Applications for Dual-Energy CT in Oncology

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Disclosures

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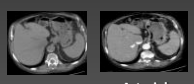
- Astellas
- Bayer
- Bracco
- GE Healthcare
- Guerbet
- Medrad
- Siemens Healthcare

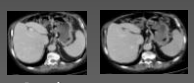
Multiparametric Approach

Single Energy



Pre-Contrast

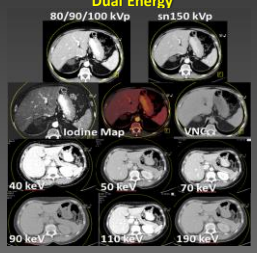
Arterial



Portal

Late

Dual Energy



Dual-Energy CT

INFORMATION

Single Energy → Qualitative & Quantitative Information

Dual Energy → Qualitative & Quantitative Information

Dual-Energy CT (DECT) in Oncology

Main applications in oncologic imaging include:

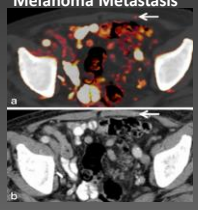
- Virtual non-contrast (VNC) images to lower radiation dose
- Improving contrast using virtual monoenergetic images (Mono)
- Quantifying iodine uptake with iodine perfusion maps

How Can DECT Be Implemented in Oncological Imaging?

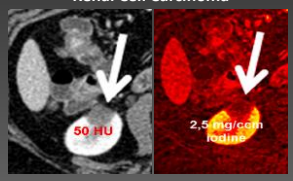
- **Material Differentiation**
  Iodine, calcium, barium, uric acid
- **Material Detection and Quantification**
  1) **Tumor detection**
  2) **Tumor characterization**
  3) **Evaluation of response to therapy**
  4) **Detection of oncologic-related disorders (e.g. pulmonary embolism)**

Iodine Map

Melanoma Metastasis



Renal Cell Carcinoma



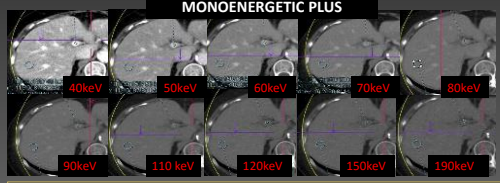
1. Lesion Detection

2. Iodine Quantification

Simons D et al. Eur Rad 2014

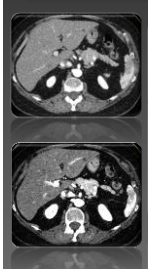
Monoenergetic Imaging

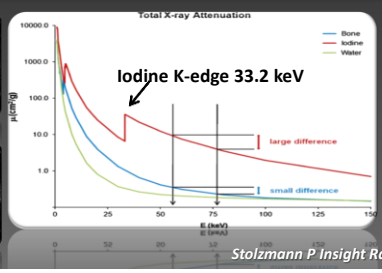
MONOENERGETIC PLUS



- Lesion detection and contrast medium reduction (higher attenuation at lower keV levels
- Metallic artifacts reduction (high keV levels)

Approaching Iodine K-edge





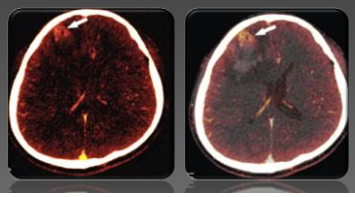
120 kVp

40 keV

Stolzmann P Insight Radiol 2011

Head

DECT may be useful in detecting underlying tumors in patients with intracerebral hemorrhage of unknown origin



