Non Ionizing Radiation Methods for Real Time Motion Management

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Disclosures

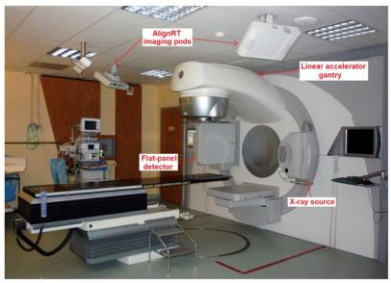
- Accuray
- Siemens
- Varian
- ViewRay advisory board

Methods to Review

- No X-rays or gamma rays!
- Optical
- Radiofrequency
- Ultrasound
- MRI

Optical

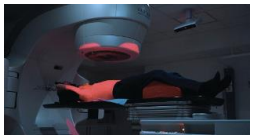
- AlignRT - VisionRT



From Fassi et al, JACMP 16 (2015)

VisionRT

- Projects infrared dot pattern
- IR camera offset from projector
- Camera sees distorted pattern – correlated with distance



Evaluation

- Peng et al (Med Phys 37, 5421, 2010) characterized system
- Stereotactic head
- Compared against Cone-Beam CT and Varian SonArray optical tracking system
- Origins within 1.3mm/0.7°
- 0° couch within 0.9mm/0.4°
- Displacements >10mm and 3° within 3.0mm (CBCT) and 0.4mm (SonArray)
- Couch angles to 90° (SonArray only), 1.2mm/0.7°

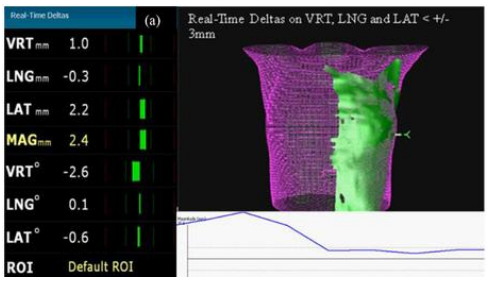
Gating with Optical

- CT and RT gating
  - Respiratory tracking (gating trigger)
  - Breath hold

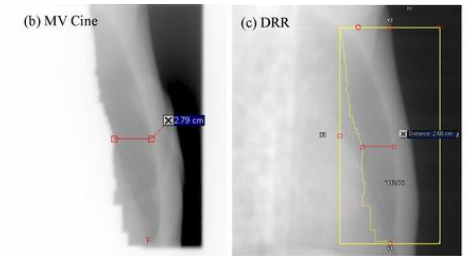
Dynamic Breath Hold

- Rong et al (PLOS one, 9, e97933, 2014)
- Left sided breast and CW patients
- DIBH CT sim (RPM)
- MV Cine images to check intrafraction positioning
- Chest wall distances quantified accuracy
- Found RPM insufficient alone for optimal positioning

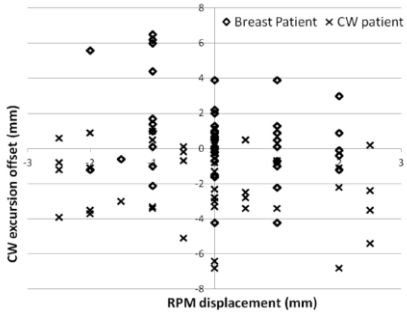
Rong et al



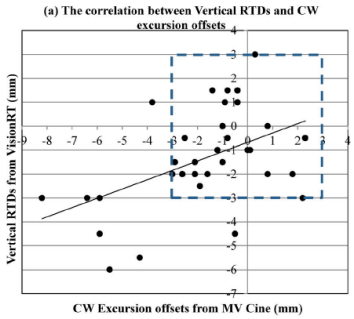
Rong et al



RPM Versus CW Extension



AlignRT versus CW Extension



Catalyst (C-RAD)

- Freislederer et al, Radiation Oncology, 2015
- Tested on Elekta Synergy
- Developed phantom for dose and film measurements

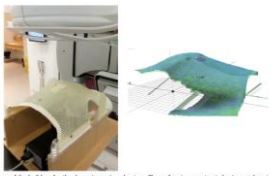


Figure 1 Left: Image of the build-up for the dynamic moving phantom. The surface is reconstructed using mask material. Right: The phantom as it is perceived by the Catalyst™ software.

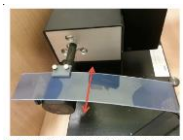
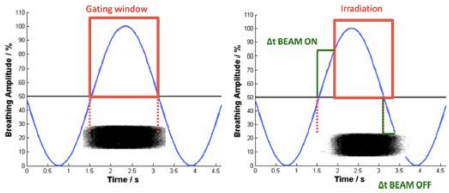


Figure 2 The custom-built extension for the film measurements. Here the extension is placed on the moving rod of the phantom and is moved only in the horizontal direction (red arrow).

