A comparison phantom study of image quality analysis, among conventional single energy CT, dual source dual energy CT, and twin beam dual energy CT

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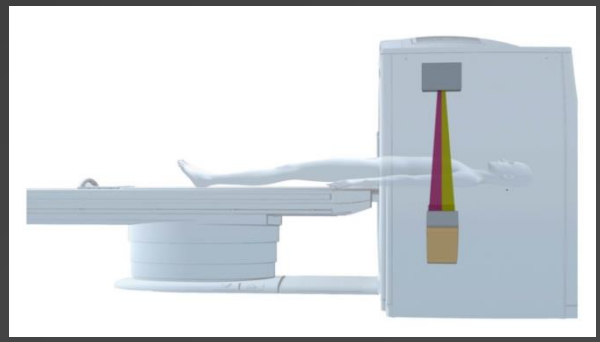
Introduction

- Virtual monochromatic spectral (VMS) images are synthesized from low and high energy images using dual energy CT (DECT).
- VMS images can reduce beam hardening artifacts and provide improved image quality.
- Single source CT scanner with twin beam can provide DECT images by scanning with a split beam with different filters.



https://www.healthcare.siemens.com/computed-tomography/options-upgrades/clinical-applications/twinbeam-dual-energy

Purpose

- To compare image quality among single energy CT, virtual monochromatic spectral images of dual energy CT with dual source, and those with twin beam.

Materials and methods

- Phantom
  - A small adult sized liver phantom (Kyoto Kagaku, Kyoto, Japan)
  - Designed to mimic the CT attenuation of the hepatic parenchymal enhancement during the portal phase (120HU) using iodine materials
  - To simulate the attenuation of hypervascular tumors, three spheres (1.5cm, 1cm, 0.5cm, respectively) consisted iodine materials (150HU) were embedded in the liver insert.
  - To represent larger patient, one or two fat-rings of pork wrapped up the phantom.

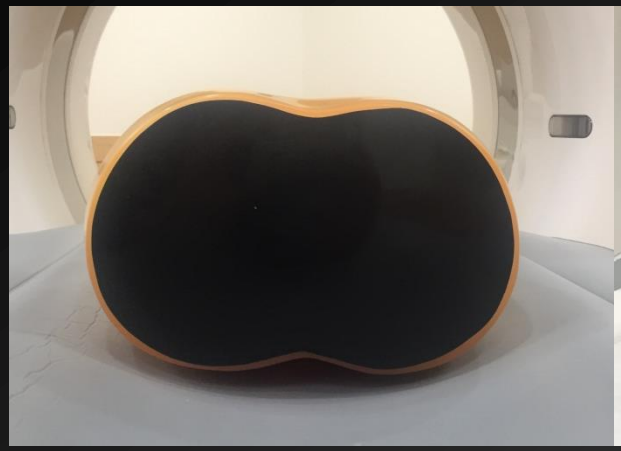
	Small	Medium	Large
Anteroposterior diameter (cm)	18.5	23.5	28
Mediolateral diameter (cm)	30	36	40
Circumference (cm)	84	92	101

Materials and methods

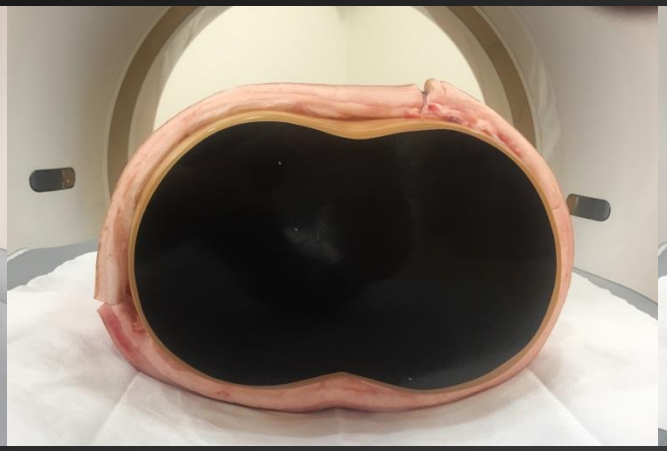
- MDCT technique
  - For phantom size, four polychromatic single energy scans (80, 100, 120, and 140 kVp) and dual energy scan were performed using a single source twin beam scanner (SOMATOM Definition Edge; Siemens Healthineers, Forchheim, Germany) with filtered back projection (FBP) and advanced modeled iterative reconstruction (ADMIRE, level 2), respectively.
  - The other dual energy scan using dual source scanner (SOMATOM Definition; Siemens Healthineers, Forchheim, Germany) was obtained with FBP reconstruction.
  - Virtual monochromatic spectral images were generated from dual energy scans at 5-keV intervals (range, 40~140 keV).

