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

C Clifton Ling

Varian Medical Systems

Memorial Sloan Kettering Cancer Center

Steven Leibel, M.D.
1947-2008

Clinical Innovator

Compassionate Physician

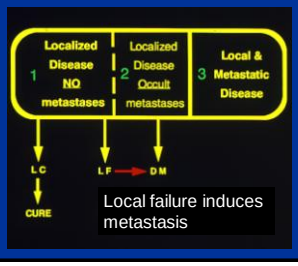
Gifted Teacher

THE BIOLOGICAL BASIS FOR CONFORMAL THREE-DIMENSIONAL RADIATION THERAPY

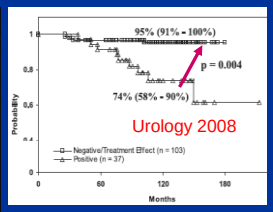
IJROBP 1991

STEVEN A. LEIBEL, M.D.,* C. CLIFTON LING, PH.D.,† GERALD J. KUTCHER, PH.D.,† RADHE MOHAN, PH.D.,† CARLOS CORDON-CORDO, M.D., PH.D.‡ AND ZVI FUKS, M.D.*

Departments of Radiation Oncology,* Medical Physics,† and Pathology,‡ Memorial Sloan-Kettering Cancer Center, 1275 York Ave., New York, New York, 10021



Local failure induces metastasis



Improved LC decreases mets & increases survival rate

Clinac 2100C circa - 1989

6-Field 3D-CRT

Dose-escalation, limited by rectal NTCP*

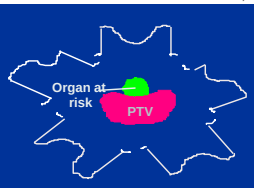
New method needed for dose ≥ 81 Gy

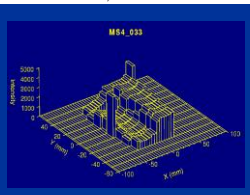
*Emami et al (1991)

CONFORMAL RADIATION TREATMENT OF PROSTATE CANCER USING INVERSELY-PLANNED INTENSITY-MODULATED PHOTON BEAMS PRODUCED WITH DYNAMIC MULTILEAF COLLIMATION

IJROBP 1996

C. CLIFTON LING, PH.D., CHANDRA BURMAN, PH.D., CHEN S. CHUI, PH.D., GERALD J. KUTCHER, PH.D., STEPHEN A. LEIBEL, M.D., THOMAS LOSASSO, PH.D., RADHE MOHAN, PH.D., THOMAS BORTFELD, PH.D.,* LARRY REINSTEIN, PH.D.,† SPIRIDON SPIROU, PH.D., X. H. WANG, PH.D., QIUWEN WU, PH.D., MICHAEL ZELEFSKY, M.D. AND ZVI FUKS, M.D.





Permitted dose escalation to 86 Gy

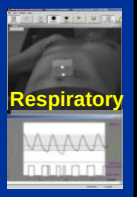
I was a patient at mskcc in 1997 who benefited from his pionnering work in radiation treatment for prostate cancer for which I have been eternally grateful.My thoughts and prayers are with his family and his colleagues
Comment by: Robert Young bIRMINGHAM, at February 10, 2008 01:08 PM