Latency Measurement



Results

Gating level	Relative dose (10 x 10 cm^2 field)	Relative dose (20 x 20 cm^2 field)
50%	99.41 ± 0.07%	99.59 ± 0.05%
40%	99.43 ± 0.04%	99.53 ± 0.04%
30%	99.45 ± 0.52%	99.46 ± 0.04%
20%	98.81 ± 0.05%	99.09 ± 0.05%
10%	97.85 ± 0.04%	98.28 ± 0.05%

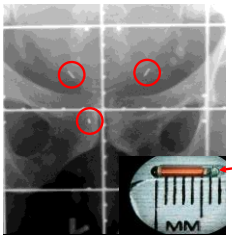
Beam off delay = 215 ± 69 ms
Beam on delay = 851 ± 100 ms

Calypso (rf)

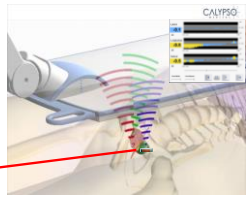
+

Implanted RF beacon
Antenna array aligned with linac coordinate system

Calypso

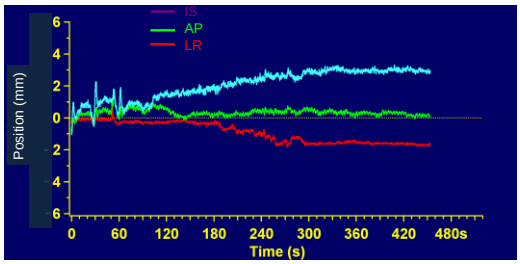


Calypso System

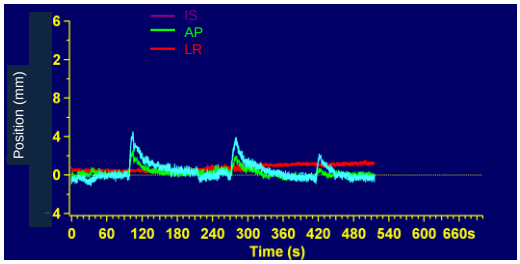


Measurements at 10 Hz
Sub-mm resolution
Real-time tracking
Potential for fast correction

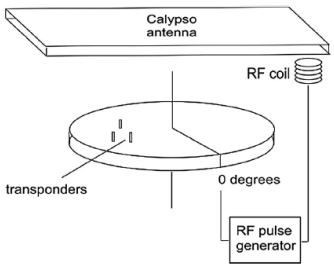
Real Time Motion Data – Patient 1



Real Time Motion Data – Patient 2



Dynamic Calypso Motion



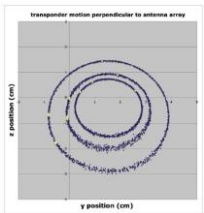
Murphy et al Red J 72, 259-299 (2008)

Results

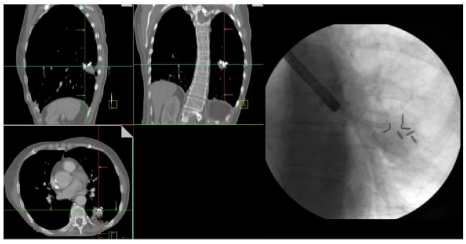
Table 1. Standard deviation (in centimeters) of 100 (x,y) position measurements vs. position for stationary transponders

	Angular table position					
Axis	0°	60°	120°	180°	240°	300°
x-axis SD						
Transponder 1	0.032	0.044	0.040	0.035	0.028	0.024
Transponder 2	0.027	0.041	0.034	0.024	0.021	0.017
Transponder 3	0.041	0.051	0.038	0.029	0.028	0.026
y-axis SD						
Transponder 1	0.023	0.022	0.028	0.037	0.048	0.036
Transponder 2	0.023	0.021	0.022	0.026	0.037	0.028
Transponder 3	0.029	0.025	0.030	0.033	0.058	0.039

Abbreviation: SD = standard deviation.

