



Daily Localization: EPID & MV Cone-Beam CT

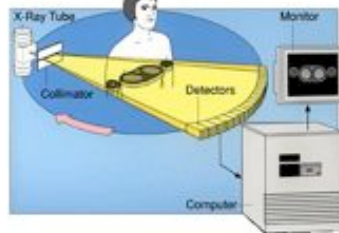
Jean Pouliot, Ph.D.

Professor
UCSF Comprehensive Cancer Center
San Francisco

- **Description of MVCBCT**
 - Fan Beam vs Cone Beam
 - Basic Principles and Characteristics
 - Image Samples
- **Workflow of IGRT with MVCBCT**
 - Acquisition, Reconstruction & Registration
 - Absolute Positioning & Alignment Precision
- **Clinical Applications**
 - Patient positioning
 - Monitoring of anatomical changes
 - Target delineation with CT non-compatible objects
 - Tomosynthesis, Brachytherapy, etc.
 - Dose calculation to assess dosimetrical impact (DGRT1)
- **Dose-Guided Radiation Therapy (DGRT1 and DGRT2).**

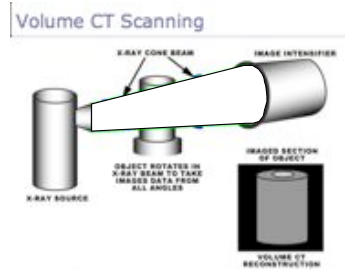
Basic Principles of MV CBCT

Fan beam CT



1 slice per rotation

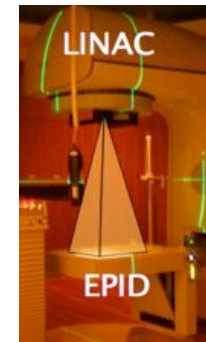
Cone-beam CT



Entire volume in 1 rotation

Basic Principles of MV CBCT

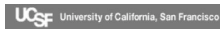
- MVision™ generates a 3D image of the patient anatomy from the same x-ray beam (6MV) used for treatment.
- Image and x-ray beam share the same isocenter.
- Patient 3D anatomy in treatment position, moments before dose delivery.



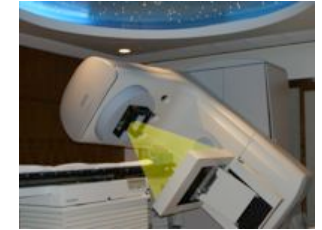
MV CBCT: Main Features

- Very low dose-rate linac beam (0.005 M.U. per degree)
- Beam Pulse Triggered Acquisition Mode (Synchronized pulse-panel readout)
- High sensitivity a-Si Panel EPID (Optimized for MV)
- Integrated workstation: EPID deployment, image acquisition, reconstruction, fusion with CT, patient alignment, treatment delivery

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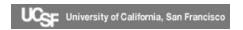


Basic Characteristics of MV CBCT

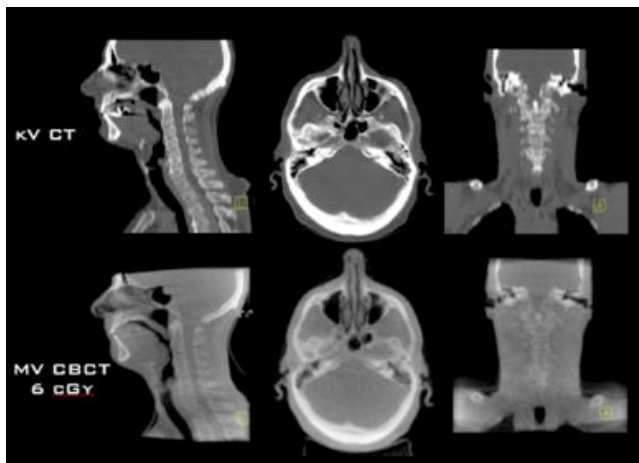


- Half rotation: 200 degrees
- Acquisition ~ 45 seconds
- Acquisition + Reconstruction < 2 min.
- 27 cm x 27 cm x 27 cm Field of View
- Volume of 256 x 256 x 270
- Pixel size (0.5 mm)³
- Typical dose: 2 to 9 cGy
- Accurate Electron Density

