

Evaluation of the Iterative Model Reconstruction (IMR) algorithm for four-dimensional computed tomography (4DCT)

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PURPOSE & BACKGROUND

- 4DCT assesses tumor motion in thoracic and abdominal radiotherapy.
- 4DCT delivers 2-12 times higher radiation dose than conventional 3DCT [1].
- Iterative model reconstruction (IMR) is shown in 3DCT to reduce dose by 57-95% without sacrificing resolution [2], but it hasn't been systematically evaluated for 4DCT.
- This study evaluates IMR, with several settings, in 4DCT and compares it to standard Filtered Back Projection (FBP) and a hybrid iterative method (iDose⁴).

Goal: Determine whether IMR can safely reduce 4DCT dose without compromising image quality.

MATERIALS & METHODS

- Two phantoms (CIRS lung motion phantom 008A, CATPHAN 604 with polystyrene sleeve) were scanned using low-pitch helical 4DCT across a range of mAs.
- Images were reconstructed using FBP, iDose⁴, and IMR at several level settings (1, 2, 3) and tissue settings (Soft, Routine, Sharp).
- Contrast-to-noise ratio (CNR) was compared across mAs and reconstruction types using the lung lesion in the lung motion phantom.
- Spatial frequency at 50% MTF, CT numbers of sensitometry targets, and low-contrast target visibility were analysed across mAs and reconstruction types using the CATPHAN.
- A liver patient 4DCT image was reconstructed with IMR, iDose⁴, and FBP for visual comparison.
- Clinical reviewers (radiation oncologists and dosimetrists) assessed images for contouring suitability.

RESULTS

- CT numbers of sensitometry targets were consistent (± 5 HU) across all reconstruction types.
- Lung lesion CNR was the lowest for FBP and the highest for IMR level 3 with the Soft setting across all mAs (Fig. 1).
- IMR level 1 with the Routine setting at 200 mAs matched iDose⁴ CNR at 800 mAs, suggesting up to fourfold dose reduction potential (Fig. 1).
- IMR at all levels with the Routine and Sharp settings, had greater spatial resolution than FBP and iDose⁴ at all mAs except at 217 mAs (Table 1).
- For IMR, the Sharp setting gave the best spatial resolution but the lowest CNR; the Soft setting gave the best CNR but the lowest spatial resolution.
- IMR improved low-contrast target visibility over iDose⁴, with 0.5% targets visible at 1200 mAs, but accentuated faint artifacts at lower mAs (Fig. 2).
- In a liver patient, IMR level 2 with the Sharp setting showed superior contrast and edge definition, and was unanimously preferred by clinical reviewers (Fig. 3).

