The CyberKnife SRS/SBRT System

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CyberKnife Unit
San Antonio, Texas

Introduction

CyberKnife Components
- Treatment Delivery (G3 Platform San Antonio)
  - Robot (modified German auto manufacture)
  - Mounted modified industrial 6MV linac
  - 6D remote motion patient couch

Treatment Planning
- Closed network system
- Inverse planning – optimization (MultiPlan)
- Plan loaded in tx console for delivery

Introduction

Image Guidance
- Two orthogonal ceiling mounted x-ray tubes
- Real time silicon image receptors
- Correlate with 45 deg obq DRR’s from plan

Methodology
- Intra-cranial = 100 nodes, 12 angles, 80 cm spherical surface
- Extra-cranial = 100 nodes, 12 angles, 100 cm ellipsoidal surface

Introduction

Treatment Methods
- Static (3 Translation-3 Rotation Directions)
- 6D Skull Tracking
- Spine Tracking (fiducial-less)
- Fiducial Tracking (gold seed markers)

Dynamic – Synchrony Motion Tracking
- Static plan
- Setup correlation between respiratory surrogate (beacons on chest) and fiducial(s) in target
- Subsequent tracking follows beacons with updates at each IGRT imaging session

Treatment Planning

PC – Based, Inverse Planning System
- Contour Target(s), Critical Structures
- MRI/PET/CT Fusion capable
- Treatment in 3 “Paths” (Lt, Cnt, Rt)
- Choose cyl. Collimator (5-60 mm)/path
- Beams weighted to optimize target coverage, critical structure avoidance

Contour Structures
Treatment Planning

- Choose min/max Monitor Units
- Realtime display of Target DVH as calculation proceeds
- Iterative or Simplex algorithms available
  - Iterative allows interruption of calculation, ability to change parameters and continue
  - Simplex drives down to a solution with criteria presented and displays solution

Treatment Planning

- Usually, draft plans are developed with different collimators, eg. - number of beams, beam weights, Mu's will differ
- Physician(s) evaluate plans and choose "best" plan to treat (DVH, 3 plane display)
- This plan is moved to treatment console for subsequent treatment.
- This is a “closed loop” network

Beam Evaluation Screen

Patient Treatments w/ CK

- Patient is approved for CK SRS/SBRT by their carrier
- Tiducial placement scheduled, if necessary
- Planning CT (MRI or PET fusion) done
- Physician draws targets, critical structures
- Several draft plans done: RO chooses
- Plans sent to console for DRR, RX, TX
Fiducials for Synchrony Motion Tracking

Beacons for Synchrony Motion Tracking

Synchrony™ Respiratory Tracking System

- Synchrony camera
- Synchrony tracking markers
- Fiber optic sensing technology
- Tracks patient's respiratory motion

Synchrony Correlation Screen
Site Mix in San Antonio

- We treat in 4 daily treatment slots: 8 am, 10 am, 1 pm and 3 pm
- We do validations on all Synchrony pts and some XSight patients
- We’re divided ~50% cranial/spine and 50% extra-cranial
- We use Synchrony on lung, pancreas, liver and upper abdominal lesions

Staffing

- CyberKnife housed in the Methodist Hosp. Cancer Center
- 2 FTE Therapists, 1 FTE Nurse/coordinator
- 1 FTE Physicist, 1 FTE Dosimetrist, 1 B/U Physicist
- In 2006, we treated ~200 pts, ~500 treatments (3rd busiest in US)

Quality Assurance

- After commissioning, QA is performed on a daily, monthly and annual basis
- A modified TG51 calibration protocol is used
- We have 12 collimators from 5mm to 60mm in diam with which we plan & treat
- Everything is normalized to 1.0 for the 60mm collimator at d’max (6MV=1.5 cm)

Quality Assurance

- Calculation algorithm uses Output Factors for each collimator, TMR tables for each collimator as fcn of depth, OCR tables for each collimator as fcn of depth
- Head algorithm uses 800 mm SAD; Body algorithm uses 900-1000 mm SAD
- 100 nodal “stopping points” for both head and body w/ 12 angles possible at each

Collimator Output Factors
**Methodist Cancer Center at San Antonio, Tx**

**Output Factor Table**

<table>
<thead>
<tr>
<th>Coll. (mm)</th>
<th>Value</th>
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<tr>
<td>5</td>
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<tr>
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<td>10</td>
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<tr>
<td>40</td>
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<tr>
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<tr>
<td>60</td>
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</table>

**“Birdcage” Daily Cal Jig**

Require daily calibrations due to non-sealed monitor chambers.
Accuray going to sealed chamber in near future.

**End to End Static QA Test**

- CIRS head phantom with “ball cube” target is used to test overall positional accuracy of system.
- Load ball cube with Gaf Chromic film in orthogonal arrangement in phantom.
- Irradiate according to plan.
- Scan films into software program.
- Require < 1mm positional accuracy.
Gaf Chromic E2E Results

Synchrony QA
Using modified CIRS Dynamic Phantom
Table 1: Plan Summaries and Results

<table>
<thead>
<tr>
<th>Date</th>
<th>IDL Dose</th>
<th>Ant/Lt</th>
<th>Ant/Sup</th>
<th>Avg. %a</th>
<th># non-zero beams</th>
<th># fiducials tracked</th>
<th>Total position error (mm)</th>
<th>Average Tx. Time (min)</th>
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<td>31.2</td>
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<td>11/13</td>
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<td>4</td>
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Note: The table above summarizes the plan summaries and results for different dates. The columns include date, IDL dose, anterior/lateral dose, anterior/suppose dose, average %a, number of non-zero beams, number of fiducials tracked, total position error, and average Tx. time. The entries show the specific details for each plan, highlighting the accuracy and time taken for each session.