Summary of Scanning and Reconstruction parameter

Parameter	Single energy CT				Twin beam DECT	Dual source DECT
Tube voltage (kV)	80	100	120	140	Au/Sn120	140/80
Tube current (mA)	828	391	228	150	723	72/396
Gantry revolution time (sec)	0.5	0.5	0.5	0.5	0.33	0.5
pitch	0.35	0.6	0.6	0.6	0.25	0.6
CTDIvol (mGy)	15.4	15.4	15.4	15.36	15.4	15.35
Scan time (sec)	10.09	6.19	6.19	6.19	9.4	10.7
Detector collimation (mm)	128*0.6	128*0.6	128*0.6	128*0.6	64*0.6	64*0.6
Acquisition mode	helical	helical	helical	helical	helical	helical
Filed of view (cm)	50	50	50	50	50	26
Reconstruction thickness (mm)	0.3	0.3	0.3	0.3	0.3	0.3
Reconstruction interval (mm)	0.3	0.3	0.3	0.3	0.3	0.3
Reconstruction	FBP & ADMIRE	FBP & ADMIRE	FBP & ADMIRE	FBP & ADMIRE	FBP & ADMIRE	FBP



Small sized phantom



Medium sized phantom

Large sized phantom

Virtual monochromatic spectral images at 40keV with twin beam and ADMIRE

Materials and methods

- Data analysis
  - Circular regions of interest (ROI) were placed on the largest high attenuating sphere and adjacent parenchyma.
  - The standard deviation of the back ground ROI was evaluated as the index of image noise.
  - To ensure consistency, all of the measurements were performed five times for each lesion and mean values were calculated.
  - Tumor-to-liver contrast to noise ratio (CNR) was estimated as one index of CT image quality
    - $CNR = (ROI_{lesion} – ROI_{liver})/ SD_{noise}$

