Dual Energy Imaging with Dual Source CT Systems

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Dual Energy Radiography

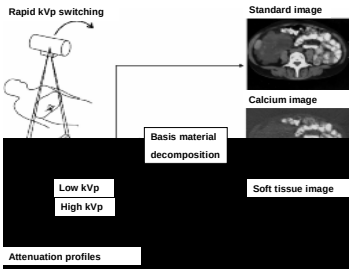
Radiograph | Bone image | Tissue image

2 energies ⇨ 2 materials

Armato SG III. *Experimental Lung Research*. 2004;30 (suppl 1):72-77.

kV Switching with SOMATOM DRH – in the 80s

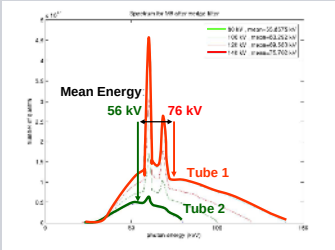
- **Calculation of material selective images:**
- **Calcium and soft tissue**



W. Kalender: Vertebral Bone Mineral Analysis, Radiology 164:419-423 (1987)

Principle of Dual Energy CT

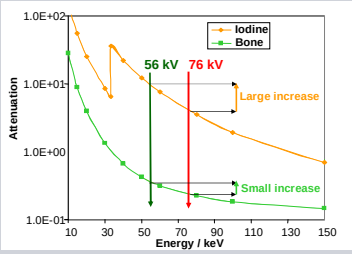
- Data acquisition with different X-ray spectra: **80 kV** / **140 kV**



- Different mean energies of the X-ray quanta

Principle of Dual Energy CT

- Many materials show different attenuation at different mean energies



- Reason: different attenuation mechanisms (Compton vs photo effect)

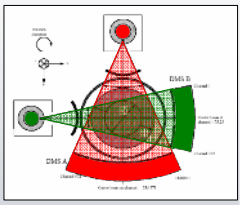
SOMATOM **Definition**
The World's First Dual Source CT

Faster than Every Beating Heart

- gated mode / same kV
- high temporal resolution (80ms)
- Cardiac imaging

One-Stop Diagnosis in Acute Care

- non gated mode / same kV
- low temporal resolution
- Obese patients, low kV scanning



Beyond Visualization with Dual Energy

- different kV (gated and non-gated)

Spectra of Dual Energy Applications

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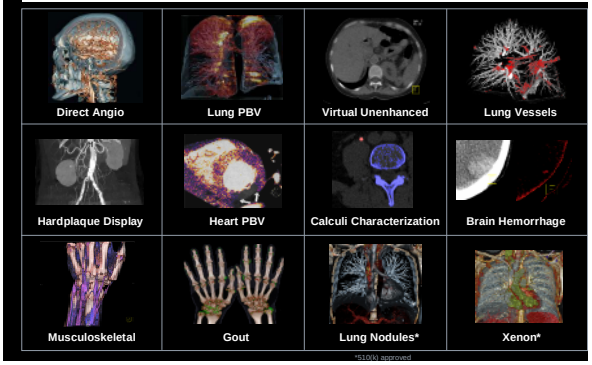


*510(k) approved

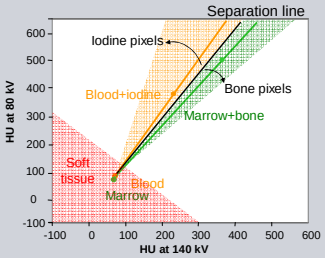
"Contrast Enhanced Viewing" using Dual Energy Information in Addition to Simple Image Mixing

- **Basic application: Enhanced viewing, contrast optimization**
- Contrast enhanced studies: Iodine has much higher contrast at 80 kV
- Non-linear, attenuation-dependent blending of the images combines benefits of 80 kV (high contrast) and mixed data (low noise)

Courtesy of CIC Mayo Clinic Rochester, MN, USA

syngo Dual Energy
Direct subtraction of bone

- **Modified 2-material decomposition: Separation of two materials**
  - → Assume mixture of **blood + iodine (unknown density)**
    and **bone marrow + bone (unknown density)**

