GE Healthcare

APT Seminar, Session Firmenkonzepte

GSI Gemstone Spectral Imaging

Nürnberg, 13.Juni 2015

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Vertreten durch:

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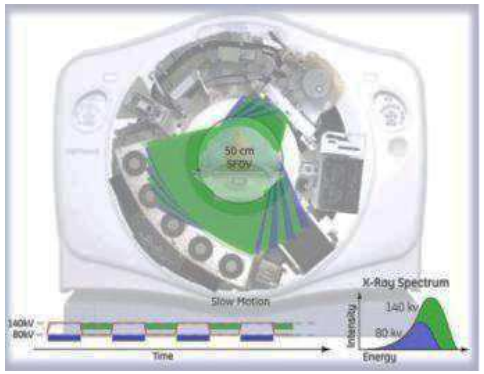
Region DACH

imagination at work

Evaluation der Dual Energy Verfahren am Markt

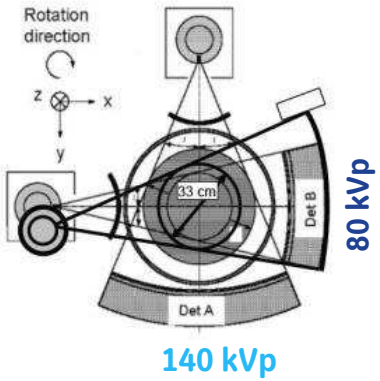
80 kVp
140 kVp



kV Switching

GSI Gemstone Spectral Imaging

- 1 Röhre & 1 Detektor (7000 views/s)
- 1 Rotation + Ultra-fast kV-switching
- 2 Energien simultan/ortsgleiche Erfassung
- Sehr gute Energieauflösung
- Zeitliche Auflösung (<0,3 ms)
- Vollständiges FoV (50 cm)
- Nachweis kleinster Jodmengen
- Weitestgehend dosisneutral
- Breites klinisches Anwendungsspektrum

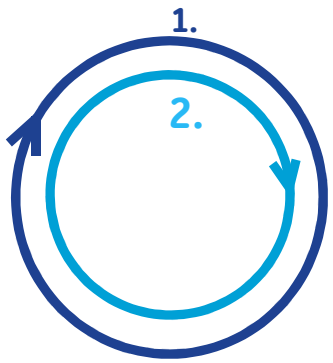


Dual Source

- 2 Röhren & 2 Detektoren
- 1 Rotation
- Asymetrisches Detektorpaar schränkt FoV (33 cm) ein; Fokus Cardiac Scan
- Überlagerter Strahlengang; Trennung durch Filter -> Dosis
- Hohes Scattering
- Nicht ortsgleiche Erfassung; ungeignet für Monochromatische Bilder
- Zeitl.Auflösung 66-75 ms
- erhöhte Dosis

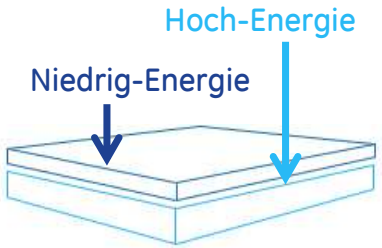
Split-Beam

- 1 Röhre & 1 Detektor
- Mind. 2 Rotation
- Beide Energiespektren werden aus einer Röhre erzeugt
- Trennung durch Filter
- Schlechte Energietrennung
- Energien werden zeitlich versetzt aqkuiriert
    - Zeitl. Auflösung 280 ms
- Zeitl. Auflösung abhängig von Rotationszeit, Pitch muss niedrig sein (<0,5)



Rotate-Rotate

- 1 Röhre & 1 Detektor
- 2 Rotationen (=2 Scans)
- Klinisch sehr eingeschränkt nutzbar wegen geringer zeitlicher Auflösung (>300 ms-500 ms)
- Sehr hohe Dosis



2-Ebenen

- 1 Röhre & 1 Detektor
- 1 Rotation
- Akquisition in nur 1 Energie (120 kV) – eingeschränkte Mono-chromatische Information
- Technische Herausforderung: Separierung von Hoch- und Niedrigenenergie
- Dosis, Bildqualität?

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DGMP Deutsche Gesellschaft für Medizinische Physik e.V.

Ultra-fast kV Switching

Herausforderungen

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Herausforderungen im kV Switching

Gemstone Spectral Imaging

Detektor/Scintillator

- Sehr hohe Primärgeschwindigkeit
- Sehr kurzes Nachglühen
- Erfassungsrate mind. 3500-4000 views/s und mehr

Generator

- Ultra-schnelle Schaltzeiten <1ms oder schneller
- Spannung zw. 70/80kV – 140 kV
- Messung der Spannung im Generator zw. den Schaltzeiten
- Messung kleiner Spannungswerte
- Regelung der Spannung, kein Überschwingen
- Leistungsreserven für ultra-schnellen Aufbau der Spannungsspitze im Dual Energie Modus

Röhre

- Fokusierung des Spot; der Spot muss bei beiden Spannungen an gleicher Stelle und mit gleicher Größe anliegen
- Selbst moderne Röhren mit elektromagnetischer Ablenkung sind nicht geeignet

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Dual Energy

Energieauflösung

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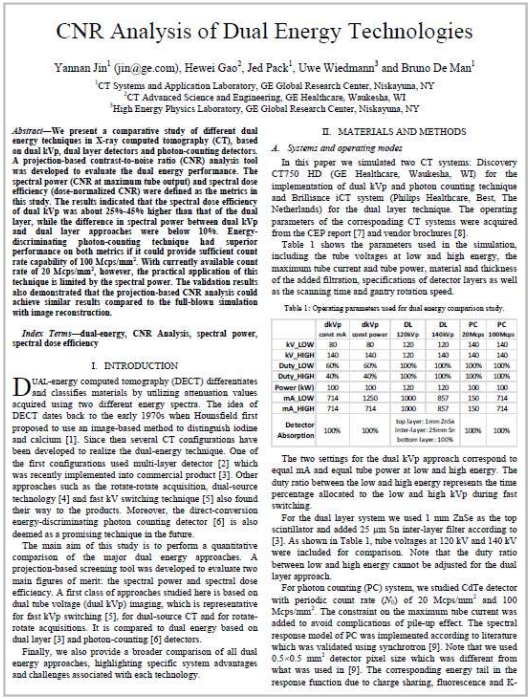
Energieauflösung/-trennung

Schlüsselkriterium für Dual Energy



CNR Analysis of Dual Energy Technologies

Yannan Jin[1] (jin@ge.com), Hewei Gao[2], Jed Pack[1], Uwe Wiedmann[3] and Bruno De Man[1]

[1]CT Systems and Application Laboratory, GE Global Research Center, Niskayuna, NY
[2]CT Advanced Science and Engineering, GE Healthcare, Waukesha, WI
[3]High Energy Physics Laboratory, GE Global Research Center, Niskayuna, NY

Abstract—We present a comparative study of different dual energy techniques in X-ray computed tomography (CT), based on dual kVp, dual layer detectors and photon-counting detectors. A projection-based contrast-to-noise ratio (CNR) analysis tool was developed to evaluate the dual energy performance. The spectral power (CNR at maximum tube output) and spectral dose efficiency (dose-normalized CNR) were defined as the metrics in this study. The results indicated that the spectral dose efficiency of dual kVp was about 25%-45% higher than that of the dual layer, while the difference in spectral power between dual kVp and dual layer approaches were below 10%. Energy-discriminating photon-counting technique had superior performance on both metrics if it could provide sufficient count rate capability of 100 Mcps/mm². With currently available count rate of 20 Mcps/mm², however, the practical application of this technique is limited by the spectral power. The validation results also demonstrated that the projection-based CNR analysis could achieve similar results compared to the full-blown simulation with image reconstruction.

