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Scatter correction of sparsely acquired 4D cone-beam CT by Bayesian Monte Carlo extrapolation

S. J. BLAKE[1*], O. DILLON[1] and R. T. O'BRIEN[1]

1 ACRF Image-X Institute, Faculty of Medicine and Health, The University of Sydney, Sydney, Australia
*samuel.blake@sydney.edu.au

ACRF IMAGE X INSTITUTE

THE UNIVERSITY OF SYDNEY

AUSTRALIAN CANCER RESEARCH FOUNDATION

INTRODUCTION

BACKGROUND

X-ray scatter reduces cone-beam CT (CBCT) image quality and may **contribute up to 75% of the image signal** **(Fig 1.)**

Sparsely-acquired 4D CBCT uses fewer projections while imaging and can **reduce imaging dose by 50 – 70%** [1].

Monte Carlo (MC) simulations can **accurately model** scatter signals but are **inefficient and impractical** for clinical use, requiring millions of CPU-hrs to simulate a complete scan [2].

STUDY AIMS

1. **Extrapolate scatter signals** from "cheap" MC simulations using **Bayesian statistics** and **substantially reduce** the computational burden relative to pure MC methods.
2. **Evaluate scatter correction performance** on **sparsely-acquired 4D CBCT images** relative to an alternative method, the **uniform scatter correction (USC)** method [3].

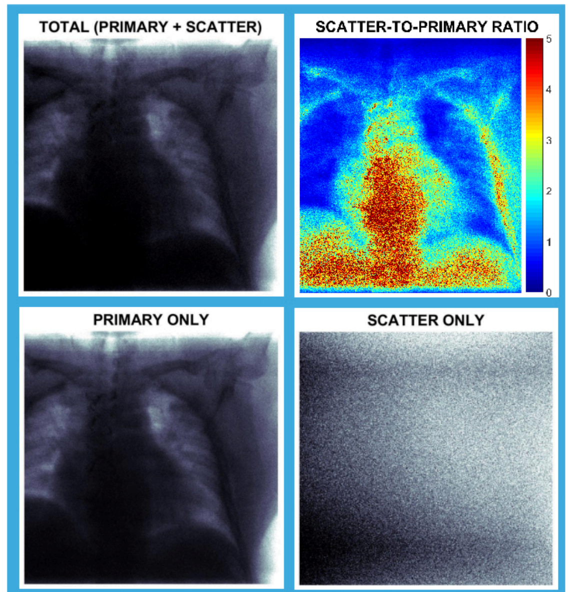

Fig 1. A MC-simulated projection showing the relative contributions of primary and scatter radiation to the total image signal.

METHOD

The study design is shown in **Fig 2.**

1. Sparse CBCT projections were acquired (N = 200) and binned into 10 respiratory phases. **Uncorrected** projections were reconstructed into a 4D volume using FDK [4].
2. The **Uniform Scatter Correction (USC)** method [3] was implemented as a gold standard. The mean intensity of each projection was multiplied by $S_f = 0.24$ and subtracted prior to reconstruction.
3. Our **Mixed Bayesian Monte Carlo (MBMC)** method modelled the each projection's scatter distribution using TOPAS [5]. Noisy signals were smoothed by Bayesian extrapolation and subtracted from the projections prior to reconstruction.

