addition, the Iris QA technique from the vendor can at best detect changes around 0.2 mm. Changes of 0.25 mm in this study resulted in average dose differences as large as -7.3%. Eliminating the use of the smaller collimator sizes (7.5mm & 10mm) reduced the dose difference to a max of -3.5% for -0.25mm and 3.2% for 0.25mm. Plans needing small collimator sizes in close proximity to critical structures should instead utilize the fixed cones.
Validation and Use of the “Iris Quality Assurance Tool”

V. Baart, M. Devillers, E. Lenaerts

Presented by: Veronique Baart, MS

**Objectives:** On the CyberKnife (Accuray Inc., Sunnyvale, CA), beam collimation is achieved by either 12 fixed circular collimators or a 12-sided variable aperture collimator, called Iris. The “Iris Quality Assurance tool”, hereafter referred to as “Iris QA”, is a film-based tool provided by Accuray, allowing for reproducibility checking of Iris field sizes. The aim of this work is first to validate Iris QA and secondly to analyse Iris aperture reproducibility over 2 years.

**Methods:** The Iris QA consists in a phantom and a film analysis software. Gafchromic® EBT2 films placed into the phantom were irradiated and scanned by an Epson V750 Pro flat-bed scanner following Accuray recommendations. Two methods of analysis are available in the software. The first calculates an equivalent diameter that is the diameter of a circle with the same area as the thresholded region. The second calculates a profile diameter based on the average of 12 profiles taken at equally spaced angles around the centroid of the thresholded region. Standard deviation (SD) of these 12 profiles is also calculated for each field size.

First, to validate Iris QA, we performed repeated measurements of blank pixel value, optical density (OD) threshold and fixed collimator field sizes. OD threshold is set by irradiating 4 films with the 15 mm fixed collimator. It is defined as the average diameter of these scanned films that matches the nominal 15 mm diameter. Films of different collimators were scanned 10 times and then re-scanned with intervals of 15 to 360 minutes.

Secondly, to analyse Iris short-term reproducibility, we performed repeated measurements of Iris field sizes. To ascertain Iris long-term reproducibility, we have used the Iris QA every month for 2 years.

**Results:** Results from both methods differ by less than 0.1 mm. Unless otherwise indicated we present the equivalent diameter results.

First, blank pixel value measured three times in the same film batch presents a difference of up to 3% leading to a difference of 2% in OD threshold but no difference in measured field sizes. OD thresholds defined three times in a same batch show a difference of less than 0.5%. Films read 10 times consecutively show a measured field size increase of up to 0.5% attributed to lamp heating. Analysis of films scanned with different time intervals after irradiation shows an increase in field diameters of up to 2% of field sizes over 6 hours. This increase is less than 0.6% of field sizes during the last 2 hours. The SD of measured diameters for fixed collimators is inferior to 0.07 mm. The SD of the measured 12 profiles for each fixed collimator is inferior to 0.09 mm.

Secondly, the SD of Iris diameters measured repeatedly corresponds to less than 0.5% of field sizes for apertures larger than 12.5 mm. However for apertures of 5, 7.5 and 10 mm SD reaches 1.5% of field sizes. The SD of the measured 12 profiles for Iris collimator, due to the 12-sided collimator shape, ranges from 0.11 to 0.51 mm, increasing with Iris field size. The 5 mm aperture is an exception since the SD reaches 0.21 mm. This beam has an elliptical shape while in the treatment planning system it is modelled as a circular field. Over 2 years, we performed Iris QA 28 times. The mean SD for all field sizes is less than 1.5% of field sizes larger than 12.5 mm. However it reaches 3.4, 2.5 and 1.7% of Iris field sizes of 5, 7.5 and 10 mm respectively.

**Conclusions:** First, Iris QA is a reliable tool to verify the reproducibility of Iris field sizes with an accuracy better than 1.5%. Secondly, excellent short-term and long-term reproducibility of Iris field sizes is observed. Currently, in our institution, the three small Iris collimators are not used due to elliptical shape of the 5 mm collimator and the greater uncertainty we observed.
Design and Development of a Novel SBRT Plan Verification System

Nathan Childress, David Eklund, Mathieu Zhang, and Eli Stevens

Presented by: Nathan Childress, PhD, DABR

**Objectives:** SBRT presents unique treatment plan verification challenges. Traditional verification systems rely on Clarkson calculations, which can be inaccurate for small fields or heterogeneous anatomy. This is further complicated by the difficulty in obtaining accurate per-patient measurements of small-field plans. Current systems also do not test other critical aspects of the treatment plan such as DVH objectives, treatment time, and gantry/patient collisions. We propose a novel system, Mobius3D, that incorporates automatic verification of several treatment plan aspects to increase patient safety and clinical efficiency.

**Methods:** Mobius3D has been developed to automatically perform checks on treatment plans. A plan is transmitted to the system via DICOM-RT (including CT, 3D dose, structures, and beam information). The plan is automatically imported and dose is recalculated using an independent 3D collapsed cone algorithm. Dose calculations use reference beam models to maintain independence from the planning system calculated dose. DVHs are determined for all structures for both the planning system-calculated dose and the recalculated dose. Structures in the treatment plan are paired to reference structures via customizable name matching rules. RTOG recommended DVH objectives for each reference structure are then analyzed. A 3D gamma comparison is performed to validate dose calculation accuracy. The minimum gantry to patient (or couch) surface is calculated for each beam by modeling the gantry as a cylinder and detecting surfaces in the patient CT scan. Treatment time is estimated for each beam using dose rate and gantry, collimator, and MLC delivery speeds. All verifications are categorized with pass (green), warn (yellow), or alert (red) indicators. The system has been tested using a suite of benchmark plans with known errors, as well as distributed to several clinics for independent beta testing.

**Results:** Mobius3D was able to automatically and correctly identify errors in DVH objectives, dose calculations, gantry/patient collisions, and undeliverable MLC motions. Dose verifications for SBRT plans in multiple anatomic sites were tested with IMRT and VMAT delivery techniques. At beta sites, good agreement between Mobius3D, Varian Eclipse, and Philips Pinnacle3 calculations was observed in most cases. Clinical efficiency of plan checks was increased by automatic detection of a wider range of errors. Color coding all results increased the ease of analyzing detailed plan verification reports. Verifying the deliverability of all beams reduced first treatment day issues and delays. Plan verifications were generally completed in 5-10 minutes for VMAT deliveries, and 1-2 minutes for other delivery methods.

**Conclusions:** A system was developed that automatically performs a 3D secondary dose calculation and several other validations on a treatment plan. Automatic analysis of the final treatment plan decreased clinical plan checking time. Patient safety was increased by checking many aspects of the treatment planning computer (3D heterogeneous dose calculation, DVH calculations, beam modeling, etc.) were functioning properly for every generated plan. Mobius3D has successfully completed benchmark test cases and beta testing, and is now released as a clinical verification system.
Imaging Dose Measurements for the CyberKnife
X-Ray Cameras and Potentials for Dose Reduction

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Presented by: Oliver Blanck, Dipl. Inf.

**Objectives:** The CyberKnife uses stereoscopic x-ray imaging for patient alignment and motion compensation during image guided radiosurgery / radiation therapy (IGRT). In some parts of Germany it recently became mandatory to monitor and report imaging doses for IGRT especially for the CyberKnife. In our center an imaging dose monitoring system (IDMS) was mounted on both x-ray sources in early 2012 (PTW / Accuray Monitor Amplifier T16032 and Monitor Chamber T34066). In this study we first present a quality assurance (QA) measure for this system and dose measurements for the first 4 months of patient treatment. In a second step we analyzed the image acquisition and processing chain to show potential for reductions of the imaging doses.

**Methods:** For QA of the IDMS system we used gafchromic XRQA2 film (Ashland / ISP, USA) to assess the relevant field sizes and the Unfors XI (Raysafe, USA) to verify the measurements. We statistically analyzed the doses of 74 treated patients in 221 fractions with the different tracking modalities. We also analyzed the difference between the first and subsequent fractions and the contribution of LINAC head leakage to the measurements using an End-2-End (E2E) test without imaging for calibration. Afterwards, we analyzed the different pre-processing steps for fiducial marker triangulation. A stereo-camera calibration was performed on the x-ray cameras. Using this calibration all fiducial positions visible by the CyberKnife system were simulated and projected onto the flat-panel detectors. In this way the minimal area of the x-ray detectors was determined.

**Results:** The relevant field size for found to be 20.78cm x 27.54cm for Camera A and 23.58cm x 27.39cm for Camera B for our system. The IDMS compared well with the reference measurements of the Unfors XI showing 8.52cGy/cm\(^2\) versus 8.845cGy/cm\(^2\) (3.7\%) for Camera A and 9.43cGy/cm\(^2\) versus 9.65cGy/cm\(^2\) (2.3\%) for Camera B. The measured mean surface dose to the patient of a standard stereo x-ray acquisition (120kv/100mV/100ms) was 0.3mGy which matched well to reports in literature. The LINAC head leakage contributed 0.05cGy/cm\(^2\) per MU delivered to the IDMS during the E2E test. For the first 74 treatments we measured a leakage corrected mean total patient imaging dose of 15.10mGy for 6DSkull, 55.78mGy for XSight Spine, 84.95mGy for XSight Lung and 144.15mGy for Sychrony with Sychrony for an average of 3 fractions given in our center. Number of stereo images per fraction ranged from a mean of 31 for XSight Spine to a mean of 64 for Sychrony whereas treatment time averaged between 30 and 50 minutes. The dose difference between the first and sub sequent fractions ranged from -5\% (6DSkull) to -25\% (Sychrony). Our image processing analysis revealed that only 91\% (vertical) and 62-67\% (horizontal) of the flat-panel detectors could be used for marker detection, while the rest of the detector area stays unused. Limiting dose exposition to actively used areas only could theoretically decrease the overall dose by more than 40\%.

**Conclusions:** We demonstrated the clinical use and quality assurance of the IDMS for the CyberKnife. High imaging doses are giving to the patient especially in fractioned Sychrony treatments however these doses are small compared to the skin doses due to the treatment beams. Nevertheless, following the ALARA principle there is potential for dose reduction. Technically, dose exposition could be limited to the usable areas of the flat-panel detectors. Furthermore, the reduction of images from the first to subsequent fractions demonstrated that there is high potential for dose reduction through intelligent imaging strategies.
Circumferential or Sectored Beam Arrangements for Stereotactic Body Radiation Therapy (SBRT): Impact on Target and Normal-Structure Dose-Volume Metrics


Presented by: James A. Tanyi, PhD

Objectives: Beam arrangements for SBRT of lung tumors follow personal or institutional preferences. While beam entry over the contralateral lung is avoided by some groups, others favor a more evenly spaced circumferential beam arrangement. We compared two beam arrangements; sectored (beam entry over ipsilateral hemithorax) and circumferential (beam entry over ipsi- and contralateral lung), for static-gantry IMRT delivery techniques with respect to dose gradient and exposure of normal organs at risk.

Methods: Data from 132 patients treated by SBRT for primary NSCLC formed the basis of this study. Structures analyzed for dose exposure were the 4DCT-derived internal target volume (ITV), planning target volume (PTV, 5 mm expansion of ITV), spinal cord and the esophagus (delineated extending 5 slices above and below the PTV), ipsilateral (excluding PTV) and contralateral lung, respectively. Two treatment plans were generated per dataset: (1) IMRT plans using sectored beam arrangement (IMRT-s), and (2) IMRT plans using circumferential beam configuration (IMRT-c). Prescription dose (PD) was 60 Gy (12 Gy/5 fx) to 95% of the PTV, and maximum PTV dose of 150%. Standardized optimization techniques were used on all plans. For lungs, mean doses (MLD), V5, V10, and V20 were recorded. Plan conformity indices, a measure of dose gradient, were computed; CI80, CI60 and CI40 (ratio of volume of 80%, 60%, and 40% isodose, and PTV volume. Maximum dose (Dmax), D5 and D50 for spinal cord and esophagus were computed. Dose parameters were analyzed with respect to tumor location (upper, middle, and lower lobes).

Results: ITV for the current study ranged from 0.9-162.9 cm3 (mean=20.9). IMRT-s planning resulted in significant decrease in contralateral MLD, V5, V10 and V20 when compared with IMRT-c (all p< 0.001). This finding applied to all tumor sites analyzed (all p<0.001). Ipsilateral lung dose exposure did not show statistical differences between IMRT-s and IMRT-c. While nominal reductions of Dmax, D5 and D50 for the spinal cord in IMRT-s plans did not reach statistical significance (p = 0.57, 0.18, and 0.19), the respective measures for esophagus were significantly lower than in IMRT-c plans (20.9%, 15.0%, and 22.6%; all p<0.001). Dose gradient improved with IMRT-s technique. Reductions in CI80, CI60, and CI40 were 1.4%, 3.5% and 8.1%, respectively.

Conclusions: Sectored IMRT beam arrangements showed dosimetric advantages over circumferential beam arrangements in terms of dose gradient and contralateral lung sparing. Further studies are needed to evaluate the clinical relevance of the current findings.
Validation of the Use of Commercial MU Second Check Programs in Radiosurgery

Ronald J. Lalonde, PhD

Objectives: To determine under what conditions a commercial MU checking program may be used to validate SRS/SBRT calculations from a treatment planning system.

To establish guidelines for commissioning and validating MU checking programs for radiosurgery.

To compare MU calculations with treatment planning system calculations in homogeneous, inhomogeneous phantoms and in patient data sets.

Methods: Beam data from a Varian Truebeam linac was used to commission both the Varian Eclipse treatment planning system and the Radcalc MU calculation program for small field sizes (down to 1.0 cm) used in radiosurgery. Point dose calculations were performed for both theoretical and physical homogeneous and heterogeneous phantoms, and for patient CT data sets in the cranium and in the body, and for open (conformal) and modulated fields. Point dose comparisons were made between the planning system and the MU check program for field sizes from 3x3 cm² to 0.5x0.5 cm², and for modulated fields with average leaf pair opening (ALPO) from 2.0 cm to 0.5 cm.

Results: Radcalc homogeneous dose calculations for conformal fields in phantom agreed with Eclipse to within acceptable tolerances (< 5%) for all field sizes down to 1.0 cm diameter (circular targets). However, in heterogeneous (lung equivalent) media, Radcalc point doses for a 1.0 cm diameter target were 20% greater than Eclipse. Calculations of modulated plans varied with both field size (similar to conformal fields) and degree of modulation (as measured by average leaf pair opening). Modulated plans agreed within acceptable tolerances for ALPO of 1.5 cm or greater. In patient CT datasets, the results were similar, with acceptable agreement between Radcalc and Eclipse for field sizes 1.5 cm or greater in the lung, and 1.0 cm or greater in the cranium.

Conclusions: Commercial MU check programs may be used to confirm radiosurgery doses within certain limitations. Careful validation of the programs should be performed before routine use in clinical calculations.
Geometric Evaluation of Intrafraction Motion during Frameless Intracranial Stereotactic Radiosurgery (SRS)

Catherine M. Kato, James A. Tanyi, Charlotte Kubicky Carol M. Marquez, Martin Fuss

Presented by: James A. Tanyi, PhD

Objectives: To quantify intrafraction motion during frameless intracranial stereotactic radiosurgery (SRS) using the six-degree-of-freedom (6DOF) stereoscopic x-ray imaging system.

Methods: Patient immobilization was accomplished by either a custom-fitted three-piece bivalve-style thermoplastic mask (BrainLAB AG, Heimstetten, Germany) or a three-point fixation Orfit mask system (Orfit Industries, Wijnegem, Belgium). Frameless positioning was based on online 6DOF stereoscopic x-ray (ExacTrac) imaging followed by online volumetric image guidance (CBCT) for residual error assessment. At least one mid-treatment ExacTrac acquisition was performed for motion assessment. The difference between the patient’s position at the start and at the time of reassessment was determined and labeled intrafraction motion.

Results: A cohort of 180 sequential patients that were subjected to frameless cranial SRS formed the basis of the current analysis. In total, 350 intrafraction ExacTrac image sets were evaluated (mode 1; range 1-3). Intrafraction translational motion was -0.1 mm (SD=0.7; range: -2.5–2.0), 0.0 mm (SD=0.8; range: -2.5–2.1), and 0.1 mm (SD=0.8; range: -2.3–2.8), in the vertical, longitudinal and lateral directions, respectively. The 3D vector was 1.1 mm (SD=0.7; range: 0.0–3.5). Intrafraction rotational alignment errors was 0.0 degrees (SD=0.8; range: -2.8–2.7), 0.0 degrees (SD=0.4; range: -1.1, 1.4), and 0.1 degrees (SD=0.7; range: -2.2–2.7) in the yaw, roll and pitch directions, respectively. Frequency of absolute motion in any direction >1 mm, >1.5 mm and >2 in any direction was 33%, 15% and 5% respectively. Frequency of 3D vector motion >1 mm, >1.5 mm and >2 was 48%, 25% and 10% respectively.

Conclusions: Intrafraction motion during frameless SRS delivery is typically small, albeit non-negligible. While motion along one or more room axes and 3D motion vectors >2 mm were observed no more than 10% of times, this finding may provide a rationale for development of planning target volume margins. Frequent intra-treatment positioning assessment can significantly contribute to the precision of frameless intracranial SRS.
Properties of Gafchromic EBT3 and MDV3 Film and Application for Quality Assurance in Robotic Radiosurgery

O. Blanck1,2, H.W. Breyer2,3, D. Rades1, J. Dunst1, G. Hildebrandt4

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2 CyberKnife Center Northern Germany
3 German Physics GmbH
4 University Clinic Rostock, Department of Radiation Oncology

Presented by: Oliver Blanck, Dipl. Inf.

Objectives: Gafchromic MD55 and later EBT2 film have been widely used for routine and delivery quality assurance (DQA) for the CyberKnife and recommendations for schedules and passing criteria were made in the AAPM Task Force 135 Report. Recently Ashland / ISP (USA) developed newer versions of the films: EBT3 and MDV3. Our objective was to investigate the properties of EBT3 and MDV3 and their clinical use for CyberKnife QA.

Methods: For our study ISP provided samples of EBT3 and MDV3 film as well as laser cut fits for the CyberKnife phantoms such as the BallCube2 (BC2). First we analyzed the dose response curves using the different color channels also for higher doses. We then compared 25 different End-2-End (E2E) tests using EBT3 to the results of 50 E2E tests previously done with EBT2. We also tested EBT3 and MDV3 with 25Gy. For delivery QA with EBT3 we ran 15 complex treatment cases scaled to mean 8Gy (+/- 2Gy) maximum dose projected on the BC2 with either the head phantom (intracranial) or the moving platform with hemisphere (extracranial). We evaluated our results using FilmQA™ version 3.0 beta (3Cognition, USA) using the registration function for the BC2 and the image processing toolbox to reduce noise in the scans. We used an acceptance criteria of > 98% pixels passing Gamma for 2% Dose / 2mm Distance-to-agreement (DTA) at the 50 % Isodose. As further evaluation for system accuracy we obtained a maximum search for Gamma 1% Dose / 1mm DTA with > 90% pixels passing and < 1mm spatial corrections in FilmQA. To analyze the sensitivity of our methods we ran 5 DQA tests before and after DeltaMan correction. All our tests were done under 1 hour.

