SBRT:
Indiana University Experience
. . . 15 19 20 years and counting . . .

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Definition

• SBRT – Stereotactic Body Radiation Therapy

  • “Technology that uses elements of 3D conformal therapy in addition to stereotactic targeting while incorporating systems for decreasing the effects of lung and other organ movements that would otherwise translate into target motion.”¹

Stereotactic Ablative Radiotherapy-SAbR

• Stereotactic Body Radiation Therapy (SBRT)

  – Began as an extension of SRS and shares some of the same characteristics.
    • Dose heterogeneity inside the tumor.
    • Sharp dose gradient outside the tumor.
    • Highly effective patient immobilization.
    • Use of many beams.

  – Some of the early pioneering work was carried out in the Department of Radiation Oncology, IU Health, University Hospital.

  – From 1997 – 2016 over 1100 SBRT patients were planned and treated at IUSM / IU Health.
Definition

• SBRT requires:
  – Hypofractionation with markedly increased dose per fraction.
  – Dramatic reduction in size of the treatment volume.
  – Significantly reduced elapsed treatment time.¹

• SBRT requires:
  – A high level of confidence in the accuracy of treatment delivery practices.²
  – Effective immobilization and tumor motion management.

• ² AAPM Task Group Report 101: Stereotactic body radiation therapy
The Evolution of SBRT

How did it all start?
The Evolution of SBRT: 1992

• Pre-SBRT: June, 1992
  – Lung Cancer patient presents for HDR brachytherapy application of 2-3 fractions.
  – In some cases the bronchoscopy could not be completed because the obstruction was too large.
  – What was the alternative?
  – After much thought and planning . . .
    • At the simulator, an isocenter was placed on the patient at the point of the blockage by the pulmonologist under bronchoscopic guidance.
    • First endobronchial treatment given using non-coplanar composite arcs, with the couch at 0 degrees, 30 degrees, 330 degrees and 90 (270) degrees.
    • Dose 10 Gy x 1 fraction and all entrance and exit dose was off-cord.
    • Planned with AECL Theraplan TPS using manual contours taken from a reconstruction of a diagnostic spiral CT.
    • Following 2 week break, patient returns and HDR fraction given.
Non-Coplanar Conventional Arcs with couch @ 0, 90, 30 and 330 degrees.

No entrance or exit beams through the spinal canal, achieved stop/start angles.

• Pre-SBRT: December, 1994
  – Acquisition of Render Plan 3D TPS.
  – Enabled 3D targeting and reconstruction of bronchial obstruction.
  – Enabled 3D planning of non-coplanar arcs described above.

• Pre-SBRT: November, 1996
  – Indiana University acquired the Stereotactic Body Frame from Elekta as part of the purchase of Gamma Knife for SRS.

• Pre-SBRT: February, 1997
  – The first patient, using the non-coplanar arcs was treated in the Elekta stereotactic frame for bronchial obstruction.
The Evolution of SBRT: 2000 - 2006

- **2000**
  - 1st patient treated on Phase I Dose Escalation prospective study for non-small cell lung cancer (NSCLC). [IU only]

- **2002**
  - Phase I study for NSCLC completed and closed.
  - Phase I/II study for liver metastases opened.

- **2004**
  - Phase II trial (RTOG 0236) opened for medically inoperable NSCLC.
  - Phase I/II trial for Hepatocellular carcinoma (HCC) opened at IU.

- **2006**
  - Phase II study for NSCLC completed and results published.¹
The Evolution of SBRT: 2006 - 2013

• 2007 - 2009
  – Phase II study for liver metastases completed.
  – Phase I study for primary HCC completed.
  – Phase II study for primary HCC opened.
  – Phase I/II study for liver metastases results published.
  – Phase I study for HCC results published.

• 2010 - 2013
  – RTOG 0813 for centrally located NSCLC, 10 Gy x 5 fractions
  – RTOG 0915 to study less toxic regimen 12 Gy x 4 fractions versus 34 Gy x 1 fraction
Initial Phase I Trial - NSCLC

Extracranial Stereotactic Radioablation: Results of a Phase I Study in Medically Inoperable Stage I Non-Small Cell Lung Cancer.


