Mitigation of irregular respiration in cine 4DCT

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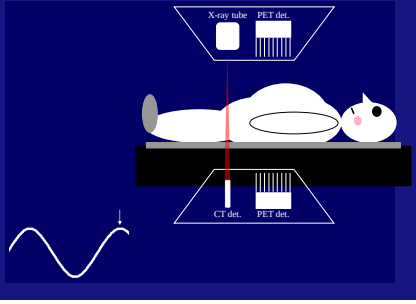
Outlines

- Review of cine 4D-CT
- Issues with irregular respiration
- Mitigation of irregular respiration in cine 4D-CT
- Summary

FB helical CT data acquisition

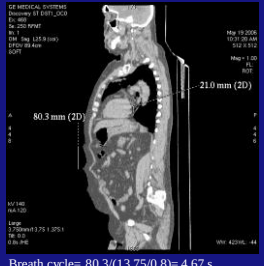


Breathing Artifacts

Protocol: 16 ×0.625 mm, 0.8 s gantry rotation, pitch 1.375

Speed: 13.75 mm/0.8 s or 17.2 mm/s

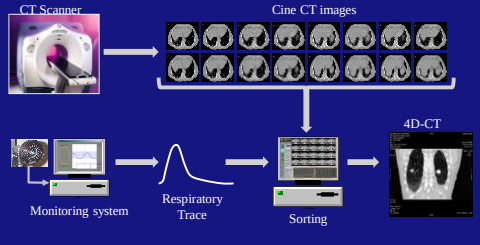
Artifacts to physiological info



Breath cycle= 80.3/(13.75/0.8)= 4.67 s

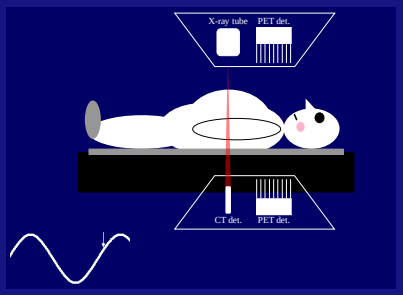
Heart rate= (21/(13.75/0.8)) $^{-1}$ × 60= 49 bpm

Cine 4D-CT workflow



Pan et al, Med Phys '04

Cine CT acquisition



Cine 4D-CT Protocol

- 4, 8 or 16 slices of 2.5 mm per rotation
- Scan duration = breathing cycle + 1 sec
- Ensure RPM is recording the respiratory waveform
- Start cine CT scan (2 to 3 min)
- Dose is < 50 mGy for chest and < 75-100 mGy for abdomen

Motion phantom experiment

4 sec cycle and 2 cm peak to peak motion

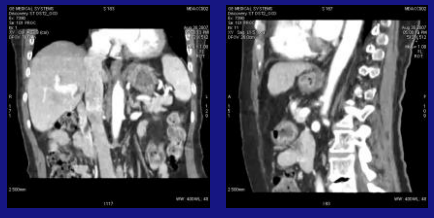
Pan et al, Med Phys, '04

Effect of 4D gating on phantom imaging

Helical CT ***4D CT***

Gating preserves the shape and size of the object

4D-CT patient study with contrast



Effects of 4D-CT on implantable defibrillator and pacemaker

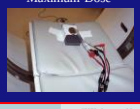
Effects of CT Irradiation on Implantable Cardiac Rhythm Management Devices[1]

Radiology

Cynthia H. McCollough, PhD
Jie Zhang, PhD
Andrew N. Primak, PhD
Wesley J. Clement, BSEE
John R. Buysman, PhD

Purpose: To prospectively measure the response of a variety of models of implantable cardiac rhythm management devices (ICRMDs) to the radiation delivered by computed tomography (CT), for both maximum and typical dose levels.

