Stereotactic Body Radiation Therapy Quality Assurance Educational Session

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SBRT fundamentals

- Extra-cranial treatments
- Single or small number (2-5) of fractions
- Stereotactic immobilization
- Image guidance
- Control of organ motion

Outline

- Published guidelines
  - ASTRO / ACR
- AAPM Task Group 101 report
- UC Davis experience
  - Commissioning
  - Ongoing QA
- UC Davis FMEA of SBRT delivery

ASTRO / ACR guidelines (2010)

- Qualifications and roles of personnel
- Quality control / safety
- Simulation and treatment
- Potters L, Kavanagh B, Galvin JM, et al. **American Society for Therapeutic Radiology and Oncology (ASTRO) and American College of Radiology (ACR) practice guideline for the performance of stereotactic body radiation therapy.** *Int J Radiat Oncol Biol Phys*. 2010;76:326–332

ASTRO / ACR guidelines (2010)

- Generic / formulaic
- Somewhat nonspecific
- Lacks the word “recommend”

AAPM Task Group 101 (2010)

- Comprehensive, readable report (24 pages, 24 authors), Benedict et al Medical Physics, Vol. 37, No. 8, August 2010
- Distinguishing features 3D CRT – SBRT
  - Increased number of beams
  - Non-coplanar beams
  - Small or no margins for penumbra
  - Inhomogeneous dose distribution

AAPM Task Group 101 - Recommendations

- Patient selection
  - SBRT is still developing
  - Patients should be treated either on or according to NCI (RTOG) or similar protocols
  - Ensures strict guidelines for volumes, prescriptions etc, developed by leaders in the field are followed
  - Clinical trials should be employed for new indications

AAPM Task Group 101 - Recommendations

- Simulation and imaging
  - Guidelines including length of scan and slice thickness
  - Ensure target and organ at risk coverage, 1 – 3 mm slices
  - ^{18}FDG PET for enhanced specificity and sensitivity, useful for staging
  - Resolution limit of PET

AAPM Task Group 101 - Recommendations

- Treatment planning
  - Very high local control – GTV and CTV are identical
  - ITV and PTV concepts
    - PTV margin 5mm radial and 1cm sup / inf
  - With 4D CT sup / inf margin reduced to 5mm

AAPM Task Group 101 - Recommendations

- Calculation grid size
  - Published IMRT data shows a 2.5mm grid gives 1% accuracy in high dose gradients
  - 4mm grid c.f. 1.5mm grid gives 5.6% difference for prescribed dose
  - Use 2mm grid for SBRT calculations

AAPM Task Group 101 - Recommendations

- Heterogeneity correction
  - Convolution / superposition accounts for recoil electron transport
  - Radiological Physics Center thorax phantom and RTOG 0236
  - Pencil beam algorithms not recommended

Acceptance testing, commissioning and quality assurance

TABLE V. Summary of published QA recommendations for SBRT and SBRT-related techniques.

Source	Purpose	Proposed test	Reported achievable tolerance	Proposed frequency
Ryu *et al.*, 2001[a]	End-to-end localization accuracy	Stereo x ray/DRR fusion	1.0 to 1.2 mm root mean square	Initial commissioning and annually thereafter
Ryu *et al.*, 2001[a]	Intrafraction targeting variability	Stereo x ray/DRR fusion	0.2 mm average, 1.5 mm maximum	Daily (during treatment)
Verellen *et al.*, 2003[b]	End-to-end localization accuracy	Hidden target (using stereo x ray/DRR fusion)	0.41 ± 0.92 mm	Initial commissioning and annually thereafter
Verellen *et al.*, 2003[b]	End-to-end localization accuracy	Hidden target (using implanted fiducials)	0.28 ± 0.36 mm	Initial commissioning and annually thereafter
Yu *et al.*, 2004[c]	End-to-end localization accuracy	Dosimetric assessment of hidden target (using implanted fiducials)	0.68 ± 0.29 mm	Initial commissioning and annually thereafter
Sharpe *et al.*, 2006[d]	CBCT mechanical stability	Constancy comparison to MV imaging isocenter (using hidden targets)	0.50 ± 0.5 mm	Baseline at commissioning and monthly thereafter
Galvin *et al.*, 2008[e]	Overall positioning accuracy, including image registration (frame-based systems)	Winston–Lutz test modified to make use of the in-room imaging systems	≤ 2 mm for multiple couch angles	Initial commissioning and monthly thereafter
Palta *et al.*, 2008[f]	MLC accuracy	Light field, radiographic film, or EPID	<0.5 mm (especially for IMRT delivery)	Annually
Solberg *et al.*, 2008[g]	End-to-end localization accuracy	Hidden target in anthropomorphic phantom	1.10 ± 0.42 mm	Initial commissioning and annually thereafter
Jiang *et al.*, 2008[h]	Respiratory motion tracking and gating in 4D CT	Phantoms with cyclical motion	N/A	N/A
Bissonnette *et al.*, 2008[i]	CBCT geometric accuracy	Portal image vs CBCT image isocenter coincidence	± 2 mm	daily