Results: The EBT3 laser cut films agreed within a mean difference of 0.15 mm and 0.25mm to the EBT2 films and to the BC2 (EBT2 to BC2 mean difference 0.29mm) of the measured edges, slits and holes. A good working range for EBT3 was found to be 1-10Gy and 1-40Gy (Max 50Gy and 60Gy) and for MDV3 1-70Gy and 5-100Gy (max 120Gy and >120Gy) for the red and green color channel respectively. The darkening in first 12 hours ranged from 1-2% (MDV3) to 4-5% (EBT3). The E2E tests with EBT3 showed on average 0.59mm offset (Min 0.04, Max 0.94, SD 0.236) and the E2E tests with EBT2 showed on average 0.42mm offset (Min 0.04, Max 1.28, SD 0.272). All DQA tests with EBT3 passed with average 99.1% and 94.7% pixels passing Gamma 2%/2mm without and 1%/1mm with average spatial corrections of 0.69 mm (0.67/-0.1/-0.1 Left/Sup/Ant). The results compared well with the FilmQA corrected results of the E2E tests with average 0.68mm offset (0.43/-0.14/-0.17 Left/Sup/Ant). All 5 DQA tests made before DeltaMan correction (E2E mean offset 1.27mm) failed Gamma 2%/2mm (mean 96.8%) without and Gamma 1%/1mm with spatial corrections (mean 1.29mm) demonstrating sensitivity of our methods.

Conclusions: The use of laser cut EBT3 film provided high spatial and absolute dose information for radiosurgery QA and DQA and is usable in clinical routine. With our methods we found excellent agreement between the film and the planned dose with maximum film doses below 10Gy using the red color channel for EBT3. For higher doses the green color channel of EBT3 or the MDV3 film can be used. Even though our DQA methods were able to detect small system offsets further enhancements these and further studies to investigate dose sensitivity should be investigated. Ultimately a consensus on DQA is desirable within the physics community.

The authors would like to thank Xiang Yu of Ashland / ISP for providing the films, Gary Gluckman of 3Cognition for providing the beta version of FilmQA and Daniela Poppinga / Bjoern Poppe of the Carl von Ossietzky University Oldenburg for helpful discussions.
PHYSICS WORKSHOPS & SYMPOSIA

SRS/SBRT DOSIMETRY WORKSHOP
Presented by Steven Goetsch, PhD, Stephen Kry, PhD, Brian Wang, PhD and Jun Yang, PhD
Moderated by Ian Cowley, PhD and Charlie Ma, PhD

MONTE CARLO SYMPOSIUM
Presented by Ian Cowley, PhD, Stephen Kry, PhD, Charlie Ma, PhD and Jun Yang, PhD
Moderated by Mary Ellen Masterson-McGary, MS, MA and Fang-Fang Yin, PhD
QA & SAFETY IN SRS/SBRT SYMPOSIUM
Presented by Steven Goetsch, PhD, Per Halvorsen, MS, DABR, FACR and Todd Pawlicki, PhD
Moderated by Steven Goetsch, PhD and Dave Taylor, MS
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Comparison of Single versus Two Fractions of Radiosurgery for Brain Metastases: A Prospective Randomized Study

Mustafa Cengiz, Gokhan Ozyigit, Yildiz Yukselen Guney, Alpaslan Mayadagli, Gulhan Guler, Mihriban Kocak, Naciye Ozseker, Bulent Kucukplakci, Melis Gultekin

Presented by: Mustafa Cengiz, MD

Objectives: To evaluate response rate and toxicity of single versus two fractions of stereotactic radiosurgery (SRS) for brain metastases in a prospective randomized study.

Methods: Patients with brain metastases in RPA classes I and II were randomized to single dose of SRS (Arm A) and 2 fractions of SRS (Arm B) with CyberKnife® system. Eligible patients were required to have 3 or less metastasis and largest tumor size should be less than 4 cm. Patients were excluded if RPA score is 3 or if neurological functional status was 3 or more. The primary tumor location was lung in 54 patients, breast in 13 patients, and other sites in 12 patients. SRS dose was decided according to tumor size. If tumor size was 2 cm or less, SRS dose was 22 Gy single dose or 2x14 Gy. If tumor size was between 2.1-3 cm, SRS dose was 18 Gy single dose or 2x12 Gy. If tumor size was between 3.1-4 cm, SRS dose was 15 Gy single dose or 2x10 Gy. All patients received whole brain irradiation of 25 Gy in 10 fractions within 2 weeks after completion of SRS.

Results: A total of 79 patients were enrolled in this trial from 3 centers of Turkey. The median follow-up is 8.2 months (range between 0.5-23.6). The clinical features of two arms were similar with regard to RPA score, ECOG performance status, tumor size and number of metastases. Twenty-seven patients died of disease. One-year actuarial local control rate was 77.5% for all patients. There was no significant difference between 1-year actuarial local control rate of two arms (78 % for arm A vs. 64.3 % for Arm B, p=0.5). We could not find any prognostic factors that may affect local control. One year overall survival for all patients was 48 %. There was no significant difference between two arms (43% for Arm A vs. 55.6 % for Arm B, p=0.28). The neurological functional status and performance status were found to be significant prognostic factors determining overall survival, whereas RPA scores did not have any significant impact on survival. We observed only one brain necrosis around lesion in Arm A.

Conclusions: Our study did not show any difference of single fraction SRS and two fractions SRS with regard to local tumor control, overall survival and toxicity in the management of brain metastases.
**Pseudoprogression at Stereotactic Re-Irradiation: A Prognostic Factor in Recurrent Glioblastoma**

Gözde Yazici, Mustafa Cengiz, Gökhan Özyigit, Gülnihan Eren, Hüseyin Kivanç, Ferah Yıldız, Fadil Akyol, Murat Gürkaynak, Faruk Zorlu

Presented by: Mustafa Cengiz, MD

**Objectives:** Treatment choices for patients with recurrent glioblastoma (GBM) are sparse and the results are unsatisfactory. This retrospective study aimed to analyze the results of reirradiation using an image-guided, fractionated frameless stereotactic radiotherapy (SRT) technique in patients with locally recurrent GBM.

**Methods:** In total, 37 patients with the diagnosis of recurrent GBM were treated between September 2009 and December 2011. SRT was performed using a CyberKnife (Accuray, Sunnyvale, CA) and a median of 5 fractions (range: 1-5). Doses ranged from 1400 cGy to 3200 cGy (median: 3000 cGy). Gross tumor volume (GTV) was determined based on contrast-enhanced T1 images and a 1-3-mm margin was added to define the planning target volume (PTV).

**Results:** Median follow-up was 9.3 months. In all, 5 patients had lesion regression, 14 had stable disease, 8 had progression, and 7 had pseudoprogression. Median survival following SRT was 10.6 months and overall survival was 35.5 months. The median time from SRT to progression was 7.9 months. Among the patients, those with pseudoprogression had significantly longer survival after the first magnetic resonance imaging (MRI) evaluation (P = 0.012). Median survival in patients with pseudoprogression was 20 months. Median GTV volume was 24 cc (range: 2cc-81cc). Patients with a GTV <24 cc had significantly longer survival following SRT than those with a GTV =24 cc (P = 0.015). Median survival in the patients that received chemotherapy after SRT was 16.8 months, versus 9.7 months in those that did not receive chemotherapy (P = 0.062).

**Conclusions:** Our study showed that stereotactic re-irradiation for GBM is safe and effective treatment. SRT is completed with a few fractions, is very useful in patients with a short life expectancy and should be offered to patients with good performance status and well-demarcated lesions. One should be aware of pseudoprogression during patient follow up after re-irradiation, that indicates good prognosis.
Successful Treatment of Neoadjuvant Chemotherapy and CyberKnife Radiotherapy for Pineal Parenchymal Tumor of Intermediate Differentiation

Ataru Fukuda, Hiroaki Shiratori, Isao Kitahara

Presented by: Ataru Fukuda, MD, PhD

Objectives: We report the case of a patient with pineal parenchymal tumor of intermediate differentiation, in which neoadjuvant chemotherapy and CyberKnife radiotherapy were performed to improve the degree of surgical resection for tumor reduction and to prevent postoperative meningeal dissemination. Good treatment outcomes were obtained.

Methods: During evaluation for headaches, pineal tumor and hydrocephalus were incidentally identified in this 22-year-old man. The diagnosis was made by neuroendoscopic third-ventricle fenestration and biopsy. As neoadjuvant therapy, chemotherapy (IFO 1700 mg, CDDP 38 mg, and etoposide 110 mg) was administered for 5 days. This was followed 1 month later by 5 fraction stereotactic radiotherapy with CyberKnife (prescription dose, 3522 cGy; D95, 73.23%; tumor volume, 5725 mm3). Tumor reduction was observed 1 month after CyberKnife radiotherapy.

Results: Craniotomy and tumor resection were performed, achieving complete macroscopic resection. Intraoperative findings showed no changes due to radiotherapy, including arachnoid thickening or adhesions between tumor and surrounding normal tissue. After neoadjuvant therapy, histopathological findings showed cytoplasmic vacuolization, irregular unevenness of nuclei, and some nucleoplasm and nucleolus membrane leakage. Postoperatively, despite diplopia and slight memory impairment, the patient was improved. Currently, as of 3 years postoperatively, no findings suspicious of local recurrence or meningeal dissemination have been identified.

Conclusions: Neoadjuvant chemotherapy and CyberKnife radiotherapy is a good choice of treatment for pineal parenchymal tumor of intermediate differentiation.
Comprehensive Review of MR Imaging Changes following Adjuvant Focal Radiation Therapy after Surgical Resection of Intracranial Metastases


Presented by: Maged Ghaly, MD

Objectives: To retrospectively evaluate the effectiveness of adjuvant focal stereotactic radiotherapy (SRT) and stereotactic radiosurgery (SRS) after brain metastasis resection.

Methods: MR images of patients from our institution who were treated with adjuvant focal radiation following resection of intracranial metastases between 01/2010 and 09/2012 were reviewed and analyzed. The volume of the surgical bed at initial treatment and for each follow-up was computed using the following formula: (4π/3)*A*B*C (with A, B, & C defined as the largest diameter in all three orthogonal planes). Volume changes were correlated with radiation treatment variables and histopathology. RECIST guidelines version 1.1 was used to assess treatment response. Imaging responses after adjuvant multiple or single fraction focal radiation were compared using chi-square. Lesions meeting the criteria of progressive disease were evaluated for tumor progression versus radiation effect with FDG-PET, MR spectroscopy, T1/T2 mismatch, and with surgical biopsy when appropriate.

Results: 53 patients with 54 lesions were available for follow-up with serial MRI from 0.2–24.5 months (5.00 ± 6.73 months--mean ± SD) after treatment. Resection beds in 34 lesions (63%) were > 3 cc. 26 surgical beds (48%) with a median volume of 8.1 cm3 were treated with 3-fraction SRT with a median dose of 24 Gy (range 19.5–27 Gy). The remaining 28 target volumes (52%) with a median volume of 5.3 cm3 were treated with SRS with a median dose of 18 Gy (range 16–20 Gy). Lung, GU, and GI primaries constituted approximately 50%, 17%, and 13% of metastases in both groups. Local control was achieved in 47 lesions (87%). Local control was significantly better for lesions treated with adjuvant SRT (96%) than for lesions treated with SRS (79%) respectively (P = 0.01). The resection bed volume was increased in 7 patients on at least 1 follow-up MRI—1 in the SRT group (biopsy proven necrosis) and 6 in the SRS cohort. Of these, 2 had surgically documented progression and T1/T2 match was present in 3 (consistent with a high probability of progressive tumor), and T1/T2 mismatch (i.e. likely necrosis) was seen in 1. Six patients in each group suffered intracranial distant failure.

Conclusions: Adjuvant SRT can be an advantageous course of treatment following resection of intracranial brain metastases. Higher focal radiation doses than those typically used in palliative regimens, offer excellent tumor control. Frameless stereotactic approaches facilitate fractionation when medically appropriate and may exploit well-studied radiobiological principles to clinical advantage.
Survey of Hypofractionated Brainstem Dose Tolerance Limits
Over the Past 40 Years

Jimm Grimm, PhD, Jinyu Xue, PhD, Gregory Kubicek, MD, H. Warren Goldman, MD, PhD,
Tamara LaCouture, MD, Yan Chen, PhD, Lesley Hughes, MD, Ellen Yorke, PhD

Presented by: Jimm Grimm, PhD

Objectives: To review the variety of brainstem dose tolerance limits that have been in clinical use and to gain an understanding of true brainstem dose tolerance, which may be higher for small volumes than some current guidelines suggest.

Methods: Based on statistical outcomes analysis of several studies, QUANTEC reported that a conservative 12.5Gy maximum brainstem dose would keep complications below 5% for single fraction radiosurgery. If alpha/beta \( = 2 \), the corresponding biological equivalent dose (BED) according to the linear quadratic (LQ) model is 90.6Gy. Other studies have used up to 15 - 20Gy brainstem radiosurgical limits (BED2 = 127.5 - 220Gy). The first use of radiosurgery to treat trigeminal neuralgia (TN) was published by Leksell in 1971 and in early TN cases the maximum brainstem dose was also generally limited to 12 - 15Gy, and eventually escalated to 37.5Gy (BED2 = 740.6Gy). By 2003 an escalated maximum brainstem dose of 45Gy in a single fraction (BED2 = 1057.5Gy) was published. Although some clinicians still prefer to limit the maximum brainstem dose to 15 - 20Gy in TN treatments, others continue to place the isocenter as close to the root entry zone of the trigeminal nerve as possible, with the brainstem receiving 50% of the 90Gy prescribed dose. A literature survey of TN radiosurgery revealed virtually no severe toxicity. Patient survival for TN is generally good; nevertheless publications with three-year and longer followup are rare. Published brainstem dose tolerance is investigated and compared with the dose-volume data in TN radiosurgery. We also performed a biological modeling study of dose-volume data in brainstem for TN treated with Gamma Knife, CyberKnife and Linac-based radiosurgery. Fractionated dose tolerance limits are also reviewed.

Results: The highest known maximum brainstem dose limit of 45Gy in a single fraction has been in clinical use for treatment of TN for more than 10 years with remarkably low complication rates. The predominant side effect after TN radiosurgery is mild to moderate facial numbness, with few other severe radiation toxicities observed. The biologically effective dose (BED) of 45Gy in a single fraction is much higher than any brainstem dose tolerance currently cited in conventional fractionation or other single or hypofractionated treatments. In contrast, the acoustic neuroma, AVM and vestibular schwannoma studies referenced by QUANTEC are based on statistical outcomes analysis so there are in fact other real tolerance limits to the maximum brainstem dose in the range of 12.5 to 17.5Gy. Possible factors are discussed that could explain why such higher brainstem doses are feasible for TN treatments. Current models are suggestive but need extensive analysis with detailed dose-volume clinical data.

Conclusions: The actual human brainstem dose tolerance has not changed over the years, but our understanding of it has. The accuracy to which we can treat targets near the brainstem has improved over the years, as well as our ability to accurately image the anatomy. The result of TN radiosurgery suggests that under conditions of meticulously accurate dose delivery, a very small volume of brainstem can tolerate drastically high dose without causing any clinically severe injury. Further investigation of the best predictive dose-volume metrics of brainstem toxicity is warranted.
Complication Probability for Hearing Analysis for Acoustic Neuroma Patients after CyberKnife Stereotactic Radiosurgery

Abdul Rashid, Ph.D., Sana D. Karam, M.D., Ph.D., Alexander Tai, B.S, K. William Harter, M.D., and Sean Collins, M.D., Ph.D.

Presented by: Abdul Rashid, PhD

Objectives: In this study, a predictive model was generated to estimate the probability of hearing risk as a result of acoustic schwannoma radiosurgery.

Methods: The maximum doses and grade of the complications from cochlea were imported into the DVH Evaluator where the probit dose response model was fitted using the maximum likelihood algorithm. The models fitting parameters were optimized to provide the best fit to the observed complication data for acoustic neuroma patients treated with Cyberknife Stereotactic radiosurgery at the Medstar Georgetown University Hospital.

Results: The two standard maximum point dose tolerance limits for cochlea in five fractions are Timmerman’s 27.5Gy limit and the TG-101 25Gy limit. From this dataset for Grade 3 complications the predicted risk level of these dose tolerance limits are 12.2% and 7.5%, respectively. This is based on only two events so it is a good early indication of risk level but much more statistical power is needed from longer follow up.

Conclusions: Cochlea maximum doses can be used to estimate the hearing risk analysis from acoustic neuroma radiosurgery. More clinical data and further study will lead to refinement of this study.
**Stereotactic Radiation for Brain Metastases with CyberKnife: The Hamilton Experience**

Waseem Sharieff MD PhD FRCPC, Jeffrey N Greenspoon MD MSc FRCPC, Todd Newton MRT(T), Stephen Gauld MRT (T) CMD, Tom Chow PhD, Thorsteinn Gunnarsson MD MSc, Rocco De Villiers MBChB FRCSC, Anthony Whitton MBBS, FRCR FRCPC

Presented by: Kara Schnarr

**Objectives:** To describe patient characteristics, clinical outcomes and prognostic factors of local control, survival and radiation necrosis associated with stereotactic radiation therapy for brain metastases.

**Methods:** Since, the inception of Cyberknife stereotactic program in Hamilton, prospective data are being collected in a web-based database. These data were analyzed with descriptive statistics; means and standard deviations for continuous data and frequencies and percentages for categorical data. Kaplan-Meir and Cox regression will be used to analyze local control, survival and toxicity.

**Results:** From October 2009 to October 2012, 279 patients with brain metastases were treated with stereotactic radiation therapy. Out of 279, 162 (58%) had lung cancer, 36 (13%) had melanoma, 31 (11%) had breast cancer, 18 (6%) had gastrointestinal malignancy, 15 (5%) had renal cell carcinoma, and the rest were genitourinary, gynecological or unknown primaries. Mean age was 64 ± 11 years, Karnowfsky scale was 79 ± 12 and Mini Mental Score was 29 ± 1.3. A total of 582 lesions were treated; 450 (77%) in the cerebral hemispheres, 121 (21%) in the cerebellum, 6 (1%) in brainstem, others in thalamus, pituitary and cerebello-pontine angle. Out of 582 lesions, 500 (85%) were treated with single fraction. Doses ranged from 12-25 Gy for single-fractionated regimens, and 18-25 Gy for multi-fractionated regimens. Median PTV was 726 (IQR 175-2611) mm³ for single and 9135 (IQR 6626-14683) mm³ for multi-fractionated regimens. Four (0.6%) lesions underwent radiation necrosis.

**Conclusions:** This is a large series from a single institution comprising of a wide variety of metastatic brain lesions. Clinical outcomes data are being analyzed for rates of local control, survival, and toxicity; prognostic factors will be identified. Knowledge learnt would help further refine patient selection to minimize toxicity.
Meningioma Patients Treated with CyberKnife Radiosurgery –
A Review of 23 Patients

Damon E. Smith, Sanjay Ghosh, Colin Chu

Presented by: Damon E. Smith, MD

Objectives: To define the rate of tumor control and factors associated with relief of symptoms and radiation-related complications after Cyberknife radiosurgery (CKRS) for patients with imaging defined intracranial meningiomas.