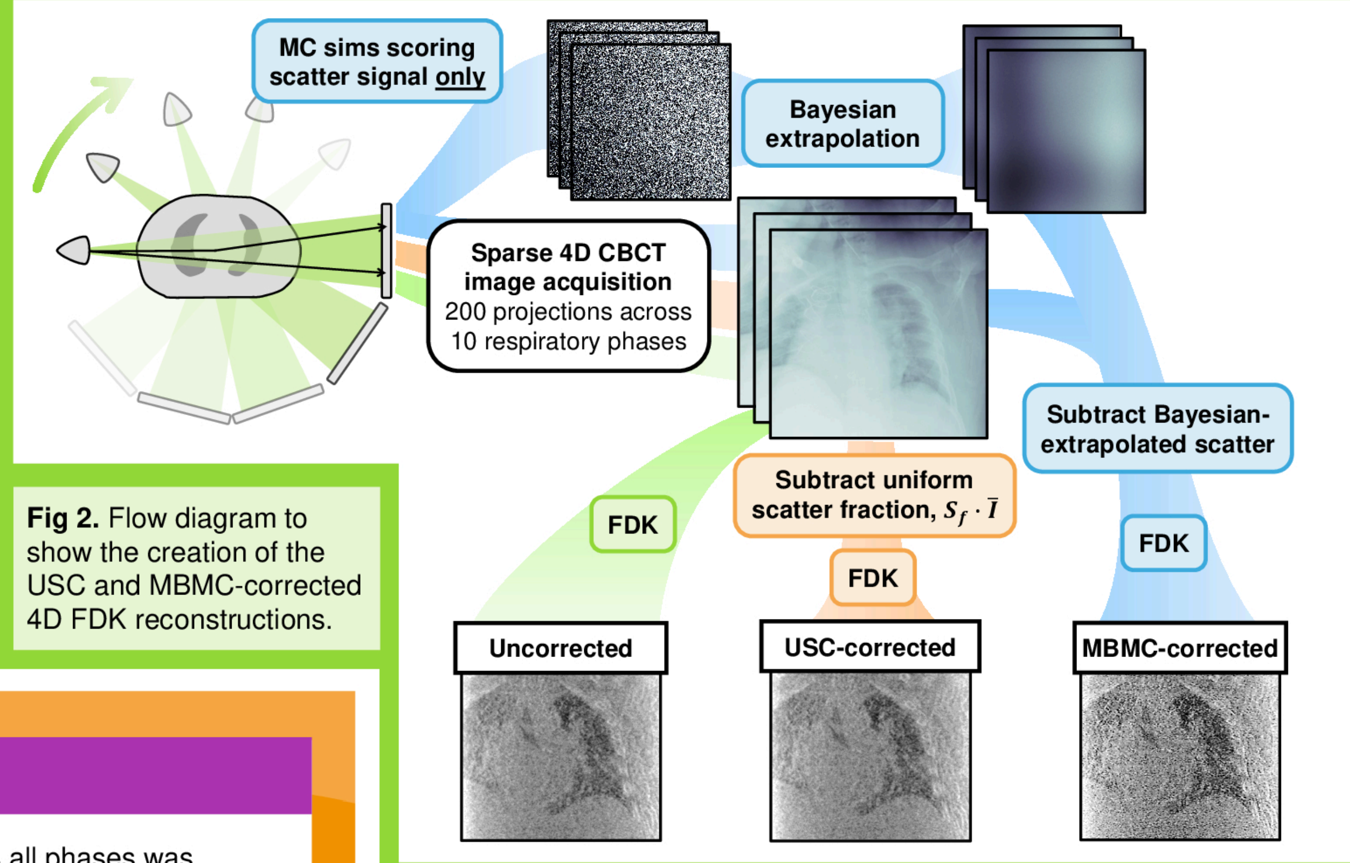

Fig 2. Flow diagram to show the creation of the USC and MBMC-corrected 4D FDK reconstructions.

RESULTS

The uncorrected, USC-corrected and MBMC-corrected 4D FDK reconstructions are presented in **Fig 3.** The mean ± SD contrast-to-noise ratio (CNR) across all phases was **1.8±0.5**, **1.6 ±0.3** and **1.7±0.4** for the uncorrected, USC-corrected and MBMC-corrected volumes, respectively. CNR for the higher quality MBMC-corrected volume was **2.3**.

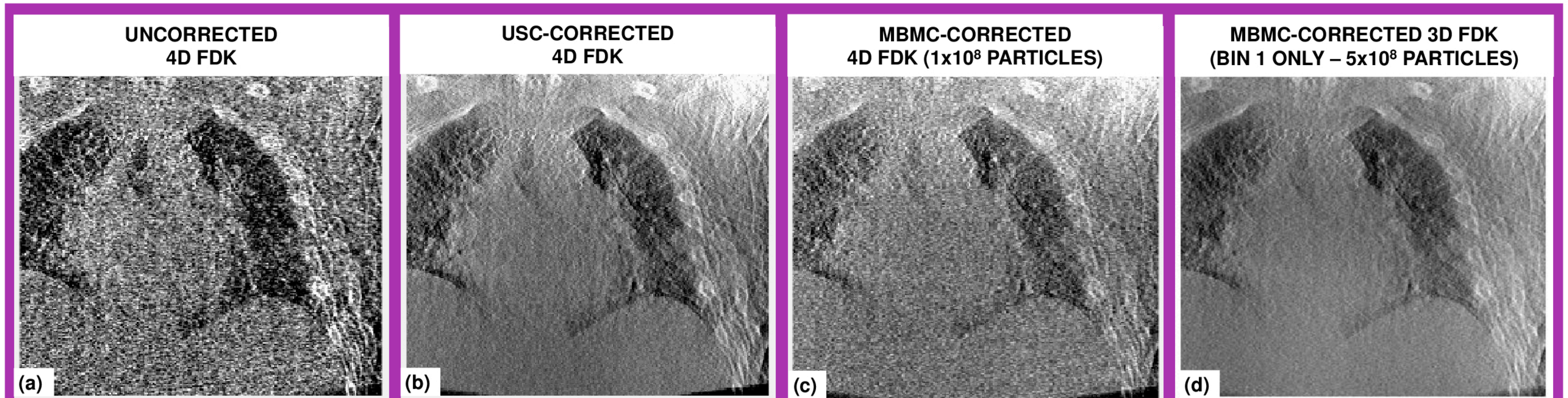

Fig 3. Sparse-view 4D CBCT reconstructions performed (a) without scatter correction (b) with the USC correction, and (c) with the MBMC scatter correction method. (d) Bin 1 of the MBMC-corrected reconstruction when a factor of 5 times more particles were used to simulate the scatter signal.

CONCLUSIONS

Noisy "cheap" 4D CBCT scatter images **can be accurately smoothed** using Bayesian extrapolation methods.

The MBMC method **did not significantly increase reconstruction CNR** with 10^8 particles/projection (3,500 CPU-hrs/phase). However **superior CNR was realised** with 5×10^8 particles/projection (17,500 CPU-hrs/phase).

Work is ongoing to determine the **optimal number of particles** simulated in the MBMC model to improve image quality while maintaining efficiency.

REFERENCES

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