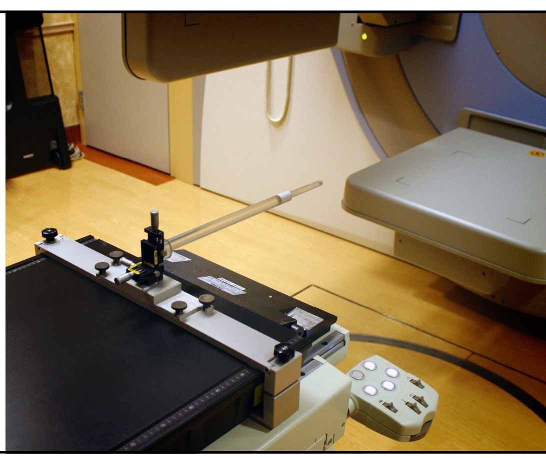
End to end test
Winston Lutz test
CBCT stability
MLC accuracy

UC Davis experience as example

- Background
- Commissioning experience
- Ongoing (patient specific) QA

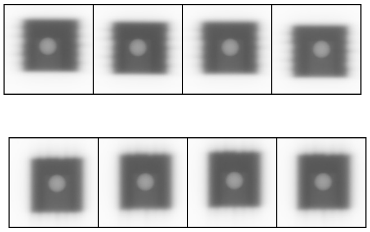
Commissioning SBRT at UC Davis

- Digital Winston Lutz test
- Fitting volunteers in SBRT frame
- Phantom (end to end) studies
  - RPC lung phantom



Digital Winston Lutz test

– four cardinal gantry angles, collimator 0 and 90



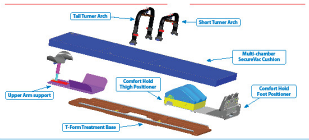
Commissioning SBRT at UC Davis

- – Digital Winston Lutz test
- – Fitting volunteers in SBRT frame
- – Phantom studies
  - RPC lung phantom

Positioning Checklist
OmniV® SBRT System (RT-4500)

BIONIX RADIATION THERAPY

Patient Name ______ Date ______
Area of RX– orientation ______ Patient I.D. ______



T-Form Treatment Base
Indexed to couch @ ______ & ______
SecureFit Bar TOP: ◯ A1 ◯ B1 ◯ C1
SecureFit Bar Bottom: ◯ A2 ◯ B2 ◯ C2 ◯ D2

Upper Arm Support
Index to Base:
◯ A ◯ B ◯ C ◯ D ◯ E ◯ F
Vertical Height:
◯ A ◯ B ◯ C ◯ D ◯ E ◯ F
Superior to Inferior: ______
6 5 4 3 2 1

(Left Arm)	Forearm Cups	(Right Arm)
◯ L1 ◯ L2		◯ R1 ◯ R2
◯ 0° ◯ 45°		◯ 0° ◯ 45°

Thigh Positioner
◯ With Riser ◯ Without Riser

SecureVac Cushion Used
◯ T-Vac Cushion (T-Shape, 2 Chamber)
◯ Tri-Vac Cushion (3 Chambers)
Other: ______

Foot Positioner
Foot Plate Position:
◯ A ◯ B ◯ C ◯ D ◯ E ◯ F ◯ G ◯ H
Foot Plate Angle: ◯ 1 ◯ 2

(Left Foot)	Cup Position	(Right Foot)
◯ A^2 ◯ A^1		◯ A^1 ◯ A^2
◯ B^2 ◯ B^1		◯ B^1 ◯ B^2

Cup Padding: ◯ In ◯ Out

Turner Arches

Short Arch	Tall Arch
Index to Base @ ______	Index to Base @ ______
Vertical Index (S1-S9) ______	Vertical Index (T1-T16) ______
Respiratory Plate Fine Adjustment (1-9) ______	Respiratory Plate Fine Adjustment (1-9) ______