Index Terms—dual-energy, CNR Analysis, spectral power, spectral dose efficiency

I. INTRODUCTION

DUAL-energy computed tomography (DECT) differentiates and classifies materials by utilizing attenuation values acquired using two different energy spectra. The idea of DECT dates back to the early 1970s when Hounsfield first proposed to use an image-based method to distinguish iodine and calcium [1]. Since then several CT configurations have been developed to realize the dual-energy technique. One of the first configurations used multi-layer detector [2] which was recently implemented into commercial product [3]. Other approaches such as the rotate-rotate acquisition, dual-source technology [4] and fast kV switching technique [5] also found their way to the products. Moreover, the direct-conversion energy-discriminating photon counting detector [6] is also deemed as a promising technique in the future.

The main aim of this study is to perform a quantitative comparison of the major dual energy approaches. A projection-based screening tool was developed to evaluate two main figures of merit: the spectral power and spectral dose efficiency. A first class of approaches studied here is based on dual tube voltage (dual kVp) imaging, which is representative for fast kVp switching [5], for dual-source CT and for rotate-rotate acquisitions. It is compared to dual energy based on dual layer [3] and photon-counting [6] detectors.

Finally, we also provide a broader comparison of all dual energy approaches, highlighting specific system advantages and challenges associated with each technology.

II. MATERIALS AND METHODS

A. Systems and operating modes

In this paper we simulated two CT systems: Discovery CT750 HD (GE Healthcare, Waukesha, WI) for the implementation of dual kVp and photon counting technique and Brilliance iCT system (Philips Healthcare, Best, The Netherlands) for the dual layer technique. The operating parameters of the corresponding CT systems were acquired from the CEP report [7] and vendor brochures [8].

Table 1 shows the parameters used in the simulation, including the tube voltages at low and high energy, the maximum tube current and tube power, material and thickness of the added filtration, specifications of detector layers as well as the scanning time and gantry rotation speed.

Table 1: Operating parameters used for dual energy comparison study.

	dkVp const mA	dkVp const power	DL 120kVp	DL 140kVp	PC 20Mcps	PC 100Mcps
kV_LOW	80	80	120	120	140	140
kV_HIGH	140	140	120	140	140	140
Duty_LOW	60%	60%	100%	100%	100%	100%
Duty_HIGH	40%	40%	100%	100%	100%	100%
Power (kW)	100	100	120	120	100	100
mA_LOW	714	1250	1000	857	150	714
mA_HIGH	714	714	1000	857	150	714
Detector Absorption	100%	100%	top layer: 1mm ZnSe inter-layer: 25mm Sn bottom layer: 100%		100%	100%

The two settings for the dual kVp approach correspond to equal mA and equal tube power at low and high energy. The duty ratio between the low and high energy represents the time percentage allocated to the low and high kVp during fast switching.

For the dual layer system we used 1 mm ZnSe as the top scintillator and added 25 μm Sn inter-layer filter according to [3]. As shown in Table 1, tube voltages at 120 kV and 140 kV were included for comparison. Note that the duty ratio between low and high energy cannot be adjusted for the dual layer approach.

For photon counting (PC) system, we studied CdTe detector with periodic count rate (N_0) of 20 Mcps/mm² and 100 Mcps/mm². The constraint on the maximum tube current was added to avoid complications of pile-up effect. The spectral response model of PC was implemented according to literature which was validated using synchrotron [9]. Note that we used 0.5×0.5 mm² detector pixel size which was different from what was used in [9]. The corresponding energy tail in the response function due to charge sharing, fluorescence and K-

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Table 1: Operating parameters used for dual energy comparison study.

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Vergleichstudie contrast-to-noise-ratio:
kV Switching – Dual Layer - Photoncounting Publikation

Energieauflösung/-trennung

Contrast-to-Noise-Ratio Studie

Table 4: Overview of different implementations of dual energy technologies

	Spectral CT			Image-based Dual Energy CT	
	Fast kVp switching	Dual layer	Photon-counting	2T2D	Rotate-Rotate
Projection MD Capable	+	+	+	−	−
Temporal Skew	<1ms	0ms	0ms	80ms	500ms
Adjustable Duty Ratio	+	−	+	+	+
Full FOV	+	+	+	−	+
Cross Scatter	None	Between 2 layers	None	Between 2 beams	None

Tab. 4

Note that the projection-based approaches grouped as 'spectral CT' can provide beam hardening-free monochromatic images with the potential for quantitative analysis; in contrast, the image-based approaches grouped as 'dual energy CT' are straightforward to implement but the beam hardening artifacts in the reconstructed datasets undermine the MD accuracy.

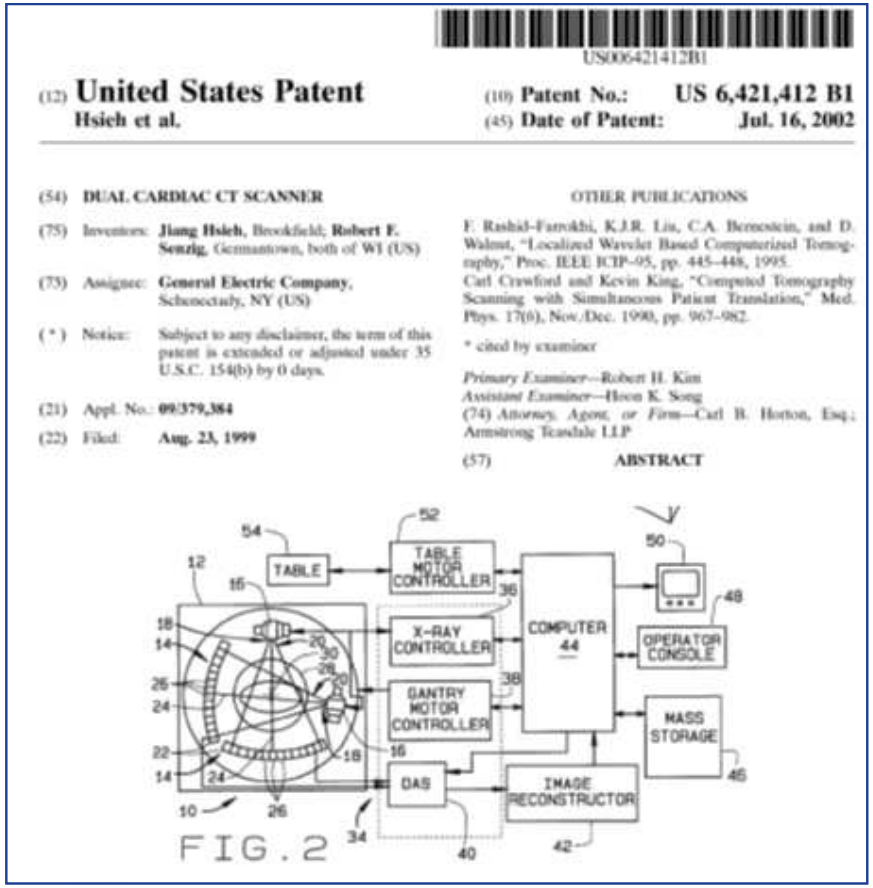
kV-Switching:

