



Robustness of Deep Learning-Based Motion Compensated 4D-CBCT Reconstruction to Out-of-Distribution Data

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BACKGROUND & PURPOSE

- 4D-CBCT can enhance the accuracy of image-guided radiation therapy in the presence of breathing motion.
- Deep learning (DL)-based motion-compensated (MoCo) reconstruction has been developed to improve the quality and efficiency of 4D-CBCT reconstruction.
- DL may suffer from performance degradation when the testing data substantially deviates from the training data distribution.

Aim: To investigate the robustness of DL-based 4D-CBCT MoCo reconstruction method to out-of-distribution data.

MATERIAL & METHODS

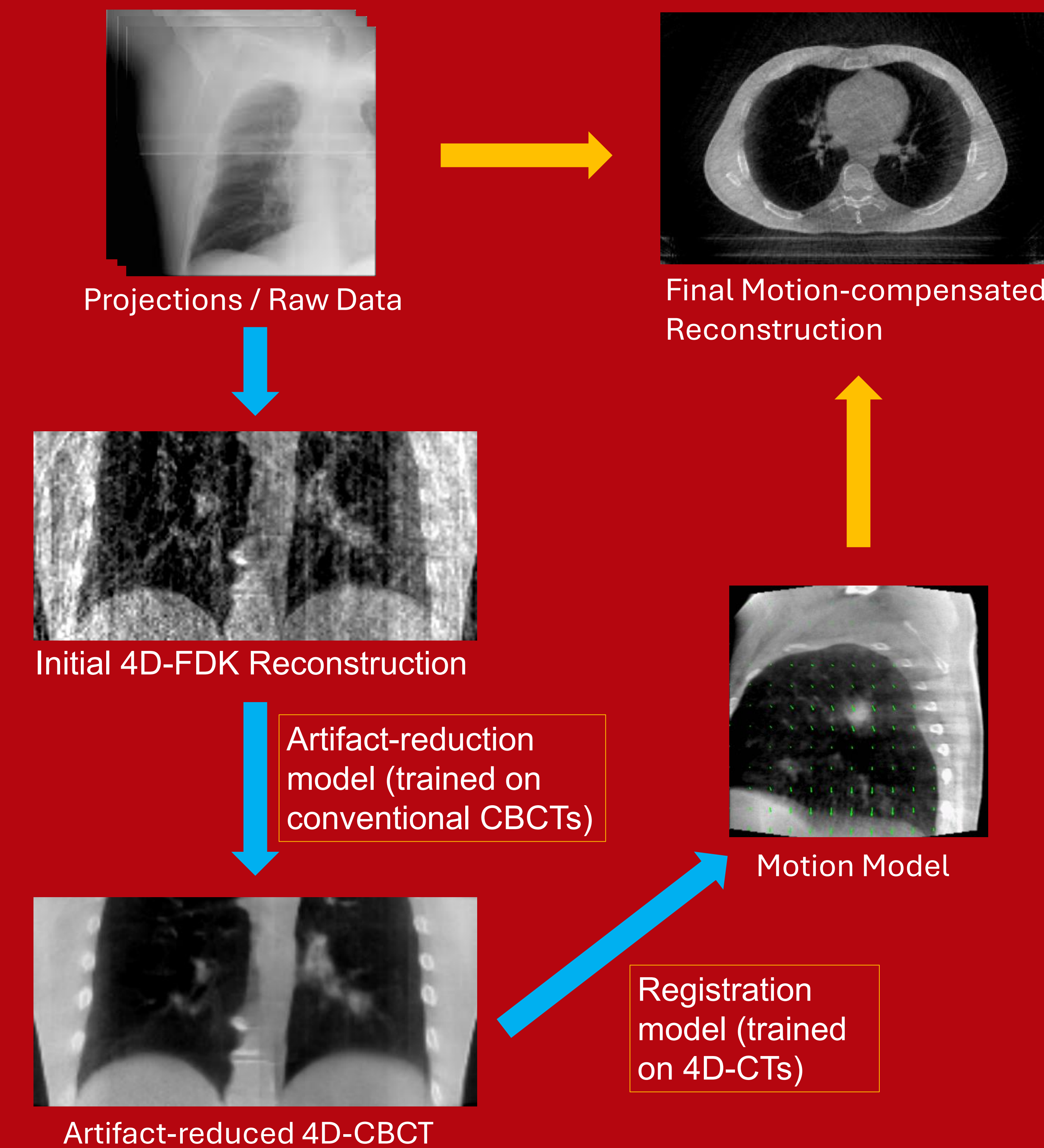
An **artifact-reduction model** trained on 47 CBCT scans acquired using the conventional CBCT imager on a C-arm LINAC (Varian Edge), to enhance Feldkamp–Davis–Kress (FDK)-reconstructed 4D-CBCT images.