Respiratory Belt
Index to Base @ ______
Velcro Belt @ ______ & ______
Pressure Gauge @ ______
Insert: ◯ Yes ◯ No

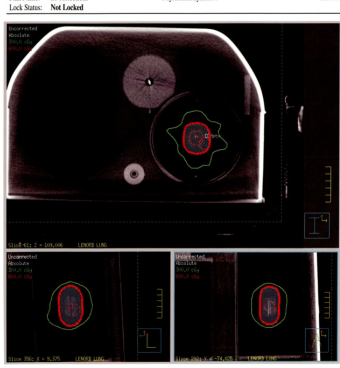
Accessory
Fiducial Arch (not pictured above)
◯ Yes ◯ No
Indexed to base railings @ ______

Commissioning SBRT at UC Davis

– Digital Winston Lutz test
– Fitting volunteers in SBRT frame
– Phantom studies
  • RPC lung phantom

Pinnacle³

Patient Name: LENORD LUNG, ,	Date/Time: Thu Aug 30 09:33:35 2007	Revision: R01.P01.D04	Page: 1 of 1
Patient ID: 11111111	Comment:	Planner:	Scaling: Fill Page
Plan Name: no corrections	Physician/Physicist: /	Institution: UC-Davis Cancer Center	
Lock Status: Not Locked			



Radiological Physics Center, MD Anderson

Anthropomorphic phantom

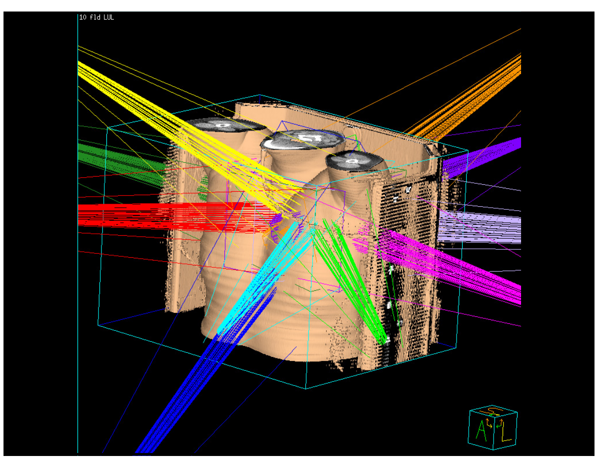
RTOG lung trial credentialing

Phantom loaded with detectors

Scan, plan, treat, return for readout

UC Davis SBRT practice

- Linac based – Elekta platform
  - Static non-coplanar
  - Limited number of IMRT plans

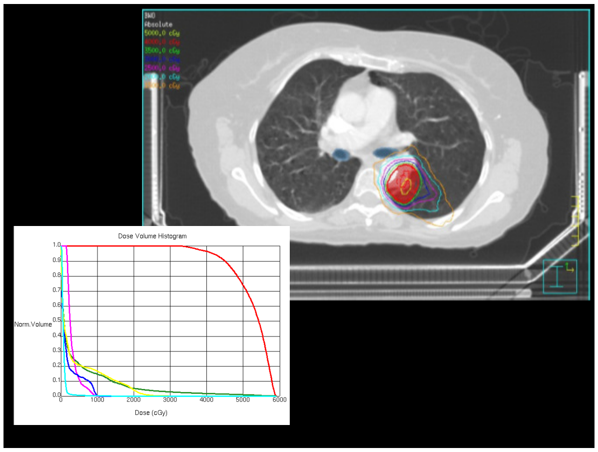


UC Davis SBRT practice

- Stereotactic frame – abdominal compression

UC Davis SBRT practice

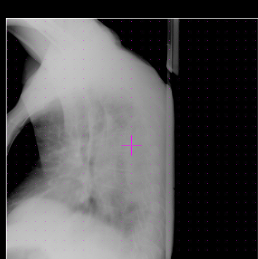
- Heterogeneity correction
- Pinnacle planning system v.9.0

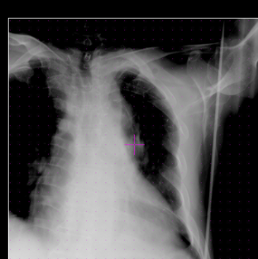


UC Davis SBRT practice

- Fluoroscopy to evaluate diaphragm motion
- Cone Beam CT for on set alignment

Kilovoltage PlanarView images (XVi)





UC Davis patient specific QA processes

- Patient specific QA
  - Physics check of co-registration 4D CT
  - Plan review / chart rounds
  - Patient dry run
  - Map check and Quasar delivery QA
  - Daily diaphragm motion view and cone beam CT
  - Procedural pause / time out
  - Physics presence throughout delivery