1. Kein Dual-Energy-bedingtes Scattering
2. Quantitative Analyse mit hoher Genauigkeit, da kein negativer Einfluss durch Beam-hardening
3. Im gesamten FOV

kV-Switching

Meilenstein: Gemstone Scintillator

2002: Dual Source – Patent



US006421412B1

(12) **United States Patent**
Hsieh et al.

(10) **Patent No.: US 6,421,412 B1**
(45) **Date of Patent: Jul. 16, 2002**

(54) **DUAL CARDIAC CT SCANNER**

(75) Inventors: **Jiang Hsieh**, Brookfield; **Robert F. Senzig**, Germantown, both of WI (US)

(73) Assignee: **General Electric Company**, Schenectady, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/379,384**

(22) Filed: **Aug. 23, 1999**

OTHER PUBLICATIONS

F. Rashid-Farokhi, K.J.R. Liu, C.A. Berenstein, and D. Walnut, "Localized Wavelet Based Computerized Tomography," Proc. IEEE ICIP-95, pp. 445–448, 1995.
Carl Crawford and Kevin King, "Computed Tomography Scanning with Simultaneous Patient Translation," Med. Phys. 17(6), Nov./Dec. 1990, pp. 967–982.

* cited by examiner

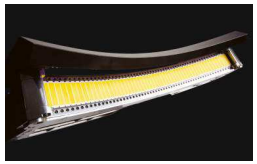
Primary Examiner—Robert H. Kim
Assistant Examiner—Hoon K. Song
(74) *Attorney, Agent, or Firm*—Carl B. Horton, Esq.; Armstrong Teasdale LLP

(57) **ABSTRACT**

FIG. 2

2009: Markteinführung neuer Scintillator

Gemstone



- Gemstone: Oxid aus der Famillie der Seltenen Erden in einer synthetisierten Kristallstruktur

Scintillator	Views/Rotation
Gemstone	2.500
GOS (Gd_2O_2S)	700-1.100

Gemstone Spectral Imaging

Dual Energy mit 1 Röhre und 1 Detektor

Gemstone Detektor für optimale Energietrennung

100-fach schnellere Primärgeschwindigkeit / 4-fach kürzeres Nachglühen
⇒ Ca. 2,5-fach höhere Erfassungsrate (7000 views/s)
⇒ Höchste räumliche Auflösung am Markt (0,23mm)

Ultra-schneller kV-Wechsel

<0,3ms Schaltzeit zwischen 80 und 140 kV
Volles 50 cm DFOV - für jeden Untersuchungsbereich

Rohdatenberechnung statt Bilddaten

Hohe Genauigkeit der Materialtrennung
101 monochromatische Bilder pro Rotation von 40 – 140 keV

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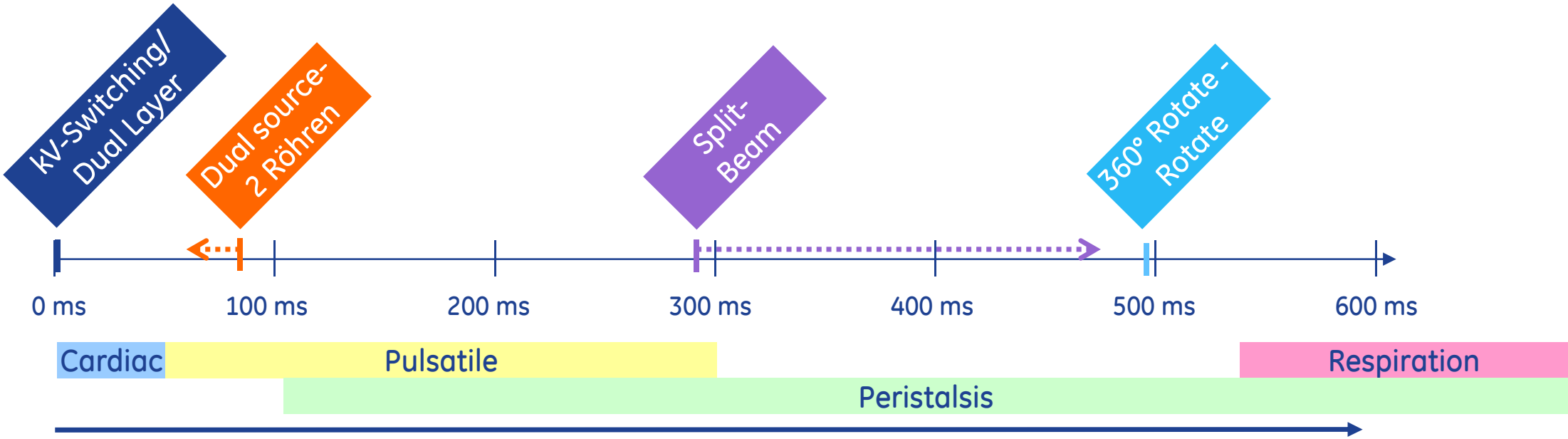
Gemstone™ - Paradigmenwechsel durch 100 x schnelleres Detektormaterial

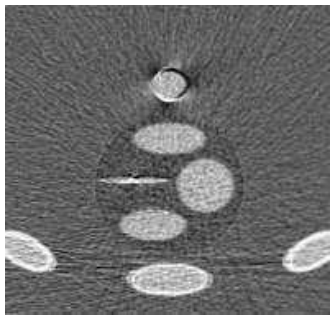
Zeitliche Auflösung ist entscheidend

kV-Switching führend



Bewegungstypen:

