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Dynamic range reducer for C-arm cone-beam CT acquisitions: initial prototype and evaluation

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INTRODUCTION

Previous work [1] has shown that standard scans with automatic exposure control (AEC) saturate the detector in air and skin for weight-bearing CT scans of the knees, as well as other scans. A low-dose scan that does not saturate will underexpose more attenuating regions. A dynamic range reducer (DyRaR) aims to solve this issue by moving independently controlled wedge filters to reduce the intensity of the beam in air and skin and reduce the overall dynamic range of the image (Fig. 1).

AIM

Flat panel detectors are commonly used for cone-beam CT, but they have limited dynamic range, leading to overexposure in air or near the skin line. For many scans, this leads to inferior image quality near the surface of the patient, excess dose, and extra scatter. For example, in weight-bearing CT of the knees, the patella may be difficult to visualize. We have constructed a prototype dynamic range reducer (DyRaR) that can attenuate the intensity of the beam outside or near the edge of the patient while conforming to the patient's shape.

METHODS

The prototype DyRaR comprises 8 brass wedges (4 on each lateral side) that can be independently controlled by linear actuators. Brass was selected for its machinability, and the wedges have a maximum thickness of 1.5 mm that taper down medially to zero thickness. The DyRaR was mounted to the collimator of a C-arm system, and cone-beam CT scans of a Catphan phantom were acquired with and without the wedges attenuating the edge regions. Separate air scans with the DyRaR were acquired to normalize the CBCT scans.

RESULTS

The prototype DyRaR was mounted to the collimator of a C-arm system (Fig. 2). Cone-beam CT scans of a Catphan 600 phantom with and without the DyRaR were acquired and reconstructed with and without correction (Fig. 3). The corrected images demonstrate promising results for the DyRaR scan. The remaining artifact will be addressed through beam hardening correction of the wedges and by directly estimating the wedge positions in the projection images.

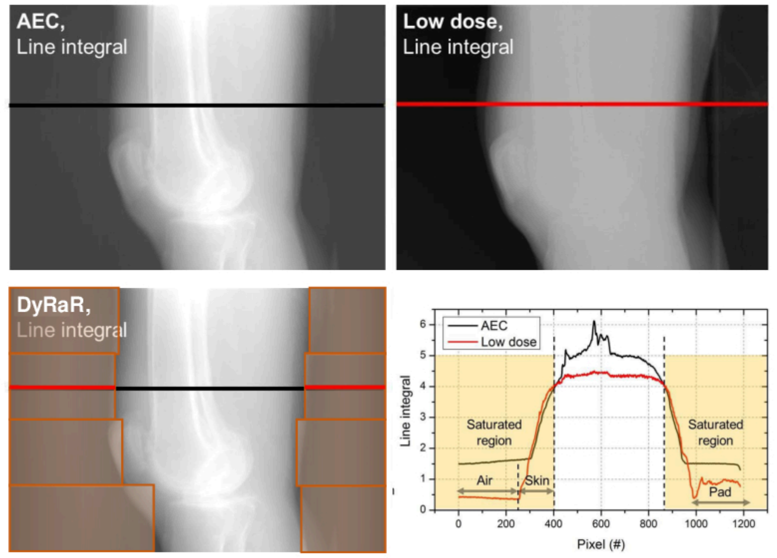

Fig. 1. Previous work using both a standard (AEC) and low dose acquisition for knee scans [1]. A DyRaR would combine the best of the two acquisitions in a single acquisition, providing detailed information about the knees without overexposing elsewhere.

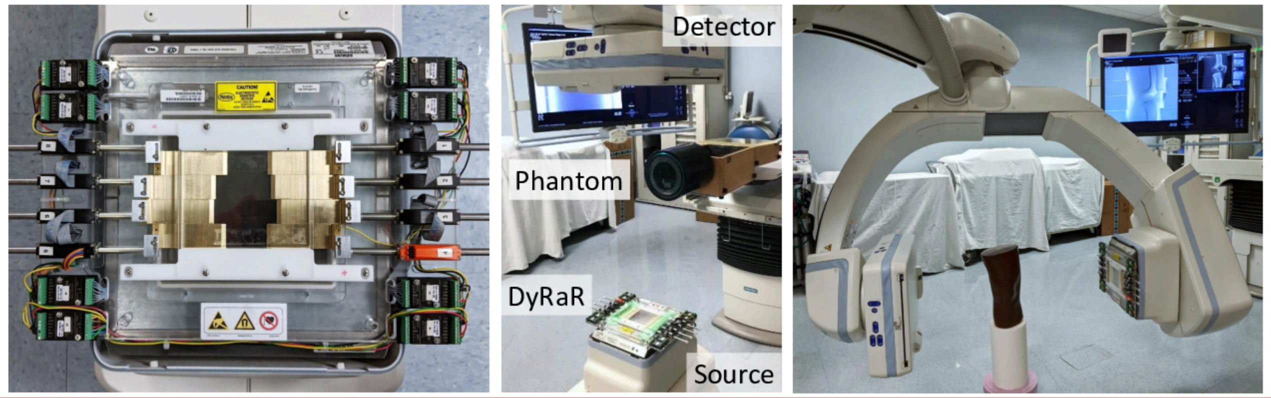

Fig. 2. (left) Prototype DyRaR mounted to collimator of C-arm system. (center) Cone-beam CT scans of a Catphan phantom were acquired with and without the DyRaR. (right) Horizontal scan of upright knee phantom.