Sens 94%

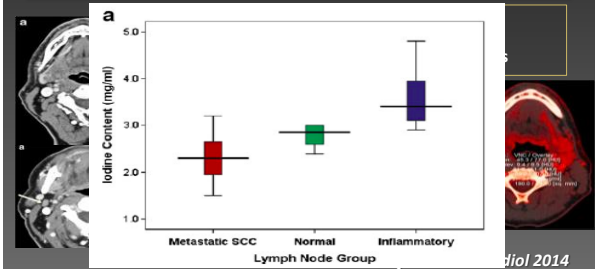
Spec 97%

Kim SJ AJNR 2012

Head and Neck

- Differentiating metastatic lymph nodes
- Improved head and neck tumor staging and assessment

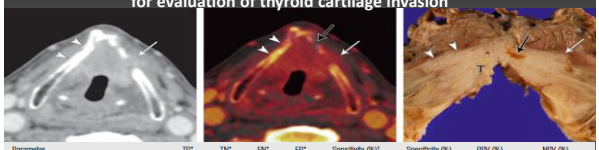
Head and Neck



diol 2014

Head and Neck

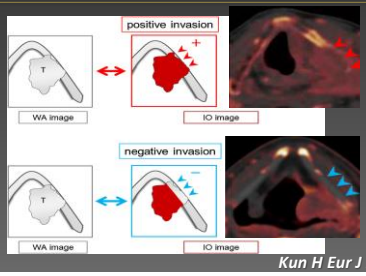
DECT can increase diagnostic performance and reproducibility for evaluation of thyroid cartilage invasion



Parameter	TP*	TN*	FN*	FP*	Sensitivity (%)†	Specificity (%)	PPV (%)	NPV (%)
Thyroid cartilage invasion ($n = 30$)								
WA images alone	6	16	1	7	86 (6/7)	70 (16/23)	46 (6/13)	94 (16/17)
WA plus IO images	6	22	1	1	86 (6/7)	96 (22/23)	86 (6/7)	96 (22/23)
Cricoid cartilage invasion ($n = 26$)								
WA images alone	4	21	0	1	100 (4/4)	95 (21/22)	80 (4/5)	100 (21/21)
WA plus IO images	4	22	0	0	100 (4/4)	100 (22/22)	100 (5/5)	100 (21/21)

Kuno H Radiology 2012

Head and Neck

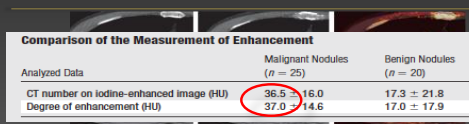


Kun H Eur J Radiol 2013

Lung

- The ability of DECT to visualize and quantify the iodine uptake of nodules may help in differentiating benign from malignant pulmonary nodules
- VNC data-set can help in reducing radiation dose

Lung



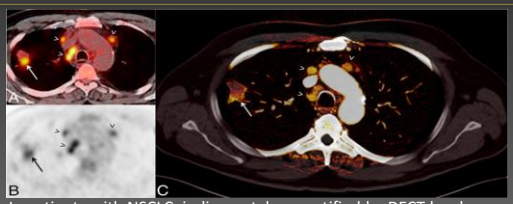
Comparison of the Measurement of Enhancement

Analyzed Data	Malignant Nodules ($n = 25$)	Benign Nodules ($n = 20$)	*P* Value
CT number on iodine-enhanced image (HU)	36.5 ± 16.0	17.3 ± 21.8	.001
Degree of enhancement (HU)	37.0 ± 14.6	17.0 ± 17.9	<.001

	Iodine Map	Degree Enhancement
Sensitivity	92%	72%
Specificity	70%	70%
Accuracy	82.2%	71.1%

Chae EJ Radiology 2008

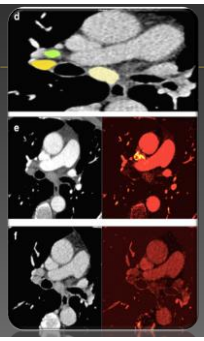
Lung



In patients with NSCLC, iodine uptake quantified by DECT has been shown to correlate with metabolic activity on FDG-PET

Schmid-Bindert G Eur Radiol 2012

Lung



Arterial Enhancement Fraction (AEF)

