New Technologies in Modern Radiotherapy

Cheng B Saw, Ph.D.
Chair, Asian-Oceanic Affairs of AAPM
Director - Physics, Northeast Radiation Oncology Centers
President, CBSaw Publishing, LLC
Harrisburg, PA, USA

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/
Perspective I

- Radiotherapy is a technologically driven medical specialty
- Technology has transformed the practice of radiotherapy

- Modern Radiotherapy is here to STAY !!
Perspective II

- **What is Modern Radiotherapy?**
  - We no longer use mechanical methods of deriving patient contours !!
  - We no longer use manual methods of creating isodose distributions !!

International Workshop: New Technologies in Modern Radiotherapy, Chulabhorn Hospital, Bangkok, Thailand, August 22th – 25th, 2012
Perspective III

- **When did Modern Radiotherapy started?**
- In what ways have technology transformed the practice of modern radiotherapy?
- **How fast is the technology moving?**
- **Are we keeping pace (QA and patient safety)?**

---

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/

International Workshop: New Technologies in Modern Radiotherapy, Chulabhorn Hospital, Bangkok, Thailand, August 22th – 25th, 2012
Perspective IV

Treatment of Spine:
No longer – PA field
Perspective V

Treatment of Head & Neck:
No longer – bilateral fields
Perspective VI

Treatment of Prostate:
No longer – box fields
Time Outline I

- (3D-TPS) – Modern Radiotherapy
- CRT/ IMRT/ IGRT
- SBRT
- Adaptive & Particle Therapy
Historical Perspectives I

When Modern Radiotherapy Started?
- Introduction of 3D Treatment Planning System
- [Early 1980 – NCI Sponsored Projects]

Chapter 1
3-D Radiation Treatment Planning: NCI Perspective

Sandra Zink, Ph.D.

In recognition of the importance of 3-D treatment planning in radiation therapy and the promise of improved technological capabilities, the National Cancer Institute (NCI) launched a series of research initiatives in the early 1980s to evaluate the potential of 3-D treatment planning and to make recommendations to the NCI for future research. Five Collaborative Working Groups (CWGs) were funded between 1982 and 1994 to focus on 3-D treatment planning and interstitial brachytherapy (see Table 1). Several reports as well as a special issue of the International Journal of Radiation Oncology and Physics and a textbook resulted from these efforts (see following section). In addition to documenting the results of their treatment planning evaluations, the reports contained recommendations for future research and consensus guidelines for the radiation therapy research community.
Historical Perspectives II

[When?] – 3D Treatment Planning System

- TPS manufacturers became involved in early 1990
- By 1996, FDA cleared both MIMiC and CORVUS
- Image-based 3D TPS
Historical Perspectives III

[Why?] – Imaged-Based 3D TPS

- Exquisite Patient Anatomy
- Preserved Spatial Relationship between Patient Anatomy and Target Volume
- Allow for Precise Targeting
Historical Perspectives IV

[Why?] – 3D Treatment Planning System

- Many ways of deriving Target Volume Information
  - Anatomy
  - Biokinetic
  - Chemical
Historical Perspectives V

[Why?] – 3D-TPS
- Precise Targeting
- CORVUS

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/

August 22th – 25th, 2012
Historical Perspectives VI

[Other Advantages?] – 3D Treatment Planning System
- Auto extraction of patient body contour
- Tissue heterogeneity correction
- 3D volume calculations
- Inclusion of biological information through image fusion

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/
Historical Perspectives VII

[Implement?] – 3D Treatment Planning System

- Conformal radiation therapy (CRT)
- Intensity modulated radiation therapy (IMRT)

Time Line: 2001

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/
Historical Perspectives VIII

Treatment technique - CRT
- Target volume delineation
- BEV must show that the MLC shape conforms to the projection of the target
Historical Perspectives IX

Treatment technique - IMRT
- Target volume delineation
- MLC shape may not conforms to the target projection
- fluence modulation

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/
Historical Perspectives X

IGRT (Aspect 1)
- target definition thru image fusion

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/

Enterprise-wide 3D can deliver value in a wide variety of clinical situations. Image courtesy of Carestream Health.
Historical Perspectives XI

IGRT (Aspect 2)
- CRT and IMRT require precise targeting
- What is precise targeting?
  More precise setup
  More precise positioning
  More precise localization
Historical Perspectives XII

IGRT (Target localization)
- On-board imager
- In-room system
- CT-on-rail
- Ultrasound system
- ....