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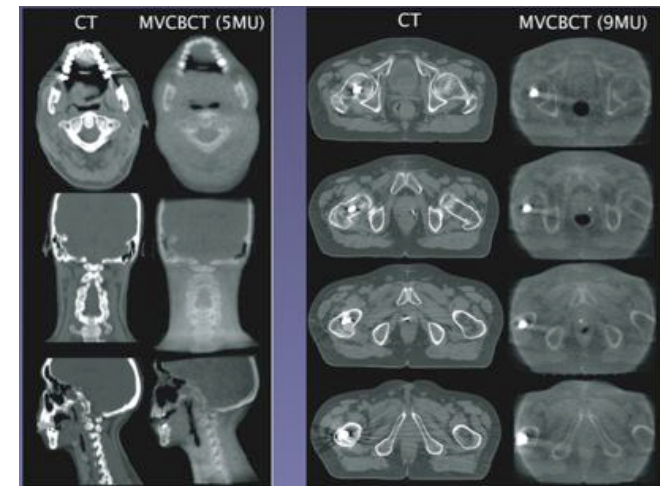
MV CBCT



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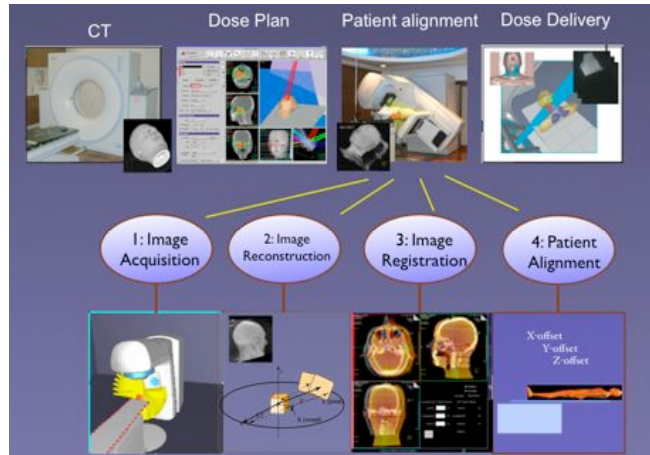
MVCBCT



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MV CBCT / UCSF

Workflow of IGRT with MV CBCT

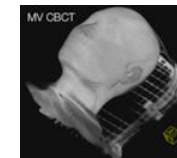
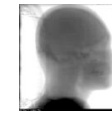


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Workflow of IGRT with MV CBCT

- 1) The patient and the cone-beam acquisition mode are selected at the treatment console.
 - 2) The linac gantry is placed in starting position, namely 270 degrees.
 - 3) During the acquisition, the gantry rotates 200 degrees until it reaches its final position, 110 degrees.
- During the rotation, a portal image is acquired at each degree. The reconstruction of the cone-beam image starts immediately after the first portal image has been acquired.



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MV CBCT - CT Registration

4) Upon completion of the reconstruction image, the cone-beam image is automatically loaded in the Adaptive Targeting Software™, and the CB to CT image registration is performed automatically in few seconds using a mutual information algorithm.



- 5) Proper alignment is validated and manual alignment can be performed when fine-tuning is required.
- 6) The couch translation off-set values required to obtain the best alignment of the patient at isocenter are displayed. The couch is moved remotely from the treatment console according to these values and the patient is ready for treatment.

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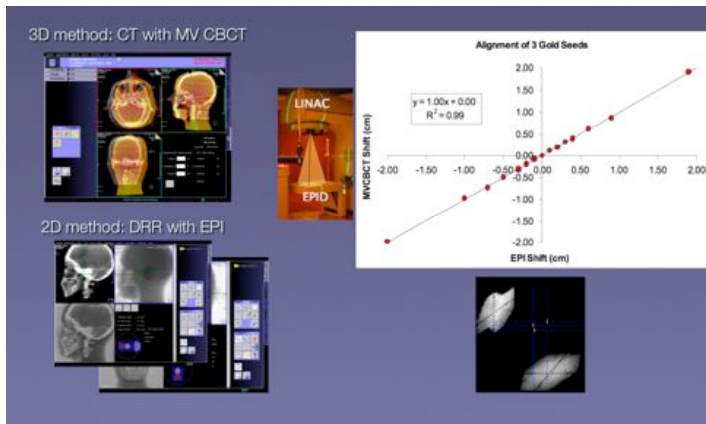
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Setup Methods