Ratio of early and late post-contrast iodine uptake

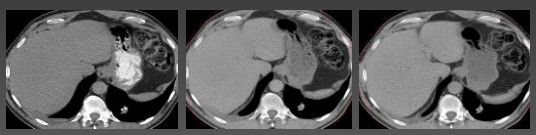
Key Points
- *Dual-phase DE-CT is beneficial for mediastinal lymph node assessment in NSCLC.*
- *Arterial to venous iodine uptake ratio was higher in enlarged lymph nodes.*
- *Change of arterial enhancement fraction correlated to therapy response.*

Baxa J Eur Radiol 2014

Liver

- Radiation dose reduction using the VNC data-set
- Nodule detection and characterization
  (Iodine Map & Monoenergetic Imaging 50-55/70-75 keV)
- Evaluation of response to therapy

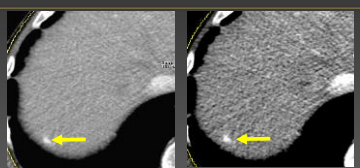
Non-Contrast Liver CT



Real | Virtual Arterial | Virtual Portal

Which One is the Real, the Virtual Arterial and the Virtual Portal Unenhanced?

Lowering the kV…

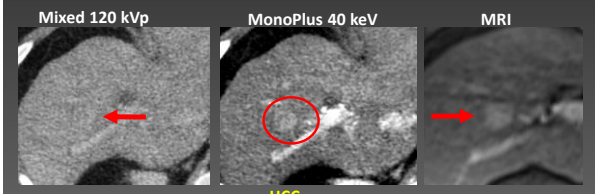


120 kVp | 80 kVp

Improved lesion detection and conspicuity
(HCC, hypervascular metastases)

Robinson E Invest Radiol 2010, Altenberd J Eur Rad 2010, Marin D Radiology 2009

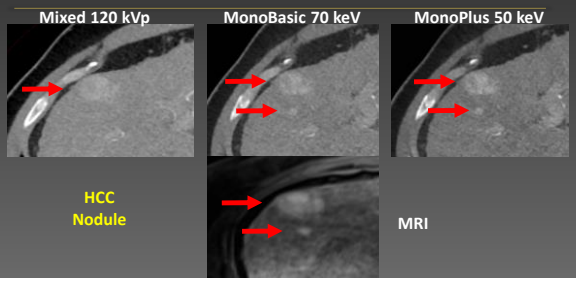
…Switching to the keV



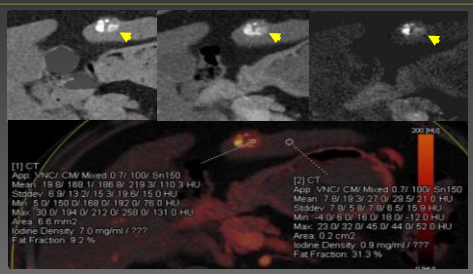
HCC

Virtual Monoenergetic Images at low keV may improve lesion detection and conspicuity

Liver Lesion Detection



Recurrent HCC after TACE

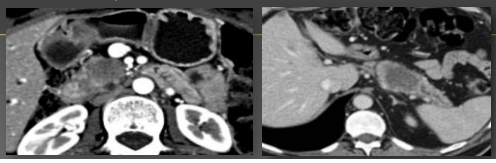


Pancreas

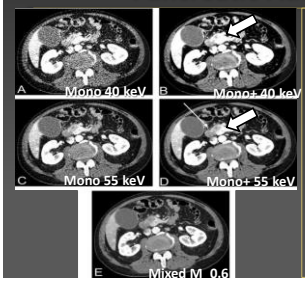
- DECT can increase the visualization of small (< 2 cm) or isoattenuating pancreatic adeno-ca
- Cystic lesion characterization (Serous vs Mucinous)
- Neuroendocrine tumor detection

