3D-CRT, IMRT, IGRT, BIGART – the continuing Saga –
In Tribute to Steven Leibel, M.D.

C Clifton Ling
Varian Medical Systems
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Steven Leibel, M.D.
1947-2008
Clinical Innovator
Compassionate Physician
Gifted Teacher

THE BIOLOGICAL BASIS FOR CONFORMAL THREE-DIMENSIONAL
RADIATION THERAPY

IJROBP 1991

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Urology 2008

Improved LC decreases mets & increases survival rate

Clinac 2100C circa - 1989

6-Field 3D-CRT

Dose-escalation, limited by rectal NTCP*

New method needed for dose ≥ 81 Gy

*Emami et al (1991)
What a loss in many ways! I have had multiple great teachers & mentors, but Steve Leibel was my favorite attending MD when I was a resident. I think of him as having been the single most important person in teaching me about radiotherapy.

Comment by: Penny Sneed, UC San Francisco

Steve was a fantastic physician, a terrific teacher and a joy to work with,... fondly remember many hours spent in front of a computer discussing his patients' treatments or the latest research project..... an invigorating mix of teaching and brainstorming with some fun thrown in on ... it was impossible to end the session without a renewed sense of purpose and inspiration. His care for his patients, his interest in physics and its role in radiation oncology, his humility and wonderful sense of humor impressed us all deeply and will not be forgotten.

Comment by: Margie Hunt, MSKCC, NY
Trilogy
MLC
Respiratory
On-Board Imager
 Portal Imager

A Plethora of Image-Guidance Offerings
Bewildering Array of IGRT Technologies

Ultrasound
Fluoroscopic Tracking
Portal Imaging
Markers

Ultrasound
Fluoroscopic Tracking
Portal Imaging
Markers

Siemens PRIMA TAM
TomoTherapy HI-ART™
Elekta Synergy
Varian OBI™

MV CT
MV CT

“Add-on” IGRT Systems
E.g. RealEye, Calypso, AlignRT

Control console
Clinac 2100C
Circa - 2009
Circa - 1989

Ear 1 with CRT and CRT
Ear 2 with CRT and CRT

“Add on” IGRT Systems
E.g. RealEye, Calypso, AlignRT

Control console
Clinac 2100C
Circa - 2009
Circa - 1989
Vetting
• What, when and how?
• Clinical outcome data?
• Reliance on surrogates, e.g.
  - Set-up error reduction
  - Organ motion compensation
• Other factors, e.g. ease-of-use

Integration

Major Challenge

Integration
• Direct / Indirect
• Efficiency / Workflow Streamlining
• Data transfer / Error reduction
• Automated QA procedures
• Tx Planning and Treatment Delivery
**TrueBeam: Console**

- **Old**
  - 1 screen from s/w standpoint
  - Integrate Treat, OSS, Clinac, optical motion management

- **New**

**Examples of research using the TB**

**CHOREOGRAPHING COUCHANT COLLIMATOR IN VOLUMETRIC MODULATED ARC THERAPY**

Yihui Yang, PhD, " Peng Zhan, PhD, " Linda Hooshfigh, MS, " Joanne Xiong, MS, " Je Yang, PhD, " Mark Chan, PhD, " Kathryn Beal, M.D., " Guobing Xu, PhD, " and Marcie Hens, M.S. 

Department of "Medical Physics and Radiology Oncology, Memorial Sloan-Kettering Cancer Center, New York, NY

**Combining the concepts of:**
- River of desire (McShan, Kessler, Fraass 95)
- Combined dynamic gantry/couch movement in SRS (Podgorsak et al 1988)
- VMAT/RapidArc (Yu, Otto ……..)

**Supervisor – a key to true integration**

- "Brain" of TrueBeam: control all nodes based on Tx/Image Design
- Data communication based on a 10 milli-sec cycle (i.e. machine status information, Treatment Console and In-Room Monitors, etc)
- Coordinates Image acquisition and dose delivery
Target/OAR Overlap – $F(\theta_g, \theta_c)$

$$\text{CA} = 0; \quad \text{GA} = -60$$

$$\text{CA} = 45; \quad \text{GA} = 100$$

$$\text{CA} = 85; \quad \text{GA} = 60$$

Optimum RapidArc (Couch/Gantry) Trajectory

RapidArc
- 177 MV Control Points

MV Control Pt
MV + kV Control Pts

RapidArc / CBCT
- Divide each CP into two
- One for MV RA delivery
- One for kV CBCT (without MV)
- MV scatter-free projections used for CBCT reconstruction
CBCTs acquired during a prostate VMAT

- ~2.5 min for 2 Gy RA Tx with CBCT (can be improved)
- MV-scatter free CBCT / RapidArc: proof of concept

**Biology Optimization**

difficult to extremely difficult

*Two Classes of Biol. Optimiz.* (status in yellow)

- **Population-averaged** (gradually / carefully used)
  - Outcome data based models, e.g. NTCP
- **Patient-specific** (experimental, validation needed)
  - Predictive assays, biol. images, gene chip data

**Clinical NTCP estimates** 1991 – recently

“Evaluation of treatment planning for external beam radiation therapy”
Emami et al - Int J Radiat Oncol Biol Phys, Vol 21 #1

At that time

- CT simulation: rare
- 3D CRT: new frontier
- DVHs: a new tool
- IMRT: theoretical
"Emami" update
QUANTEC
Quantitative Analysis of Normal Tissue Effects in Clinic
IJROBP Vol 76

Biological Target Volume?

CT
GTV
Target volume
Tumor cell density
Hypoxia

• FDG

Tumor growth
Biological Eye View
Radiobiological treatment plan

• IUDR


From Ellen Yorke

Physical Conformality
Biological Conformality
Evidence-Based Multi-Dimensional Conformal Therapy

Radiation Therapy 2010?

Closing session: The future of IGRT
Cost-benefit analysis of IGRT
Michael Baumann, Dresden, Germany

IGRT – What’s next?
Clifton Ling, New York, USA

From M Kessler
Improving the 6 Ds of image-guidance

• Detection / diagnosis / staging
• Delineation of target
• Determining biological attributes
• Dose planning / delivery
• Delivery assurance - IGRTD
• Deciphering treatment response

Multi-Sensor Data Fusion

Combined CT/PET - MRI/PET

From M Kessler

Molecular and functional imaging

What does the information represent?
- Markers of specific features
- Surrogate markers

From Daisne J et al. Radiology 233:99-100, 2004

BIGART 2010 Conference Summary – D Olson

From Dag Olson – 2010 BIGART
Tumour biological features

- Hypoxia...again!
- Proliferation
- Repair
- Cellular RT sensitivity
- Vasculature
- ...

must be able to quantify the impact!

Sovik et al. IJROBP, 73:650-658, 2009

Normal tissue functional imaging

- Guide dose delivery avoiding critical parts of healthy organs
- How does the image information translate into information about:
  - organ function
  - adverse clinical effects

Shioyama et al. IJROBP 68:1349-1358, 2007

Thank you for your attention!