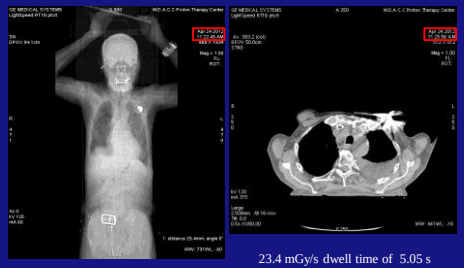
Maximum Dose



Typical Dose

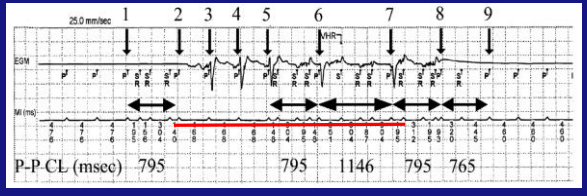
Conclusion: CT irradiation at typical clinical doses results in oversensing of ICRMDs in the majority of devices tested, although the identified effects were predominantly transient.

4D-CT patient



23.4 mGy/s dwell time of 5.05 s

4D-CT induced interference



The duration of interference was exactly identical to the duration of cine CT scan duration.

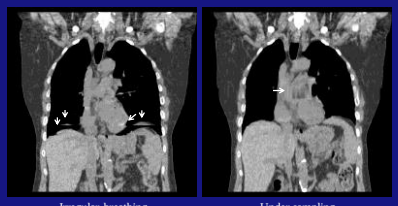
Attention should be to pacing dependent patient.

Pan et al, J. Nuc Card, 2018

Artifacts of 4D-CT

Basic assumptions of 4D-CT

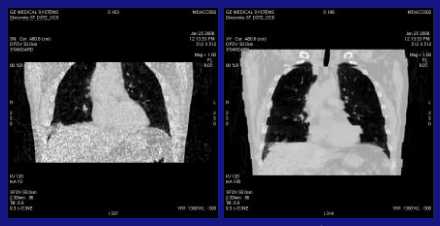
- Data acquisition for at least one breath cycle per table position
- Patient breaths regularly.



Irregular breathing

Under-sampling

Two consecutive 4D-CT scans

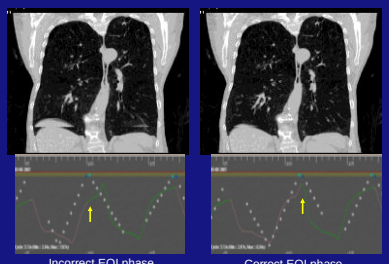


First scan

Second scan

Image quality was degraded in long imaging session

Ensure correct phase selection

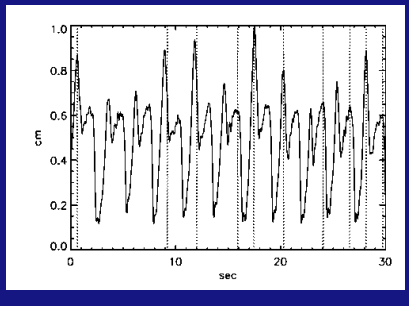


Incorrect EOI phase

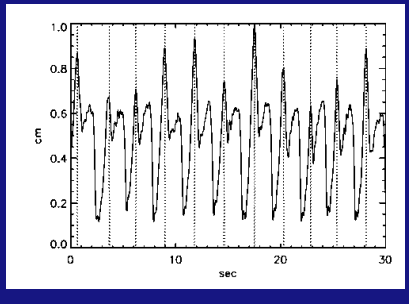
Correct EOI phase

Pan et al, Med Phys, '07

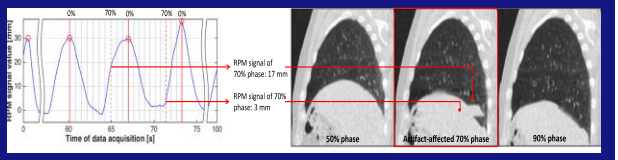
Incorrect ID of end-inspiration phases



Correct ID of end-inspiration phases



4D-CT (phase sorting issue)



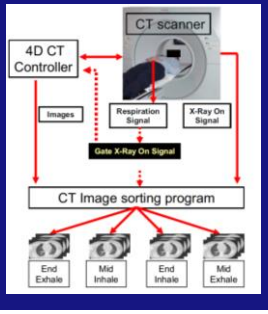
Artifact caused by irregular respiration