Pancreatic Adenocarcinoma

- Hypoattenuating solid mass in ≈ 90-95%
- Hypoattenuation due to desmoplastic fibrotic component
- CT Sensitivity:
  - > 2 cm: up to 98%



Pancreatic Adenocarcinoma



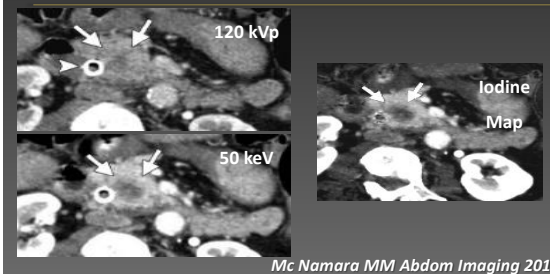
MonoPlus at low energies (keV)

Improved image quality and pancreas-to-lesion contrast in the diagnosis of pancreatic adenocarcinoma

Substantial noise reduction compared to the prior algorithm

Frellesen et al, EJR 2015

Lesion Conspicuity



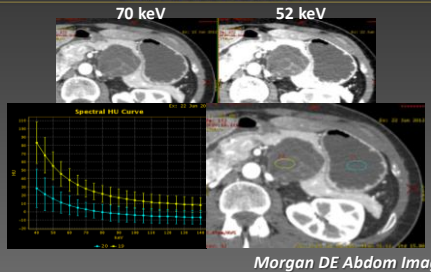
Mc Namara MM Abdom Imaging 2015

Pancreatic Cystic Lesions

- MACROCYSTIC SCN (10%)
  - Difficult DD with pseudocyst and MCN

- DD: Calcifications / intramural nodules / enhancing septa

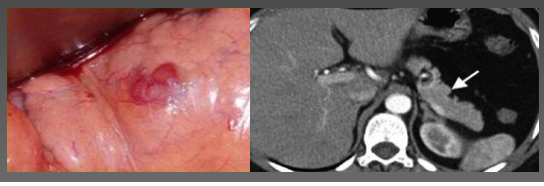
Intralesional Components Characterization



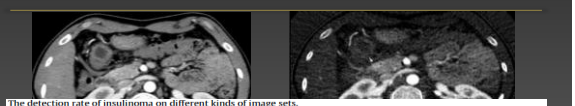
Morgan DE Abdom Imaging 2013

Insulinoma

- Pancreatic insulinomas are usually small tumors that are difficult to localize with conventional CT



Insulinoma

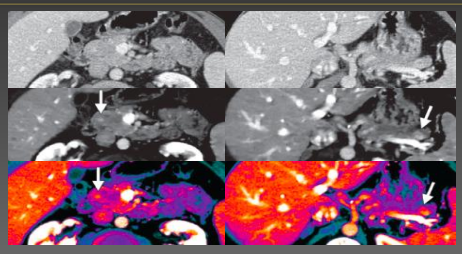


The detection rate of insulinoma on different kinds of image sets.

	MDCT	Mono	Iodine	Mono + iodine
Sensitivity	68.8%(11/16)	87.0%(20/23)	87.0(20/23)	95.7%(22/23)
P		$\chi^2 = 1.918$ 0.235	$\chi^2 = 1.918$ 0.235	$\chi^2 = 5.246$ 0.033

Lin XZ Eur J Radiol 2012

Nonfunctioning pNET (MEN 1)



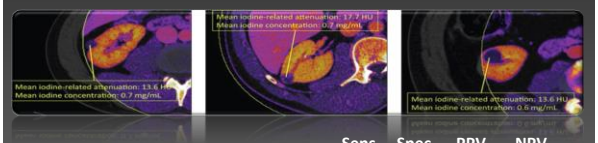
Agrawal MD Radiographics 2014

Kidney

- The differential diagnosis between benign cyst and solid tumor can be a challenge
- Iodine uptake attenuation increase of at least 15–20 HU
- DECT significantly increases reader confidence in differentiating cystic from solid renal masses
- Lesion Iodine Threshold: 0.5 mg/mL

