# Protocol-Aware Multi-Slice Deep Learning Framework for Resolution Enhancement in Conventional Coronary CT Angiography Using Photon-Counting Detector CT as Reference

*Shaojie Chang, Maryam S. Sadeghian, Du Zhang, Eric E. Williamson, Thomas A. Foley, Cynthia H. McCollough, Shuai Leng*
*Department of Radiology, Mayo Clinic, Rochester MN USA 55905-0001*

## INTRODUCTION

Coronary CT angiography (cCTA) is a rapid, non-invasive imaging method for evaluating coronary artery disease. However, conventional energy-integrating detector CT (EID-CT) can be limited by blooming artifacts from dense calcifications and coronary stents, which may obscure the lumen and overestimate stenosis severity. Improved spatial resolution can reduce these artifacts and enhance lumen visualization.

Photon-counting detector CT (PCD-CT) provides higher spatial resolution and has shown promise for reducing blooming artifacts and improving stenosis assessment. However, most clinical cCTA examinations are still performed using conventional EID-CT systems.

**In this study, we developed a protocol-aware, multi-slice deep learning model to enhance the spatial resolution of EID-CT cCTA images using resolution-matched PCD-CT data for training. By incorporating reconstruction kernel information from clinical protocols, the model improves image sharpness in all three dimensions. This AI-based approach may reduce blooming artifacts and improve coronary visualization on existing CT systems without hardware upgrades, supporting broader access to high-quality cCTA imaging.**

## METHODS

**Figure 1** illustrates the proposed protocol-aware deep learning framework for spatial resolution enhancement of EID-CT–based cCTA. The framework consists of two stages: network training using PCD-CT data and network inference using clinical EID-CT images.

For network training, eight cCTA cases were acquired on a PCD-CT scanner (NAEOTOM Alpha, Siemens Healthineers, Germany) operated in ultra-high-resolution mode. Paired low- and high-resolution datasets were generated from the same PCD-CT acquisitions. EID-CT protocol information, including the reconstruction kernel, was used to select resolution-matched PCD-CT reconstructions as low-resolution network inputs. For example, matched-kernel reconstructions Br36 were used as low-resolution inputs, while sharper-kernel reconstructions Bv72 from the same scan served as high-resolution labels.

Training samples were generated as 128 × 128 axial patches. Each network input consisted of three adjacent low-resolution slices to preserve through-plane spatial context, and the corresponding label was the central slice from the high-resolution reconstruction. The network architecture was a multi-slice U-Net composed of nine modules. Each module included convolutional layers, batch normalization, and exponential linear unit activation. Down-sampling and up-sampling were performed using max pooling and transposed convolution, respectively, and skip connections were used to preserve spatial detail.

During inference, clinical EID-CT cCTA images acquired using SOMATOM Force and SOMATOM Definition Flash scanners were processed by the trained network to generate high-resolution EID-CT images. Performance was evaluated using qualitative image assessment and quantitative lumen diameter measurements.

