Why do Patients and Their Care-Givers Need 3D and 4D Imaging?

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Imagine you finally decide to learn the status and prognosis of your lower back pain. From your MRI study the local orthopedic or neuro-surgeon makes an 8 cm midline incision over your lower vertebrae. While looking at the X-ray view-box in the operating room, as well as what can be seen of your spinal cord and the disc after removing some bony bridges, the surgeon retracts your cord and chisels out part or all of your disc. He then adds some shims or screws to help support your vertebrae. This scenario could apply to cervical vertebrae or knee surgery. Having benefited from these repairs you later encounter an episode of robotic surgery of your clogged coronaries, or a blind biopsy of your prostate because your PSA is high or your breast because your mother has breast cancer and somebody saw something suspicious on a mammogram.

In all of these procedures few physicians would claim they had confidence that what they were able to see, allowed them to do their best for you. In fact, most would complain that the lack of anatomical landmarks and adequate surgical exposure limit diminished their effectiveness and therefore the safety and efficacy of their procedures.

Therefore, how can fully 3D imaging scientists practically change the practice of medicine? The answer lies in a few realistic examples from which one can extrapolate to many surgical and non-surgical procedures that promise to improve the quality and effectiveness of medical care.

Now imagine the surgeon has made perhaps three 1 cm incisions in your back and through a stereo projection system in the operating room, the surgeon can visualize your vertebrae in virtual reality from a previously obtained Spiral (helical) CT. The surgeon can also visualize the spatial position of the operating instruments relative to the bony architecture of your spine. At his oral command he can move your virtual reality anatomy to improve viewpoints and can call on additional MRI or even SPECT or PET bone blood flow information to aid in the surgical decisions. The surgeon's tools move around unbroken bony bridges and the remodeling operation is nearly bloodless and nearly atraumatic. A similar scenario can be portrayed for cardiac surgery.

In short, 3D imaging is a method of achieving surgical exposure without surgery. Why cannot this be done by in-situ endoscopy without prior imaging? Because the 3D relations of a wide field of view is needed for safe and accurate surgery.

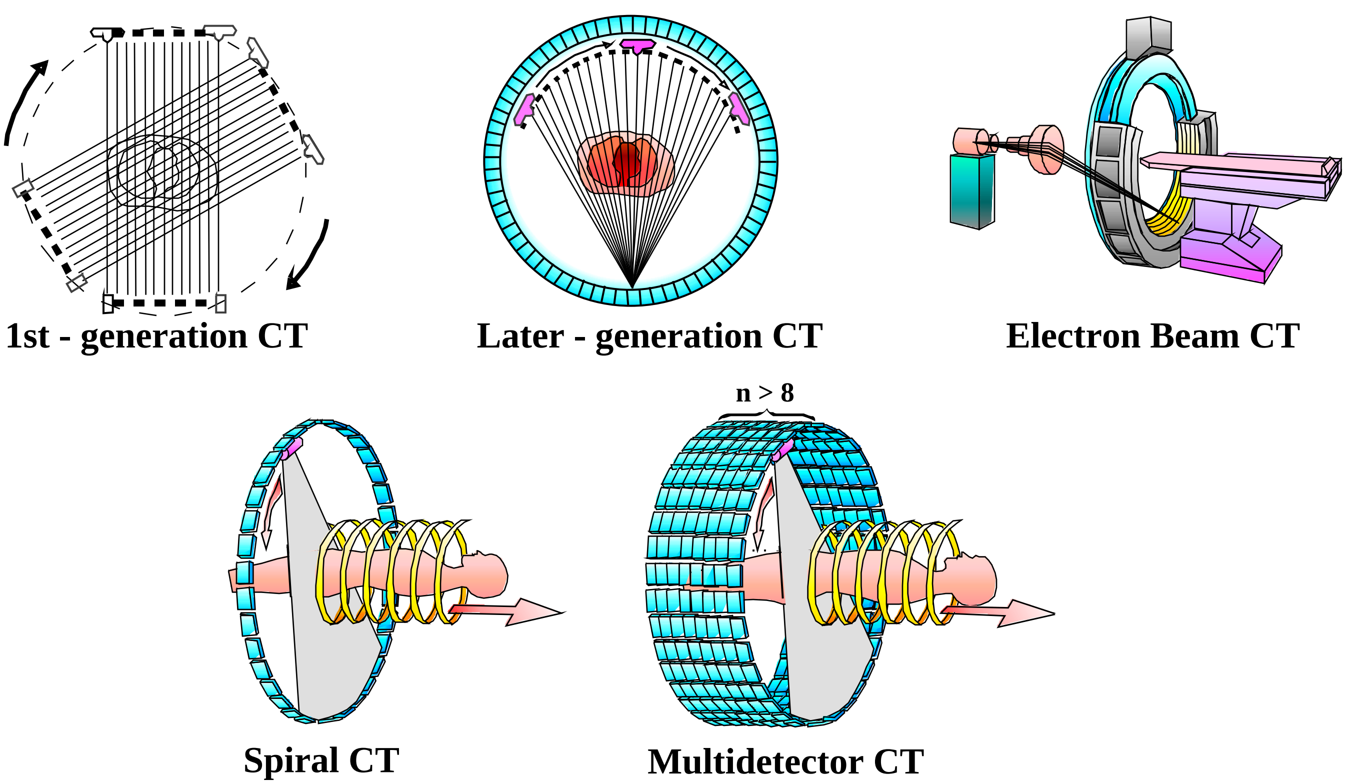
In addition to improved visualization of the spatial relationships, 3D data acquisition methods and reconstruction methods enable the realization of entirely new areas of medical imaging. One example is the recent discovery that multidetector helical CT can characterize coronary atheroma with clinically useful diagnostic resolution. The breakthrough here is a direct result of speed of volume coverage that in effect negates motion-based blurring. The volume coverage provides adequate data acquisition during a data collection sequence synchronized with the EKG window.

