Improving Initial Setup Accuracy and Treatment Efficiency

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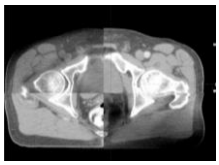
Disclosures

- I am a member of TG-302: Surface image guided RT

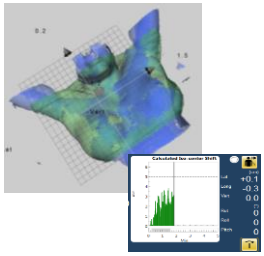
Role of Imaging in RT

- Volumetric, x-ray based imaging crucial for interfraction positioning due to highly conformal deliveries
- Limitations:
  - Added dose
  - Temporal snapshot
  - Patient posture visualization
  - No real-time monitoring
  - Motion management



Surface Imaging

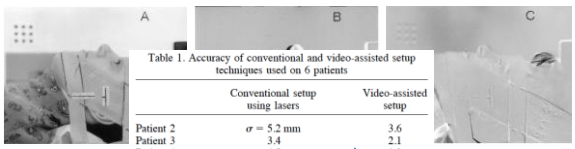
- Efficient technology for patient set-up and real-time monitoring:
  - Accurate 3D images
  - Non-ionizing, non-invasive
  - Patient posture visualization
  - Surface as surrogate for respiratory gating
  - Complement x-ray based volumetric imaging



Surface Imaging

- Why?: Improve the overall (temporal) accuracy of radiation delivery
  - Patient positioning
    - Improve inter-fractional setup accuracy (posture correction)
    - Visualize patient surface changes
    - Reduce setup time (minimize repeating x-ray imaging)
  - Patient monitoring
    - Monitor patient intra-fractionally (assess post x-ray imaging shifts)
    - Quantify inadvertent movements
    - Minimize re-imaging needs
  - Gated delivery
    - Efficient gating tool for motion management
    - Simultaneous monitoring of patient position and respiratory signal

Video-based Imaging System



Reference

l-time subtracted
ge

Table 1. Accuracy of conventional and video-assisted setup techniques used on 6 patients

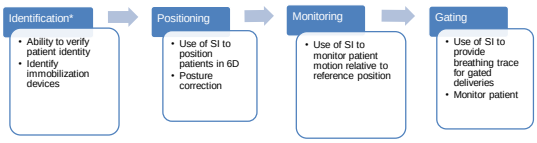
	Conventional setup using lasers	Video-assisted setup
Patient 2	$\sigma = 5.2$ mm	3.6
Patient 3	3.4	2.1
Patient 4	4.5	1.3
Patient 5	3.4	1.2
Patient 6	3.5	1.2
Patient 7	4.0	0.9
Population	3.9	1.7

Milliken BD, et al. IJROBP. 1997

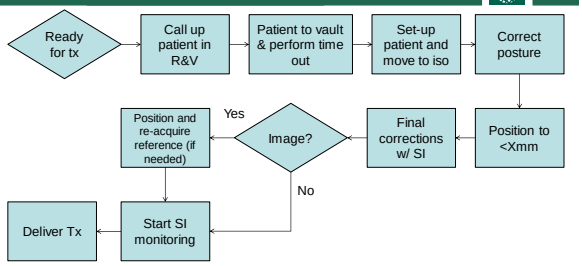
Optical Commercial Systems

- VisionRT AlignRT
- C-RAD CatalystHD
- humediQ IDENTIFY

Common SI System Overview



Typical Patient Positioning Workflow



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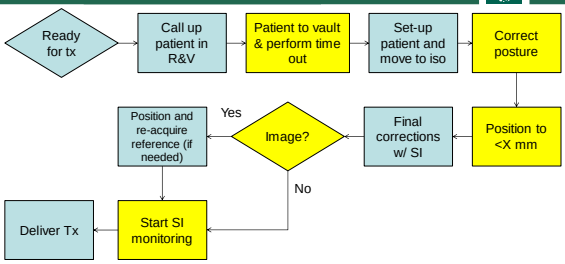


Improving Setups: PBI

- SI using a DICOM reference provides significantly better reproducibility compared to lasers or kV orthogonal imaging in 23 patients with surgical clips as reference

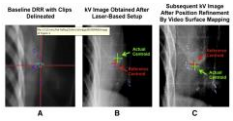


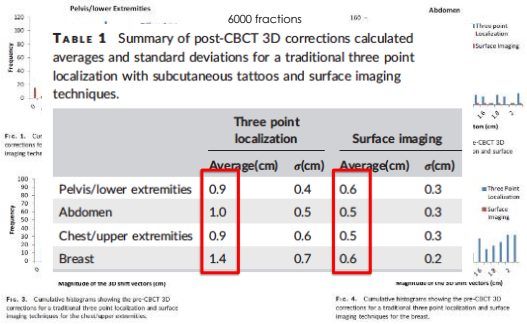
Table 2 Residual setup error

Technique	Anterior/ Posterior (mm)	Superior/ Inferior (mm)	Right/Left Lateral (mm)	Vector Spatial Deviation (mm)
Video surface mapping	1.9 ± 2.2	1.8 ± 1.9	1.8 ± 2.1	4.0 ± 2.3
Orthogonal imaging	3.2 ± 2.9	4.2 ± 3.5	4.7 ± 5.3	8.3 ± 3.8
Laser	3.9 ± 3.7	4.6 ± 3.9	4.3 ± 4.5	8.8 ± 4.2

Improvement of >50%

Chang et al 2012

Slide Courtesy of H Al-Hallaq

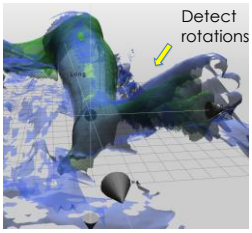


6000 fractions

TABLE 1 Summary of post-CBCT 3D corrections calculated averages and standard deviations for a traditional three point localization with subcutaneous tattoos and surface imaging techniques.