Methods: Retrospective review of 25 tumors treated in 23 patients (18 women, 5 men) having CKRS for imaging-defined intracranial meningiomas between 2006 and 2011. The mean patient age was 60 years. The majority of tumors involved the skull base (n=12, 52%) and the convexity (n=7, 30%). The mean treatment volume was 14.34 cm³ (range, .79 – 64.5 cm³); Eleven of the tumors were greater than 10 cm³ in volume. Most patients were treated with a 5 fraction course of 4.5 to 6 Gy/fraction. The mean new conformality index was 1.61 (range, 1.2-2.28). Mean follow-up is 31.7 months, ranging from 8-66 months.

Results: No patient died from tumor progression or radiation-related complications. There were no instances of in-field progression; one patient experienced marginal tumor progression outside the field (scalp nodules) which required surgical resection. The crude local control rate was 100%. Three patients experienced side effects as a result of their treatment: one patient experienced headaches secondary to edema which responded to medication which has since been discontinued, one patient with a parasagittal tumor required resection because of increasing hemiparesis, and one patient who had been previously irradiated with external beam treatment suffered radiation necrosis resulting in persistent headaches and cognitive changes despite medication. Both of the patients with more severe side effects were treated at the high end of the dose spectrum (16 Gy single fraction equivalent dose). Seven patients preseing with symptoms ranging from headaches to visual changes; in 4 of these patients the symptoms were improved or resolved at the time of last follow-up.

Conclusions: Cyberknife radiosurgery with a single-fraction equivalent dose of 12-16 Gy provides a high rate of tumor control for patients with imaging defined intracranial meningiomas, despite the large size (>10 cm³) of almost half of the tumors. Patients who were symptomatic at the time of presentation had a greater than 50% chance of improvement or amelioration of their symptoms.
CyberKnife Radiosurgery for Jugular Foramen Schwannomas: Preliminary Outcomes

EnMin Wang, Xiaoxia Liu, Xin Wang, Guanghai Mei, Li Pan, Jiazhong Dai

Presented by: EnMin Wang, MD, PhD

Objectives: Jugular foramen schwannomas are rare tumors of the brain often treated by surgical resection. Surgery may be associated with high morbidity. This study is to review our clinical and imaging outcomes after patients underwent CyberKnife radiosurgery for jugular foramen schwannomas.

Methods: Between March 2008 and December 2010, seventeen patients with jugular foramen schwannomas underwent hypofractionated CyberKnife radiosurgery. Patients with type 2 neurofibromatosis were not included. The mean age was 50 years (range, 33–72 years). Five patients had previous microsurgical resections, presented with preradiosurgery cranial nerve deficits. The other 12 patients underwent CyberKnife radiosurgery based on their neuroimaging and clinical manifestations. The tumor volume ranged from 2.6cm³ to 28.9cm³ (mean, 16.2cm³), 10 of them was larger than 10cm³ in volume. The prescription dose for one patient with a large tumor was 21.6Gy, delivered in four fractions. Five patients with small and medium-sized tumors received 19 Gy, delivered in two fractions. The remaining patients (n=11) received 19.5Gy - 22.5Gy (mean, 21.2Gy) in three fractions. The prescription dose was delivered to the 67–70% isodose line to cover the tumor margin and the number of beams was held between 150 and 200 to enhance conformality and maximize the high-dose volume within tumors. The follow-up time ranged from 18 to 48 months with a mean of 29 months.

Results: All patients had follow-up data. Local tumor control rate was 94% (16 of 17 cases). One patient died of metastases in liver and lung 16 months after CyberKnife. This patient, diagnosed as jugular foramen schwannoma by neuroimaging (CT and MRI), had metastases in liver and lung 12 months post CyberKnife radiosurgery. Eight patients had improvement in clinical status, two patients developed temporary worsening within the first 6 months, with temporarily increased tumor volume. The rest 6 patients remained their preradiosurgery status. Tumor size decreased in 14 patients, remained stable in two. The dead patient had no follow-up MRI.

Conclusions: The follow-up data indicated that CyberKnife radiosurgery is a safe and effective primary or adjunct treatment method for patients with jugular foramen schwannomas, without compression on brain stem.
The Accuracy of Retrobulbar Anaesthesia for Uveal Melanoma Treatment with CyberKnife® Fractionated Stereotactic Radiotherapy

Ela Delikgoz Soykut, Ozlem Derinalp Or, Ebru Karakaya, Aysen Dizman, Suheyla Aytac Arslan, Mehmet Balci, Rahmi Duman

Presented by: Yildiz Yükselen Guney, MD, PhD

Objectives: Depending on size and localisation of tumour, surgical approaches and sophisticated radiation delivery techniques including episcleral plaque brachytherapy, proton therapy and stereotactic radiotherapy can be treatment choices for uveal melanoma treatment. Minimum eye movement is required for optimal outcome of stereotactic treatment. For immobilisation retro or peribulbar anaesthesia are to be applied. We aimed to present our observation on changes of tumour localisation due to development of iatrogenic exophthalmos after injection of anaesthetic solution.

Methods: Case 1: A 64 year old male had a 5.5 mm uveal melanoma lesion on close proximity to left optic disc. We applied a computerised tomography (CT) simulation process while the patient was looking at a fixed point without an anaesthetic solution. We performed a second simulation after an injection of 5 cc anaesthetic solution by ophthalmologist. The two image data sets transferred to Accuray MultiPlan 3.5.2 planning station and then was fused together to create one planning CT (pCT) image. In this stage, we realised that exophthalmos has occurred in the eye in which anaesthetic solution was injected and the tumour has shifted forward approximately 2 mm.

Case 2: A 39 years old male had applied with a 8 mm uveal melanoma lesion on the left ocular bulb. Retrobulbar anaesthesia was applied by the same ophthalmologist for preparation of treatment plan and each treatment sessions. In this case, due to our experience from case 1, we didn’t apply pCT without anaesthetic solution and before each fraction we repeated pCT (including only eye region) scan with the same amount of anaesthetic solution. The patient was treated on alternate days (with one day break after each fraction). When every short pCT scans were fused with the planning scan, fused images showed that exophthalmos has occurred in the same amount on every treatment day and there was no change in the location of tumour compared to first pCT scan.

Results: Currently, RBA is applied as a complementary to improve applicability and accuracy of FSRT. There is no benefit from simulating patient without anaesthetic solution due to change in tumour localisation from anaesthetic solution related exophthalmos. Also when we gave a break between fractions in case 2 there was sufficient time for resorption of anaesthetics. So there was no collection of remaining solution for the following treatments.

Conclusions: The degree of exophthalmos depends on the amount of anaesthetic solution and the resorption time. The probability of incomplete resorption is associated with an increased exophthalmos effect and increased change of tumour location on consecutive days. This issue is significantly important for optimal outcome of treatment of these small lesions and treatment related side effects. We recommend to treat on alternate days and to perform short pCT before each fraction for checking the accuracy by doing fusion.
New Therapeutic Approach for Solitary Vertebral and Para-Vertebral Body Metastasis

Gil Sobremonte, CMD., Jason Chen, Ph.D., Sarvar Yellapragada, M.D., Mark Sultenfuss, M.D., Rajan Agarwal, M.D., Angela Zhu, M.D.

Presented by: Angela Zhu, MD

Objectives: Historically, spinal metastasis was treated with palliative intent. With improved local and systemic therapies, advanced imaging technology allows detection of metastases in their earlier phases.

We report a case of an asymptomatic T8 spinal metastasis from a lung cancer primary treated with combined IMRT and Radiosurgery.

Methods: The patient is an 80-yr old male, who underwent a surgical resection of a pT4N0M0 squamous cell carcinoma of left lung in 2009.

Post operatively, the patient underwent 3 cycles of Taxol and Carboplatin, followed by surveillance CT imaging. In June 2011, 21 months after surgery, surveillance CT showed an asymptomatic osteolytic lesion involving the right transverse process and posterior element of T8 along with a soft tissue mass. MRI and PET confirmed T8 lesion without other metastases. CT-guided needle aspiration of the T8 lesion revealed metastatic poorly-differentiated carcinoma consistent with the patient’s known lung primary.

Following the diagnosis of metastasis, the T8 vertebral body and gross tumor were treated with combined modalities. Initially, a 9-field IMRT was used to deliver 40Gy at 2Gy/day to the T8 vertebral body and gross tumor. This was followed by a single fraction 10Gy CyberKnife radiosurgery boost to the gross tumor. The total dose to the gross tumor was 50Gy. The maximum combined spinal cord dose from both plans was kept below 45Gy.

Results: A repeat PET imaging at 3 months shows disappearance of all uptake at T8, a finding that persists through 14 months post-XRT follow up. As of the last follow-up at 14 months, the patient remains neurologically intact and pain free.

Conclusions: Conclusion: In carefully selected patients, conventionally fractionated XRT combined with radiosurgery can result in complete tumor response and the possibility of rendering some patients cancer-free, despite an initial metastatic presentation. Although the ultimate likelihood of cure remains unknown, this new approach promises improved disease free survival and enhanced quality of life.
CyberKnife Radiotherapy for Bilateral Adrenal Metastases from Lung Cancer: A Case Report

Andrew Farach, MD, Yee Tham, MD and Angela Zhu, MD

Presented by: Andrew Farach, MD

Objectives: The adrenal gland is the fourth most frequent site of metastasis in lung cancer. Advances in cancer imaging have resulted in increased detection of asymptomatic adrenal lesions. In this setting, chemotherapy is the standard therapy. In retrospective surgical series adrenalectomy has been shown to positively impact survival. More recent studies have demonstrated the efficacy and safety of stereotactic body radiation therapy (SBRT) for adrenal metastases with excellent local control and survival and the potential added benefit of preserved adrenal function. The author presents a case report of a 60-year-old man with asymptomatic bilateral adrenal metastases treated simultaneously with Cyberknife SBRT.

Methods: A patient with previously treated locally advanced non-small cell lung cancer (NSCLC) was found to have asymptomatic bilateral adrenal metastases on surveillance CT scans. He received several cycles of adjuvant chemotherapy with stable lung disease; however disease progression was noted in the bilateral adrenal glands. Pre-treatment endocrinology work-up demonstrated no evidence of primary adrenal insufficiency. The lesion volumes were 20.8 cc and 15.8 cc for the right and left adrenal metastasis respectively. Cyberknife SBRT with fiducial based tracking using Synchrony was delivered simultaneously to both lesions for a total prescription dose of 5000 cGy in 5 fractions prescribed to the 52% isodose line.

Results: The patient tolerated treatment with no acute or chronic toxicity at 12 months follow-up. Follow-up CT or PET/CT at 3, 6, 9 months post-treatment showed interval response to therapy with decreased size and absent FDG avidity in both lesions. Post-treatment endocrine work-up at 3 months demonstrated mild asymptomatic adrenal insufficiency. 12 month PET/CT demonstrated sustained local control in the bilateral adrenals however interval development of FDG avid para-aortic and supraclavicular lymphadenopathy was noted. The patient remains asymptomatic and refuses hydrocortisone supplementation for adrenal insufficiency, indicating minimal to mild insufficiency.

Conclusions: SBRT is a reasonable and safe treatment option for patients with unilateral or bilateral adrenal metastases with excellent local control and potential long-term survival. Preservation of adrenal function may be possible in select cases. Further studies are indicated.
A Phase II, Single Arm, Investigative Study of IMM-101 in Combination with Stereotactic Radiotherapy-Induced Tumour Necrosis in Patients with Previously Treated Colorectal Cancer

Andrew M. Gaya, MD

Objectives: To investigate the “abscopal effect”, that is the effect on non target metastases, and the safety of IMM 101 (a suspension of heat-killed whole cell Mycobacterium obuense) in combination with radiotherapy induced tumour necrosis to a target liver metastasis in patients with heavily pretreated metastatic colorectal cancer.

Methods: IMM-101 acts as an immunoadjuvant and an immunomodulating agent, which could be beneficial to cancer patients especially in conjunction with procedures that promote immunogenic cell death. Intradermal injection of IMM-101 influences the immune system through induction of innate and Type I immunity, with promotion of cell mediated cytotoxicity. Second, induction of immunoregulation helps to control the adverse effects of chronic inflammation or inappropriate T-effector cell activity (Th2 biased) at the site of the tumour. In light of the “3Es? hypothesis of cancer (Elimination, Equilibrium and Escape) IMM-101 may have the effect of prolonging or helping to restore the “Equilibrium” state.

A 25Gy single fraction of stereotactic ablative body radiotherapy (SABR), administered by the CyberKnife system, induces tumour necrosis (immunogenic cell death) due to endothelial cell damage and vascular collapse, cell membrane breakdown, and the subsequent release of cellular material and tumour associated antigens into the circulation.

It is hypothesised that this combination of modulating the body’s immune response in the presence of increased exposure to tumour antigen will provide sufficient induction of the immune system to suppress tumour growth.

Results: Primary endpoint will be disease stabilisation rate at 24 weeks. The concepts, rationale and immunologic basis for this combination study, which is now actively recruiting, will be discussed. Quality of life effects will be discussed.

Conclusions: Combination of the immunoadjuvant and immunomodulating agent IMM-101 with radiation induced immunogenic cell death may lead to induction of appropriate immunological pathways to stabilise disease in patients with advanced cancer, and improve quality of life.
Duodenal Sparing Stereotactic Body Radiation Therapy for the Treatment of Locally Advanced Pancreatic Cancer

M. Ghaly, E. Montchal, Y. Cao, M. Marrero, L. Vijeh, V. Vinciguerra, N. Kaushik, J. Sullivan, B. Bloom, J. Knisely

Presented by: Maged Ghaly, MD

Objectives: The proximity of the pancreas to bowel presents a unique challenge for pancreatic cancer SBRT. This study explores the safety and effectiveness of a novel approach optimizing pancreatic tumor coverage and duodenal sparing.

Methods: Twenty-five patients with locally advanced pancreatic cancer (22 head/ 3 body) were treated with initial chemotherapy (Gemcitabine or 5-FU/Cisplatin) for 2-6 months. All underwent endoscopic US-guided fiducial placement in and around the tumor and had a 4D treatment planning CT scan with oral contrast. This CT was used in conjunction with EUS findings, PET, and biphasic CT scans to identify the Gross Tumor Volume (GTV) on the expiration phases. The planning target volume (PTV) was created by expanding the GTV by 2 mm. Dose-volume histogram (DVH) endpoints were constructed, keeping V7/15/20 (stomach/duodenum volumes that receive 7 Gy/15 Gy/20 Gy) <40%, /<25%/<15%; the dose to 1/3 of the duodenal circumference <20Gy and duodenal point max dose <23 Gy. Additional dose constraints included liver D50<5 Gy, ipsilateral kidney D25<5 Gy, cord D max <10Gy. Three 10 Gy fractions, normalized to the 85% isodose were delivered to the PTV on consecutive weekdays using fiducial-based respiratory motion tracking on a dedicated 6 MV linac-integrated stereotactic delivery system. The patients were then offered systemic therapy for 6 months or until tolerance or disease progression. Follow-up occurred at 4 weeks, 12 weeks, and every 3 months.

Results: All patients completed SBRT and a median of 5 total cycles of pre-and post-SBRT chemotherapy. Gross target volumes ranged from 14.2-205.7cm3 (median 39.5cm3). With a median follow-up of 10 months, 1 patient developed transient gastroparesis, 2 G 2 abdominal pain; 1 G 2 hematologic toxicity. No late toxicity was observed in 19 patients with longer follow-up (median 12 month). Twenty-three patients (92%) were free of local progression at the last follow-up visit (range 3-12 months).

Conclusions: Linac-delivered organ-sparing SBRT with chemotherapy in locally advanced pancreatic cancer resulted in excellent local control and also was well tolerated acutely and subacutely. Longer follow-up is warranted. A phase I dose-escalation study is underway.
Stereotactic Ablative Body Radiotherapy (SABR)
for Pancreas Cancer: Lessons to Learn from Toxicity

Dr. Christy Goldsmith, Prof. Pat Price, Dr. Nicholas Plowman

Presented by: Christy Goldsmith, MD, FRCR, MRCP, BSc

Objectives: To examine the influence of patient specific factors, treatment planning variables, and treatment delivery parameters on toxicity and treatment outcome.

Methods: 48 patients with unresectable pancreatic tumours were studied. All were treated with CyberKnife at Harley Street Clinic, London, between 2009 and 2012. Patient specific factors, including tumor site, stage and previous treatment, were retrieved from patient records. A majority of patients (n=45, 94%) had fiducials sited. Three patients (6%) were tracked with XSight Spine. Following planning scans, 45 patients (93%) received 18–36Gy in 3 fractions (BED 29-79, a/ß ratio of 10 for tumour control). A single patient received 10Gy in 1 fraction, and 2 patients (4%) received 25Gy/5# (BED 38Gy10). Dose was prescribed to the Median 66% isodose, (Range = 52-78%). The Synchrony system was used for tumor tracking in all who had fiducials sited. Treatment planning and delivery variables, including dose/fractionation, biologically equivalent dose (BED), and planning target volume (PTV), were prospectively collected. Acute and late toxicity was scored using EORTC Common Toxicity Criteria Adverse Events version 3 (CTCAEv3).

Results: 79% of patients had pancreatic head tumors, 17% body tumors and 4% tail tumors. The majority (90%) had T3 or T4 unresectable primary pancreatic cancer. A majority of patients (77%) had received prior chemotherapy, 21% had undergone previous surgery, and 23% had received prior radiotherapy. Most patients (65%) had 3 or more fiducials sited for tracking purposes. Median PTV size was 69cc (Range 16cc-259cc), Median BED was 51 Gy10 and Median treatment time was 67 minutes per fraction.

Acute toxicity rate was low: 34% showed no acute toxicity and 52% showed toxicity = grade 2. The most common all grade acute toxicities were fatigue(26%), nausea(22%) and abdominal pain(20%). Only 3 (7%) patients had grade 3 acute toxicity (obstructive jaundice, fatigue and pain, respectively).

To date, median follow-up is 208 days (7 months).

Late toxicity (= grade 2) has been experienced by four patients. One patient had Grade 2 late toxicity (nausea and abdominal pain) a year after CyberKnife, the patient had been too frail to receive prior chemotherapy. A further patient had Grade 3 duodenal haemorrhage 4 months after CyberKnife treatment, with stable disease on imaging at this time, although endoscopy reported “tumour erosion of the duodenum”. There were two cases of duodenal stricture possibly related to CyberKnife treatment. Investigation into the aetiology of the strictures in these cases is ongoing.

One patient has importantly converted to resectable (and therefore potentially curable) status.

After full statistical analysis of patient factors, treatment planning, and treatment delivery parameters and outcome (toxicity) data, there did not appear to be any statistically significant relationships, but this may be because toxicity incidence was low. This is likely to reflect good patient selection, highly conformal treatment planning (Median nCI=1.18), and accurate treatment delivery. Ongoing data collection and analysis, including inter-fraction shifts of the Target/Organ At Risk interface due to duodenal filling changes, may reveal additional information.

