External Beam Radiation Therapy (EBRT)

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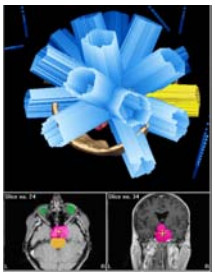
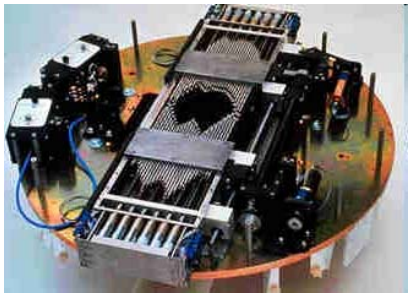
Almost the same as radiosurgery, except: the target can be anywhere in the body, the field is larger, field is irregular from any beam direction, we use multiple/many treatment fractions, and tissues tend to move (sometimes a lot)

Shape the form of each beam – Multi-Leaf collimation (MLC)

Plan

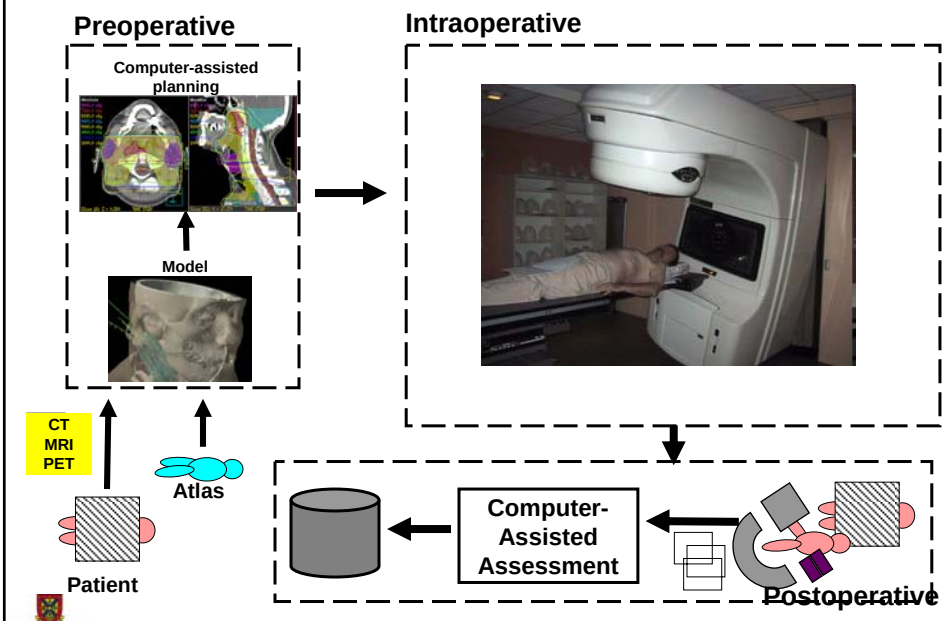


Treatment action



