AMERICAN ASSOCIATION of PHYSICISTS IN MEDICINE
Improving Health Through Medical Physics

AAPM 2021
JULY 25–29 | VIRTUAL
63RD ANNUAL MEETING & EXHIBITION

CREATIVE SCIENCE. **ADVANCING MEDICINE.**

PRINCIPLES AND APPLICATIONS OF MULTI-ENERGY CT: REPORT OF AAPM TASK GROUP 291

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PRINCIPLES AND APPLICATIONS OF MULTI-ENERGY CT: REPORT OF AAPM TASK GROUP 291

- Cynthia H. McCollough, Mayo Clinic
- Kirsten Boedeker, Canon (formerly Toshiba) Medical Systems
- Dianna Cody, University of Texas, M.D. Anderson Cancer Center
- Xinhui Duan, Southwestern Medical Center, University of Texas
- Thomas Flohr, Siemens Healthcare GmbH
- Sandra S. Halliburton, Philips Healthcare
- Jiang Hsieh, GE Healthcare Technologies
- Rick R. Layman, University of Texas, M.D. Anderson Cancer Center
- Norbert J. Pelc, Stanford University

Med. Phys. 47 (7), July 2020 0094-2405/2020/47(7)/e881/32

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WHAT, WHY, WHO

- **Charge:** To prepare a report that …
  - teaches the fundamental principles of multi-energy CT
  - describes current manufacturer implementations
  - introduces available clinical applications
  - addresses dosimetric considerations
- **Purpose:** To provide an authoritative open-access review of the topic for educational purposes.
- **Intended audience:** medical physicists, radiologists, CT technologists, and others, including end-users of multi-energy CT images, such as referring clinicians and radiation oncology physicians, physicists, and dosimetrists.

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WHEN

- **TG approved:** RSNA 2016
- **Work started:** January 2017
- **Draft submitted for AAPM review process:** January 2018
  - CT Subcommittee, Imaging Physics Committee, Science Council
  - Revisions requested at each stage
- **Draft approved by AAPM and sent to *Medical Physics*:** August 2019
  - Revisions requested
- **Published online:** May 2020
- **Published in print:** July 2020
- **Presented at AAPM Annual Meeting:** July 2021

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PRINCIPLES AND APPLICATIONS OF MULTI-ENERGY CT: REPORT OF AAPM TASK GROUP 291

- **Introduction and Clinical Motivation**
  - C McCollough, Mayo Clinic, Rochester, MN
- **Physical Principles of Multi-energy CT**
  - T Flohr, Siemens Healthcare GmbH, Forchheim, BY, DE
- **Technical Implementations of Multi-energy CT**
  - X Duan, UT Southwestern Medical Center, Dallas, TX
- **Clinical Applications and Dosimetric Considerations**
  - C McCollough, Mayo Clinic, Rochester, MN

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CT Clinical Innovation Center

Clinical Motivation for Multi-energy CT

Cynthia H. McCollough, PhD, DABR, FAAPM, FACR, FAIMBE
Brooks-Hollern Professor of Research, Professor of Medical Physics and Biomedical Engineering
Director, CT Clinical Innovation Center and X-ray Imaging Research Core
Department of Radiology, Mayo Clinic, Rochester, MN

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Disclosures

- Research support
  - NIH (EB017095, EB028590, EB028591)
  - Mayo Clinic Discovery Translation Grant
  - Siemens Healthcare
- Board membership
  - ISCT, Vice-president

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FUNDAMENTAL PRINCIPLE

Acquire data with *different beam spectra* to exploit the energy-dependent nature of CT numbers

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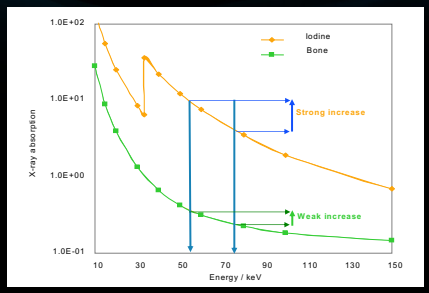
Spectral separation is key!



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Clinical Motivation

- CT number depends on x-ray attenuation
  - Physical density (g/cm3) [electron-density]
  - Atomic number (Z)
- Different materials can have the same CT number if atomic number differences are offset by appropriate density differences
- Multi-energy CT
  - Allows separate determination of effective Z and density
  - Provides material composition and concentration

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Not a new idea

"Two pictures are taken of the same slice, one at 100 kV and the other at 140 kV. . . so that areas of high atomic numbers can be enhanced. . .

Tests carried out to date have shown that iodine (Z = 53) can be readily differentiated from calcium (Z = 20)."

Hounsfield GN. Computerized transverse axial scanning (tomography): Description of system. *Br J Radiol.* 1973;46:1016–1022.

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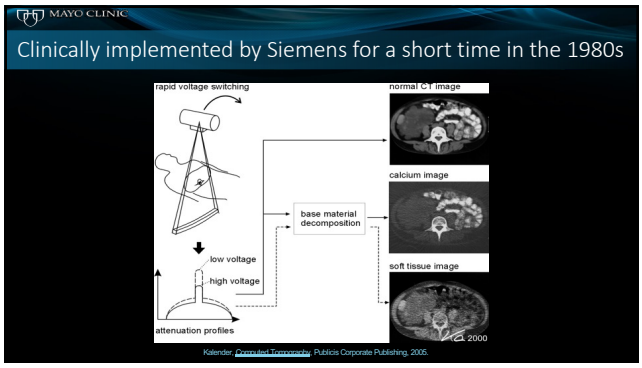
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Clinically implemented by Siemens for a short time in the 1980s
rapid voltage switching
normal CT image
calcium image
base material decomposition
soft tissue image
low voltage
high voltage
attenuation profiles
2000
Kalender, Computed Tomography, Publicis Corporate Publishing, 2005.

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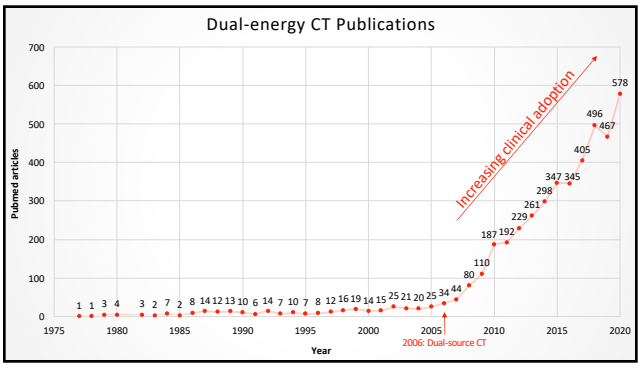
Dual-energy CT Publications
Pubmed articles
Year
Increasing clinical adoption
2006: Dual-source CT
1 1 3 4 3 2 7 2 8 14 12 13 10 6 14 7 10 7 8 12 16 19 14 15 25 21 20 25 34 44 80 110 187 192 229 261 298 347 345 405 496 467 578

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