Herz:	<50 ms
Puls:	~50-300 ms
Peristaltik:	~100 –1000 ms
Respiration:	~1000 msec



Bewegungsartefakte bei geringer zeitlicher Auflösung

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Dual Energy

Klinische Relevanz

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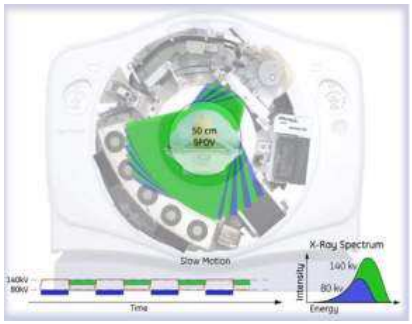
Monochromatische Bildberechnung

ROHDATEN vs Bilddatenraum



Term mit/ohne Berücksichtigung nicht linearer Daten (Rohdaten)

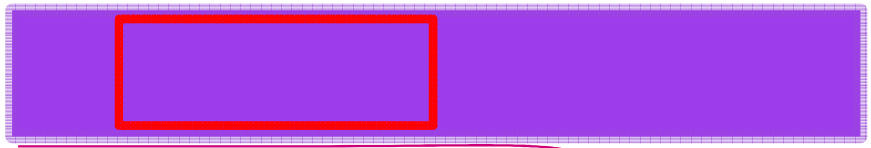
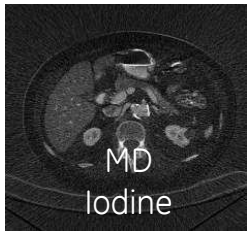
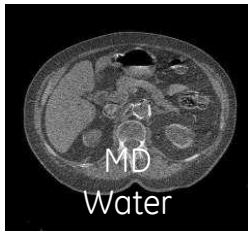
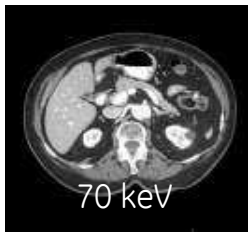


Image Reconstruction







Monochromatisch

Vorteile bei Rohdatenverwendung:

- Korrektur von Aufhärtungsartefakten z.B. HSG
- Exakte HU-Werte – unabhängig vom Patientendiameter
- Trennung von Materialien, z.B. Wasser & Jod
- Virtuelle Nativ-Bildgebung
- Materialquantifizierung in mg/cm3
- Nachweis kleinster Jodanreicherungen
- Guter Kontrast auch bei geringen Jodmengen möglich
- Hochgradige Reduktion von Metallartefakten

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GSI Gemstone Spectral Imaging

Klinische Ergebnisse

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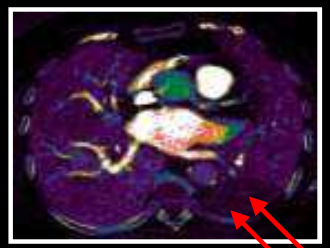
GSI (Gemstone Spectral Imaging) zur Charakterisierung von Läsionen

EMERGENCY



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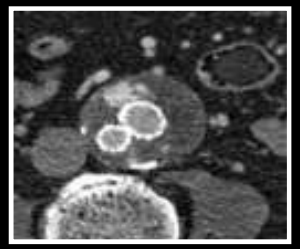
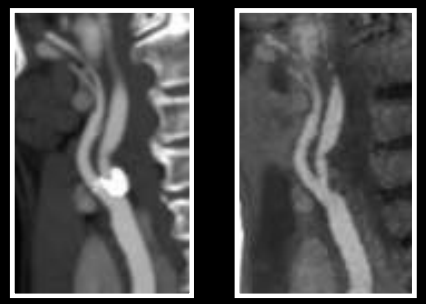


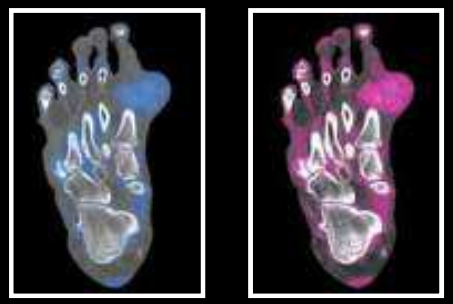
Stent-
Blutungen

VASCULAR



Stenosenbeurteilung

ANDERE



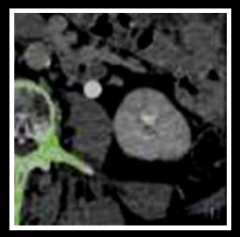
Harnsäure-Calcium Differenzierung

ONKOLOGIE

Charakterisierung von Läsionen

VIRTUELLE NATIVBILDGEBUNG

Blutung

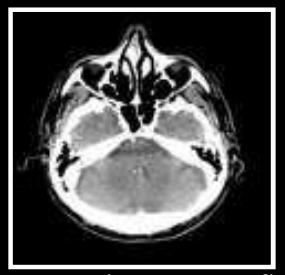


Nierensteine

GSI (Gemstone Spectral Imaging) zur Bildqualitätsverbesserung

KONTRAST U. AUFHÄRTUNG

Optimierter Kontrast



Reduzierte Aufhärtungsartefakte
In monoenergetischen Bildern

METALL ARTEFAKT REDUKTION BEI PROTHESEN

METALL ARTEFAKT REDUKTION NACH CHIRURGISCHEM EINGRIFF

Neuro clips

Aorta clips

METAL ARTEFAKT REDUKTION ALLGEMEIN

Iliac Stent

Metallimplantat

Zahnartefakte

RIVA Stenose

Patientenhistorie

- 57-j alter Patient
- Coro 2010: 50%ige RIVA Stenose

Akquisition

- GSI Aquisition, 2xGSI-62, 0,35s, 40 mm
- Padding: Ruhe 80 ms, Stress 0 ms
- ASiR GS 70
- 400µg Regadenoson Bolus
- KM: 71 ml 100%, 30 ml 30%, 60 ml 0%, flow 5ml/s,

Dosisbericht

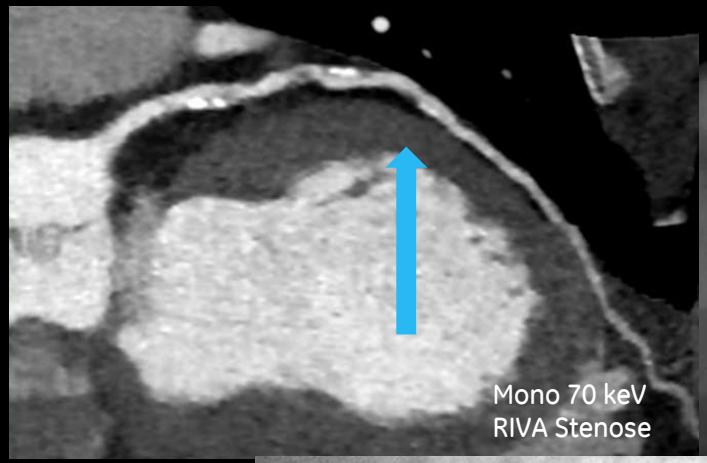
Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)
1	Scout	-	-	-
200	Axial	178.500-178.500	19.71	9.85
2	Cine	176.750-181.125	14.26	149.68
201	Axial	178.500-178.500	18.39	9.20
3	Cine	176.750-181.125	10.06	105.65
			Total Exam DLP:	274.38