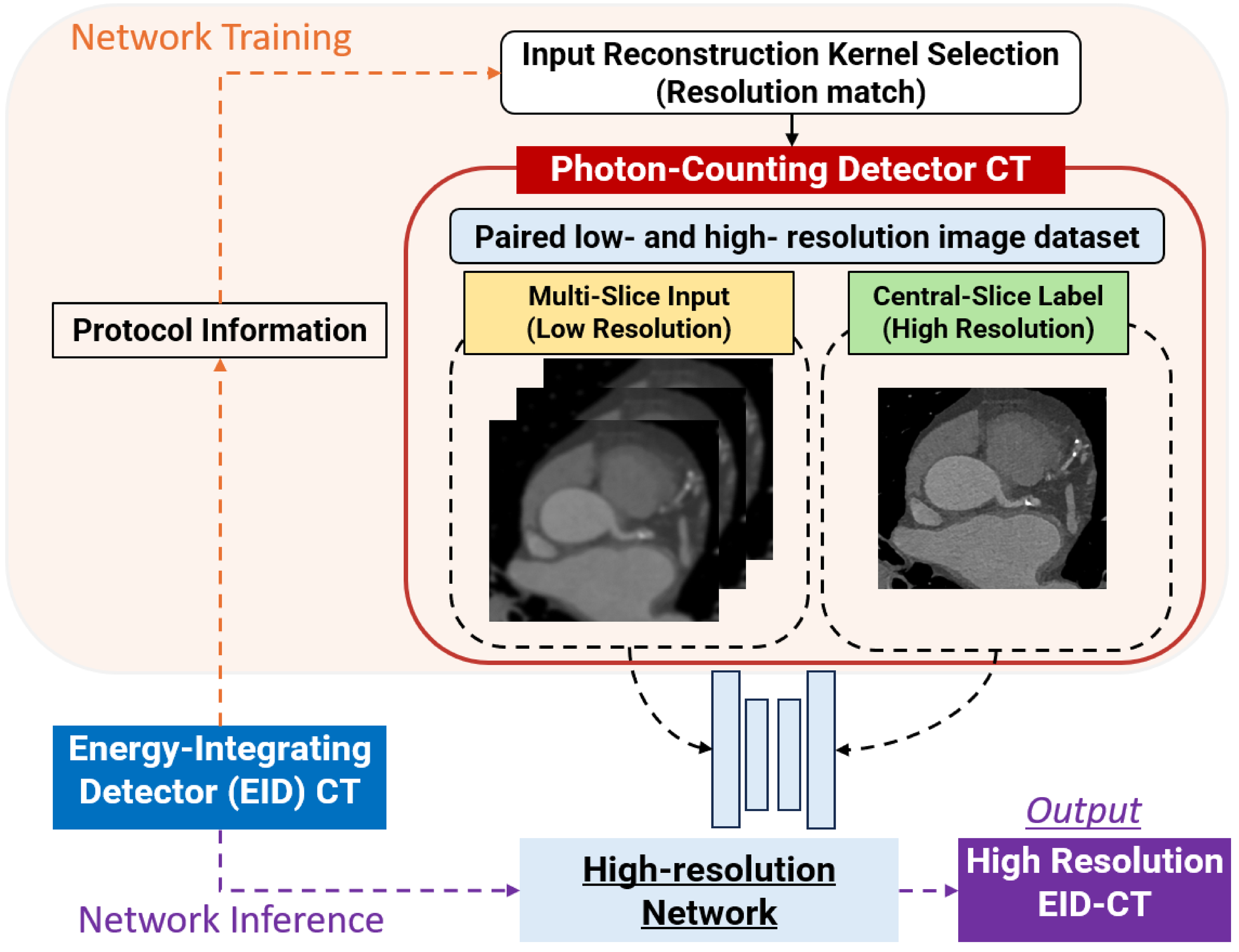


**Figure 1**. Proposed protocol-aware deep learning framework for spatial resolution enhancement of EID-CT–based cCTA. During training, EID-CT protocol information is used to select resolution-matched PCD-CT reconstructions as low-resolution inputs, while sharper PCD-CT reconstructions from the same scan serve as high-resolution labels. Multi-slice axial inputs are paired with central-slice high-resolution labels to preserve through-plane spatial context. During inference, clinical EID-CT cCTA images are processed by the trained high-resolution network to generate high-resolution EID-CT images with improved sharpness and reduced blooming artifacts.

## RESULTS

**Figure 2** shows that the proposed model enhanced spatial resolution across all three dimensions in a representative cCTA case acquired using SOMATOM Force. Coronal and sagittal reformats demonstrated improved through-plane sharpness and vessel continuity, particularly along the z-axis. In axial views, calcified plaques and coronary artery borders appeared sharper, with reduced blooming artifacts. Line profile analysis across coronary calcification showed steeper intensity transitions and an increased apparent lumen diameter after enhancement, indicating improved spatial resolution and reduced calcium blooming.