Energy	Dose Rx	Which lung	Lobe location	PTV volume (cc)	# of fields	% PTV receiving Rx dose	IDL	%PTV receiving minimum 45Gy (90%TD)	hot spot in PTV (>5%)	Vol outside PTV >52.5 Gy/PTV Vol	Conformality Index
6MV	1250cGy x4fx	Right	upper	16.83	8	95.0%	76.20	99.7%	Y	2.00%	1.07

Max dose at 2cm from PTV (Gy)	Ratio of 50% dose volume/ PTV volume	density correction	Spinal cord dose (Gy) (Max)	Esophagus (Gy)(max)	Ipsi Brachial plexus (Gy) (max)	Trachea & Ipsilateral Bronchus (Gy) Max)	V20 total lung (<10%)	Heart 30Gy (max)	Comments/ Skin max
21.50	3.98	yes	10.6	16.5	18.9	18.3	3.01%	0.5	18.9 Gy

Dose constraints:

Spinal cord max < 22Gy, < 0.35cc < 18Gy

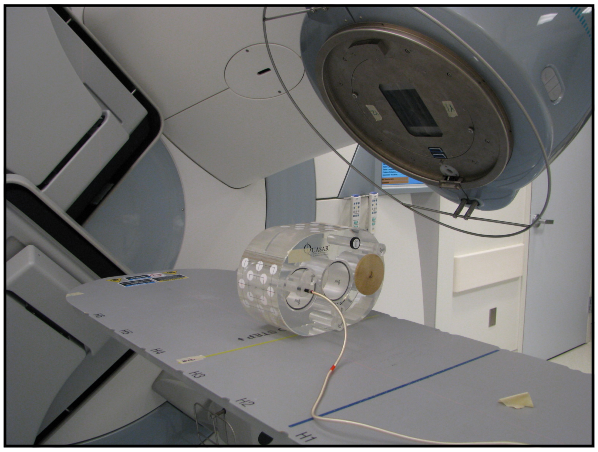
Esophagus < 5cc to 15Gy, max < 25Gy

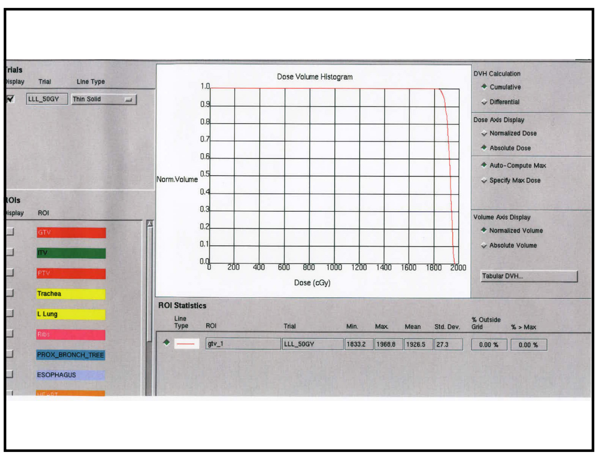
Lung V20 < 10%, < 1500cc < 11.6Gy

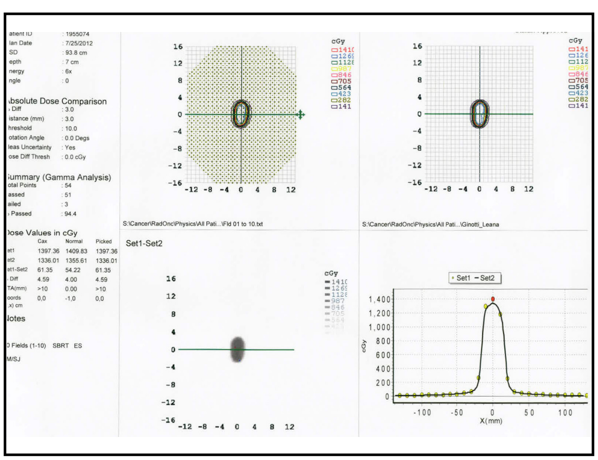
Heart Max < 30Gy, < 15cc to 26Gy

Central airways Max < 30Gy, < 4cc to 15Gy

Patient dry run




Dose Volume Histogram
Norm.Volume
Dose (cGy)
DVH Calculation
Cumulative
Differential
Dose Axis Display
Normalized Dose
Absolute Dose
Auto-Compute Max
Specify Max Dose
Volume Axis Display
Normalized Volume
Absolute Volume
Tabular DVH...
ROI Statistics
GTV
ITV
PTV
Trachea
L Lung
PROX_BRONCH_TREE
ESOPHAGUS