IGRT Technologies

Ultrasound

kV Radiographic

Portal Imaging

Siemens PRIMATOM™

TomoTherapy Hi-Art™

Elekta Synergy™

Varian OBI™

Siemens Artiste™

kV CT

MV CT

kV and MV Cone-beam CT
Historical Perspectives XIII

IGRT (Patient Setup)
- On-board localization using fiducial markers on linac
Historical Perspectives XIV

IGRT (Target Localization)

- MVCT localization on the Tomotherapy

http://sites.google.com/site/cbsaw2009/
Historical Perspectives XV

IGRT (Patient Motion)
- Vision RT for managing patient motion
Historical Perspectives XVI

Motion Management
- Motion tracking

Increase Treatment Time by $\times 3.4$ (30% Duty Cycle)

- Inspiration: 1.0 Sec.
- Expiration: 2.5 Sec.
- Breathing Period: 3.5 Sec.
- Mean Interval: 30% - 75%

INHALE
Gated Motion: 10 min
EXHALE
Beam Enable
Beam Hold

Seconds

August 22$^{\text{nd}}$ – 25$^{\text{th}}$, 2012

http://sites.google.com/site/cbsaw2009/
Historical Perspectives XVII

Time Line:

- 2001 IMRT (3 volumes)
- 2006 IGRT (4 volumes)
SBRT I

Trends in Imaging & Oncology (Dec 2010)
- SBRT is a new and growing treatment technique

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/
TECHNOLOGICAL ADVANCES CONTINUE

Radiation Oncology

Facilities must balance patient benefits with available financial resources.

By R. Scott Krewson, CPA, MBA

Additional treatments. Additionally, what about patient safety when utilizing new technologies? Patient safety issues and trends to ensure safety through compliance were raised during 2010 and are important considerations.

SBRT

Much information was generated this year regarding stereotactic body radiation therapy (SBRT)—an emerging form of image guidance-based radiotherapy treatment that delivers a high dose of radiation to the target, using either a single fraction or a small number of fractions with a high degree of precision within the body. With favorable outcomes, this treatment has attracted the attention of many physicians, and patients are becoming increasingly educated regarding SBRT as a treatment option.
An 87-year-old male with a cutaneous melanoma of the left ear with a single metastasis in the upper lobe of the right lung, treated with 50 Gy in five fractions to the lung metastasis. *images/courtesy Cheng B. Saw, PhD, and Heath Mackley, MD, of Penn State Hershey Cancer Institute*
SBRT IV

- SBRT is an extension or evolution from SRS (stereotactic radiosurgery)
- High dose in few fractions, extra care is demanded when performing SBRT just like SRS

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/
RAPID COMMUNICATION

ACUTE SKIN TOXICITY FOLLOWING STEREOTACTIC BODY RADIATION THERAPY FOR STAGE I NON–SMALL-CELL LUNG CANCER: WHO’S AT RISK?

Bradford S. Hoppe, M.D.,* Benjamin Laser, M.D.,* Alex V. Kowalski, B.A.,† Sandra C. Fontenla, B.A.,† Elizabeth Pena-Greenberg, R.N.,* Ellen D. Yurke, Ph.D.,† D. Michael Lovelock, Ph.D.,† Margie A. Hunt, M.S.,† and Kenneth E. Rosenzweig, M.D.*

*Departments of Radiation Oncology and †Medical Physics, Memorial Sloan-Kettering Cancer Center, New York, NY.

Why EXTRA-ORDINARY CARE is needed?

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/
What is wrong with this SBRT Plan?

Conventional RT
- Keep the dose delivery simple to avoid mistakes
- Use few fields
From: B. Kavanagh - AAPM Presentation

Radiation toxicity
- SBRT
- hypofractionation
- poor treatment planning

Phase II Results, Toxicity
No RILD, no Gr 4-5 toxicity of any kind
1 case of grade III soft tissue toxicity

Insufficient number of fields

Photo taken 8 mos after SBRT
At last followup 17 post-SBRT lesion controlled.
Necrosis is slowly healing.
SBRT VIII

From: R. Timmerman – AAPM Presentation

SBRT IX

Advances In Technology Per Varian Centerline Oct 07
- Speed
- Precision

RapidArc
The Next Dimension in Speed and Precision

Paperless Medical Records: Two New Cancer Centers Rely on ARIA

Treating Challenging Cases at Stanford University Cancer Center

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw
SBRT X
A Phase II Trial of Stereotactic Body Radiation Therapy (SBRT) in the Treatment of Patients with Medically Inoperable Stage I/II Non-Small Cell Lung Cancer

RTOG 0618

A Phase II Trial of Stereotactic Body Radiation Therapy (SBRT) in the Treatment of Patients with Operable Stage I/II Non-Small Cell Lung Cancer