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

Clinac 2100C
circa - 1989

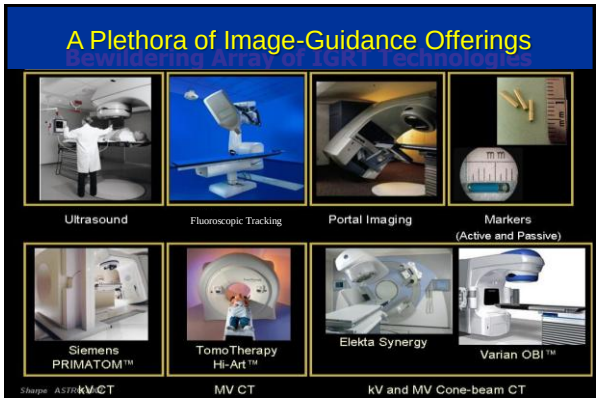
MLC



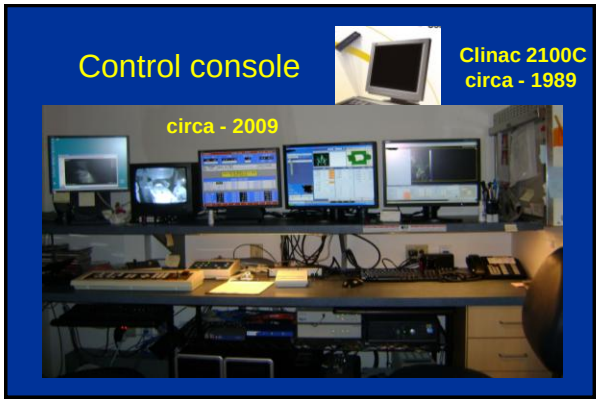
Respiratory

Portal Imager


MLC
Trilogy
Respiratory
Portal Imager
On-Board Imager


A Plethora of Image-Guidance Offerings
Bewildering Array of IGRT Technologies
Ultrasound
Fluoroscopic Tracking
Portal Imaging
Markers
(Active and Passive)
Siemens
PRIMATOM™
TomoTherapy
Hi-Art™
Elekta Synergy
Varian OBI™
kV CT
MV CT
kV and MV Cone-beam CT


"Add-on" IGRT Systems
e.g. RealEye
Calypso
AlignRT
Each with CPU and CRT


Control console
Clinac 2100C
circa - 1989
circa - 2009

Major Challenge

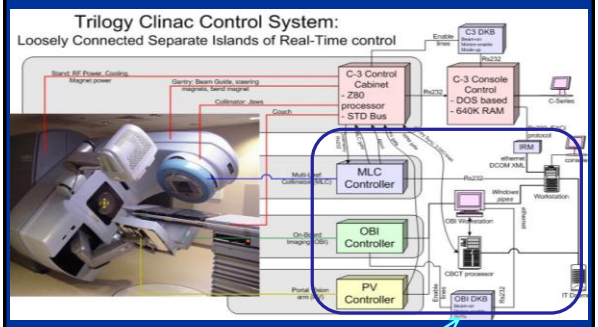
Vetting

- 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

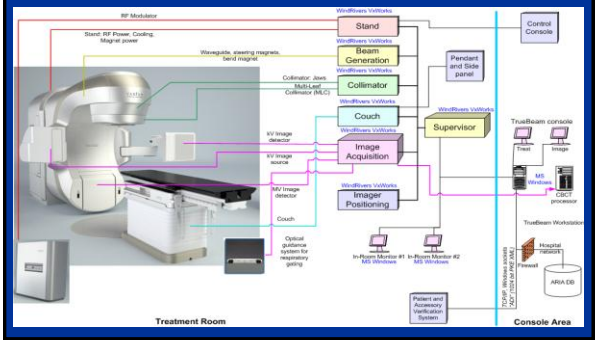
Integration

- Direct / Indirect
- Efficiency / Workflow Streamlining
- Data transfer / Error reduction
- Automated QA procedures
- Tx Planning and Treatment Delivery



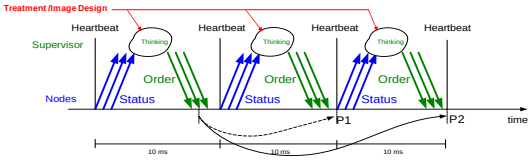
Devices added to the "C-series" Linac

TrueBeam™
Heart of TrueBeam—The Control System



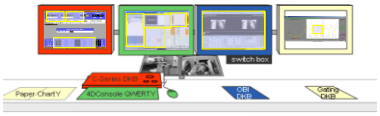
Supervisor – a key to true integration

- "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

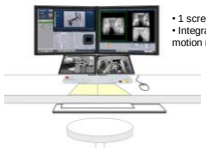


TrueBeam: Console

Old



New



- 1 screen from s/w standpoint
- Integrates Treat, OBI, Clinac, optical motion management