Results

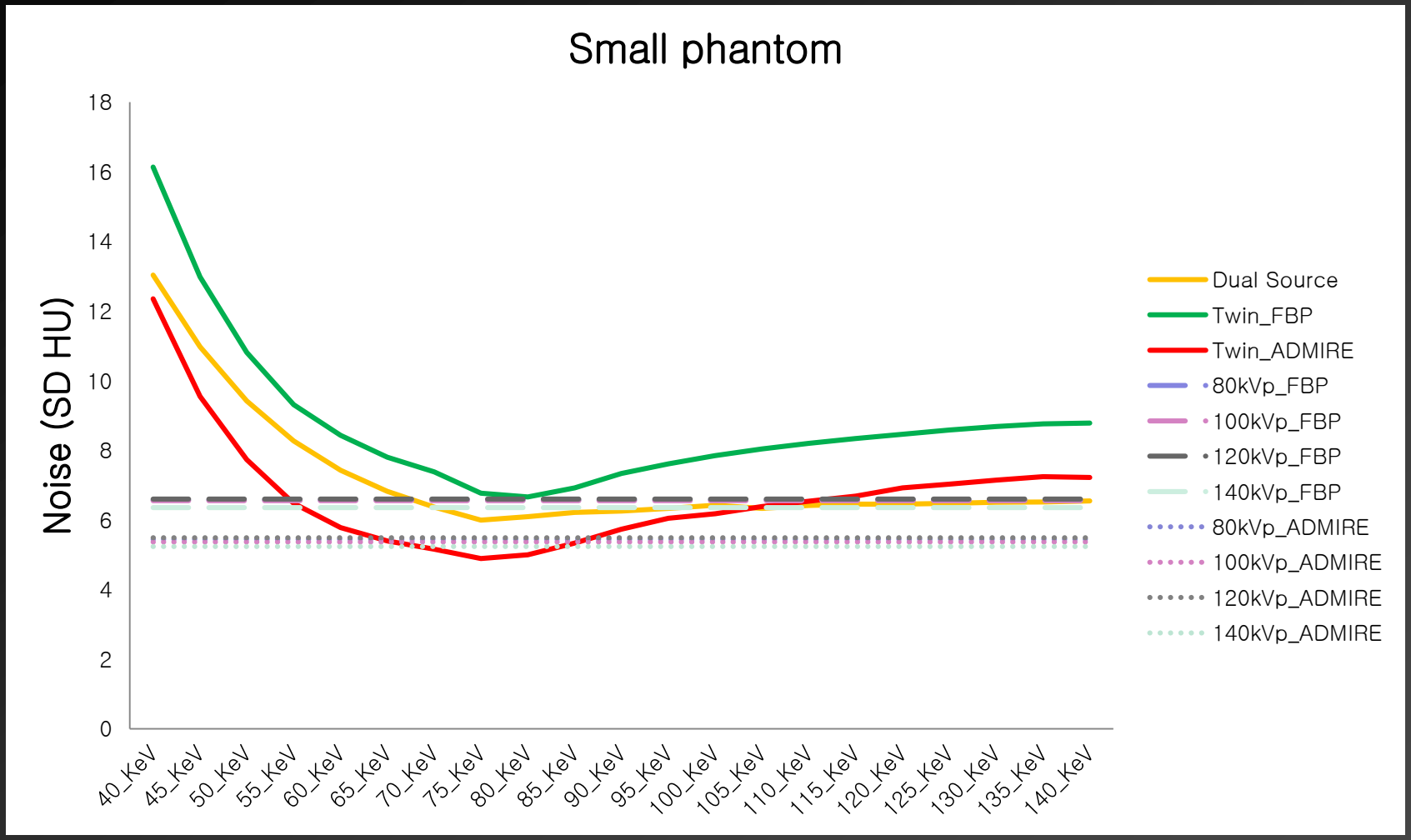


Fig 2. Graph shows mean standard deviation of back ground region of interest for the small sized phantom on VMS images with various scanned and reconstructed types, and on SECT images with various kVp and reconstructed types. The lowest noise level was noted at 75 keV with twin beam and ADMIRE. Noise levels on VMS images in the 65~85 keV with twin beam and ADMIRE were lower than those of 120 kVp CT images with ADMIRE ($p<0.05$).