RTOG 0813

Seamless Phase I/II Study of Stereotactic Lung Radiotherapy (SBRT) for Early Stage, Centrally Located, Non-Small Cell Lung Cancer (NSCLC) in Medically Inoperable Patients

RTOG 0915

A Randomized Phase II Study Comparing 2 Stereotactic Body Radiation Therapy (SBRT) Schedules for Medically Inoperable Patients with Stage I Peripheral Non-Small Cell Lung Cancer

SCHEMA

<table>
<thead>
<tr>
<th>S</th>
<th>T</th>
<th>Zubrod Performance Status</th>
<th>R</th>
<th>Stereotactic Body Radiation Therapy (SBRT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>1.0</td>
<td>Arm 1: 34 Gy in 1 fraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>2.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>3.2</td>
<td>Arm 2: 48 Gy in 4 once-daily consecutive fractions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>T Stage</td>
<td>I</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Clinical Practice Guidelines for SBRT

AAPM and ASTRO/ACR provide important consensus reports. By Cheng B. Saw, PhD, and Henry Wagner, MD

consistent documentation for prescribing, reporting, and recording SBRT treatment delivery.

Imaging's objective during SBRT simulation using CT or other imaging modalities is to provide clear visualization of patient anatomy as that anatomy appears during patient setup and throughout the treatment. SBRT simulation should be performed with the patient in the treatment position. Various immobilization devices that can support the static patient position are commercially available. SBRT shouldn't be performed on targets that can't be localized due to motion or artifacts, according to the AAPM report. Treatment planning allows the design of individualized treatment plans that optimize dose delivery to the target.

Recommendations are provided on dose heterogeneity, gradient and fall-off, beam selection and beam geometry, calculation grid size for treatment planning, and normal tissue tolerance. Data on normal dose tolerance are still limited. Image guidance localization, which provides the finest level of localization to reduce spatial uncertainty in target positioning, is critical to SBRT. The AAPM report also discusses various image-guidance techniques.

On the other hand, the ASTRO/ACR publication—also released in 2010—concentrates primarily on the qualification, credentialing, professional relationship, and development of the resources associated with...
Stereotactic body radiation therapy: The report of AAPM Task Group 101

Stanley H. Benedict, Chairman\textsuperscript{a)}
\textit{University of Virginia Health System, Charlottesville, Virginia 22908}

Kamil M. Yenice, Co-Chairman
\textit{University of Chicago, Chicago, Illinois 60637}

David Followill
\textit{University of Texas MD Anderson Cancer Center, Houston, Texas 77030}

James M. Galvin
\textit{Thomas Jefferson University Hospital, Philadelphia, Pennsylvania 19107}

William Hinson

\textbf{Med Phys 37: 4078 –4101 (2010)}

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/
REPORT

AMERICAN SOCIETY FOR THERAPEUTIC RADIOLOGY AND ONCOLOGY (ASTRO) AND AMERICAN COLLEGE OF RADIOLOGY (ACR) PRACTICE GUIDELINE FOR THE PERFORMANCE OF STEREOTACTIC BODY RADIATION THERAPY


*Department of Radiation Medicine, Long Island Jewish Medical Center, New Hyde Park, New York; †Department of Radiation Oncology, University of Colorado, Denver, Aurora, Colorado; ‡Department of Radiation Oncology, Thomas Jefferson University, Philadelphia, Pennsylvania; §Methodist Cancer Center, San Antonio, Texas; ¶Department of Radiation Oncology, MD Anderson Cancer Center, Houston, Texas; **Department of Radiation Oncology, Mayo Clinic, Rochester, Minnesota; ‖Department of Radiation Medicine, Memorial Sloan-Kettering Cancer Center, New York, New York; ‡‡Department of Radiation Medicine, Lankenau Medical Center, Wynnewood, Pennsylvania; §§Department of Radiation Oncology, University of Wisconsin, Madison, Wisconsin; ¶¶Department of Radiation Oncology, University of Florida, Jacksonville, Florida; ††Department of Radiation Medicine, University Hospitals Case Medical Center, Cleveland, Ohio; †††Department of Radiation Oncology, Albany Medical College, Albany, New York.
Heavy Particle I

Thailand Workshops
2002 – 70 participants
2004 – 57
2007 – 140
2012 – >200

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/

International Workshop: New Technologies in Modern Radiotherapy, Chulabhorn Hospital, Bangkok, Thailand, August 22th – 25th, 2012
Last Slide

Thank You for your participation

If you need chamber cables, physics instruments, contact me: cbsaw2003@yahoo.com

cbsaw2003@yahoo.com
http://sites.google.com/site/cbsaw2009/