



Respiratory Motion Management for SABR Lung Planning

Laura Howard
Higher Principal Clinical Scientist
Lead SRS /SRT Physicist
laura.howard4@nhs.net

Overview



- Why do we need motion management?
- Accounting for motion
- Techniques for respiratory motion management

SABR

Stereotactic:
high geometric
precision

Ablative RT:
large dose per
fraction

Small targets
 $ITV \leq 6$ cm

Small PTV
margin

3 - 8
fractions

Steep dose
gradients

Reproducible
immobilisation

Highly
conformal

Reduce
tumour motion

Account for
tumour motion

Motion Management Options



1. Ignore (i.e. account for motion)

- 3D scan with increased PTV margin
- 4D-CT scan

2. Reduce Motion

- Abdominal compression
- Breath hold
- Active breathing control

3. Track the Motion

- Combine with respiratory gating (movement ≥ 2 cm, AAPM TG-101)

Least sophisticated



Most sophisticated

Motion Management for SABR

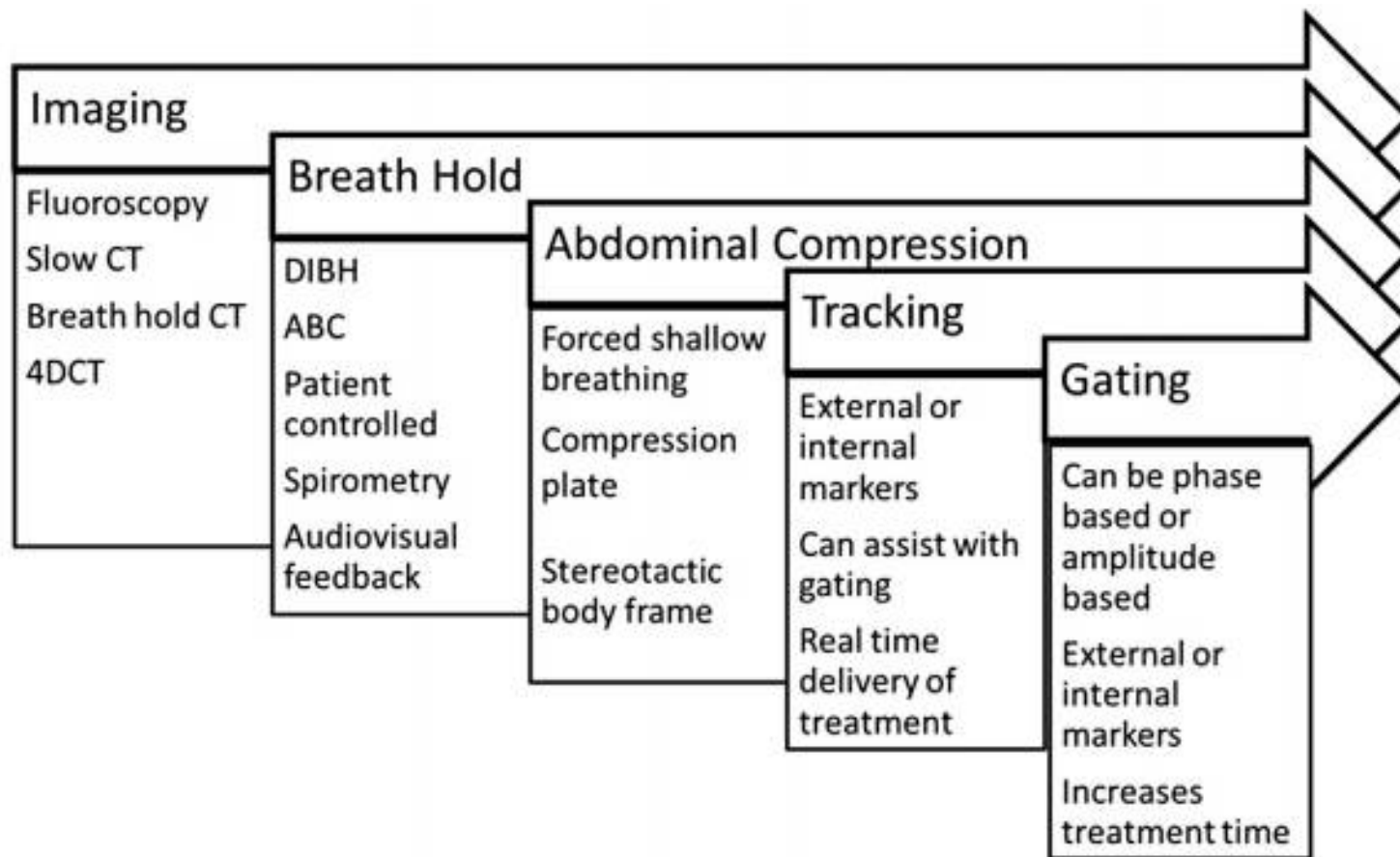
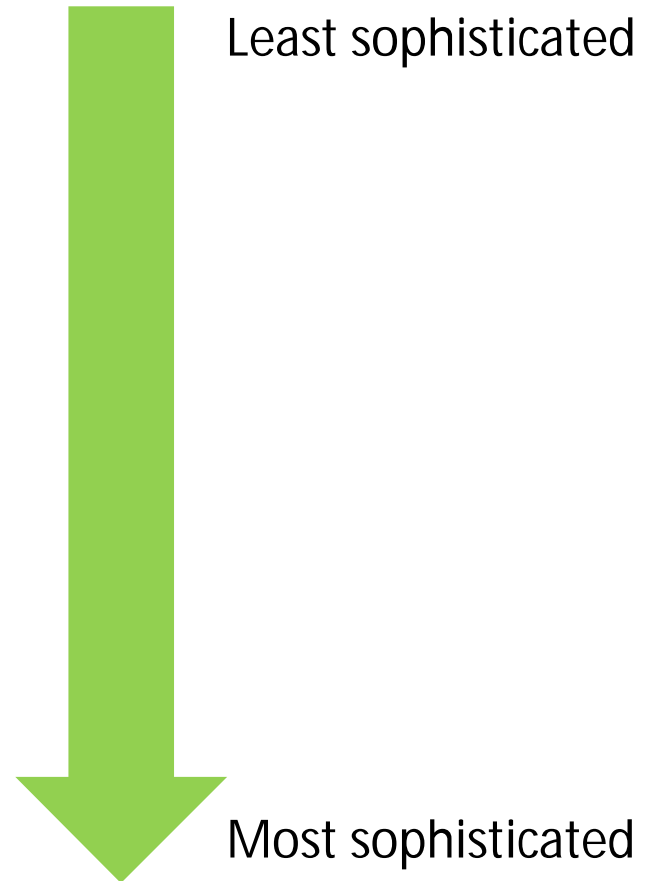


Fig 2. Schematic of key components of motion management.

Cole et. al (2014), Clin. Onc.