2000 - 2002

37 patients: clinically staged as T1 or T2 with comorbidities that precluded surgery

This treatment regimen was so new and so potentially dangerous that this was the only patient population we were allowed to use.
Initial Phase I Trial - NSCLC

• Dose Escalation Levels
  – Level 1  800 cGy/fx, 3 fx to 2400 cGy
  – Final Level  2000 cGy/fx, 3 fx to 6000 cGy

• Dose Limiting Toxicity
  – Any Grade 3 or Grade 4 toxicities of pericardium, esophagus, or ascribed to the protocol.

• Normal Tissue Constraints

<table>
<thead>
<tr>
<th>Organ</th>
<th>Max Pt</th>
<th>Dose(cGy/fx)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal Cord</td>
<td>any point</td>
<td>600</td>
<td>18 Gy</td>
</tr>
<tr>
<td>Esophagus</td>
<td>any point</td>
<td>900</td>
<td>27 Gy</td>
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<tr>
<td>Aorta</td>
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<td>Heart/pericardium</td>
<td>any point</td>
<td>1000</td>
<td>30 Gy</td>
</tr>
<tr>
<td>Proximal Bronchus</td>
<td>any point</td>
<td>1000</td>
<td>30 Gy</td>
</tr>
<tr>
<td>Brachial Plexus</td>
<td>any point</td>
<td>800</td>
<td>24 Gy</td>
</tr>
</tbody>
</table>
Initial Phase I Trial - NSCLC

- Local Control Data
  - Both T1 and T2 groups reached and tolerated 60 Gy doses
  - 87% of patients had response to treatment;
  - 27% had a complete response
  - After 15 months, six patients had local failure, all of whom had received <1800 cGy per fraction

- Conclusion
  - Very high radiation dose treatments were tolerated in this population of medically inoperable patients with Stage I NSCLC using ESR techniques.
    
    . . . and that is all we were trying to accomplish.
RTOG 0236 Phase II Trial

• 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. ¹

  – Activated May 26, 2004
  – Multi-institutional follow up study to the IU Phase I trial
  – Central Zone area of exclusion
  – Dose Escalation
    • 20 Gy in 3 fractions
    • 22 Gy in 2 fractions
Phase II Study: Results and Conclusions

• Results
  – 70 patients completed therapy
  – 2 year overall survival 54.7%
  – median overall survival 32.5 months

• Toxicity
  – Graded using the NCI Common Toxicity Criteria, version 2.0
  – Peripheral Lung: 83% had 2 year freedom from severe toxicity
  – Mid Lung: 54% had 2 year freedom from severe toxicity

• Conclusions
  – High rate of local control was achieved
  – Regimen not recommended for patients with tumors near the central airway.
Evolution of Treatment Planning

- Treatment Planning 1997 - 2006
  - 3D Render Plan (Precise Plan)

- Treatment Machine
  - Siemens KD2 non-MLC based linear accelerator

- Patient Position
  - Elekta Body Frame with 3D Coordinate System

- Treatment Fields
  - 10-12 non-coplanar, non opposing beams
  - Apertures using Cerrobind blocking
  - Milled compensators to deliver high dose in the middle of the GTV with rapid fall off from the edges of the PTV.
The Evolution of Planning: 1997 - 2006

• Elekta Stereotactic Body Frame

Render Plan TPS (Precise Plan) Graphics with Elekta Frame 2003
Shaping the Dose: Compensator Design

♦ GTV & PTV outlined on generic CT.
♦ Layers of Bolus applied to skin surface.
  ♦ Each layer of decreasing width.
  ♦ Each layer assigned density of lead.
♦ Compensator designed to deliver a uniform dose across the targets (GTV and PTV) through the bolus.
♦ Compensators were milled out of Cerrobend, for a range of field sizes from 6x6 to 12x12.
♦ Treatment delivered without bolus, resulting in dose distribution with higher dose in the middle, rapidly falling off dose at the periphery of the field.
The Evolution of Planning: 1997 - 2006

- Shaping the Isodose via Milled Compensator

The goal of compensation was to remove the effects of the flattening filter, giving a higher dose in the middle with rapid fall off.

