Improving Structure Delineation for Radiation Therapy Planning Using Dual-Energy CT

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Introduction

- Conventional poly-energetic CT is the most widely used imaging modality for radiation therapy (RT) planning. CT data is used for defining target volumes and distinguishing them from surrounding organs at risk (OAR).
- Issues:
  - Poor image contrast
  - Other modalities often unavailable for registration
  - Registration uncertainty
  - Metal implants → artifacts, photon starvation
  - Manual vs. auto segmentation
- Solution: Dual-energy CT (DECT)
  - Can be used to derive mono-energetic images (MEIs) and material decompositions (i.e. I maps, fat maps, perfusion maps)

Table 1: Quick Facts

Conventional CT	DECT
Commercially available in 1972	Commercially available in 2006
Single acquisition	Dual acquisition
120 kVp X-rays	80 and 140 kVp X-rays
Average price $968,600 (Modern Healthcare 2014)	Price starts at $1,821,000 for Siemens

Methods

- DECT data acquired for 20 representative patients of different tumor with dual-source simultaneous scanning and single-source sequential scanning
- Sequential DECT data: Dual Spiral Dual Energy
- Dual-source DECT data: DS scanner
- Metal artifacts: spine case CT vs. DS-DECT scans treated with metal artifact-reducing algorithm (iMAR)
- Contrast enhancement: 10 pancreatic cancer cases

Results

Figure 1: Metal artifact reduction for spine and prostate cancer patients

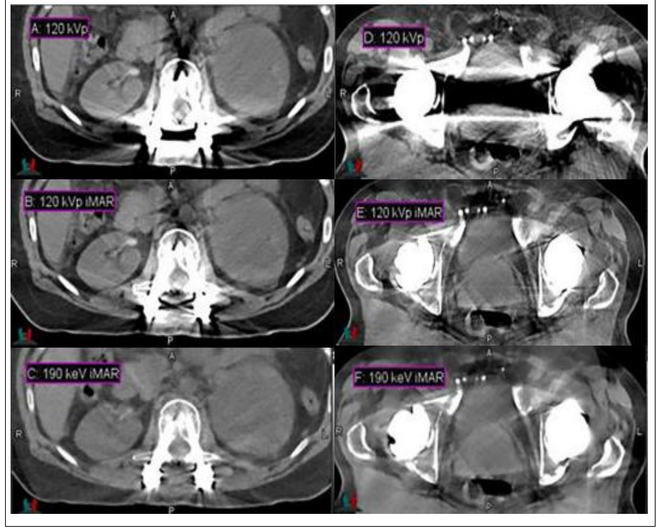


Figure 2: MEI Contrast Enhancement for pancreatic cancer patients

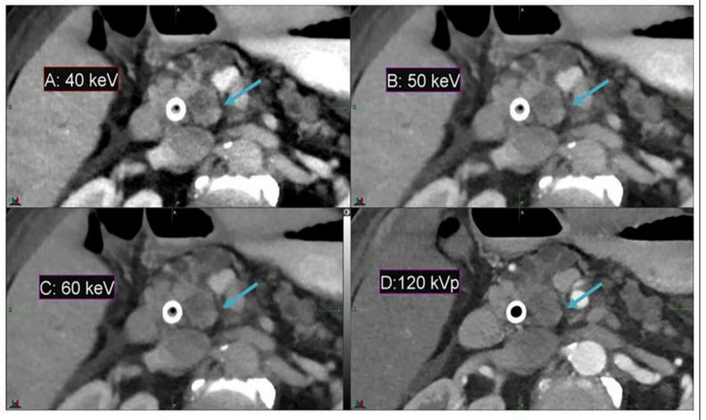
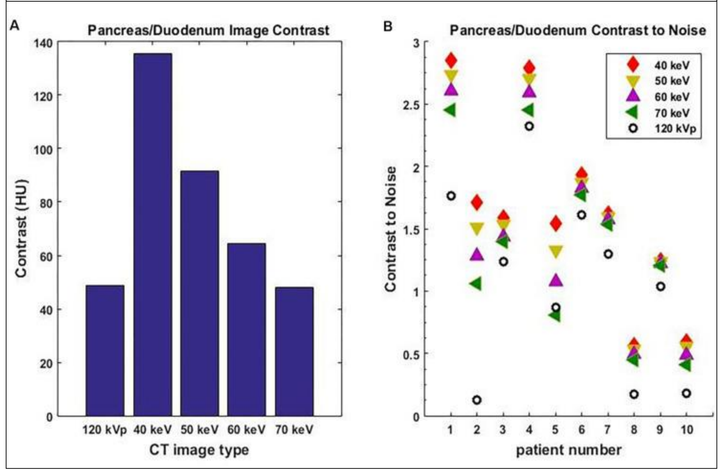


Figure 3: MEI Contrast Enhancement



- Volume of artifacts for five patients with titanium implants was reduced by over 95% for 190-keV MEIs compared to 120-kVp CT images.
- When comparing 40-keV MEIs to conventional CT, soft tissue contrast between the duodenum and pancreatic head was enhanced by a factor of 2.8.
- For a cholangiocarcinoma patient, contrast between tumor and surrounding tissue was increased by 96 HU and contrast-to-noise ratio was increased by up to 60% for 40-keV MEIs compared to conventional CT.
- Simultaneous dual-source DECT also preserved spatial resolution and reduced motion artifacts compared to sequential DECT as evidenced by the identification of vasculature in a pancreas patient.
- A 367-cm^3 region of photon starvation was identified by low CT numbers in the soft tissue of a mantle patient in a conventional CT scan but was eliminated in a 190 keV MEI.

Conclusions

- The use of DECT for RT simulation offers clinically meaningful advantages through improved simulation workflow and enhanced structure delineation for RT planning.