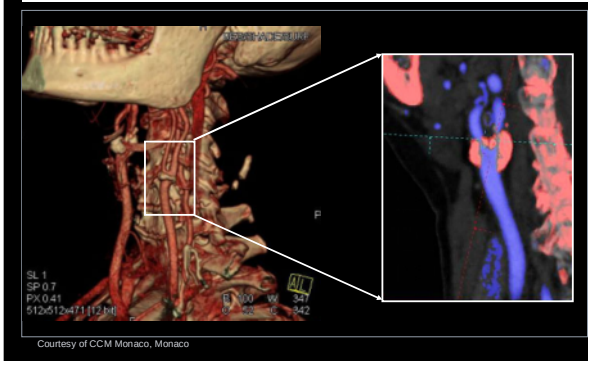


syngo Dual Energy
Direct subtraction of bone

- **Modified 2-material decomposition: Separation of bone and Iodine**
- **Automatic bone removal without user interaction**
  - → Clinical benefits in complicated anatomical situations:
    - → Base of the skull
    - → Carotid arteries
    - → Vertebral arteries
    - → Peripheral runoffs

Courtesy of Prof. Pasovic, University Hospital of Krakow, Poland

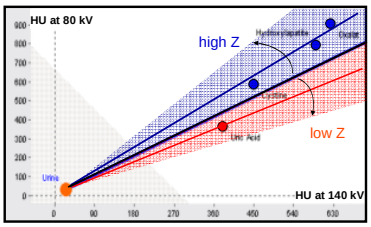
*syngo*DualEnergy
Differentiation between hard plaques and contrast agent

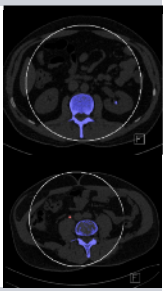


Courtesy of CCM Monaco, Monaco

Image Based Methods

- **Modified 2-material decomposition: Characterization of kidney stones**
  - → Urine + calcified stones / uric acid stones





***syngo* Dual Energy Musculoskeletal**
Visualization of tendons

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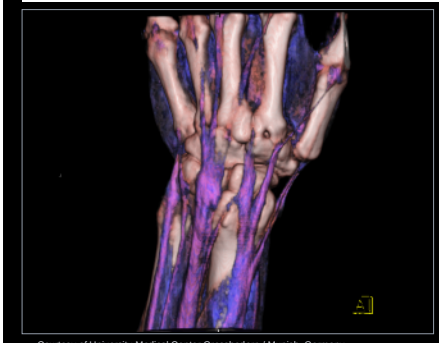

SOMATOM Definition

World's first DSCT

Spatial Res. 0.33 mm
Rotation 0.5 sec
Scan time: 4 s
Scan length: 133 mm
140/80 kV
Eff mAs 80/150

Spiral Dual Energy

Courtesy of University Medical Center Grosshadern / Munich, Germany

***syngo* Dual Energy**
Visualization of Tendons: Tibialis posterior tendon rupture

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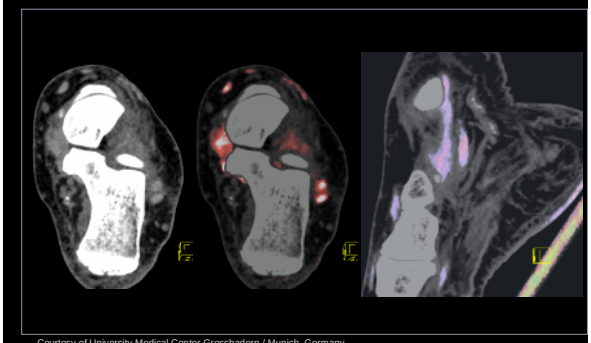


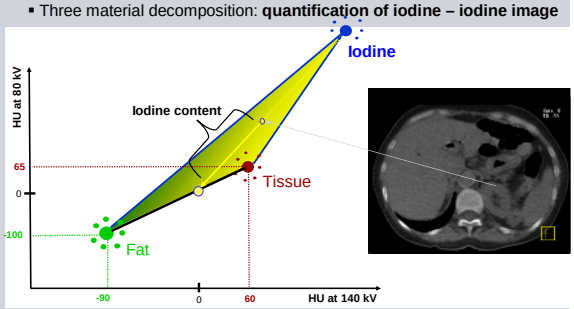
Courtesy of University Medical Center Grosshadern / Munich, Germany