A **registration model** trained on 31 sets of 4D-CT scans, to enable real-time motion modeling for rapid MoCo reconstruction.

Two out-of-distribution datasets for robustness evaluation:

- **Across different anatomies:** A canine dataset acquired using a conventional CBCT imaging platform.
- **Across different imaging platforms:** 1-minute free-breathing (FB) scans paired with 6-second breath-hold (BH) scans acquired on a ring-gantry Varian Halcyon system with HyperSight imaging.

Motion-compensated 4D-CBCT reconstruction pipeline using deep learning-accelerated high-quality motion modeling



RESULTS

Performance on canine dataset

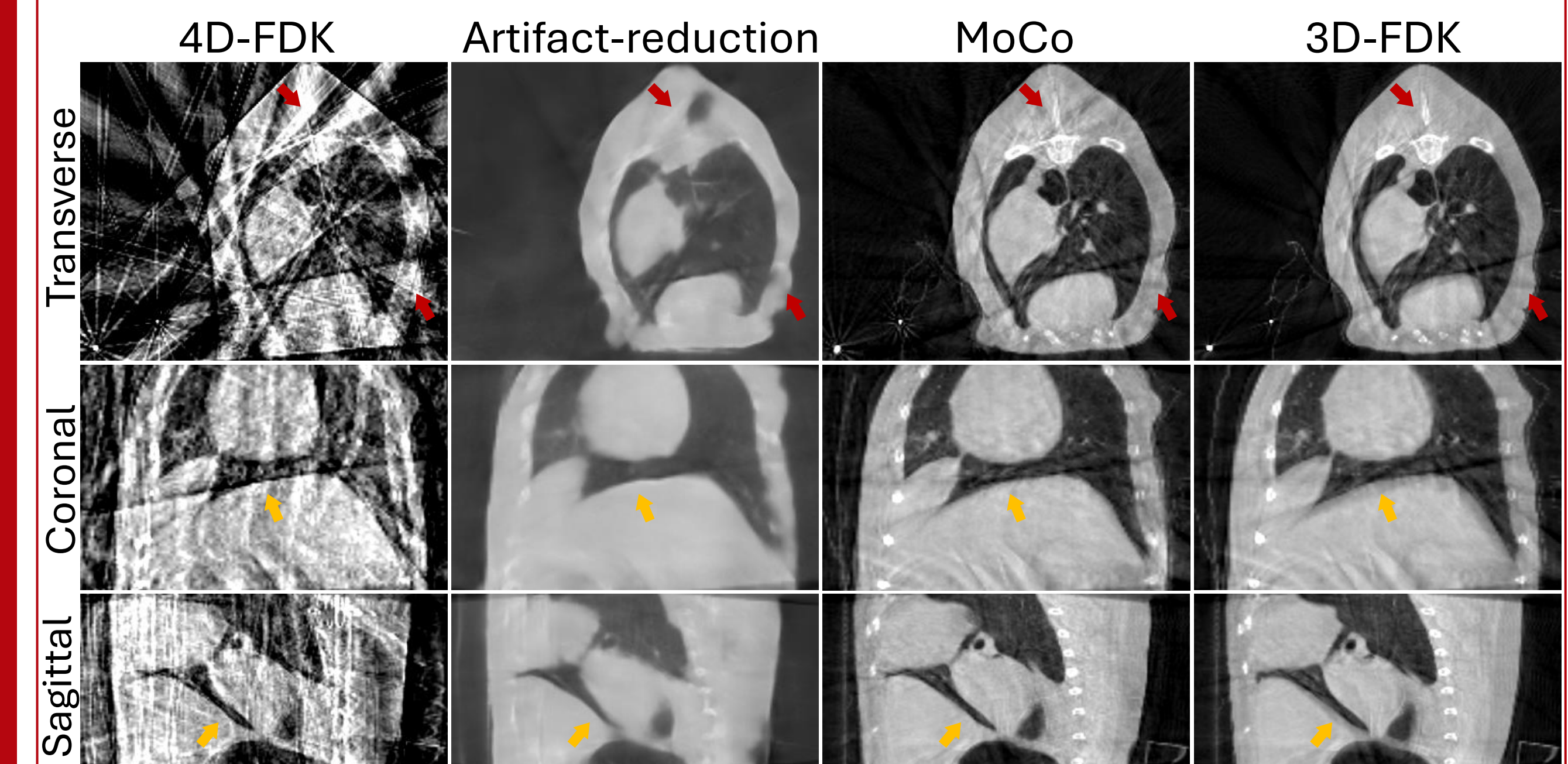


Figure 1. Reconstruction of a canine scan using 3D-FDK with all projections as reference.