Chandarana H AJR 2011

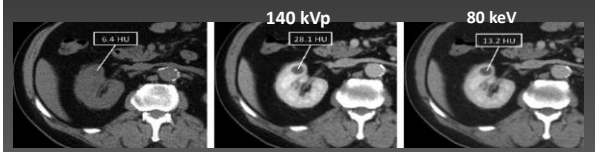
Kidney



		Sens	Spec	PPV	NPV
Iodine-related attenuation:	15 HU	91.4%	93.3%	91.4%	93.3%
Iodine concentration:	0.5 mg/mL	100%	97.7%	97.2%	100%

Mileto A AJR 2014

Kidney



Conclusion: Dual-energy multi–detector row CT with reconstruction of virtual monochromatic images at an optimal energy level can overcome renal cyst pseudoenhancement.

Mileto A Radiology 2014

Incidental Adrenal Masses

- Incidental adrenal masses occur in up to 5% of CT examinations
- Most of these lesions are benign even in oncologic patients (adrenal adenomas)
- Characterization: Unenhanced + Enhanced CT
  - Unenhanced + Venous + Delayed

Incidental Adrenal Masses

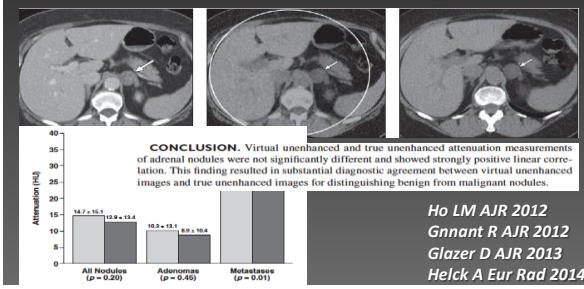
1. Unenhanced CT:
   Threshold 10 HU
   - Lipid Rich Adenoma: Sens 71%, Spec 98%
2. Absolute Washout: (E−D)/(E−U)]×100
   Threshold 60%
   - Lipid Rich/Lipid Poor: Sens 88%, Spec 96%
3. Relative Washout: (E−D)/E×100)
   Threshold 50% at 9 min
   - Lipid Rich/Lipid Poor: Sens 98%, Spec 100%

Boland GW AJR 1998, Caoili EM AJR 2000, Caoili Radiology 2002

Incidental Adrenal Masses

- DECT can improve characterization of adrenal nodules:
- VNC replacing True Unenhanced data-set
- Material Density Analysis
- Low kV imaging
- Monoenergetic Imaging

Virtual Unenhanced Images



CONCLUSION. Virtual unenhanced and true unenhanced attenuation measurements of adrenal nodules were not significantly different and showed strongly positive linear correlation. This finding resulted in substantial diagnostic agreement between virtual unenhanced images and true unenhanced images for distinguishing benign from malignant nodules.

Ho LM AJR 2012
Gnnant R AJR 2012
Glazer D AJR 2013
Helck A Eur Rad 2014

Material Density Analysis

- Material Density Analysis:
  - Sens 96%, Spec 100%
- Non Enhanced CT:
  - Sens 67%, Spec 100%

Mileto A Radiology 2014

Material Density Analysis

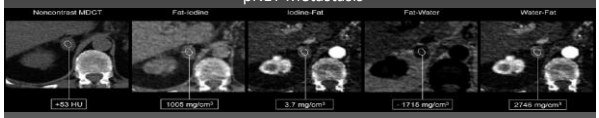
Lipid Rich Adenoma

Lipid Poor Adenoma

Mileto A Radiology 2014

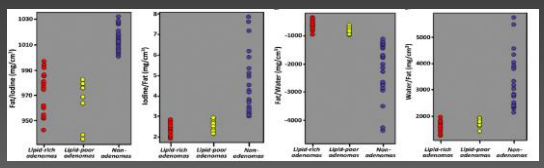
Material Density Analysis

pNET Metastasis



Mileto A Radiology 2014

Material Density Analysis



Mileto A Radiology 2014

Material Density Analysis

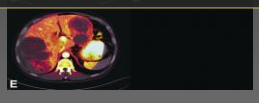
- Material decomposition based on the difference in absorption characteristics for different elements.
- Fat, Iodine, Water (mg/ml)