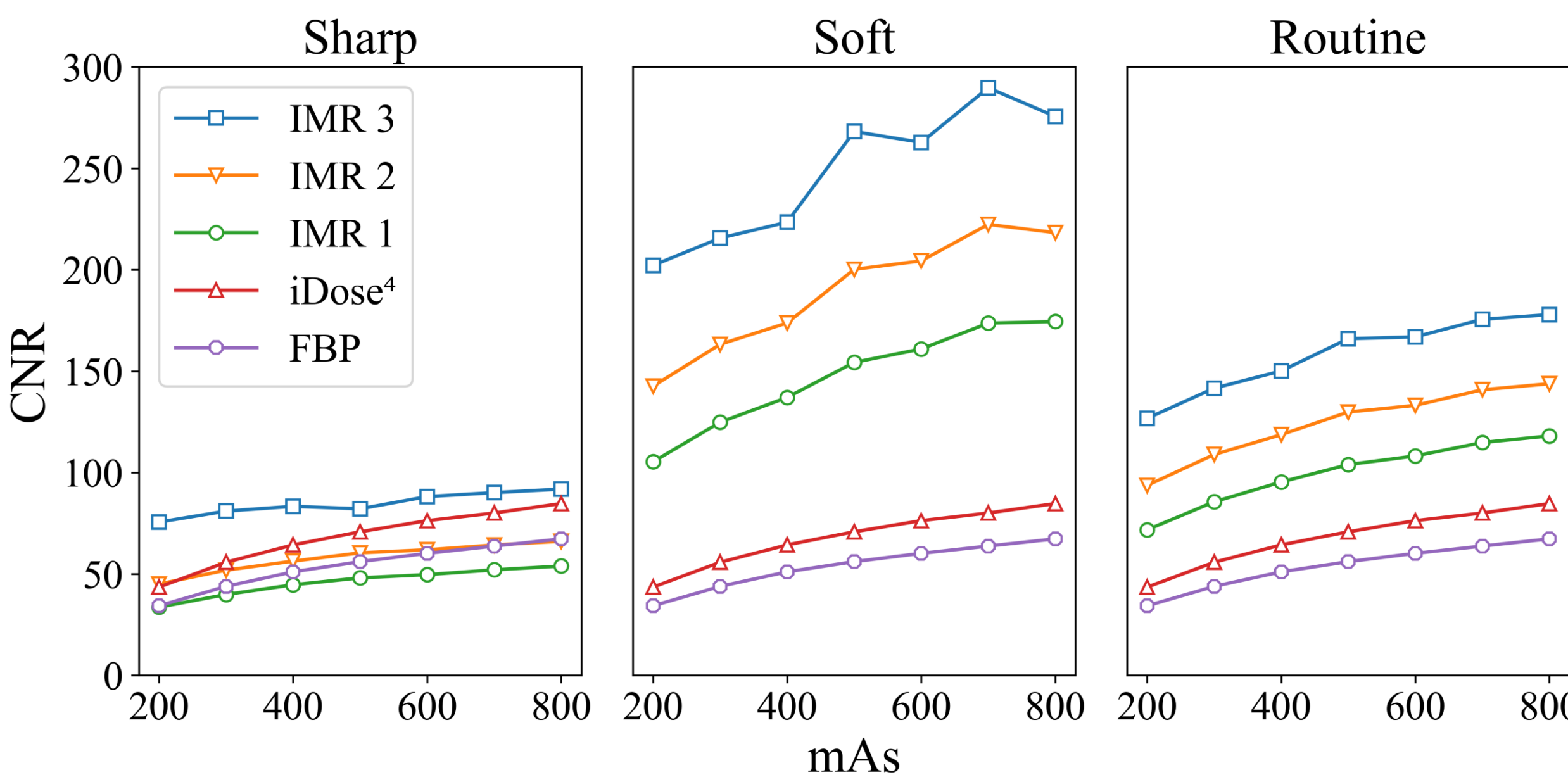


Figure 1. CNR of spherical lesion in lung phantom in 50% phase images as a function of mAs for various reconstruction algorithms.