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2D vs 3D Setup Methods

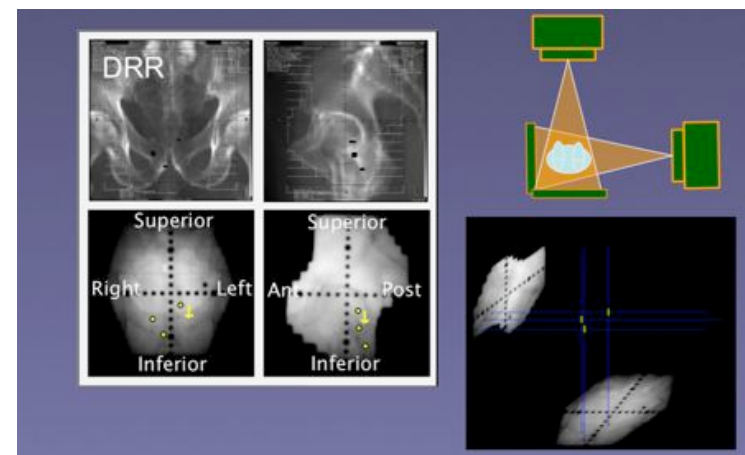


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Patient positioning

- Head & Neck
- Lung
- Spine
- Chest
- Breast
- Prostate

Daily Prostate Alignment EPID + Markers



Prostate Motion Management at UCSF

- Accuracy (Aubin et al. 2002): Global accuracy ~ 1.5 mm
- Patient tolerance to implant (Downs et al. 2002): Side effects < biopsy
- BAT vs. EPID (Langen et al. 2003): User variability
- Visibility of Markers (Aubin et al. 2003): 1 x 3 mm
- Migration & Positional Stability (Pouliot et al. 2003): sigma ~ 1.3 mm
- Obese patients (Millender et al. 2004): Patient setup > organ motion
- Post-Prostatectomy (Schniffer et al. 2005): . . . Prostate bed moves, but less
- Intra-fractional motion (Lometti et al. 2006): Minutes, not seconds
- Long-term f-up w/ MRS (Pickett et al. 2006): . . . Shorter metabolic atrophy

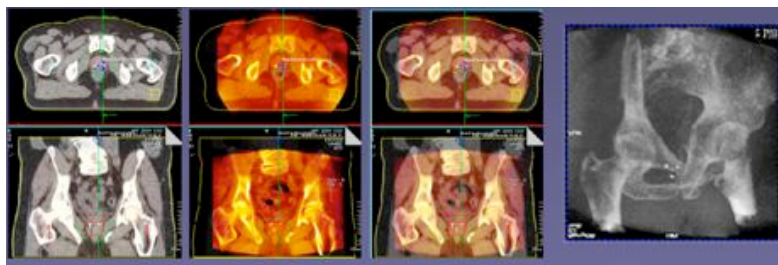
Intra-Fractional Prostate Motion Study

- Prostate is stable during short time periods (i.e. radiation delivery)
- Prostate motion more likely during longer time periods (i.e. between setup and radiation delivery)
- Motion appears to be due mostly to gas in the colon/rectum
- Respiration has little effect on organ motion

* Results of this study submitted to IJROBP May 2006

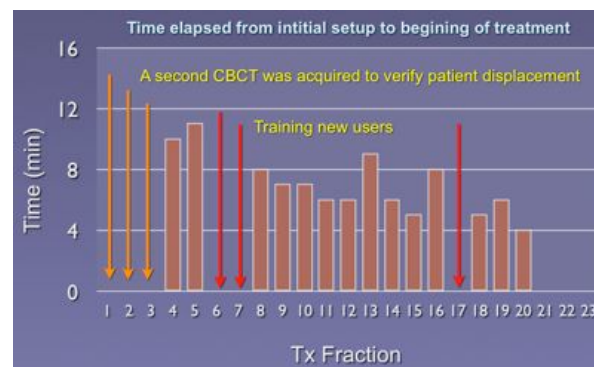
Prostate Alignment with MV CBCT

Reference CT MV CBCT 50% Blend
CT-MV CBCT



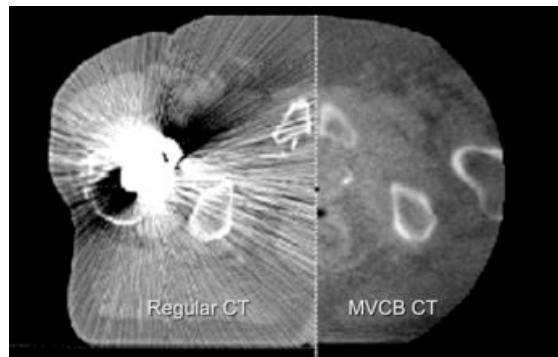
Provides additional information over EPID+markers:
 - Rectum, bladder, etc.
 - Prostate contours -> DGRT1

Time required for IGRT with MVCBCT Daily prostate alignment



Hip Prosthesis

Complementing CT with MVBCT for planning purpose



Organ Segmentation with Hip Prosthesis



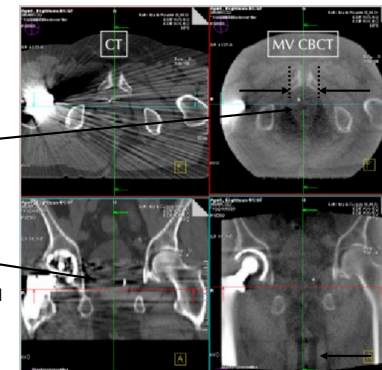
"In 2005, in Europe and U.S., more than 500,000 hip joints have been replaced."