	n	HU CU	2.5–5 mm mg/mL Water	2.5–5 mm mg/mL Fat	2.5–5 mm HU 140 keV
Adenoma	12	−8.5 (13.9)	994 (8)	986 (8)	5.44 (8.8)
Lipid-poor adenoma	4	27.4 (8.8)	1011 (5)	1002 (4)	24.0 (4.4)
Malignant lesion (metastasis or primary)	8	40.9 (12.3)	1014 (13)	1006 (13)	28.5 (13.7)
Myelolipoma	7	−71.9 (24.0)	940 (11)	933 (10)	−59.7 (12.4)
Hyperplasia	6	17.4 (6.0)	998 (8)	989 (9)	18.1 (9.6)
Adenomatous hyperplasia	10	−7.4 (11.4)	993 (10)	984 (10)	9.8 (9.5)
P (ANOVA)		<0.001	<0.001	<0.001	<0.001

Morgan DE JCAT 2013

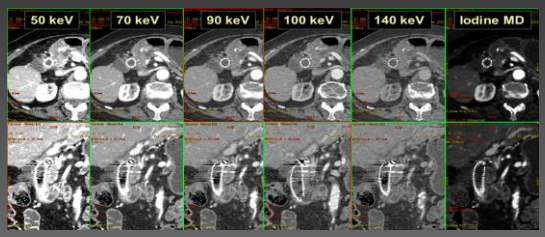
GIST

- Iodine-related attenuation (IRA) of DECT correlates with the Choi criteria
- DECT showed significantly higher IRA in progressive (23.3 9.5 HU) lesions compared with stable or regressive (17.8 9.1 HU) lesions



Apfaltrer P Invest Radiol 2012

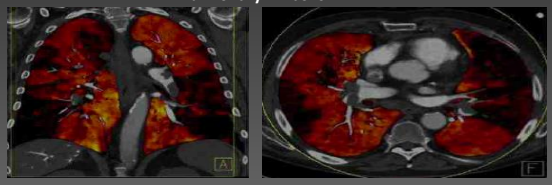
Metal Artifact Reduction



Morgan DE Abdom Imaging 2013

Oncological Related Disease

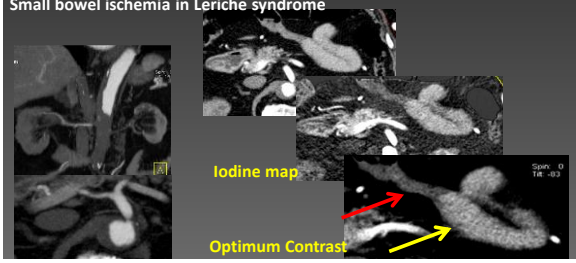
Pulmonary Embolism



Meinel FG Invest Radiol 2013

Oncological Related Disease

Small bowel ischemia in Leriche syndrome



What Reconstructions Do We Need in Clinical Practice?

Combined Approach

1. Mixed 120 kVp
2. Virtual Unenhanced Image (VNC)
3. Virtual Monoenergetic Images

   (50-55 keV Mono+ or 70-75 keV Standard Mono)
4. Iodine Map

Use Iterative Reconstruction

Summary

- DECT can significantly improve lesion detection and characterization (MonoPlus and Iodine Map)
- Assessment of response to therapy and quantification of enhancement
- Radiation dose reduction with VNC imaging
- Oncologic related disease and metallic artifacts reduction


Thank you!
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