Feasibility of TG-299 implementation for clinical photon-counting CT

Hadley DeBrosse, PhD, Kiattichart Chartkunchand, PhD, Lindsay Douglas, PhD, Kevin Little, PhD
Department of Radiology, The Ohio State University

THE OHIO STATE UNIVERSITY
WEXNER MEDICAL CENTER

Introduction

TG Report No. 299 describes multi-energy CT quality control (QC) but was published prior to the widespread use of photon-counting CT (PCCT). To develop PCCT-specific QC, this work **evaluates the feasibility of the annual physics tests detailed in TG299** given the clinical software tools currently available.

Terminology of PCCT *(Siemens Naeotom Alpha class)*

- **T3D** Low Energy Threshold images, incorporating all counts above a 20 keV threshold. Most similar to conventional energy-integrating CT.
- **SPP** Spectral post-processing reconstructions that preserve spectral information and can be retrospectively reconstructed at any energy but are typically displayed at a single keV.
- **VMI** Virtual monoenergetic images, available as a post-processing option or at the scanner.
- **VNC** Virtual non-contrast images, available as a post-processing option or at the scanner.
- **Iodine** Iodine map reconstruction. *Caution: does not remove Calcium.*
- **Quantum*plus* (Q+)** Routine imaging mode for all standard applications, including VMI, VNC, and Iodine map. Available with 120/140 keV and allows full spectral information

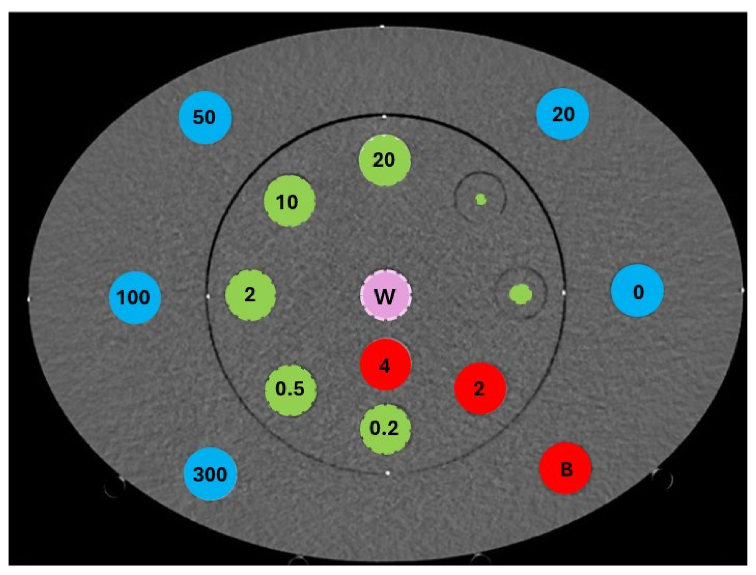
Method for implementing TG-299 – *3 scans to implement MECT tests:*

Note: analysis procedures and tolerances are detailed in TG-299

1. Adult Abdomen protocol (Quantum*plus* (Q+) preserves spectral information needed) → VMI, SPP, T3D → Image viewer → *Uniformity Artifacts, Noise Magnitude, Spatial Resolution, Low Contrast Detectability*
2. Adult Abdomen protocol (Quantum*plus* (Q+) preserves spectral information needed) *With calcium and iodine inserts* → VMI: 40 keV, 70 keV, 100 keV → Image viewer *for scanner-produced VMIs* → *VMI CT number accuracy*
3. CTA Thorax protocol* (Quantum*plus* (Q+) preserves spectral information needed) → VNC → Image Viewer → *VNC Accuracy*; SPP → *Syngo.via Dual energy workflow* → *Material density quantification Differentiation task accuracy*

**Note: this study was done at acceptance testing, prior to protocol optimization. Ideally, use protocol optimized for material quantification and differentiation*

Results



Calcium in Water · Iodine in blood · Iodine in Water · Water

Figure 1. Map of calcium, iodine, and other inserts used in the MECT phantom (*Sun Nuclear*).

