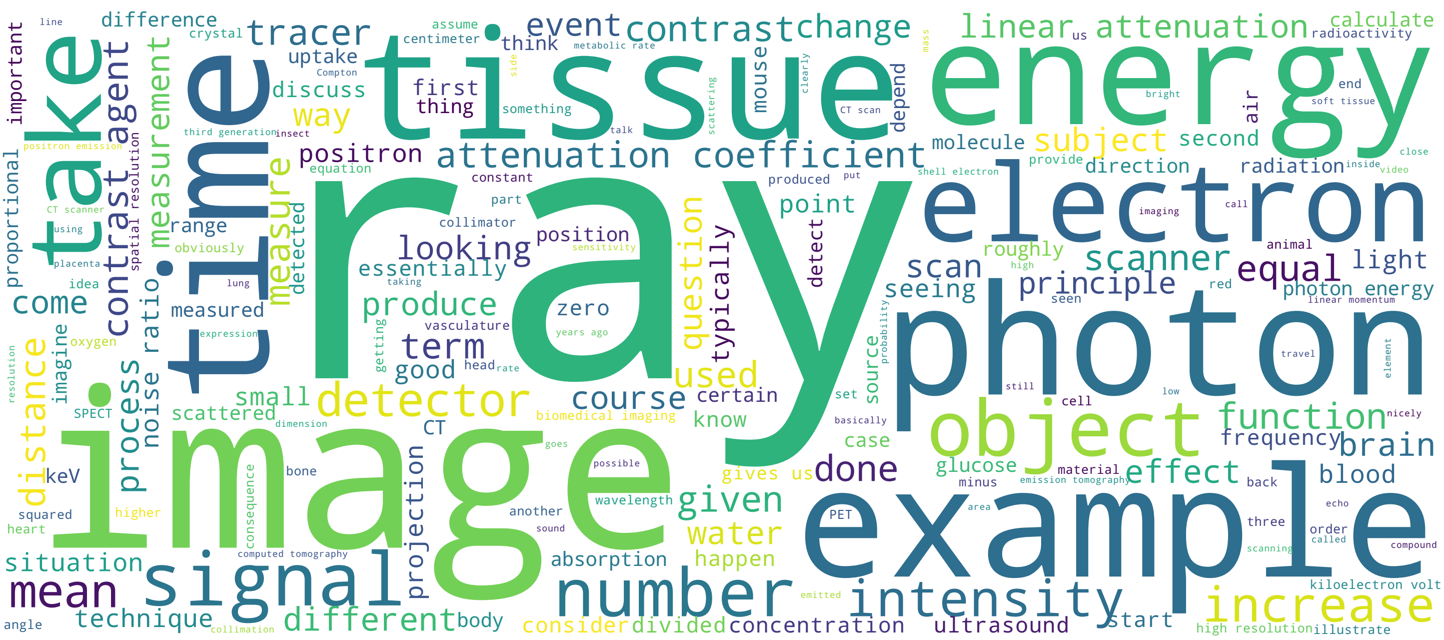
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