1. Accounting for Motion



3D-CT Planning Scan



- Fast 3D-CT
 - Tumour captured at a random position
- Slow 3D-CT
 - Improved imaging of average tumour position
 - Significant blurring (motion artefact) leads to difficulties in target delineation



Increase PTV margin to account for motion

4D-CT Planning Scan



- 4D-CT is the most important radiotherapy motion management strategy for most lung patients (Korreman et. al, 2009)



Account for motion with an internal tumour volume (ITV)



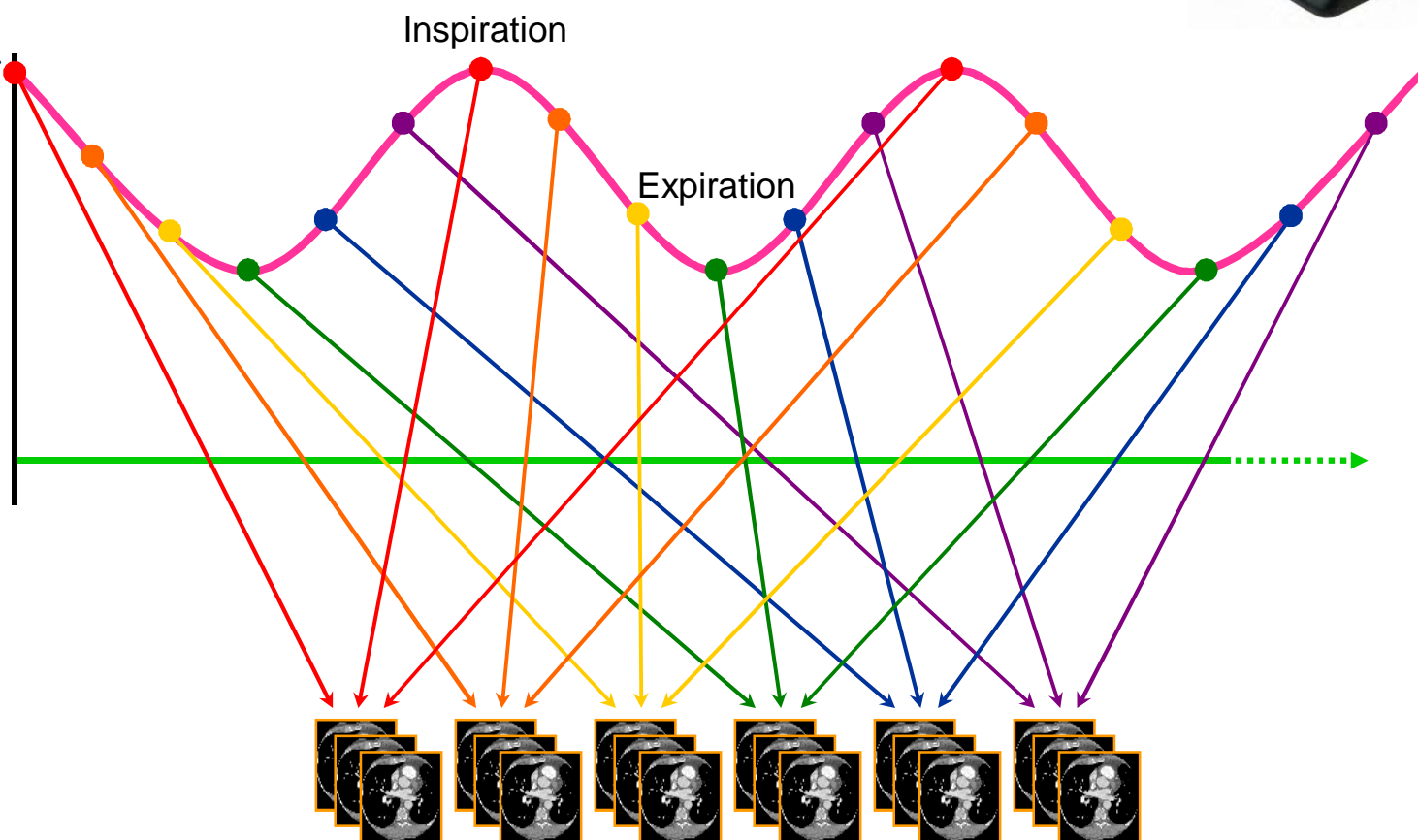
4D PTV margin smaller than 3D PTV margin

Internal Tumour Volume (ITV)

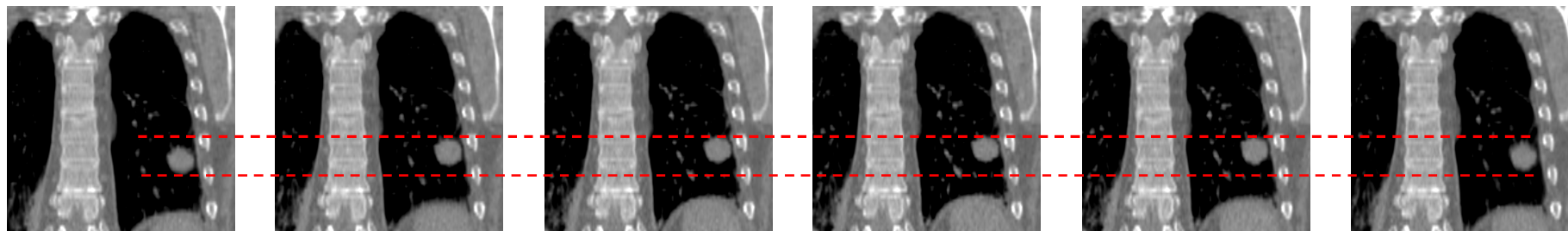


The internal tumour volume (ITV) is the CTV plus a margin to account for variation in the position, volume and/or shape (ICRU 62)

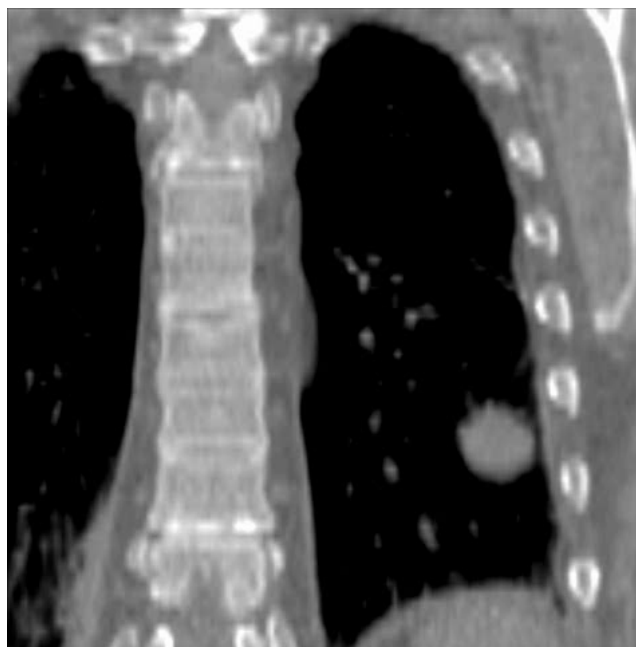
Respiratory waveform



4D-CT Planning Scan



Six bins of a 4D-CT data set



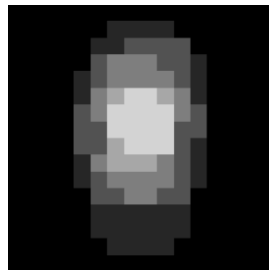
Movie

4D-CT Planning Scan



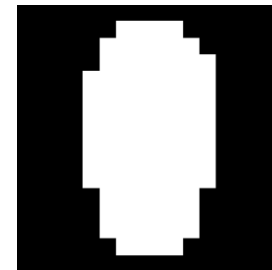
Six bins of a 4D-CT data set

Two artificial image data sets are constructed from the 4D-CT data:



Average Intensity Projection
(AIP)

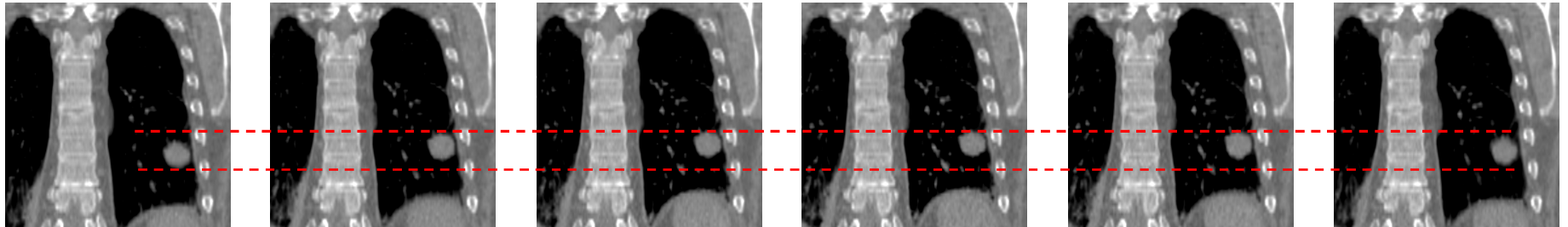
(Outlining OARs & dose
calculation)