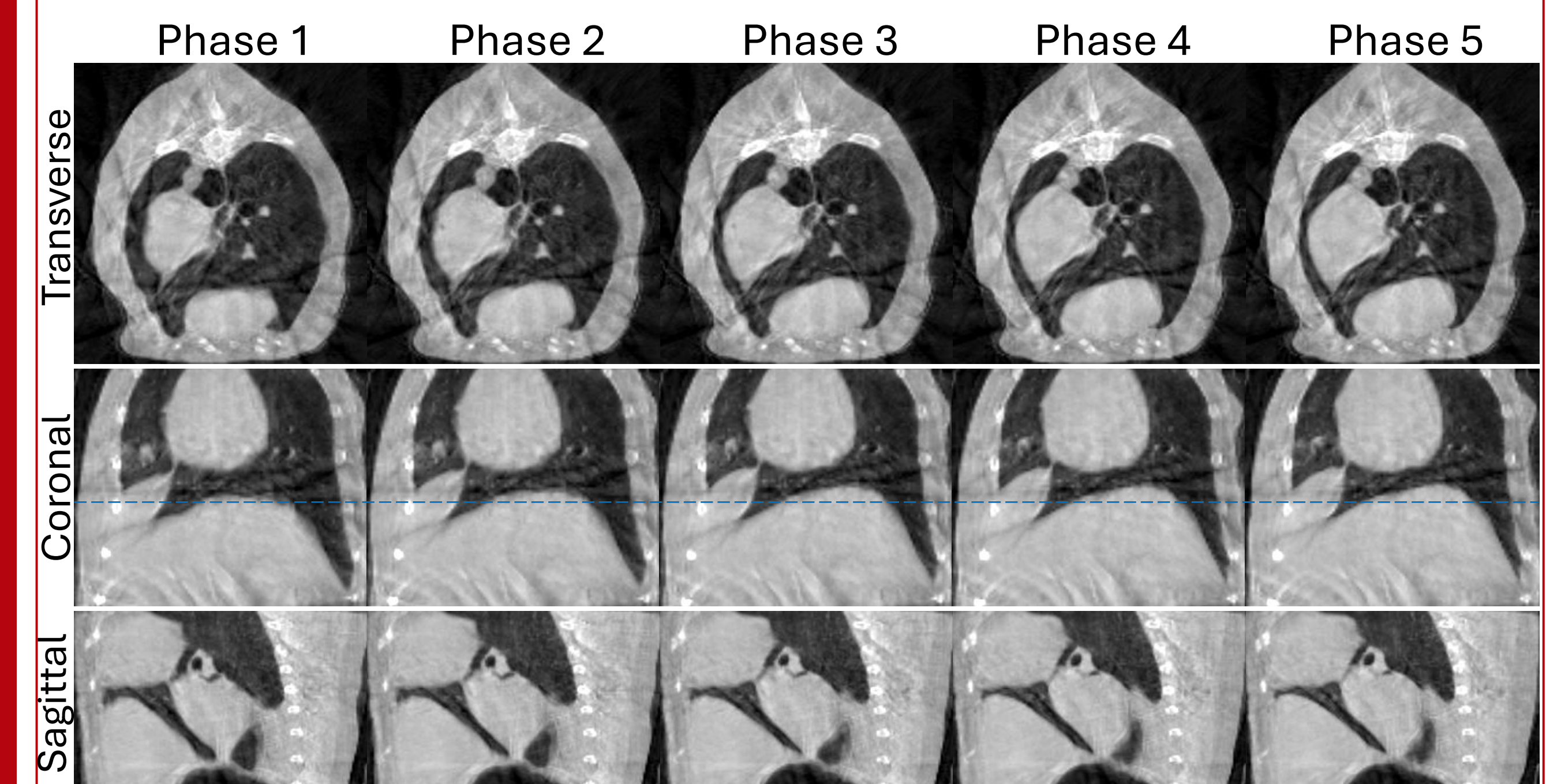


Figure 2. MoCo-reconstructed breathing cycle for the canine scan, from end-inhale (phase bin 1) to end-exhale phase (phase bin 5).

