An Overview of Emerging Technologies in Radiation Oncology

Craig McKenzie, CMD
Director Medical Dosimetry

Intro

Good afternoon and thank you for the opportunity to share with you at this year’s meeting

I would like to Thank Christopher J Moore for sharing about his personal experience receiving RT

I appreciate how he sought out specific professionals based upon the care he needed. From the surgeon who saved his leg from possible amputation because of his expertise. To selecting the RT center with the better equipment.

And the wisdom to not make tweaks to his own plan that he knew were insignificant
Disclaimers

I have no disclosures with this presentation

Intro

Today I’d like to invite you into the Miami Cancer Institute to explain our concept of Multi-Technology RT

MTRT is the use of any and all RT delivery systems to provide a tailored course of treatment using the techniques best suited for the individual patient’s needs

This can be from…
Tumor size and location
Fractionation schema based on pathology
Underlying conditions such as ability to hold breath or not move
Prior treatments or other health conditions
Severe claustrophobia
Personal Message

The important thing here is… Whichever equipment you have, I’m sure you are doing your best to get the most out of it’s benefits. This is Good!!!

This presentation touches the adage that when you only have a hammer everything looks, and possibly get’s treated, like a nail.

Miami Cancer Institute

An entire “tool box” to skillfully use according to their unique properties. Our goal is customized delivery for each patient’s unique circumstances.

Varian® True Beam™, CyberKnife® M6™, Radixact™, Gamma Knife® Icon™, Viewray® MRidian™, Linac, Brachytherapy & HDR, Proton Therapy - PBS.
MCI RadOnc Leadership

Minesh Mehta, MD
Alonso Gutierrez, PhD, MBA

Miami Cancer Institute

Miami metro area, gateway to Central and South America And beyond

Baptist Health South Florida (Non-profit) (Faith based)

Physics/Dosimetry Team

Miami Cancer Institute
BAPTIST HEALTH SOUTH FLORIDA
**Easy transportation between rooms**

Photon Hallway

**Miami Cancer Institute**

- MCI is one of only a few cancer treatment centers in the world to provide every available radiation therapy technology in one location. Dedicated to using all technologies to the fullest extent in compliment with one another.

VMAT
Whole Ventricle
18Gy

Proton - PBS
Pineal Boost
12Gy

Composite
30Gy
## Miami Cancer Institute

- Multidisciplinary patient care, Cutting-edge technology and Innovative cancer treatments
- Genomic Medicine Laboratory complimenting diagnosis, uniquely customized targeted therapy, clinical trials and research
- Dedicated Pediatric support services with a Children’s Infusionarium designed by a Imagineer
- International outreach for clinical education and collaboration
- Alliance with Memorial Sloan Kettering
- Gourmet teaching kitchen
- Meditative Gardens and Massage Therapy for patients

## Unique Opportunity

We believe we may be the only center to have the complete freedom to use any and all technologies, not only to compare in a moments notice but the ability to also select and delivery on multiple units depending on the best solution for the patient. Not only about isodose lines.

Multi-Technology RT approach for the best “lifespan results”!

*Long (and short) term side effects*
Pillars of RT Planning

Target Coverage
The reason for RT

Target

OAR protection
“Do no harm”

OAR
Pillars of RT Planning

Target Coverage
The reason for RT

Dose Homogeneity
*except for Stereotactic RT

Target

OAR

OAR protection
“Do no harm”

OAR

Pillars of RT Planning

Target Coverage
The reason for RT

Dose Homogeneity
*except for Stereotactic RT

Target

Dose conformity
ALARA, Integral dose

OAR

OAR protection
“Do no harm”
**Therapeutic Index**

- Methods to modulate TI:
  - Radiosensitizers/Radioprotectors
  - Fractionation
  - Dose rate
  - Technology

The maximum radiation dose by which death of cancer cells is locally controlled and the minimum radiation dose by which cells in normal tissues have low acute and late morbidity (Thoms J, Bristow RG).

**Long term side effects carried for a Lifetime**

Most of the physicians we work with want to see the dose conforming around the target, especially when abutting a critical structure with dose limits that are lower than the targeted Rx dose.
Plan specific dose distributions

| 4 Field Box | VMAT, yet dose bath | Protons, integral dose |

But which is better?

