Slide 1

Development and Application of Digital Human Phantoms

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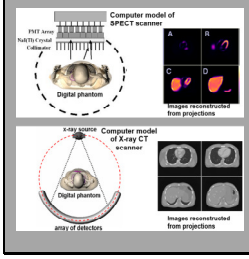
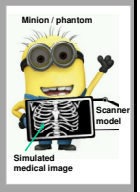
Medical Imaging Simulation





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Medical Imaging Simulation

- Advantages:
  - Exact anatomy of the computer phantom is known providing a gold standard to evaluate, improve, and compare devices and techniques
  - Computer phantoms have the potential to model different anatomies and medical situations providing a large population of subjects from which to perform research
  - No worries about overexposing the phantoms to radiation or being sued by them (IRB approval not needed)
- Simulation provides a virtual domain to perform studies that would be impossible with human subjects

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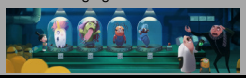
Computational Phantoms

- Limitations:
  - Realistic models of anatomy are vital
  - A variety of anatomically variable phantoms are needed to mimic the population at large
  - Without such, simulated results may not be indicative of what would occur in live experiments
- The development of realistic computational models is one of the most active areas of research in imaging and radiation dosimetry



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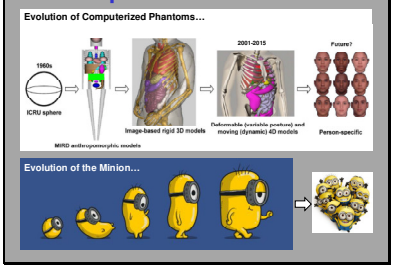
Computational Phantoms



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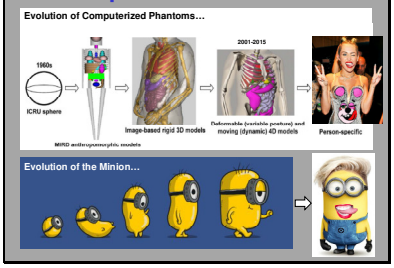
Computational Phantoms



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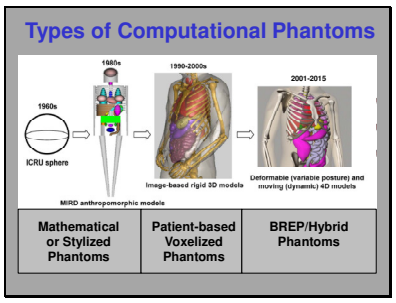

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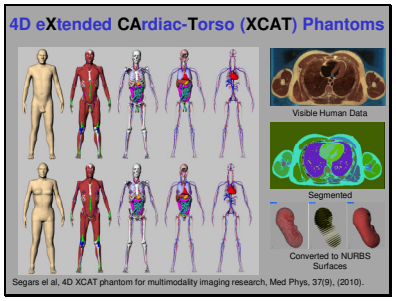

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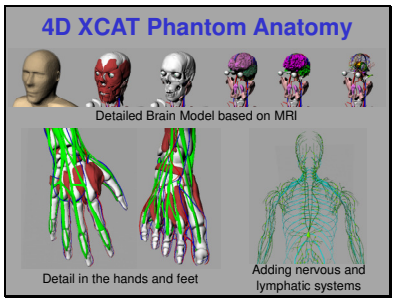

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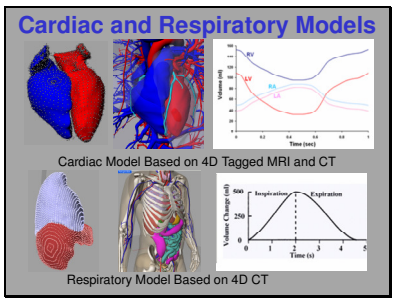

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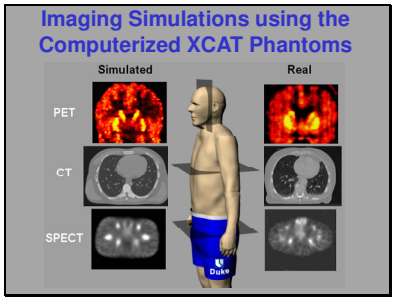