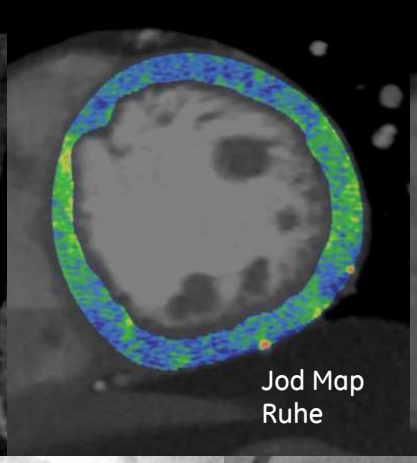
GSI: one stop shop mit 3,84 mSv

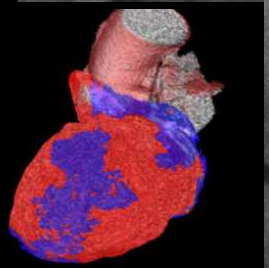
Coronare CTA + Perfusionsbildgebung für Hämodynamische Relevanz

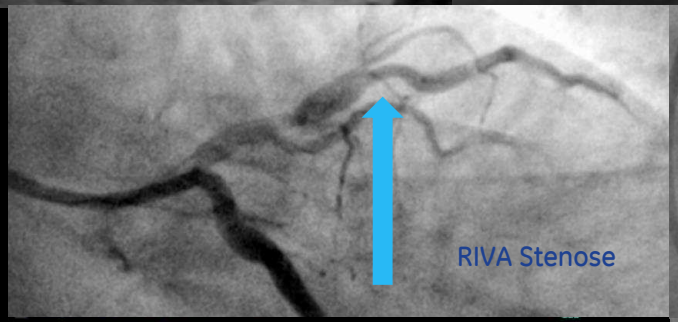
* Obtained by EUR-16262 EN, using an adult cardiac of 0.014*DLP

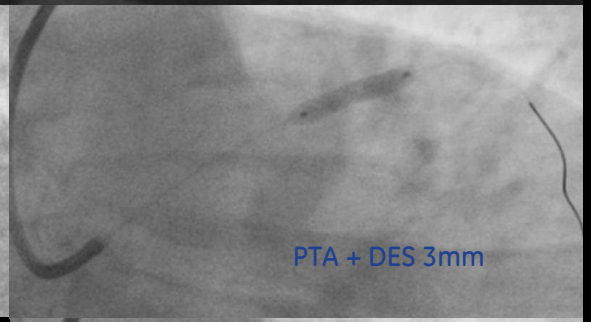
Courtesy of Dr. Ahlers, Radiomed Wiesbaden, Germany

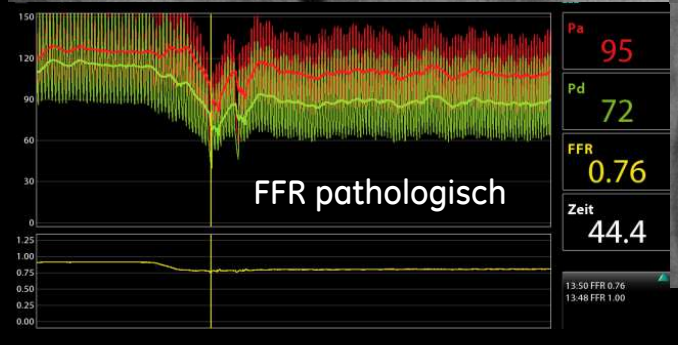


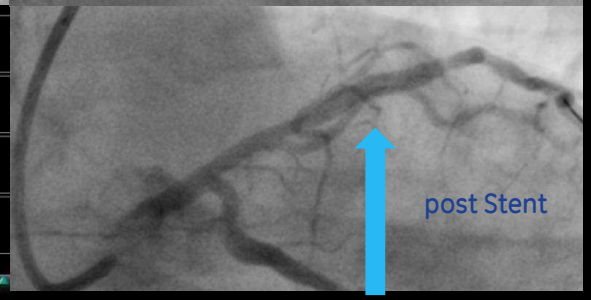






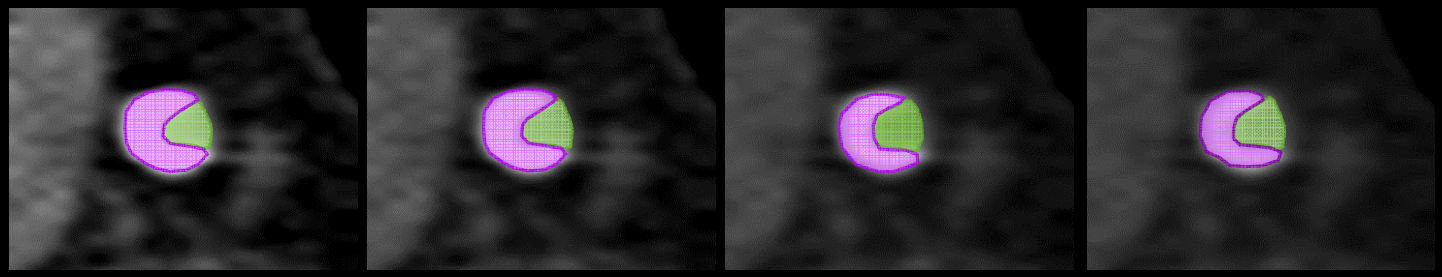




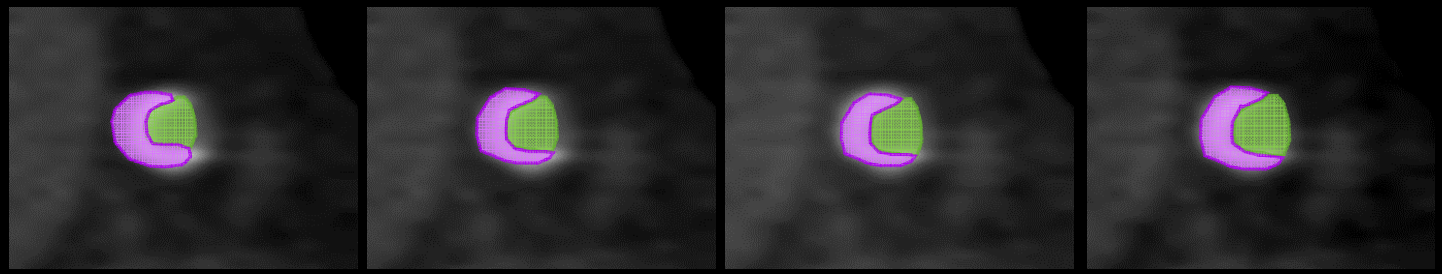


Spectral Imaging am Herzen

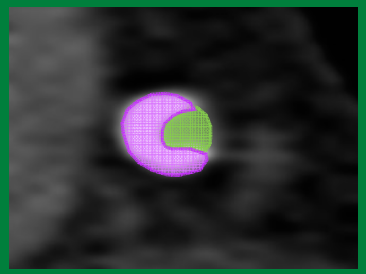
Bessere Lumenvisualisierung durch monoenergetische Bilgebung



