Moderne Bestrahlungstechniken der perkutanen Strahlentherapie

Dr. Roberto Mini

Advanced Positioning Center

ExacTRAC xray 6D

Desired Capabilities

- Fast imaging verification at treatment position with good image clarity
- Simplified process for ease of use in a busy department by all therapists
- Visualization of internal structures eliminating skin shift
- Detection and compensation for internal organ movement
- Reproducible, allowing for tight margins for dose escalation and IMRT
- Patient-friendly and not time-consuming
- Real-time monitoring

ExacTrac X-Ray 6D

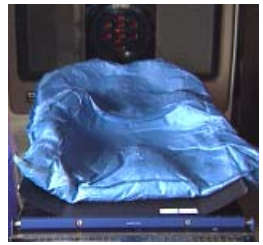
Key Components

- **Reflective Body Markers**
  - Visible in CT data
  - Positions of your choice
  - Individual Marker Configuration

- **Infrared Camera Technology**
  - Detection of patient position
  - Permanent patient monitoring
  - Tracking accuracy 0.3mm

- **System Hardware**
  - Touch screen in Linac Room
  - Flat screen in Linac Control Room

- **Vacuum Cushion & Patient Tray**
  - Carbon Fibre Patient Tray for stable immobilization, individual vacuum cushion for reduction of skin shift to 2mm



ExacTrac X-Ray 6D

Precise final patient positioning using Infrared Tracking

- Incorporation of correction shift as defined by Image Fusion
- Fine-tuning of patient position with manual or automatic couch movement

Necessary shift

ExacTrac X-Ray 6D

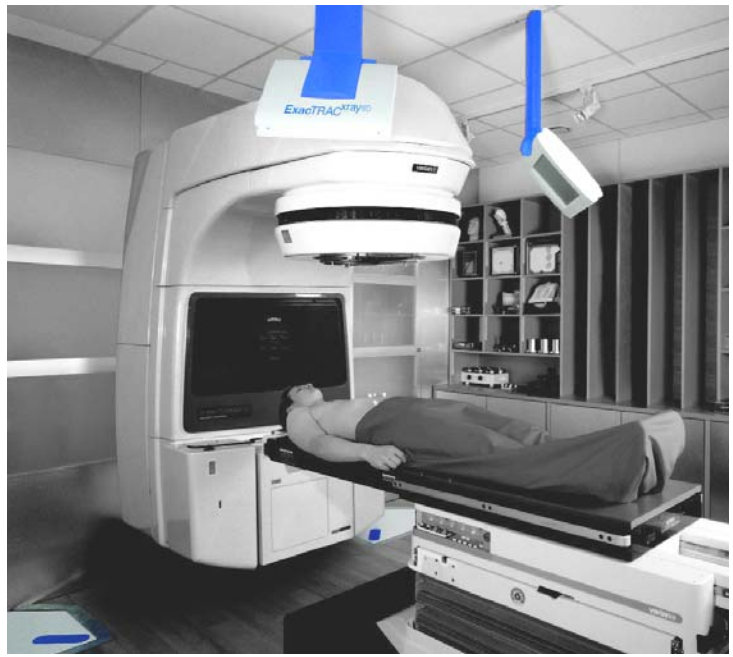
Precise final patient positioning and Treatment delivery using Infrared Tracking

- Automatic patient positioning using the ExacTrac infrared tracking technology
- Second X-ray procedure possible for verification and documentation
- Treatment Delivery with permanent tracking of patient's position and movement

ExacTrac X-Ray 6D

Key Aspects

- Set-up accuracy 2mm[1,2]
- 3 min for imaging and correction shift[3]
- May be used daily for all patients
- Integrates into existing clinical routine without Radiation Oncologist involvement
- Combines precision, stability and certainty of patient set-up



1) Image-Guided and Intensity-Modulated Radiosurgery for patients with Spinal Metastasis. Ryu S, *et al.*; CANCER April 15, 2003 / Volume 97 / Number 8: 2013-2018

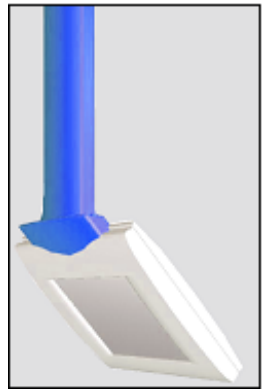
2) A Technique for Intensity Modulated Radiosurgery (IMRS) for Spinal Tumors. Yin F-F, *et al.*; Med. Phys. 29 (12), December 2002: 2815–2822

3) Automated Patient Set-up using stereoscopic x-ray imaging and real-time infrared. Verellen D, *AAPM Scientific Presentation* 2003

ExacTrac X-Ray 6D

X-Ray Components

- **Flat Panel System**
  Ceiling mounted a-Si detectors
  for high quality digital images
  Resolution: 512 x 512 Pixels
  Receptor area: 20.4 x 20.4 cm²
  Accuracy: ± 0.2 mm



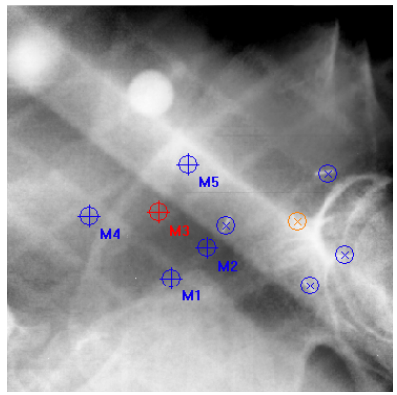
- **X-Ray Sources**
  Recessed 50cm into the floor
  Voltage: 150 kV
  Nominal focal spot: ∅ 0.6 mm
  Radio-translucent covers

ExacTrac X-Ray 6D

Positioning based on internal structures

Allows for most accurate target localization prior to each treatment

- **Bony structures**
- **Implanted radio-opaque markers**
- **Eliminates inaccuracies caused by skin shift that occur with traditional external markers**

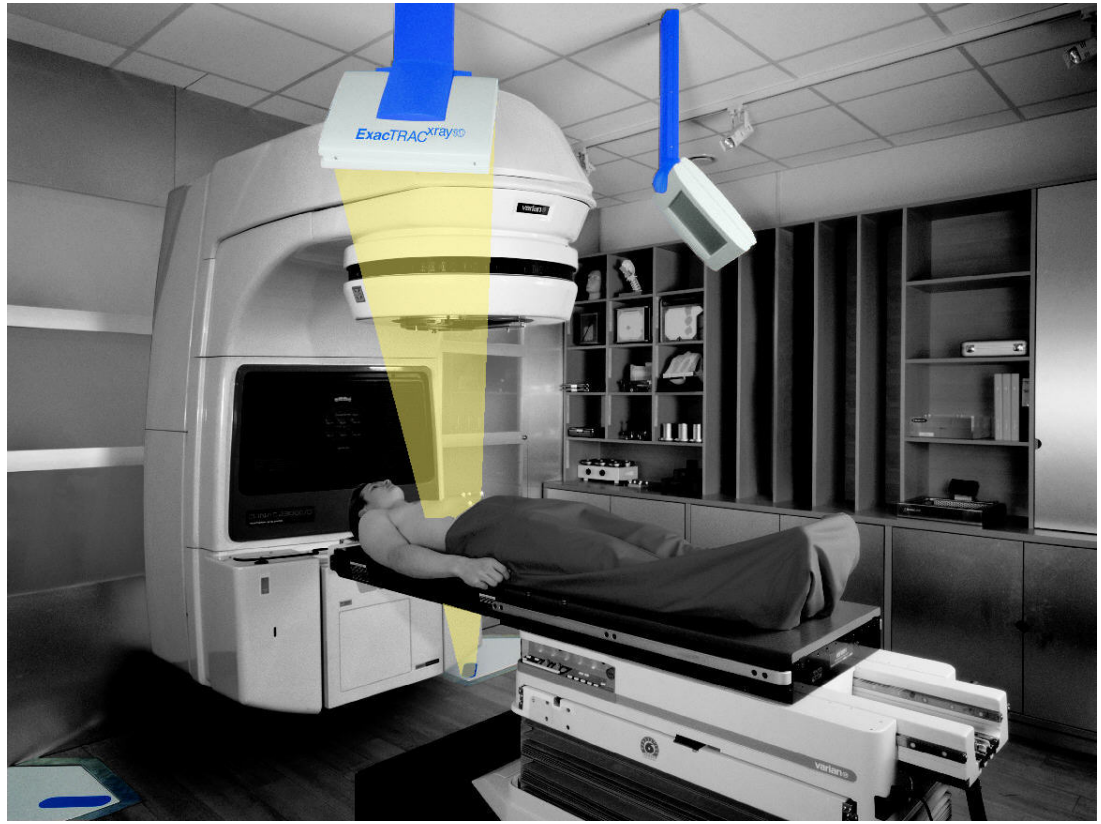


ExacTrac X-Ray 6D

Procedure

- Acquisition of first X-ray image

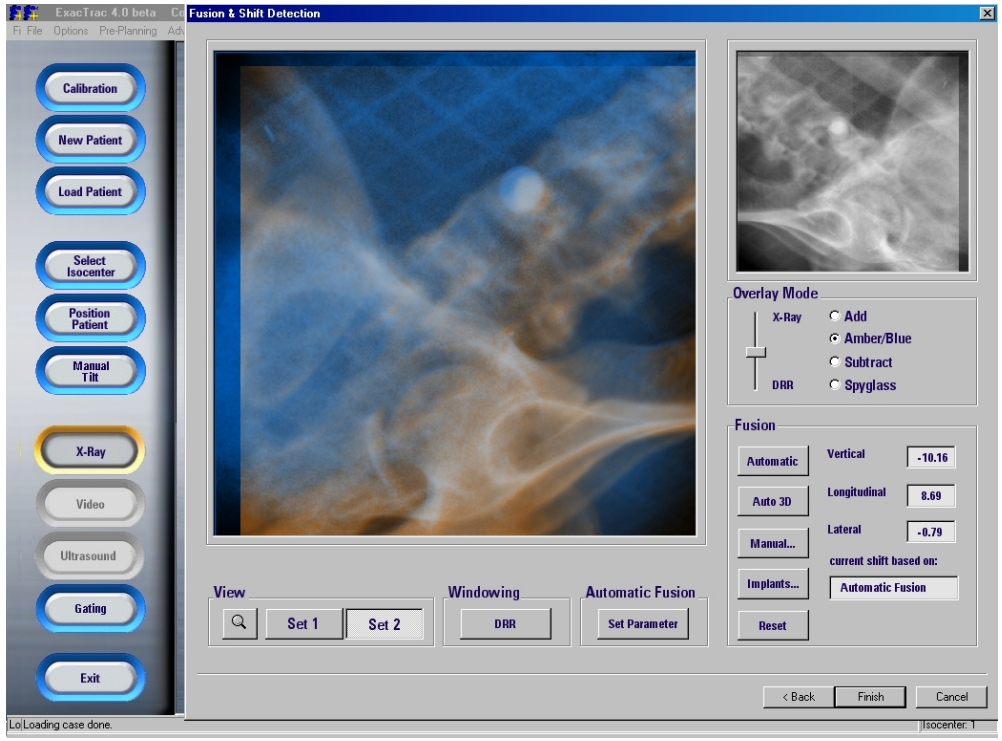
- Acquisition of second X-ray image



ExacTrac X-Ray 6D

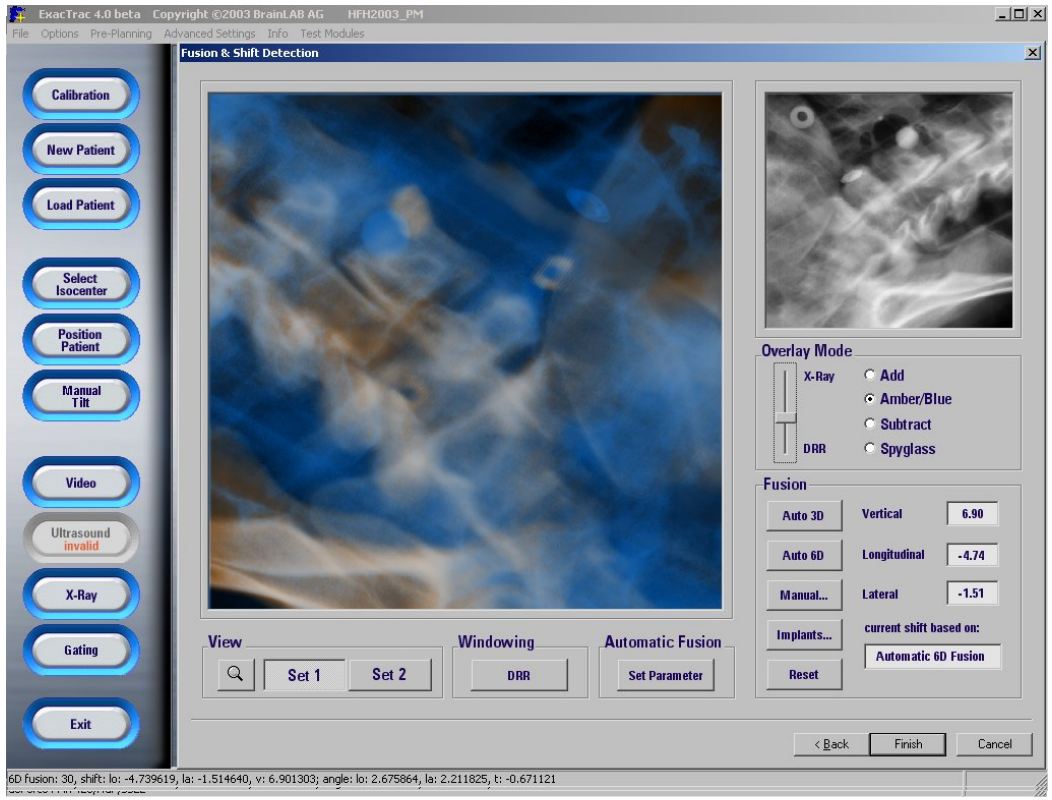
Procedure

- DRRs from treatment planning CT in identical plane to X-Ray Images are compared to live X-Ray images
- Automatic image fusion and detection of shift (set-up error)
- No definition of anatomical landmarks required



ExacTrac X-Ray 6D

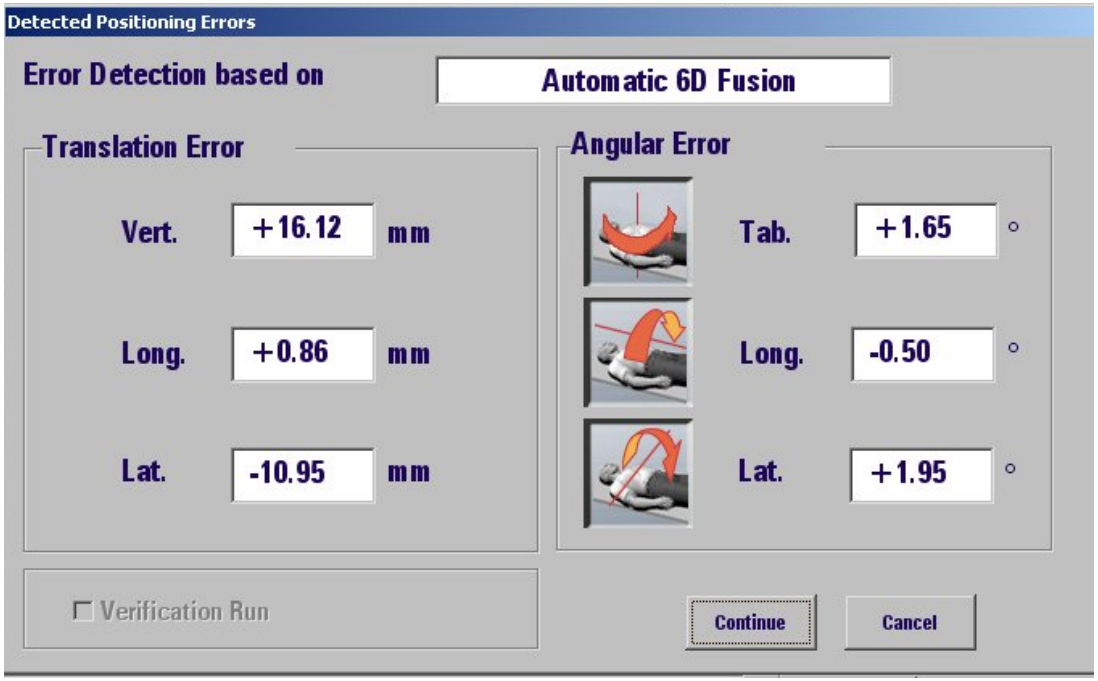
3D vs 6D Fusion



- 3D Fusion for determination of xyz set-up error
- 6D Fusion taking rotation into account for better match