4.5 Computed Tomography: Examples & Summary

Fundamentals of Biomedical Imaging

Prof. Rolf Gruetter



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Video

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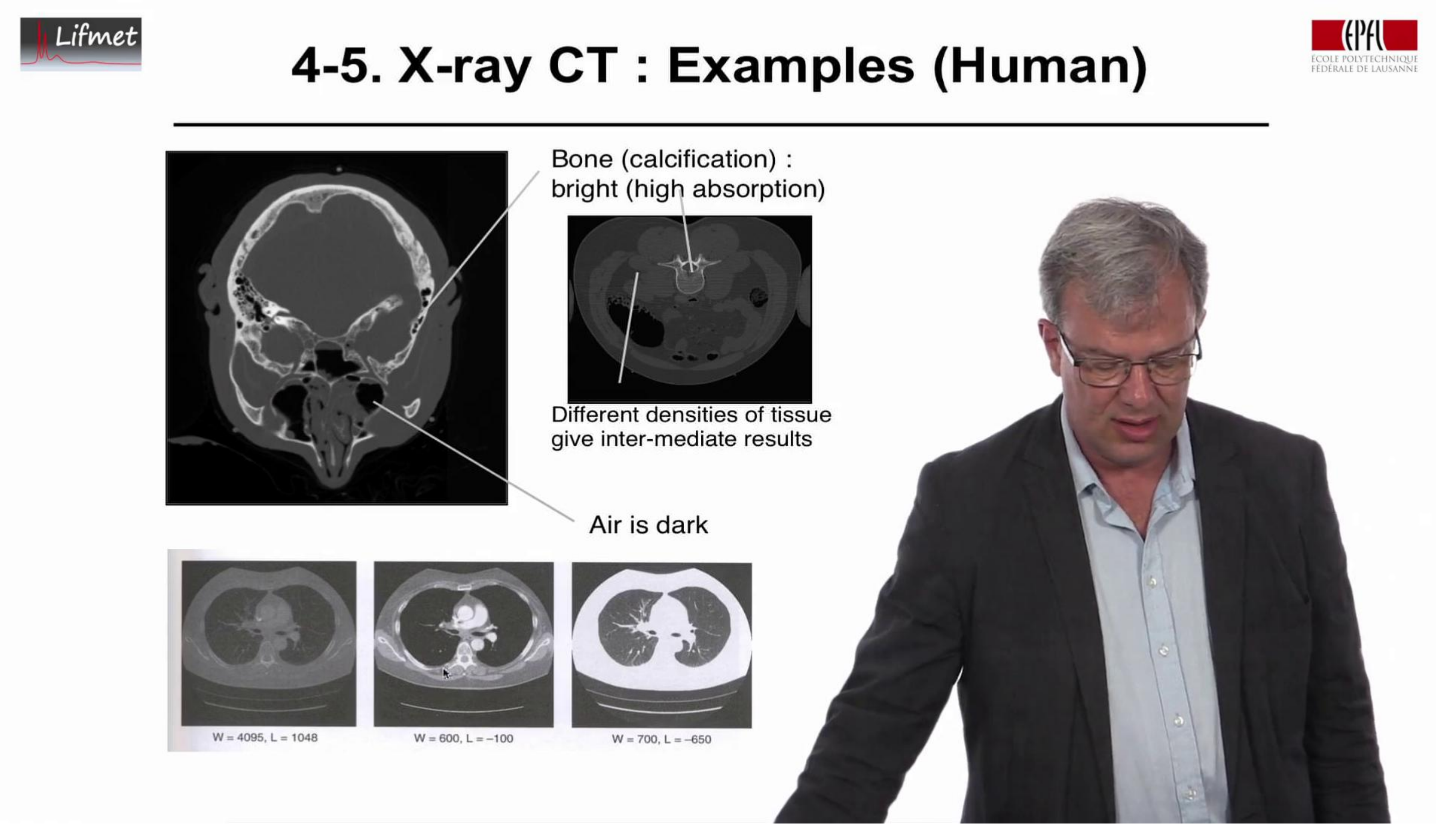
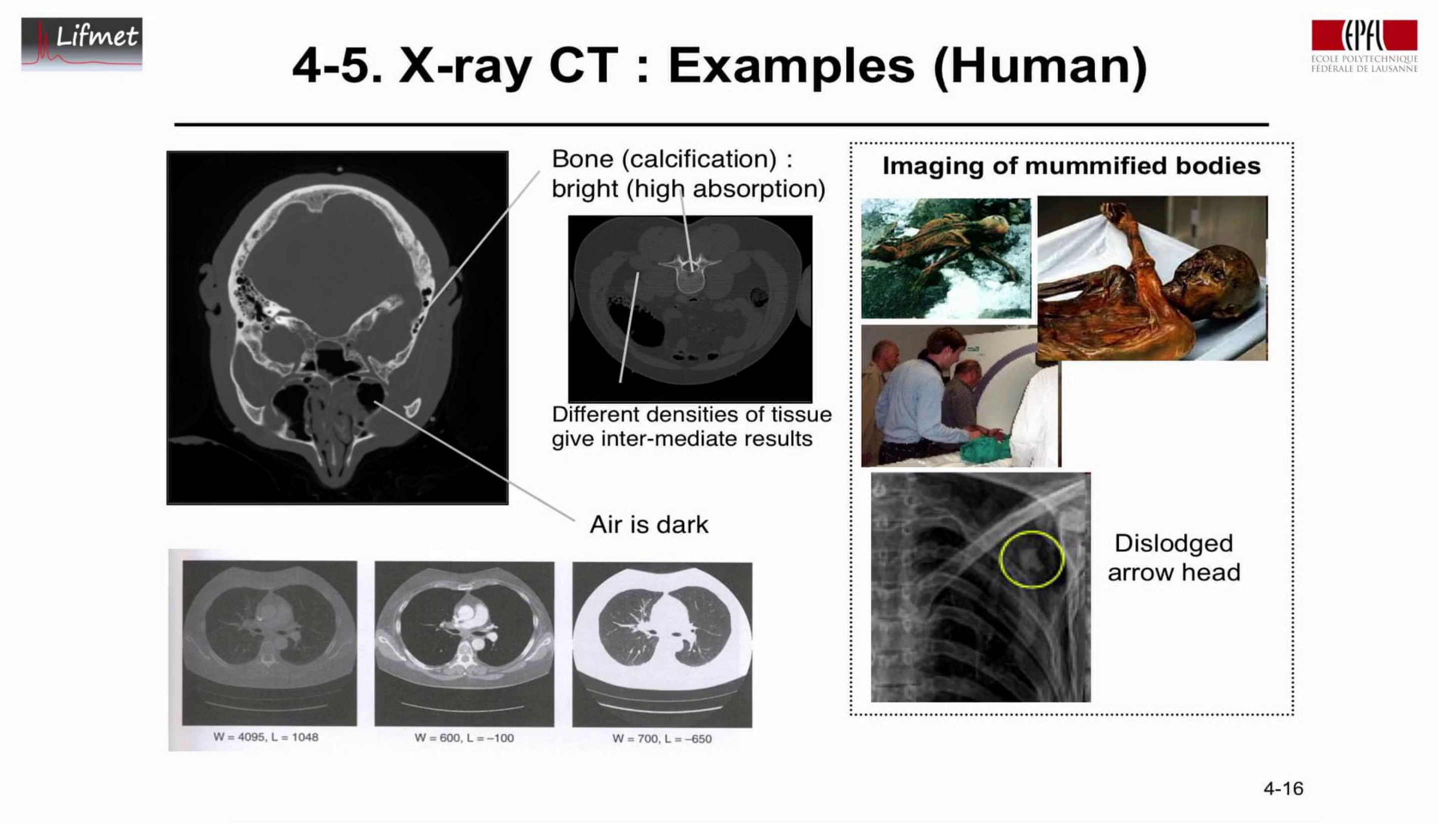