Fastest treatment because patient cannot hold still...3D (shortest beam-on times)
Conformal tissue sparing for a 70yo...VMAT or Proton
Lowest Integral dose for a 40yo...Proton

Plan specific dose distributions

| 4 Field Box | VMAT, yet dose bath | Protons, integral dose |

If your only criteria is high to intermediate conformal doses which would you choose?
Which is the best backup when the primary machine needs maintenance?
**MCI – RT Technology**

- TrueBeam Linac
- Tomo
- CyberKnife
- Gamma Knife
- MR Linac
- Proton - PBS

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**First Impressions…**

- TrueBeam Linac
- Tomo
- CyberKnife
- Gamma Knife
- MR Linac
- Proton - PBS

- Radiation type: Multiple MVs
- Isocenter: Isocentric
- IGRT: Inter-fraction
  - KV-CBCT, MV/MV/SIG
  - MVCT, Stereoscopic KV/KV
- IGRT: Intra-fraction
  - KV triggered imaging, Calypso, SIG
  - Surface Image Guidance, Cine kV
  - Infrared Marker, Planar Cine MR

- Ideal clinical indications:
  - Universal
  - H & N, Comp. Breast, Long Tx Fields, Junction fields
  - Motion tracking, non-coplanar delivery
  - Cranial Stereo.
  - Diaphragmatic motion, adaptive capability
  - Universal, lower integral dose, pediatric, re-irradiation
TrueBeam Varian
3 Linear Accelerators (one HD120)

- Linear Accelerator (6X, 10X, 15X and electrons)
- Millenium MLC 120 leaves (central 20cm FS with 5mm and peripheral with 10mm)
- 40 X 40 field size
- HD MLC 120 leaves (central 8cm FS with 2.5mm and peripheral with 5mm)
- 34 X 22 max FS
- IGRT:
  - CBCT
  - Vision RT (SGRT)
- High Doserate Output (MU/min) for TBI, TBE, Grid Therapy (.decimal), etc.

TPS: Eclipse and RayStation

Multifunctional, sufficient and efficient for most cases
Relatively quick treatment for high through put
3D, IMRT, VMAT, SBRT

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TomoTherapy Radixact Helical Linac

- Linac based helical delivery system (6X)
- MLC 64 Binary, 6mm width
- Jaws settings 1cm, 2.5cm, 5cm
- No collimator rotation

- All axial-helical delivery (co-planar)
- 85cm bore
- Couch lateral shift and roll
- MVCT (artifact reduction) 10rpm
- 1000 MU/min dose rate
- Shift from outside lasers to treatment position is 70cm

TPS: Precision and RayStation (MCO)

Larger, longer, more convexed targets especially abutting OARs (H&N, Breast, Pelvis, Spine, Pediatrics)
IMRT, Tomo Direct

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CyberKnife M6 Robotic Linac

- Linac on a Robotic pedestal and Robo-couch (6X)

- Aperture attachment:
  - Cones (12 fixed collimators from 5mm to 60mm)
  - Iris (Double layered offset hexagonal leaves)
  - MLCs (3.85mm at 80cm SAD with 10cm x 11.5cm max FS, Step and Shoot)

- Stereotactic Realtime Image Guidance
- Target tracking
- Non-Isocentric with variable SAD per beam

TPS: Precision

Can be very conformal
SBRT: Intracranial, Spine, Lung

Trackable solid tumors or a surrogate (if you see it, you can track it)
Synchrony tracking

CyberKnife M6 Tracking

- X-ray Sources
- Image Detectors

Intracranial
Spine
Soft Tissues
Lung
Prostate

Stereotactic Tracking
SBRT Tracking
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GammaKnife Icon Radiosurgery

- Radiosurgery delivery system
- 192 Cobalt-60 sources in a circular array to focus the radiation
- Collimator spot sizes are 4mm, 8mm and 16 cm
- Frame-based for single fraction treatment
- Frameless treatment (mask) for fractionated treatment
- CBCT

TPS: GammaPlan
Planned with pre-treatment imaging then evaluated with CBCT to make adjustments to coordinates with Adaptive DoseControl

High precision in the Brain
Smaller targets in the Brain
Very conformal

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MRIdian – MR Linac ViewRay

- This is the Linac based system (6MV FFF)
  - legacy model was Cobalt
- 138 MLCs (5mm at isocenter) double stacked
- 24 X 27 field size
- No collimator rotation
- All co-planar beam arrangement
- Static Step and Shoot

- 90cm SAD

0.35 Tesla MR for IGRT with Gating
Promising pretreatment Adaptive planning
Shift from outside lasers to treatment position is 155cm
Couch has capacity for a +/- 7cm lateral shift

IMRT Lung, Liver, any target with motion or abutting an OAR

MRgRT

- 0.35T MR
- 6MV, FFF linear accelerator
- Adaptive radiotherapy
"Normal Tissue" Gating

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Proton Therapy PBS
IBA - 3 Gantry system

- 3 Beam-matched treatment rooms with identical environments
- PBS
- 6D robotic patient positioning
- IGRT: CBCT
- C-Rad Catalyst and 4D Sentinel (SIGRT)
- Ambient lighting from Philips
- Validating a Script generated Grid and Lattice Therapies

Ambient Patient Experience
Philips
First Step…

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Technology Triage

Early Stage Lung Cancer

TrueBeam
- Breath-hold?
- Compression (ITV)?
- Fast delivery?
- Volumetric imaging?
- Yes?