ExacTrac X-Ray 6D

3D vs 6D Fusion



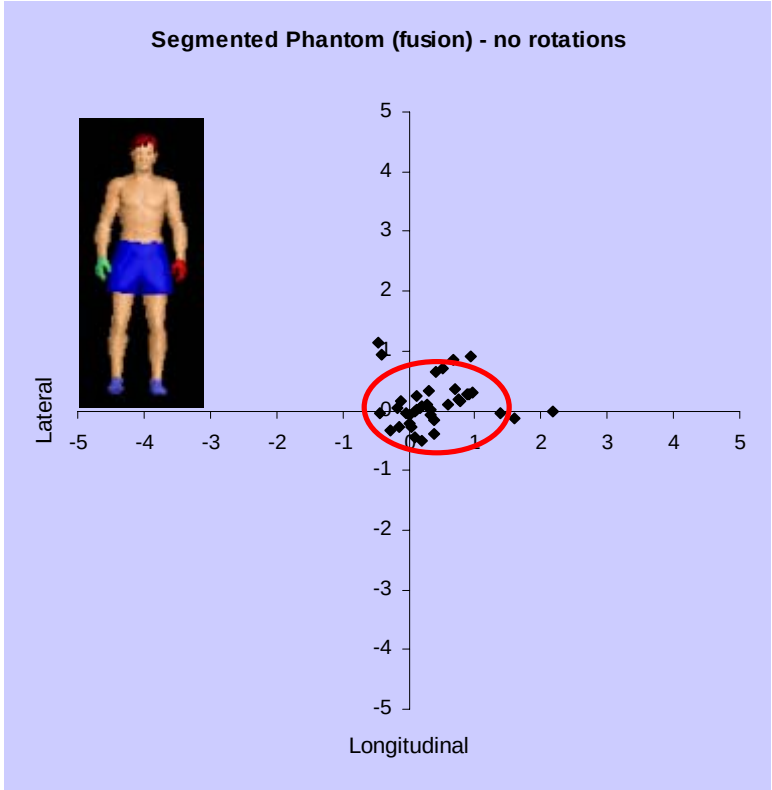
- Display of 3D shift corrected for by automatic table movement
- Display of 6D angular shift around isocenter

Clinical Results

Study on positioning accuracy

Segmented phantom, positioning based on bony structures

- **Accuracy for each axis:**
  - ***Average error 0.4mm***
  - ***Standard deviation 0.5***

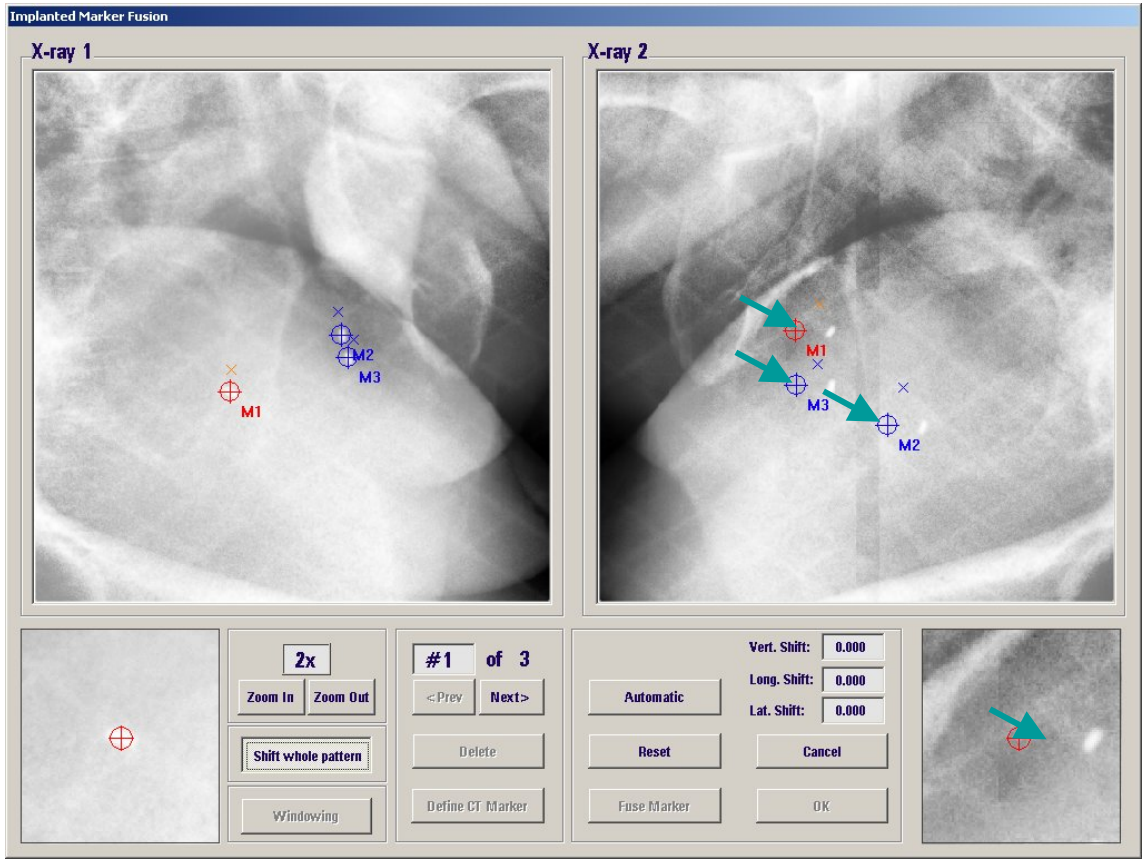


Quality assurance of a system for improved target localization and patient set-up that combines real-time infrared tracking and stereoscopic X-ray imaging. Verellen, D. *et al*. Radiotherapy and Oncology 67 (2003) pp.129 – 141

ExacTrac X-Ray 6D

Implanted Markers

- Markers in soft tissue (prostate) allow detection of current organ position
- Alternative to bony anatomy
- Automatic Marker Detection



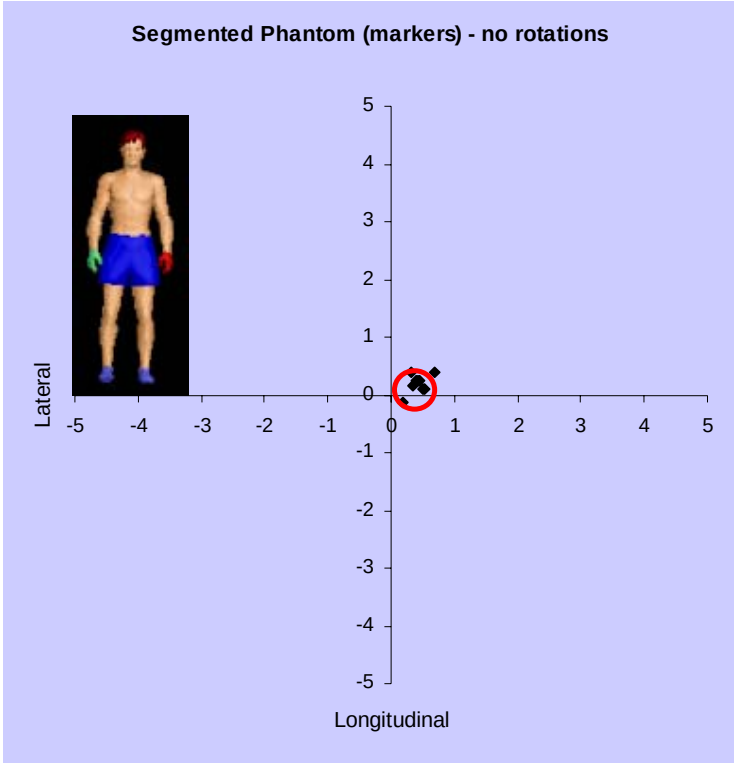
Clinical Results

Study on positioning accuracy

Segmented phantom, positioning based on implanted markers

- **Accuracy for each axis:**
  - ***Average error 0.5mm***
  - ***Standard deviation 0.3***

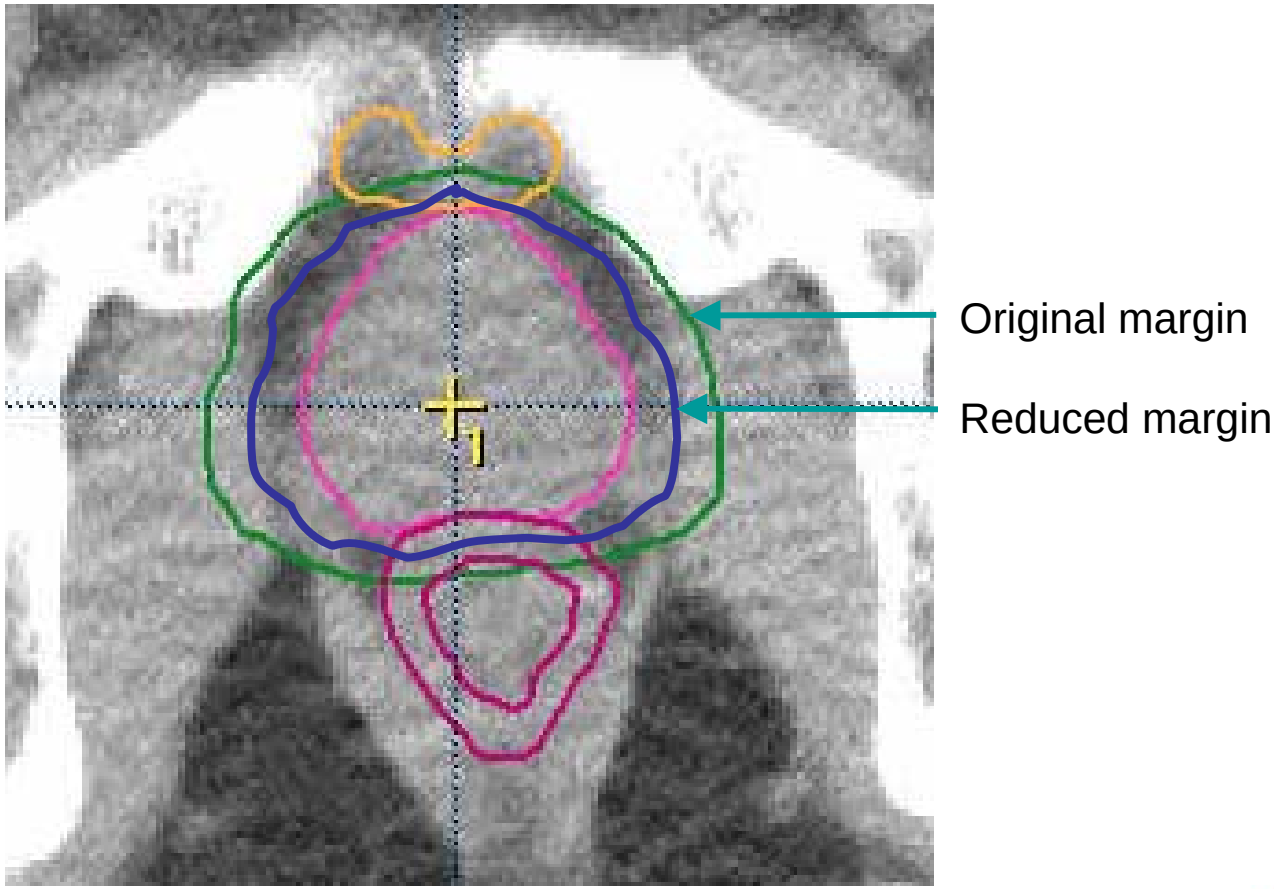
- **Implanted markers allows precise positioning of the actual target volume eliminating daily organ shift relative to skeletal frame!!**



Quality assurance of a system for improved target localization and patient set-up that combines real-time infrared tracking and stereoscopic X-ray imaging. Verellen, D. *et al*. Radiotherapy and Oncology 67 (2003) pp.129 – 141

Clinical Rationale

Greater set-up reliability and accuracy = reduced margin for uncertainty



ExacTrac X-Ray 6D

Real-Time Monitoring

- Patient monitoring during treatment
- User-defined thresholds
- Visual indication on Linac Console

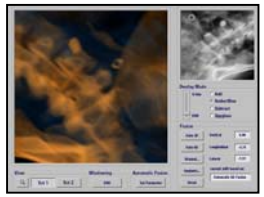
ExacTrac X-Ray 6D

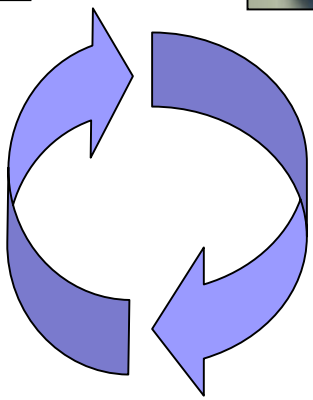
Integrated Procedure

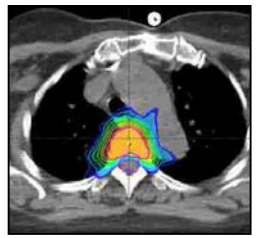
Patient Monitoring during beam-on time

Virtual Simulation to CT-visible Body Markers

Target shift calculation, Table movement

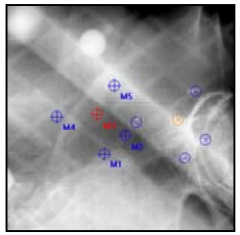






Integration to TPS for conventional & IMRT

Skeletal Frame or Implanted Markers



Automated Patient Positioning

Automated Verification using X-Ray imaging

ExacTRAC xray 6D

Thank you

CyberKnife

Stereotaktische Radiochirurgie

Dr. Wolfgang Weber

Accuray Europe

Zusammenfassung CyberKnife

. . . „Paradigmen-Wechsel“ in der Strahlentherapie

Mensch ➡ Maschine

Maschine ➡ Mensch

System CyberKnife

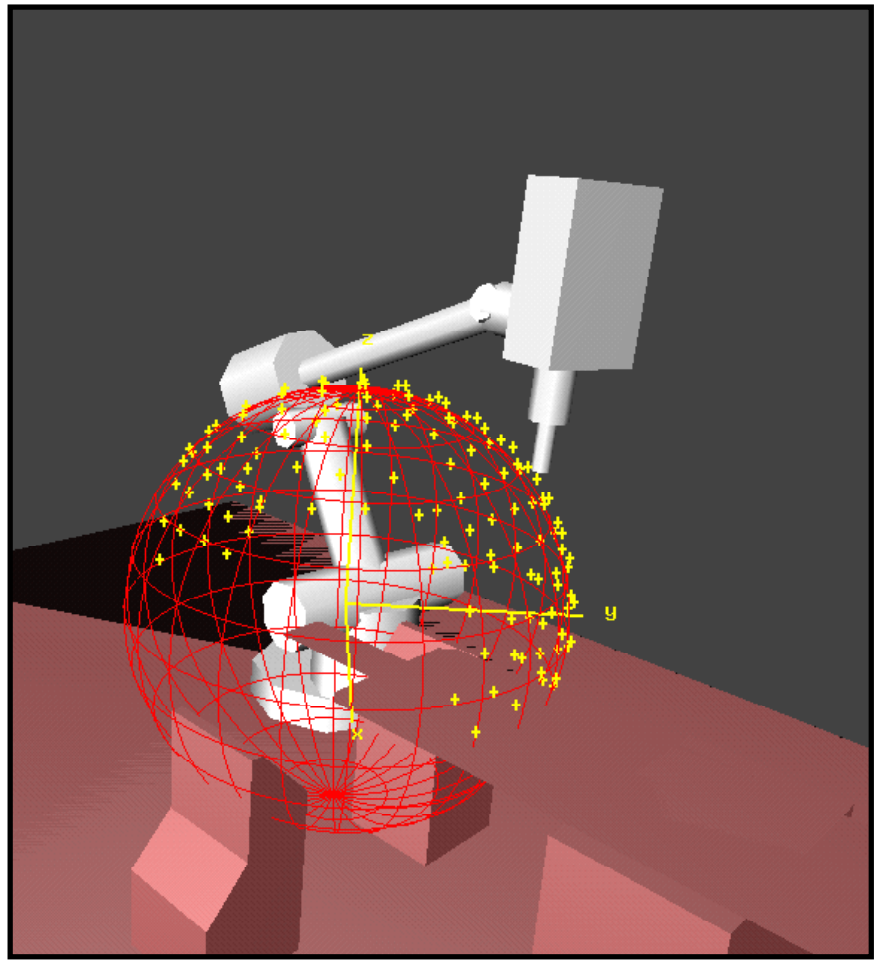
non-koplanare & non-isozentrische Bestrahlung (1)