Other examples of 3D and 4D methods are dynamic MRI for studying the motion of bony joints and of the heart. Of particular interest is our proposed method for evaluating the motion of the human vertebral column. Even methods of in-vivo microscopy, as for example 50 μm resolution imaging, of the human cortex require 4D acquisition methods and motion compensation algorithms. As shown in the accompanying figures, the evolution of instruments continues to make demands on scientists who can create algorithms to optimize the data collection from these new geometries. Examples of these applications alert us to the importance for 4D algorithms that encompass the following applications:

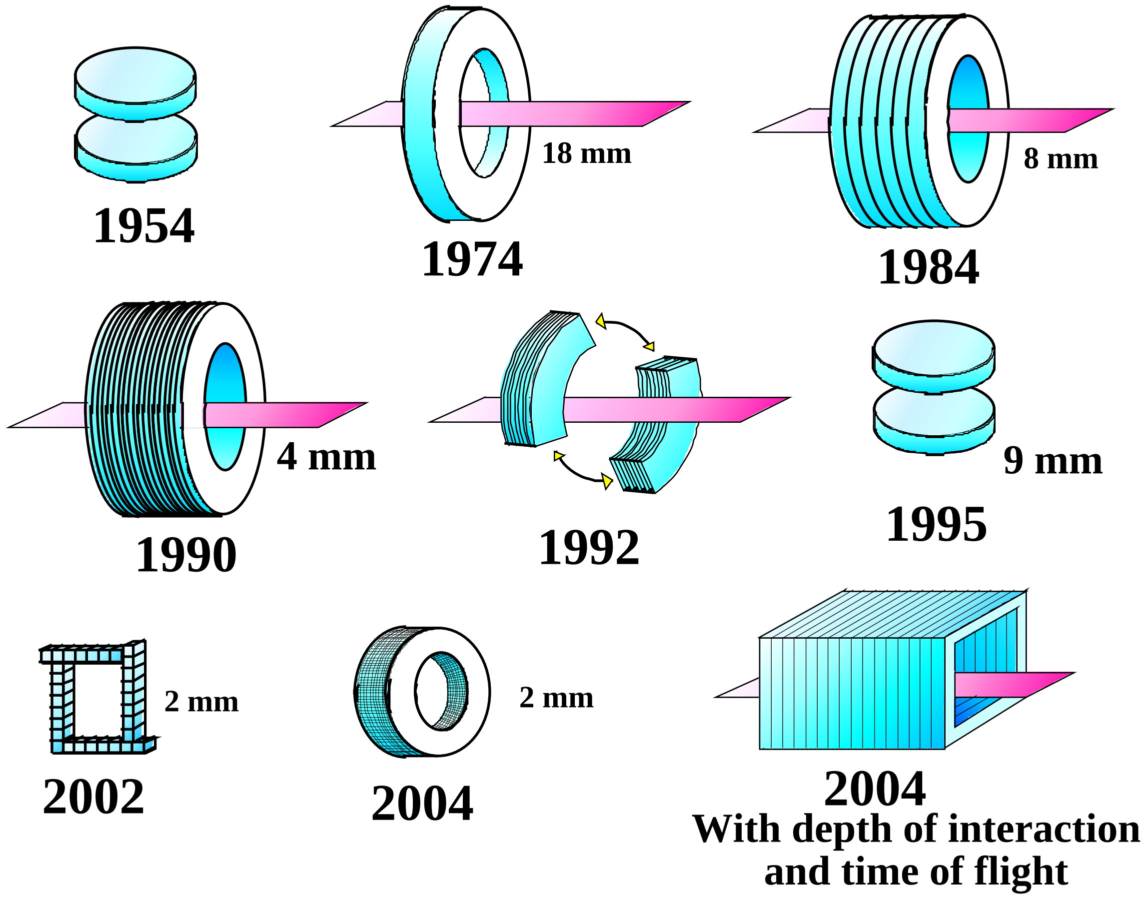
- Motion compensation and motion imaging in SPECT and PET
- Kinetic parameter extraction in dynamic SPECT
- Tensor tomography
- Diffusion tensor imaging
- Cardiac motion parametric imaging
- Motion parametric imaging
- Shoe fit optimization by dynamic MRI.