The US Academy of Orthopedic Surgeon

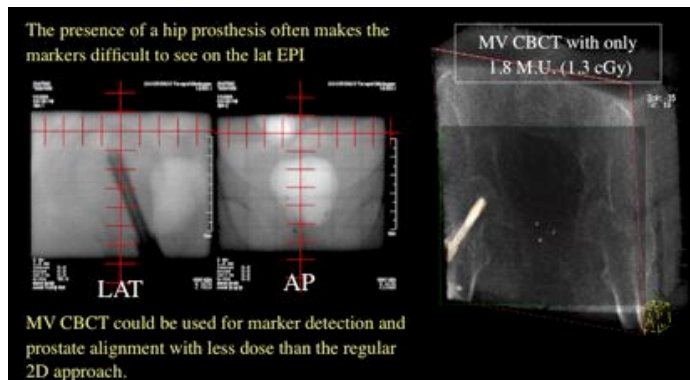
The MV CBCT images are particularly useful to help delineating:

- The anterior rectum wall.
- The lateral extension of the prostate in the median plane.
- The bladder neck

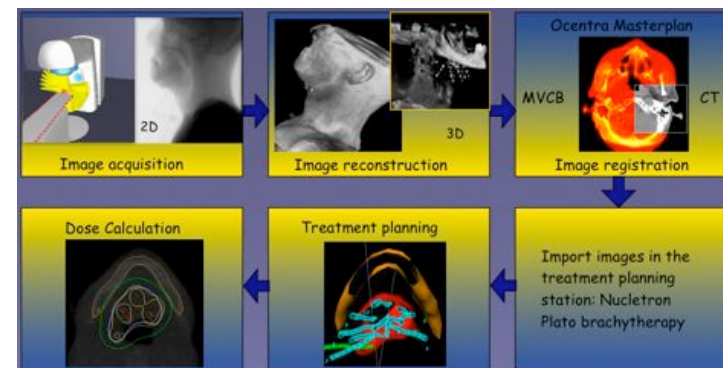
The prostate volume contoured with the help of MV CBCT was often smaller than what could be guessed from the regular CT in presence of artifacts, preventing overdosage of the rectum.



Patient Setup: Prostate

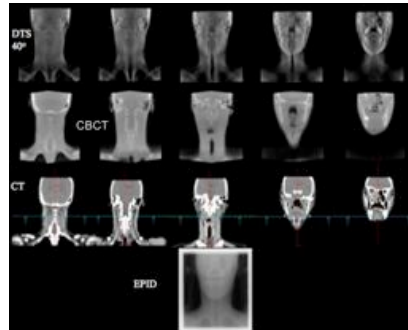


MVCBCT procedure for HDR Brachytherapy



M. Descovich, ABS-2006

Digital Tomosynthesis (DTS)



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Paraspinous Tumors

Case report

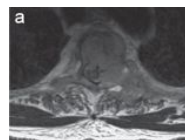
- Surgery + supporting hardware + post-op IMRT
- Spinal cord tolerance limits Dx (palliative)
- Image hardware artifact
 - impairs target delineation
 - hinders treatment verification
- MV CBCT -> Target definition
 - > Daily 3D patient alignment
 - > Improved confidence Px (curative)

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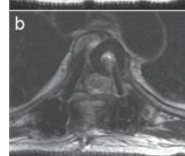
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Treatment of Paraspinous Tumors in the Presence of Orthopedic Hardware