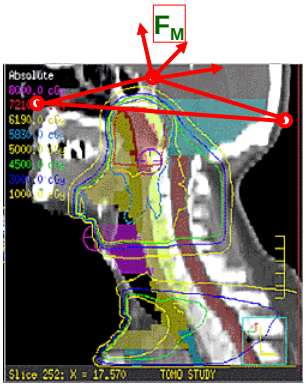
MLC unit, add-on to the LINAC

EBRT as Surgical CAD/CAM

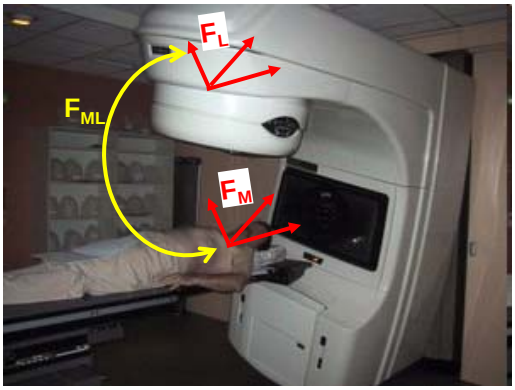


The key is F_{ML} registration…

Pre-operative

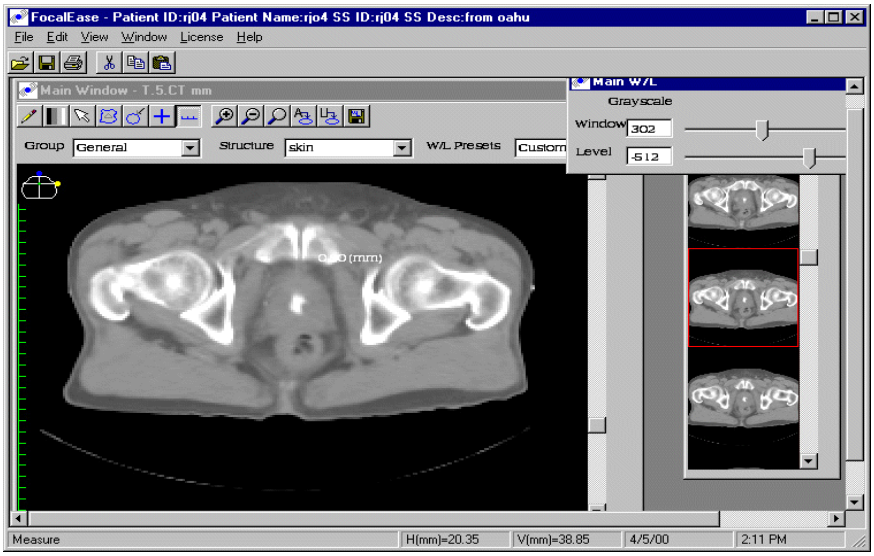


Intraoperative



register Anatomy/Plan to Linac in each treatment fraction

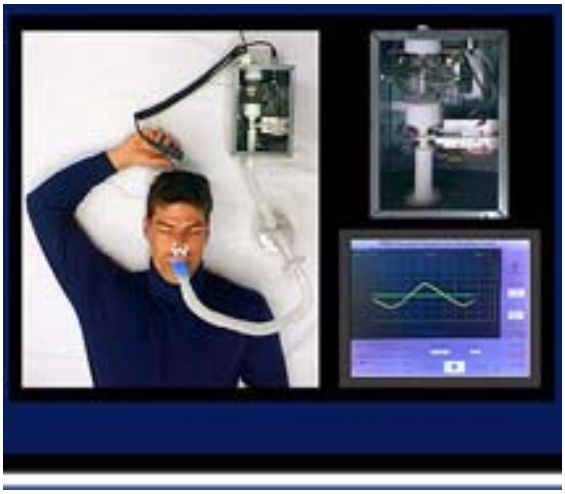
Inter-fraction motion – “The Dancing Prostate”



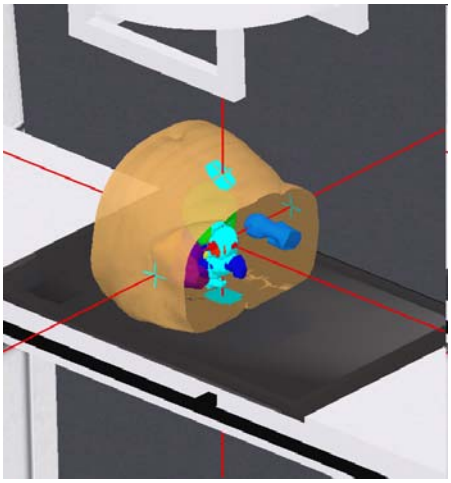
Credit: Andrew Zitman, MD, (MGH)

In-treatment motion reduction w/ passive restraints (some examples)

