New Horizons in CT

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X-ray Computed Tomography - Faster and Ever Faster

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„Confrontation“ of Imaging Modalities

The situation in the 1980’s as seen by Radiology:

„CT is dead!“

Mousosaurus Rex

New Horizons in CT !?

- State of the art in CT
- Multi-source CT
- Dual energy CT
- Spectral, functional and molecular CT
- X-ray detectors
- Dose management
- Dedicated scanners
- Higher resolution at lower dose
- …
State of the Art in Multi-slice Spiral CT

- Rotation time per 360°: 0.27 - 0.35 s
- Slice width: 0.5 - 0.6 mm
- Simultaneously scanned slices: 64 (- 520)
- 2-coverage per rotation: 40 - 160 mm
- Scan times "whole body": 2 - 20 s
- Scan range: >1000 mm
- Isotropic spatial resolution: 0.4 - 0.6 mm
- Effective dose: <1 - 10 mSv

Typical values for high-performance scanners

28 s scan time at 0.4 mm isotropic resolution

DSCT: High scan speed

- Spiral CT angiography
  - Scan range: 700 mm
  - Pitch: 2.8
  - Rot. time: 280 ms
  - Scan time: 1.8 s
  - Dose: 1.4 mSv

State of the art: Detectors

Module: 64 rows × 16 channels

- Anti-scatter grid
- Geometric efficiency is the weak point!
- Scintillator
- Reflector
- Optical coupling
- Photodiode

Detector with 55 modules, i.e. 880 channels × 64 rows

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New Horizons in CT !?

CT Imaging using rotating C-arm Systems

- Image Intensifiers
- Flat-Panel Detectors

Robot-driven C-arm Systems

- Prototype in operation since June 2006
- Product installation in November 2007
Examples of modern FDCT systems for orthopedic extremity imaging

- Medplan Oy, FI Verity flexible system

FDCT-Scanner für den HNO-Bereich „DVT“

- NewTom 9000 by QR s.r.l./AFP Imaging Corp. Italy
  - 12 bit image intensifier + CCD
  - Scan volume: 15 x 15 x 20 cm³
  - 110 kV

- KaVo 3D eXam by KaVo Dental GmbH, Germany
  - 14 bit flat detector
  - Scan volume: 16 x 16 x 13 cm³
  - 120 kV


Dedicated breast CT scanner at UC Davis

(since about 2005)

Several research groups active in the USA at present.

Cone-beam CT geometry

Images: Courtesy of John Boone, UC Davis

Results: Overall, CT was equal to mammography for visualization of breast lesions. Breast CT was significantly better than mammography for visualization of masses (p<0.002); mammography outperformed CT for visualization of microcalcifications (p<0.006).

Conclusions: Some technical challenges remain, but breast CT is promising and may have potential clinical applications.

Lindfors KK, Boone JM et al. Radiology 2008; 246:725-733

Requirements on breast CT

- Full 3D imaging capabilities
- High spatial resolution (min. 100 µm) for the detection of microcalcifications
- Good soft tissue delineation
- Dynamic scanning for the differentiation of benign and malignant lesions
- Dose levels similar to conventional mammography
- Integrated biopsy facility

... but without painful compression

Breast CT

- Necessary technology
- Expected performance of dedicated high-resolution low-dose breast CT
High-resolution CT

Micro-CT scan of surgical specimens

DCIS specimen * embedded in paraffin

Micro-CT
40 µm resolution

* Specimen provided by M. Beckmann, Erlangen

Breast CT scanner concept

Transition from
single-circle flat detector to spiral CT detector

Photon-counting energy-discriminating CdTe detector

100 % geometrical and absorption efficiency


Phon counting CdTe detector

• Curved detector built up scalable of discrete CdTe tiles with 100 µm pixel size
• Count rate: 10^8 ph./mm²/s
• Frame rate: 1000 proj./s
• Two thresholds for energy discrimination
• Detection efficiency and geometric efficiency close to 100% (exceeding the performance of today’s CT detectors)

Detection principles

Scintillator Scintillator (structured) Direct converter

Point Spread Functions (PSF)

Absorption efficiency, %

<table>
<thead>
<tr>
<th>Detector material</th>
<th>Primary spectrum (no absorber)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CdTe 60 kV 120 kV 60 kV 120 kV</td>
</tr>
<tr>
<td>Tube voltage</td>
<td>60 kV 99.9 120 kV 91.3 60 kV 96.8 120 kV 86.3</td>
</tr>
<tr>
<td>Thickness</td>
<td>1.00 mm 1.00 mm 1.40 mm 100.0 95.2 98.9 93.1</td>
</tr>
</tbody>
</table>

Photon counting CdTe detector

Absorption efficiency, %

CdTe offers close to 100% geometric efficiency since there are no discrete detector pixels and septa.
Patient- and biopsy-friendly gantry

Demands
- Comfortable patient positioning with coverage of the full breast and the axilla
- Variable table height (ca. 70 - 170 cm)
- Sequential and spiral scanning (25 cm in 12 s)
- Easy access to the patient for biopsy and therapy

Dedicated CT of the breast

High-resolution spiral CT of the breast at very low dose: concept and feasibility considerations

Kalender WA; Althoff F. Patent application 2010

Simulation results for breast CT

Phantom
14 cm diameter
10 cm length

Scan parameters
2 s / 2000 proj. / 360°
100 µm FFD
Dose: 3 mGy AGD

Model-based Iterative Reconstruction
σ = 19 HU
σ = 630 HU

System Spatial Resolution

32 mm phantom with 10 µm tungsten wire
Modulation Transfer Function (MTF)

C = 0, W = 1000

Expectations for high-res. breast CT

- Good detectability of
  - microcalcifications of 100-150 µm diameter,
  - soft tissue lesions of 2 mm diameter,
  - at an AGD of 2 to 4 mGy!
- Dynamic contrast-enhanced scanning for improved analysis of differential uptake.
- A “one-stop shopping” modality for complete diagnostic workup on one device.
- System tests in the second half of 2013, clinical tests in 2014.

Thank you for your attention!