Unfortunately, the FFF beams in use today, do not significantly achieve this goal unless using large field sizes. Theoretically, a FFF beam would be ideal.
Initial Phase I Trial for Liver Metastases

• A Phase I Trial of Stereotactic Body Radiation Therapy (SBRT) for Liver Metastases
  – University of Colorado (Denver) and Indiana University (Indianapolis).

• Rationale
  – Liver is the most common site for metastasis of GI cancer.
  – 70,000 patients a year develop liver mets in the US.
  – Less than 5000 cases are amenable to resection.

• Patient Population
  – Eligibility criteria included, but was not limited to:
    • 1-3 liver mets from any solid tumor except germ cell or lymphoma
    • Maximum tumor diameter < 6 cm
    • Karnofsky status > 60%
    • No prior radiation therapy to liver.
Initial Phase I Trial for Liver Metastases

• Prescription
  – Dose Escalation Level 1  12 Gy x 3 fx to 36 Gy
  – Final Escalation Level  20 Gy x 3 fx to 60 Gy

• Constraints for Normal Tissues
  – Uninvolved Liver (liver – GTV)  ≥ 700 ml < 15 Gy
  – Spinal cord maximum  6 Gy/fx (total 18 Gy)
  – Stomach / Small Intestine max  10 Gy/fx (total 30 Gy)
  – Total Kidney Volume  < 35% can receive > 15 Gy

• Conclusions
  – Results showed that it was safe to deliver 60 Gy with 3 fractions of 20 Gy using SBRT techniques for patients with 1-3 discrete liver mets and adequate hepatic function, as long as 700 ml of uninvolved normal liver received less than 15 Gy total dose.
Multi-Institutional Phase I/II Trial - Liver

• Multi-Institutional Phase I/II Trial of Stereotactic Body Radiation Therapy for Liver Metastases 2003-2007

• Objectives
  – Local Control @ 6 months to be determined by CT, MR or PET.
  – Length of survival with/without loco-regional recurrence or new liver or other distant metastatic disease.
  – Disease Free Interval
  – Overall Survival

• Results & Conclusion
  – 47 patients with 63 lesions
  – @7.5 months only 3 lesions had local progression.
  – The trial demonstrated that high dose SBRT is safe and effective for the treatment of patients with 1-3 hepatic lesions.
Phase I / Phase II Hepatocellular CA

• Phase I Feasibility Trial of Stereotactic Body Radiation Therapy for Primary Hepatocellular Carcinoma 2004-2008
  – Indiana University
  – Purpose: to determine the feasibility and toxicity of SBRT for primary Hepatocellular Carcinoma (HCC).
  – Why?
    • 5th most common cancer in the world
    • 3rd most common cancer related death
    • Increasing incidence in the US, related to ↑ rates of Hepatitis C
    • 70% of HCC patients develop cirrhotic livers
    • Most are not surgical candidates because of proximity to blood vessels.
    • Many have cirrhosis, active hepatitis and multifocal disease.
Phase I / Phase II Hepatocellular CA

- Eligibility Criteria
  - Child’s A: 1/3 uninvolved liver $\leq$ 10 Gy; 500 cc uninvolved liver $<$ 7 Gy
  - Child’s B: 1/3 uninvolved liver $\leq$ 15 Gy; 500 cc uninvolved liver $<$ 12 Gy

- Planning Summary
  - Planning Technique @ IU, based on technique from lung SBRT.
  - Child’s A Dose Escalation: from 36 Gy to 48 Gy in 3 fractions
  - Child’s B Dose Escalation: from 36 Gy to 42 Gy in 3 fractions...
    - Limiting toxicity was reached at 42 Gy in 3 fractions.
    - Continuation of Phase II study using 40 Gy in 5 fractions.