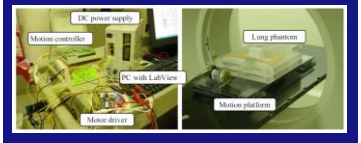
Werner et al, Radiation Oncology, '17

Solutions for mitigating artifacts

- Acquisition of more than two respiratory cycles
  - Additional time for data selection and more radiation to patient
- Repeat acquisition of the positions with irregular respiration
  - Additional tool for merging the data of regular respiration and more radiation to patient
- Repeat the 4DCT study
  - Repeat scan may not be better than the first scan and more radiation to patient
- Prospective gating, i.e., acquisition of only the regular data
  - Keall et al in 2007

Prospective 4D-CT on Single-slice CT





Implemented on Philips PQ5000

Keall et al, Australas Phys. Eng. Sci. Med. 2007

Prospective cine 4D-CT

(w/o hardware and software)

IOP Publishing | Institute of Physics and Engineering in Medicine — Physics in Medicine & Biology

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Note

New prospective 4D-CT for mitigating the effects of irregular respiratory motion

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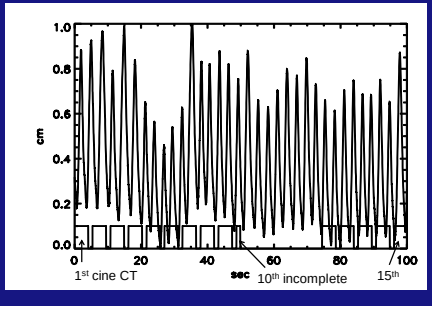
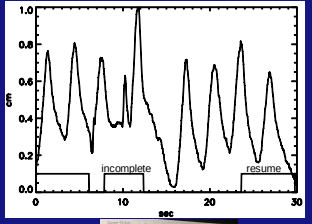
CrossMark

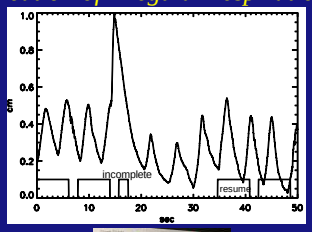
Observation



Identification of irregular respiration 1

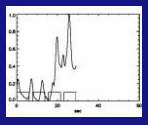


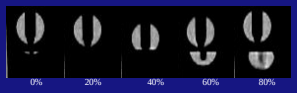
Identification of irregular respiration 2



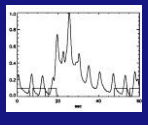
Phantom Experiment

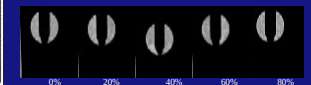
Irregular respiration in conventional 4D-CT



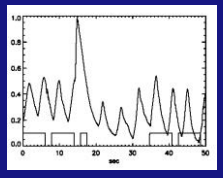


Skip irregular respiration in Prospective 4D-CT





Prospective 4D-CT (1)

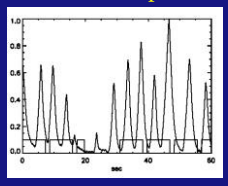


End inspiration

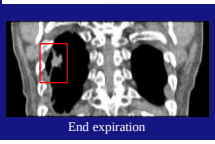
End expiration

End inspiration with irregular respiration

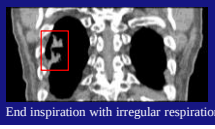
Prospective 4D-CT (2)



End inspiration



End expiration



End inspiration with irregular respiration

Retrospective reconstruction to remove the images of irregular respiration

Retro	Scan Type	Retro Start	Retro End	No. of Images	Thick (mm)	Interval	Time
Y	One Full 0.5 sec.	140.000	197.500	96	8 x 2.5	0.500	0.0 6.0
Y	One Full 0.5 sec.	160.000	177.500	96	8 x 2.5	0.500	0.0 6.0
N	One Full 0.5 sec.	180.000	197.500	32	8 x 2.5	0.500	0.0 2.1
Y	One Full 0.5 sec.	180.000	197.500	96	8 x 2.5	0.500	0.0 6.0

Steps of prospect cine 4D-CT

- Stop acquisition during irregular respiration
- Resume acquisition when regular respiration
- Remove incomplete data in retrospective reconstruction
- Repeat as many times as needed
- Not applicable to helical 4D-CT
  - Once the scan is stopped, it can not be resumed.

Summary

- 4D-CT scans can interfere with the function of defibrillator or pacemaker. Attention should be to pacing dependent patient.
- Prospective cine 4D-CT can be implemented to help reduce artifacts without cost.