Examples of research using the TB

PHYSICS CONTRIBUTION

CHOREOGRAPHING COUCH AND COLLIMATOR IN VOLUMETRIC MODULATED ARC THERAPY

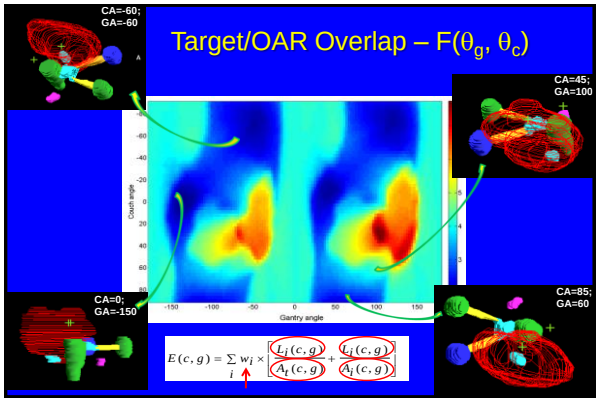
IJROBP 7/15/11

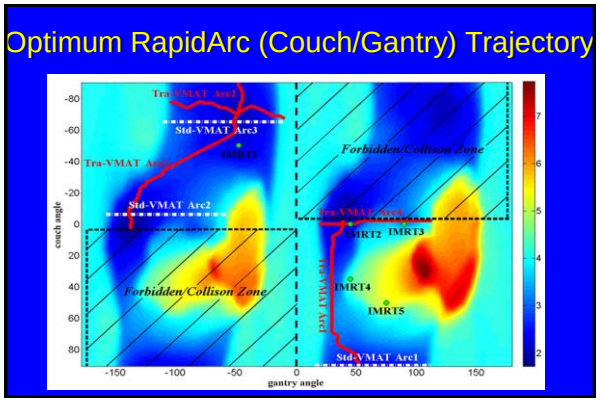
YINGLI YANG, PH.D.,* PENGPENG ZHANG, PH.D.,* LAURA HAPPERSETT, M.S.,* JIANPING XIONG, M.S.,* JIE YANG, PH.D.,* MARIA CHAN, PH.D.,* KATHRYN BEAL, M.D.,† GIG MAGERAS, PH.D.,* AND MARGIE HUNT, M.S.*

Departments of *Medical Physics and †Radiation 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 ……)





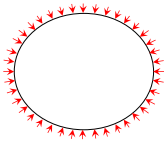
Joint Imaging-Therapy Scientific Session - Cone-Beam CT

Monday	2:00:00 PM - 3:50:00 PM	Room: Ballroom C

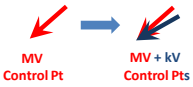
MO-D-BRC-3	**Concomitant RapidArc® and Acquisition of KV-CBCT with Minimal MV Scatter**
Byline	C Ling[12], P Zhang[1]*, M Sun[2], M Hunt[1], (1) Memorial Sloan Kettering Cancer Center, New York, NY, (2) Variann Medical System, Palo Alto, CA

In press – Green Journal

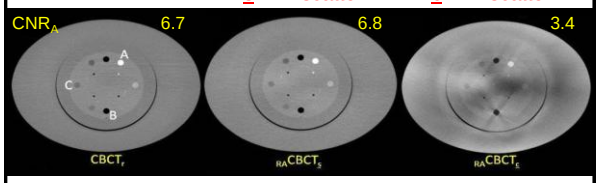
RapidArc
- 177 MV Control Points



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



Reference CBCT | CBCT / RapidArc s MV scatter | CBCT / RapidArc c MV scatter



- 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

Biological Optimization
difficult to extremely difficult

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

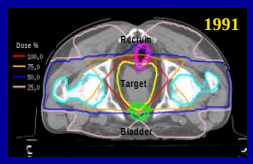
- **Population-averaged** (gradually / carefully used)
  Outcome data based models, e.g. NTCP
- **Patient-specific** (experimental, validation needed)
  Predictive assays, biol. images, gene chip data

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**



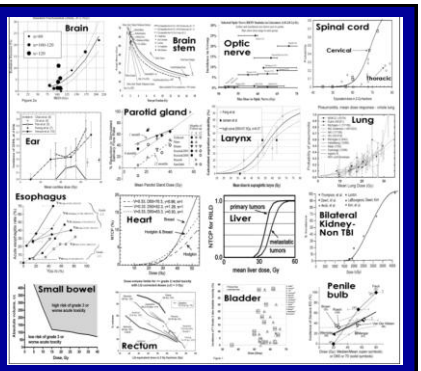
From Ellen Yorke

'Emami" update

QUANTEC

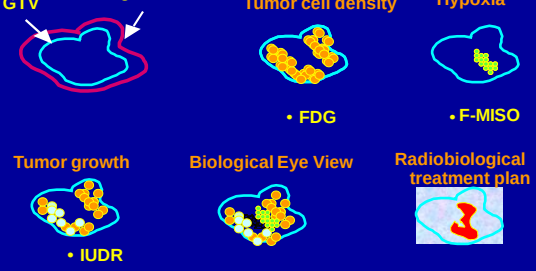
Quantitative
Analysis of
Normal **T**issue
Effects in **C**linic

IJROBP Vol 76



From Ellen Yorke

Biological Target Volume?