- Results & Conclusions
  - 17 patients with 25 lesions enrolled; 10 patients disease free in 2010
  - 6 patients followed treatment with a liver transplant
  - **SBRT is a non-invasive and well tolerated therapy in adequately selected patients.**
Achieving the Goals of Treatment Planning
Treatment Planning Goals

• The Prescription
  – Prescribed to an isodose line with 70 – 90% (usually 80%)
  – Attempts to mimic the dose distribution of GK-SRS.
    • High dose / fx
    • Conformal to PTV
    • Rapid fall-off to adjacent tissues
    • Dose heterogeneity within the PTV is desired!
      Higher central dose to GTV because > hypoxic fraction.
Treatment Planning Goals

• The Rationale
  – Highly ablative dose in a few fractions (typically < 5 fractions)
  – Promotes cell death, while allowing time for repair and repopulation of normal tissues.

• Dose Heterogeneity
  – Optimally, the GTV will receive ~10% greater dose than the outside edges of the PTV.
  – Sharp dose gradient outside the tumor is desired.
  – Requires effective patient immobilization.
  – Requires use of multiple non-coplanar static fields or dynamic arcs.
Defining the Targets

- **GTV**
  - To be delineated by the physician using multi-modality imaging

- **ITV**
  - 4DCT optimal for target definition
  - Contoured by physician using MIP (lung) or minIP (liver).

- **PTV**
  - ITV + margin expansion
  - Margin expansion: 5 mm around the ITV
  - What if there is no ITV drawn?
    - Expansion should be 5 mm axially around the tumor and 10 mm in the superior-inferior direction.
    - Breathing motion is the largest in the longitudinal direction.
SBRT Anatomic Sites

• The BIG “Three”
  – Lung
    • Non Small Cell Lung Cancer
    • Lung Metastasis
  – Liver
    • Metastasis
    • Hepatocellular Carcinoma
  – Spine Metastasis

• Other Sites
  – Pancreas
  – Prostate
  – Kidney, Bile Duct
  – Any solitary lesion
Planning Concerns: The Setup

• Positioning and Reproducibility: Critical Factor for SBRT
  – Approved Positioning Device
    • Elekta Frame with Vac-Lok and diaphragmatic control device
    • Fluoroscopic evaluation of diaphragmatic movement (<0.5 cm) and/or 4D-CT
    • CT scan with IV contrast
    • GI contrast patients with medial liver lesions or in the caudate lobe
    • MRI scan or PET-CT fusion, if lesions not visualized in CT
SBRT approved immobilization device should be used.
A number of vendors manufacture and sell approved devices.

BODY Pro-Loc
Immobilization System

This is not a commercial, just informative!
Planning Concerns: The Setup
Motion Management

- The Assessment of Motion
  - Fluoroscopy
    - Visualization of motion prior to the initiation of the planning CT acquisition
  - 4D CT (or MRI)
    - Is used to assess the extent of motion
    - Can be used to create an ITV, adding internal motion to the target volume

- Controlling the Motion
  - Compression Device
  - Regulated Breath-Hold
  - Gating
  - Tracking
Planning Concerns: The Setup

A. Compression plate

B. Gating

C. Breath-Hold

D. Tracking
Planning Concerns: The Setup

- Image Guided Radiation Therapy (IGRT) should be utilized for each fraction.

Motion Management cannot be minimized.
Using CBCT for Set-Up Verification

**Before Registration**

**After Registration**

**AXIAL**

**CORONAL**

**SAGITTAL**
The CT Simulation

• Scan Length
  – Should include any potential organs at risk in their entirety.
  – Should include the entrance point of all non-coplanar beams.

• For Accurate Contouring:
  – Slice thickness < 3 mm recommended
  – 4DCT for imaging moving tumors
    • MIP for Lung ITV
    • MinIP for Liver ITV
    • Average data set for dose calculations
    • Average data set for reference for CBCT localization at the time of treatment.
  – MRI should be used for contouring the targets for spine SBRT
Planning Concerns: the Contouring

Contouring is Critical

Be sure that you understand the accepted contouring guidelines.