Conclusions: Toxicity was low, below that of contemporary studies. Patient, planning and delivery factors did not appear to be related to toxicity, suggesting that dose escalation may be less risky to duodenum/small bowel than previously thought. However, the low incidence of serious duodenal late toxicity experienced highlights the need for caution and further study to investigate contributory factors.
Prospective Evaluation of CyberKnife Fractionated Stereotactic Radiosurgery for High Risk Prostate Cancer

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Presented by: Timothy A. Jamieson, MD, PhD

Objectives: We have treated over 200 low/intermediate risk prostate cancer patients with CyberKnife since January 2011, to 35Gy in 5 fractions at the Southeast Georgia Health System Cancer Care Center in Brunswick. Our center has historically treated high risk prostate cancer with either 75.6 Gy of external beam with androgen ablation therapy (AAT) or a combination of radioactive seed implant (to deliver a higher biologically effective dose (BED) to the prostate) and 45 Gy of external beam (to cover seminal vesicles and extracapsular tissue, as well as to adequately cover any low dose regions within the prostate implant). Data from Katz in treating high risk disease with 45 Gy plus CyberKnife boost, or CyberKnife monotherapy, has been encouraging. We developed a prospective protocol to treat high risk patients with CyberKnife in order to noninvasively deliver a high BED (>90 Gy) relatively homogeneously not only to the prostate but also to the extracapsular tissue and seminal vesicles.

Methods: Patients with Gleason score =8 and PSA =30, or Gleason 6 or 7 with PSA between 20 and 30, were prospectively enrolled. The PTV was generated by expanding the prostate and seminal vesicles by 3mm posteriorly, 5mm elsewhere, except 8mm laterally on high Gleason side. The isodose line was chosen to allow at least 95% of the PTV to receive 36.25 Gy. Use of AAT was at the discretion of the referring urologist.

Results: Enrollment began in January, 2011. Fifteen patients have been treated to date. Fourteen qualified due to Gleason =8, and one with Gleason 6 with high PSA. The treatment plans had a median of 197 beams (range 144-226), median isodose prescription of 84% (80-85), and median maximum dose of 43.2 Gy (42.7-45.3). Ten patients received a median of 1 (range 1-4) AAT injections prior to CyberKnife treatment, and all but one have discontinued this therapy. There have been no PSA failures at a median follow up of 12 months. Median PSA at diagnosis was 7.0, at 12 months 0.2, and at 18 months 0.2. There have been no Grade 3-5 acute side effects, and no grade 1-5 late side effects. Three patients (20%) developed acute grade 1 GI toxicity (mild diarrhea) and none had grade 2 GI toxicity. Twelve patients (80%) developed transient acute grade 1-2 urinary toxicity, typically mild dysuria and increased nocturia, that correlated with V36.25 of bladder (median 4.1 cc vs. 1.0 cc in those with and without toxicity, respectively, p<0.01). Two of 5 patients with V36.25 = 1.5cc and 10/10 with V36.25 > 1.5cc developed grade 1 or 2 acute GU toxicity. There was no significant difference in maximum bladder dose (median 39.2 Gy vs. 38.6 Gy) or maximum PTV dose (43.4 Gy vs. 43.2 Gy) in those with and without toxicity, respectively. No DVH variable correlated with the mild GI toxicity.

Conclusions: CyberKnife fractionated stereotactic radiosurgery for high risk prostate cancer, designed to homogeneously cover the prostate and seminal vesicles with a high BED, is well tolerated and initial results are encouraging. We recommend a bladder V36.25 of = 1.5 cc to minimize risk of Grade 1/2 GU toxicity. Obviously more patients and longer follow up are necessary to better assess efficacy and long term toxicity. Updated results will be presented.
Correlation of Higher Maximum Tumor Dose and Lower Conformality to Tumor Response in SBRT of Lung

Pushkar Desai, M.S., Blas Caroprese, Ph.D., Heidi McKellar, M.D.

Presented by: Pushkar Desai, MS

Objectives: A high conformality index is the hallmark of most SRS/SBRT treatments. However, we have observed that a treatment plan that delivers the 60Gy dose to a lower isodose line in the 80–82 % range to 98% volume, and therefore a maximum SBRT lung dose of 73Gy to 75Gy in tumor has an accelerated tumoricidal response.

Methods: CyberKnife™(G-3), Multiplan™V4.5.0 planning system. Synchrony™. Our lung SBRT patients are tracked using fiducials with Synchrony or without fiducials using LOT™ (Lung Optimized Tracking) delivering 60 Gy in three fractions.

Results: A conformal plan (normally 60Gy to greater or equal to 90% isodose line and 95% PTV volume coverage) is easily achievable with Multiplan™. We have observed that patients treated with 60 Gy in 3 fractions to the 80% to 82% isodose surface covering 98% of tumor volume have an accelerated tumoricidal response as evidenced from patient PET examinations performed at 3 months. Patients planned using this scheme, have a pronounced response at 3 months, versus patients planned using the same dose scheme but to a higher isodose line, and therefore a higher conformity index.

Conclusions: From our follow-up study we conclude that patients treated with this schema, have an accelerated response at 3 months versus patients treated with a conformal plan. We attribute this to the higher maximum dose at the core of the tumor in this case as compared to the lower maximum dose in tumor in the case of a highly conformal higher isodose tumor volume covered plan.
Lung Reirradiation with Stereotactic Body Radiotherapy (SBRT)

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Presented by: Elizabeth Ester, MD

Objectives: There is limited available data on the use of SBRT in reirradiation of lung tumors.[1,2,3] We reviewed the survival, recurrence pattern and toxicity following SBRT after previous thoracic radiotherapy at the University of Minnesota Medical Center.

Methods: From August 2006 through October 2012, fourteen tumors in thirteen patients with either biopsy confirmed Non-Small Cell Lung Cancer or patients with presumed NSCLC who were medically unable to undergo biopsy, were retreated with SBRT. Four tumors were centrally located. Patients were treated with 9 or 10 Gy per fraction for a total of five fractions, delivered every other day. Eligible patient charts were retrospectively reviewed to evaluate survival, recurrence pattern and toxicity following reirradiation. NCI-Common Terminology Criteria for Adverse Events (CTCAE) v4.0 was used to evaluate toxicity.

Results: The median age of patients at the time of SBRT was 67.9 years (Range 45.9-86.7 years). One patient did not complete the prescribed course of SBRT and was therefore excluded from analysis. The median duration of follow-up for remaining patients was 11.4 months (Range 0.9-38.3 months). Ten patients had received prior conventional thoracic radiation with a median dose of 6120 cGy. Two patients received previous SBRT with curative intent. The median time to reirradiation with SBRT was 19.7 months (Range 4.7-84.7 months). Following reirradiation with SBRT, eight patients (67%) had progressive disease. There were five distant recurrences, two regional recurrences and only one patient developed an isolated local recurrence. Local control of the retreated tumors was 92%. There have been six deaths, all of which were in patients with progressive disease, at a median of 17.6 months from completion of SBRT. Four patients (33%) are alive and disease free, a median of 14.0 months from completion of SBRT. There was one grade 2 toxicity, described as lobar atelectasis occurring six months following SBRT. There was one grade 3 toxicity occurring in a patient who developed oxygen dependence four months following SBRT. There were no grade 4 or 5 toxicities.

Conclusions: SBRT is a reasonable salvage therapy for lung tumor recurrence in patients previously treated with thoracic radiotherapy, offering good local control and resulting in acceptable toxicity. However, controlling regional and systemic progression of disease remains a challenge. Further evaluation of this treatment option is warranted.
OBJECTIVES: To report the clinical outcome of treatment using robotic Stereotactic Body Radiotherapy (SBRT) for patients with primary or secondary lung lesions ineligible for surgery, or refusing surgical intervention. The target volume determination was predominantly supported by fused treatment planning PET CT, and metabolic imaging was also widely applied in evaluation of clinical outcome.

METHODS: Between April 2010 and March 2012, one hundred and nineteen patients with a total of 130 lung lesions were treated with 40 to 60 Gy in 3 to 5 fractions using Cyberknife (Accuray, Sunnyvale, US). Median age at treatment was 71 years (range 40-93). Primary NSCLC represented 59 % of the lesions and 24% were oligometastases. 17 % were a mixed group consisting of local relapse or intrapulmonary metastases of a former lung cancer, or solitary lymph node recurrence. Large or centrally located lesions were not excluded. Risk adapted fractionation schemes were applied in order to reduce toxicity. For this analysis, treatments were classified in high dose (H, 67%) and low dose (L, 33%) groups in function of BED higher or lower than 120 Gy10. In 95% of the cases PET CT images acquired in treatment position were applied to help delineation. For all patients a GTV to PTV margin of at least 5 mm was taken. Histological confirmation was available in 65% of the lesions. Lesion tracking (with or without fiducials) was done where possible (44%). The mean and median follow up time (FUP) were 13 and 14 months, respectively. Inclusion criteria for the present analysis were a minimum of 6 months of FUP or the availability of at least one control PET CT examination. Toxicity was prospectively evaluated using CTCAE ver4.

RESULTS: The actuarial 1-, and 2 year Kaplan–Meier local control rates for lesions treated with high doses were 94 and 76%, compared to 74 and 68% for the low-dose group (p=0.011). Overall survival for the whole study population at 1 and 2 years was 84 and 67%, respectively. During the follow up 85% (n=107) of the lesions were evaluated using PET CT, in addition to a contrast enhanced CT. In a total of 52 (49%) cases out of this 107 we observed a complete metabolic response. 41 out of these 52 lesions were treated in the “high dose range”, representing 47 % of lesions treated with a BED higher than 120 Gy10 . Severe acute toxicity was observed in 2 patients, one with a Grade 3 radiation pneumonitis, requiring hospitalisation, and one with a possibly treatment-related pulmonary haemorrhage causing death (Grade 5 toxicity). Severe late toxicity was observed in 1 patient presenting a Grade 3 sick sinus syndrome, requiring a pacemaker implantation. Rib fracture was observed in 3 patients (< Grade 2). One patient developed Grade 2 recurrent laryngeal nerve palsy. Grade 2 late radiation pneumonitis was observed in 11 patients. Grade 2 pneumothorax after transthoracic marker placement occurred in 6 cases.

CONCLUSIONS: In our mixed study population of primary and secondary, central and peripheral lung lesions, robotic SBRT showed 1-, and 2 year local control rates comparable to published data, especially in the high dose group. An important proportion of this latter group developed a documented complete metabolic response. The rate of severe toxicity was low.
Accuracy of Breath-hold CT and Treatment Planning for Lung SBRT

Dominique Mathieu, Charles Martel, Marie-Pierre Campeau, Édith Filion, Toni Vu, Jean-Francois Carrier

Presented by: Dominique Mathieu, B.Eng.

Objectives: At Centre hospitalier de l'Université de Montréal (CHUM), lung stereotactic body radiotherapy treatments (SBRT) can be delivered with several machines including a Cyberknife unit. Treatment planning includes a four-dimensional computed tomography (4DCT) scan during free breathing (FB) to evaluate tumor range of motion and a breath-hold (BH) CT scan, preferably at end-expiration (EE), used for dose calculation. The aim of this study is to measure conformity of tumor position on BH CT scans relative to natural tumor path during FB and to evaluate the benefits of Abches (Apex Medical, Inc). Abches is a breathing monitoring device that allows the patient to self-control the respiratory motion of the chest and abdomen.

Methods: In 53 lung cancer patients (17 inferior lobes), 4DCT and BH CT images were obtained. For 12 patients, BH CT scan was acquired using Abches device. Natural tumor motion was assessed by using local rigid registration of region of interest on the end-inspiration (EI) and EE phases of the 4DCT scan. Tumor motion was modeled as a linear movement since no patient showed significant hysteresis trajectory on 4D analysis. Absolute differences between BH and EE 4DCT phase were also measured.

Results: The average natural movement amplitude of gross tumor volume (GTV) was (1.2±1.2) mm, (2.2±1.9) mm, and (5.6±6.4) mm in medio-lateral, anterior-posterior, and cranio-caudal (CC) directions, respectively. The CC motion of GTV in lower lobe was larger than in upper lobe (10.7±8.9) mm vs (3.3±3.0) mm. Among the 41 patients scanned without Abches, 26 (63%) presented tumor position on BH CT scan closer to EE than to EI 4DCT phase. Among the 12 patients scanned with Abches, the proportion was 75%. For the 53 BH scans, 40 (75%) showed a GTV standing within a 3 mm radius of tumor trajectory observed on 4DCT. For marginal BH, GTV displacements perpendicular to natural tumor path were as great as 6.3 mm, 6.4 mm and 10.5 mm and couldn't systematically be avoided using Abches.

Conclusions: Tumor position during BH CT may not accurately correspond to positions observed on FB 4DCT, cases done with Abches monitoring device included. Hence, accurate and custom 4D analysis for each individual patient is recommended for treatment planning. The benefits of using Abches would need further evaluation in a larger cohort of patients. For real-time respiratory tracking treatment on Cyberknife (Fiducial, Xsight lung), using marginal BH CT for dose calculation could result in an underestimation of the effective dose to organ at risk. For patients treated with an internal target volume technique on Cyberknife (Xsight spine), treatment planning based on a marginal BH may result in significant increase in treatment volume.
Initial Lung SBRT Case Treated at a Free-Standing Radiation Oncology Facility

Don Stacy, MD DABR; Frederick Albrink, MD DABR; David Musich, MD DABR; Jill Brislin, CMD, RT(R)(T); Jodi Daves, MS

Presented by: Don Stacy, MD, DABR

Objectives: Retrospectively review the initial lung SBRT case treated at a free-standing radiation oncology facility.

Methods: An experienced SRS/SRT (stereotactic radiosurgery/radiotherapy) radiation oncologist retrospectively analyzed the initial lung SBRT (stereotactic body radiation therapy) case treated at a free-standing radiation oncology facility. The analysis consisted of chart and treatment plan reviews and interviews with staff members involved in the planning and treatment of the patient. The experienced SRS/SRT radiation oncologist compared the actual lung SBRT patient evaluation and management to lung SBRT patient evaluation and management as recommended per RTOG 0915 protocol.

Results: PATIENT: On 05/02/12 a 75 year-old medically inoperable white female with stage 1A, T1aN0M0, right non-small cell lung carcinoma was evaluated by a radiation oncologist for consideration of definitive management at a free-standing radiation oncology facility with SBRT capability. A radiation oncology treatment planning CT simulation was performed on 05/24/12. Treatment planning was performed in conjunction with experienced SRS/SRT Vantage Oncology radiation oncologists. The patient’s right upper lung tumor received SBRT to 48 Gy in 4 fractions using a 2 arc Rapid Arc plan from 06/12/12 through 06/15/12. The patient developed transient Grade 1 costochondritis during the 1st week after SBRT, a minor complication anticipated due to the location of the patient’s tumor. Restaging PET/CT scan on 08/01/12 revealed a partial radiologic response, typical for reimaging performed shortly after SBRT.

PROCESS: The actual lung SBRT patient evaluation and management conformed closely to lung SBRT patient evaluation and management as recommended per RTOG 0915 protocol. The patient evaluation and management and treatment planning and delivery processes were identified by the experienced SRS/SRT radiation oncologist as minor areas of opportunity for improvement. The patient evaluation issue noted was non-use of a patient eligibility checklist. The patient management issue noted was post-SBRT reimaging at an atypical time (less than 12 weeks after SBRT rather than greater than or equal to 12 weeks after SBRT). Treatment planning issues noted were as follows: minor dose constraint deviations on the final treatment plan and some non-critical normal structures not contoured. Treatment delivery issues noted were as follows: use of non-stereotactic-specific immobilization equipment and lack of linac/facility SBRT credentialing.

Conclusions: The initial lung SBRT patient at a free-standing radiation oncology facility was treated appropriately with only inconsequential deviations from lung SBRT as recommended per RTOG 0915 protocol. These minor issues can easily be addressed as the multidisciplinary SBRT team at the facility continues to develop the SBRT program.
CyberKnife Radiosurgery for Lung Cancer: Is There a Size Limit?

Angela Zhu, MD

Objectives: A case of early stage “resectable” lung cancer is reported in which a primary tumor greater than 6 cm in diameter was treated only with CyberKnife (CK) Radiosurgery. After 16 months of follow-up, a complete response has been observed.

Methods: A 70-year-old male was diagnosed with a peripheral NSCLC of the right upper lobe (RUL) in January 2011. Computerized tomography (CT) of the chest showed a RUL mass measuring 6.3 x 4.7 x 4.5 cm, without hilar or mediastinal lymphadenopathy. Positron emitted tomography (PET) revealed an SUV of 14.5 without evidence of regional or distant metastasis. Biopsy was consistent with squamous cell carcinoma of the lung. Endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) was negative for hilar and mediastinal diseases. The patient’s cancer was staged as cT2bN0M0, cStage IIA. Meanwhile, pre-treatment pulmonary function testing (PFTs) showed a FEV1 of 1.58-1.71L (2.4-4.2L reference range), which was only 46-52% of the predicted value. Diffusing capacity of the lung for carbon monoxide (DLCO) of 16.9 (24.4-40.8ml/mmHg/min reference range), which was only 52% of reference.

Although offered surgical resection, the patient declined and instead elected to pursue aggressive precision radiation. Percutaneous gold fiducial markers were placed under CT guidance. On the planning CT, the gross tumor volume measured 98cc, around which margin was added in the course of designing a treatment (Rx) plan. The patient was treated with CyberKnife radiosurgery alone using a total dose of 70Gy (14Gy x 5) over 6 days.

Results: At one month follow-up, chest x-ray demonstrated a 3.7 x 2.6cm lesion (6.3 x 4.7cm prior to CK Rx). Serial CTs and PETs were used for subsequent follow-up. On the most recent PET (16 months post CK), the SUV at the previous tumor site was 2.1. The patient remains asymptomatic and specifically there has been no radiographic or clinical evidence of pneumonitis. Follow-up PFTs at 14 months show an unchanged FEV1 of 1.67L (2.6-4.2L reference range), 50% of reference; DLCO of 13.5 (25-41.4ml/mmHg/min reference range), 41% of reference.

Conclusions: Despite having a very large lung cancer, the patient we report here has had an excellent preliminary response to CK SRS. This outcome suggests that CyberKnife radiosurgery can produce seemingly complete tumor responses without apparent toxicity among highly selected lung cancers as large as 6cm in diameter. Although the ultimate likelihood of cure remains to be determined, this new approach enables a shorter course of radiation while holding out the promise of both improved local control and disease free survival.
Stereotactic Body Radiotherapy for Recurrent Oropharyngeal Cancer -
Influence of HPV and Smoking History

Clump DA, Vargo JA, Rwigema JC, Davis K, Ferris R, Heron DE, Quinn A, Burton S

Presented by: David Clump, MD, PhD

Objectives: Prospective clinical data has identified 3 distinct risk groups of head-and-neck cancer patients based on HPV status and smoking history. The low-risk group has considerably better outcomes in local-control (LC) and overall survival (OS). Despite this, local recurrences are still common across all the sub-groups. SBRT ± cetuximab has emerged as a promising salvage strategy for locally-recurrent, previously-irradiated head-and-neck cancer (rHNC) relative to conventional re-irradiation ± chemotherapy. However the influence of HPV and smoking status remains unknown in the setting of salvage strategies.