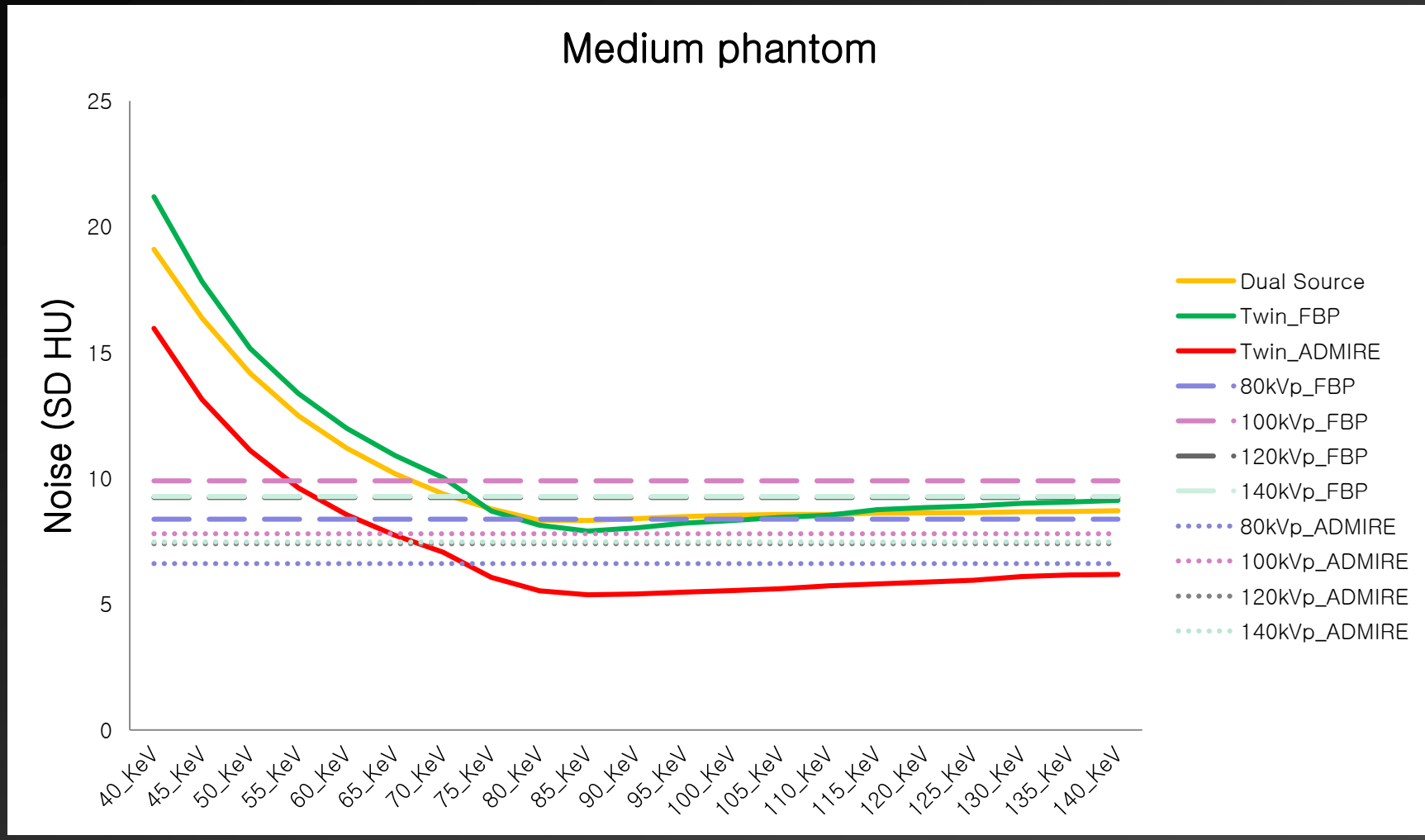


Fig 3. In the medium sized phantom, the lowest noise was noted at 85 keV with twin beam and ADMIRE. Noise levels on VMS images in the 70~140 keV with twin beam and ADMIRE were lower than those of 120 kVp CT images with ADMIRE ($p<0.001$).