In-treatment motion reduction w/ Active Breathing Control



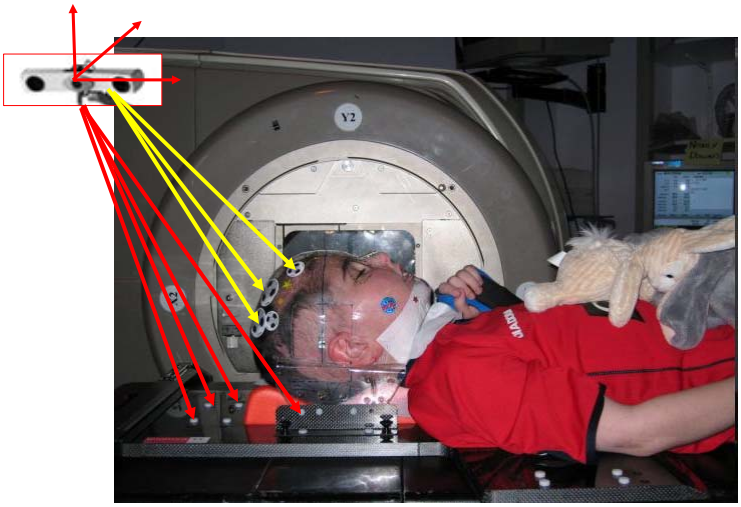
Pre-op: skin tattoos and markers
Intra-op: Linac's room laser