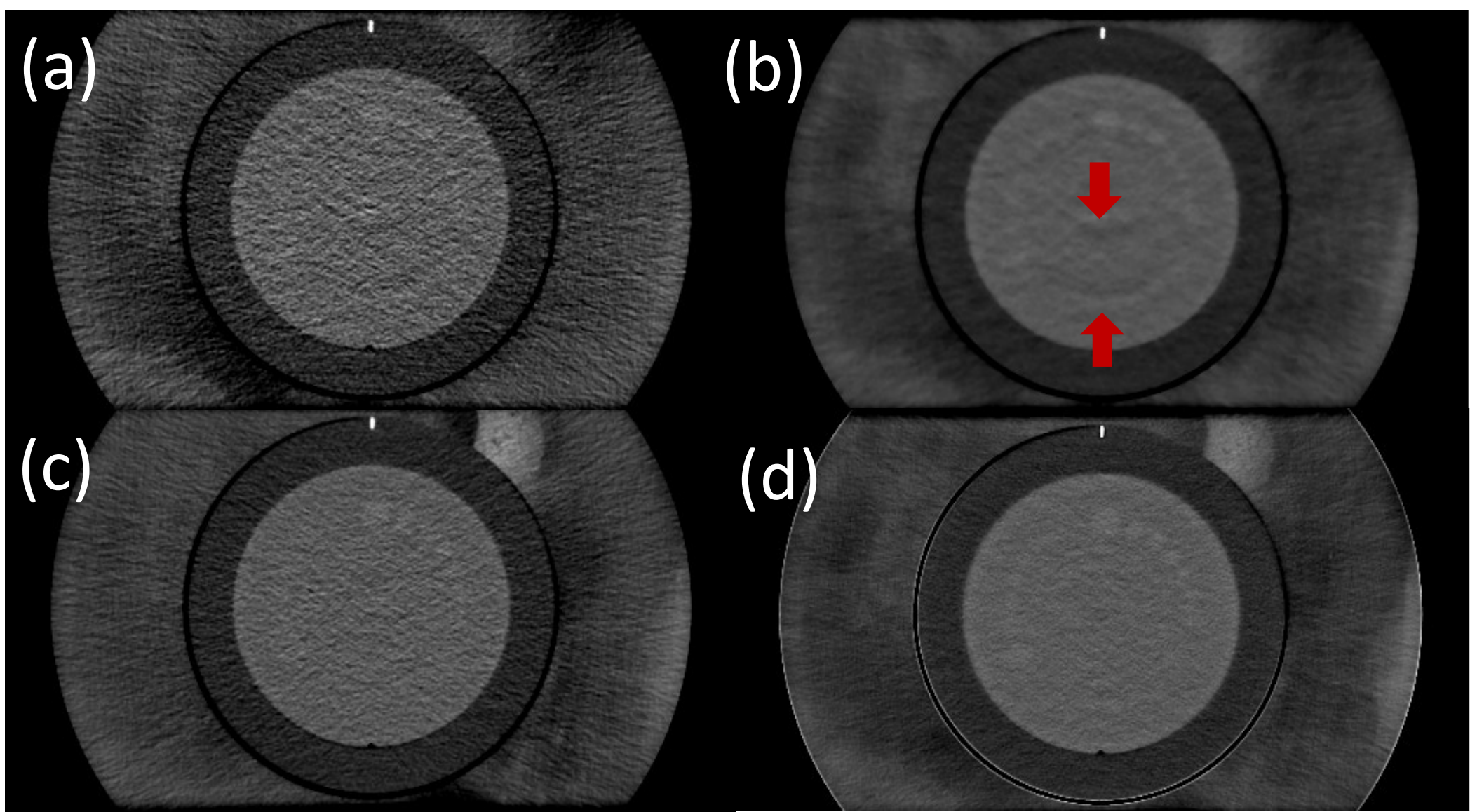


Figure 2. Low contrast section of CATPHAN with sleeve using average of 10-phases. (a) 400 mAs, iDose⁴ (b) 400 mAs, IMR 3 Soft (c) 1200 mAs, iDose⁴ (d) 1000 mAs, IMR 2 Sharp. Red arrows indicate accentuated artifacts.

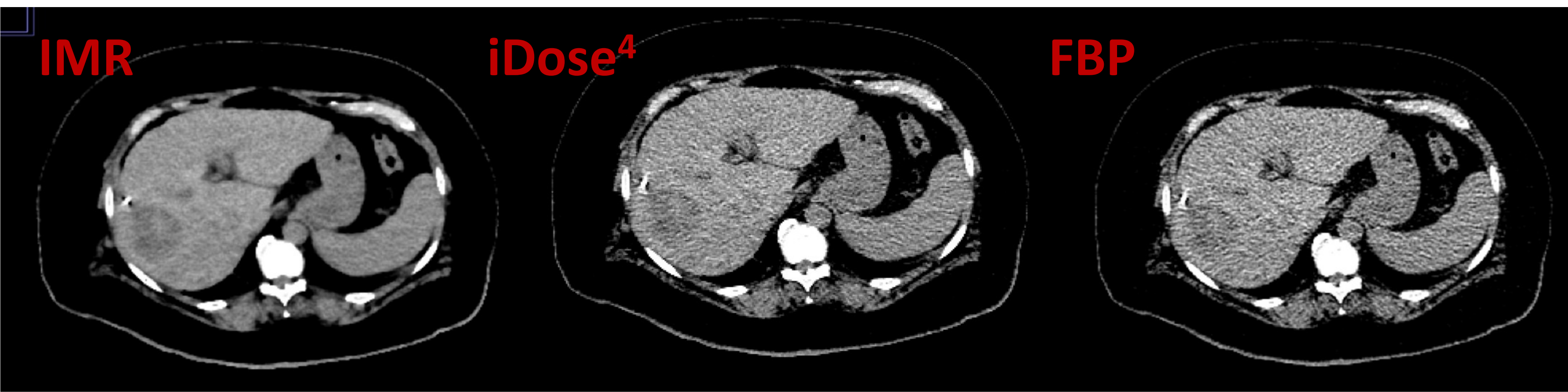


Figure 3. Liver image (phase 0%, 900 mAs): left (IMR level 2, Sharp), middle (iDose⁴), and right (FBP).

mAs	FBP	iDose ⁴	IMR1			IMR2			IMR3		
			Soft	Rout.	Sharp	Soft	Rout.	Sharp	Soft	Rout.	Sharp
217	2.84	2.78	2.07	2.29	2.86	2.03	2.22	2.79	2.00	2.52	2.71
400	2.87	2.84	3.07	3.55	4.12	3.03	3.48	4.18	3.00	3.41	4.16
600	2.82	2.77	2.95	3.37	4.32	2.91	3.32	4.35	2.87	3.28	4.30
800	2.96	2.90	2.87	3.47	4.34	2.82	3.39	4.32	2.78	3.31	4.31
1000	2.99	2.94	2.96	3.64	4.29	2.92	3.57	4.28	2.88	3.51	4.26
1200	2.87	2.84	3.09	3.86	4.54	3.05	3.80	4.53	3.02	3.75	4.52

Table 1. Spatial frequency at 50% MTF (lp/cm) using average of 10-phases for various mAs and reconstruction algorithms measured on the CATPHAN with sleeve

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KEY POINTS & CONCLUSION

- CNR and spatial resolution were generally improved using IMR compared to FBP and iDose⁴, with the CNR/resolution trade-off tuneable using tissue and level settings.
- IMR with the Routine setting offers a balanced improvement and is a reasonable starting point clinically.
- Clinical reviewers preferred IMR level 2 with the Sharp setting for liver lesion contouring.

4x

Key Finding: Objective metrics suggest an up to fourfold dose reduction potential for lung 4DCT using IMR.

REFERENCES

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- [2] Ribert N, Southard R, Hamman SM, Robison R. Evaluation of low-contrast detectability for iterative reconstruction in pediatric abdominal computed tomography: a phantom study. Pediatric Radiology. 2016;50:345-356.