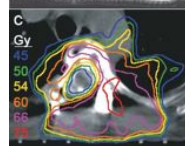
a. Preoperative T2
fat spin-echo MRI



b. Postoperative
pure T2 MRI with
image artifact



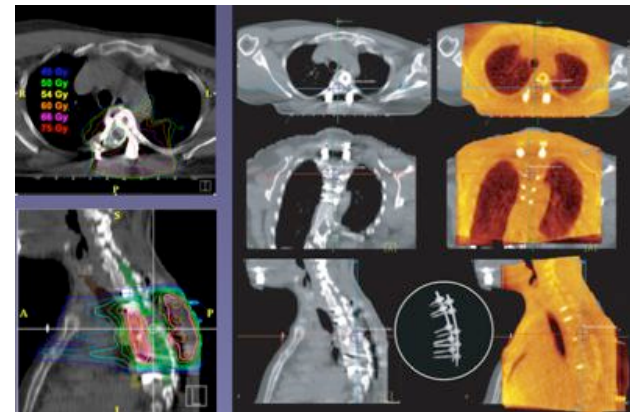
c. IMRT Plan
with 9 axial beams



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IGRT with MVCBCT of Paraspinous Tumors in the Presence of Orthopedic Hardware

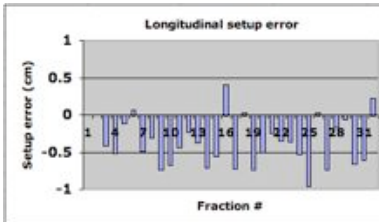
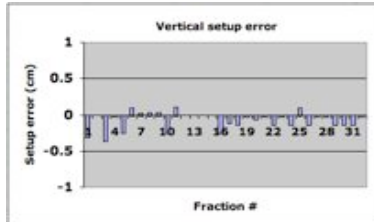
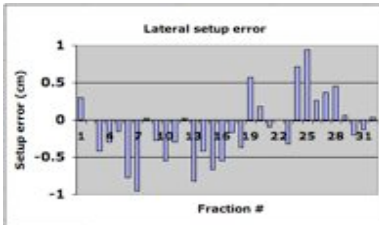


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Paraspinous Tumors: Patient Setup Case Report

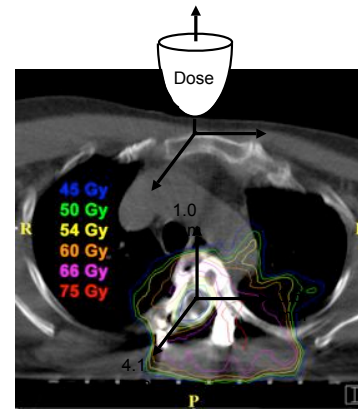
Daily Setup Errors (cm)



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Paraspinous Tumors: Dosimetric Impact



Without daily corrections:
(simulated in TPS)

Maximum dose ($D_{0.1cc}$) to Spinal cord
would have increased from 51 to 61 Gy.

The CTV coverage decreased by 5 Gy.

Daily setup errors detected via MV CBCT were critical for both protection of spinal cord tolerance and maintenance of CTV coverage.

Hansen *et al.*, Int. J. Radio. Biol. Phys. 2006, in press

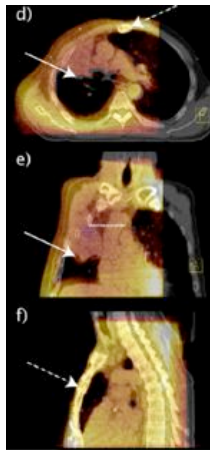
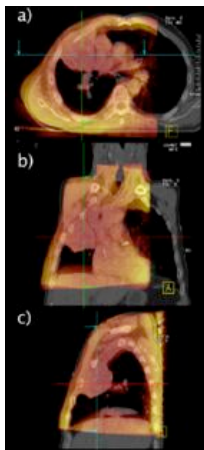
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MVCBCT: Lung

Aligned with MV CBCT

Aligned according
to EPI



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Positioning: Patients

- 8 patients treated for head and neck cancers
- 18 pairs of 2D portal images corresponding to MV CBCT from same day
- Isocenter shifts calculated (2D: DRR vs. EPI, 3D: planning CT vs. MV CBCT)
 - 3D: best overall bony alignment
- Isocenter shifts compared 2D to 3D