SBRT Protocols are very specific about the fine details of contouring normal tissue volumes.

If you don’t have guidelines from a specific protocol, you should use the RTOG contouring guidelines for normal tissues.
Planning Concerns: the Contouring

- In the Lung
  - Uninvolved Lung: Total Lung - GTV
  - Proximal Bronchial Tree
  - Esophagus: includes tissue rim
  - Heart: includes the pericardium
  - Skin
  - Chestwall & Ribs
  - Brachial Plexus
  - Great Vessels
Planning Concerns: the Contouring
Planning Concerns: the Contouring

- In the Liver
  - Uninvolved Liver: Total liver – GTV
  - Stomach and Duodenum
  - Small Intestine
  - Kidneys
  - Proximal Heart
  - Gallbladder
  - Chestwall / Ribs
  - Skin (0.5 cm wall)
  - Any adjacent colonic loop
Treatment Planning – the Beam Arrangement

• The Beam Arrangement & Beam Energy
  – From 1997 to 2001
    • 7 field non-coplanar beam arrangement
    • No parallel opposed fields
    • Goal: to achieve as much conformality as possible while limiting the dose to normal tissues
    • For Lungs: 6x
    • For Liver: 15x/16x
  – From 2001 to present
    • 10-12 non-coplanar static fields (no parallel opposed fields should be used)
    • Dynamic arcs (VMAT)
The Beam Arrangement

Why was the change from 7 beams to >10 beams implemented?

**TOXICITY**

to normal tissues,

*including but not limited to, the skin.*
Treatment Planning Techniques: Dose Heterogeneity

• Historical Method
  – Milled Compensator for each field

• Current Methods
  – Field in Field utilizing dynamic MLC
  – Inverse Treatment Planning (IMRT)
  – Dynamic Arc Treatment (VMAT)

• Why would you choose to use a field-in-field method when IMRT or Arcs are so much more efficient to plan?
  – Early protocols prohibited the use of IMRT methods and later protocols discouraged its use.

  **WHY?**
Treatment Planning Techniques

• Any SBRT is, in fact, a form of intensity modulated dose.
  – However, inverse planning is sometimes not recommended by the SBRT protocols, unless absolutely necessary to protect a critical structure.

• Why?
  – Small segments of very high and very low dose may be adjacent to each other and even slight breathing motion could potentially result in the wrong segment over the target or normal tissue.
  
  – *It is not wrong to use intensity modulation and in many facilities is the treatment method of choice for efficiency of dose delivery.*

  – *Just Be Aware! This is where reproducibility and motion management are KEY.*
The Calculation – Beam Energy

- **Beam Energy: the Lung** Does it make a difference?: **YES**
  - Lung/Tissue Interface
    - Two materials of widely differing Z values
    - Low energy 6MV (≤ 10MV) recommended, even for extended depths

**6x Plan:**
90% volume = 111.92 cc  6cm diameter

**16x Plan:**
90% volume = 104.63 cc  5.8cm diameter
The Calculation – Beam Energy

• **Beam Energy – The Liver:** Does it make a difference? *Maybe*
  
  — Typically, the Liver PTV is surrounded by tissue equivalent structures, rather than air.
    • High energy beams may be used to reduce maximum doses and dose to the skin.

  — Sometimes the PTV is in the dome of the liver and extends into the lung. In these cases,
    • Low energy beams are probably best for any beams traversing through the air.
The Calculation Algorithm

- The Calculation Algorithm – does it make a difference? **YES!**
  - Pencil Beam Algorithm
    - Not an accurate representation of heterogeneities in the lung.
    - Leads to an overestimation of dose in lung.
  - Direct Monte Carlo algorithms are best but not convenient
  - Model Based algorithms: Convolution-Supraposition, AAA, Collapsed Cone should be used.

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**Eclipse Pencil Beam Algorithm**

**Eclipse AAA Algorithm**
The Calculation Algorithm

• Dose Volume Histogram from the Eclipse Planning System
  – Pencil Beam vs AAA
  • Calculation of dose for SBRT patient with lesion in mid-lung.