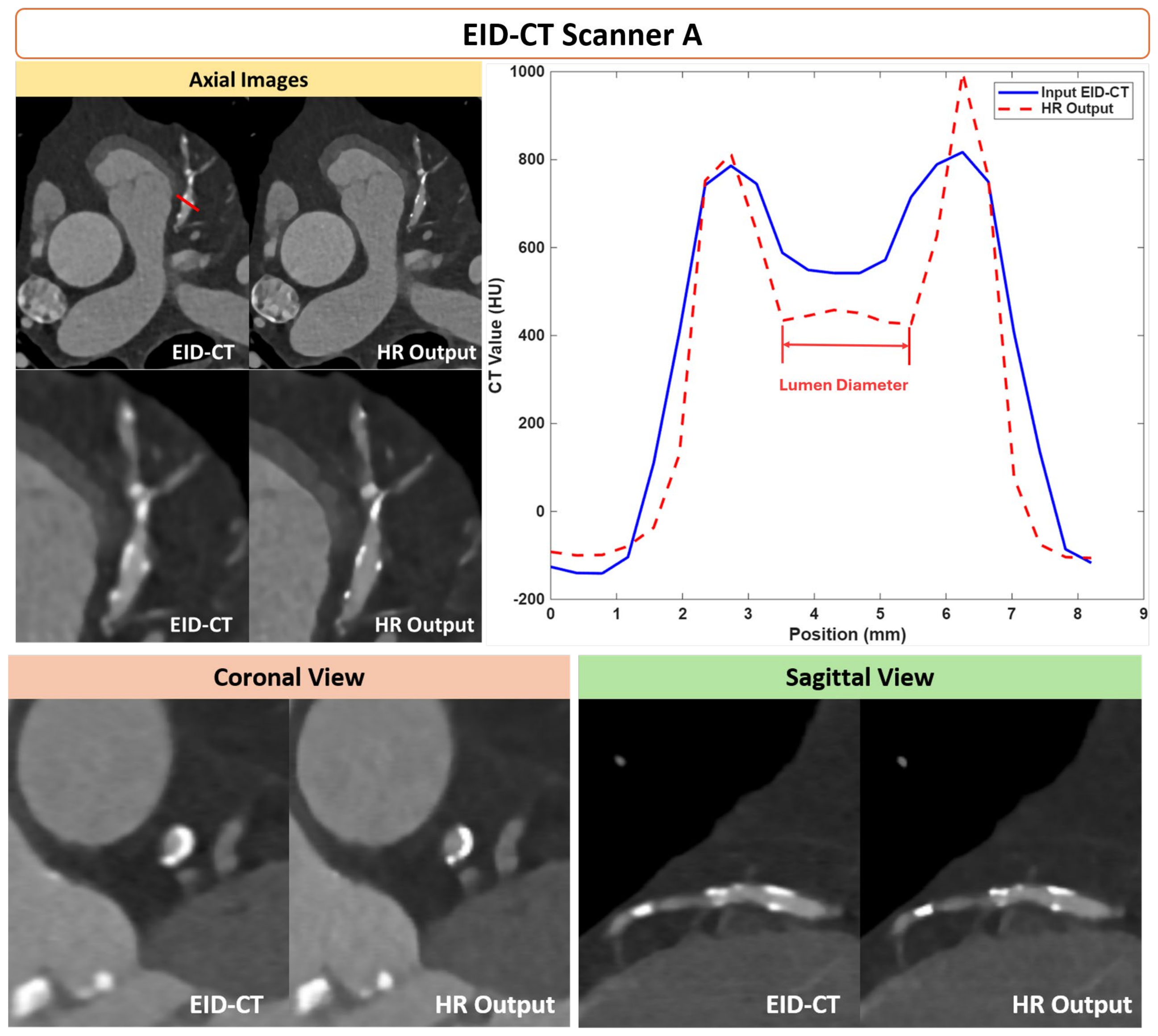


**Figure 2.** Representative case from a Force Scanner. The HR output shows improved sharpness and clearer vessel boundaries across all dimensions compared with input EID-CT. The line profile across coronary calcification demonstrates steeper intensity transitions and increased apparent lumen diameter. Images are displayed at WW/WL = 1500/400 HU.

**Figure 3** shows another representative cCTA case acquired using SOMATOM Definition Flash. In axial views, the enhanced images demonstrated sharper calcified plaque margins and coronary artery borders, with reduced blooming artifacts and improved lumen visualization. These findings suggest that the proposed protocol-aware method can generalize across different EID-CT scanners and improve spatial resolution in clinical cCTA images acquired using conventional CT systems.