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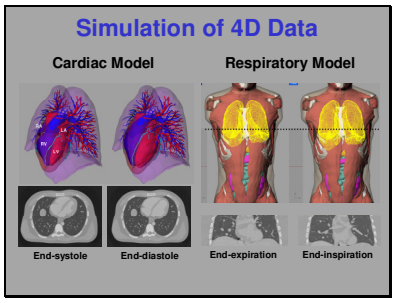

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Anatomical Variations

- Have a standard model for an adult male and female
- Modeling patient variability is essential for imaging studies
- Results for one may not be indicative of others

Standard male and female adult

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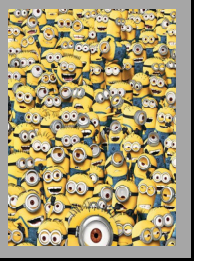
Anatomical Variations

- Need population of realistic phantoms to represent the public at large
- Number of phantoms is limited due to time to segment patient data (many months to a year per phantom)



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Population of 4D XCAT Phantoms

- Using methods from computational anatomy, we've developed a more efficient method
- Create a population of hundreds of detailed phantoms to represent the public at large from infancy to adulthood
- Each model is based on patient CT data from Duke Database
- Include cardiac and respiratory motions for 4D simulations
- Library of 4D phantoms

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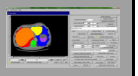
Phantom Construction

- Segment patient CT data (bones and major organs) to create an initial model
  - Fit arms/legs to patient model using XCAT models scaled to patient size
- Select template XCAT phantom that best matches the patient target
  - As the library grows, get better templates
- Utilize mapping algorithm to morph template XCAT to the target model
  - Defines unsegmented structures (vessels, muscles, tendons, ligaments)
  - No need to segment all structures



Template XCAT

Patient Target

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Phantom Construction

- Anatomy is checked for accuracy
- Using this technique, a phantom can now be completed in days instead of months

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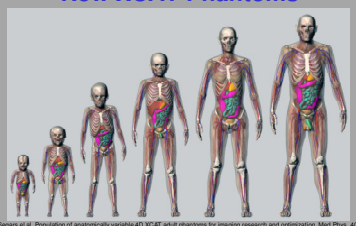
New XCAT Phantoms



Segars et al. Population of anatomically variable 4D XCAT adult phantoms for imaging research and optimization, Med Phys, 40, (2013).
Norris et al. A set of 4D Pediatric XCAT Reference Phantoms for Multimodality Research, Med Phys, 41, (2014).
Segars et al. The development of a population of 4D pediatric XCAT phantoms for imaging research and optimization, Med Phys, (2015).

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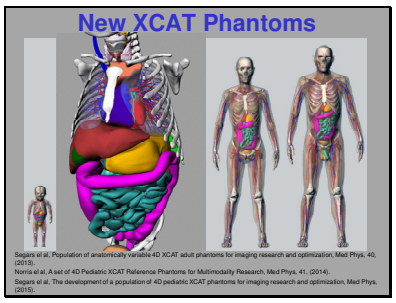

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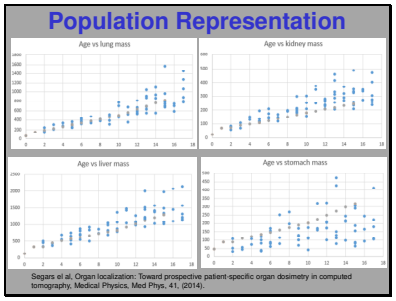

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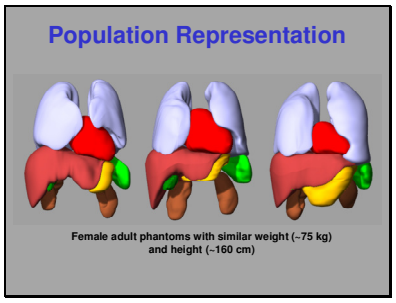