 جني Heterogeneity Corrections
 genie The algorithm discussion directly relates to the topic of heterogeneity corrections.

 جني Consequences of Algorithm & Heterogeneities
 genie Typical dose prescriptions for lung metastatic patients are reduced from 60 Gy to 54 Gy, so that biologically you are delivering equal doses.
Planning Concerns: Normal Tissue Dose

• The Radiobiological Theory of SBRT – Hypothesis Testing
  – A few large doses (e.g. > 10 Gy/fx) radiation treatments work better at controlling cancer than many small radiation treatments (e.g. 2Gy/fx).
  – Radiation toxicity is more dependent on volume than dose for parallel functioning tissues like the peripheral lung and liver.

• The Effect of Fractionation
  – Normal tissue cells have a higher survival rate than tumor cells.
  – A single fraction is more lethal than fractionated dose.
  – SBRT combines these two facts:
    • Large Fraction Dose
    • Retain some fractionation for protection of normal tissues.
Planning Concerns: Normal Tissue Dose

• How did we know what normal tissue constraints to use? – GOOD QUESTION!

“In the early days of SBRT, normal tissue tolerances were carefully considered and a set of dose limits derived.”

“Based on some experience, some derivation, and considerable speculation for 3 fraction treatments – not validated with long term data.”

Robert Timmerman, MD

Parallel and serial organ functionality were considered.

Problem 1: How do accepted dose limits (Emami, QUANTEC) for conventional fractionation translate to SBRT fractionation / dose schemes?

Problem 2: What about the different affects for serial and parallel organs?
Planning Concerns: Normal Tissue Dose

IT’S AN ONGOING PROCESS!

Initial OAR’s for SBRT Lung:

- Spinal Cord
- Esophagus
- Proximal Bronchial Tree
- Trachea
- Heart
- Uninvolved Lung
- Aorta

Soon afterwards we added:

- Brachial Plexus
- Chestwall/rib
- Skin

WHY? Based on surveillance and follow-up.
Planning Concerns: Normal Tissue

• TODAY:
  – There are published constraints for SBRT.
    • RTOG SBRT Specific Protocols
    • AAPM TG-101
    • Other SBRT Specific Protocols

• Remember:
  – Conventional dose constraints cannot be used with SBRT dose / fractionation schemes!
Planning Concerns: Toxicity

• Toxicity – A Complex Topic
  – Grade 1-2 fatigue, pneumonitis, nausea, diarrhea
  – Grade 3-4 pneumonia, pleural effusion, apnea, vocal cord palsy, skin burn
  – Grade 5 death

• Example of Potential Toxicity:
  – LOCATION, LOCATION, LOCATION
  – Target is adjacent to chest wall and ribs.
  – Target is lies in almost the same coronal plane as the spinal cord.

21 cGy Isodose Volume Displayed
Planning Concerns: Toxicity

- Central Lung Lesion
  - Adjacent to the Proximal Bronchial Tree / Great Vessels / Heart
  - Demonstrates the importance of Motion Management
  - Example of Inverse Planned Treatment Fields
Planning Concerns: Toxicity

- Liver Lesion:
  - Adjacent to Loop of Bowel, Chestwall, GI structures, Rt Kidney
Planning Concerns: Toxicity

• Peripheral Lung Lesion
  – Skin, Chestwall/Rib, Spinal Cord

• The Problem: All beams except the laterals will converge at the same point of exit or entry on the posterior chest wall. Great care must be taken to protect the skin.

• Sometimes high energy beams from the posterior only can help to minimize the maximum skin dose.
SBRT Plan Evaluation

• Evaluating the SBRT Plan:
  – Dose Volume Histogram
    • Is a valuable tool – but not enough.
  – Viewing Isodose on every slice:
    • Can show you where the maximum doses occur in the volume.
    • Displays where the minimum, or lack of coverage, occurs.
  – Conformality Index (ICRU 50/62)
    • Ratio of Prescription Isodose Volume / PTV Volume < 1.2
    • Ratio of 50% Prescription Isodose Volume / PTV Volume < 3.0-3.9.
      – The value is dependent on the PTV diameter.
  – Body – (PTV + 2cm)
    • Used to evaluate the dose fall off 2 cm in all directions from the PTV.
SBRT Plan Evaluation

Will the plan evaluation criteria (indices) always be met?