Tomotherapy
- Claustrophobic Volumetric imaging?
- Non-coplanar?
- Yes?

CyberKnife
- Trackable?
- Fiducials?
- Arms restriction?
- Large motion?
- Yes?

MR Linac
- Breath-hold?
- FB gating?
- Claustrophobic?
- Lateral lesion?
- Volumetric imaging?
- Yes?

Proton-IMPT
- Large motion?
- Insurance?
- Volumetric imaging?
- Breath-hold?
- Yes?

Comparative Plans

Treat patient with best quality plan
Prostate SBRT

Clinical Objectives

<table>
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<tr>
<th>Structure</th>
<th>Constraint</th>
<th>TrueBeam/ RapidArc</th>
<th>IBA Proton PBS</th>
<th>CyberKnife MRI</th>
<th>ViewRay MR Linac</th>
<th>Radixact (TomoTherapy)</th>
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<tr>
<td>Rectum</td>
<td>$D_{max} \leq 41.2$ Gy</td>
<td>✔</td>
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<td>$D_{1cc} \leq 38.5$ Gy</td>
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<td>$V_{24Gy} \leq 25%$</td>
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<td>$D_{mean} \leq 16.4$ Gy</td>
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<td>Urethra</td>
<td>$D_{max} \leq 42$ Gy</td>
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<td>Bladder</td>
<td>$D_{mean} \leq 42$ Gy</td>
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<td>$V_{40Gy} \leq 10%$</td>
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<td>$V_{50Gy} \leq 50%$</td>
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<td>$D_{max} \leq 29$ Gy</td>
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<td>Small Bowel</td>
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<tr>
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<td>$V_{10cc} \leq 10$ cc</td>
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<td>$D_{1cc} \leq 21.6$ Gy</td>
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</table>
Protons vs. IMRT: Head and Neck

Tomotherapy vs. 3 field IMPT

20-25 Gy “savings” to the oral cavity:

What Does This Mean?

Widesott et al, IJROBP 2008

*25 Gy (25 Sv) of Unnecessary Radiation

Slide courtesy of Steve Frank, MDACC

12,500
H&N CTs
(2 mSv)

5,000,000
Intraoral X-Rays
(0.002 mSv)

25,000x
General Public Annual Limit (1.0 mSv)

+83%
Additional Cancer Risk*
(12,500 CTs, 65 yo)

Proton Therapy

Protons to the Vertex of the head for Meningioma 54Gy / 30fx

Orig Diag ALL at age 2 (Cobalt) remission
34yo Multifocal Meningioma, 3 surgeries
Recurrent Atypical Meningioma Lt Cavernous sinus
42yo Male

PreOp test plan
Atypical Meningioma

Dose difference

Life long consequences of Radiation and Chemo
Near optic apparatus
Multifocal lesions
CK to Lt Temporal Lobe lesion
25Gy / 5fx
MTRT

Vertex Too large for CK (Proton)

Lesion in the Cavernous Sinus (CK) 25Gy / 5fx

Proton (solid) Cyberknife (dots)
Cyberknife SBRT

<table>
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<tr>
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<th>CyberKnife</th>
<th>CyberKnife</th>
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</table>

Integral dose and Cognitive performance
Best technology is not easily evident...

Comparison Esophagus

3DCRT: 4-field static photons; IMRT: 5-field modulated photons; PBT: 2-field passive scatter protons (PAILPO)
Liver Comparison

Proton

X-ray

For early stage breast cancer, prone photon RT is a good option to lower heart dose

Left Breast  Right Breast

Most patients treated to breast only are suitable for prone setup and will not require Protons

Ares et al., UROBP 2009
Comparison Breast Pectus Excavatum

3D, Breath-hold  VMAT, Free-B  Protons, Free-B

Mean heart dose
3D: 302 cGy  VMAT: 1075 cGy  IMPT: 4 cGy

On going lessons…

• Difficult to guess the best technology for some cases so we methodically work through the best solutions for the patient and continue learning from it
• Multi-technology RT approach appears to be beneficial in a non trivial number of cases
• MCI’s array of technology provides a unique environment that allow us to determine and provide the highest quality care to our patients

Courtesy Kotecha
Credits: Thank you for your help

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Man Yam  
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Rene Hernandez  
Hayden Guerrero  
Jairo Mercado

Thanks for your attention