Towards multidimensional radiotherapy: biological imaging and conformality. Int J Radiat Oncol Biol Phys. 2000.

Physical Conformality

Biological Conformality

Evidence-Based Multi-Dimensional Conformal Therapy

Radiation Therapy 2010?

Image-Guided and Adaptive Radiotherapy - Aarhus, June 5-7, 2008

Closing session: The future of IGRT

Cost-benefit analysis of IGRT
Michael Baumann, Dresden, Germany

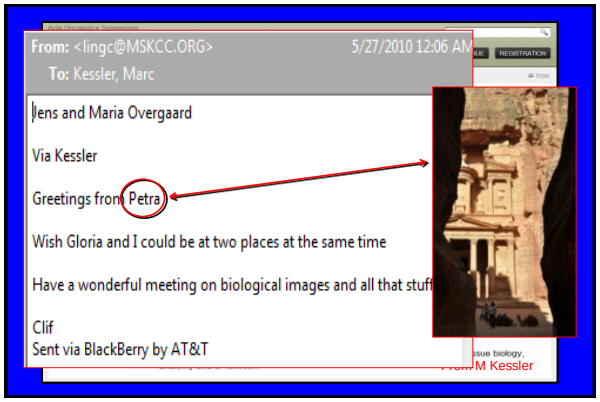
IGRT – What's next?
Clifton Ling, New York, USA

• Adaptation of dose delivery based on anatomic changes, etc

From M Kessler

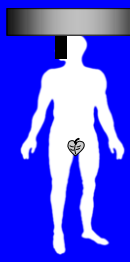
Improving the 6 Ds of image-guidance

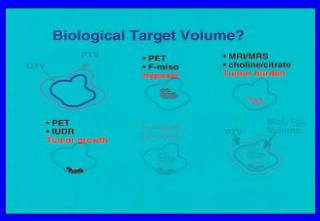
- Detection / diagnosis / staging
- Delineation of target
- Determining biological attributes
- Dose planning / delivery
- Delivery assurance - IGRTD
- Deciphering treatment response



From M Kessler

Multi-Sensor Data Fusion



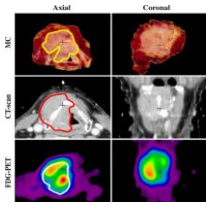


Combined CT/PET - MRI/PET

From M Kessler

BIGART 2010 Conference Summary – D Olson

Molecular and functional imaging



Daisne J et al. Radiology 233:93-100, 2004

What does the information represent ?

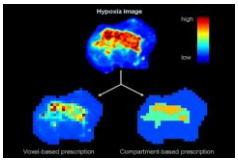
- Markers of specific features
- Surrogate markers

Validation !

From Dag Olson – 2010 BIGART

BIGART 2010 Conference Summary – D Olson

Tumour biological features



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

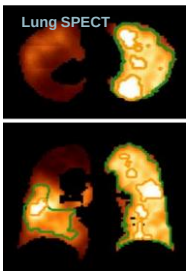
- Hypoxia…again !
- Proliferation
- Repair
- Cellular RT sensitivity
- Vasculature
- …

⇩

must be able to quantify the impact!

From Dag Olson – 2010 BIGART

BIGART 2010 Conference Summary – D Olson



Shioyama et al
IJROBP 68:1349-1358, 2007

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

From Dag Olson – 2010 BIGART

Acta Oncologica, 2010; 49: 884–887 informa

EDITORIAL

Biology-guided adaptive radiation therapy – presence or future?

CAI GRAU[1], DAG RUNE OLSEN[2], JENS OVERGAARD[3], MORTEN HØYER[1], JACOB CHRISTIAN LINDEGAARD[1] & LUDVIG PAUL MUREN[1,4]

The very concept of biology-guided adaptive radiation therapy rely on a number of critical components; for some a rather robust empirical support is now emerging, for others the empirical basis is yet to be established. It is therefore more than relevant to quote author William Gibson: "The future is here. It's just not evenly distributed yet." [42].

Thank you for your attention!