Methods: All patients (n=29) with rHNC of the oropharynx salvaged with SBRT ± cetuximab from February 2005 through January 2010 were retrospectively reviewed. SBRT consisted of primarily 40-50Gy in 5 fractions delivered on alternating days over 1.5-2 weeks. Concurrent cetuximab was administered at a dose of 400mg/m2 of day -7 followed by 250mg/m2 of day 0 and +7 in n=19 patients (68%) including patients on our prospective institutional protocol UPCI 06-093 (results not yet reported).

Results: The 6-month actuarial LC for the entire cohort was 50%. Patients with HPV positive disease (n=6) had 6-month LC of 60% vs 46% for (n=22) HPV negative/not-recorded (p=0.524). The 6-month LC for never smokers was 83% vs 25% for smokers with <40 year pack history vs 29% for heavy smokers with =40 year pack history (p=0.013). The 6-month OS for the entire cohort was 74%. The 6-month OS for HPV positive patients was 83% vs 71% for HPV negative/not-recorded (p=0.195) with no significant difference in OS by smoking status (p=0.612).

Conclusions: Never smokers and patients with HPV positive rHNC cancers have a trend towards superior LC and OS following salvage SBRT ± cetuximab comparable to the definitive setting which may permit differentially aggressive salvage strategies by risk-group stratification as data continues to emerge supporting salvage SBRT ± cetuximab for rHNC.
Stereotactic Ablative Body Radiotherapy (SABR) to Lymph Node Oligometastases – UK Experience & Clinical Outcome: An Update

Dr. Christy Goldsmith, Dr. Alex Martin, Dr. Nicholas Plowman, Dr. Andrew Gaya

Presented by: Christy Goldsmith, MD, FRCR, MRCP, BSc

**Objectives:** We report the acute toxicity and clinical outcome of SABR delivered to lymph node oligometastases.

**Methods:** Between February 2009 and July 2012, 37 consecutive patients with unresectable nodal metastases were treated with SABR delivered via the CyberKnife system. The median age was 61 (range 42-86 years). Of these patients, 29 (78%) had node-only metastases, while 8 patients (22%) had dominant nodal lesions as part of oligometastatic disease, defined as up to five metastases. A PET scan confirmed disease extent in 31 patients (84%).

14 (38%) had received prior conventional radiotherapy to the target nodal site. Patients had been pre-treated with a median of 2 lines of systemic therapy (Range 0-7). Disease Free Interval prior to SABR was recorded. A total of 41 lymph node sites were treated, anatomical location of sites treated: Neck (n=3), Thorax (n=14), Abdomen (n=14), and Pelvis (n=10). Histopathology of Primary: Colorectal (n=12), Breast (n=8), Urological (n=6), Lung (n=4), Gynae (n=3), and Other/Unknown primary (n=4).

Median CTV to PTV margin was 2 mm (range 0-5mm). PET or MR fusion were used if appropriate to aid target delineation in addition to the Contrast-enhanced CT planning scan.

The dose/fractionation regimes used were 18Gy single, 24-36Gy in 3 fractions (BED 43 - 79 Gy10 assuming a/β=10) and 35-47Gy in 5 fractions (BED 60- 91Gy10). The most commonly used regime was 24Gy in 3 fractions (14 patients, 38%). Dose was prescribed to the median 66% isodose (range 48-78%). 23 patients had fiducials inserted (14 of these tracked with Synchrony), and 18 sites were tracked using X-Sight Spine.

Primary endpoint was radiological progression at the treatment site.

Secondary end-points included Progression Free Survival (PFS) and Overall Survival (OS). PFS was defined as the time to progression, or death, whichever came first. All endpoints were calculated from the date of the first radiation treatment.

**Results:**

Acute toxicity data was available for 28 patients (76%). 61% had no acute toxicity. Grade 1-2 toxicity was experienced by 34%, most commonly Grade 1 fatigue. There was one case of grade 2 to grade 3 pain escalation in a disease progressor following SABR to a pelvic lymph node metastasis.

There have been 2 cases of Grade 3 late treatment-related toxicity. Both patients had received prior conventional radiotherapy.

Follow up information was available for 34 patients (92%), with a total of 36 treatment sites, at median follow up 14 months. There was evidence of in-field disease progression in 5 sites (14%) giving a crude local control rate of 86%. All that progressed locally were treated with the lowest BED regimes (of 43Gy10). Local Control was 100% in those treated to a BED of at least 50Gy10.

Distant disease progression was documented in 18 patients (53%), translating to a Freedom from Distant Disease Progression rate of 47%.

Three patients have died, giving a crude Overall Survival rate of 88%. The cause of death was disease progression in all patients.

An analysis by histopathology of the primary showed a particularly favourable response in Colorectal Cancer patients with a Median progression-free survival of 22 months.

**Conclusions:** SABR is a feasible and well-tolerated treatment for patients with lymph node oligometastases. Local control rates in this series are very good, with a Local Control rate of 100% when SABR is prescribed to a threshold BED of 50Gy10 ie, single fraction>18Gy, >27Gy in 3 fractions, or >35Gy in 5 fractions. Colorectal histology is associated with a more favourable outcome versus other histology (Median Progression Free Survival of 22 months).
Stereotactic Body Radiotherapy for Metastatic Melanoma

Josephine Kang, M.D., Ph.D.(1), Anand Mahadevan, M.D.(2)

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(2) Department of Radiation Oncology, Beth Israel Deaconess Medical Center, Boston, MA and Harvard Medical School, Boston, MA

Presented by: Anand Mahadevan, MD

Objectives: Stereotactic body radiotherapy (SBRT) is a non-invasive radiation delivery technique that allows high doses of radiation to be safely targeted to tumors. Radiobiologic studies suggest malignant melanoma has a low alpha/beta ratio, and may respond favorably to such hypofractionation. In this study, we evaluate outcomes after SBRT in patients with metastatic melanoma.

Methods: A retrospective review of all cases of metastatic melanoma treated with SBRT at the study institution was conducted. Tumors were excluded if they were located in the brain, or had less than 3 months follow-up. 20 consecutively treated patients (34 tumors) were identified. SBRT was delivered using the Cyberknife system (Accuray, Sunnyvale, CA) with fiducial and vertebral anatomy-based targeting to metastatic lesions in the chest (n=16), spine (n=9), pelvis/abdomen (n=6), H&N (n=2), and liver (n=1). Six cases of SBRT (5 spine, 1 chest) were in previously irradiated sites, and seven tumors were oligometastases.

Radiation dose ranged from 8 Gy x 1 fraction to 9 Gy x 5 fractions; the most common regimen was 8 Gy x 3. Median treated volume was 46.4 cm³ (range, 7.8-455.7 cm³).

Results: Median follow-up was 20.7 months (range, 3-60.4 months) and median age at time of radiation was 49 (range, 28-88 years). At time of last follow-up, 8 patients were still alive and 12 had died, with median survival of 22.3 months from time of SBRT. Overall, 80% of patients achieved local control; tumor progression was noted in 8 sites at a median time to failure of 19.7 months (range, 2.1 – 34.3 months). All cases of tumor progression occurred in the lung, in patients who developed uncontrolled systemic disease. Site (log-rank p=0.008) and size of treated volume (log-rank p=0.045) were significant for local control on univariate analysis.

No cases of radiation-induced toxicity occurred.

Conclusions: SBRT is an effective treatment choice for metastatic melanoma, providing durable local tumor control with limited morbidity. Tumors that are larger in size, or located in the lung, may have decreased likelihood of long-term control.
Radiosurgical Ablation of the Renal Nerve: Minimally Invasive Therapeutic Approach to Treat Refractory Hypertension?

Patrick Maguire, Edward Gardner, Thomas Fogarty, David Chamberlain, and Jonathan Tay.

CyberHeart Inc., Portola Valley, CA, Sutter Medical Institute, Sacramento, CA, and Reno Cyberknife, Reno, NV

Presented by: Patrick Maguire, MD, PhD

Objectives: Treatment of refractory hypertension remains an unmet clinical need that carries serious renal and cardiovascular morbidity and mortality. Recently a variety of medical device companies are attempting to treat this problem via catheter ablation of the renal sympathetic nerves from inside the renal artery. We wished to determine if radiosurgery, aided by CyberHeart contouring software, could be used to accomplish this ablation.

Methods: Six Hanford mini-swine underwent placement of a fiducial percutaneously at the renal vein via the IVC, under general anesthesia. CT scanning and Treatment planning was accomplished using CyberHeart CardioPlan© software and MultiPlan© (Accuray Inc., Sunnyvale, CA). A variety of treatment plans were delivered (40-50 Gy) to achieve renal nerve ablation either by treating renal nerves that were circumferential to the renal arteries, or to the aortic-renal ganglion. Plasma and tissue Norepinephrine levels were followed through the follow-up period (4-6 months) as a surrogate for sympathetic activity. Kidneys, renal arteries and aorta were studied histologically at the end of the follow-up period.

Results: All animals survived to the follow-up point. There were no in-life adverse events. Gross pathology was unremarkable. Norepinephrine levels decreased, on average, by 64% during follow-up. Histology documented moderate ablation changes in the renal nerves. 75% of the renal nerves were within 1.0 mm to 3.0 mm from the lumen. No renal artery demonstrated transmural medial injury or thrombus.

Conclusions: Radiosurgical ablation with its inherent pre-planning capability and precision potentially offers an attractive therapeutic option to treat this clinically unmanageable condition.
Imaging Dose Measurements for the CyberKnife X-Ray Cameras and Potentials for Dose Reduction

O. Blanck¹, R. Bruder³, S. Ipsen³, S. Seifert², S. Wurster², D. Rades¹, J. Dunst¹, G. Hildebrandt⁴, A. Schweikard³

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Presented by: Oliver Blanck, Dipl. Inf.

Objectives: The CyberKnife uses stereoscopic x-ray imaging for patient alignment and motion compensation during image guided radiosurgery / radiation therapy (IGRT). In some parts of Germany it recently became mandatory to monitor and report imaging doses for IGRT especially for the CyberKnife. In our center an imaging dose monitoring system (IDMS) was mounted on both x-ray sources in early 2012 (PTW / Accuray Monitor Amplifier T16032 and Monitor Chamber T34066). In this study we first present a quality assurance (QA) measure for this system and dose measurements for the first 4 months of patient treatment. In a second step we analyzed the image acquisition and processing chain to show potential for reductions of the imaging doses.

Methods: For QA of the IDMS system we used gafchromic XRQA2 film (Ashland / ISP, USA) to assess the relevant field sizes and the Unfors XI (Raysafe, USA) to verify the measurements. We statistically analyzed the doses of 74 treated patients in 221 fractions with the different tracking modalities. We also analyzed the difference between the first and subsequent fractions and the contribution of LINAC head leakage to the measurements using an End-2-End (E2E) test without imaging for calibration. Afterwards, we analyzed the different pre-processing steps for fiducial marker triangulation. A stereo-camera calibration was performed on the x-ray cameras. Using this calibration all fiducial positions visible by the CyberKnife system were simulated and projected onto the flat-panel detectors. In this way the minimal area of the x-ray detectors was determined.

Results: The relevant field size for found to be 20.78cm x 27.54cm for Camera A and 23.58cm x 27.39cm for Camera B for our system. The IDMS compared well with the reference measurements of the Unfors XI showing 8.52cGy/cm² versus 8.84cGy/cm² (3.7%) for Camera A and 9.43cGy/cm² versus 9.65cGy/cm² (2.3%) for Camera B. The measured mean surface dose to the patient of a standard stereo x-ray acquisition (120kv/100mV/100ms) was 0.3mGy which matched well to reports in literature. The LINAC head leakage contributed 0.05cGy/cm² per MU delivered to the IDMS during the E2E test. For the first 74 treatments we measured a leakage corrected mean total patient imaging dose of 15.10mGy for 6DSkull, 55.78mGy for XSight Spine, 84.95mGy for XSight Lung and 144.15mGy for Fiducial with Synchrony for an average of 3 fractions given in our center. Number of stereo images per fraction ranged from a mean of 31 for XSight Spine to a mean of 64 for Synchrony whereas treatment time averaged between 30 and 50 minutes. The dose difference between the first and subsequent fractions ranged from 5% (6DSkull) to 25% (Synchrony). Our image processing analysis revealed that only 91% (vertical) and 62-67% (horizontal) of the flat-panel detectors could be used for marker detection, while the rest of the detector area stays unused. Limiting dose exposition to actively used areas only could theoretically decrease the overall dose by more than 40%.

Conclusions: We demonstrated the clinical use and quality assurance of the IDMS for the CyberKnife. High imaging doses are giving to the patient especially in fractioned Synchrony treatments however these doses are small compared to the skin doses due to the treatment beams. Nevertheless, following the ALARA principle there is potential for dose reduction. Technically, dose exposition could be limited to the usable areas of the flat-panel detectors. Furthermore, the reduction of images from the first to subsequent fractions demonstrated that there is high potential for dose reduction through intelligent imaging strategies.
Properties of Gafchromic EBT3 and MDV3 Film and Application for Quality Assurance in Robotic Radiosurgery

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2 CyberKnife Center Northern Germany  
3 German Physics GmbH  
4 University Clinic Rostock, Department of Radiation Oncology

Presented by: Oliver Blanck, Dipl. Inf.

Objectives: Gafchromic MD55 and later EBT2 film have been widely used for routine and delivery quality assurance (DQA) for the CyberKnife and recommendations for schedules and passing criteria were made in the AAPM Task Force 135 Report. Recently Ashland / ISP (USA) developed newer versions of the films: EBT3 and MDV3. Our objective was to investigate the properties of EBT3 and MDV3 and their clinical use for CyberKnife QA.

Methods: For our study ISP provided samples of EBT3 and MDV3 film as well as laser cut fits for the CyberKnife phantoms such as the BallCube2 (BC2). First we analyzed the dose response curves using the different color channels also for higher doses. We then compared 25 different End-2-End (E2E) tests using EBT3 to the results of 50 E2E tests previously done with EBT2. We also tested EBT3 and MDV3 with 25Gy. For delivery QA with EBT3 we ran 15 complex treatment cases scaled to mean 8Gy (+/- 2Gy) maximum dose projected on the BC2 with either the head phantom (intracranial) or the moving platform with hemisphere (extracranial). We evaluated our results using FilmQA\textsuperscript{TM} version 3.0 beta (3Cognition, USA) using the registration function for the BC2 and the image processing toolbox to reduce noise in the scans. We used an acceptance criteria of > 98\% pixels passing Gamma for 2\% Dose / 2mm Distance-to-agreement (DTA) at the 50 \% Isodose. As further evaluation for system accuracy we obtained a maximum search for Gamma 1\% Dose / 1mm DTA with > 90\% pixels passing and < 1mm spatial corrections in FilmQA. To analyze the sensitivity of our methods we ran 5 DQA tests before and after DeltaMan correction. All our tests were done under 1 hour.

Results: The EBT3 laser cut films agreed within a mean difference of 0.15 mm and 0.25mm to the EBT2 films and to the BC2 (EBT2 to BC2 mean difference 0.29mm) of the measured edges, slits and holes. A good working range for EBT3 was found to be 1-10Gy and 1-40Gy (Max 50Gy and 60Gy) and for MDV3 1-70Gy and 5-100Gy (max 120Gy and >120Gy) for the red and green color channel respectively. The darkening in first 12 hours ranged from 1-2\% (MDV3) to 4-5\% (EBT3). The E2E tests with EBT3 showed on average 0.59mm offset (Min 0.04, Max 0.94, SD 0.236) and the E2E tests with EBT2 showed on average 0.42mm offset (Min 0.04, Max 1.28, SD 0.272). All DQA tests with EBT3 passed with average 99.1\% and 94.7\% pixels passing Gamma 2\%/2mm without and 1%/1mm with average spatial corrections of 0.69 mm (0.67/-0.1/-0.1 Left/Sup/Ant). The results compared well with the FilmQA corrected results of the E2E tests with average 0.68mm offset (0.43/-0.14/-0.17 Left/Sup/Ant). All 5 DQA tests made before DeltaMan correction (E2E mean offset 1.27mm) failed Gamma 2%/2mm (mean 96.8\%) without and Gamma 1%/1mm with spatial corrections (mean 1.29mm) demonstrating sensitivity of our methods.

Conclusions: The use of laser cut EBT3 film provided high spatial and absolute dose information for radiosurgery QA and DQA and is usable in clinical routine. With our methods we found excellent agreement between the film and the planned dose with maximum film doses below 10Gy using the red color channel for EBT3. For higher doses the green color channel of EBT3 or the MDV3 film can be used. Even though our DQA methods were able to detect small system offsets further enhancements these and further studies to investigate dose sensitivity should be investigated. Ultimately a consensus on DQA is desirable within the physics community.

The authors would like to thank Xiang Yu of Ashland / ISP for providing the films, Gary Gluckman of 3Cognition for providing the beta version of FilmQA and Daniela Poppinga / Bjoern Poppe of the Carl von Ossietzky University Oldenburg for helpful discussions.
Sensitivity of a Commercial Diode Array for Use in the Rapid Assessment of CyberKnife IRIS Variable Collimator Performance

Gerald A. White, M.S., Gregory L. Gibbs, M.S., Gyöngyvérbulz, M.S., Kate Dikeman, M.S.

Presented by: Gyöngyvérbulz, MS

Objectives: To describe the sensitivity of a general purpose commercially available diode array for verifying the size of the radiation field from the CyberKnife (CK) IRIS variable collimator.

Methods: The technique uses a conventional diode array (Sun Nuclear Profiler) with the array at an extended distance of 320 cm. The array is positioned on its side at the end of the fully retracted CK patient table facing the linac. The linac is positioned with the central axis of the beam orthogonal to the surface of the Profiler. Sensitivity is determined by both interpolation between collimator sizes and by advancing the device towards the x-ray source, thus varying the effective radiation field size at the detector.

Table and gantry position coordinates are shown in the table below. (The coordinates are for a CK installation with the robot position on the left side of a supine patient.) The projection of the 4 mm diode spacing back to the 80 cm field definition distance gives an effective spacing of 1 mm, sufficient to confirm proper operation of the IRIS. The Profiler is centered using the CK internal laser. Beam data acquisitions are made using 600 MU to provide the same number of collected sample points on the Profiler.

Robot and Table Positions
(Installation geometry dependent)

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<th>Axis</th>
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<th>Alternate coordinate</th>
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<td>99.14</td>
</tr>
</tbody>
</table>

Table Axis Position (mm)
Y  -73.0
Z  273.6
X  914

Results: Differences on the order of 0.14 mm (range 0.03 mm to 0.83 mm) are detectable.