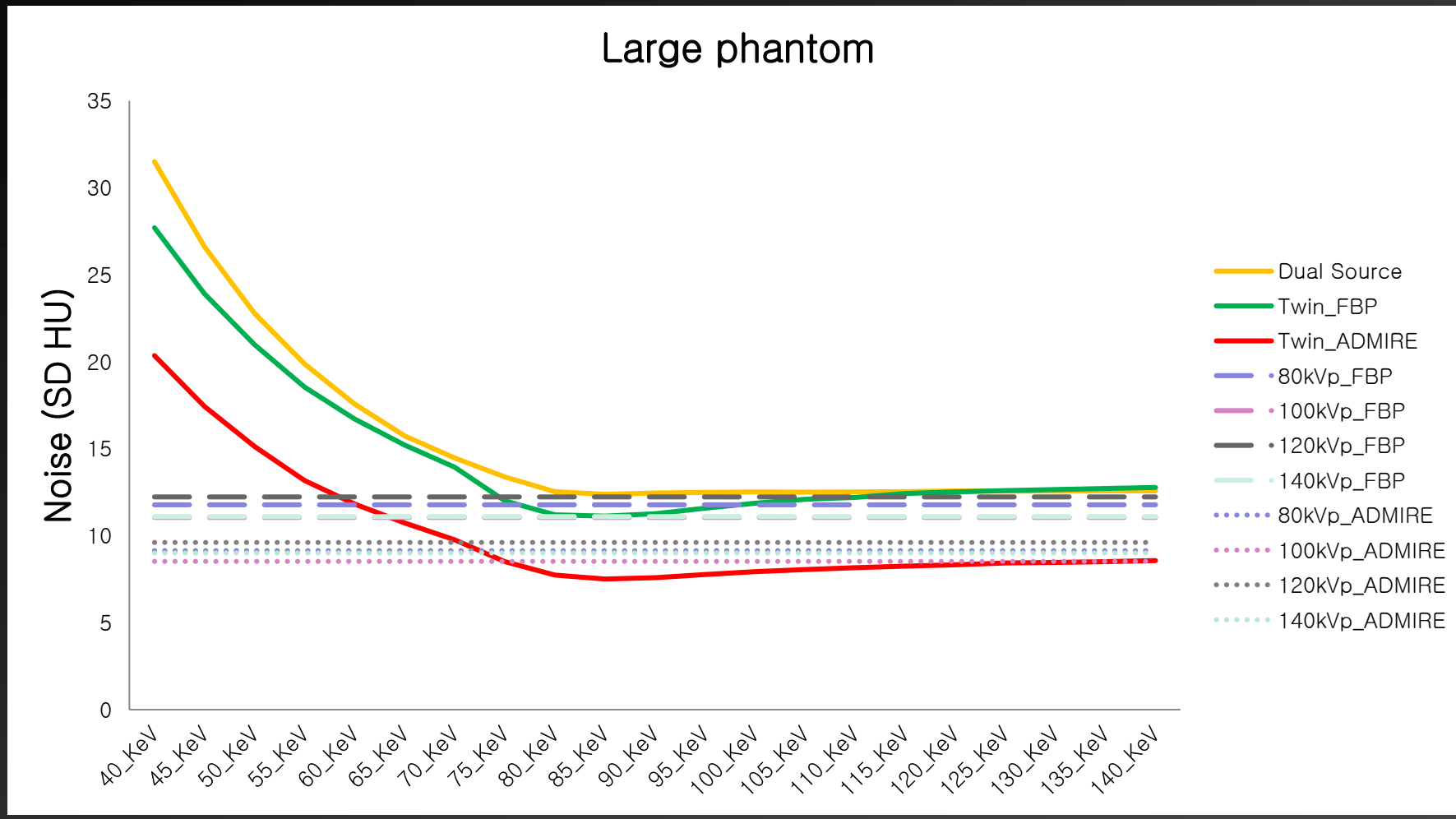


Fig 4. In the large sized phantom, the lowest noise was noted at 85 keV with twin beam and ADMIRE. Noise levels on VMS images in the 75~140 keV with twin beam and ADMIRE were lower than those of 120 kVp CT images with ADMIRE ($p<0.001$)