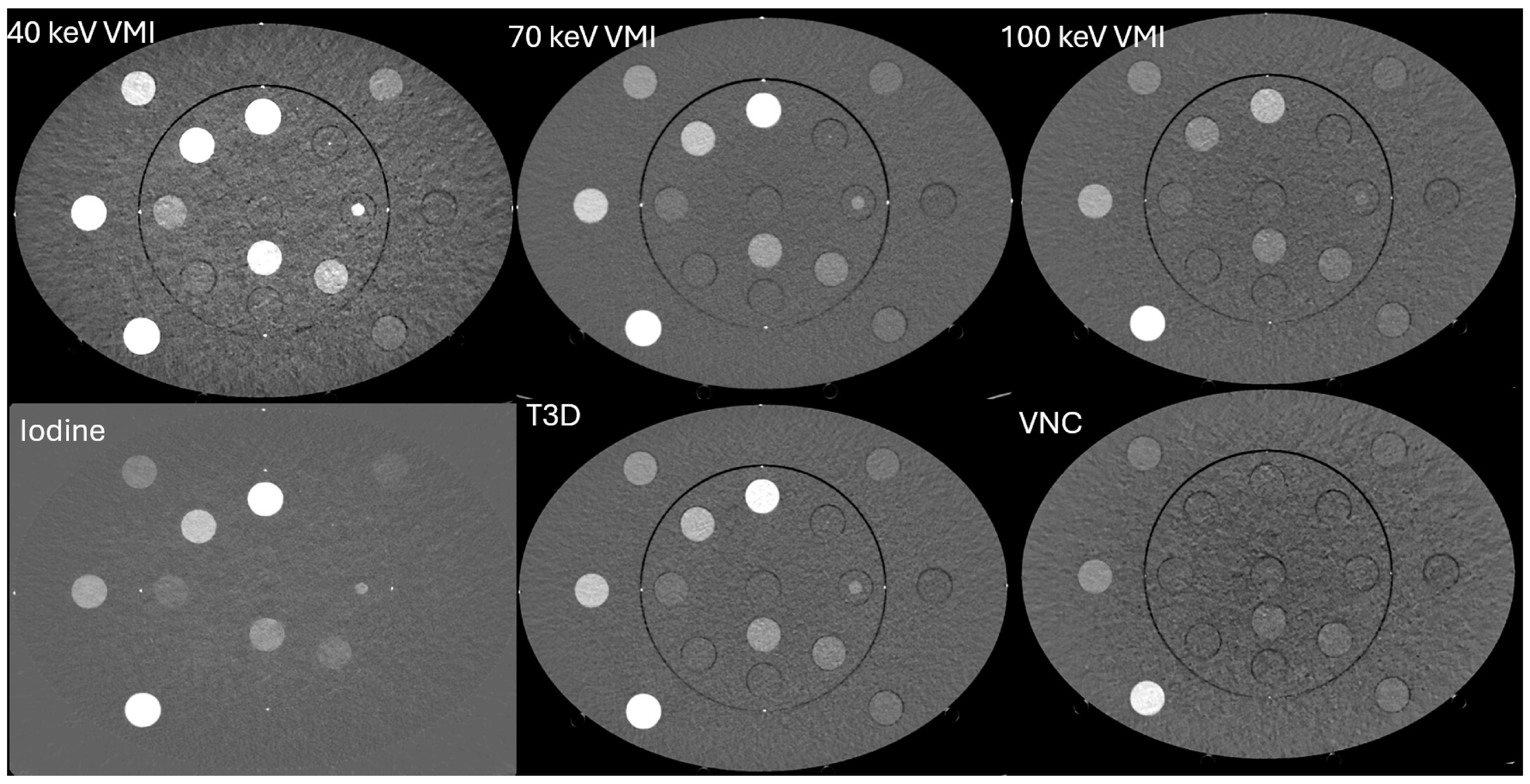


Figure 2. Selection of image reconstructions available on the PCCT scanner used for a MECT phantom containing inserts of various iodine and calcium concentrations.

VNC Accuracy - *Implementable*

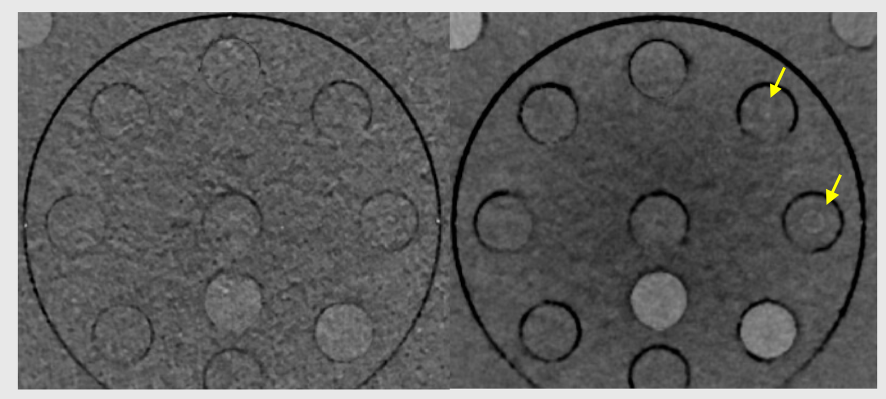


Figure 3. MECT phantom containing iodine inserts. Left: VNC CTA Thorax, Right: **VNC Adult abdomen, showing incomplete iodine subtraction (yellow arrows).**