40 keV 50 keV 60 keV 70 keV



80 keV 100 keV 120 keV 140 keV

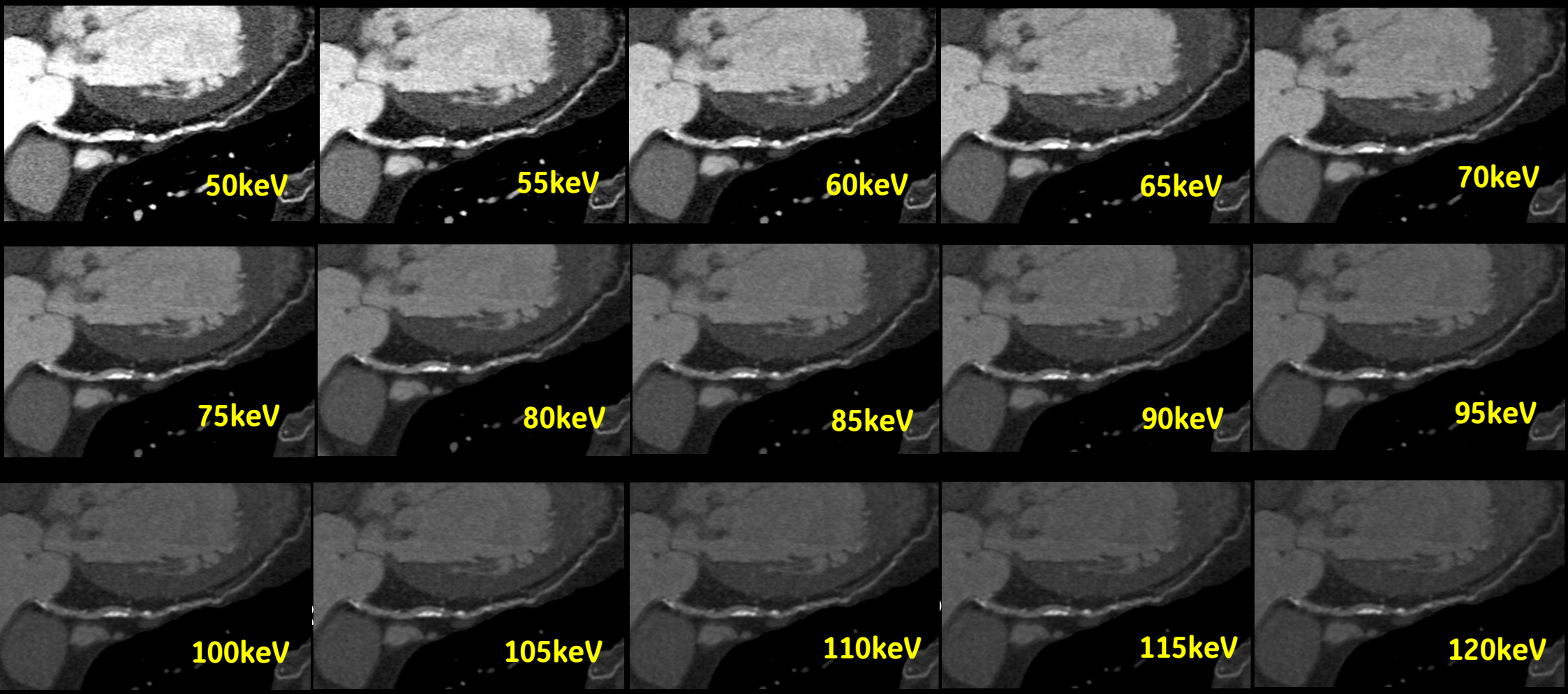


SECT 120 kVp

GE imagination at work

Courtesy of Pr Müller-Hülsbeck, Dr Lehrke, Diako Flensburg, Germany

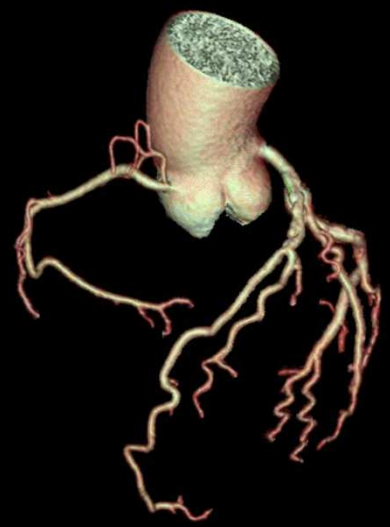
GSI Cardiac – Minimierung des Calciumbloomings