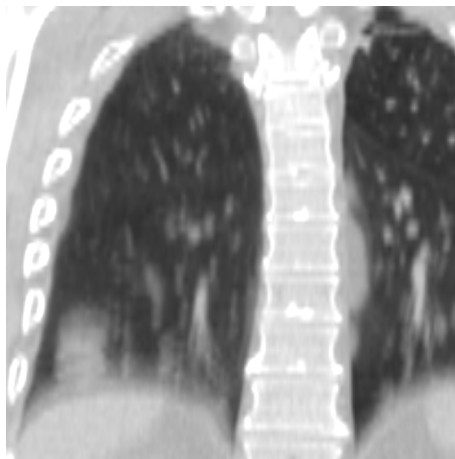
Maximum Intensity Projection
(MIP)

(Outlining ITV; NEVER dose
calculation)

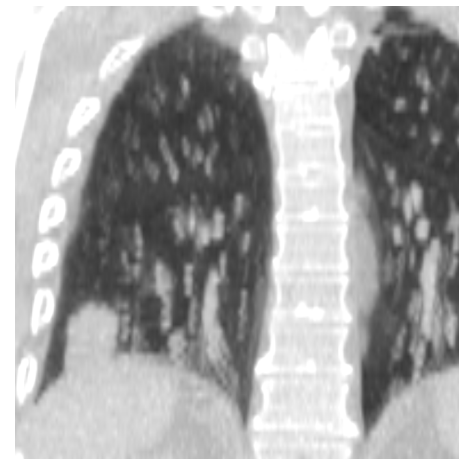
4D-CT Planning Scan



Six bins of a 4D-CT data set



Average Intensity Projection (MIP)



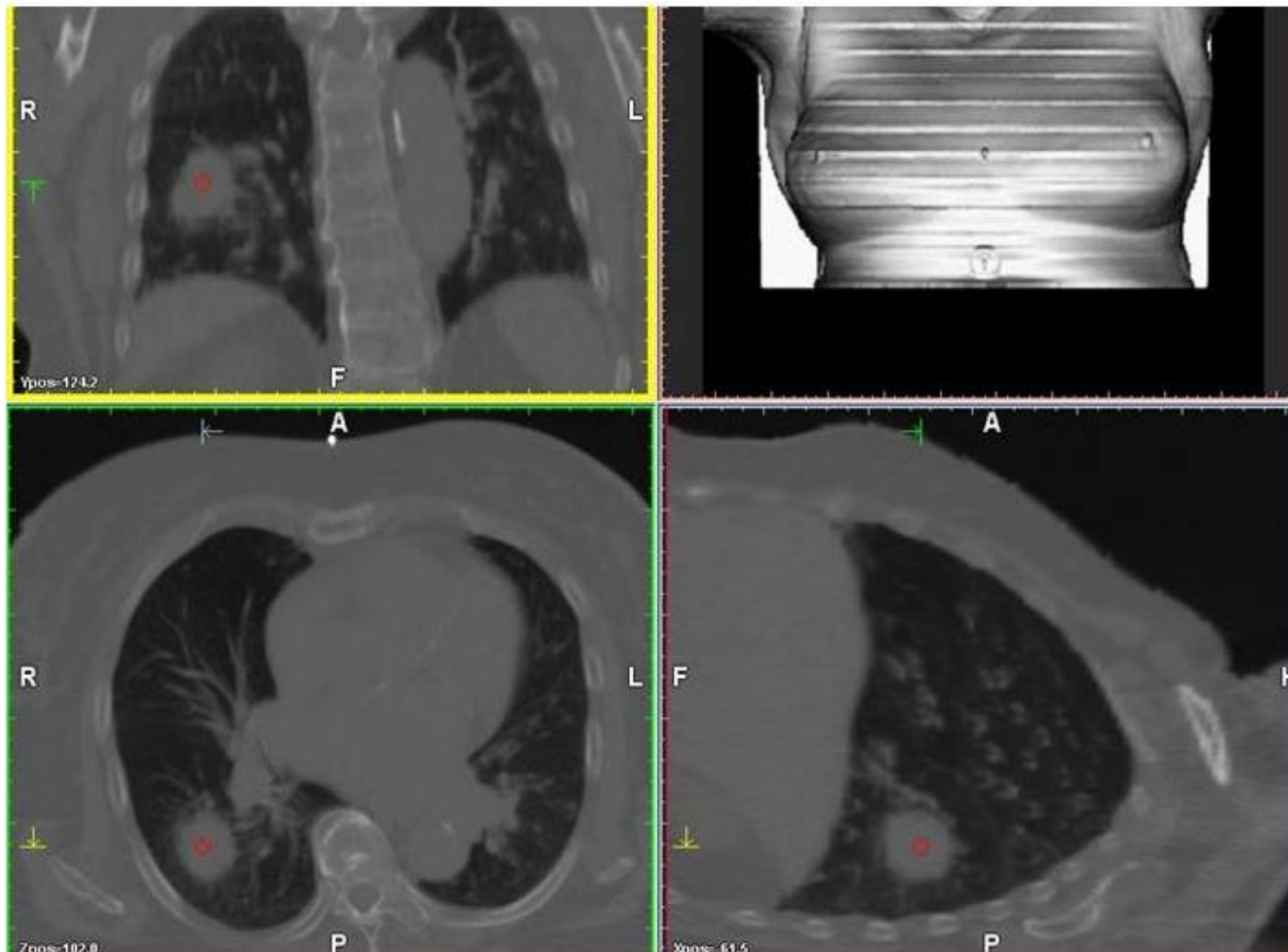
Maximum Intensity Projection (MIP)

4D-CT Scanning Considerations



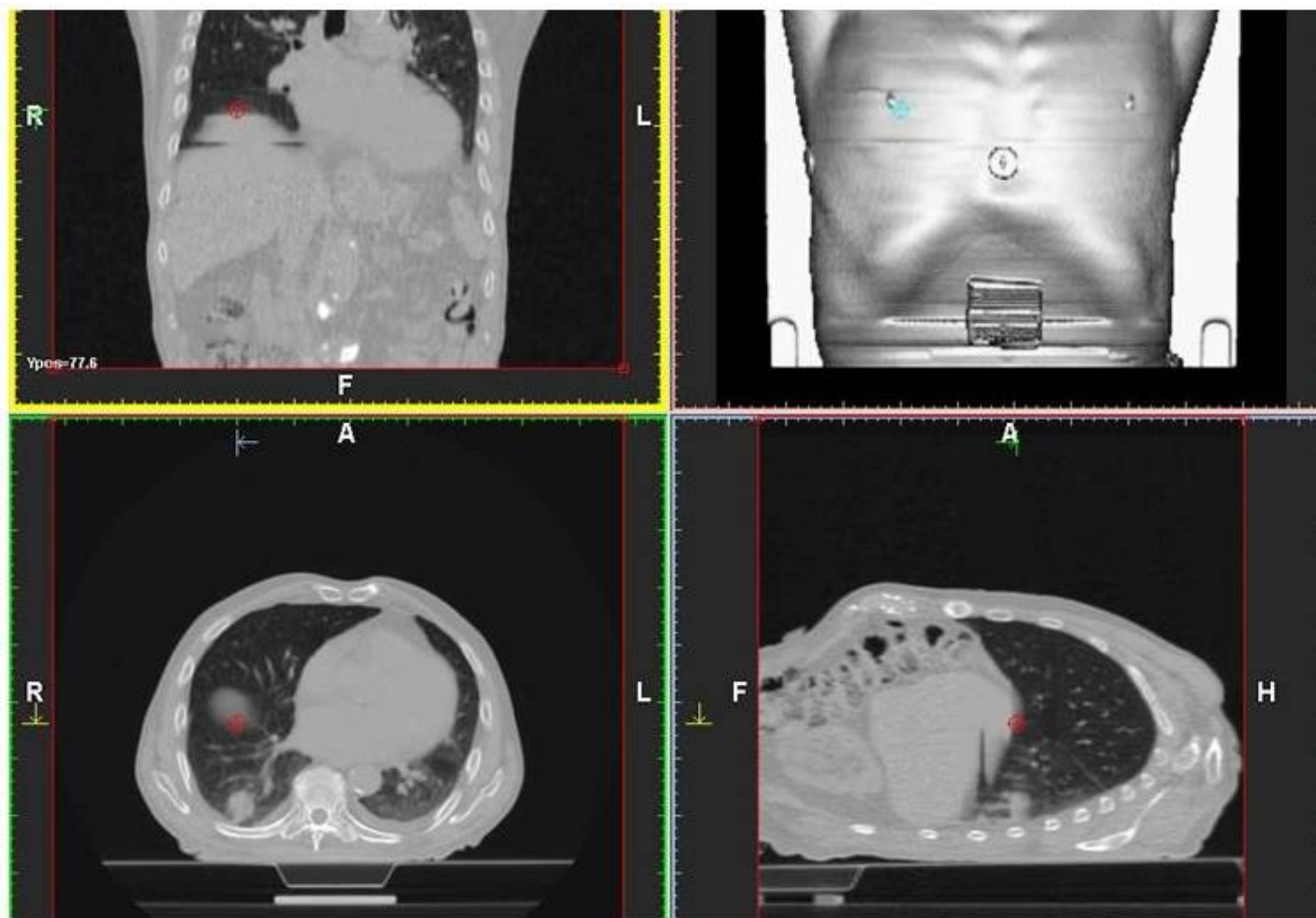
- Requires regular and consistent breathing for accurate binning of data
- If the couch pitch is set too high, under-sampling will occur leading to poor quality 4D-CT data *Ford et. al (2003), Med. Phys.*
- Exceptionally fast or slow rates of breathing cause problems:
 - Inaccurate placement of “tags”
 - Tube overheating
- Coached breathing may be required