100 Strahlpositionen (“nodes”)

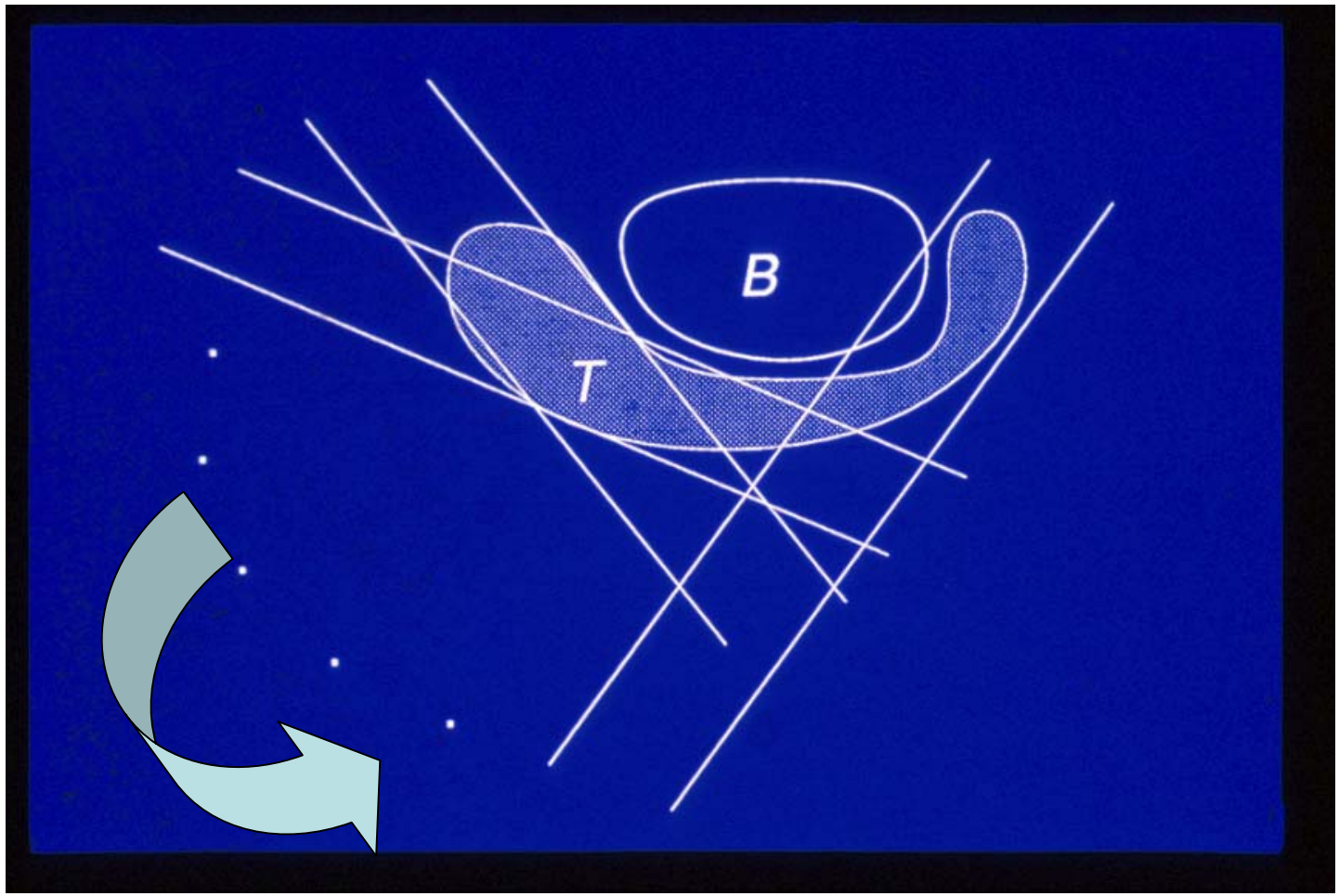
12 Strahlrichtungen pro node

verschiedene Behandlungs-”Pfade” (paths):

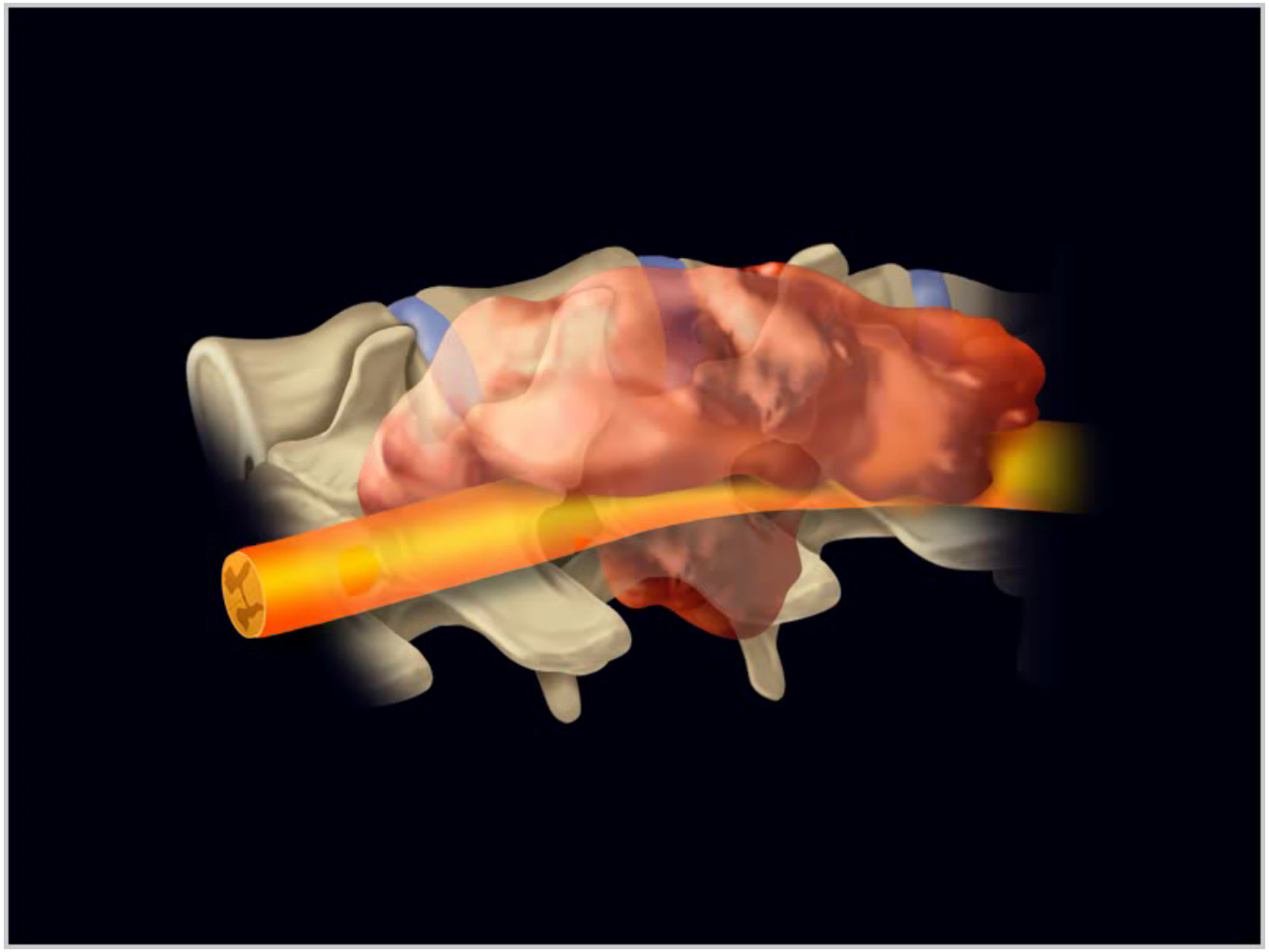
- **für intra- und extracraniale Bestrahlung**
- **einfache und zusammengesetzte Pfade (versch. Kollimatoren)**



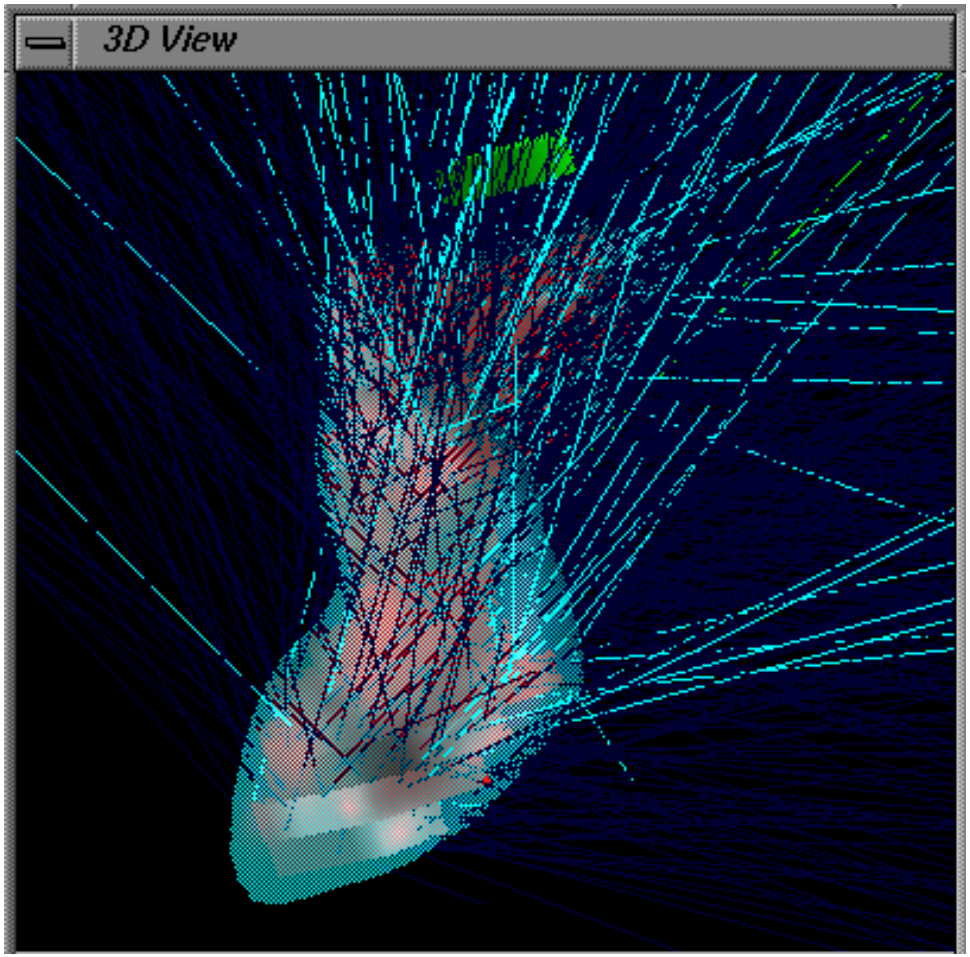
non-koplanare & non-isozentrische Bestrahlung (2)



CyberKnife:
Radiochirurgische Präzision und Konformität



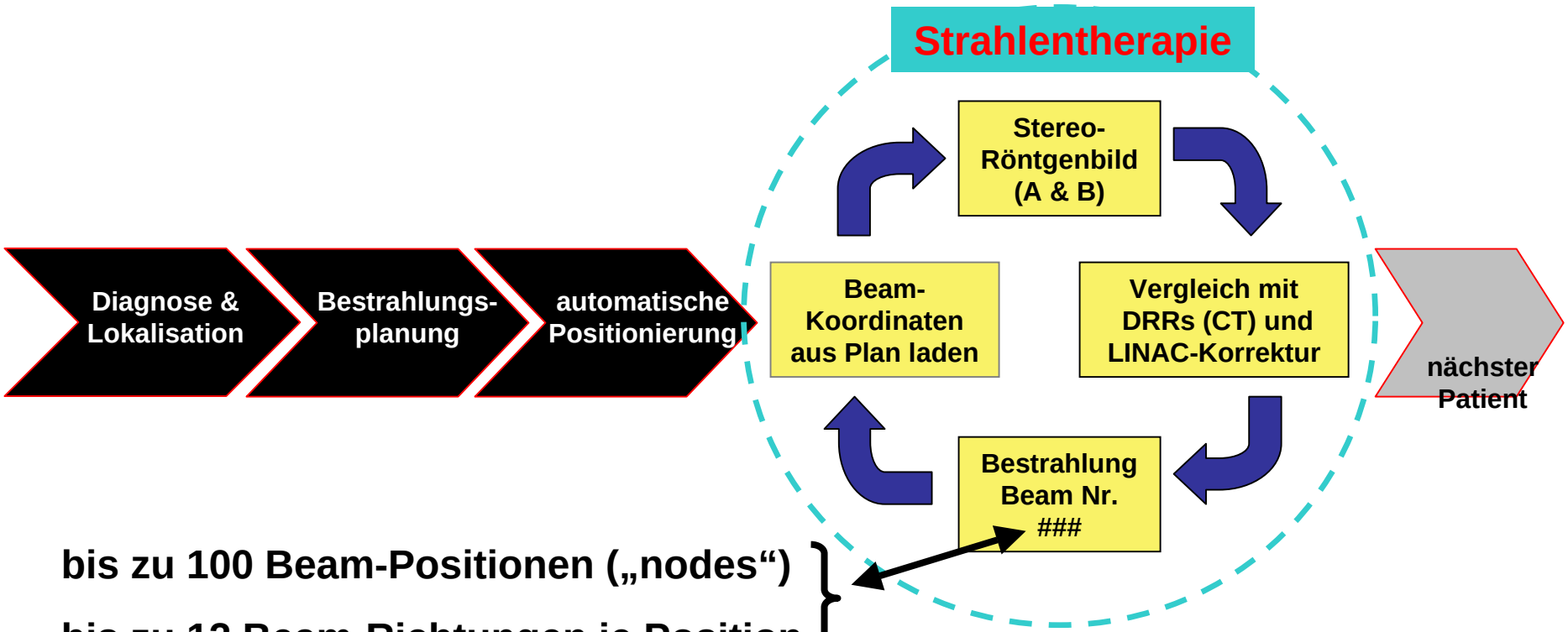
Radiochirurgische Präzision mittels komplexer Strahlverteilungen