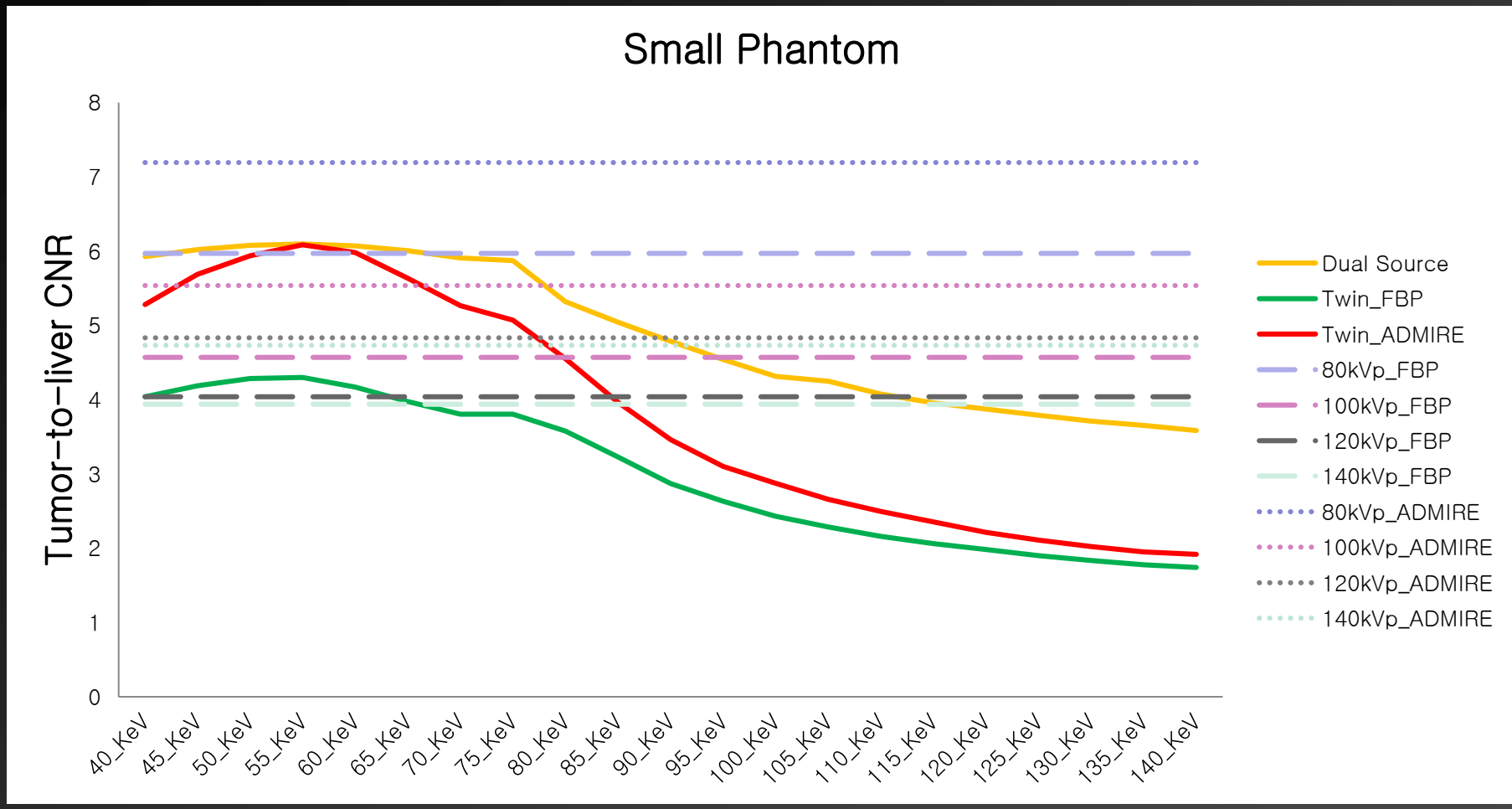


Fig 5. Tumor-to-liver contrast-to-noise ratio (CNR) for the small sized phantom.
Tumor-to-liver CNR was highest at 80kVp with ADMIRE. On virtual monochromatic spectral (VMS) images, optimal tumor-to-liver CNR was noted at 55keV regardless scanned and reconstructed types. The CNRs on VMS images with DSDE scan were significantly higher than those of twin beam scans with ADMIRE and FBP ($p<0.001$). The CNRs on VMS images in the 40~75keV with twin beam and ADMIRE were higher than those of 120 kVp CT images with ADMIRE ($p<0.01$)