Inadequate Sampling



Streaks

Adequate Sampling but Variation in Breathing

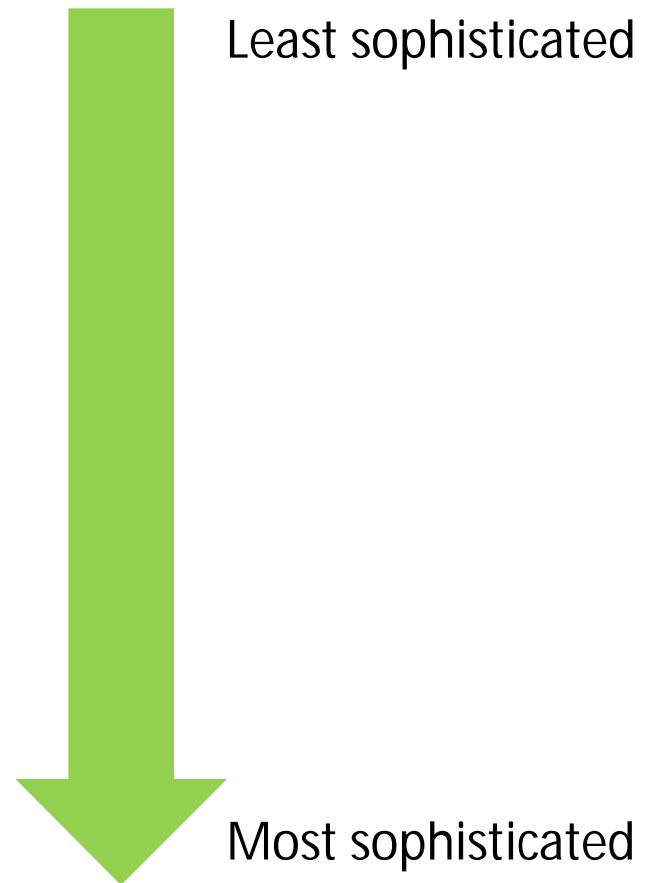


4D-CT Scanning Considerations



- 4D-CT results in higher dose than 3D-CT:
 - e.g Philips Brilliance CT scanner: (DLP) ~ 2.5 x DLP for 3D-CT
 - For other scanners, dose implications of 4D-CT can be considerably more (e.g. 10 bins requiring 10 x the dose)

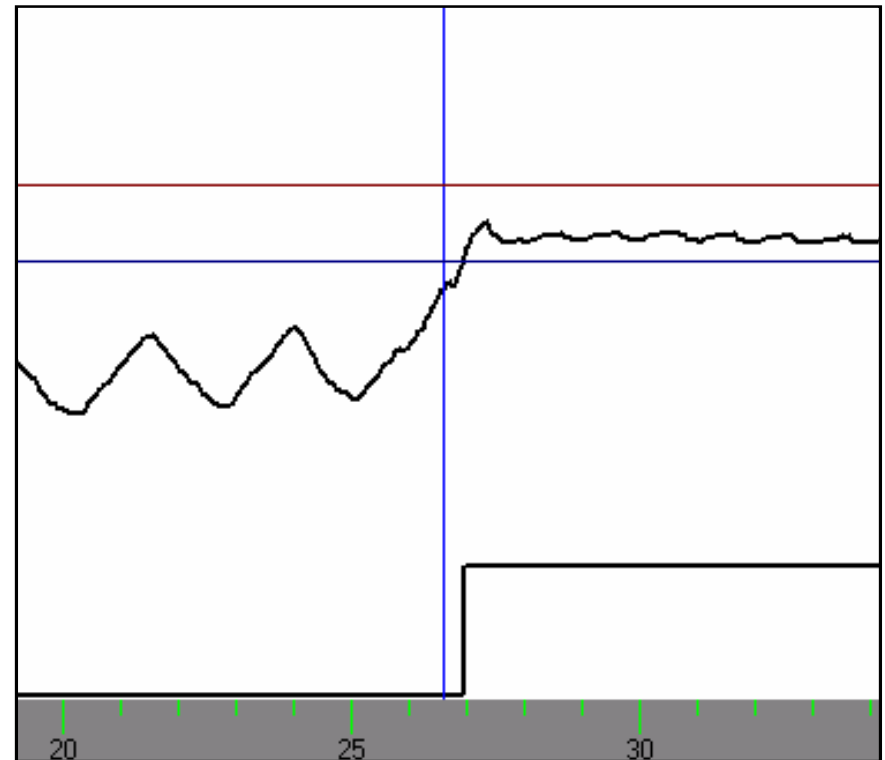
2. Reducing the Motion



Breath-hold



- Planning CT in breath-hold
- Treatment in breath-hold
- Visual coaching can be used to ensure consistency of breath-hold



Active Breathing Control



- Spirometer-based, reproducible breath-hold
- e.g. exhale to 75% of lung volume
- Reduced motion artefacts c.f. 3D-CT in free breathing
- Literature indicates ≤ 2 mm motion can be achieved – assess motion (and reproducibility) under fluoroscopy / 4D-CT for **own cohort**



<https://www.elekta.com>

Abdominal Compression

- Passive reduction in motion
- A number of studies demonstrate significant reduction in motion e.g. Heinzerling et. al (2008), Baba et.al (2009)
- Indexing for accurate and reproducible set-up
- Potentially greater impact for lower-lobe
- Can lead to more erratic breathing in some cases