	Three point localization		Surface imaging	
	Average(cm)	σ(cm)	Average(cm)	σ(cm)
Pelvis/lower extremities	0.9	0.4	0.6	0.3
Abdomen	1.0	0.5	0.5	0.3
Chest/upper extremities	0.9	0.6	0.5	0.3
Breast	1.4	0.7	0.6	0.2

Improving Setups: Extremity



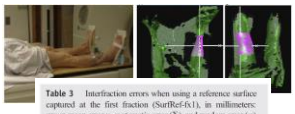


Table 3 Interfraction errors when using a reference surface captured at the first fraction (SurfRef-fx1), in millimeters: group mean error μ, systematic error (Σ), and random error (σ)

Direction	Systematic errors (mm)		Random errors (mm)
	Mean (μ)	SD (Σ)	σ
VRT	2.9	3.3	3.0
LNG	−0.6	3.7	4.3
LAT	0.4	4.3	2.8
3D	7.6	3.9	4.2

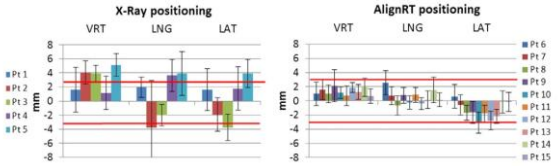
3D, 3 dimensional; LAT, latitudinal; LNG, longitudinal; VRT, vertical.

Gierga et al 2014

Improving Setup: Chestwall

Can surface imaging improve the patient setup for proton postmastectomy chest wall irradiation?

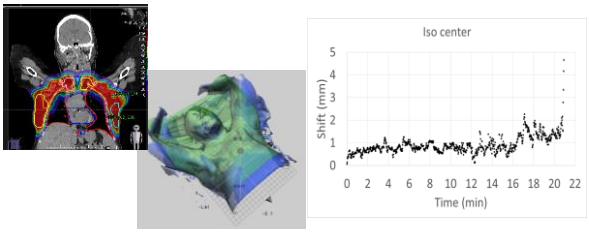
Estelle Batin PhD*, Nicolas Depauw PhD, Shannon MacDonald MD, Hsiao-Ming Lu PhD



Average reduction >50%

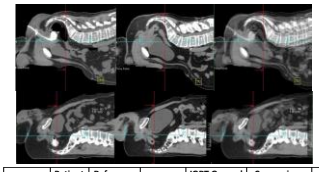
Batin et al. PRO. 2016

SI Efficiency Proton PBS Treatments



Treatment fraction completed in 21 minutes

Improving Setup: Pelvis



- Surface may not be a reliable surrogate, especially in prone position due to challenges in reproducing pelvic tilt, back shape and differences in organ filling. (Zhao et al 2016)

Site	Patient No	Reference Surface	System	IGRT Ground Truth	Comparison Type	Patient Positioning	Metric reported	AP (mm)	CC (mm)	RL (mm)
Pelvis	10	DICOM	AlignRT (2-camera)	CT-on-rails (weekly)	Prospective comparison of paired data	Supine: Alphacradle	Mean Residual Shift: Supine	3.7	5.1	2.8
						Prone: bellyboard	Mean Residual Shift: Prone	5.1	6.3	6.0

Slide Courtesy of H Al-Hallaq

SI Initial Setup Efficiency

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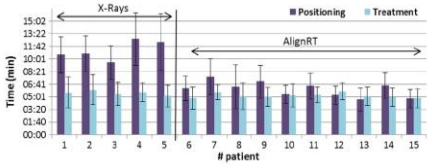


μ = 11min → 6min ~50%

Batin et al. PRO. 2016

SI Initial Setup Efficiency

- Reduce filming frequency
- Increase throughput

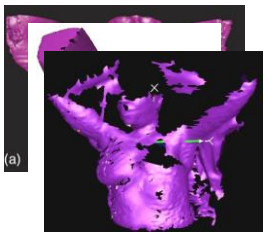
The University of Chicago Medicine WBRT

n=50	Before AlignRT	AfterAlignRT
% of Patients with shifts < 1cm	64%	92%
% of Patients with shifts < 1cm; total time < 30mins	44%	72%

Slide Courtesy of H Al-Hallaq

Practical SI Considerations

- Reference image issues
  - Resolution & breathing motion
  - CT FoV
  - HU threshold
  - Reference image fidelity
- ROI selection
  - Large: posture correction
  - Small: tracking
- Learning curve
  - Therapist education
  - Comfort level



Conclusions

- Use of SI technology has increased in recent years
- SI technology has shown to improve accuracy in initial setup for a number of disease sites
- Improvements in overall treatment time have been shown with SI
- Practical issues with SI need to be considered to ensure accurate positioning of patients

Thanks for your attention