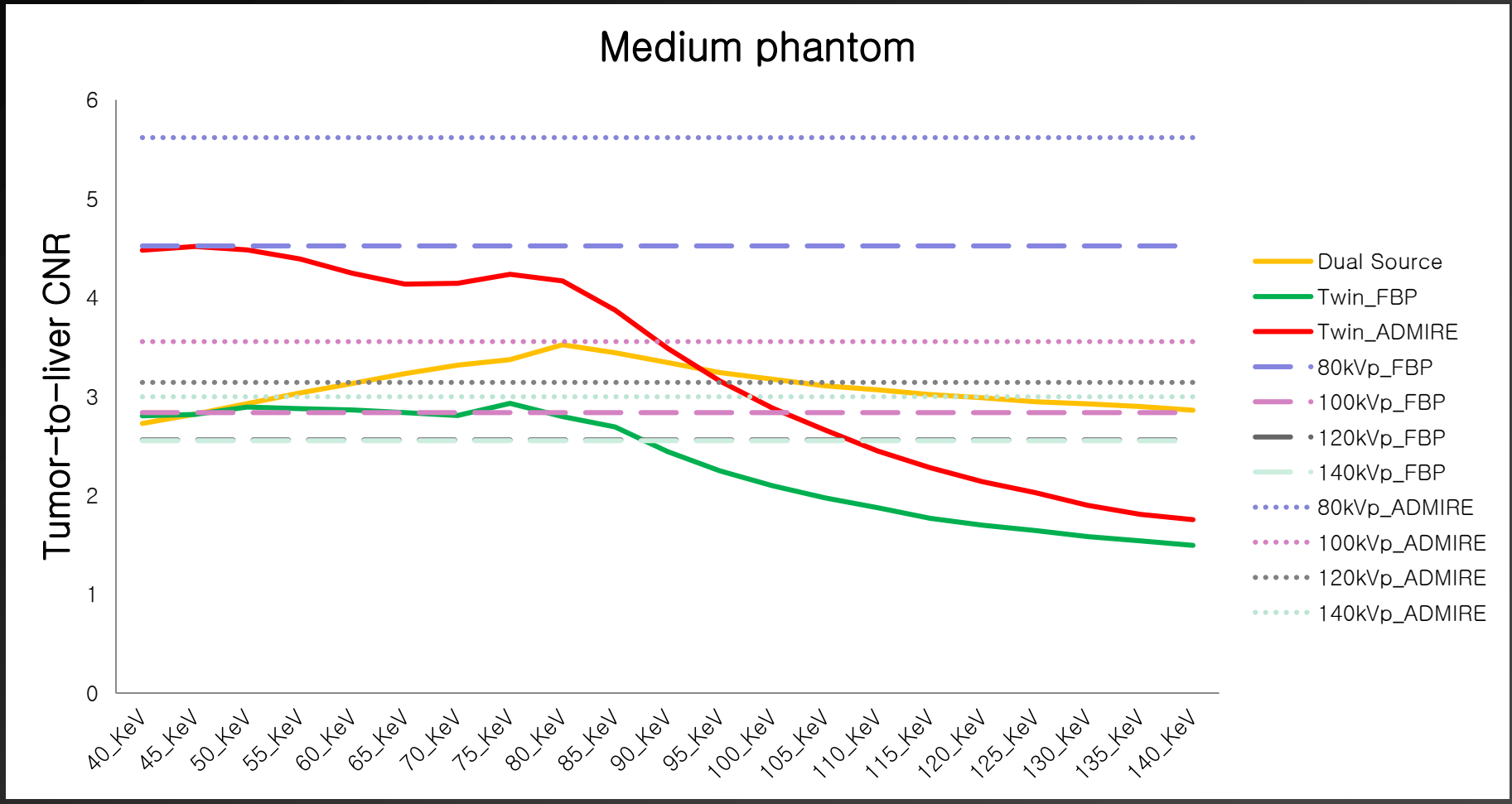


Fig 6. In the medium sized phantom, tumor-to-liver CNR was highest at 80kVp with ADMIRE. On virtual monochromatic spectral (VMS) images, the highest tumor-to-liver CNR was seen at 50keV with twin beam and ADMIRE. Optimal tumor-to-liver CNRs were noted at 80 keV with DSDE scan and 75keV with twin beam and FBP. The CNRs on VMS images in the 40~95keV with twin beam and ADMIRE were higher than those of 120 kVp CT images with ADMIRE ($p<0.001$)