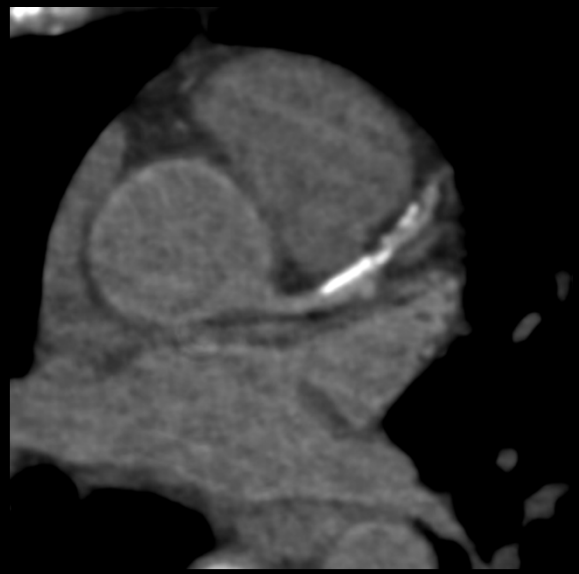


Images courtesy of Dr Ghekiere, CHC St-Joseph Liège, Belgium

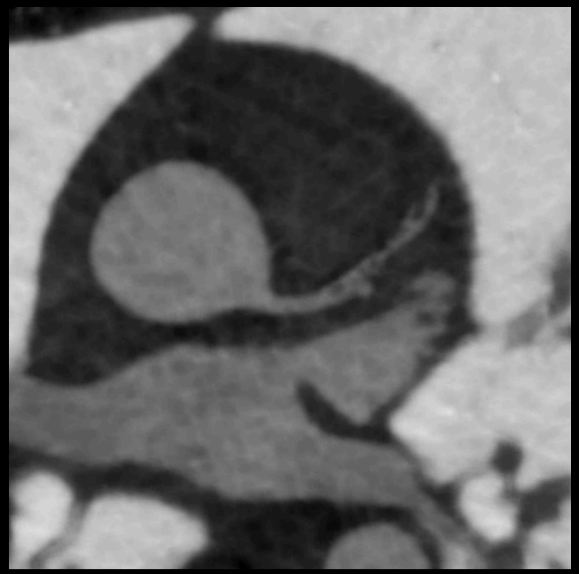
GSI Cardiac

Trennung von Kalk und KM
+ Gefäßanalyse





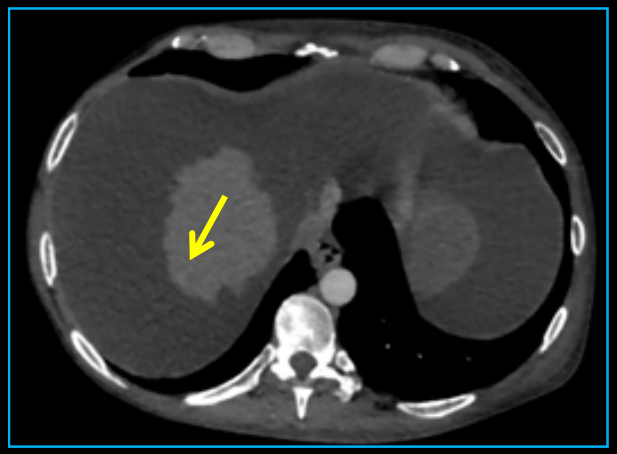
HAP



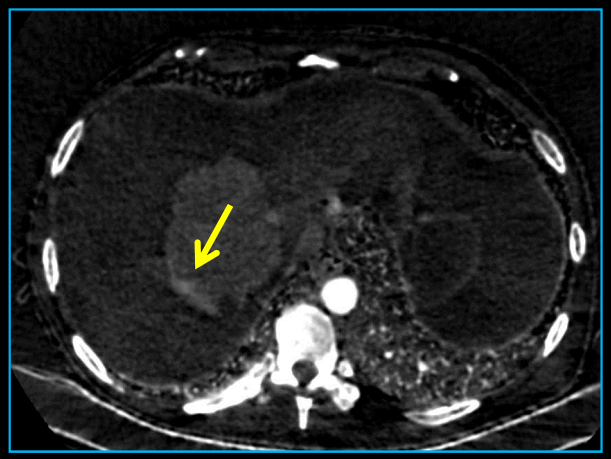
Jod

Spectral Imaging

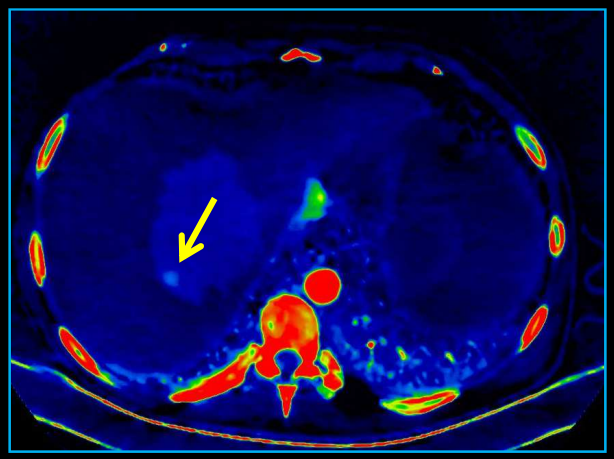
Onkologie: Charakterisierung von kleinsten Läsionen



Classic 120 kVp image



Monochromatic images 55 KeV



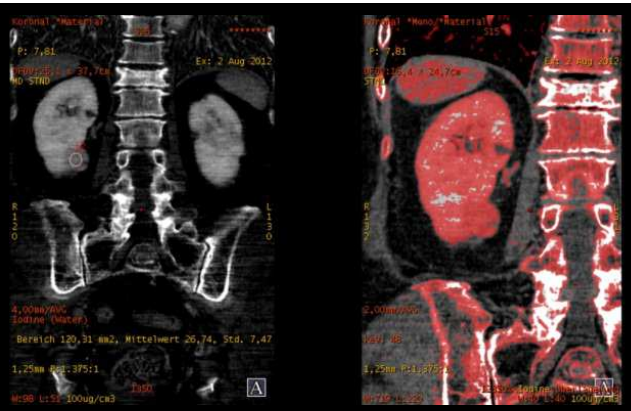
MD Iodine (Water) Color Map

58 Jahre, Zirrhose

Follow up eines hepato-cellulären Karzinoms

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	S56.000-I190.250	5.29	164.28	Body 32
3	Helical	S58.250-I175.350	10.76	320.60	Body 32
3	Helical	S58.250-I362.550	9.47	459.41	Body 32

Images courtesy of Pr A Luciani, CHU Henry Mondor , France



Iodine measurement in MD image
2,67 mg/cm3 -- suspicious for renal tumor
(according to publication from Kaza et al. 2011)

Distinguishing Enhancing From Nonenhancing Renal Lesions With Fast Kilovoltage-Switching Dual-Energy CT

Ravi K. Kaza[1]
Elaine M. Caoili
Richard H. Cohan
Joel F. Platt

OBJECTIVE. The purpose of this article is to evaluate the accuracy of dual-energy CT in distinguishing enhancing from nonenhancing or equivocally enhancing renal lesions.

MATERIALS AND METHODS. We retrospectively reviewed fast kilovoltage-switching dual-energy renal mass CT performed in 39 patients. On the contrast-enhanced dual-energy CT scans, renal lesions were graded subjectively for enhancement using iodine density

TABLE 2: Detection of Enhancement in Renal Lesions Using Differing Iodine Density Thresholds

Iodine Density Threshold (mg/cm³)	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value	Accuracy
≥ 1	95 (78.9–99.1)	41.3 (36.1–42.6)	33.9 (28.2–35.4)	96.3 (84.3–99.3)	54.2 (46.4–56.2)
≥ 1.5	90.9 (75.5–97.4)	80.3 (74.8–82.7)	62.5 (51.9–66.9)	96.1 (89.4–98.9)	83.1 (74.9–86.6)
≥ 2	90 (75–96.9)	93.7 (88.9–95.8)	81.8 (68.2–88.1)	96.7 (91.8–99)	92.8 (85.5–96.1)
≥ 2.5	70 (51.9–78.1)	96.8 (91.1–99.4)	87.5 (66.9–97.7)	91 (85.6–93.5)	90.4 (81.6–94.3)
≥ 3	65 (49–65)	100 (94.9–100)	100 (75.4–100)	90 (85.4–90)	91.6 (83.9–91.6)

Note—Data are percentage (95% CI).