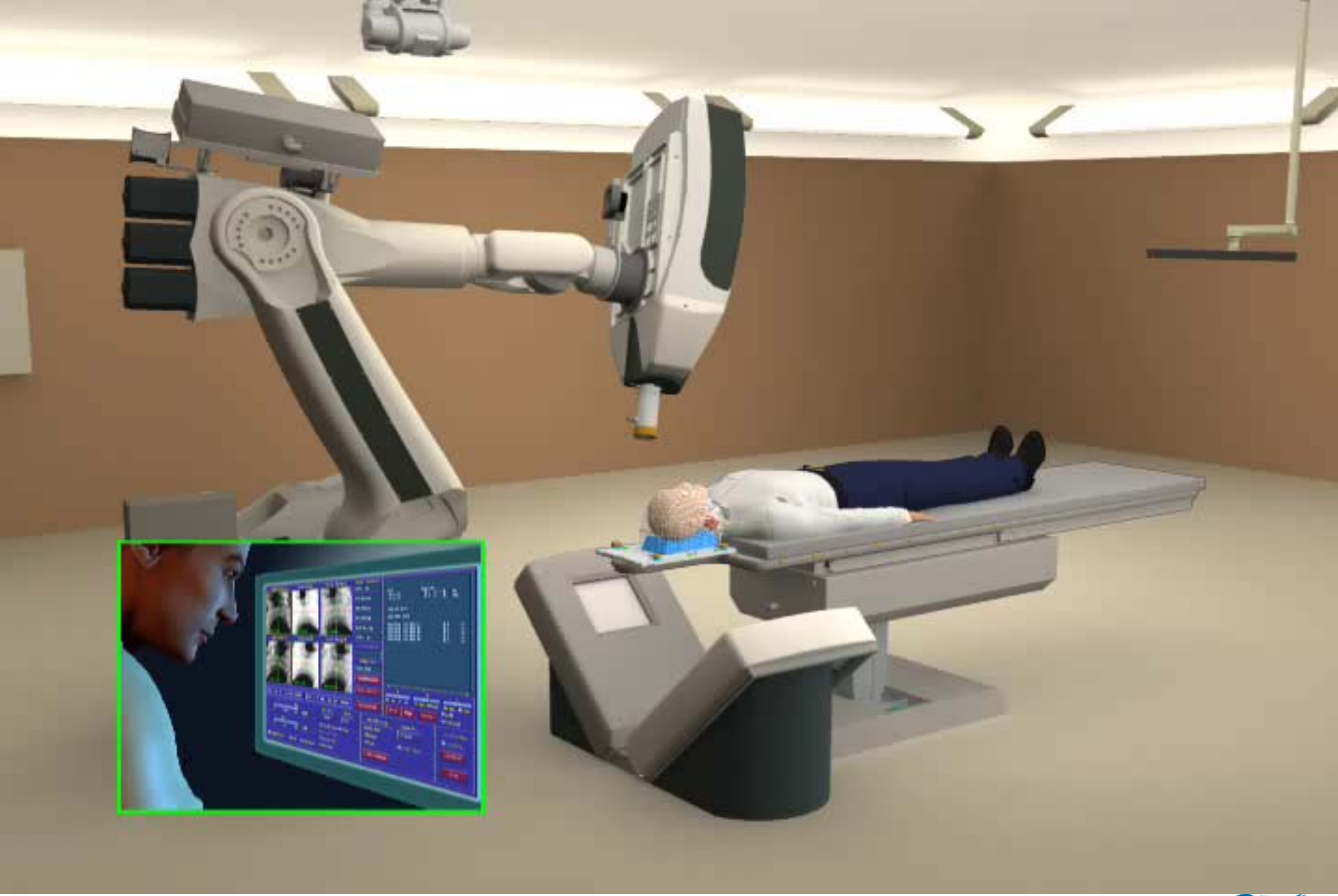


Dosis-Verteilung, erzeugt durch ca. 150 unabhängig applizierte “pencil beams”

Mit Erlaubnis der University of Texas Southwestern Medical Center

CyberKnife “single fraction treatment”





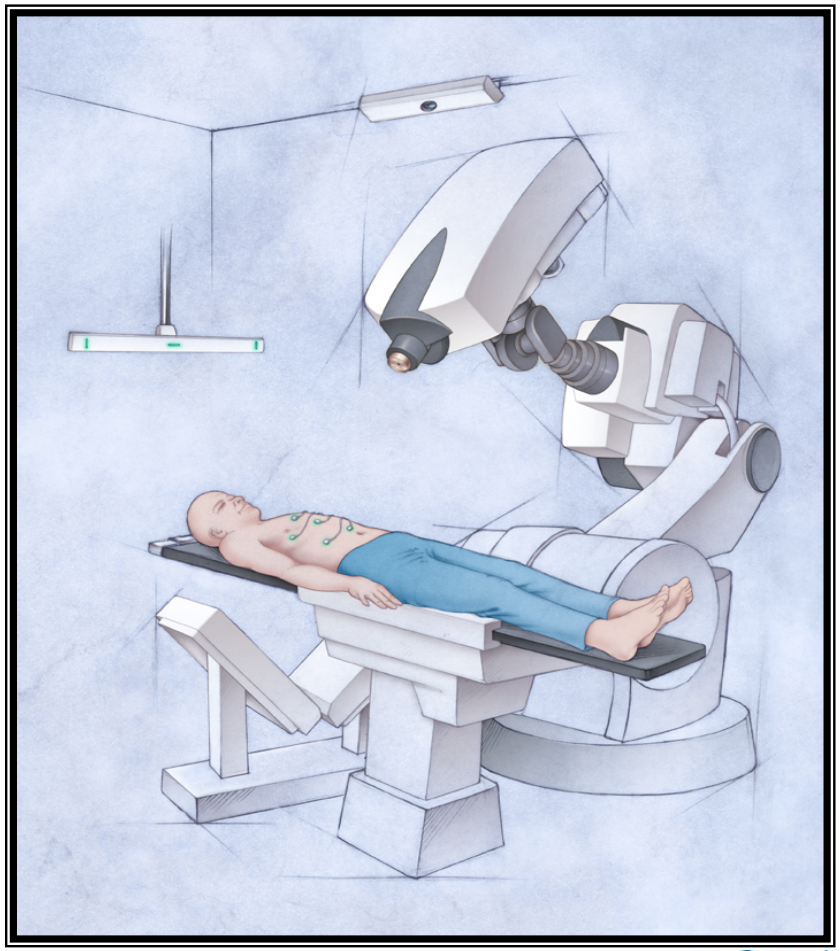
Synchrony™
Dynamische Positionskorrektur bei bewegtem Zielvolumen

1. gleichzeitiges Messen der Oberflächen-Bewegung durch IR-LED-System und Bestimmung der inneren Organbewegung mittels Röntgen-System A & B

2. Berechnung eines Korrelations-Modells: interne vs. externe Bewegung

3. kontinuierliche Bestrahlung des be-wegten Organs durch Verfolgen der externen Bewegung durch LEDs

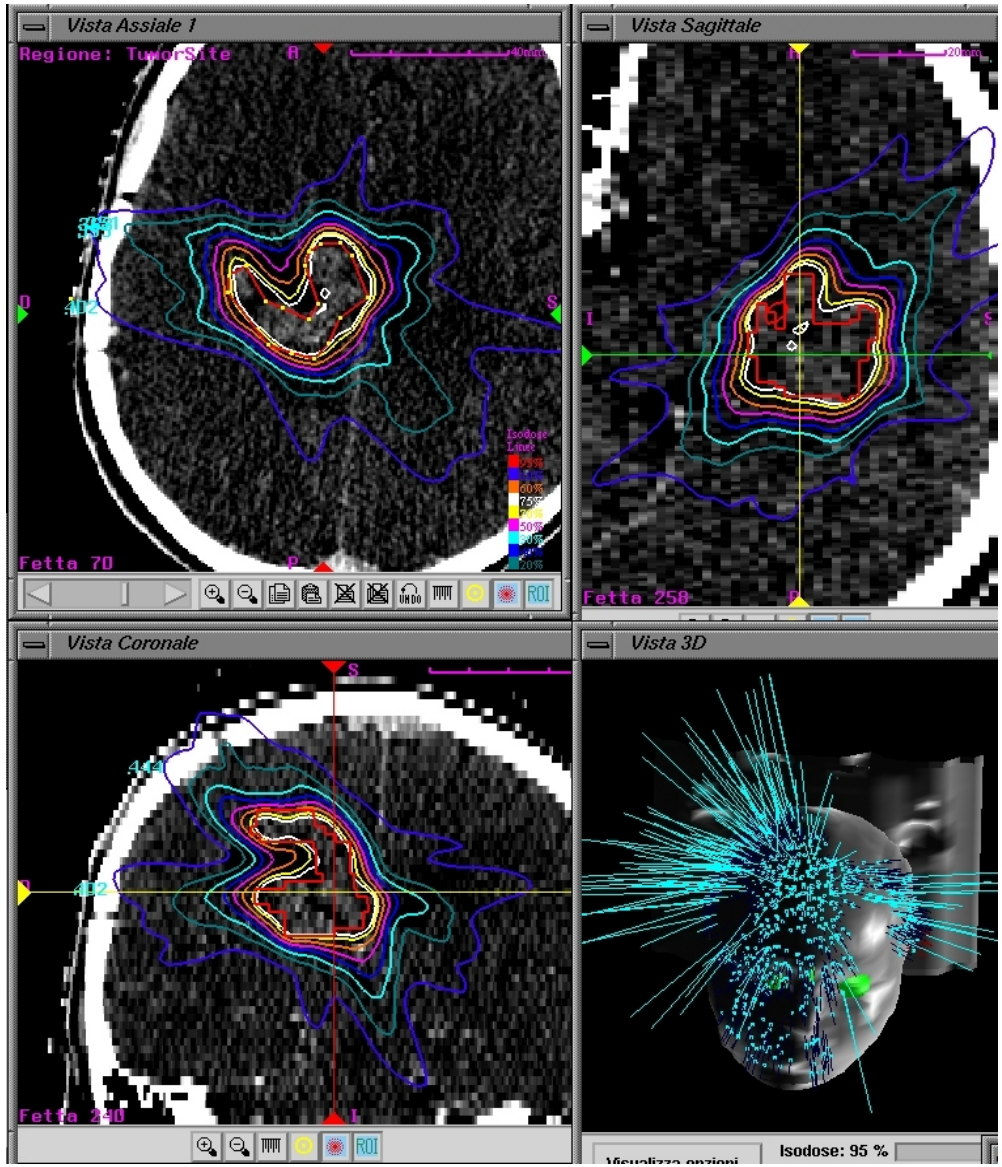
4. iterative Korrektur der Korrelations-funktion durch systematisch wiederholte Röntgenaufnahmen



C-förmiges Rezidiv (Gliom)

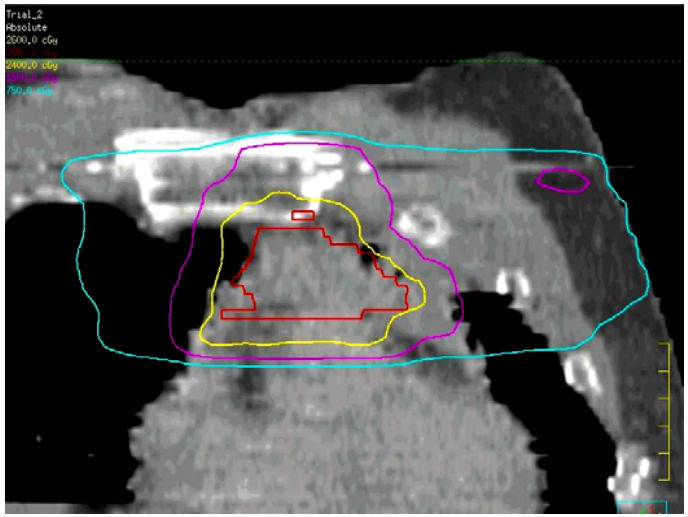
Referenz - Isodose: 75%

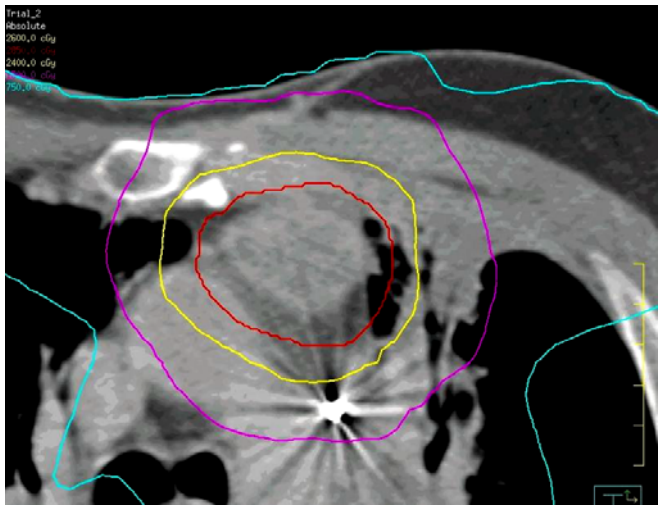
Isodosen bei 10% - 70%



Adenocarzinom der Lunge

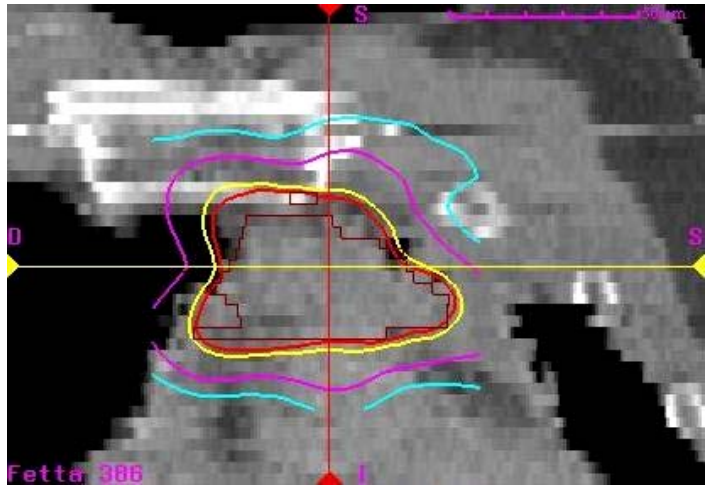
IMRT (CI = 2.6)

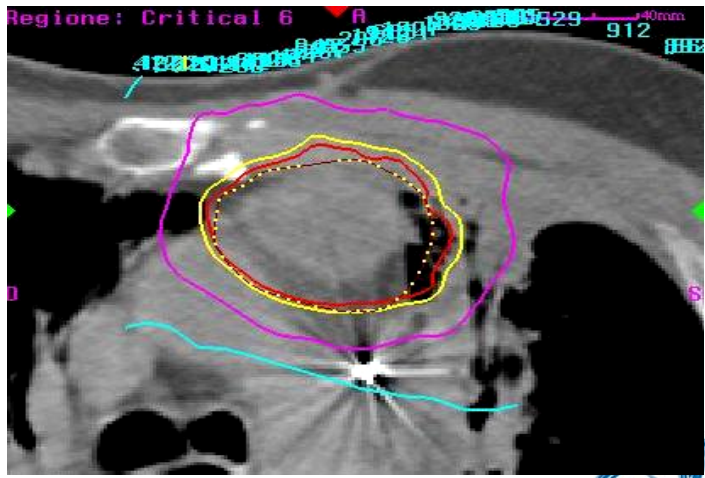




95 %
75 %
50 %
25 %

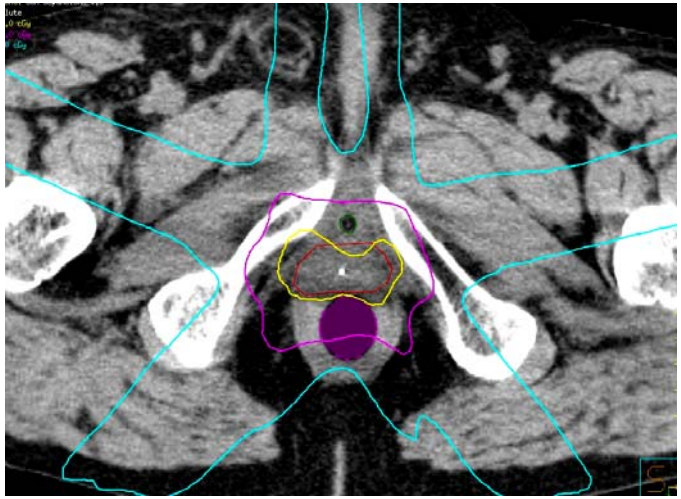
Cyberknife (CI = 1.3), 1 x 30 Gy

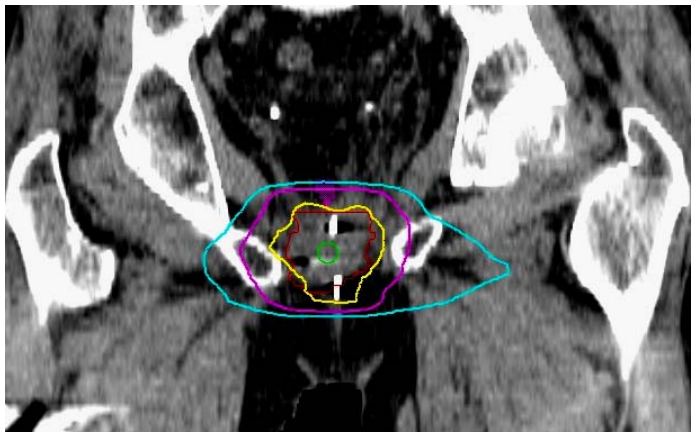


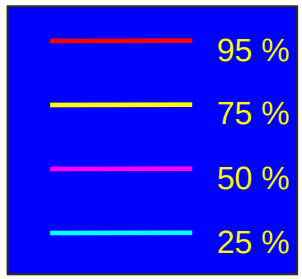


Prostata - Tumor

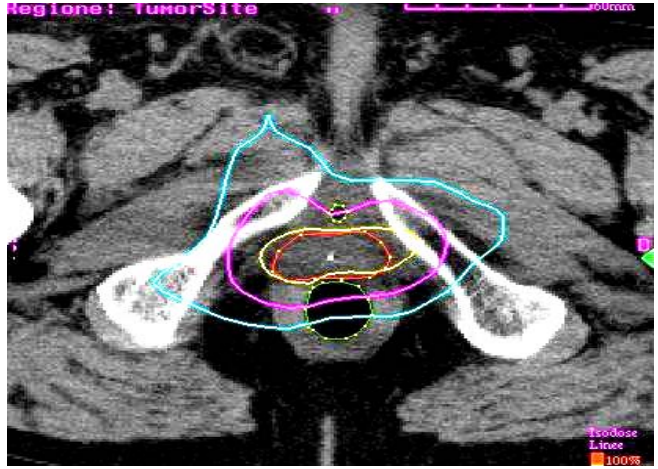
IMRT (CI = 1.8)