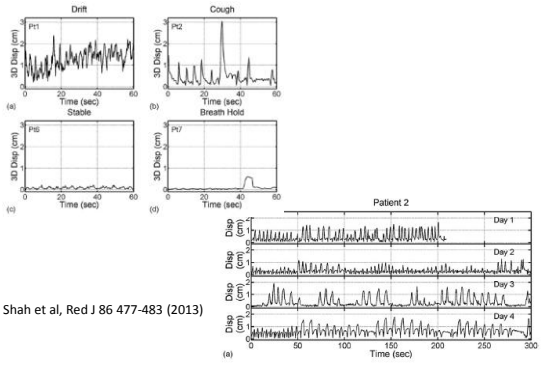


Lung Calypso



Shah et al, Red J 86 477-483 (2013)

Lung Calypso



Shah et al, Red J 86 477-483 (2013)

Ultrasound

- Kubota et al Med Phys 41 092901 (2014)
- Developed home made system

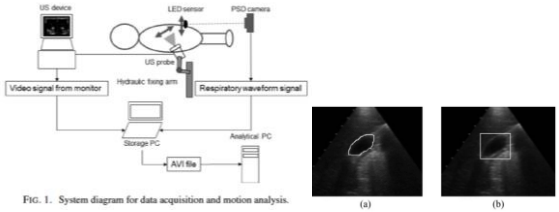
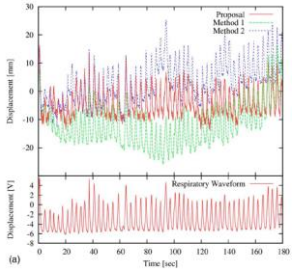


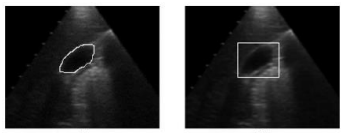
FIG. 1. System diagram for data acquisition and motion analysis.

Kubota et al

- Looked at normal organs
- Correlated breathing waveform to analyzed ultrasound image (2D of 3D image)
- Center deviation approx 1.6mm



Tracking



MRI

- Advantages
  - Arbitrary (optimized) image orientation
  - No contact hardware (except for coils)
  - No implants (unless markers)
  - Commercially available
  - Potential for 3D
- Disadvantages
  - Only 3 in the world
  - Cost > Linac + other systems

Stereotactic Ablative Liver Metastasis Radiation

50Gy in 5 Fx

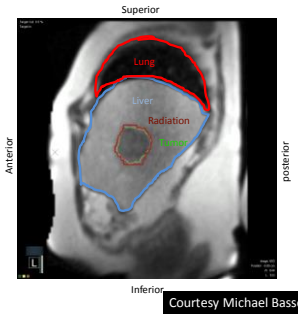
Patient driven repeated breath-hold technique with a high duty cycle

Radiation beam is only on when tumor is in proper position

Contrast used to highlight the tumor and allow daily tracking

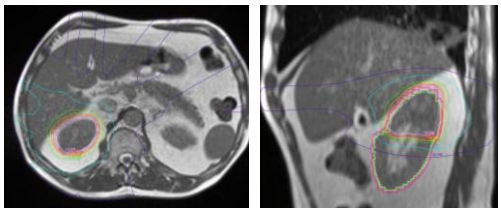
Unique to be able to see and track actual tumor (not a surrogate) in realtime

MRI Tracking During Treatment



Courtesy Michael Bassetti

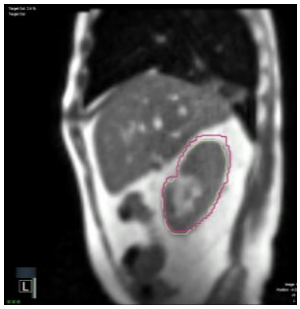
Superior Pole Kidney SBRT



Courtesy Michael Bassetti

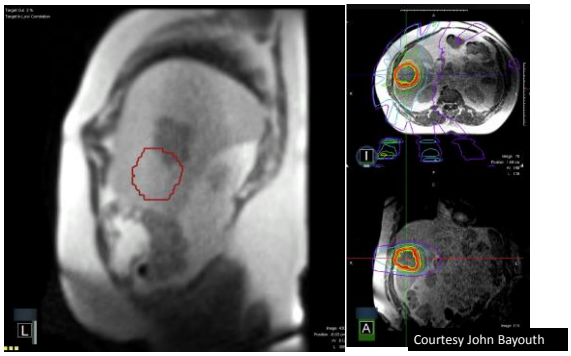
Superior Pole Kidney SBRT

- Tumor tracking required to spare uninvolved kidney
- Tracking algorithm works very well with nice contrast difference
- Track the entire kidney with 98% within PTV for beam on



Courtesy Michael Bassetti

Patient Coached To Correct Amplitude



Conclusions

- Many options for non-ionizing radiation real-time motion management
- Some commercial solutions
- Challenging to integrate potential solutions into clinical workflow
- Have potential for improving treatment planning conformality and delivery accuracy