

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 obliq 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 cyln. Collimator (5-60 mm)/path
- Beams weighted to optimize target coverage, critical structure avoidance

Contour Structures



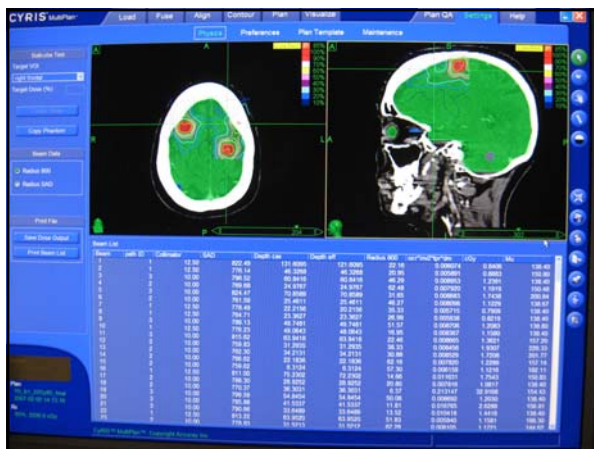
Treatment Planning

- 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

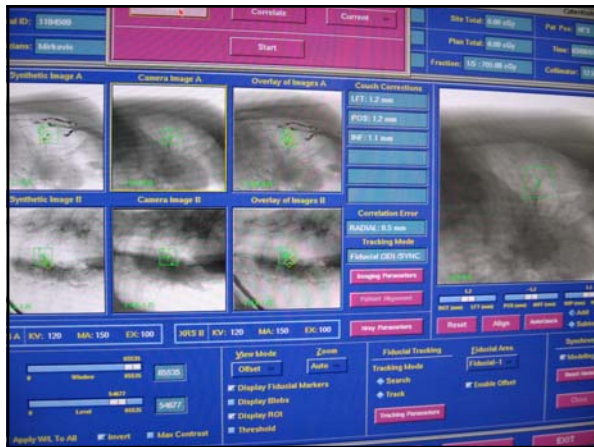


Patient Treatments w/ CK

- Patient is approved for CK SRS/SBRT by their carrier
- Fiducial 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

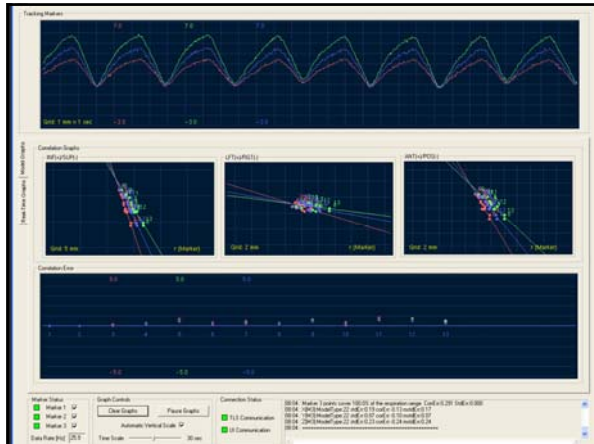
Synchrony™ Respiratory Tracking System

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



The image shows a person wearing a black sleeveless vest with several vertical white strips, which are the tracking markers. A Synchrony camera is mounted on a stand to the left of the person, aimed at them.

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 60 mm in diam with which we plan & treat
- Everything is normalized to 1.0 for the 60 mm 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

15 depth (mm)

OUTPUT FACTOR TABLE

Colim. (mm)

5		0.672
7.5		0.872
10		0.922
12.5		0.947
15		0.964
20		0.966
25		0.977
30		0.983
35		0.985
40		0.989
50		0.998
60		1

Methodist Cancer Center at San Antonio, Tx

“Birdcage” Daily Cal Jig

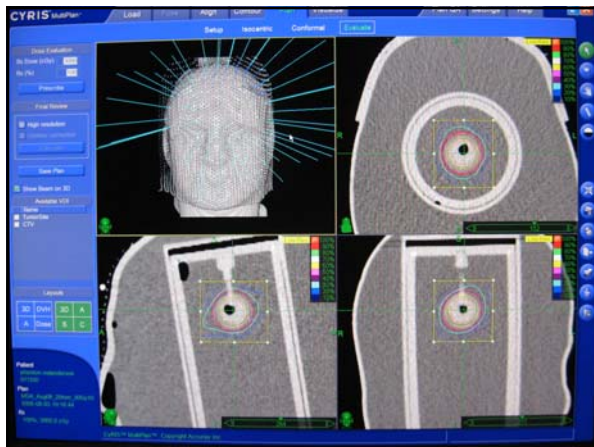
Require daily calibrations due to non-sealed monitor chambers