In this segment, I want to provide some examples some image examples to illustrate the type of images that CT can provide. This is the image of a human head. We have bright, we have high electron densities and this is bone high absorption. We can see the skull here. We see the sinuses here; the air is dark, these are the sinuses. That's the stuff that clogs up when you have a cold. We're looking here at an image of the abdomen. Here's the spinal cord. This is the spine so again we're seeing calcification absorption, and we have, obviously, different densities of tissue that give us intermediate results. There are not so easily discernible here. We have in here in the lungs and the air outside [billow] intensity. Now I mentioned earlier that the Hounsfield unit allows us to quantify the pixel intensity. So we can actually-- the operator can set the pixel intensity on the computer display to depict different contrasts. So here is just the same image, taken the same image here, displayed in different ways. Here is one way. We don't really see much. It's rather grayish. And here is a different highlight we're seeing very nicely, we're seeing the ribcage here; we're seeing the spine back here, and if we want to see soft tissue contrast, we can extend the contrast to see the very low intensity.

Notes

Summary

0m 04s



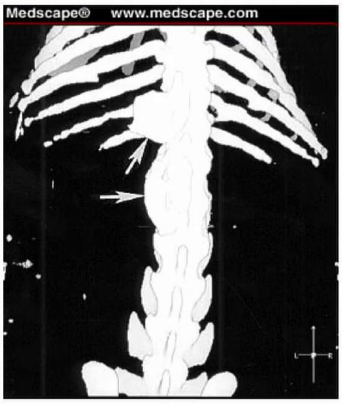
Here we're starting to see [villa] contrast here in the lungs but obviously stuff that has very high absorption on the outside is now very bright. So we can play with the look up table of image presentation. Now there's a very famous example here from the Alps, from our mountains, not in Switzerland I must say, [inaudible] the Austrian Italian Alps, at the Austrian Italian border this gentleman was discovered following the retreat of the glaciers. He lived some 4,000 years ago, and the question was how did he die? That was the curiousity. It's a mummified body. We do not want to go in with a scalpel and cut him open. And his name is Otzi, so here he is wrapped nicely in a blanket entering the CT scanner and that's what people have done and what was found is that there was an arrowhead that was dislodged in his shoulder, around here, so probably he died of consequences of being shot by an arrow up there in the mountains 4,000 years ago. So this is a way where modern biomedical imaging was used to understand what happened to this person 5,000 years ago showing this dislodged arrowhead.

Notes

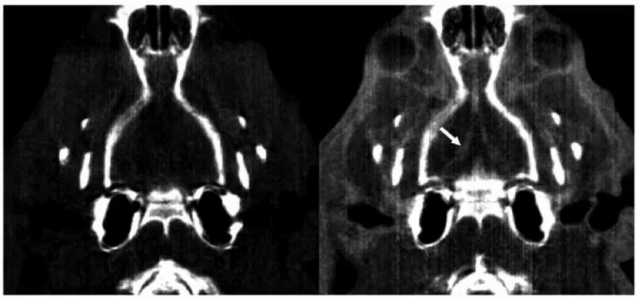
Summary

1m 48s

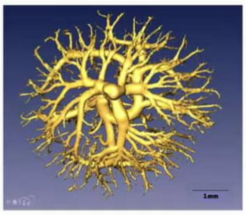
CT: Examples (mouse)



3D CT scan of rodent spine
- treated with human mesenchymal stem cells
  - (transduced with the human BMP-9 gene via an adenoviral vector)
- significant bone formation at the treatment sites (arrows)



Pre- Post-contrast



13μm micro CT of mouse placenta vasculature

Micro-CT of mouse femor bone

4-17

I want to go on with some examples from mouse imaging. This is the rodent spine, so it's a 3D image CT scan of the spine that is human mesenchymal stem cell treatment, and there is at the site of treatment, there is significant bone formation here and here, in these parts of the image. Here's an example from the head of an animal. This is pre-contrast agent injection. There's not much we can see here and after contrast agent has been injected we start to see some intensity here at this part of the vasculature. Same approach, we can take contrast agents and, for example, MHD the vasculature of the placenta of a mouse. Now imagine how small a mouse is, imagine how small a placenta is for mouse embryos in a mouse mother, and this is the vasculature of the placenta of a mouse with 13 micron spatial resolution. And finally here an example of the mouse femur bone with growth hormone treatment looking at the bone here and then if you look at the structure inside we see the difference in structure here, how this is effected by the treatment. We can very clearly see this very nicely with high resolution CT, micro CT.