Conclusions: A general purpose commercially available diode array can be used to quickly and accurately characterize the field size of the Cyberknife IRIS variable collimator system with sub-millimeter accuracy subsequent to service, software recalibration, software upgrades or associated with routine QA. This technique avoids the time consuming and cumbersome water tank scanning with a diode and the difficulties associated with image based measurements (CR or radiochromic film) that require time consuming and careful calibration and choice of threshold values.
Surface Dose Comes from Imaging Units of CyberKnife System: A Dosimetric Study

Abdulmecit Canbolat, Faruk Zorlu, Ali Dogan, Murat Gürkaynak

Presented by: Abdulmecit Canbolat, MS

Objectives: CyberKnife System (CKS) uses stereoscopic X-ray imaging not only for patient set up, but also for real-time target tracking throughout treatment delivery process. In this study, it is aimed to measure surface doses from CKS imaging system using different tube parameters.

Methods: CT images of Alderson Rando phantom with 2.5 mm slice thickness was transferred to treatment planning system of CKS. The plan isocenter was located on the abdominal region of Rando phantom in order to use the flatness of its surface. Five measurement points were selected to calculate the average surface dose in the image field. Following setup verification of the phantom, the crossing point of sagittal and transverse lasers was accepted as central point of our measurements. The other four measurement points were selected as ±5 cm distance from our central point and ±5 cm distance from out of image field in cranio-caudal direction. The changes in surface dose from imaging system were investigated using various combination of exposure parameters, i.e. energy & mAs. The selected energy parameters were 90, 100, 110 and 120 kV while mAs parameters were 10, 30 and 90 mAs. These values are in the available range of the X-ray tube. Three TLDs and one gafchromic film (3x3 cm²) were located on the each measurement points. Dose loading of the TLD and film sets was performed by exposing 80 times to get reliable single image dose.

Results: As expected, the dose per image increases with higher parameter couple. The increase in dose per image was observed in both the higher mAs value for the same energy and the higher energy for the same mAs value. On the other hand, the dose per image for each energy increases approximately with the factor of 2.50 while shifting the mAs parameter with the factor of three. For the TLD measurements, the parameter couple of 90 kV and 10 mAs have the lowest surface dose of 0.16±0.02 mGy while the couple of 120 kV and 90 mAs have the highest surface dose of 2.40±0.04 mGy, as well as film measurements 0.20±0.01 and 2.41±0.03 mGy, respectively. The doses are decreasing significantly in the out of image field for both measurement systems (? 50% dose of center image).

Conclusions: The surface dose of X-ray imaging depends on the parameter couple kV and mAs in CKS. If the number of image is increase, contribution of surface dose is increase. The number of required image for each case varies with the location of a disease and CKS treatment options, i.e. breath (Syncrony Respiratory Tracking), vertebra bones (Xsight Spine Tracking), and cranial bones (6D-Skull Tracking) tracking. For our department, cumulative real-time images used for patient has changed in the range of 40 and 150. This situation reveals the requirement of consideration of additional surface dose exposed by imaging process. Therefore, while we choose the optimal lowest tube parameters without compromising from the quality of imaging, also we use minimum number of images without compromising from the quality of treatment.
Pretreatment Verification of Small Field Dosimetry for SRS/SBRT using MapCheck 2TM and Ion Chamber

Kai Dou, Ph.D., Fritz Lerma, Ph.D., and M. Jacobs, MD

Presented by: Kai Dou, PhD

**Objectives:** To evaluate the MapCHECK 2TM diode array (Sun Nuclear Model 1175) in use for rotational dosimetric verification of Varian TrueBeam RapidArc treatment technique and to further evaluate small filed dosimetry for the techniques of SRS and SBRT where one brain SRS case was studied with multitechniques of MapCHECK 2TM and Standard Imaging EXRADIN Ion Chamber A16.

**Methods:** MapCHECK 2TM diode array has been widely used for IMRT QA due to their ease of use and immediate read-out of results and needs to be investigated for SRS/SBRT pretreatment verification being compared with multi-techniques such as micro-ionization chamber, SRS diode, Gafchromic film and Varian EPID. A Standard Imaging LUCY 3D QA phantom with Standard Imaging EXRADIN Ion Chamber A16 was used for the absolute dose measurement. Varian Eclipse treatment planning system with the AAA and AcurosXB algorithms was used for treatment planning. PTW SRS diode and Gafchromic EBT2 films were employed for commissioning the small fields. Both distance and gamma analysis were used for a verification of a VMAT plan by comparing discrepancy between the planned and measured data. Two approaches were examined for this study. The first was to attach the MapCheck 2TM to the gantry head of a Varian TrueBeam accelerator and 100 cm SAD was set with a 5cm equivalent depth. The other is to place the MapCheck 2TM on the TrueBeam couch where the couch attenuation is included. The all-in-one composite QA was compared with separate QA.

**Results:** The interleaf leakage was found for the condition by attaching MapCheck 2TM to the linac head. The hot spots have an interval of 5 mm or 10 mm appeared on the data analysis using DoseLab and these intervals are just equal to the leaf width projected to the isocenter. The observed hot spots were apparently reduced using the second approach by placing the MapCheck 2TM on the couch. A very good linear relation of measured dose vs. given monitor unit was obtained by using a normal incidence of photons. An angular dependence of given dose indicated that the obvious attenuation without the couch involved was observed at between 5 and 10 degree of incident beam to the MapCheck 2TM surface. A maximum attenuation of 4.5% was deduced from the couch involved measurement, which is consistent with the ion chamber measurement. A composite QA showed a higher pass rate than an individual beam delivery.

One case of a brain tumor of a maximum dimension of 1.5 cm was examined with A16 chamber compared with the MapCheck 2 measurement. The MapCheck 2TM data were analyzed with the absolute and Gamma under the criteria of 1.5%/1.5mm/10%THR and the pass rate ranged from 91.2% to 100% for the separate beam QA and the composite field QA showed a higher pass rate. The Standard Imaging LUCY 3D QA phantom with Standard Imaging EXRADIN Ion Chamber A16 was aligned using IGRT in order to assure the A16 chamber in the correct position. The chamber position was also checked with the chamber reading at a gantry position of 0, 90, 180 and 270 degree. The measured separate beam QA with the planned data was found an average difference of 2.2%. A similar difference was found for a composite field measurement.

**Conclusions:** Static and dynamic properties of MapCHECK 2 showed that it is a promising tool for rotational dosimetry and even for small field dosimetry.
Forcing the Optimizer: The Dose Control PTV

James Hevezi, Ph.D. and Paiman Ghafoori, M.D.

Presented by: James Hevezi, PhD

Objectives: To illustrate the use of the dose control PTV in CyberKnife planning.

Methods: The dose control PTV is generated by copying the PTV onto itself and labeling with a new name. A plan is generated and prescription isodose line is chosen that covers both conformally. Subsequently, the PTV is labeled "Dose Control PTV" and recontoured to expand or contract depending on conformal coverage of the original (physician generated) GTV/PTV. Further calculations will force the optimizer to attempt conformal coverage of the Dose Control PTV, thus more closely covering the GTV/PTV with the prescription isodose line.

Results: The Dose Control PTV concept has been used successfully on many of our CyberKnife planned patients at the Austin CyberKnife Center. Representative examples will be presented.

Conclusions: A new concept of the Dose Control PTV has been used successfully where the original optimizer plan does not conform to the target well enough. The concept forces the optimizer to better cover the target conformally.
Combining Biocompatible Metallic Materials to Optimize Implanted Marker Visualization across All Imaging Platforms for High Precision Radiotherapy

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Objectives: To determine the optimal biocompatible material(s) for an implantable marker that satisfies all of the current requirements for SRS, SBRT and IGRT that is clearly visible across all of the imaging platforms currently used to provide high precision stereotactic radiation therapy. We describe a uniquely distinctive implanted fiducial marker called the FusionCoil that images well across all of these platforms.

Methods: A large variety of combinations of materials were tested for biocompatibility, and image performance. After the testing was concluded we settled on a patent pending combination of pure gold and surgical grade titanium. The final design is an open helix pure gold coil with securely segmented titanium nodes providing flexibility, nonmigrating characteristics and is optimized for visualization across all planning and localization imaging platforms.

The marker was first tested for the potential corrosive nature due to the combination of dissimilar metals. Then a battery of imaging studies was performed including CT, MR, US, MV-CBCT, kV-CBCT, MV and kV planer images. Additional MR specific testing is required if the implanted device is to be labeled "MRI Safe".

Finally, (10) patients had this marker and a standard hollow gold coil implanted on the right and left sides of the prostate gland.

Results: We utilized MTA Associates in Mt. View, CA to perform the cyclic polarization (ASTM F2129) corrosion testing; the marker did not exhibit any breakdown potential and was deemed safe from a corrosion perspective. The marker was then tested for MR compatibility using four separate tests that measure:
- Magnetically Induced Displacement Force on Medical Device
- Magnetically Induced Torque
- Measurement of Radio Frequency Induced Heating
- Evaluation of MR Image Artifacts
The marker had acceptable reading for all four tests and was deemed MRI compatible.

The marker was then placed in a tissue equivalent phantom and all of the aforementioned imaging studies were performed. The marker is clearly visible in each of the imaging platforms.

In all cases (10) where the FusionCoil was implanted on the patient’s left side of the prostate gland it was readily visible for all of the imaging formats used while the hollow gold coil was not visible at all in the MR study.

Conclusions: The combination of these biocompatible materials has proved to produce the optimal implanted marker for all of the imaging formats currently used to plan and deliver image-guided radiotherapy. The marker has been cleared by the US FDA and carries the CE mark.
Validation of the Use of Commercial MU Second Check Programs in Radiosurgery

Ronald J. Lalonde, PhD

**Objectives:** To determine under what conditions a commercial MU checking program may be used to validate SRS/SBRT calculations from a treatment planning system.

To establish guidelines for commissioning and validating MU checking programs for radiosurgery.

To compare MU calculations with treatment planning system calculations in homogeneous, inhomogeneous phantoms and in patient data sets.

**Methods:** Beam data from a Varian Truebeam linac was used to commission both the Varian Eclipse treatment planning system and the Radcalc MU calculation program for small field sizes (down to 1.0 cm) used in radiosurgery. Point dose calculations were performed for both theoretical and physical homogeneous and heterogeneous phantoms, and for patient CT data sets in the cranium and in the body, and for open (conformal) and modulated fields. Point dose comparisons were made between the planning system and the MU check program for field sizes from 3x3 cm² to 0.5x0.5cm², and for modulated fields with average leaf pair opening (ALPO) from 2.0 cm to 0.5 cm.

**Results:** Radcalc homogeneous dose calculations for conformal fields in phantom agreed with Eclipse to within acceptable tolerances (< 5%) for all field sizes down to 1.0 cm diameter (circular targets). However, in heterogeneous (lung equivalent) media, Radcalc point doses for a 1.0 cm diameter target were 20% greater than Eclipse. Calculations of modulated plans varied with both field size (similar to conformal fields) and degree of modulation (as measured by average leaf pair opening). Modulated plans agreed within acceptable tolerances for ALPO of 1.5 cm or greater. In patient CT datasets, the results were similar, with acceptable agreement between Radcalc and Eclipse for field sizes 1.5 cm or greater in the lung, and 1.0 cm or greater in the cranium.

**Conclusions:** Commercial MU check programs may be used to confirm radiosurgery doses within certain limitations. Careful validation of the programs should be performed before routine use in clinical calculations.
Comparison of Dose Distributions in Lung Tumors Calculated by Ray-Trace and Monte Carlo Algorithms Implemented in CyberKnife Treatment Planning System

Matulewicz L, Stapor-Fudzinska M, Slosarek K.

Presented by: Lukasz Matulewicz, PhD

**Objectives:** Accurate dose calculation is essential to advanced stereotactic body radiation therapy (SBRT) especially for treatment planning involving heterogeneous patient anatomy.

The aim of the study was to compare dose distributions calculated using the Ray-Trace and Monte Carlo algorithms for CyberKnife (Accuray Inc.) treatments of lung tumors.

**Methods:** Retrospective comparisons were made between the Ray-Trace and Monte Carlo algorithms for ten heterogeneous CyberKnife lung treatment plans. Clinically acceptable plans were calculated using the Ray-Trace algorithm and then recalculated with Monte Carlo, keeping the same beam orientations and monitor units. The dose distributions using both algorithms were calculated in the entire patient volume. For both algorithms, comparison of target dose and coverage was made.

**Results:** In the retrospective comparison of the Ray-Trace and Monte Carlo calculations for lung treatment plans, the Ray-Trace algorithm overestimated the dose and coverage of the target volume by average value $3.57\% \pm 2.03\%$ and $22.09\% \pm 13.34\%$, respectively. In this sample we did not found a linear correlation between the evaluated parameters and the target volume.

**Conclusions:** This study shows that the Ray-Trace algorithm overestimates the dose to the target for lung cancer. Monte Carlo is expected to become widely used for dose calculation in SBRT, especially for the treatment of target volumes in lung.
Comparison of Simultaneous-Integrated Boost (SIB) for Prostate Cancer Patient using CyberKnife, Tomotherapy and VMAT

Stapor-Fudzinska M, Matulewicz L, Slosarek K, Miszczyk L

Presented by: Małgorzata Stąpór-Fudzińska, MS

Objectives: The aim of the study was to test the feasibility of planning a hypofractionated high-dose treatment for prostate cancer using SIB technique with CyberKnife system (Accuray Inc.) and to compare the dose distribution of with two other radiotherapy techniques: Tomotherapy (Accuray Inc.) and VMAT (Varian Inc.).

Methods: For realistic prostate cancer patient the following critical organs were contoured for conformal avoidance: bladder, bladder wall, rectum, heads of femur and skin. The gross tumor volume (GTV)-1 was the area of the boost dose 30Gy. The planning target volume (PTV)-1 encompassed GTV-1 plus a 3 mm margin. PTV-2 was the entire prostate gland with a prescribed dose of 15 Gy. For the same contour set four treatment plans were calculated using the following techniques: VMAT 6MV, VMAT 20MV, Tomotherapy (6MV) and CyberKnife (6MV). SIB was planned in three fractions.

Results: The degree of conformity was evaluated with a Conformity Index (CI) that for PTV-1 was 1.33, 1.39, 1.24 and 1.08 using VMAT 6MV, VMAT 20MV, Tomotherapy (6MV) and CyberKnife respectively.

Conclusions: This case demonstrates the feasibility of planning SIB with CyberKnife system. Moreover, the CyberKnife offers the similar target coverage to the other techniques but the best conformity. In addition, the crucial advantage of CyberKnife is a real-time tumor tracking possibility. To more clearly define the impact of SIB for prostate cancer with CyberKnife, further investigations are required.
Circumferential or Sectored Beam Arrangements for Stereotactic Body Radiation Therapy (SBRT): Impact on Target and Normal-Structure Dose-Volume Metrics


Presented by: James A. Tanyi, PhD

Objectives: Beam arrangements for SBRT of lung tumors follows personal or institutional preferences. While beam entry over the contralateral lung is avoided by some groups, others favor a more evenly spaced circumferential beam arrangement. We compared two beam arrangements; sectored (beam entry over ipsilateral hemithorax) and circumferential (beam entry over ipsi- and contralateral lung), for static-gantry IMRT delivery techniques with respect to dose gradient and exposure of normal organs at risk.

Methods: Data from 132 patients treated by SBRT for primary NSCLC formed the basis of this study. Structures analyzed for dose exposure were the 4DCT-derived internal target volume (ITV), planning target volume (PTV, 5 mm expansion of ITV), spinal cord and the esophagus (delineated extending 5 slices above and below the PTV), ipsilateral (excluding PTV) and contralateral lung, respectively. Two treatment plans were generated per dataset: (1) IMRT plans using sectored beam arrangement (IMRT-s), and (2) IMRT plans using circumferential beam configuration (IMRT-c). Prescription dose (PD) was 60 Gy (12 Gy/5 fx) to 95% of the PTV, and maximum PTV dose of 150%. Standardized optimization techniques were used on all plans. For lungs, mean doses (MLD), V5, V10, and V20 were recorded. Plan conformity indices, a measure of dose gradient, were computed; CI80, CI60 and CI40 (ratio of volume of 80%, 60%, and 40% isodose, and PTV volume. Maximum dose (Dmax), D5 and D50 for spinal cord and esophagus were computed. Dose parameters were analyzed with respect to tumor location (upper, middle, and lower lobes).

Results: ITVs for the current study ranged from 0.9–162.9 cm3 (mean=20.9). IMRT-s planning resulted in significant decrease in contralateral MLD, V5, V10 and V20 when compared with IMRT-c (all p< 0.001). This finding applied to all tumor sites analyzed (all p<0.001). Ipsilateral lung dose exposure did not show statistical differences between IMRT-s and IMRT-c. While nominal reductions of Dmax, D5 and D50 for the spinal cord in IMRT-s plans did not reach statistical significance (p = 0.57, 0.18, and 0.19), the respective measures for esophagus were significantly lower than in IMRT-c plans (20.9%, 15.0%, and 22.6%; all p<0.001). Dose gradient improved with IMRT-s technique. Reductions in CI80, CI60, and CI40 were 1.4%, 3.5% and 8.1%, respectively.

Conclusions: Sectored IMRT beam arrangements showed dosimetric advantages over circumferential beam arrangements in terms of dose gradient and contralateral lung sparing. Further studies are needed to evaluate the clinical relevance of the current findings.
Geometric Evaluation of Intrafraction Motion during Frameless Intracranial Stereotactic Radiosurgery (SRS)

Catherine M. Kato, James A. Tanyi, Charlotte Kubicky Carol M. Marquez, Martin Fuss

Presented by: James A. Tanyi, PhD

Objectives: To quantify intrafraction motion during frameless intracranial stereotactic radiosurgery (SRS) using the six-degree-of-freedom (6DOF) stereoscopic x-ray imaging system.

Methods: Patient immobilization was accomplished by either a custom-fitted three-piece bivalve-style thermoplastic mask (BrainLAB AG, Heimstetten, Germany) or a three-point fixation Orfit mask system (Orfit Industries, Wijnegem, Belgium). Frameless positioning was based on online 6DOF stereoscopic x-ray (ExacTrac) imaging followed by online volumetric image guidance (CBCT) for residual error assessment. At least one mid-treatment ExacTrac acquisition was performed for motion assessment. The difference between the patient’s position at the start and at the time of re-assessment was determined and labeled intrafraction motion.

Results: A cohort of 180 sequential patients that were subjected to frameless cranial SRS formed the basis of the current analysis. In total, 350 intrafraction ExacTrac image sets were evaluated (mode 1; range 1-3). Intrafraction translational motion was -0.1 mm (SD=0.7; range: -2.5–2.0), 0.0 mm (SD=0.8; range: -2.5–2.1), and 0.1 mm (SD=0.8; range: -2.3–2.8), in the vertical, longitudinal and lateral directions, respectively. The 3D vector was 1.1 mm (SD=0.7; range: 0.0–3.5). Intrafraction rotational alignment errors was 0.0 degrees (SD=0.8; range: -2.8–2.7), 0.0 degrees (SD=0.4; range: -1.1, 1.4), and 0.1 degrees (SD=0.7; range: -2.2–2.7) in the yaw, roll and pitch directions, respectively. Frequency of absolute motion in any direction >1 mm, >1.5 mm and >2 in any direction was 33%, 15% and 5% respectively. Frequency of 3D vector motion >1 mm, >1.5 mm and >2 was 48%, 25% and 10% respectively.