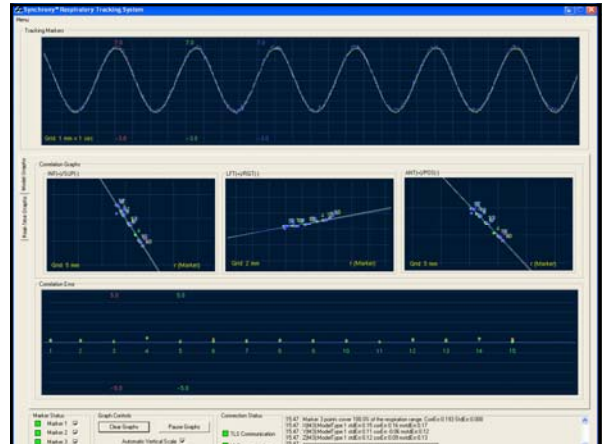
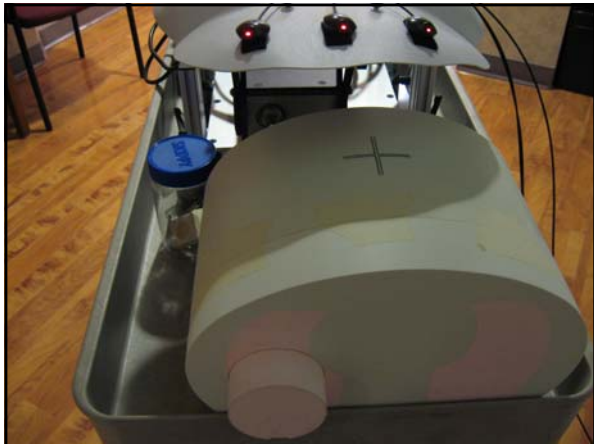
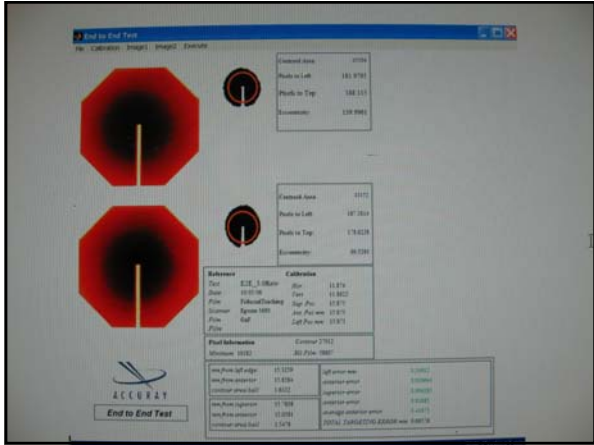
Accuray going to sealed chamber in near future



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





Processed Gaf Chromic Films

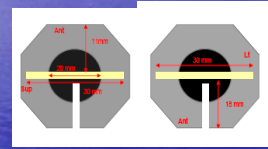


Table 1. Plan Summaries and Results

Dose	IDL	# fx	Collim size	# nonzero beams	# fiducials tracked	Avg Tx. Time (min)	Total position Error (mm)	IDL Dose Ant/Sup	IDL Dose Ant/L1	
1	30	70	3	10, 20	69	3, 2	95	0.5839	31.2	31.9
2	30	70	3	10, 20	69	2	93	0.44852	30.1	31.1
3	30	80	3	20	54	4	77	0.74401	30.6	30.6
4	30	80	3	20	34	4	70	0.7628	30.6	30.4
5	30	70	3	15	68	4	90	0.70993	29.2	29.7
6	30	70	3	20	80	4	98	0.69578	29.1	28.8

0.5636