Notes

Summary

3m 21s

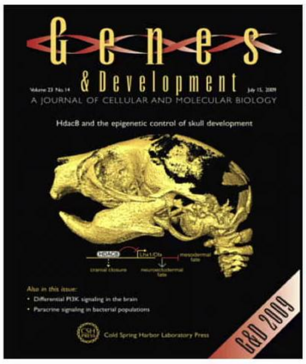
CT: Summary

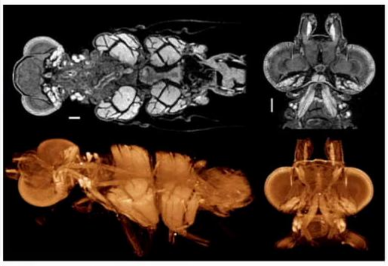
Main **contrast** is bone vs. soft tissue (or air) (calcium content i.e. e^- density ρ)

Contrast agents (increase Z_{eff}) allow depiction of vessel architecture and lesions

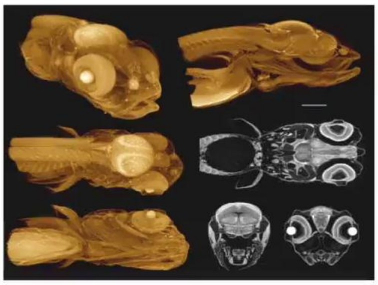
SNR and CNR:

1. Intensity can be increased by cathode current
2. High spatial resolution possible (limited only by radiation dose in humans)





Insect with iodine contrast agent



Fish larvae

4-18

So now I want to do a brief summary of CT. Computer tomography is done by x-ray absorption, that's the main contrast mechanism and the main contrast that we can see is bone versus soft tissue or air, and this is the underlining reason for that is that one primarily measures the electron density, rho. One can use a contrast agents which increase the effective **Z** to depict vascular architecture or legions. So contrast agents are useful; they can be used in addition. Here's an example of genetic research. We have insects. This is an insect with iodine contrast agent. We have beautiful contrast in these images here of this insect profused with an iodine bearing contrast agent. Now some considerations on single to noise ratio and contrast to noise ratio. In principle we can just increase the cathode current until we saturate the filament. So we can increase this intensity and so we can increase the SNR to almost unlimited levels, and therefore we can have a very high spatial resolution. That's what we see here. With this very high spatial resolution image of the insect. However, in humans we are limited by the radiation dose that we can apply this to. Here's another example.

Notes

Summary

4m 52s

CT: Summary

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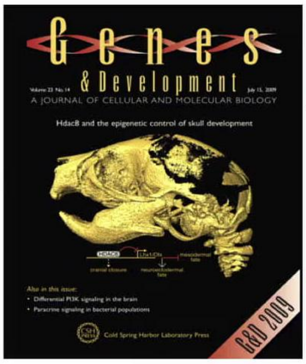
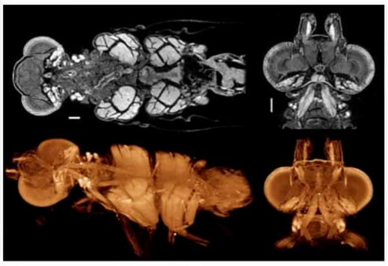
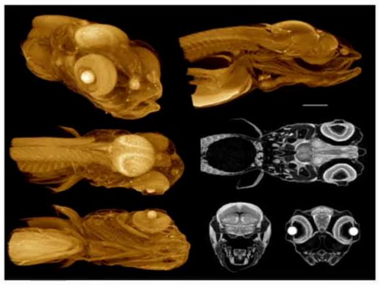




Insect with iodine contrast agent



Fish larvae

4-18

This is fish larva, just imagine how small the fish larva are. These are the eyes of this fish and again, very high resolution images. We see the brain here, spinal cord here. Very high resolution is possible in animals where we are less concerned with radiation exposure.

Notes

Summary

6m 31s

How have CT scanners evolved ?