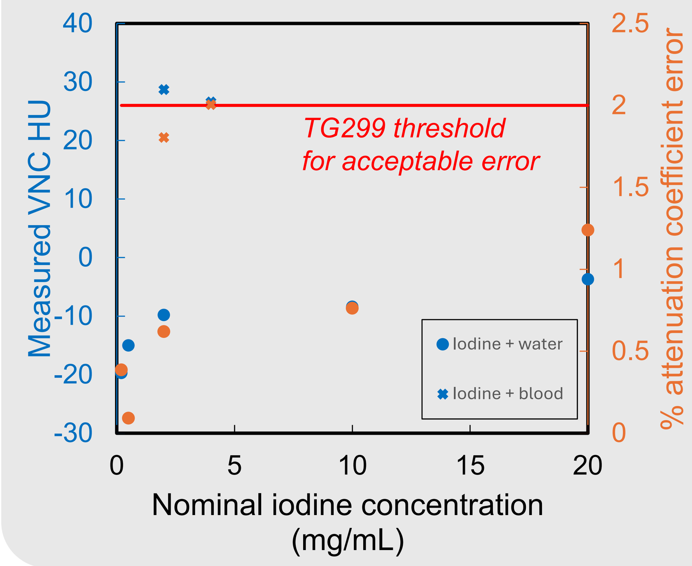


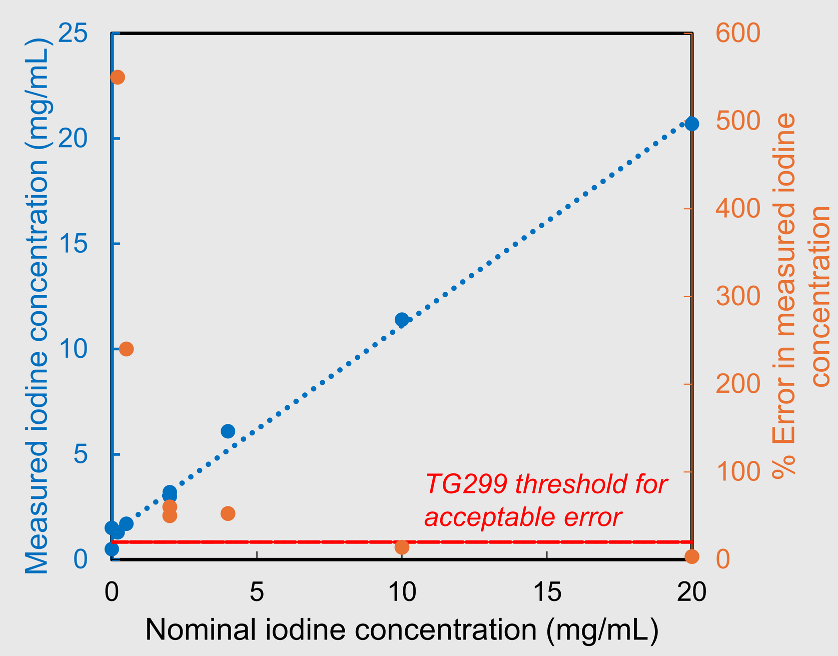
Figure 4. Left axis: measured HU of iodine inserts after subtraction in a VNC reconstruction, as a function of original concentration. Right axis: percent attenuation coefficient error. Iodine in blood inserts show higher error than Iodine in water.

Material Quantification – *Not fully implementable*

Figure 5. Using *syngo.via* version VB80F, iodine concentrations could only be measured with the Liver VNC application class under the Dual energy workflow (adult abdomen protocol), **which yielded erroneous iodine concentrations.** Calcium could not be measured.

If necessary, the linear relationship between measured and nominal iodine concentrations (blue line) could be used for iodine quantification after careful verification over a range of clinical use cases.

Future software versions (i.e., VC10) should allow for iodine and calcium concentration measurements.