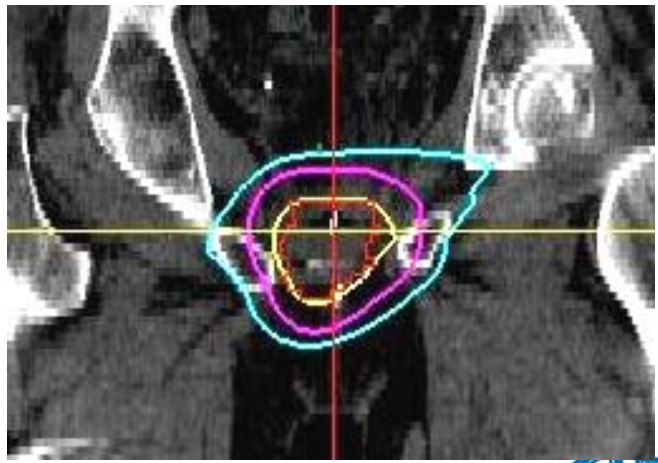




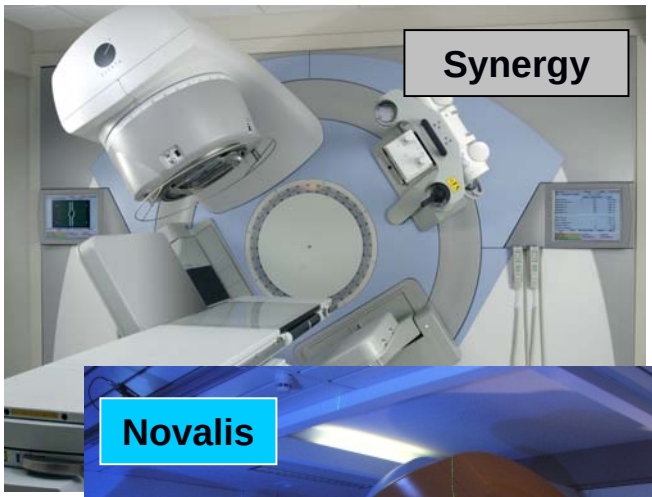


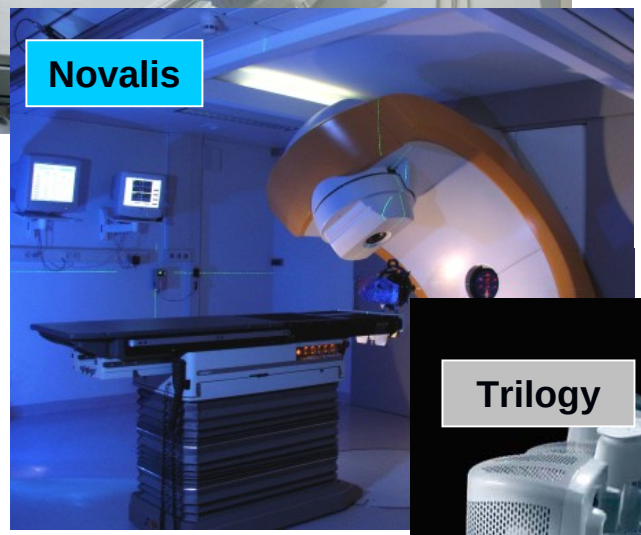
Cyberknife (CI = 1.3), 3 x 10 Gy



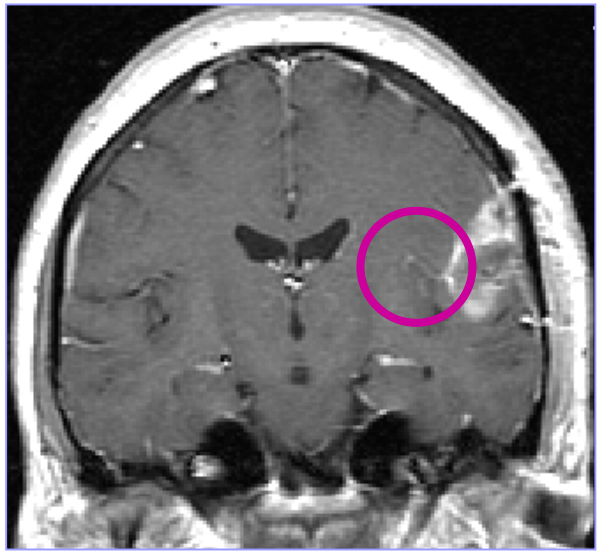


IMRT - Szenario 2005





- schnelleres & genaueres Patienten-Setup
- 100% Gantry-basierte Systeme (6 MV)
- Genauigkeit ca. 2.5 mm (nur bei Setup)
- keine bildgeführte Korrektur (Unterbrechung der Bestrahlung notw.)
- nur koplanar und isozentrisch



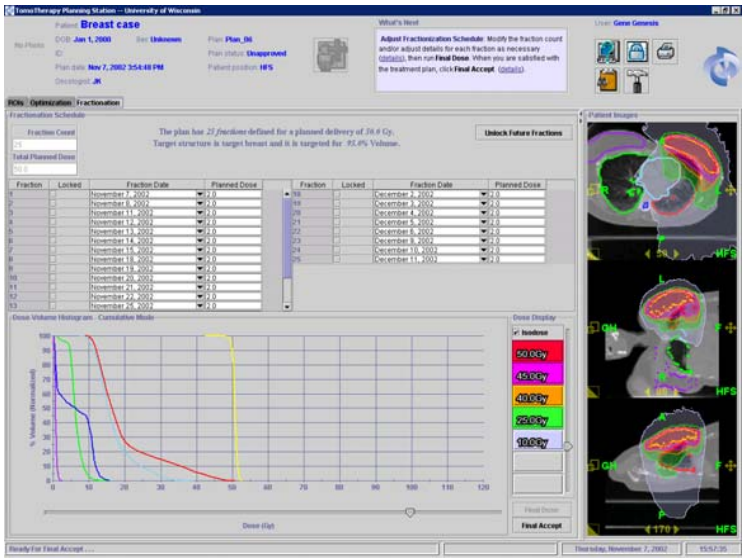
geometrische Schwierigkeiten bei dezentralen Läsionen

SRS - Szenario 2005

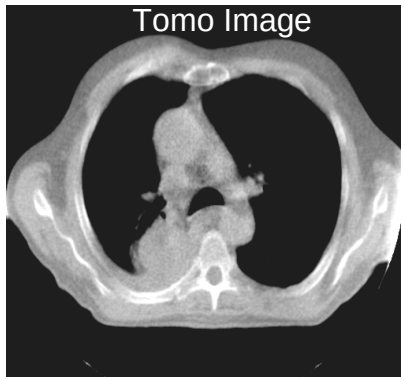
- non-isozentrisch & non-koplanar
- gesamte klinische Genauigkeit < 1.0 mm
- 100 % real-time bildgeführte Korrektur
- kont. Bestrahlung bewegter Organe
- Einzel- & Hypofraktionierung
- automatisches Patienten-Setup
- 100 % rahmenlos

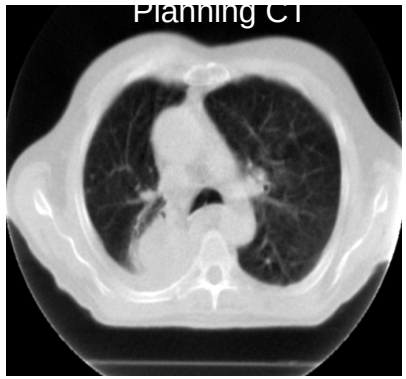

Tomorrow
begins with
Tomo

Tomo Integration: one system from plan, to image guidance, to treatment delivery.