Gout: Application

Vancouver General Hospital, Canada

Applications of Dual Energy CT

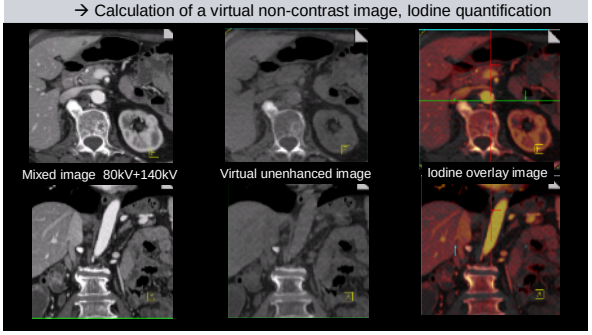
- Three material decomposition: **quantification of iodine – iodine image**



- Removal of iodine from the image: **virtual non-contrast image**

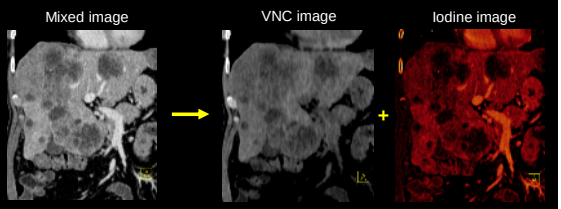
Image Based Methods

- **Most promising application: 3-material decomposition**
  → Calculation of a virtual non-contrast image, Iodine quantification



Applications of Dual Energy CT

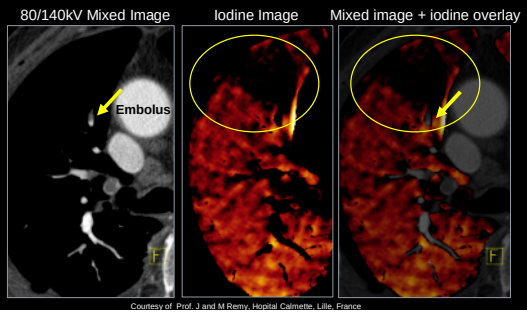
- **Virtual non-contrast image and iodine image:**
- Characterization of liver / kidney / lung tumors
  - Solve ambiguity: low fat content or iodine-uptake
  - Quantify iodine-uptake in the tumor and at the tumor surface
    → Differentiation benign - malignant
- Monitoring of therapy response



Courtesy of University Hospital of Munich - Grosshadern / Munich, Germany

Applications of Dual Energy CT

- **Quantification of iodine to visualize perfusion defects in the lung**
- Avoids registration problems of non-dual energy subtraction methods

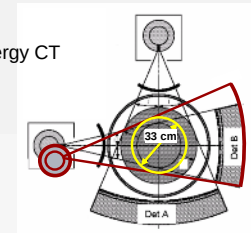


Courtesy of Prof. J and M Remy, Hopital Calmette, Lille, France

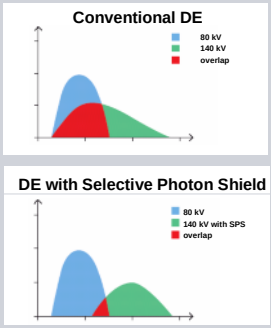
SOMATOM Definition Flash
Latest Generation of Dual Energy CT

System Design

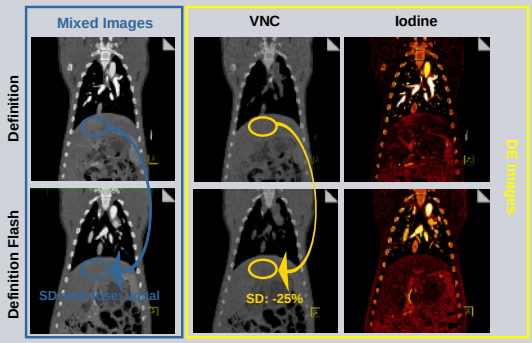
- Two X-ray tubes at 95°, each with 100 kW
- Two 128-slice detectors, each with 64x0.6mm collimation and z-flying focal spot
- SFOV A/B-detector: 50/33 cm
- 0.28 s gantry rotation time
  75 ms temporal resolution



SOMATOM Definition Flash
Single dose Dual Energy



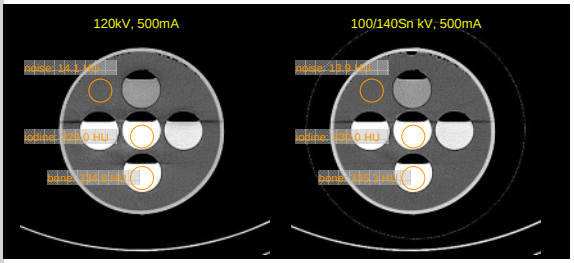
Dual Energy Imaging with Tin Filtration
'Definition' vs. 'Definition Flash': Improved DE Signal



