Applications for Dual-Energy CT in Oncology

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Disclosures

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

Multiparametric Approach

<table>
<thead>
<tr>
<th>Single Energy</th>
<th>Dual Energy</th>
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<tbody>
<tr>
<td>Pre-Contrast</td>
<td>80/120/180 kVp</td>
</tr>
<tr>
<td>Arterial</td>
<td>80/140 kVp</td>
</tr>
<tr>
<td>Portal</td>
<td>40 kVp</td>
</tr>
<tr>
<td>Late</td>
<td>70 kVp</td>
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</table>
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)
1. Lesion Detection

2. Iodine Quantification


Monoenergetic Imaging

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

Approaching Iodine K-edge

Stolzmann P Insight Radiol 2011
DECT may be useful in detecting underlying tumors in patients with intracerebral hemorrhage of unknown origin.

Sens 94%
Spec 97%

Kim SJ AJNR 2012

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

Tawfik AM Eur Radiol 2014
DECT can increase diagnostic performance and reproducibility for evaluation of thyroid cartilage invasion.

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.
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

Arterial Enhancement Fraction (AEF)
Ratio of early and late post-contrast iodine uptake

Key Points:
- Dual-phase DECT is beneficial for mediastinal lymph node assessment in NSCC.
- 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

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

Lowering the kV...

120 kVp vs 80 kVp
Improved lesion detection and conspicuity
(HCC, hypervascular metastases)

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%

Mono+ 40 keV
Mono 55 keV
Mixed M_0.6
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**

- 120 kVp
- 50 keV

**Pancreatic Cystic Lesions**

- MACROCYSTIC SCN (10%)
  - Difficult DD with pseudocyst and MCN
- DD: Calcifications / intramural nodules / enhancing septa

**Intralesional Components Characterization**

- 70 keV
- 52 keV
Pancreatic insulinomas are usually small tumors that are difficult to localize with conventional CT.

Lin XZ. Eur J Radiol 2012

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

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Kidney

<table>
<thead>
<tr>
<th>Iodine-related attenuation:</th>
<th>Sens</th>
<th>Spec</th>
<th>PPV</th>
<th>NPV</th>
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</thead>
<tbody>
<tr>
<td>15 HU</td>
<td>91.4%</td>
<td>93.3%</td>
<td>91.4%</td>
<td>93.3%</td>
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<th>Spec</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 mg/mL</td>
<td>100%</td>
<td>97.7%</td>
<td>97.2%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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Kidney

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

Unenhanced CT:
- Threshold 10 HU
  - Lipid Rich Adenoma: Sens 71%, Spec 98%

Absolute Washout: $\frac{(E-D)}{(E-U)} \times 100$
- Threshold 60%
  - Lipid Rich/Lipid Poor: Sens 88%, Spec 96%

Relative Washout: $\frac{(E-D)}{E} \times 100$
- Threshold 50% at 9 min
  - Lipid Rich/Lipid Poor: Sens 98%, Spec 100%


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

- Material Density Analysis:
  - Sens 96%, Spec 100%

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

Material decomposition based on the difference in absorption characteristics for different elements.

Fat, Iodine, Water (mg/ml)

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

Metal Artifact Reduction

Oncological Related Disease

Pulmonary Embolism
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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