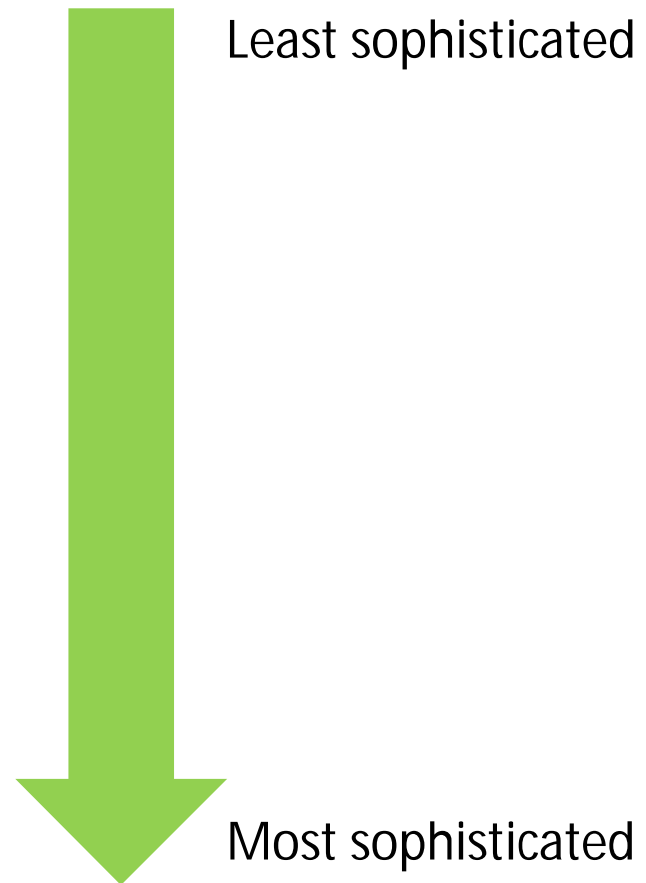


<https://www.elekta.com>



www.cdrsyst.ca

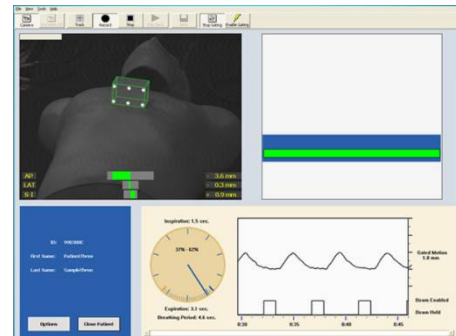
3. Tracking the Motion



Tracking Motion



Real-time Position Management
(RPM™) (Varian)



<https://www.varian.com>

Synchrony® (Accuray)



www accuray.com



www accuray.com



Cyberknife® with X-sight (Accuray)

GateRT® (VisionRT)



Calypso® (Varian)

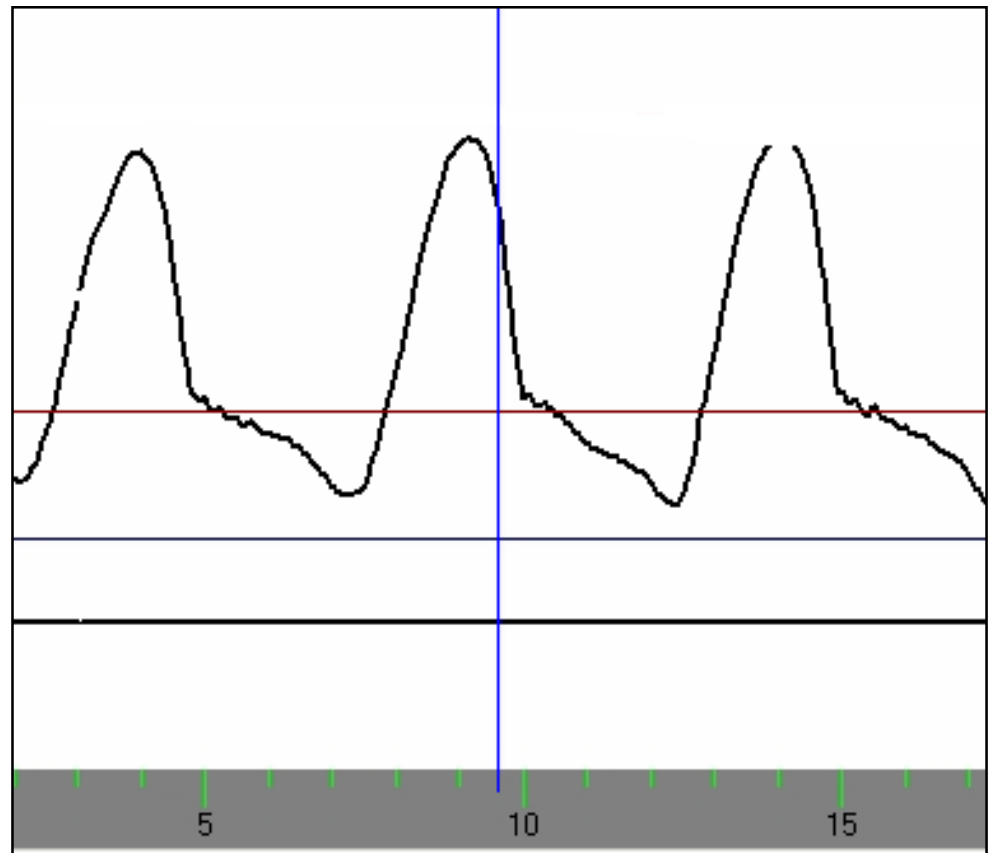


<https://www.varian.com>

Gated Treatment (with 4D Scan)



- Example: respiratory gating with RPMTM (Varian)
- Treat only in part of the respiratory cycle
- Can gate in inspiration phase or in expiration phase