Gillis, A., *et al.* IJROBP, Volume 63, 1 October 2005, Pages 2251-2256

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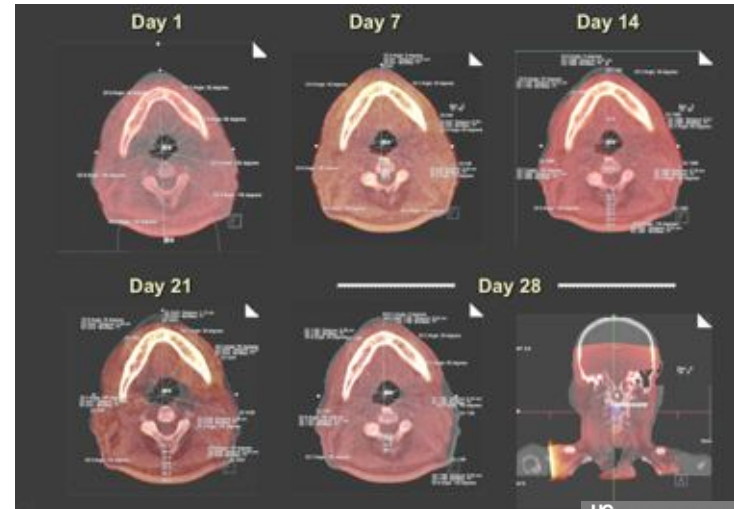
Patient setup: Head & Neck



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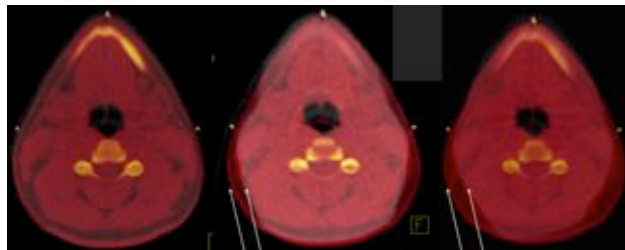
Monitor Weight Loss



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Anatomic Change: Weight Loss



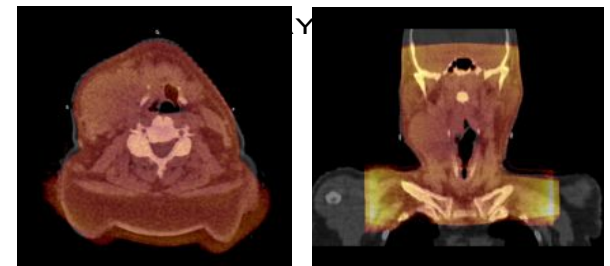
Day 0

➤ Changes more subtle, but significant if posterior beams used

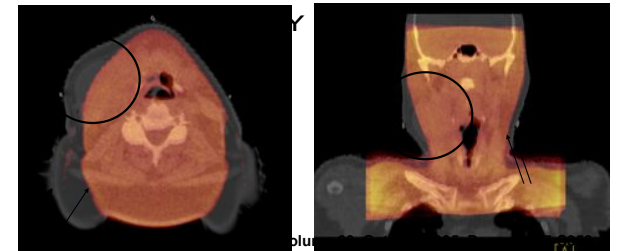
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Anatomic Changes

➤ Weight Loss



➤ Tumor shrinkage



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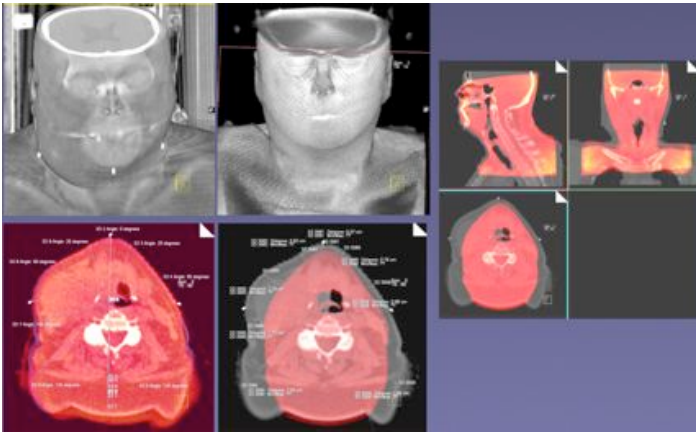
plus

(X)

Is it time to replan yet ?

3D rendering of CT

3D rendering of MV CBCT



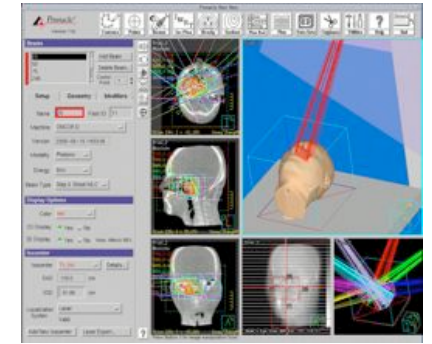
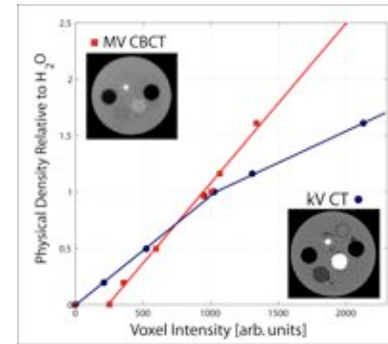
Day 1