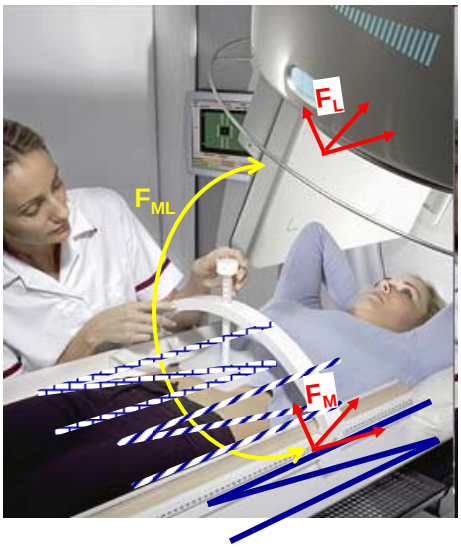
Pros:
- **easy**
- **cheap**

Cons:
- **Not realtime**
- **indirect**
- **deformation**
- **motion**

Pre-op: markers
Intra-op: tracking Linac table and markers



3xZ markers built in patient cradle

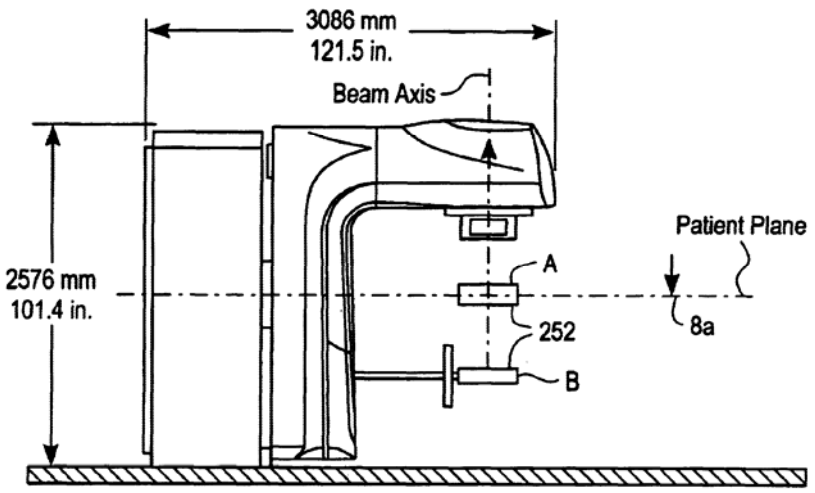


Cons: indirect, may have large error because patient goes in/out of the cast

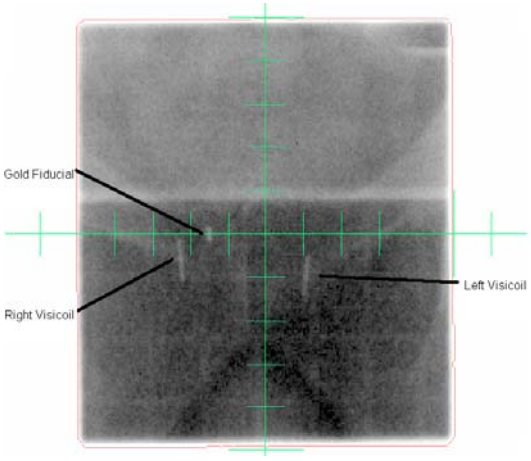
3xZ markers snapped on patient cradle

Cons: indirect, may have large error because patient goes in/out of the cast

Electronic Portal Image



Implanted markers in Electronic Portal Image

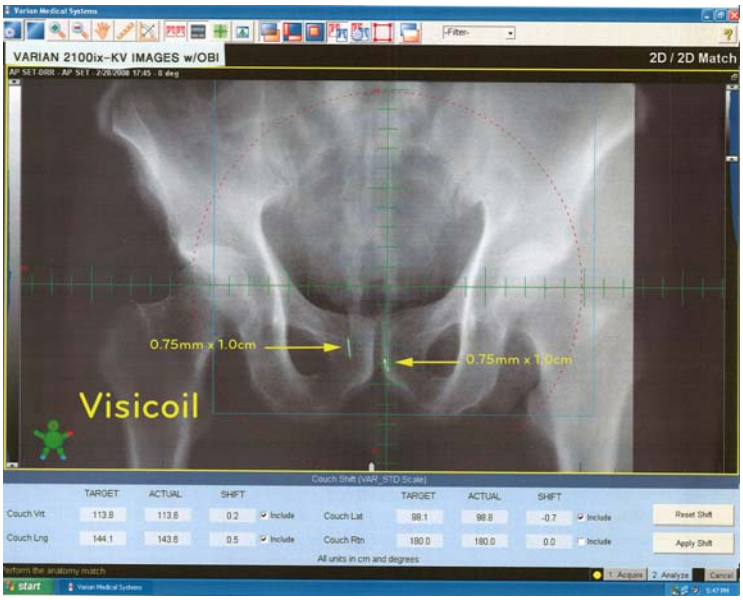


Pros: calibrated to LINAC
Cons: not realtime, poor image quality, no soft tissue

On-Board KV x-ray (Varian)

Pros: calibrated to LINAC, realtime
Cons: poor soft tissue contrast, expensive to retrofit linacs w/ x-ray

Implanted markers in on-board KV x-ray



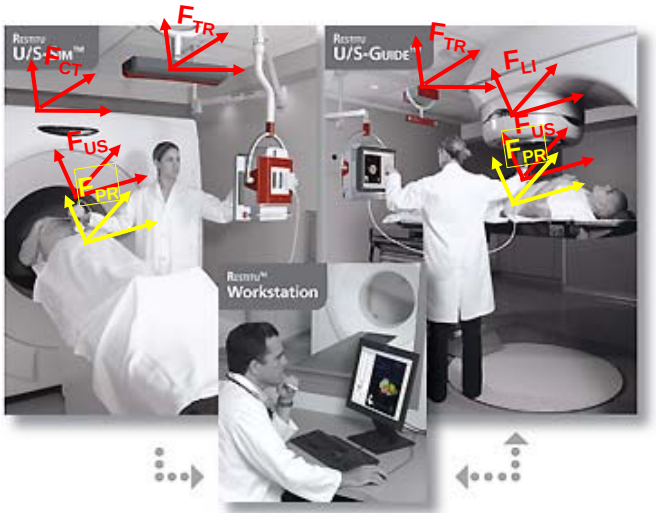
Brainlab ExacTrack – KV x-ray registered w/ Linac

Pros: calibrated to LINAC, realtime
Cons: poor soft tissue contrast, expensive to retrofit rooms w/ x-ray

Cyber Knife – Linac on robot arm registered w/ KV x-ray

Pros: calibrated to linac, realtime
Cons: poor soft tissue contrast, expensive to retrofit rooms w/ x-ray, small linac has small field & low beam energy