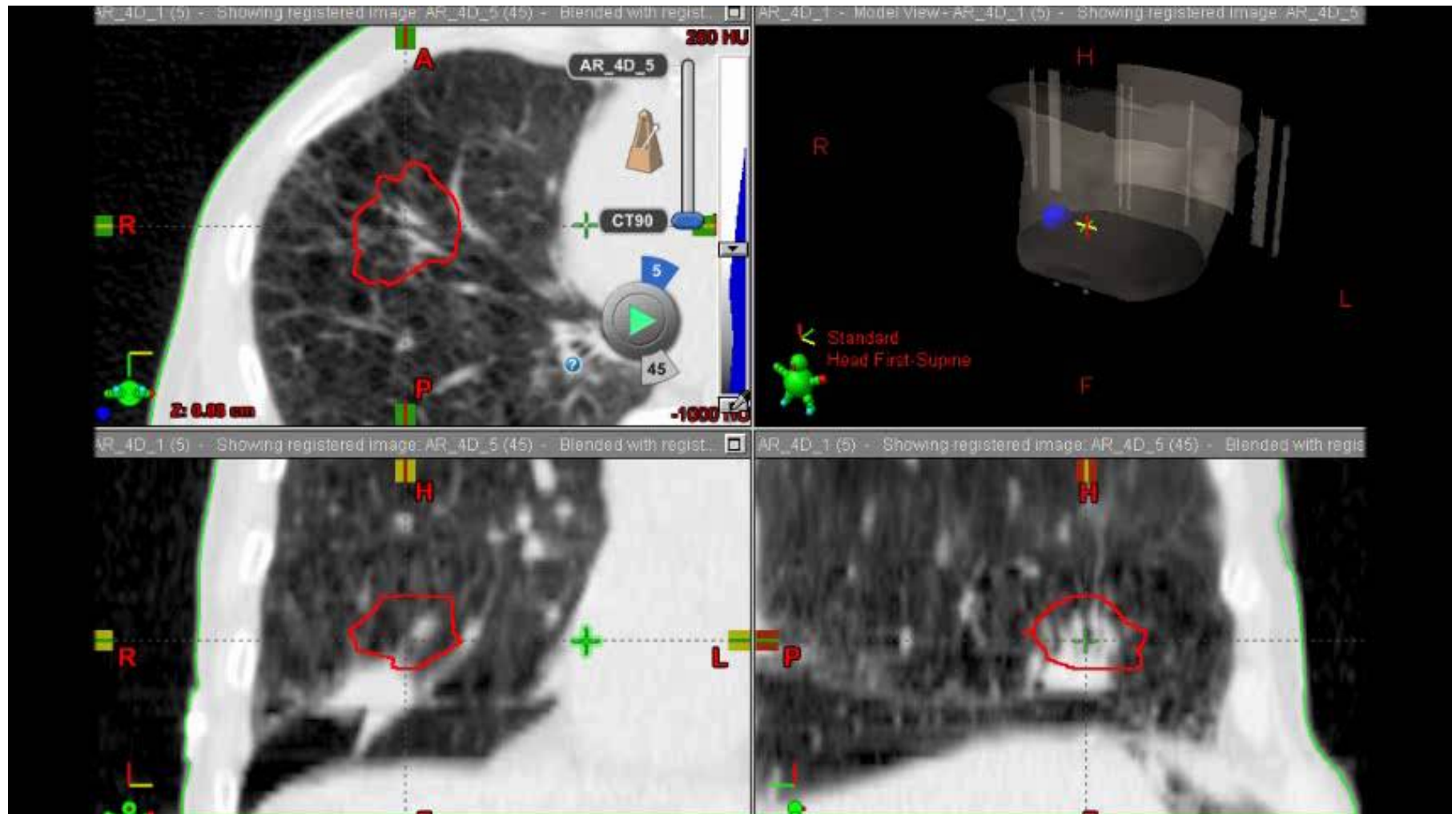


Gated Treatment

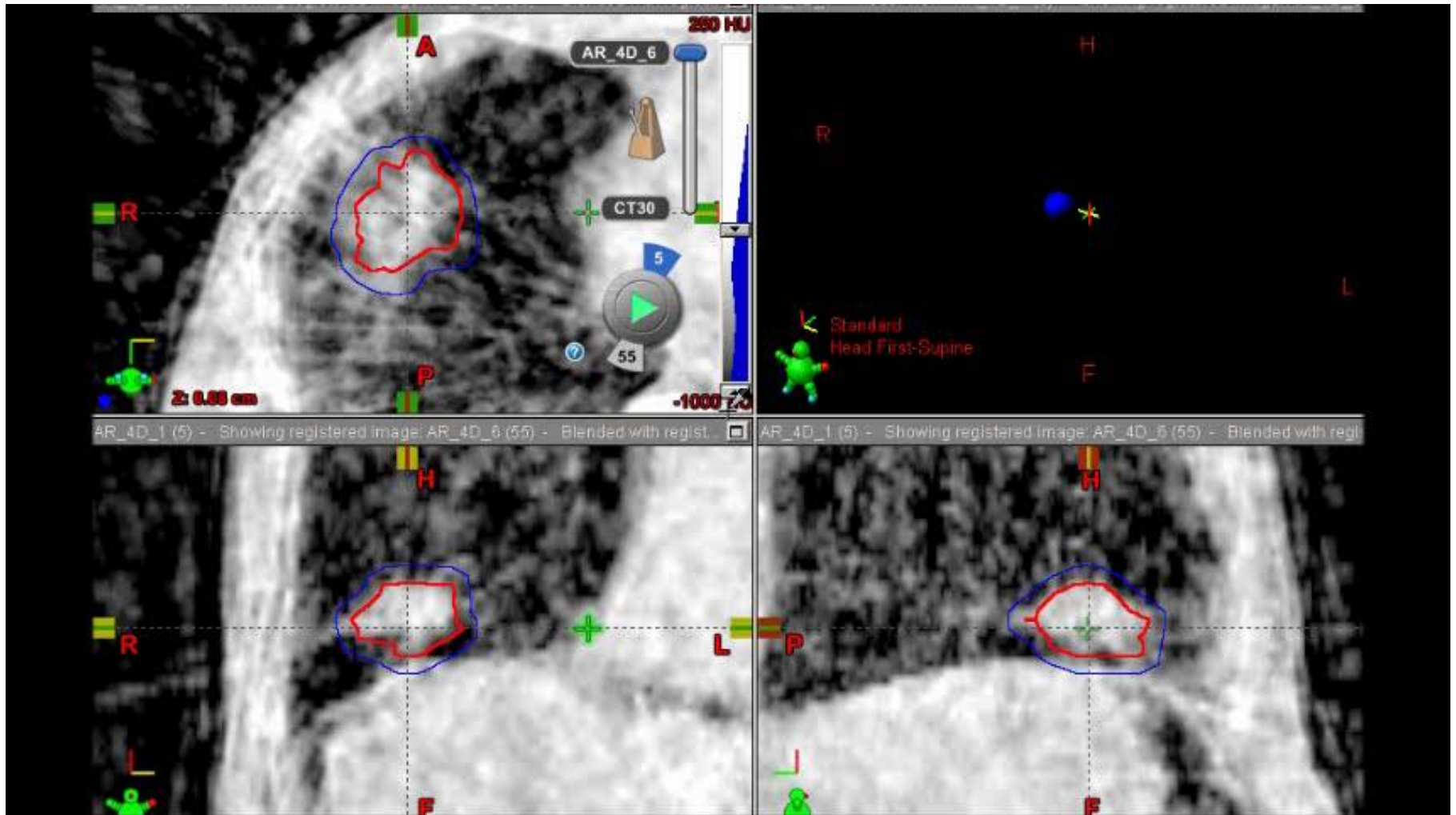


- Criteria:
 - Clinically unacceptable e.g. $V_{20\text{Gy}}$ too high
 - Tumour movement > 2 cm
 - ITV > 6 cm
 - Small tumour but with significant movement
- Choose appropriate bins based on the 4D-CT movie
- Reconstruct the AIP and MIP based only on the bins that represent the gating window to be used at treatment