Performance on HyperSight imaging system

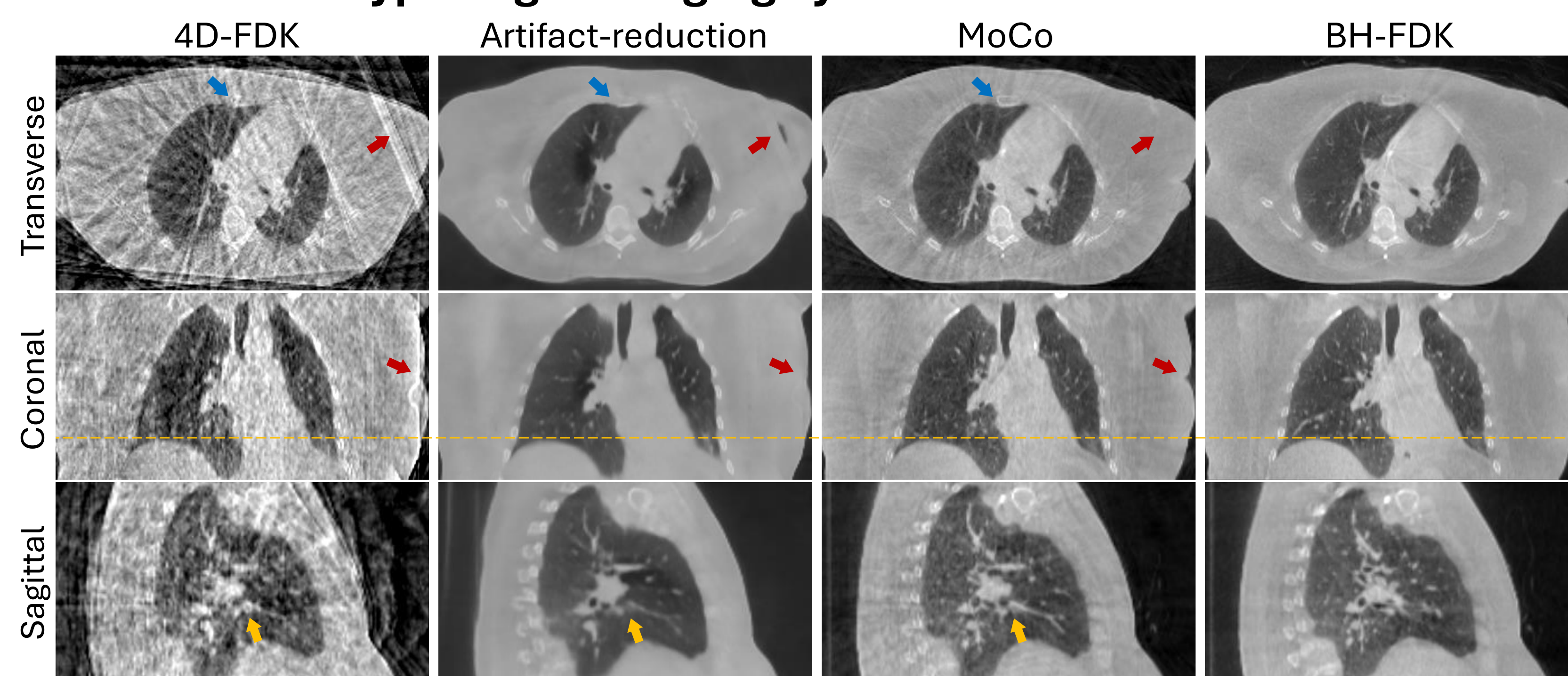


Figure 3. Reconstruction of a HyperSight patient scan using the BH image as reference.

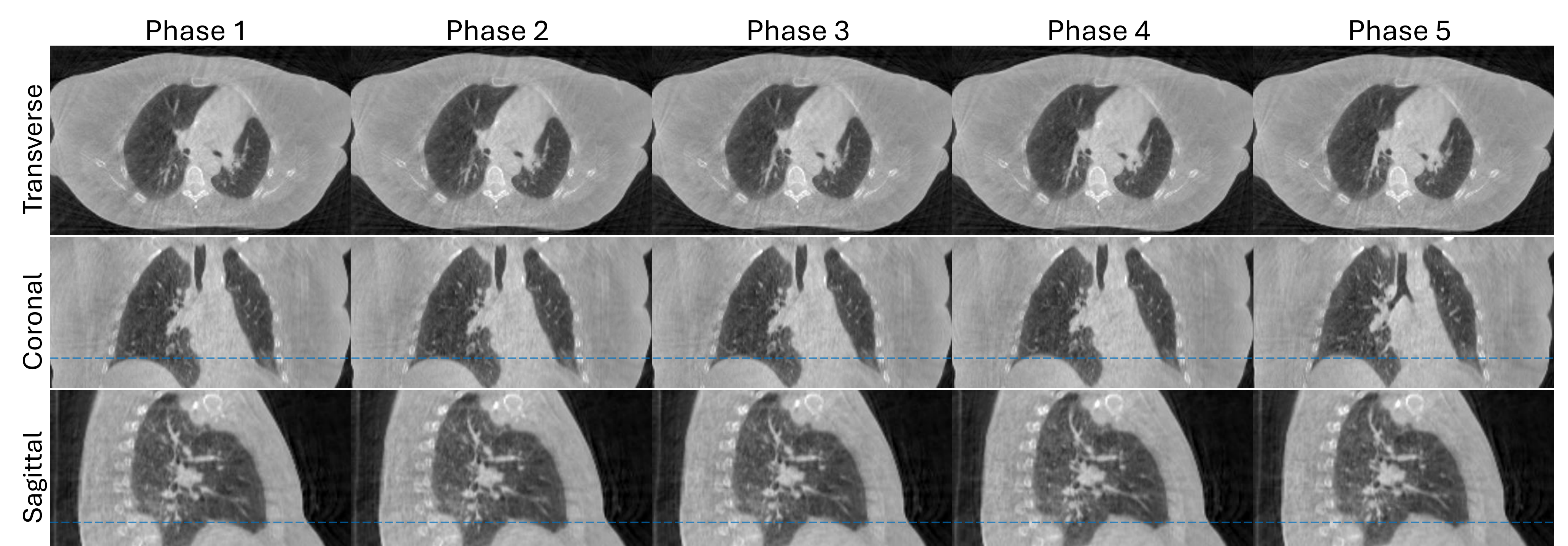


Figure 4. MoCo-reconstructed breathing cycle for the HyperSight scan.

CONCLUSIONS

- The artifact-reduction model effectively mitigated streaking artifacts in 4D-FDK reconstructions but exhibited limited generalizability to artifact patterns beyond those caused by phase binning.
- MoCo reconstruction using DL-based registration can further correct these artifacts.
- Our DL-based 4D-CBCT reconstruction method demonstrated robustness across different anatomies and imaging systems.
- Incorporating processes to address a broader range of artifact patterns is needed to further improve the robustness of DL-based 4D-CBCT methods.

REFERENCES

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- Kim E, et al. J Appl Clin Med Phys. 2024; 25:e14337.