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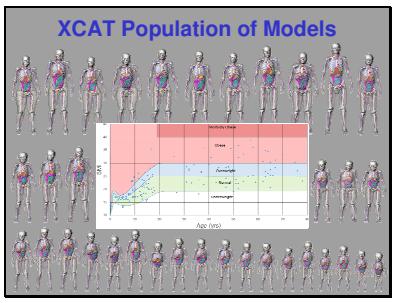

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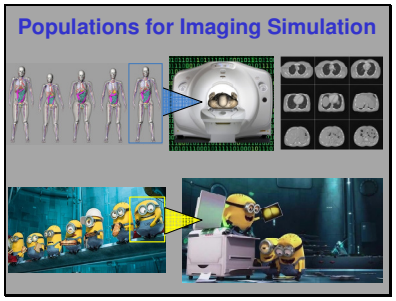

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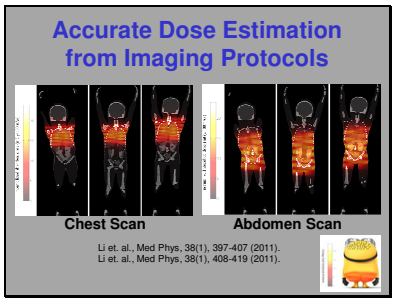

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Other Minions / Phantoms

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Other Minions / Phantoms

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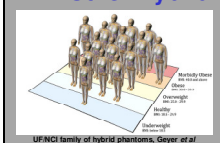
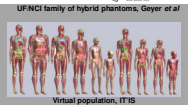
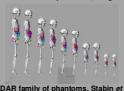
Other Hybrid Phantoms


UF/NCI family of hybrid phantoms, Geyer *et al*


RPI series of adult phantoms, Ding *et al*


Virtual population, IT'IS


RADAR family of phantoms, Stabin *et al*

Physics in Medicine and Biology, 59(18), (2014).
Review article by George Xu, Rensselaer Polytechnic Institute (RPI)

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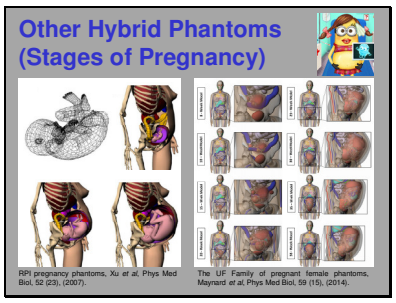

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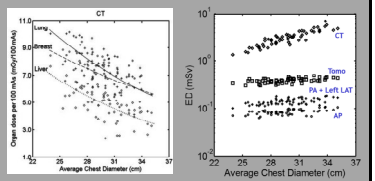
Applications

Retrospective dosimetry:

Effect of protocol and size on dose



Zhang et al, Med. Phys., 41, (2014).

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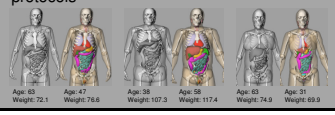
Applications

Prospective dosimetry:

Atlas-based predictions of dose for different protocols



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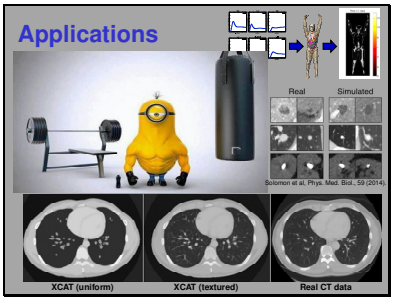
Applications



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Summary

- Much progress has been made in phantom development
  - From simple mathematical phantoms to more detailed hybrid models like the XCAT
- As phantoms get more and more sophisticated, they allow users to simulate diagnostically realistic images close to that from actual patients

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Summary

- With such, computational phantoms give us the ability to perform experiments entirely on the computer with results that are indicative of what would occur in live patients
- Provide a valuable tool to evaluate, optimize, and compare imaging techniques in terms of image quality and dose and to investigate the effects of anatomy and motion on images

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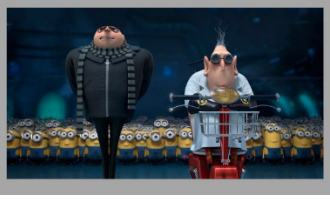
Computational Phantoms

They are one in a Minion…



Thank You!