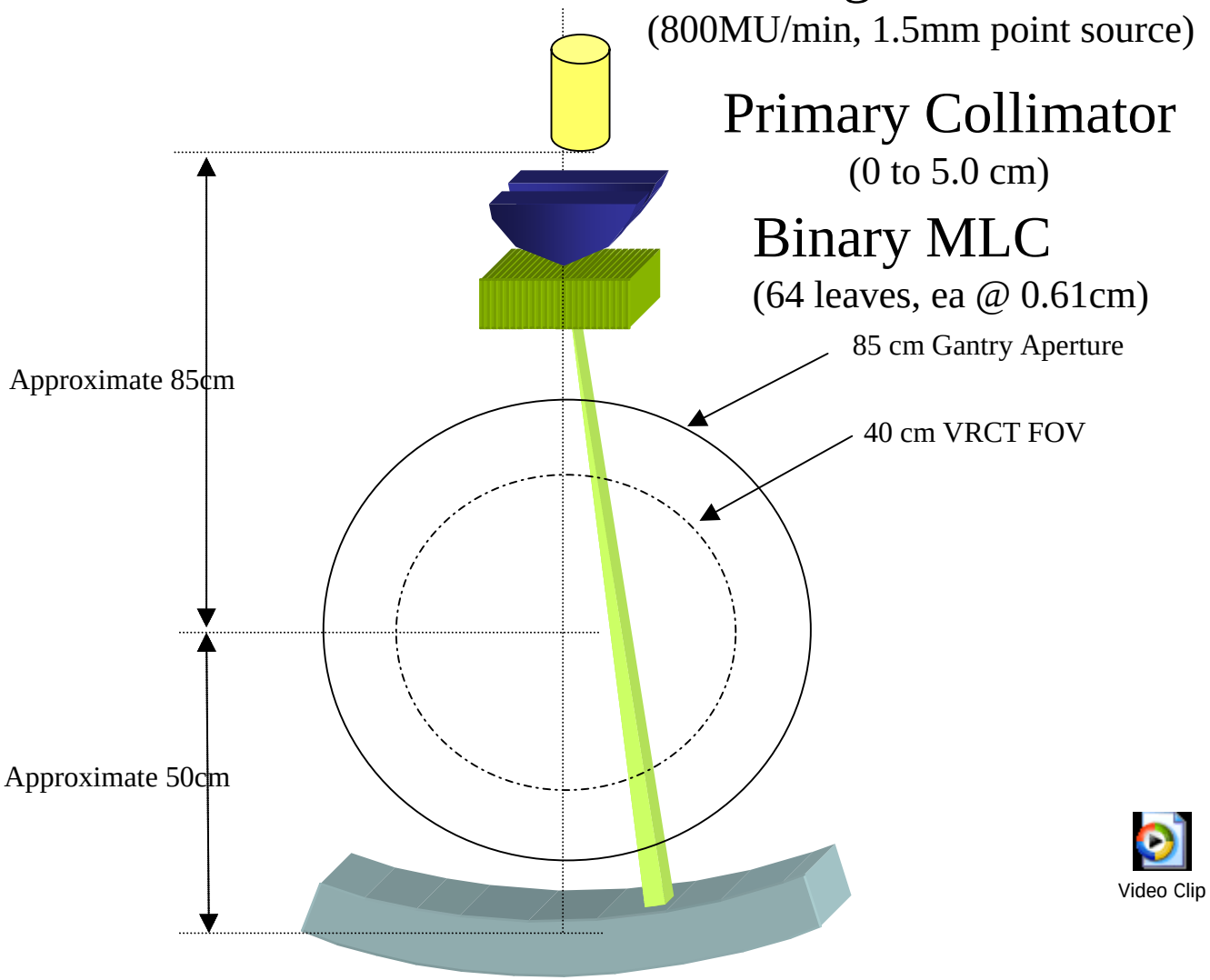
Planning





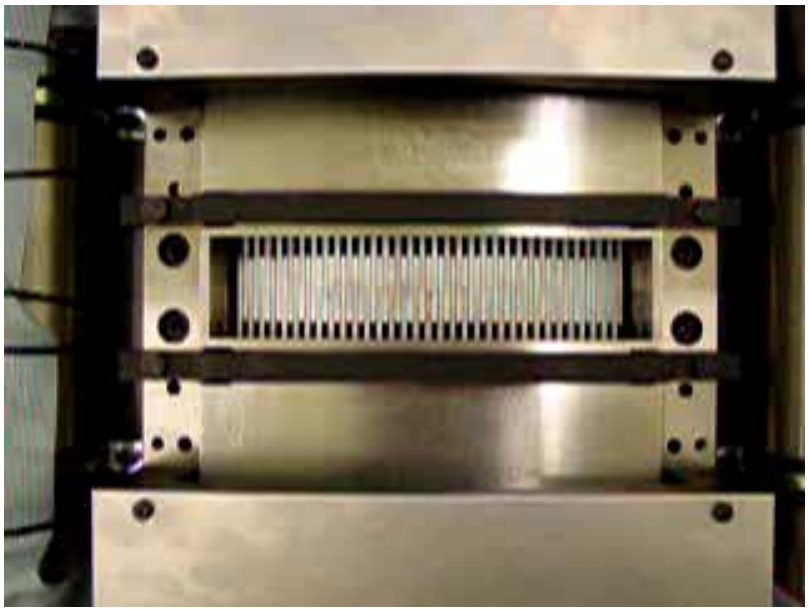
Imaging

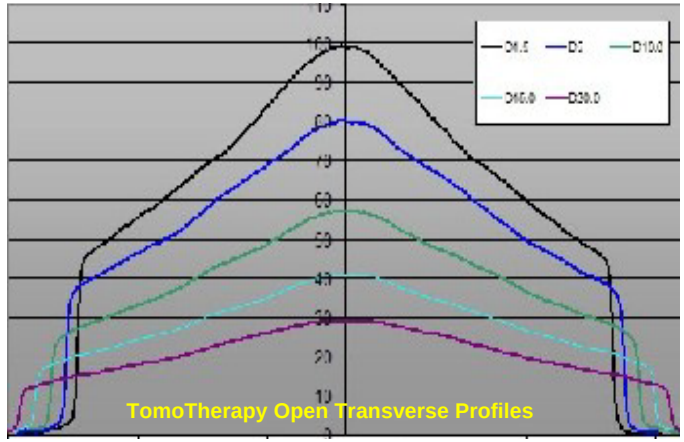
Delivery

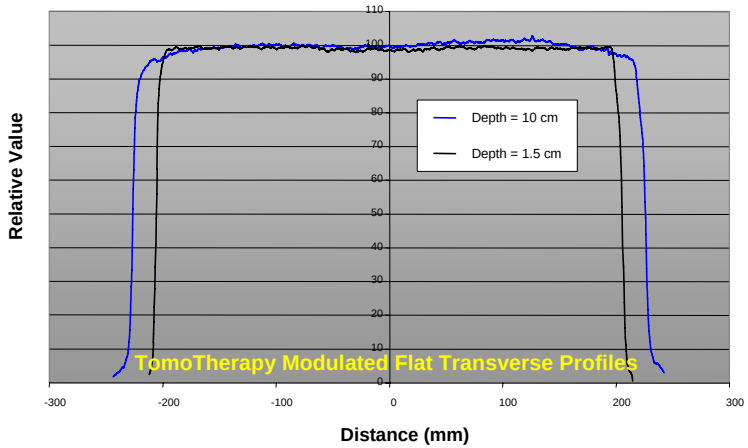


VRCT Detector System

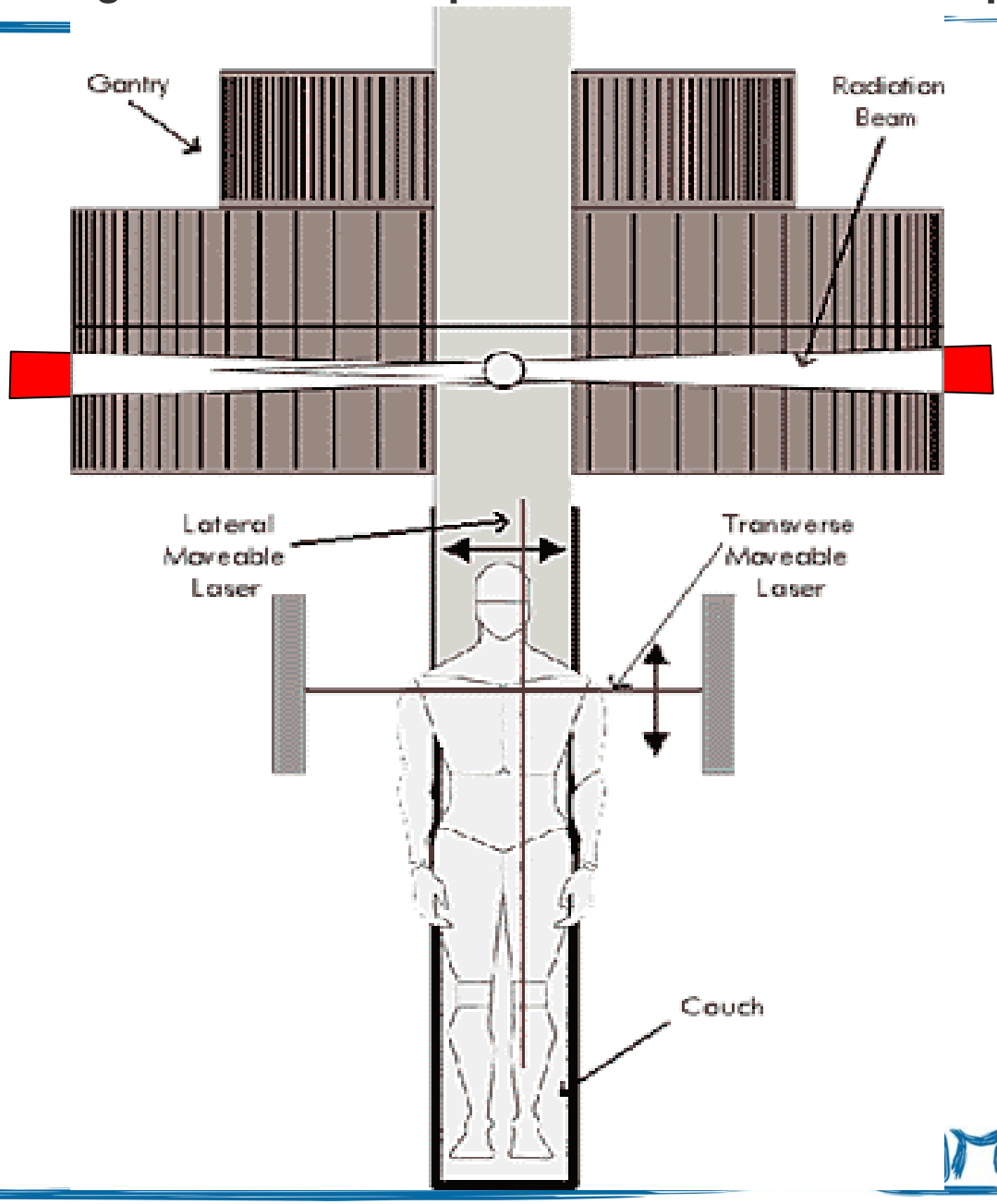
HI-ART Tomotherapy Unit





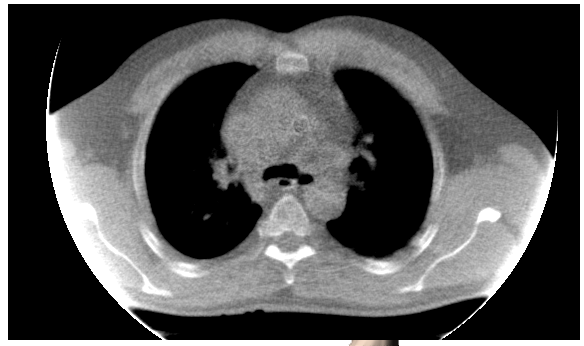


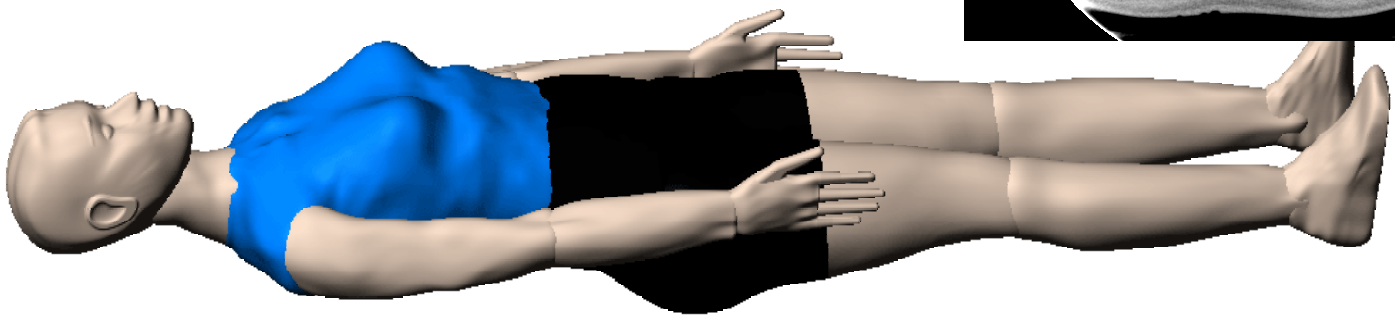
HI·ART
TomoTherapy Unit



TomoTherapy Hi·Art System

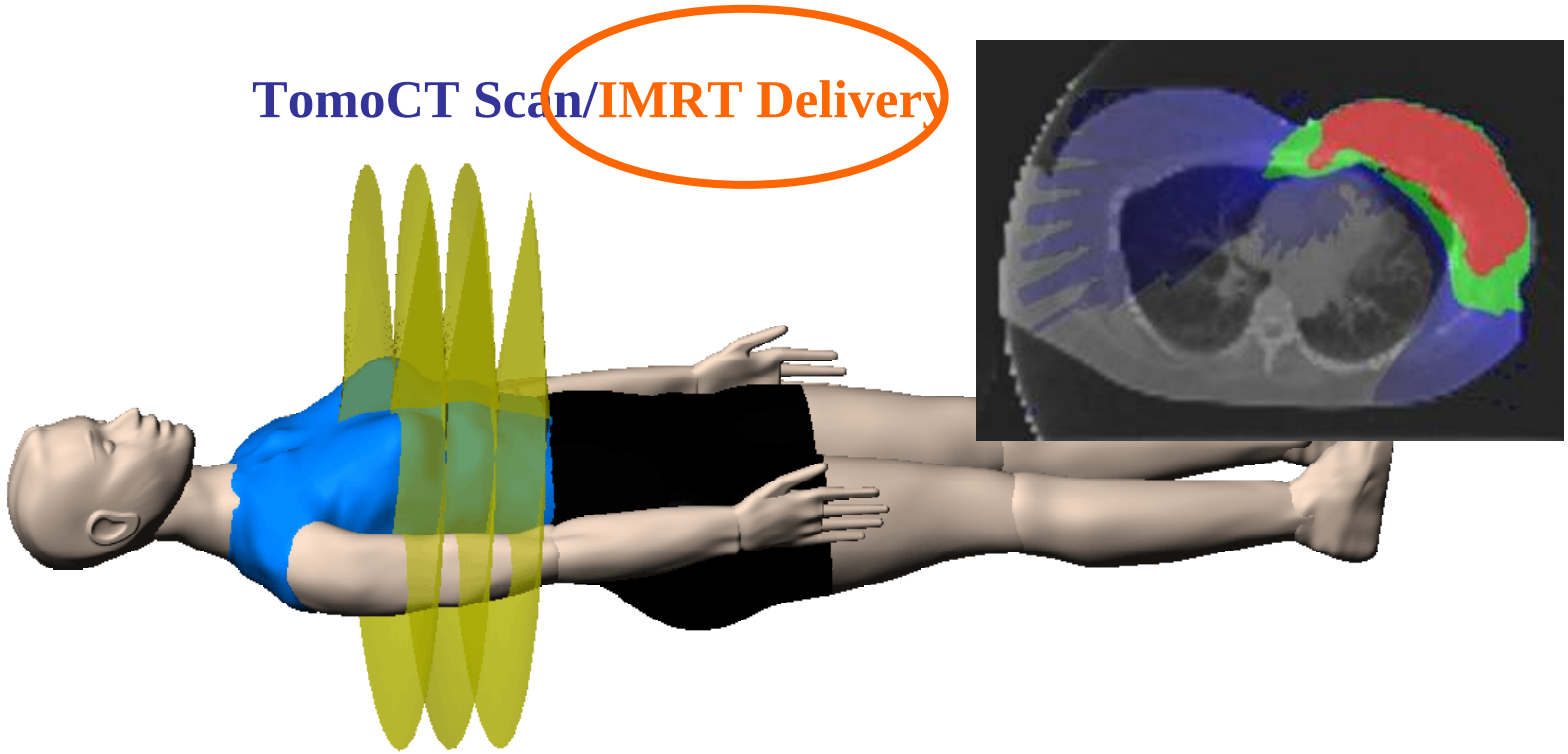
TomoCT Scan/IMRT Delivery





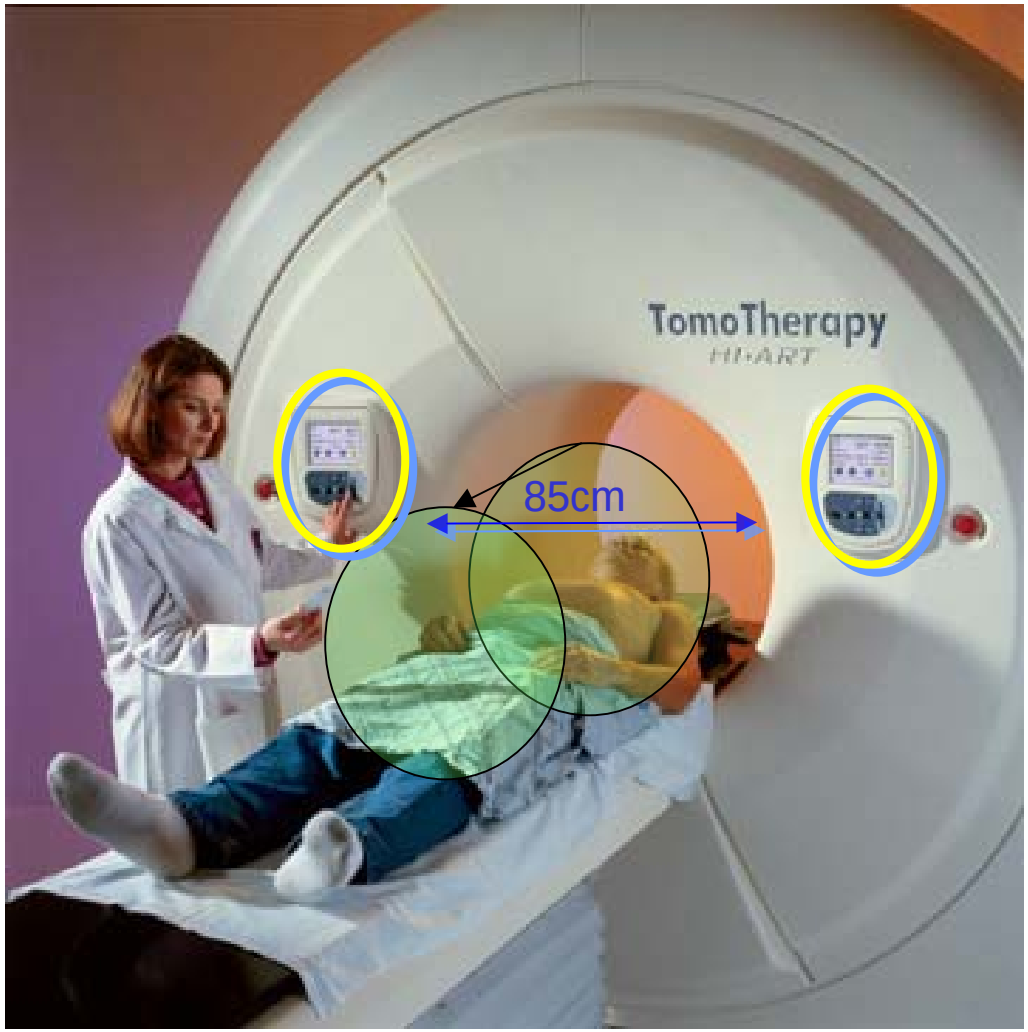
Note: Animation does not represent actual treatment