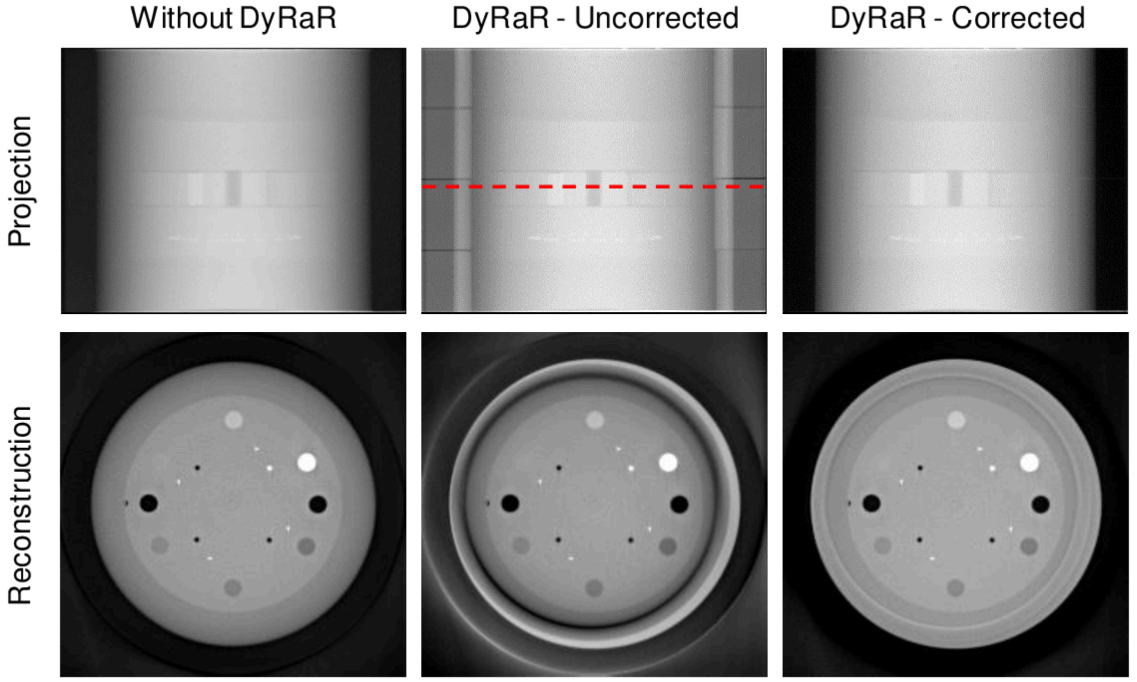

Fig. 3. (top) Projection images (post-log line integrals) are saturated in air without the DyRaR. The DyRaR reduces the signal in air by 11.0×, which can be corrected to recover the original signal. The dashed line indicates the line profile in the next figure. (bottom) Reconstructed images after correction show good recovery of the attenuated regions, although some artifact remains.

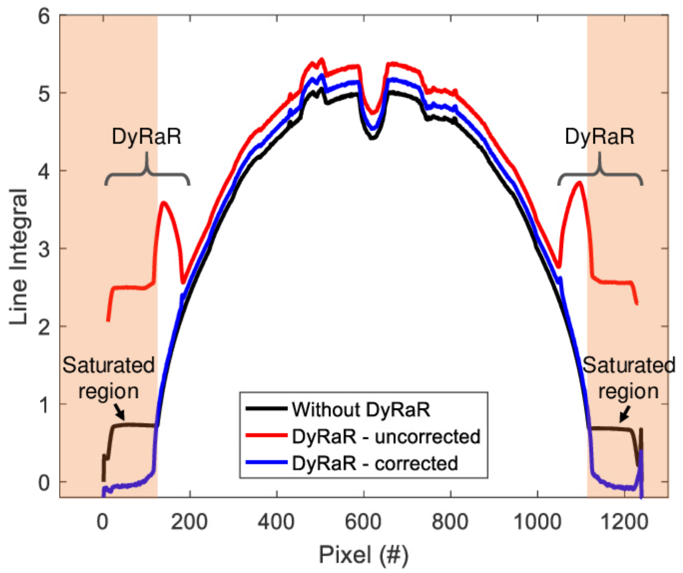

Fig. 4. Horizontal line profile of projection images. Without the DyRaR, the line integrals are overestimated in the saturated region since the measured counts are underestimated (black). The DyRaR covers the saturated region and extends into the phantom (red). After correcting for the DyRaR, the line integrals are close to 0 in air, as expected (blue). The DyRaR increases the line integrals at the center of the phantom due to additional attenuation from an acrylic base plate and top cover, as well as reduced scatter from the periphery.

CONCLUSIONS

We have demonstrated an initial DyRaR prototype and evaluated its performance on a cylindrical phantom. The DyRaR was able to reduce the intensity of the beam in air and reduce the overall dynamic range of the projection image. In future work, the DyRaR will be used to scan more complex object shapes where the 8 brass wedges move dynamically (programmed and controlled by linear actuators) to conform to object shapes at different projection views.

REFERENCES

[1] J.-H. Choi et al., "Over-exposure correction in knee cone-beam CT imaging with automatic exposure control using a partial low dose scan," in SPIE Medical Imaging: Physics of Medical Imaging, p. 97830L (2016).

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