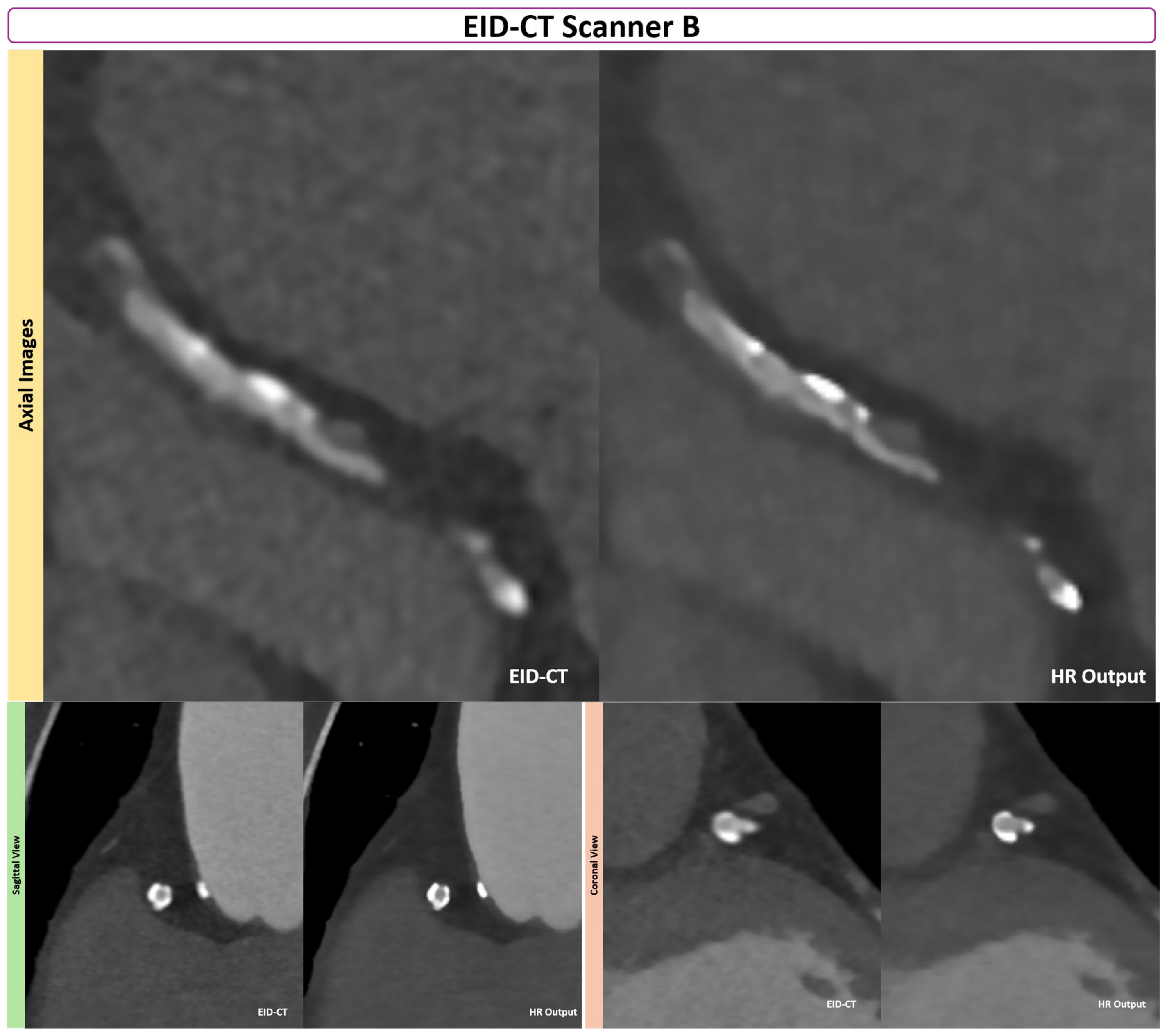


**Figure 3.** Representative cCTA case from a Flash Scanner. The HR output shows sharper calcified plaque margins, clearer coronary artery boundaries, and reduced blooming artifacts compared with input EID-CT. These results demonstrate the generalizability of the protocol-aware model across different EID-CT scanners.

## CONCLUSIONS

1. **A protocol-aware, multi-slice deep learning model trained with kernel-matched PCD-CT data enhanced spatial resolution of conventional EID-CT cCTA images in all three dimensions.**
2. **The enhanced images showed improved vessel boundary definition, better through-plane continuity, and reduced blooming artifacts from coronary calcifications.**
3. **This approach may enable high-resolution cCTA on existing EID-CT systems without hardware upgrades, supporting broader access to improved coronary imaging.**

## REFERENCES

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***Contact information: chang.shaojie@mayo.edu***