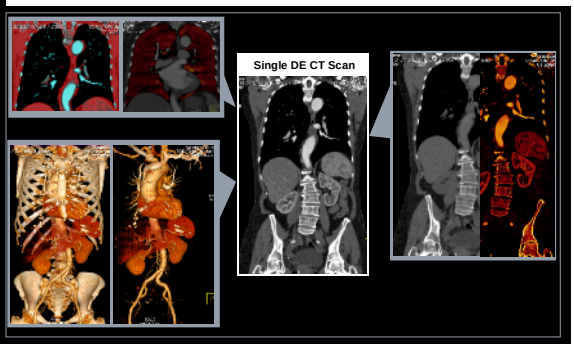
Images acquired and processed in collaboration with CIC Mayo Clinic Rochester, USA

SOMATOM Definition Flash
Impact of the Selective Photon Shield

Dose neutral DE: comparison of 120 kV and 100 kV/140 kV+0.4 mm Sn

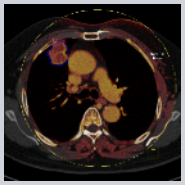


SOMATOM Definition Flash
Dual Energy Whole Body CTA: 100/140Sn kV @ 0.6mm

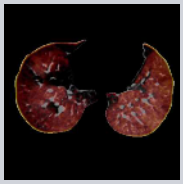


Courtesy of Friedrich-Alexander University Erlangen-Nuremberg - Institute of Medical Physics / Erlangen, Germany

New Application Classes

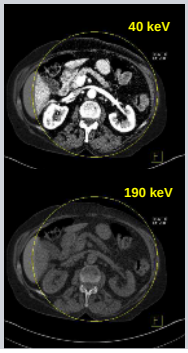


Measurement of Lung Nodule enhancement
courtesy of ASAN Medical Center, Seoul, Korea



Measurement of Xenon Concentration
courtesy of ASAN Medical Center, Seoul, Korea

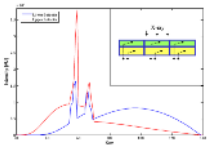
Mono-energetic imaging
courtesy of Klinikum Großhadern, Munich, Germany



Dual Energy CT

Are there alternative approaches?

- **Sequential acquisition at 80 kV and 140 kV with single source CT**
  - Registration problems (heart/lung motion, varying contrast density)
- **Fast kVp-switching during the scan with single source CT**
  - Inadequate power at low kV
  - Unequal noise for low and high kV data
- **Spectral sensitive „sandwich“ detectors**
  - Inferior spectral separation
- **Quantum counting**
  - Paralysis at high flux rate
  - Spectral overlap by fluorescence and pile-up



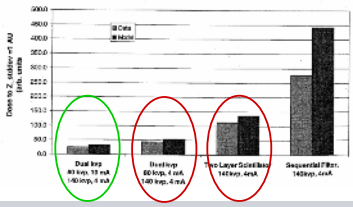
Dual Energy CT
Evaluation of alternative approaches

Atomic Number Resolution for Three Spectral CT Imaging Systems

J. Eric Tkaczyk, Rogerio Rodrigues, Jeffery Shaw, Jonathan Short, Yanfeng Du, Xiaoye Wu, Deborah Walter[b], William Lenz, Daniel Harrison, Peter Edic[a]
[a]General Electric Research, 1 Research Cir., Niskayuna, NY, USA 12309
[b]Rose Hulman Institute of Technology, 5500 Wabash Ave., Terre Haute, IN 47803-3999

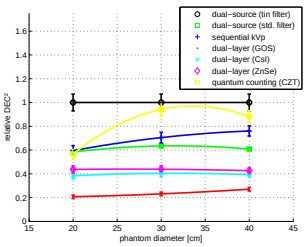
Medical Imaging 2007: Physics of Medical Imaging, edited by Jiang Hsieh, Michael J. Flynn, Proc. of SPIE Vol. 6510, 651009, (2007) · 1605-7422/07/$18 · doi: 10.1117/12.709905

Dose



Dual Energy CT
Evaluation of alternative approaches

DE Performance
@ equal dose



S. Kappler et al., *Dual-energy performance of dual-kVp in comparison to dual-layer and quantum-counting CT system concepts*, Proceedings of the SPIE Medical Imaging Conference, Volume 7258, pp. 725842 (2009)

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Thank you!