Plans for patients enrolled on a protocol must meet all criteria. Plans for patients treated off protocol may have dose limiting OAR’s that prohibit meeting all of the indices.

Always communicate with your physician and know what he/she is willing to accept.

Example of Conformal Isodose plan meeting all published index guidelines.

50% isodose volume is not protruding through the PTV+2cm volume.
Review of Treatment Plans
Treatment Plan 1 – Left Chestwall

- The Prescription: 48 Gy prescribed to 80% isodose line in 4 fractions
- Chestwall Dose: < 12cc to 30Gy  < 5cc to 40Gy  < 2cc to 45 Gy
Treatment Plan 2 – Right Chestwall

- Right Lung Chestwall Lesion
- Displayed: 50% of Rx isodose line

Prescription: 18 Gy x 3 fx to 54 Gy

Notice: conformity of 50% isodose
Treatment Plan 3 – Right Lung Lesion

- Rt Lung Lesion - Prescription: 18 Gy x 3 fx to 54 Gy

Notice the conformality when the lesion is mid-lung and not adjacent to critical structures!

A. 80% isodose volume
B. 60% isodose volume
C. 50% isodose volume
Treatment Plan 3 – Right Lung Lesion

D. 25% Isodose
Color Wash
Volume / DVH
Treatment Plan 4 – Liver Metastasis
Treatment Plan 5 – Liver Metastasis

- Liver with 2 Lesions
  - 2010  20 Gy x 3 fx to 60 Gy
  - 2012  16 Gy x 3 fx to 48 Gy

With multiple lesions and courses of treatment, all normal tissue constraints must be met for the composite plan!
Treatment Plan 6 – Liver HCC

• Liver Composite Plan for 3 Lesions
Treatment Plan 7: Spine with Cord Sparing

- 90% isodose
- 75% isodose
- 50% isodose
- 30% isodose
Treatment Plan 8: Spine with Cord Sparing

Reminiscent of Conventional Arcs with the isocenter placed in the middle of the spinal cord, a small block placed over the isocenter and dose treated with circular arc technique. Resulting isodose curve is donut shaped.
Treatment Plan 9: Rapid Arc vs static IMRT

Static IMRT: as treated

Rapid Arc
Future Directions
Current & Future Directions

• What Equipment is Currently being used?
  – 3D Linear Accelerator with Frame / Immobilization
  – IMRT, VMAT
  – Protons -- Cyberknife -- Tomotherapy

• What’s New?
  – Functional Liver, Functional Lung Based Planning
  – MR based Planning
    • For more precise targeting and improved assessment of motion
  – Analysis of Plan Robustness
    • To measure and quantify the uncertainty of the setup
Future Directions

• Planning Implications . . .
  . . . Do not change because of technology changes.

  – The goals of SBRT treatment. . .
    can be met with a variety of technological systems,
    but you can’t minimize the:

    • Reproducibility of Setup, Management of Motion, IGRT Methods
    • Defining Normal Structures, Dose Limits
    • Understanding the Implications of Hypofractionation
      – Acute Toxicities
      – Long Term Toxicities
Summary

♦ SBRT requires an adequately trained TEAM in order to be successful.

♦ Stereotactic Body Radiotherapy planning may seem demanding or even daunting, but is worth the time involved.

♦ Stereotactic Body Radiotherapy planning must be approached with awareness of the daily doses being delivered and the high potential for toxicity.

♦ Know your computer system – the calculation algorithms, calculation grid size, how it handles heterogeneity corrections.

♦ Familiarize yourself with the protocols. Reading protocols is a great way to learn the rationale for some requirements.

Be Cautious – don’t let your planning become routine!
Acknowledgements & References

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