Day 23

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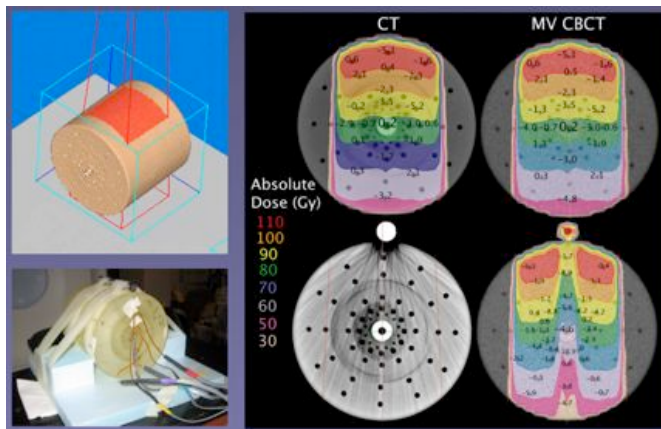
Dose Calculation using MV CBCT



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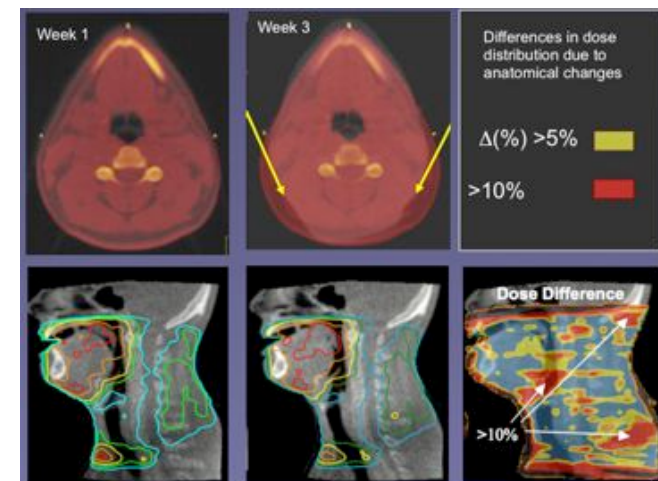
Dose Calculation using MV Cone-Beam CT



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Dosimetrical Impact of Weight Loss



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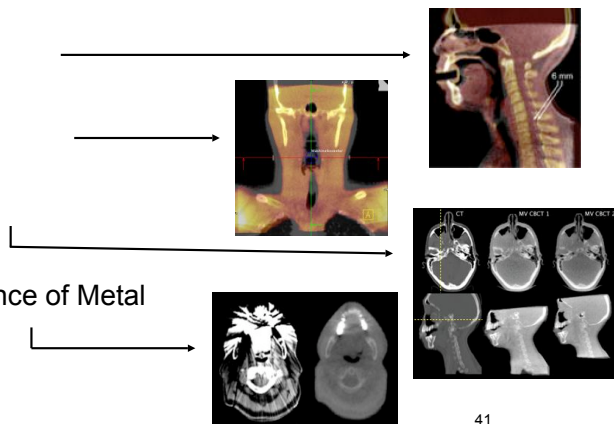
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Dose Calculation

Using MV Cone-Beam CT
(DGRT1)

To verify the dosimetrical impact of patient anatomy variations during the course of external beam radiation treatment

- Setup Error
- Weight Loss
- Soft-tissue
- In the presence of Metal



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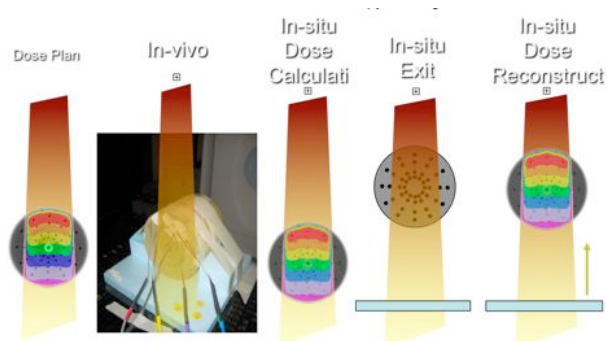
Adaptive Radiation Therapy - ART

- A radiotherapy procedure where, during the course of treatment, any deviations from the planned target location, shape or dose distribution are monitored via image guidance and other techniques and corrected for with the goal that the original prescription is fulfilled or further optimized.