Examples of current medical applications and horizons will be given in this presentation.

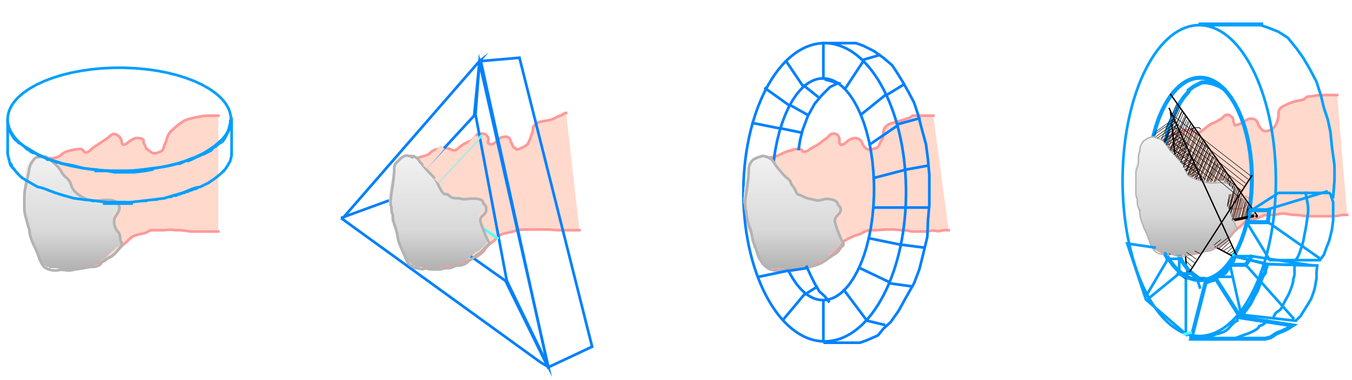
Evolution of X-ray CT



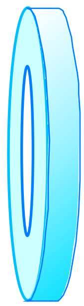
PET Developments



SPECT Developments



Magnetic Resonance Developments



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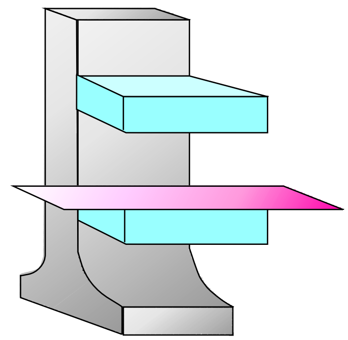

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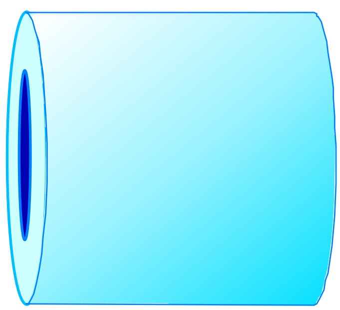

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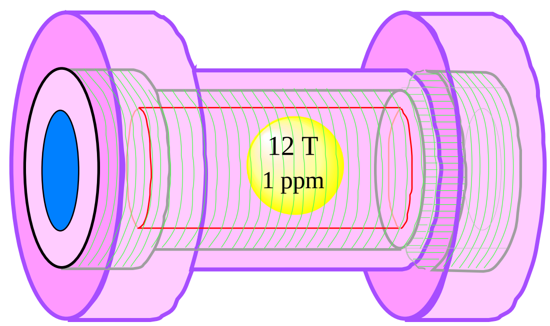

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