Kaza RK et al. AJR 2011;197:1375-1381

Images Courtesy of Dr. Ewig, Radiologie am Raschplatz,Hannover, Germany

Case Study

Endoprothese der Hüfte

Patientenhistorie

- Patient mit Hüft-TEP
- Verdacht auf Prothesenlockerung

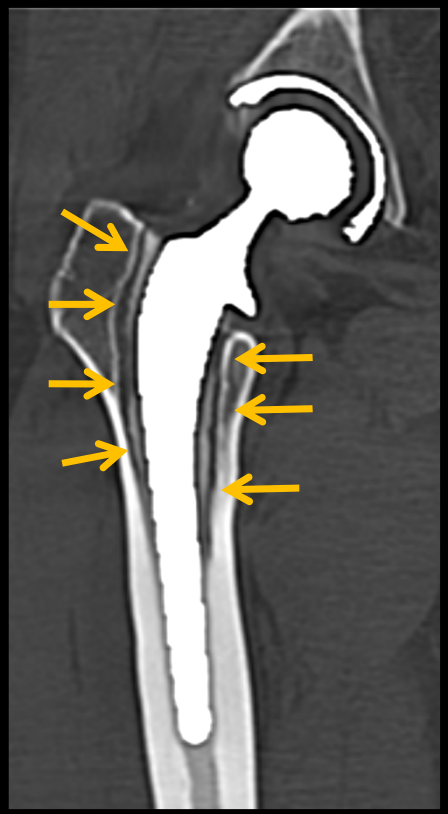
Akquisition

- GSI mit MARs
- 600 mA
- Rotationszeit: 0.8 sec – Pitch: 0.516:1

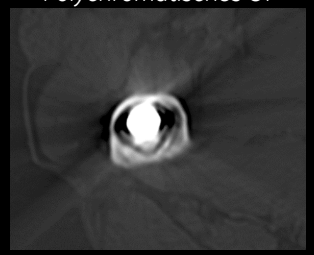
Beurteilung

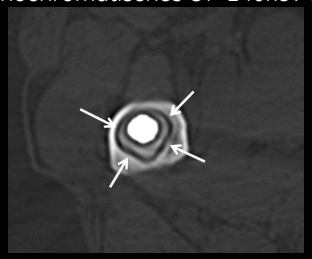
- GSI mit monochromatischen Bildern und MARs ermöglicht dem Radiologen ,die hypodense Zone zwischen Knochen und Zement zu beurteilen, welche auf eine aseptische Endoprothesenlockerung hinweist

Polychromatisches CT



Monochromatisches CT 140keV mit MARs





Courtesy of Dr Pessis, Centre Cardiologique du Nord, Saint-Denis, France

Gemstone Spectral Imaging (GSI)

RSNA 2013

Virtual Unenhanced (VUE) Images

Can Multi-material Decomposition Algorithm Generated Virtual Unenhanced (VUE) Images from Single Source Dual-energy CT meet the Qualitative and Quantitative Expectations of True Unenhanced (TUE)?

Sahani et al, RSNA 2013

Purpose

Assess the performance of VUE for abdominal AAA

Methods and Materials

33 patients True UE and VUE series
3 readers – IQ and acceptance of VUE (4-point scale) & incidental findings
quantitative HU measurements (liver, kidney, muscle, fat) – Pearson correlation coef

Results

VUE rated acceptable in all 33 exams & preferred over TUE (IQ 3 vs. 2.1).
All incidental findings were detected.
Mean HU demonstrated good to excellent correlation with TUE
Mean attenuation difference < 5HU

Conclusion

VUE images meet the clinical expectations of quality and quantitative measurements and therefore a viable replacement of TUE.

imagination at work

RSNA 2011

CT numbers accuracy with GSI

Influence of Phantom Size on Quantitative Iodine Measurement: Comparison of Dual-Energy CT with Standard CT, **Van Gompel et al. RSNA'11**

Purpose

In standard CT, attenuation measurements (HU-value) of objects are influenced by patient size mainly due to polychromatic x-ray beam hardening through the object. The purpose is to determine (1) the accuracy of the iodine concentration estimation with DECT and (2) to investigate the variation in attenuation measurements compared to standard CT.

Method and Materials

Three tubes representing iodinated blood vessels were filled with diluted (13 mg I/ml) iodine contrast (Visipaque 320, GE Healthcare) and inserted in the center of three cylindrical AAPM phantoms (CIRS, Norfolk VA.), one 23cm diameter, one 17cm and one 17cm with a Teflon ring representing bone

Results

The following data (±SD) were obtained for the three respective phantoms: HU-values of 291(±9) – 318(±9) – 325(±5) for standard CT, DECT HU-values at 70 keV of 310(±6) – 314(±5) – 315(±8), and estimated iodine concentrations (mg I/ml) of 13.2(±0.3) – 13.1(±0.2) – 13.4(±0.2).

Conclusion

The results suggest that DECT HU-values are less sensitive to variations in patient size compared to standard CT.

GSI monochromatic images give more accurate CT numbers and an accurate iodine concentration information

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Spectral Attenuation Curves With GSI

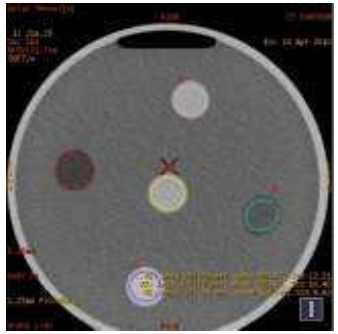
Accuracy estimation of spectral attenuation curves obtained by dual energy CT

Gompel et al. ECR'11

EUROPEAN SOCIETY OF RADIOLOGY 2011

Purpose

Quantify the accuracy of material attenuation data from synthesized monochromatic images generated by dual energy CT



Method and Materials

Two patients and a technical phantom with relevant material inserts
Attenuation curves obtained for different materials of interest

Conclusion

Based on comparison of Compton and photo-electric decomposition coefficients, we conclude that obtained attenuation data from DECT accurately match the tabulated attenuation data

The attenuation of different materials calculated by GSI at each monochromatic energy are accurate compared to tabulated attenuation curves from NIST.

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Zusammenfassung

Gemstone Spectral Imaging

Technische Ergebnisse:

- Hervorragende Energietrennung
- Exzellente zeitliche Auflösung (<0,3ms)
- Geringer baulicher Aufwand – faire Folgekosten

Klinische Ergebnisse

- Breites klinisches Anwendungsspektrum
  - 50cm FOV, geringe Dosis, Monochromatische Bilder, Quantifizierung)
- Umfänglichste klinische Validierung
- Einfache klinische Implementierung

Perspektive

- Weiterhin hohes Zukunftspotential
  - breitere Detektorformate
  - ...

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GE Healthcare

Vielen Dank für Ihre Aufmerksamkeit !

Beate Schmidt
Leitung klinische Applikation CT
Region DACH

Christian Kistner
Geschäftsbereichsleiter CT
Region DACH

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