TomoTherapy Hi·Art System

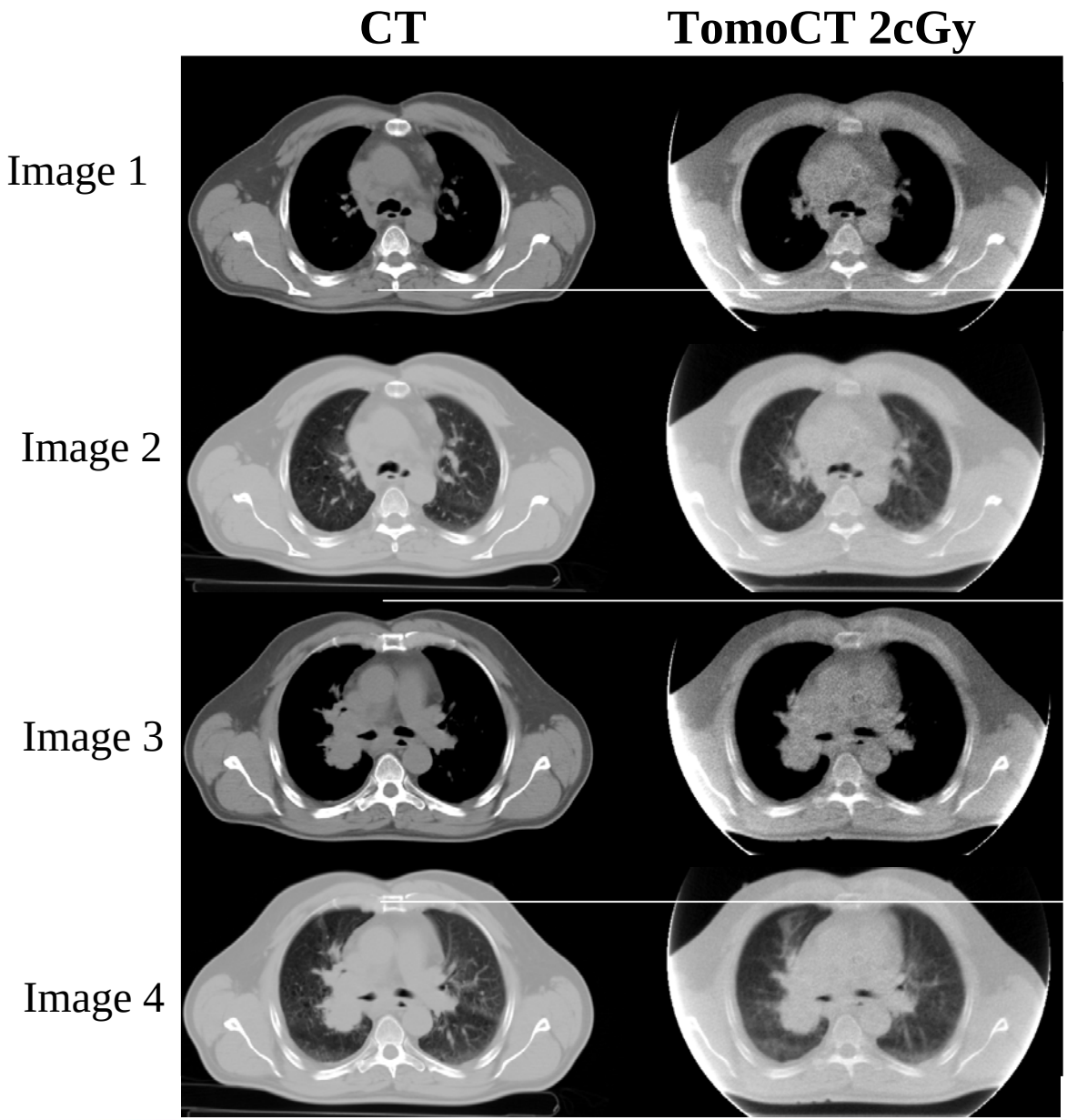


Note: Animation does not represent actual treatment

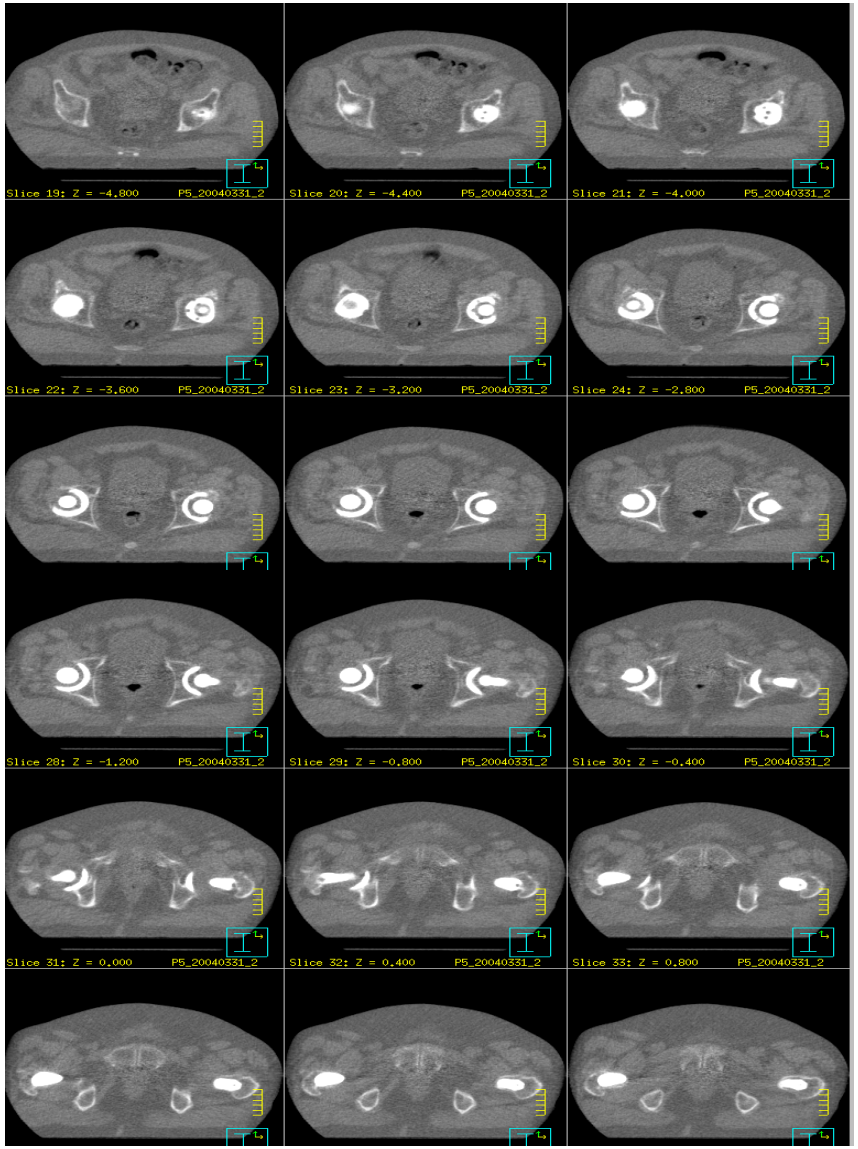
TomoTherapy HI·ART System

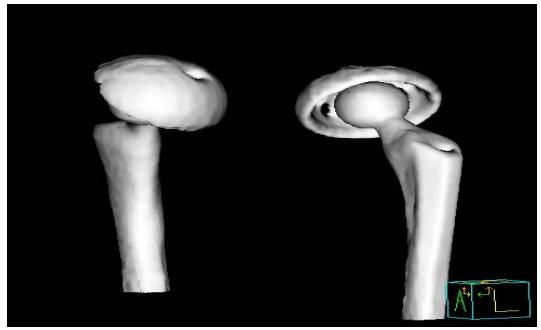


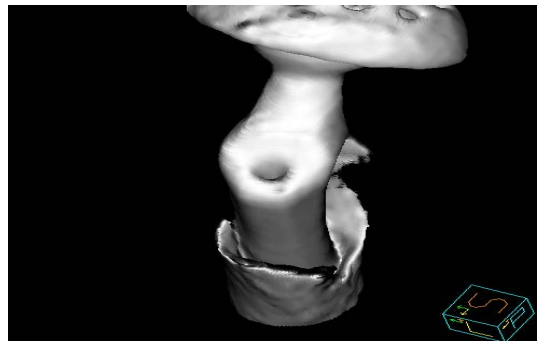
- 85 cm Opening
- 40 cm X 1.6 m IMRT Treatment Field @ Isocenter



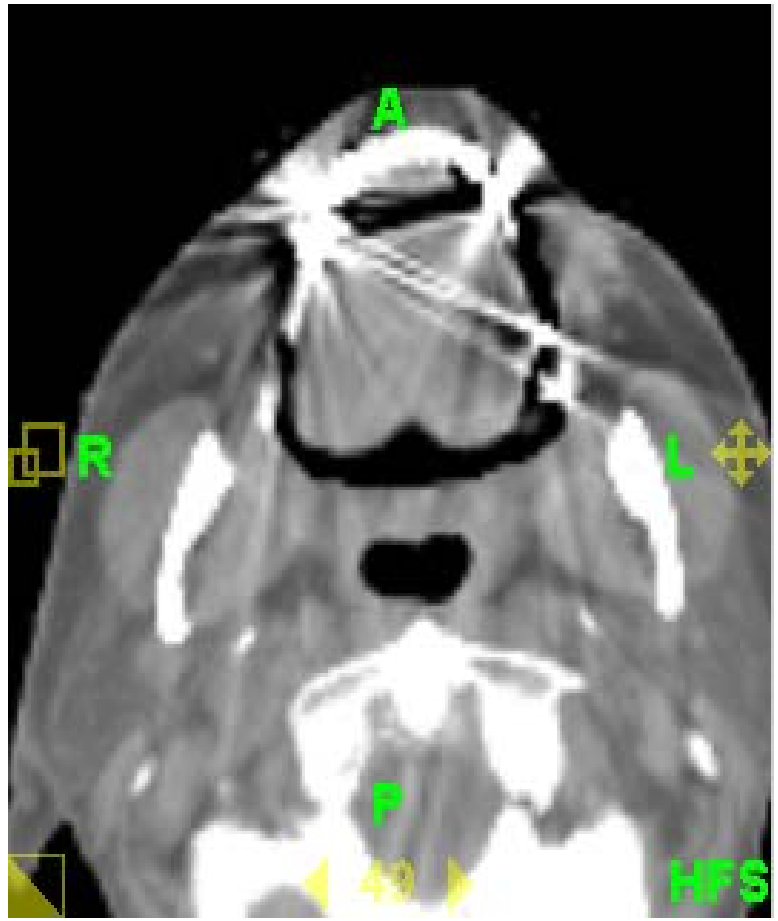
Courtesy of University of Wisconsin


Slice 19: Z = -4.800 P5_20040331_2
Slice 20: Z = -4.400 P5_20040331_2
Slice 21: Z = -4.000 P5_20040331_2
Slice 22: Z = -3.600 P5_20040331_2
Slice 23: Z = -3.200 P5_20040331_2
Slice 24: Z = -2.800 P5_20040331_2
Slice 28: Z = -1.200 P5_20040331_2
Slice 29: Z = -0.800 P5_20040331_2
Slice 30: Z = -0.400 P5_20040331_2
Slice 31: Z = 0.000 P5_20040331_2
Slice 32: Z = 0.400 P5_20040331_2
Slice 33: Z = 0.800 P5_20040331_2