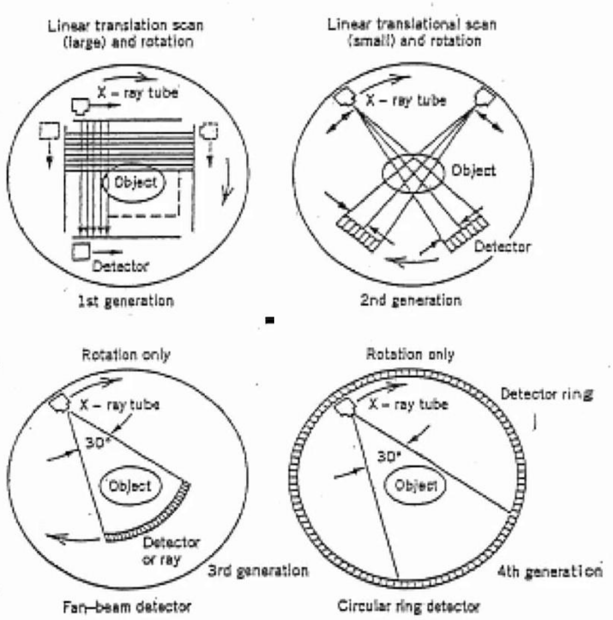
Generations of CT scanners

First Generation
- Parallel beam design
- One/two detectors
- Translation/rotation