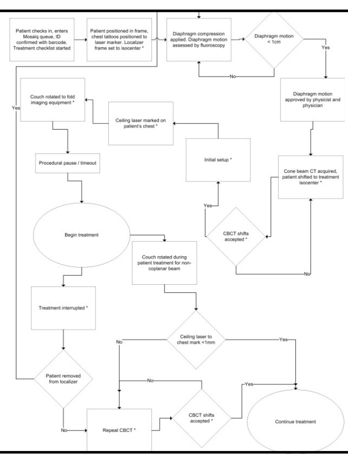

Set1-Set2
Set1 Set2
cGy
X(mm)

Failure Modes and Effects Analysis Intro:

- Process started by department interacting with hospital with QA committee
- One analysis per year
- Disciplines
  - Radiation oncologist, physicist, dosimetrist, therapist, clinical engineer, QA committee members (nurse managers)
- "Failure mode and effects analysis for lung stereotactic body radiation therapy" Perks et al Int J Radiat Oncol Biol Phys. 2012 Jul 15;83(4):1324-9. Epub 2011 Dec 22.

Failure Modes and Effects Analysis Process:

- Step by step breakdown of patient flow from every team member
- Overlap of responsibilities
  - Develop flow chart (modes)



Process:

- 28 steps for treatment
- Turn process chart into failure modes
- What do we do at this point
  - What could go wrong?
  - That could never happen?
  - But what if?

Failure modes:

- For each step in the process at least one potential failure was derived
- Three factors were associated with each mode
- Probability– detectability – severity
- Score 1 – 10 for each factor

Probability:

- Likelihood of occurrence
  - Score 1 for event happening to 1% of patients
  - Score 10 for every patient

Detectability:

- How likely are we to catch the failure
  - Score 1 for very easy to catch
  - Score 10 for almost impossible

Severity:

- The consequences of the failure reaching the patient
  - Score 1 for no dosimetric effect, may cause discomfort or inconvenience
  - Score 10 for reportable event, 20% or greater dose difference, injury or death

	Probability	Detectability	Severity
1 – 2	1% of patients	Very easy	No dosimetric effect
3 – 4	5% of patients	Human error	5% dose difference
5	Moderate	Lucky catch	10% dose difference
6 – 8	Once per day	Very difficult	Reportable, 20% difference
9 – 10	Every patient	Almost impossible	Reportable, injury / death

Risk probability number (RPN):

- Multiply three scores
  - Probability x detectability x severity
- Example – misalignment of CBCT iso
- Probability = 1
- Likelihood of detection = 6
- Severity = 10
- RPN = 1 x 6 x 10 = 60

Results:

- Choose the highest RPN's and change clinical practice
- Law of diminishing returns

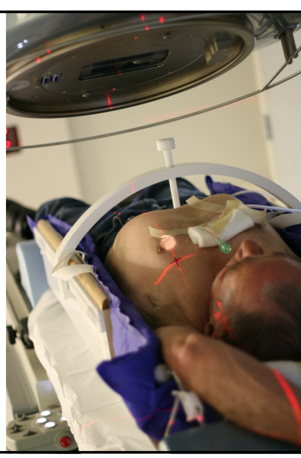
Results, UC Davis:

- Change in practice / planning technique
  - Prior to FMEA couch translations were required to fold imaging panels
  - Risk of invalidating CBCT alignment

Folding IGRT panels to allow non coplanar beams

Results, UC Davis:

- Change in practice / planning technique
  - After FMEA we devised a method of planning and rotating the couch to reduce this risk
  - Lower RPN
  - No couch translations after CBCT correction



Laser marking after CBCT shift is final and checked when couch is rotated for non coplanar beams

Results, UC Davis:

- Safety measures
  - Checklist and surgical timeout
  - MD sign off on CBCT
  - Therapist sign off on
    - Patient identity
    - CBCT shifts

Conclusion:

- FMEA is time consuming and human resource intensive
  - 100 man hours
- Valuable exercise
  - Change in technique
  - Unified protocol
  - Safety conscious

Conclusion:

- FMEA process is generic but the results are somewhat clinic specific
  - Specific to equipment
  - Workload

Take home message

- Highly effective ablative doses
- Continuously evolving field
  - IMRT and VMAT delivery methods already common
  - Single fraction treatments
  - 4D CBCT

Thank you