Gated Treatment – Planning 4D-CT

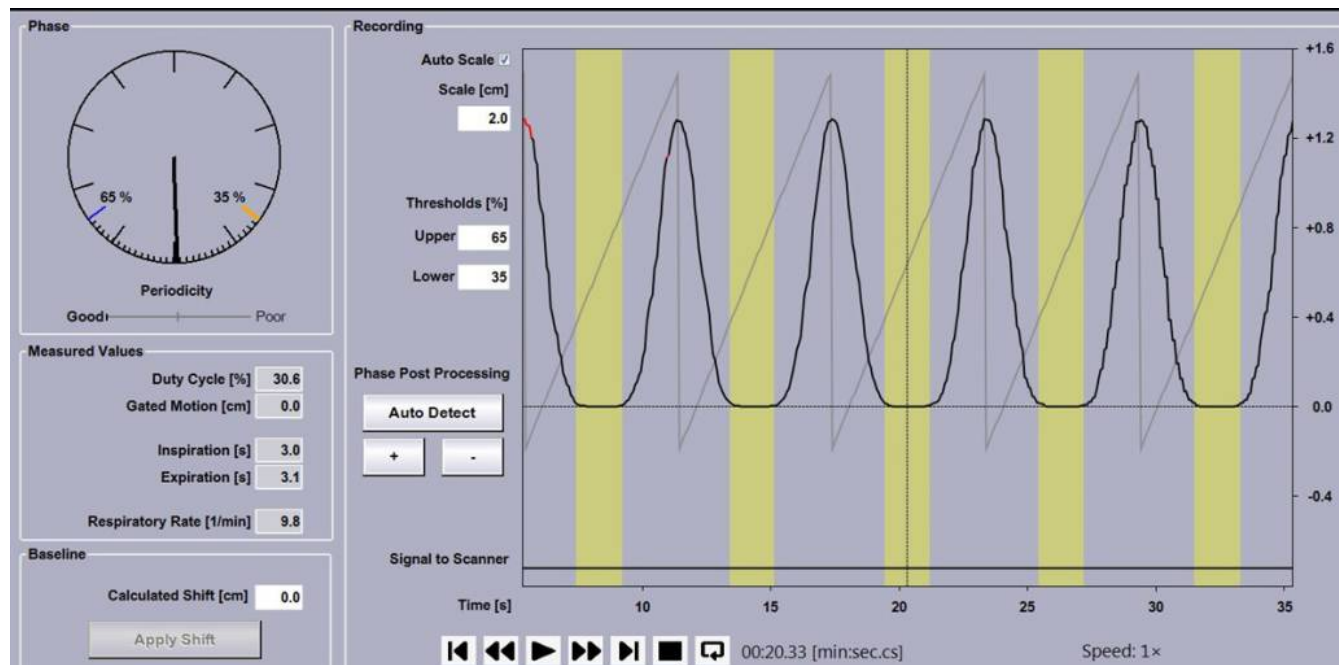


Gated Treatment – 4D CBCT

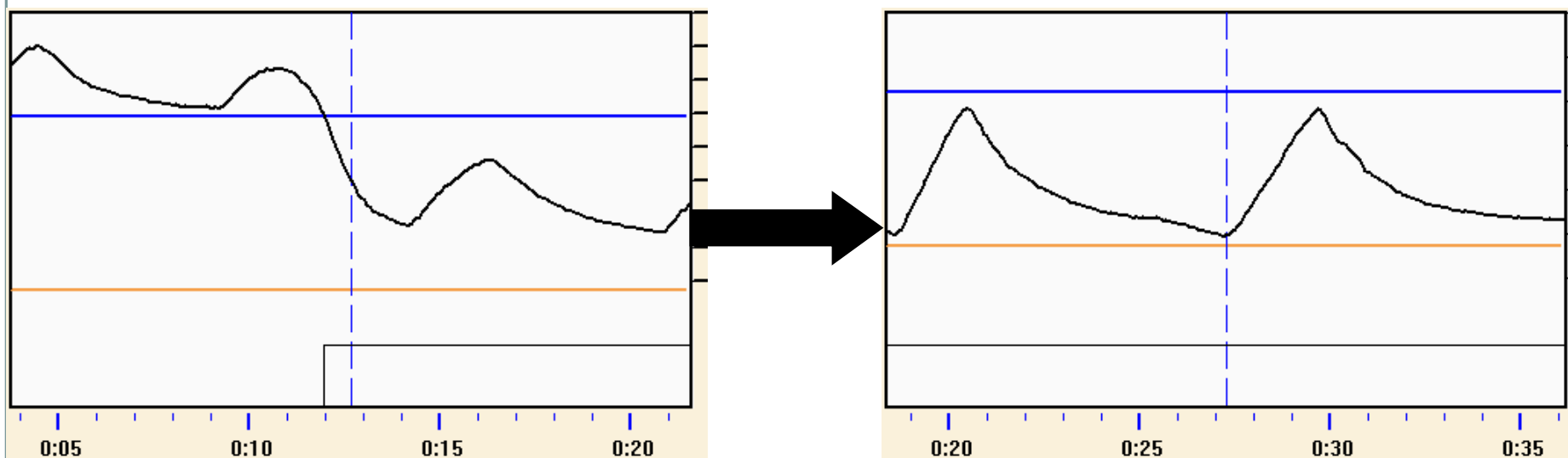


Gated Treatment: Considerations

- Which phase is more reproducible?
- How long does the patient spend in each phase?
- Phase shift between external surrogate and internal anatomy?



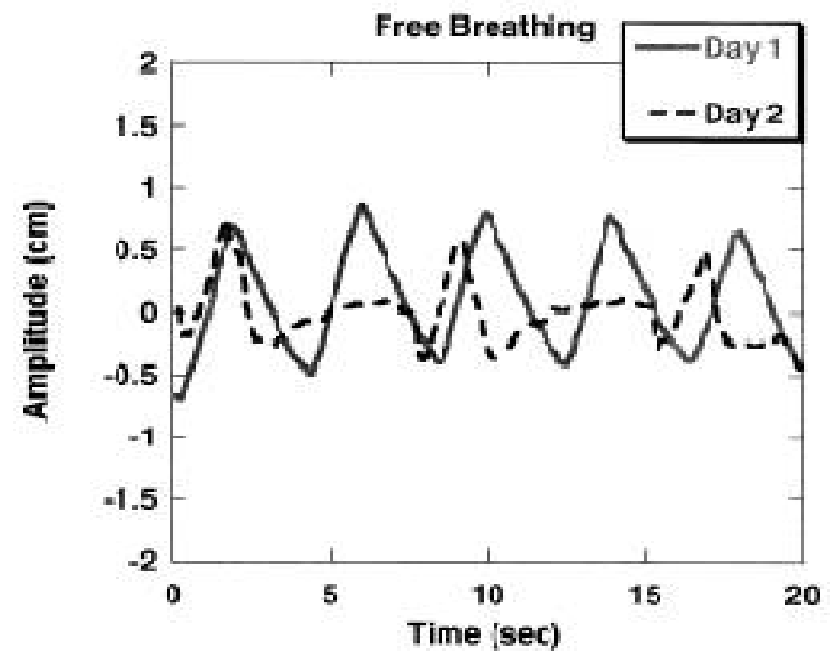
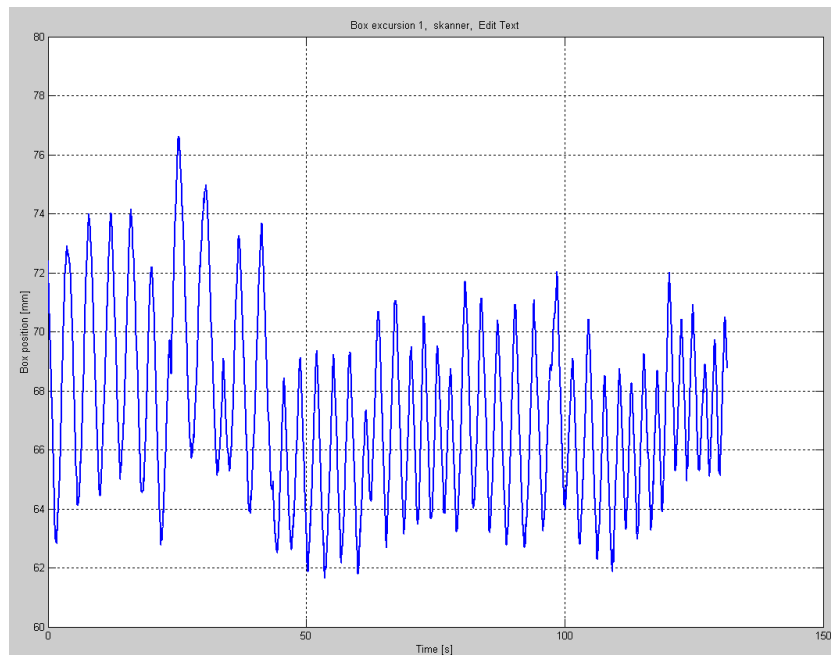
Coached Breathing for Gating



Is Coaching Necessary?



Spontaneous respiration



Kini *et al.* (2003), *Med. Dosim.*

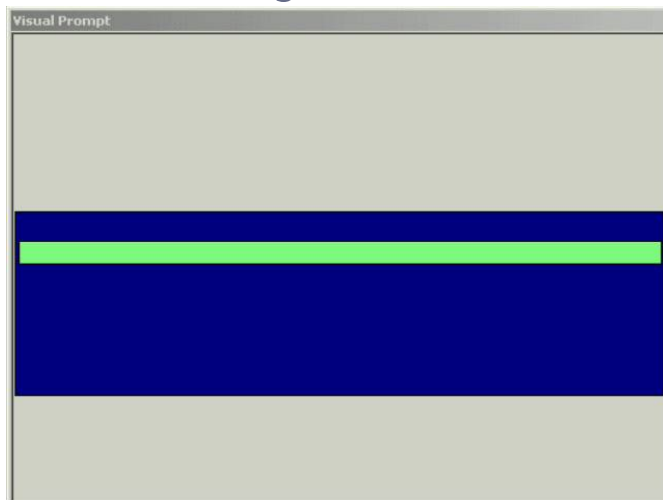


Better reproducibility required!