2nd Generation
- Small fan beam
- Translation/rotation
- Larger no. of detectors

3rd Generation
- Multiple detectors
- Large fan beam

4th Generation
- Detector ring
- Large fan beam



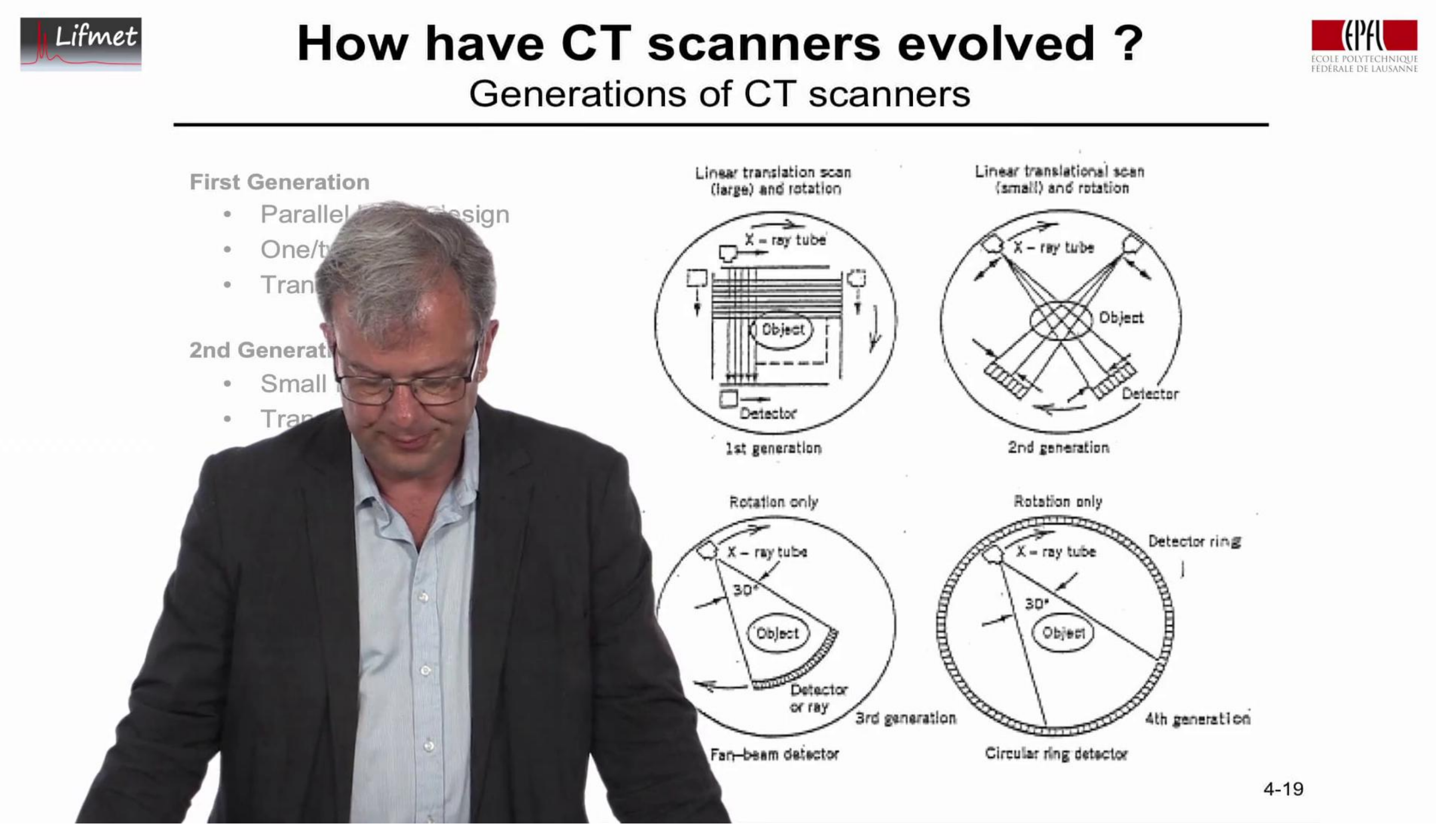
4-19

So to summarize, I've given you the basic principle of CT imagery construction, some real life considerations, and actually if you look over the decades-- this is now almost-- this is over four decades of scanner development, we have seen quite a number of generations of scanners developed.

Notes

Summary

6m 52s



We've had parallel, first generation, second and third generation, of the scanners and this is what we are seeing in the video are the different generation scanners. We're starting out with the simplest one. There was one scanner, one line collected at a time. Then we had a small fan being third generation multiple scanners, etc., so increased complexity and actually in the meantime we're up to the fifth generation scanners which are produced-- they have-- start with the third generation multiple detectors; then we have the fourth generation; we have a detector ring, a large fan beam, and nowadays actually scanning is done as the subject continuously moves through the scanner. It's a spiral way of scanning the subject, very efficient. You can scan an entire body within a few seconds and then reconstruct it, obviously, now possible with today's computing power. As to the cost of a CT scanner, it is on the order of-- depends of course on the company, depends on the currency here, but of the techniques we're discussing in this course it is... the cheapest technique aside from ultrasound, a few hundred thousand take it Euro, Dollar, or Swiss Franc, it's roughly the same thing. It's on the order of 100 to 200,000 Swiss Franc.

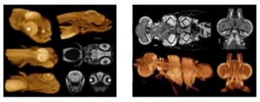
Notes

Summary

7m 19s

Credits

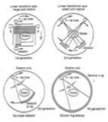
CT scanner: 1st Generation – 2nd Generation – 3rd Generation – 4th Generation
https://youtu.be/fNaCxhhhZTE - https://youtu.be/Ni4Hsi3GhXo - https://youtu.be/bdf0kXn5Eeg - https://youtu.be/AWVz3yke_bY



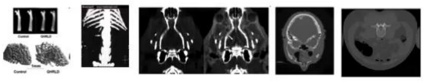
MicroCT for comparative morphology
Brian D. Metscher, BMC Physiology2009; 9:11

European Synchrotron Radiation Facility
http://physicsbuzz.physicscentral.com/2008_04_01_archive.html

Genes&Development a journal of cellualr and molecular biology
http://genesdev.cshlp.org/content/23/14.toc



"Foundations of Medical Imaging"
Fig. 6-6, from Zhang-Hee Cho, Joie J. Jones, Manbir Singh



Unidentifiable source *(from the internet)*

Notes

Summary

8m 52s