VMI CT Number accuracy - *Implementable*

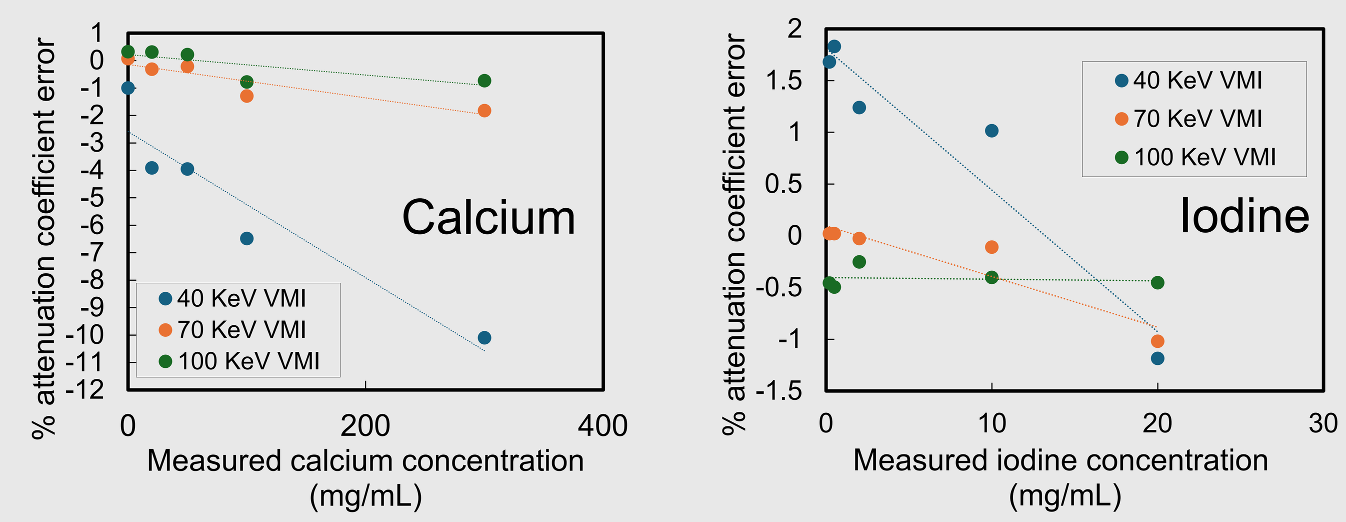


Figure 6. Percent error of HU values for various insert concentrations.

Routine MECT QC Test	Phantom	Protocol used	Reconstructions	Image Analysis software	Implementation evaluation
Image Uniformity	ACR Module 3	Adult Abdomen	40 keV, SPP, T3D	NilRead	**Implementable**
Artifact Evaluation	ACR Module 3	Adult Abdomen	40 keV, SPP, T3D	NilRead	**Implementable**
Noise Magnitude	ACR Module 3	Adult Abdomen	SPP, T3D	NilRead	**Implementable**
Spatial Resolution	ACR Module 4	Adult Abdomen	SPP, T3D	NilRead	**Implementable**
Low Contrast Detectability	ACR Module 2	Adult Abdomen	SPP, T3D	NilRead	**Implementable**
VMI CT number accuracy	MECT with iodine and calcium	Adult Abdomen	40 keV, SPP, 100 keV	NilRead	**Implementable**
Material density quantification accuracy	MECT with iodine and calcium	CTA Thorax	SPP**	*Syngo.via* Dual energy workflow	**Likely implementable with *syngo.via* VC10 software**
VNC	MECT with iodine	CTA Thorax	VNC	NilRead	**Implementable**
Differentiation task accuracy	MECT with iodine and calcium	CTA Thorax	SPP	*Syngo.via* Dual energy workflow	**Likely implementable with *syngo.via* VC10 software**
Dosimetry	CTDI	Axial Abdomen, Axial Head	N/A	N/A	**Implementable**

** TG299 recommends using iodine basis images for this test.

Material Differentiation – *Not implementable*

Due to VB80F software version of *syngo.via*.

Conclusions & Takeaways

Protocol matters: VNC performance depends on protocol.

Software as a limiting factor: *Syngo.via* VB80F prevents proper implementation of material quantification and material differentiation tests. It is expected that version VC10 will have increased functionality.

Terminology: Understanding of PCCT reconstructions, modes, and kernels is critical for implementation of TG299 tests.

Conclusion: While most TG299 QC tests are actionable, it is difficult to perform all recommended tests with currently available clinical tools. Material quantification and differentiation tasks should be carefully verified using alternative methods prior to clinical utilization.

References

R. R. Layman *et al.*, "AAPM Task Group Report 299: Quality control in multi-energy computed tomography," *Med. Phys.*, vol. 51, no. 10, pp. 7012–7037, Oct. 2024, doi: 10.1002/mp.17322.