Coaching Options



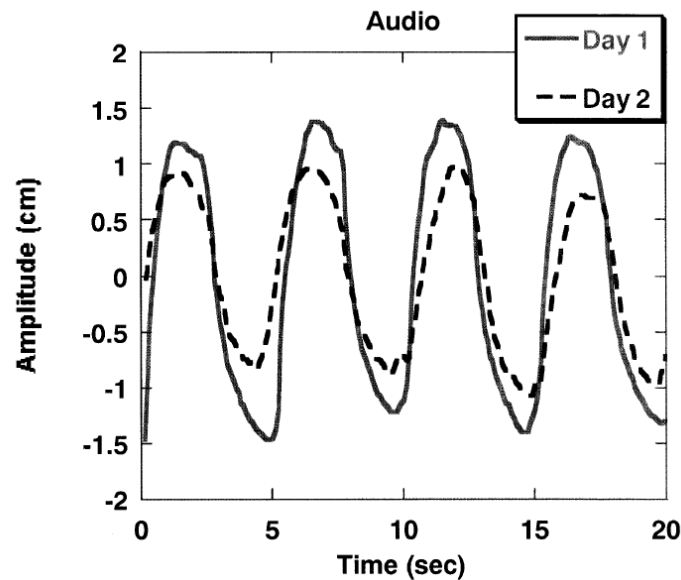
- Audio coaching
 - “Breathe in, breathe out”. Try and match to patient’s natural breathing frequency
- Visual coaching
 - e.g. Patient watches a moving bar, asked to keep the bar within pre-set range



The Effect of Coaching

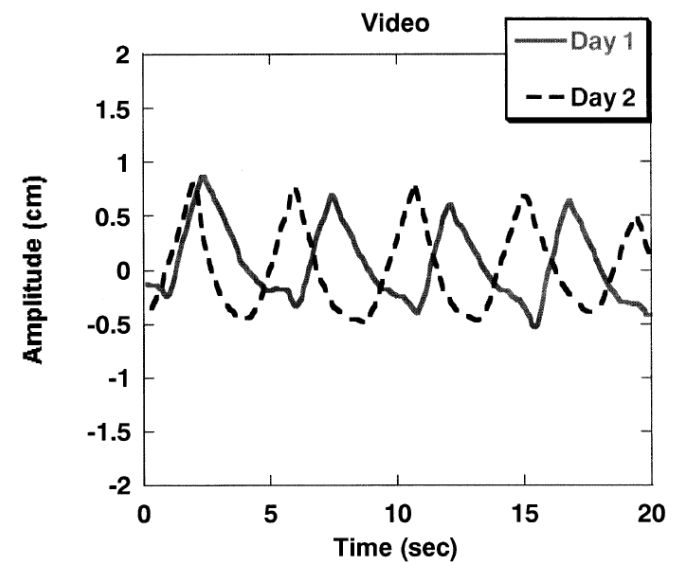


Audio coaching



Reproducible frequency

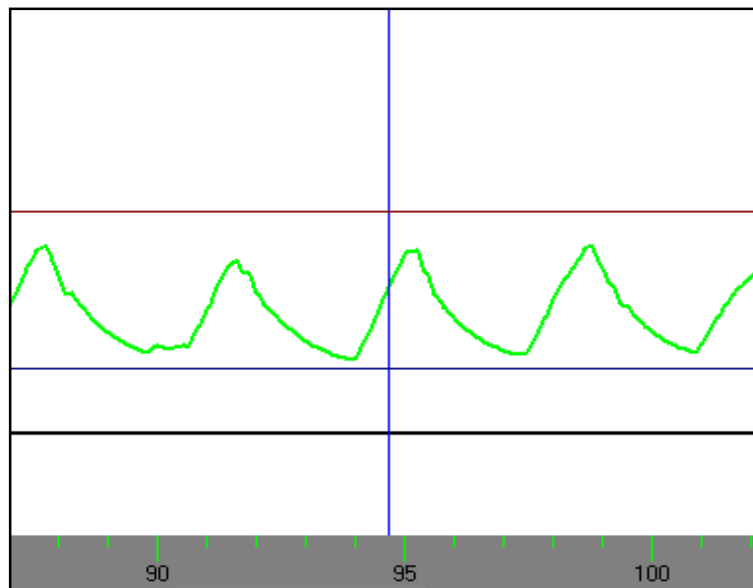
Visual coaching



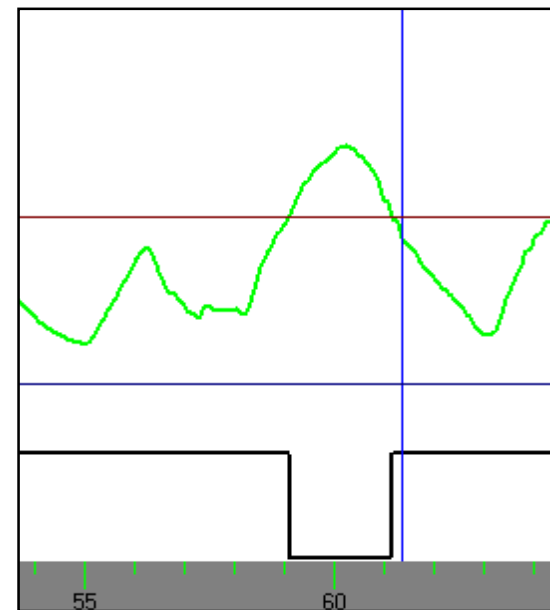
Reproducible amplitude

Kini et al. (2003), Med. Dosim.

"Back-up" or "Passive" Gating



Normal regular breathing...



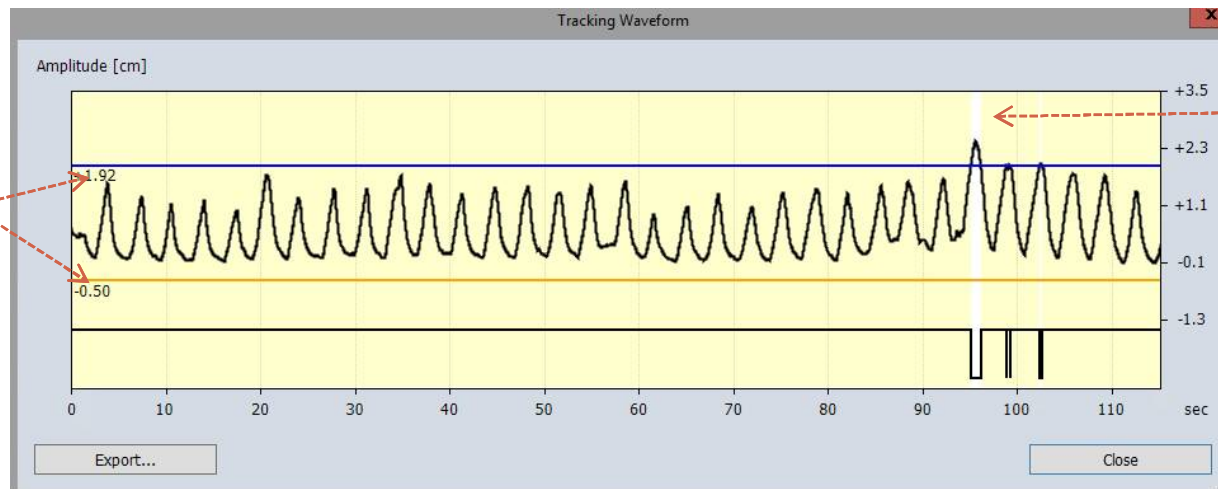
...but with irregularities where
tumour moves significantly

“Back-Up” or “Passive” Gating



- Prevents problems caused by sudden, irregular breathing (e.g. cough)
- Ensures that breathing throughout the course of treatment is consistent with the breathing trace at the 4D-CT acquisition

Window 5mm
above and
below normal
breathing
amplitude



Breathing
amplitude
exceeds
window
therefore
beam is cut
off

Acknowledgements



- Thank you to The Clatterbridge Cancer Centre and Varian Medical Systems
 - IGRT and Motion Management Clinical School