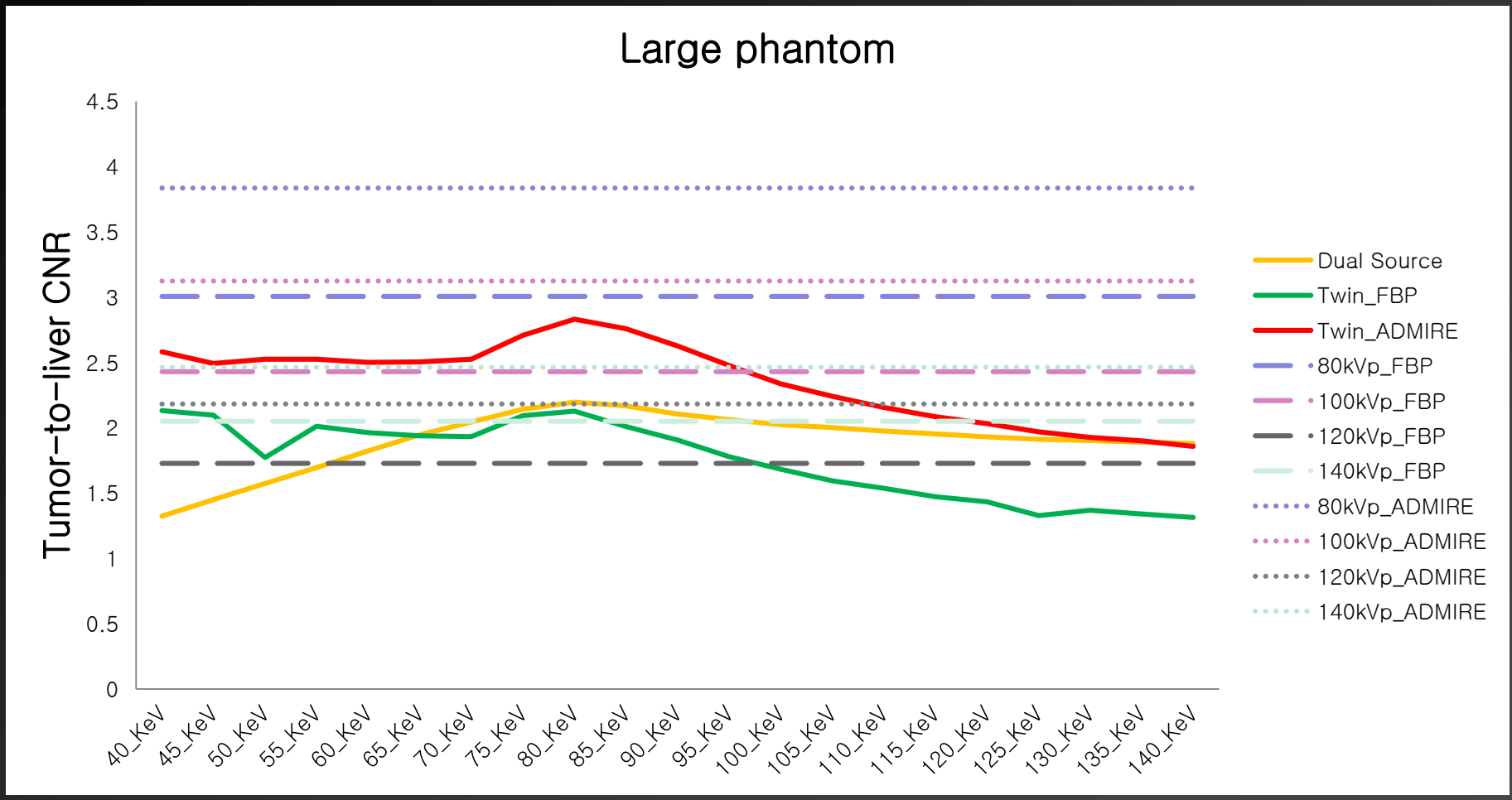


Fig 7. In the large sized phantom, tumor-to-liver CNR was highest at 80kVp with ADMIRE. On virtual monochromatic spectral (VMS) images, optimal tumor-to-liver CNR was noted at 80keV regardless scanned and reconstructed types. The CNRs on VMS images with twin beam and ADMIRE were significantly higher than those of DSDE scan ($p<0.001$). The CNRs on VMS images in the 40~105keV with twin beam and ADMIRE were higher than those of 120 kVp CT images with ADMIRE ($p<0.001$).

Conclusion

- VMS images of twin beam with ADMIRE represent significantly improved image quality than conventional 120kVp image.

- In the large sized phantom, the quantitative image quality of VMS images of dual energy CT with twin beam and ADMIRE is superior to those of dual source CT.

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