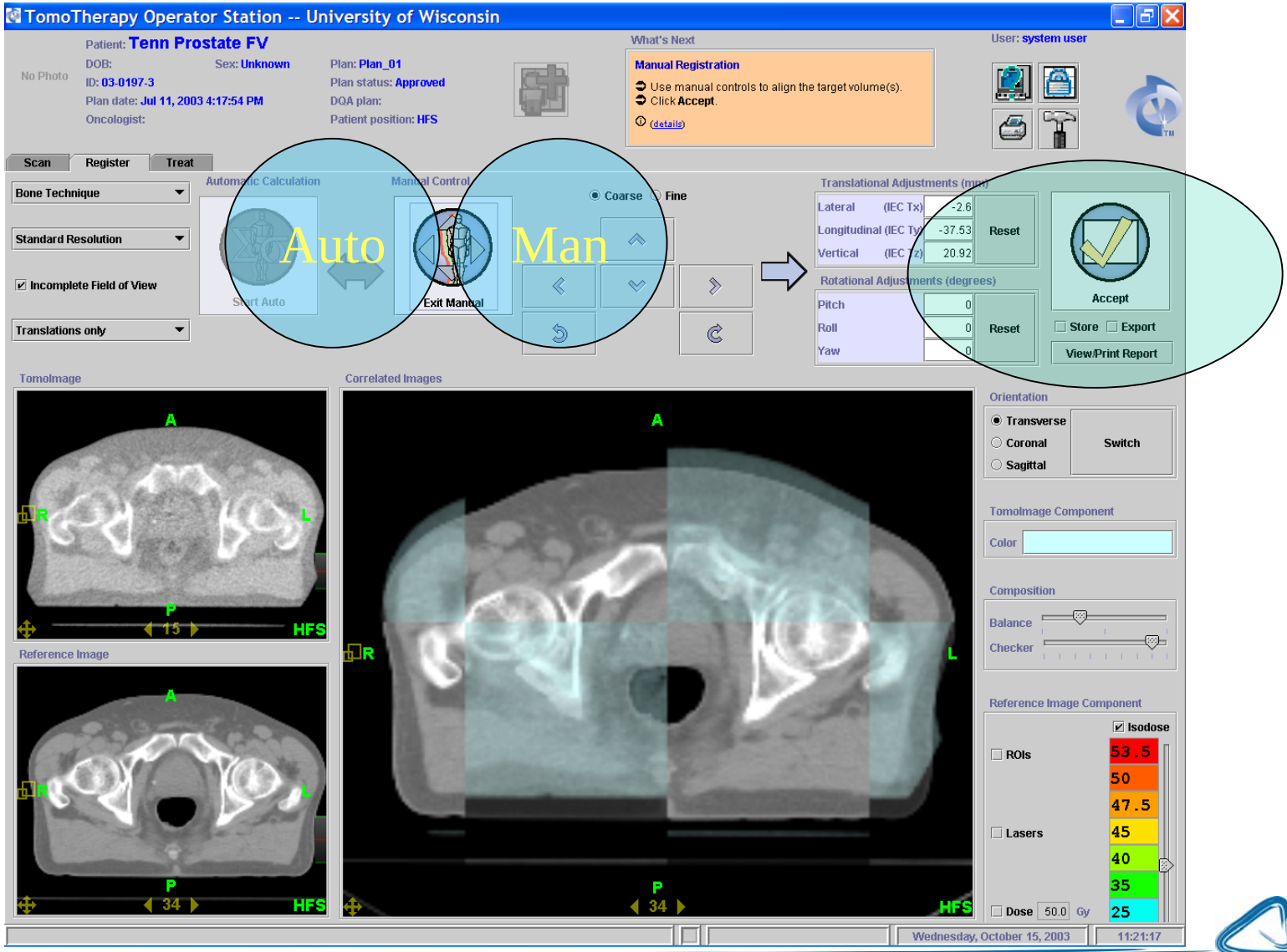


Dental Fillings

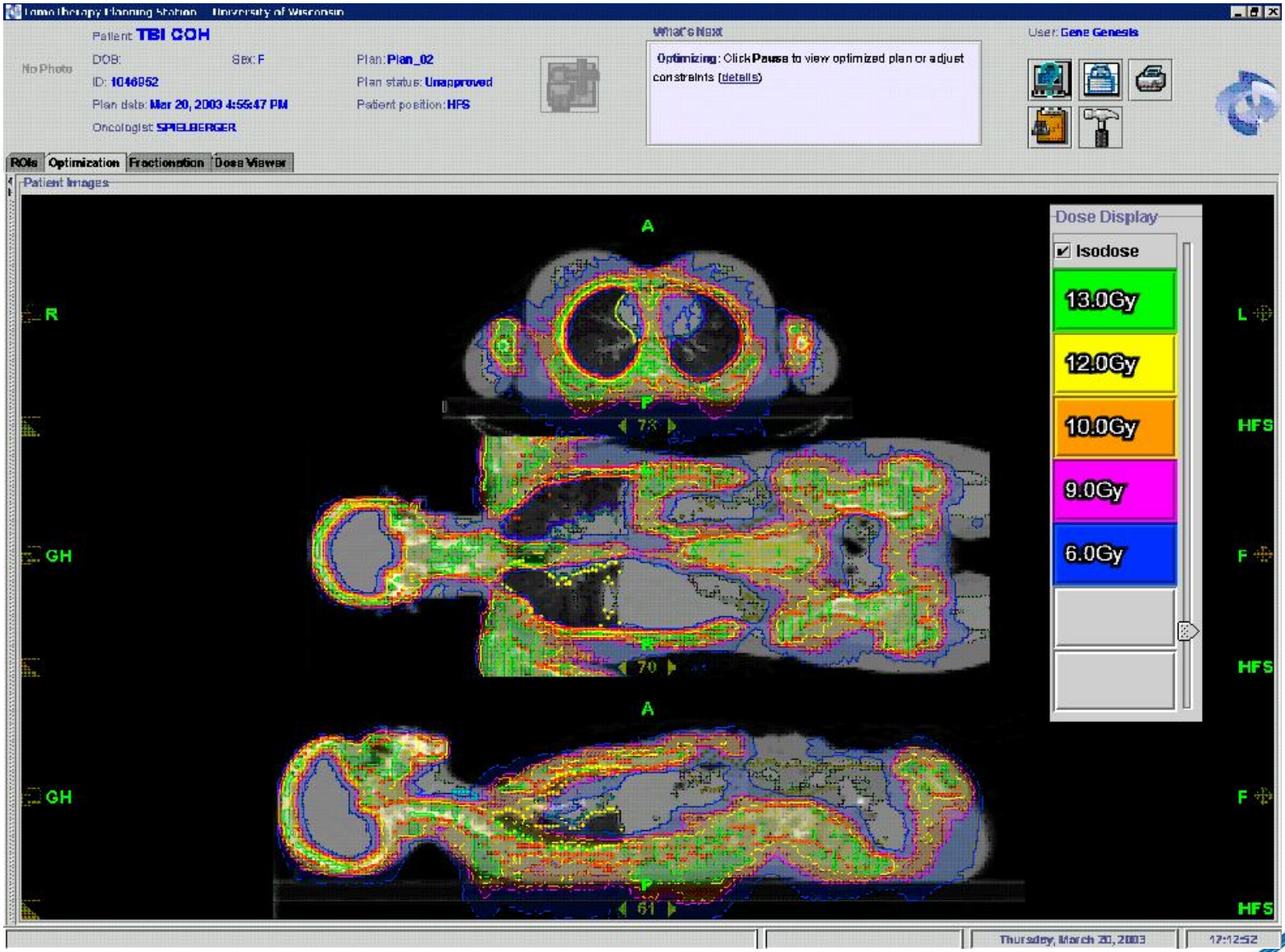


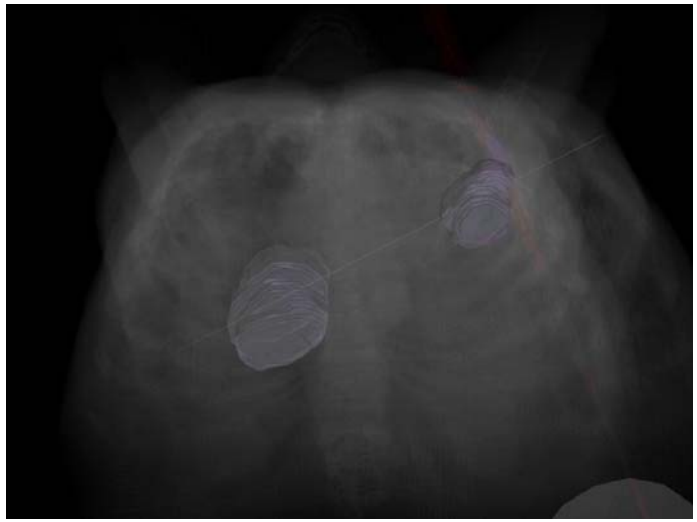
TomoCT **kVCT**

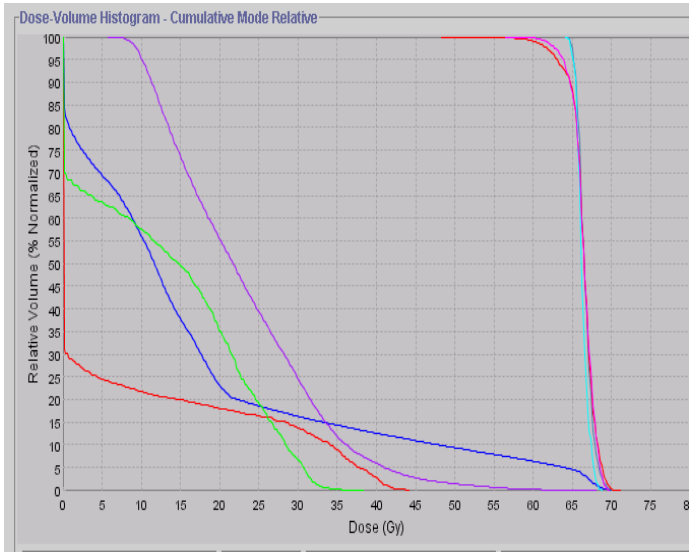
Image Registration CT to TomoCT

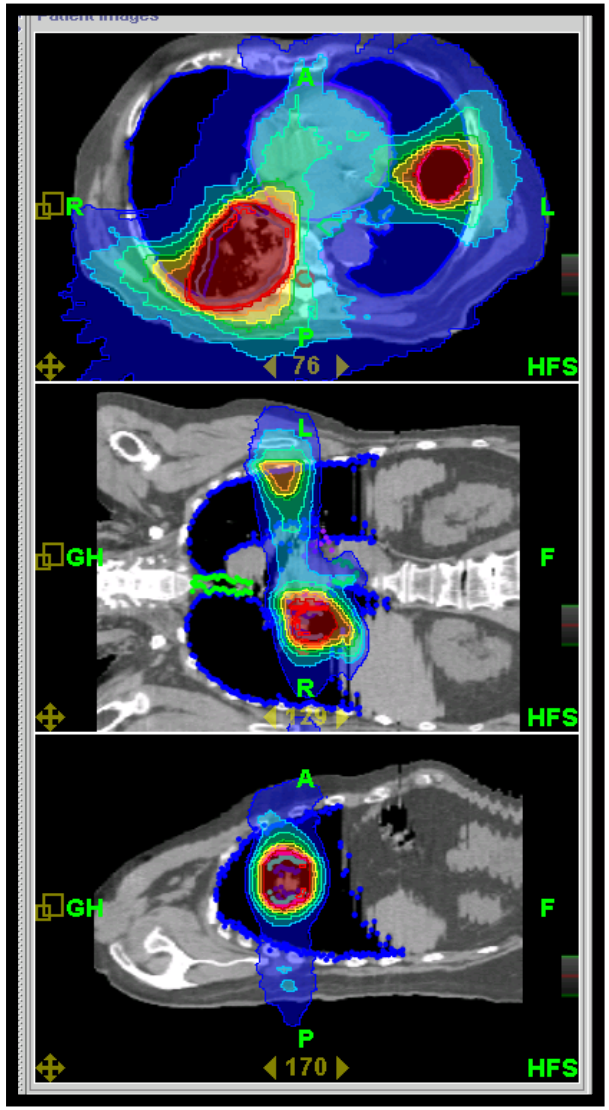


The Tomo Process Delivery:

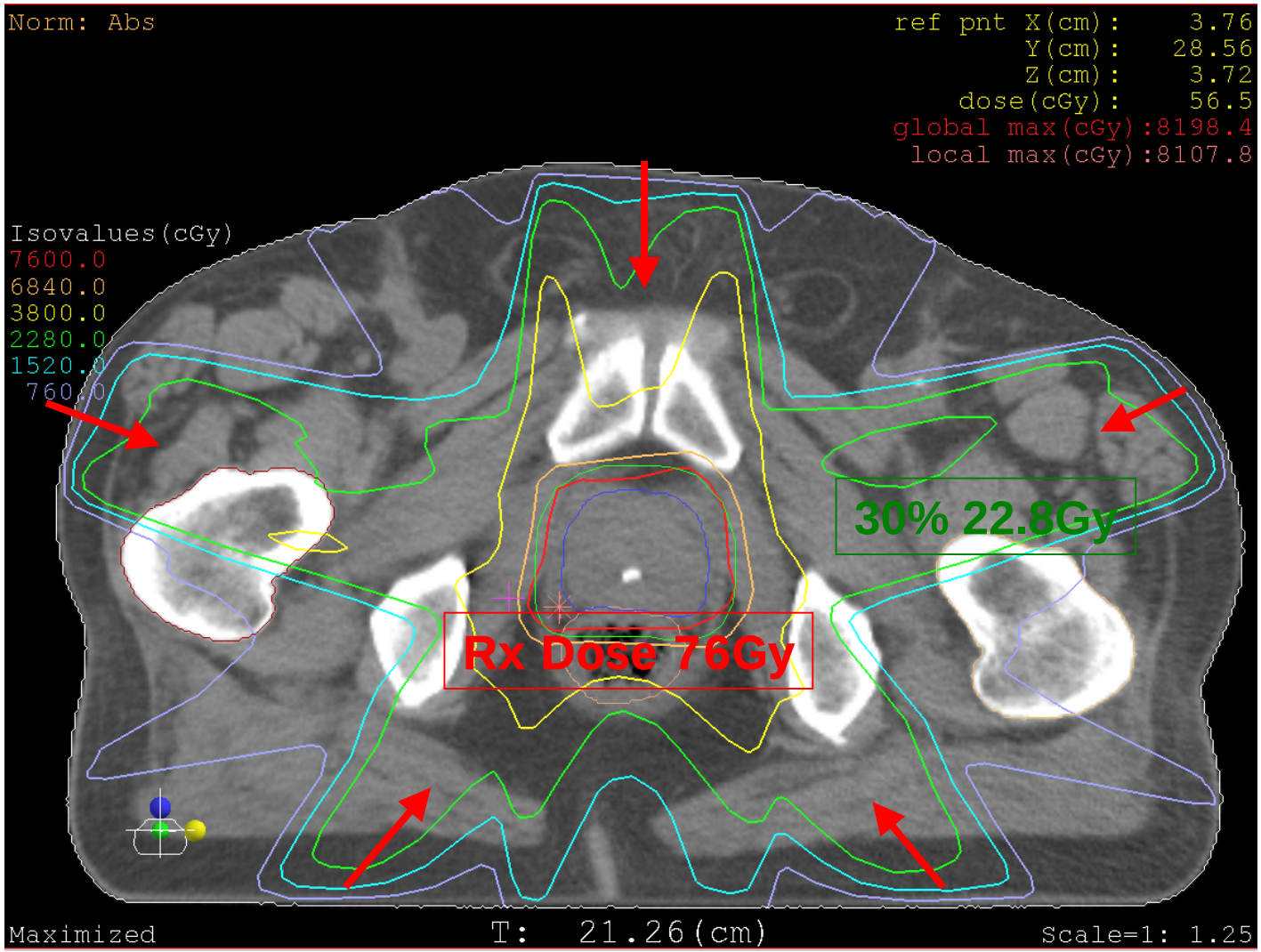

Patient: TBI COH
DOB:
Sex: F
ID: 1046952
Plan date: Mar 20, 2003 4:55:47 PM
Oncologist: SPIELBERGER
Plan: Plan_02
Plan status: Unapproved
Patient position: HFS
What's Next
Optimizing: Click Pause to view optimized plan or adjust constraints (details)
User: Gene Genesis
ROIs
Optimization
Fractionation
Dose Viewer
Patient Images
Dose Display
Isodose
13.0Gy
12.0Gy
10.0Gy
9.0Gy
6.0Gy
A
R
L
HFS
GH
F
P
78
70
61
Thursday, March 20, 2003




Dose-Volume Histogram - Cumulative Mode Relative
Relative Volume (% Normalized)
Dose (Gy)

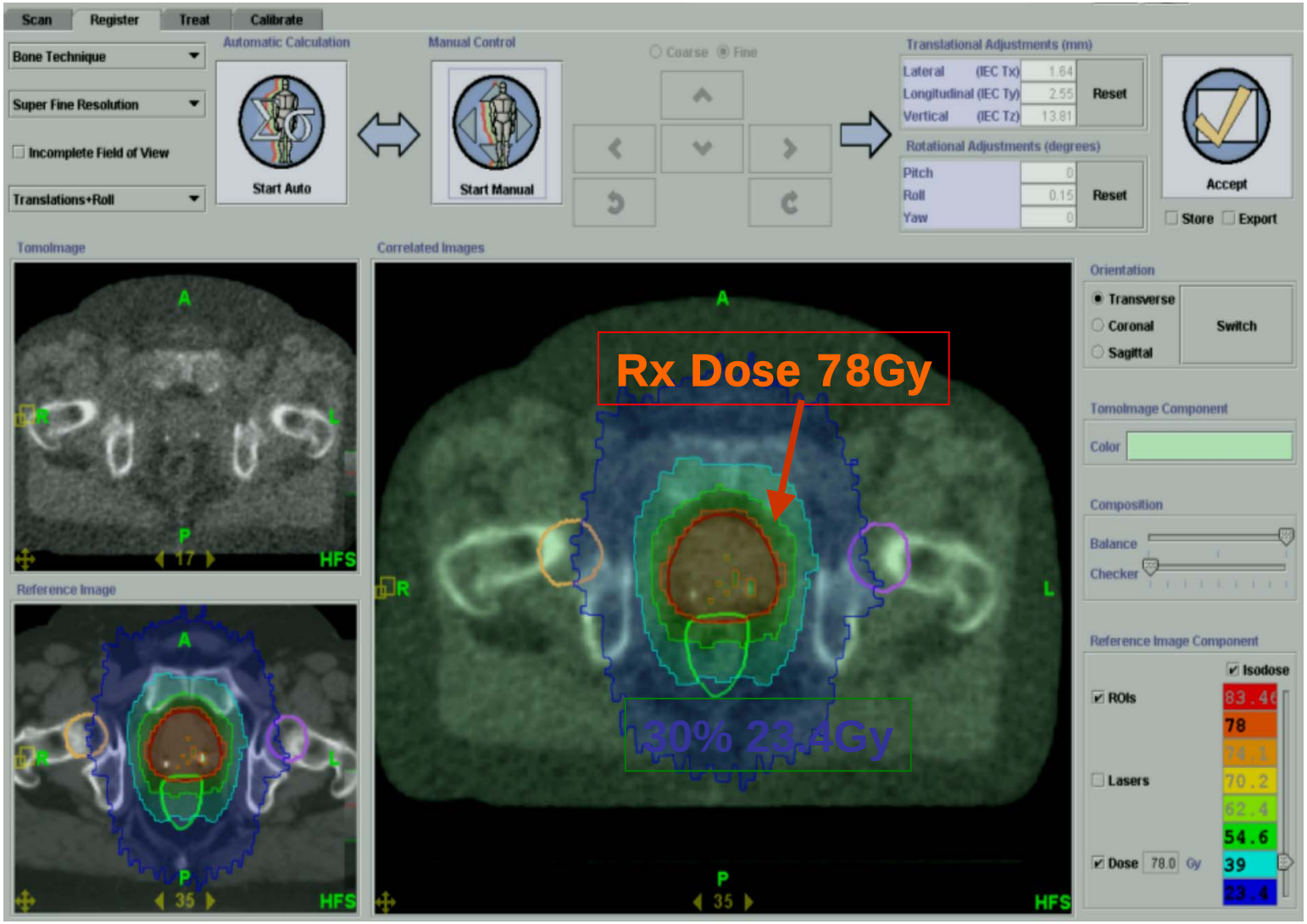

A
R
L
P
76
HFS
L
GH
F
R
129
HFS
A
GH
F
P
170
HFS
69
63
57
50
45
35
25
15

Conventional 5 Field IMRT Plan

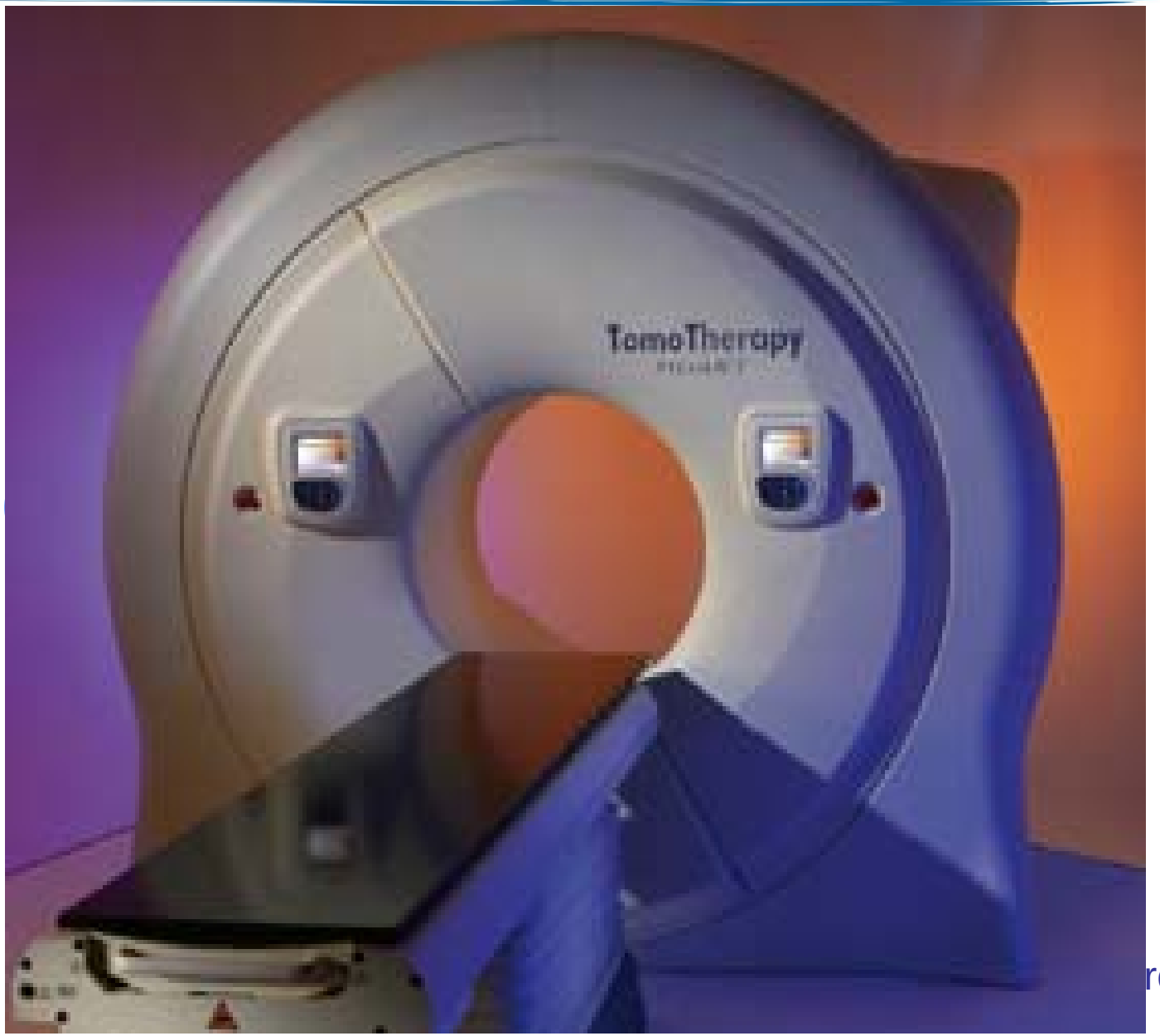


Courtesy Dr. N Mohideen, M.D., Stephanie King, CMD, LUMC

TomoTherapy Helical IMRT Plan



Courtesy Dr. Patrick Kupelian M.D., MD Anderson, Orlando, FL



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Moderne Bestrahlungstechniken der perkutanen Strahlentherapie