Conclusions: Intrafraction motion during frameless SRS delivery is typically small, albeit non-negligible. While motion along one or more room axes and 3D motion vectors >2 mm were observed no more than 10% of times, this finding may provide a rationale for development of planning target volume margins. Frequent intra-treatment positioning assessment can significantly contribute to the precision of frameless intracranial SRS.
The Impact of Interfraction Motion Variability during Hepatocellular Carcinoma (HCC) SBRT: A Preliminary 4DCT Assessment

Lucy Nam, James Tanyi, Martin Fuss

Presented by: James A. Tanyi, PhD

Objectives: To investigate changes in respiration target motion amplitude, motion trajectory, and resulting internal target volume (ITV) during 3 to 5 fraction SBRT for hepatocellular carcinoma (HCC).

Methods: Three patients with four HCC underwent 4DCT simulation, and repeat 4DCT imaging for SBRT image-guidance (11 repeat 4DCT; 3-5 repeat 4DCT/patient). All patients had previously undergone Ethiodol-based transarterial chemoembolization (TACE), which resulted in a radio-opaque stain of the HCC. Target volumes were individually delineated on 10 respiratory phases (0-90%) using an automatic threshold-based segmentation routine (Mirada Medical Ltd.; threshold 150 HU). Patterns of target motion and motion amplitude changes were evaluated over time. Correspondingly, ITV changes were also assessed.

Results: While motion trajectory appeared to be patient specific over time, inter-individual motion trajectories varied widely. Motion trajectories approximated a plane in 2/4 lesions, while the dual-lesion patient showed a complex three-dimensional motion profile. Inter-fraction variation on tumor motion assessed as centroid displacement, were 0.8 mm (SD=1.3; range: -0.1 – 4.5), 1.6 mm (SD=2.0; range: -1.4 – 6.3), and 0.6 mm (SD=4.2; range: -3.3 – 12.3) in the left-right (LR), anterior-posterior (AP), and superior-inferior directions, respectively. Similar to motion amplitude and motion trajectory, inter-individual/inter-treatment ITVs were quite variable. Changes in motion envelope (ITV) relative to baseline were -19.3% to +24.7% with the dual-lesion patient presenting with larger inter-treatment variation.

Conclusions: The current limited 4DCT data assessment indicates significant and mostly random changes in respiratory-induced target motion with consequential random changes in ITVs over time. When using very narrow planning target volume margins, his observation may prompt daily online adaptive re-planning.
**CyberKnife Stereotactic Radiosurgery for Chordoma: Preliminary Results**

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Presented by: Giancarlo Beltramo, MD

**Objectives:** Although considered slow-growing, low-grade malignancies, chordomas are locally aggressive and destructive tumors with high recurrence rates. We report preliminary results of stereotactic radiosurgery (CK/SRS) using the Cyberknife system for primary and recurrent chordomas.

**Methods:** Between March 2006 and February 2011 sixteen patients with chordoma (13 men and 3 Woman; median age, 64 years; age range, 35-80 years) were treated with Cyberknife (Accuray, Inc., Sunnyvale, CA) Stereotactic Radiosurgery at our Institution. The series included 20 lesions, forty per cent of the tumors were located in the mobile spine, 35% inside the cranium and 25% in the sacral region. Cyberknife was performed as salvage treatment for multiple recurrences in 15 lesions, as primary adjuvant therapy for four lesion and as monotherapy for 1 lesion. The prescribed tumor dose ranged from 20 to 40 Gy in four to five fractions. The treatment dose was selected on the basis of tumor size, location and proximity to critical structure. Patients were followed at 1, 3, 6, 9, and 12 months and at 6-month intervals thereafter. Evaluations included magnetic resonance imaging (MRI), information on interval history, neurological examination and pain assessment using the Visual Analog Scale (VAS) as site-specific pain. Lesions were considered non recurrent if radiographic studies indicated no evidence of local disease progression and the patient had clinically improved or was unchanged.

**Results:** Patients were followed after CK/SRS for a median of 33 months (range 4-75 months). The actuarial local control rate was 58.5% at 36 months. The overall survival rate by the Kaplan-Meyer method was 60.7% at 36 months. Ten of the sixteen patients experienced recurrence. No RTOG Grade 3 or 4 optic nerve neuropathy, lower cranial nerve palsies, hypesthesia, transiet pharestesias and radiculopathy was observed. One patient developed RTOG 3 radiation induced mielopathy at an interval of 22 months following CK/SRS treatment.

**Conclusions:** Although fractionated charged particle RT with agents such as protons or carbon ions has been advocated to deliver a potentially more radiobiologically effective treatment in patients with chordomas, Cyberknife may be an effective potentially alternative treatment option with acceptable survival rates and toxicity as reported in our experience.
**Fractionated Stereotactic Radiosurgery for Intracranial Metastases: Tumor Control**

Joel S. Katz, Marina Kushnirsky, Jonathan P.S. Knisely, Maged Ghaly, Michael Schulder

Presented by: Maged Ghaly, MD

**Objectives:** Fractionated SRS may confer radiobiologic treatment advantages in the eradication of metastatic brain tumors. We compared the results of single and fractionated SRS for patients with metastatic tumors.

**Methods:** We reviewed all patients from our institution who were treated with SRS for intracranial metastases between January 2010 and September 2012. Collected data included diagnosis, tumor location, lesion volume, and SRS dose. Local control (LC) and volume changes after fractionated or single fraction SRS were compared using t-test and \( \chi^2 \) test.

**Results:** 152 patients with 279 lesions underwent SRS. 214 lesions were available for follow-up with serial MRI from 0.2 – 24.5 months (5.00 ± 6.73 months) after SRS, with overall LC of 76%. 63 lesions had treatment volumes greater than 3 cc. Of these, 31 lesions underwent single session SRS and 32 were treated in 3 sessions. Median prescription doses for single and fractionated SRS were 20 Gy and 24 Gy, respectively. Tumor progression was observed in 9/31 lesions treated with a single session, compared with progression in only 1/32 lesion treated with 3 sessions (\( \chi^2 = 0.004 \)). Overall, lesion volume following fractionated SRS decreased by 66.6%, vs. a 66.3% decrease after single session SRS (\( p = 0.95 \)).

**Conclusions:** Fractionated SRS for patients with metastatic brain tumors yielded volumetric decrease in tumor size that was equivalent to that obtained with single session SRS. For larger tumors, LC was significantly better in patients treated with fractionated SRS. We recommend consideration of fractionated SRS for patients with metastatic tumors larger than 3 cc.
Utilizing the Fusion of a CT with a SENSE® MRI without the need of a Cisternogram for CyberKnife® Treatment of Trigeminal Neuralgia

Jerry McCoy M.S., Juan Godinez M.D., Janelle Park M.D.

Presented by: Jerry McCoy, MS

Objectives: Our objective is to show the fusion of a SENSE® MRI with a CT study set can be utilized effectively for patients who receive Stereotactic Radiosurgery with CyberKnife® in the treatment of Trigeminal Neuralgia.

Methods: From 2009-2011 seven patients were referred to the CyberKnife Center for treatment of refractory Trigeminal Neuralgia. Axial CT studies were performed on 7 patients utilizing 0.625 mm slice thickness with a thermoplastic mask setup in the treatment position. The 7 patients also received a SENSE® (SENSitivity Encoding from Philips©) T1 MRI sequence utilizing a custom made PMMA tabletop constructed to accept the baseplate and thermoplastic mask for head immobilization. Surface Coils were placed on the mask and the MRI was acquired utilizing 0.625 mm slice thickness SENSE® sequence. Fusion and registration of the CT and MRI were completed in the Multiplan Treatment Planning System ©. The overlay of the fused images was accepted once the radiation oncologist agreed sub-millimeter visual accuracy was achieved. The trigeminal nerve was then delineated on the MRI by the Radiation Oncologist and Neuroradiologist to be targeted for radiosurgery ablation. All 7 patients received a prescribed dose of 5830 cGy to a 4-6 mm section of the trigeminal nerve normalized to an average of 81% isodose surface.

Results: The delineation of the trigeminal nerve did not represent any difficulties for the radiation oncologist. Follow-up was available for all 7 patients (range 2-24 months, average 32). All patients experienced little to no pain at follow-up. 3 of the 7 patients experienced some facial numbness. All patients expressed improved quality of life after treatment.

Conclusions: The study has shown that the utilization of a SENSE® MRI fused with a CT scan has achieved similar results as reported in the literature with the use of a cisternogram with the advantage of avoiding the complications associated with such an invasive procedure as a cisternogram. We noted similar results and side effects as recently reported by other institutions with higher prescription doses.
**Integration of Navigated Transcranial Magnetic Stimulation (NTMS) Information into Radiosurgical Treatment Planning**

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Presented by: Markus Kufeld, MD, MS

**Objectives:** Evaluating the import and integration of NTMS data into Multiplan® planning software for radiosurgical treatments.

Assessing the influence of NTMS information on the decision-making of treatment indication, treatment planning, and dose finding for cerebral lesions in eloquent brain areas as motor cortex and speech area.

**Methods:** The non-invasive NTMS system eXimia® (Nexstim®; Helsinki, Finland) was used to determine the motor cortex or speech area in patients with cortical lesions.

The system uses a high-precision electromagnetic stimulation coil, combined with infrared three-dimensional (3D) neuronavigation and analytic software, to deliver magnetic stimulation to the motor cortex. This stimulation results in muscle output, which is recorded on the system’s integrated electromyogram (EMG). The skull above and around the cortical region of interest is scanned and each response is registered in a 3D magnetic resonance imaging (MRI) dataset. Points with specific EMG response are marked. The resulting MRI dataset is exportable in DICOM format and imported into the MultiPlan® (Version 4.5) planning software. After fusion with the planning computer tomogram (CT) dataset the stimulation information can be displayed in the planning dataset.

For assessing the influence of the functional information on the treatment planning procedure a questionnaire was developed, which was answered by the responsible physician. The questionnaire inquires:

1. technical aspects of data import, image fusion and processing
2. influence of functional information on contouring, dose finding or dose distribution
3. influence on treatment indication, patient information and informed consent

**Results:** Ten patients with brain metastases (5), arterio-venous malformation (AVM) (3) or recurrent meningioma (2) have been analyzed so far. All lesions but one were assumed to be located close to the motor cortex, one AVM was located in the Broca area.

Data import of NTMS information into the CyberKnife® planning software was flawless via USB stick. The 3D MRI dataset containing the functional data could be fused with the planning CT in all cases without problems and the functional information could be visualized in the corresponding planning CT dataset on the MultiPlan® workstation.

In all patients the functional information was analyzed before the treatment to evaluate the risk profile of each patient. In two cases the dose distribution was adjusted during treatment planning respecting the adjacent motor cortex. A steep dose gradient was created especially on the motor cortex side of the lesion.

In one patient with an AVM located in the Broca region the prescription dose was reduced due to the functional information, which showed speech activity in the cortical brain tissue overlaying the AVM.

**Conclusions:** The integration of NTMS data into the MultiPlan® planning software is smoothly possible. This functional information showed to be of value for risk estimation and patient information. In critical treatment situations with tumors or AVM adjacent to eloquent brain regions this visualization of functional information might confirm the physician in his decision-making or even induce changes in dose distribution or dose prescription. Prospective integration of fiber tracking as well as a functional evaluation of post radiogenic tissue alteration is planned.
Feasibility of Linac-based Flattening Filter Free (FFF) Stereotactic Radiosurgery (SRS) for Trigeminal Neuralgia

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Presented by: Rahul R. Parikh, MD

Objectives: To assess feasibility and safety of the clinical usage of Flattening Filter Free (FFF) beams for delivering ablative stereotactic radiosurgery (SRS) doses for trigeminal neuralgia (TN), by means of Varian TrueBeamSTX\(^{TM}\) (Varian Medical Systems).

Methods: 11 consecutive patients, followed by a single neurosurgeon (R.G.), diagnosed with medically refractory unilateral TN were treated at CCCNY with FFF-based SRS: 5 were left-sided, 6 were right sided. Doses ranged from 7,000 to 8,000 cGy (median dose, 7,500 cGy), and were prescribed to 100% isodose line (IDL). All patients had a stereotactic head frame placed for rigid immobilization prior to CT simulation. The CT and MR images were fused on axial, coronal, and sagittal images. The FIESTA sequences of the MRI were used for delineation of normal structures, the appropriate trigeminal nerve, and target delineation. For each patient, a 7-arc plan was devised to deliver the prescription dose in a single fraction, dosed to the 100% IDL, using a 5mm cone (as shown below, Figure 1). Prior to treatment delivery, image guided-radiotherapy (IGRT) was performed in the form of planar kV imaging to verify stereotactic frame placement and accurate positioning. At each follow-up visit, patients reported their outcomes using the Barrow Neurological Institute (BNI) pain scale.

Results: All 11 patients tolerated the procedure well and completed the treatment successfully. With a median follow-up of 3.3 months (range 1.0-9.5 months), no patient experienced greater than Grade 1 toxicities acutely or at subsequent clinical evaluation visits. There were no episodes of dysesthesia or hypoesthesia. There were no complications related to SRS. Early clinical assessment using the BNI pain scale shows promising results in the majority of patients.

Conclusions: This study showed that, with respect to acute toxicity, SRS with FFF beams is a feasible technique in 11 consecutive patients with TN. To our knowledge, this is the largest experience of modern, linac-based SRS utilizing FFF beams for TN. This modality may prove to be a viable treatment alternative for patients with TN with competitive efficacy while minimizing treatment-related morbidity.
Synchrotron-Generated Microradiosurgical Transections: A New Tool to Modulate Brain Function

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3 - European Synchrotron Radiation Facility (ESRF) - Grenoble, France

Presented by: Pantaleo Romanelli, MD

Objectives: We have investigated the ability of synchrotron-generated microbeams carrying an incident dose of 600 Gy to generate histologically evident hippocampal transections while preserving learning and memory.

Methods: An array of synchrotron generated microbeams (size: 75 µm; center to center spacing: 400 µm; incident dose: 600 Gy) was delivered to the hippocampus of 10 naive 3 week-old Wistar Han rats. This group was paired with ten untreated controls of equivalent age and weight. Weight gain was assessed weekly. 7T MR imaging was performed on the treated animals 3 months after irradiation to evaluate the development of edema and/or radionecrosis. Acute immunohistology was performed after 24 hours using pH2AX (an acute marker of DNA irreversible damage and apoptosis). Conventional brain histology (Nissl and H&H) as well as immunohistology using NeuN and GFAP was done after 3 and 6 months. Behavioral testing using an 8-arm maze was performed 3 and 6 months after irradiation.

Results: The treated rats gained weight regularly, showing no difference with the control group. 7T MR imaging revealed no sign of radio-induced edema or radionecrosis and no distortion or atrophy of the hippocampus. Immuno-histology with pH2AX performed 24 hours after the procedure revealed immediate cell death along the microbeam paths and no damage elsewhere. Clear-cut microradiosurgical transections remained stable over time, as demonstrated by immunohistology performed at 3 and 6 months. Viability of hippocampal neural progenitors was not affected by the treatment. Behavioral testing based on learning and memory tasks showed no difference between treated animals and controls.

Conclusions: Synchrotron-generated microradiosurgical transections are associated with preservation of hippocampal architecture, neurogenesis and memory. This original approach offers an interesting new way to study the hippocampal function, to prevent radio-induced dementia and to develop novel treatment avenues for mesiotemporal epilepsy.
Is There Still a Place for Stereotactic Brachytherapy for Brain Tumors in Modern Neuro-Oncology?

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Objectives: Stereotactic implantation of irradiation sources (so called stereotactic brachytherapy (SBT)) has been applied for intrinsic brain tumors and metastases for more than four decades in numerous patients. The majority of studies reported about the application of high-dose rate Iodine-125 implants (40–70cGy/h) for high-grade gliomas, including two prospective randomized trials, which compared standard treatment ± SBT [1,2]. This approach, however, was associated with high incidence of radiation induced adverse effects requiring repeated surgery and failed to proof any significant oncological benefit as compared to standard treatment regiments. Another approach using SBT was the application of low-dose rate implants (3–8cGy/h) for slow growing low-grade gliomas or brain metastases which demonstrated in several very recent publications to be associated with only little permanent deficits and almost an absence of radiation induced necrosis [3-15].

Methods: Review of the literature of SBT for CNS tumors an to display differences in technique, complications and outcome.

Results: SBT represents a highly localized treatment option for well circumscribed tumors (=4 cm) and aims as well as micro-neurosurgical resection towards the devitalisation/removal of the dense (visible) portion of tumor cells by delivering a lethal irradiation dose (=200Gy in the vicinity of the implanted source) from within the tumor while optimally sparing surrounding tissue. This makes SBT as minimal invasive and safe technique highly attractive, especially for inoperable lesions in highly eloquent locations. Furthermore, SBT can be repeated in case of local/regional recurrence and does not hinder or limit the application of EBRT. Even though class I evidence is yet lacking, recent available data for low grade gliomas, metastases and other rare CNS tumors demonstrate that progression free-and overall-survival is well comparable to this after microsurgical (complete)resection or stereotactic radiosurgery. Local tumor response is at least as effective as after EBRT or chemotherapy.

Conclusions: SBT still represents as one of the oldest neurosurgical and highly sophisticated stereotactic technique a strictly local neuro-oncological treatment option for selected patient populations deserving further attention.

Robotic Image-Guided Hypofractionated Radiosurgery (CyberKnife) in Perioptic Meningiomas

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Presented by: Silvia Sánchez-Luis, MD

Objectives: Analyze the feasibility and safety of treatment of robotic image-guided hypofractionated radiosurgery for meningiomas close to the optic tract and acute toxicity related to it.

Methods: 12 patients with meningiomas located at = 2 mm from the optical path were treated in our unit from April 2012 to July 2012. The median age was 56 years (range 40-77 years). The prescribed dose ranged from 2100 to 2500 cGy in 3-5 consecutive fractions. The max dose to chiasm and/or optic nerve was limited to = 2300 cGy.

Previous to treatment, 11 of 12 patients had mild visual field defects, one patient had no visual impairment.

Results: The median volume of the treated lesions was 11.07 cc (range 0.38 to 36.92 cc). The median rates of conformity index was 1.25 (range 1.15 to 1.18). The median prescription isodose was 84% (range 79-91%). The median maximum dose to chiasm was 2214 cGy (range 780-2384 cGy) and to optic nerve nearest 1949 cGy (range 769-2562 cGy). 100% of patients had stable radiological meningioma on MRI on their follow up, and no one had associated edema. No patient had acute toxicity on the visual pathway and 3 of 12 patients referred visual improvement. All patients met the treatment regimen without incident.

Conclusions: Attend to published literature on the treatment of meningiomas adjacent to optic pathway, robotic image-guided hypofractionated radiosurgery, can be a safe and feasible option of treatment, not yet available long-term monitoring periods.

