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 = 80.35/(13.75/0.8) = 4.67 s
Heart rate = (21/(13.75/0.8)) × 60 = 49 bpm

Cine 4D-CT workflow
**Cine CT acquisition**

- X-ray tube
- PET det.
- CT det.

**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
Effect of 4D gating on phantom imaging

Gating preserves the shape and size of the object.

4D-CT patient study with contrast

Effects of 4D-CT on implantable defibrillator and pacemaker
The duration of interference was exactly identical to the duration of cine CT scan duration.

Attention should be to pacing dependent patient.
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
Correct ID of end-inspiration phases

Incorrect 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

Prospective cine 4D-CT
(w/o hardware and software)

Note

Identification of irregular respiration 1

Observation
Identification of irregular respiration

Phantom Experiment

Prospective 4D-CT (1)
End inspiration with irregular respiration

Prospective 4D-CT (2)

Retrospective reconstruction to remove the images of irregular respiration

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 cannot 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.