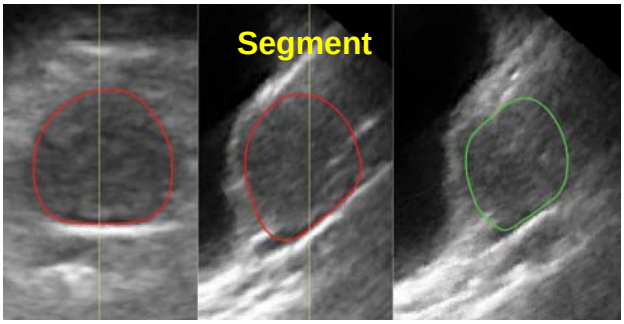
Transabdominal Ultrasound

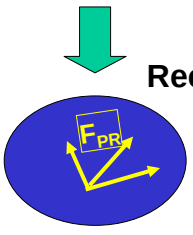


Pros: non-invasive, tracks anatomy
Cons: not realtime, poor US contrast, difficult to handle, complex

CREDIT: Resonant, RESTITU™ platform

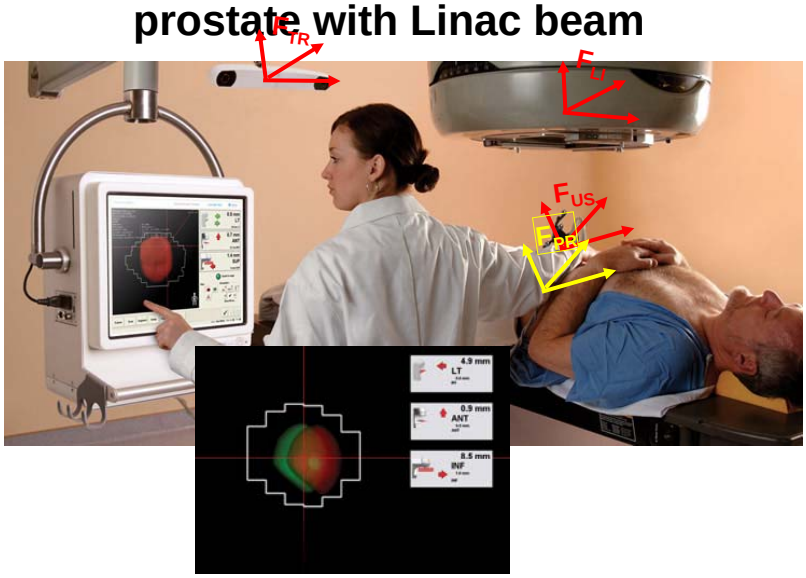
Segment & reconstruct the prostate → find anatomical coordinate frame





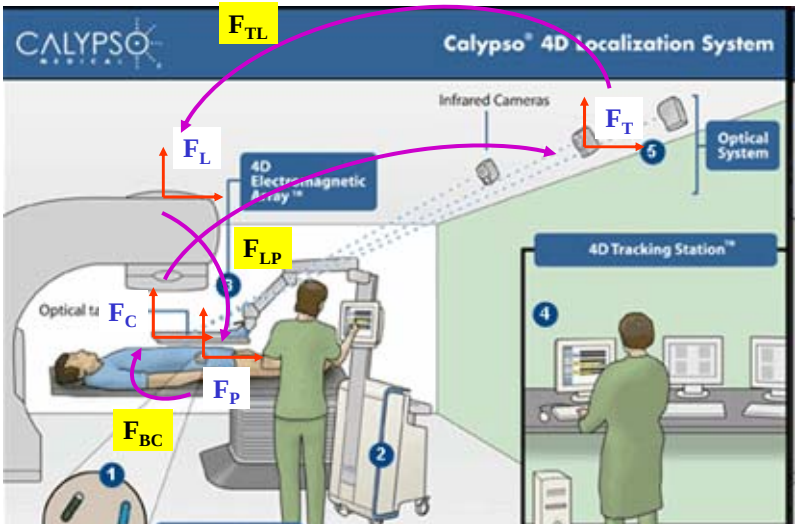
Reconstruct in 3D

Modify table position to align prostate with Linac beam



One can also track the linac instead of the US probe. Else, it's the same thing…

Calypso® implanted EM beacons



Pros: tracks anatomy in RT
Cons: invasive implantation