IGRT → DGRT

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Dose-Guided Radiation Therapy Strategies



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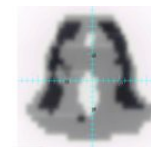
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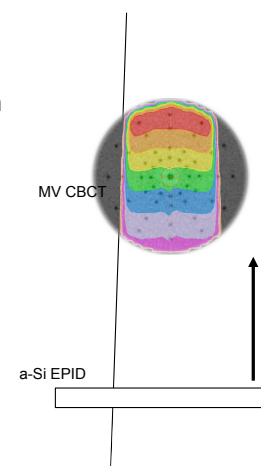
MV CBCT

In-situ Dose Reconstruction (DGRT2)

3D image of patient in treatment position
Immediately before dose delivery,
calibrated for electron density



Delivered energy fluence is measured and backprojected in volume

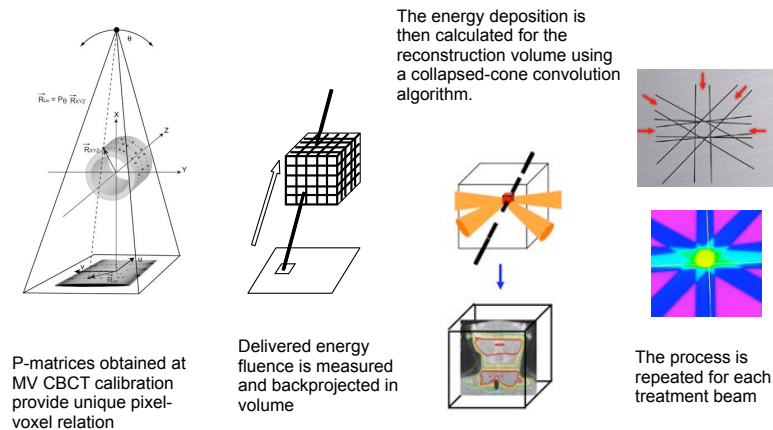


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DGRT2: In-situ Dose Reconstruction



45

In-situ Dose Reconstruction

Measured Exit Dose from EPID
+
Patient anatomy from MV CBCT = In-situ 3D Dose Distribution



- Global IMRT QA
- Will allow a feedback loop based on DOSE = DGRT

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MV CBCT: Summary

- MVision is a reliable, fast and efficient IGRT tool
-> Has been used >300 times on patients
- Provide 3D anatomy of patient in treatment position
-> Patient Setup
-> Monitoring of anatomical changes
-> Tumor evolution
- Accurate electron density for dose calculation
-> Assess dosimetric Impact
-> Planning in presence of high-Z material
-> In-situ dose calculation for DGRT1
- Facilitate dose reconstruction for DGRT2

Main Collaborators

- | | |
|-------------------------|-----------------------|
| UCSF | Siemens |
| ▪ Michelle Aubin | • Ali Bani-Hashemi |
| ▪ Jean-Francois Aubry | • Fahard Ghelmansarai |
| ▪ Kara Bucci | • Paco Hernandez |
| ▪ Albert Chan | • Dimitre Histrov |
| ▪ Josephine Chen | • Bijumon Gangadharan |
| ▪ Hong Chen | • Matthias Mitschke |
| ▪ Cynthia Chuang | |
| ▪ Martina Descovich | |
| ▪ Bruce Faddegon | |
| ▪ Amy Gillis | |
| ▪ Olivier Morin | |
| ▪ Mack Roach III | |
| ▪ Joycelyn Speight | |
| ▪ Lynn Verhey | |
| ▪ Ping Xia | |
| ▪ and several others... | |

*This work is supported
by
Siemens O.C.S.*

References

MV Cone-Beam CT:

- Pouliot et al., IJROBP, 61(2); 238-246, 2005
- Morin et al., Med. Dosi., 31(1);51-61, 2006
- Pouliot et al., Cancer et Radiothérapie, June 2006

Use of MV CBCT to complement CT for target definition in pelvic radiotherapy in the presence of hip replacement:

- Aubin et al., Brit. J. Radiol., 2006 (in press)

IGRT using MV CBCT for Treatment of Paraspinous Tumors in the Presence of Orthopedic Hardware

- Hansen et al., IJROBP, 2006 (in press)

Exit Dosimetry with EPID:

- Chen et al., Med. Phys., 33(3); 584-594, 2006

Dose Calculation with MV CBCT:

- Morin et al., submitted to IJROBP, 2006

DGRT with MV CBCT:

- Chen et al., Brit. J. Radiol (special issue on IGRT), June 2006