Despite the complex localization of these lesions, hypofractionated radiosurgery in 3 to 5 fractions is presented as a viable alternative to conventional treatment. In our series, no patient had worsening of vision or toxicity related to treatment. Long-term monitoring is needed to assess the local control of the lesion and the absence of chronic toxicity.
A Retrospective Review of SBRT for Larger Brain Metastases or Post-Resection Cavities

Kristina Young, MD, PhD, Faisal Siddiqui MD, PhD, James Tanyi, PhD, Carol Marquez, MD, Charlotte Kubicky, MD, PhD, Martin Fuss, MD, PhD

Presented by: Kristina Young, MD, PhD

Objectives: Radiation treatment for brain metastases is typically delivered by whole brain radiation (WBRT), stereotactic radiosurgery (SRS), or a combination of these modalities. However, there are patients with solitary tumors or post-resection tumor cavities that are not candidates for SRS owing to a maximum target diameter larger than 3 cm, for which an avoidance of WBRT may provide a quality of life benefit. Here we summarize treatment data and outcomes of patients who underwent stereotactic hypofractionated radiation therapy for brain metastases or resection cavities ranging from 3 to 6 cm in maximum diameter (SBRT brain).

Methods: We performed a single-institution retrospective analysis of treatment parameters and outcomes of 46 patients treated by SBRT brain between July 2007 and February 2012. The most common fractionation was 30 Gy in 5 fractions (n=21), followed by 35 Gy in 5 fractions (n=16), and 25 Gy in 5 fractions (n=4). Treatments were delivered using a BrainLab/Varian NovalisTx linear accelerator over 5 consecutive days on 30 patients, and every other day in 16 patients, respectively. Image-guidance employed daily stereotactic x-rays for 6D setup correction (ExacTrac, Brainlab), and subsequent cone-beam CT (OBI, Varian) for volumetric validation. Clinical and dosimetric data was obtained from the electronic charts. We analyzed for local tumor control, normal tissue complications, and survival.

Results: Mean follow-up was 8.3 months (range 0 to 41 months). Forty-three percent of treated metastases were non-small cell lung cancer, 15% melanoma, and 7% renal cell carcinoma. Eighty-three percent of patients underwent resection prior to radiation, 13% of tumors were intact. Twenty-six percent had tumor recur locally, with median local recurrence free survival of 3.6 months in intact tumors versus 10.1 months in resected tumors. Rate of local recurrence did not correlate with dose or histology. Thirty percent of patients had non-local in-brain failure, with median non-local brain recurrence free survival of 7.4 months. Fifty-eight percent of patients with local failure also failed elsewhere in the brain. Median overall survival was 6.3 months, 5.0 months in intact tumors versus 9.9 months in resected tumors.

Acute treatment related side effects were mild and included fatigue and focal hair loss. The incidence of radiologically evident radionecrosis was 8.7%, with average onset of 23 months. However, none of these cases showed clinical symptoms, or warranted a therapeutic intervention. Fifteen percent of patients underwent additional radiation therapy procedures, including whole brain radiation (6.5%) and additional focal radiation therapy (SRS or SBRT brain) for new brain lesions (8.7%).

Conclusions: SBRT brain for larger brain metastases and post-resection cavities can be administered with a favorable side effect profile. Outcomes after SBRT for brain metastases compare favorably to historical data for WBRT. While longer-term survival was observed, in-brain failure and/or systemic disease progression are limiting overall survival. The observed local recurrence rate warrants a prospective study of dose escalation.
CyberKnife Stereotactic Body Radiotherapy for Oligometastatic Lung Tumors

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Presented by: Giancarlo Beltramo, MD

Objectives: In patients with proven distant metastases from solid tumors systemic chemotherapy is considered the mainstay of treatment. However, in some patients, the metastatic disease may be very limited in number and site and local aggressive therapy may potentially prolong survival. In a subset of patients with limited lung metastases we hypothesized that Cyberknife Stereotactic Body Radiotherapy may improve treatments outcome.

Methods: Between February 2007 and August 2011, 60 patients, 22 female, 38 male with a median age of 69 years (range 32 – 87 years) with 78 pathologically proven pulmonary metastases not amenable to surgery, (colorectal 30, lung 15, Kidney 14, breast 7, Parathyroid 7, bladder 2, pancreas 1, endometrium 1 and melanoma 1) with a median gross tumor volume of 26 cc (range 3.55 – 240.06 cc) were referred to our Radiotherapy Department for Cyberknife stereotactic radiotherapy treatment. In 22 patients 1-3 gold fiducials were implanted inside or in the vicinity of tumor for targeting purpose, except for patients who were eligible for fiducialles x sight option. The planning treatment volume (PTV) included the GTV plus 5 mm isotropic margin, Total doses administered were 48-54 Gy in 3 to 4 fractions to the 75%-85% isodose line in patients with centrally located lesions, and 23 -30 Gy single fraction for peripheral lesions. Patients were followed with CT and PET scan to detect disease recurrence Local recurrence was defined as an increase in size of tumor following treatment as most tumors shrunk following radiation.

Results: Median follow-up was 16 months (range, 4–66 months). Kaplan-Meier local control (LC) at 1 and 2 years was 87.1% and 87.1%, overall survival (OS) at 1 and 2 Years of 82.1 and 65.2%, disease free Survival (DFS) at 1 and 2 years 67.8% and 59.6% respectively. The overall toxicity was very mild, with the majority of patients without any clinical side effect that did not interfere with their activities of daily living. In one patient with concomitant infection we observed a grade 3 acute pneumonitis, one patients developed significant thoracic pain related to high radiation dose received by the peripheral nerve.

Conclusions: Cyberknife stereotactic radiotherapy, in patients with pulmonary metastases has been shown to be a promising treatment with high local control and low toxicity profile, but a longer follow up and a higher number of patients are mandatory to evaluate effectiveness.
Stereotactic Body Ablative Radiotherapy for Early Stage Non Small Cell Lung Carcinoma

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Presented by: Giancarlo Beltramo, MD

Objectives: Although surgical resection remains the standard of care for patients with early stage non-small cell lung cancer (NSCLC), unfortunately, some patients are unable to tolerate the rigors of pulmonary resection. Recent emergence of stereotactic body radiation therapy allows for delivery of high radiation dose to the tumor while sparing normal lungs.

We evaluate the efficacy and feasibility of Cyberknife image-guide stereotactic body radiation therapy in patients with early-stage (Stage IA – IB) non small cell lung cancer (NSCLC).

Methods: From February 2005 to August 2011, a total of 71 medically inoperable patients, 12 female 59 male with a median age of 74 years (range 42 – 90 years) with pathologically proven NSCLC (squamous cell carcinoma, adenocarcinoma, large-cell carcinoma, bronchoalveolar cell carcinoma, or NSCLC not otherwise specified), diagnosed as 33 stage IA and 38 Stage Ib were referred to our Radiotherapy Department for Cyberknife stereotactic radiotherapy treatment (SBRT). Before study enrollment, patients underwent physical examination, computed tomography (CT) of the chest and upper abdomen, pulmonary function testing, and whole-body 18F-fluorodeoxyglucose positron emission tomography (PET)/CT fusion study. In 25 patients 1-3 gold fiducials were implanted inside or in the vicinity of tumor, in the other 46 pts fiducialless sight option was used for targeting purpose. In all patients a high BED 10 (> 100 Gy) was delivered to the tumor bed. The SBRT treatment dose of 48-60 Gy was prescribed to the 80% isodose volume in three-four fractions. Patients were followed with CT and PET scan to detect disease recurrence. Local recurrence was defined as an increase in size of tumor following treatment as most tumors shrank following radiation.

Results: Median follow-up was 21 months (range, 4–70 months). Kaplan-Meier local control at 1 and 2 years was 94.3% and 90.7% respectively, overall survival (OS) at 1 and 2 years was 87.3% and 65.3%, disease free Survival (DFS) at 1 and 2 years was 84.3% and 67.6%. We detected a late radiation-induced local fibrosis using CT imaging in most patients, in 2 patients we observed grade 3 pneumonitis, 1 rib fractures and 1 patient developed RTOG 4 radiation induced mielopathy at an interval of 30 months following CK/SRS treatment.

Conclusions: These preliminary results suggest that CyberKnife-based SRT is a feasible approach for primary lung cancer, offering excellent in-field tumor control and low toxicity profile. However more experience and a longer follow-up are necessary to determine the role of CK and to identify patients most likely to benefit from it.
Preliminary Results for Elderly Patients with Early Lung Cancer treated with CyberKnife®

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Presented by: Yongchun Song, MD

Objectives: To evaluate the toxicity and efficacy of CyberKnife® stereotactic radiotherapy in patients with early lung cancer aged over 70 years.

Methods: The data of 34 inoperable elderly patients with early lung cancer (20 with T1 and 14 with T2 tumors) from November 2006 to September 2010 were retrospectively reviewed. Among them, 18 were treated with the Synchrony® Respiratory Tracking System, which requires the implantation of 1-2 gold markers. The other 16 patients were treated with the X-sight® technology. A total dose of 45-60 Gy (median of 60 Gy) was delivered in 3-6 fractions.

Results: Complete response was achieved in 25 of the 34 patients (73.5%), and partial response was achieved in the other 9 (26.7%). At a median follow-up of 29 months, the primary tumor control rate was 97.1%. The one-, two-, and three-year disease-free survival rates were 85.3%, 81.6%, and 70%, respectively. The one-, two-, and three-year overall survival rates were 97.1%, 86.6%, and 80%, respectively. Slight fatigue was reported in 31 of the 34 patients (91.1%). Grades I and II radiation pneumonitis were observed in 15 of the 34 patients (44.1%). Grade III radiation pneumonitis was not observed. Pneumothorax requiring tube thoracostomy occurred in one patient (2.9%) following CT-guided fiducial placement.

Conclusions: CyberKnife® stereotactic radiotherapy is an effective therapeutic modality for elderly patients with early lung cancer. This therapy can provide a high local-control rate for primary tumors and has minimal toxicity.
Hypofractionated Stereotactic Body Radiotherapy for Organ Confined Prostate Cancer

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Presented by: Giancarlo Beltramo, MD

Objectives: Recent technological developments, intensity modulation radiation therapy and improved target localization, combined with new hypothesis on prostate radiobiology have generated enthusiasm for hypofractionated regimens. We report our early preliminary experience with Cyberknife stereotactic radiotherapy in patients with clinically localized prostate cancer.

Methods: Between July 2007 and October 2011, 107 patients with a median age of 75 years (range 60 – 86), with T1c – T2 b prostate cancer were treated with Cyberknife stereotactic radiosurgery as primary therapy at our institution. The majority of patients 59 (55%) had low risk disease, 28 pts (26%) had intermediate risk and 19 pts (19%) were in high risk group disease. Pre-treatment PSAs ranged from 1.75 to 23.88 ng.ml (median 7.4 ng.ml). The treatment regimen consists of a total dose of 38 Gy delivered at 9.5 Gy per fraction, over 4 consecutive days, with > 95% of the PTV encompassed within the prescription isodose volume. Among the entire study cohort 7 of 19 high risks patients received androgen deprivation therapy (ADT), ADT was not administered to any low – intermediate risk group patients.

Three – four gold fiducial markers were placed in prostate gland by the treating urologist using transrectal ultrasound guidance, and to allow fiducials stabilization and resolution of swelling, prostate planning study was performed one week after fiducials implantation. Treatment planning was done with CAT scan fused with MRI. A planning target volume (PTV) margin expansion of 5 mm beyond the prostate gland in all directions was used, with the exception of posteriorly where 3 mm was performed. Patients were seen in follow up by the radiation oncologists or urologist 10 days post-treatment, 1 month later and every 3 months for 2 years with PSA levels assessed at each follow up. Self administered questionnaire, such as the International prostatic Symptom Score and the International Index of Erectile Function, was used to better define urinary function and sexual activities. Toxicity analyses was performed using the Radiation Therapy Oncology Group/European Organization for Research and Treatment of Cancer (RTOG-EORTC) acute and late radiation morbidity scoring system.

Results: Acute side effects were generally mild and resolved shortly after treatment. All patients were placed on A-blockade medication at the beginning of Cyberknife treatment. IPSS scores increased over the first month of treatment but return to baseline by four months. No rtog grade 4 acute or late rectal/urinary complications was observed. 3 patients developed late Grade 3 urinary late toxicity following repeated urological instrumentation, including cistoscopy and urethral dilatation. Four patients, one with prior Turp, experienced incontinence. One 9 months after Treatment, two 12 months after the treatment, one 27 months later. One patient experienced rectal incontinence 12 months after the treatment. The actuarial median follow up is 30 months (range 12 – 60 months) The patterns of PSA response, show a gradual decline with a PSA nadir below 1.0 ng.ml after 12 months. The four years actuarial PSA relapse free survival rate is 93.9% (CI: 88.0%-99.8%) To date 5 patients failed biochemically. One low risk patient revealed local relapse 30 months after Cyberknife treatment. One high risk group patient developed bone metastases, in 2 intermediate and in 1 high risk group we observed pelvic lymph node involvement.

All patients are alive except four that died of non prostate cancer related disease.

Conclusions: Early clinical results are encouraging and we conclude that Cyberknife robotic radiosurgery is a feasible and an emerging non invasive treatment approach to deliver Hypofractionated radiotherapy for localized prostate cancer. Additional follow up is required to see if this results are durable.
The Early Result of Stereotactic Body Radiotherapy Boost for High-risk Localized Prostate Cancer

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Presented by: Yu-Wei Lin, MD, MS

Objectives: Recent understanding of radiobiology for prostate cancer suggested hypofractionation may have therapeutic advantage. Whole pelvis irradiation combined with stereotactic body radiotherapy (SBRT) boost for high-risk prostate cancer might escalate biological effective doses while without increasing toxicity. Here, we reported our early results of SBRT boost for high-risk localized prostate cancer.

Methods: From October 2009 to February 2012, 36 patients of newly diagnosed, high-risk localized prostate cancer patients were treated with whole pelvis irradiation by RapidArc and SBRT boost by CyberKnife. The whole pelvis dose was 45Gy (25 fractions of 1.8Gy). The SBRT boost dose was 21 Gv (3 fractions of 7Gy). All of these patients received hormone therapy. The toxicities of gastrointestinal (GI) and genitourinary (GU) tracts were scored by Common Toxicity Criteria Adverse Effect (CTCAE v3.0). Patterns of prostate-specific antigen (PSA) response were analyzed. Biochemical failure was defined as Phoenix definition.

Results: The median follow-up was 24 months (range, 1-36 months). The mean PSA before the treatment was 38.83 ng/ml. Mean PSA level (excluded the data of biochemical failure) after 3, 6, 12, 18, and 24 months of the radiation treatment was 0.57, 0.22, 0.15, 0.15, and 0.07 ng/ml, respectively. One mortality case was caused by antiandrogen drug-induced hepatic failure. Three biochemical failures were observed. Two of these patients disclosed with bone metastasis. The third one showed no solid evidence of vital organ metastasis. The estimated 2-year biochemical failure-free survival was 90%. The profiles for acute toxicity of GI and GU tracts were minimal. 5% grade 2 GU toxicity and 0% grade 2 GI toxicity were observed at the two-year follow-up. There was no grade 3 GI or GU, or higher toxicity event. Three months after SBRT, most toxicity scores had returned to baseline.

Conclusions: Whole pelvis irradiation combined with SBRT boost for high-risk localized prostate cancer is feasible with minimal acute toxicity and biochemical failure-free survival. Continued accrual and follow-up would be necessary to confirm the biochemical control rate and the toxicity profiles.
Optimizing Radiosurgical Treatment Planning Using the Red Shell Concept

John Lamond, Jun Yang, Jing Feng, Nina Lavere, Rachelle Lanciano, Luther Brady

Philadelphia CyberKnife

Presented by: John Lamond, MD

Objectives: We wanted to compare radiosurgical treatment planning strategies that emphasized sharp dose fall-off against those that emphasized conformality and homogeneity.

Methods: In order to achieve a radiosurgical plan with the sharpest dose fall-off, there is commonly an increase in dose heterogeneity within the target and some loss of conformality, particularly in an irregular target. We compared a variety of treatment plans using the Cyberknife treatment planning system using three clinical scenarios. In the first, the target was surrounded by normal tissue in a parallel organ alone, as commonly seen in peripheral lung cancers or liver tumors. Second, the target was surrounded by both parallel and serial organs, as seen in central lung cancers and spinal metastases. Third, the tumor had a normal structure within it, such as in prostate cancer. Radiosurgical doses used were common for the clinical scenario, at least 100 Gy10 except the palliative spinal cord case (where a dose of 8 Gy x 3 was used), and for prostate cancer (where a dose of 7.25 Gy x 5 was used). The zone of normal tissue toxicity, or Red Shell, was defined as the equivalent dose or greater than 60 Gy in 2 Gy per fraction for serial organs and 20 Gy in 2 Gy per fraction for parallel organs.

Results: In most scenarios, the plan that optimized for the sharpest dose fall-off had the smaller Red Shell, at the expense of slightly less conformity. With the Cyberknife treatment planning system, sharper dose fall-off was more easily accomplished by using an isocentric planning technique. Conformal planning technique was more useful for irregularly shaped targets and when serial organs are very near or within the PTV, such as prostate cancer or spinal metastasis.

Conclusions: More heterogeneous, slightly less conformal plans with sharper dose fall-off appeared to offer the best chance of tumor ablation while minimizing the risk of side effects in the majority of tested scenarios. The Red Shell concept may help provide a framework to help choose an optimal radiosurgical plan.
Evaluation of Extra Absorbed Dose Generated by Image Guided System of CyberKnife

Yang Dong, Feng-tong Li, Jing-sheng Wang, Zhi-yong Yuan, Yong-chun Song, Hong-qing Zhuang

Presented by: Yang Dong, MS

Objectives: To evaluate quantitatively the extra absorbed dose generated by image guided system of CyberKnife.

Methods: The exposure parameters and the average frequency of images acquisition during the treatments with G3 CyberKnife in 300 cases with various tumor locations and tracking modes were collected for analysis. The measurements of the absorbed doses in the phantom with 5 points after single exposure generated by image guided system in various exposure parameters were performed with equipment of phantom CIRS Model 002LFC and ion chamber PTW30010 included. Based on the data we collected and measured, the conclusion of how much extra absorbed dose generated by image guided system of CyberKnife the patients received during CyberKnife treatments was drawn.

Results: With an average fractions of 3.94 (the median was 4), the average exposure frequency was 36.5 times for static tracking per patient per fraction, while it was 49.2 times for dynamic tracking. The experimental results with various exposure parameters, positions and tissue densities showed that the minimum absorbed dose after single exposure was 0.5µGy, while the maximum was 385µGy.

Conclusions: Based on the results and the clinical data collected, it could be evaluated that the max absorbed dose generated by image guided system of CyberKnife in common practice with the mean fractions was 7.463cGy, which meant the 0.18% of the mean prescribed dose.
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This program has been supported in part by the following:

DIAMOND
- Varian Medical Systems

PLATINUM
- Accuray

SILVER
- Elekta

COPPER
- Kuka
- ViewRay

QUARTZ
- Brainlab
- Siemens