

INTRODUCTION

Upright radiotherapy offers physiological and dosimetric advantages. Mevion S250-FIT, world's first clinical ultra-compact synchrocyclotron-based upright proton therapy system, incorporates a novel upright CT for treatment planning and image guidance. This study presents performance evaluation of the first clinical installation of this novel system in comparison with a state-of-the-art diagnostic CT.

METHODS

CT imaging was evaluated on metrics outlined in Figure 1.

Images were scanned on the upright CT and a state-of-the-art diagnostic CT (Siemens Biograph mCT). Imaging doses were measured for both systems using standard CTDI phantom protocols.

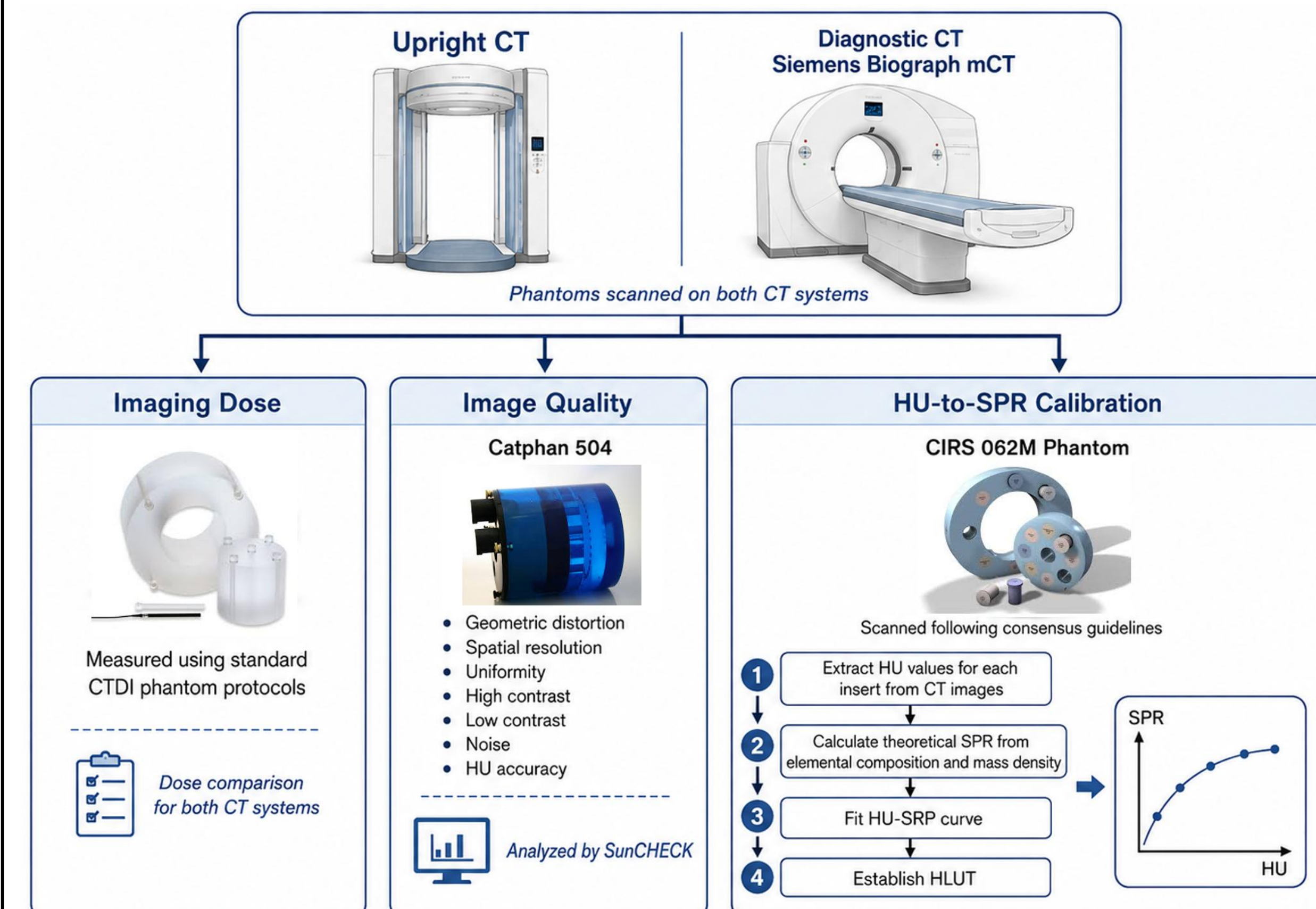


Figure 1: Method overview for upright CT performance evaluation.

METHODS/RESULTS

For the diagnostic CT, imaging doses were 12.7 mGy and 57.7 mGy for abdomen and head protocols, respectively, while the upright CT doses were 10.54 mGy and 21.45 mGy, respectively.

Catphan 504 phantom was used to evaluate image quality including geometric distortion, spatial resolution, uniformity, high and low contrast, noise, and HU accuracy analyzed by SunCHECK. Upright CT achieved image quality (Figure 2) demonstrated that the comparable to diagnostic CT in terms of geometric distortion, noise, spatial resolution, and uniformity. CT numbers were within specification for most materials, with notable deviations for air (-960.2), Delrin (336.5), and Teflon (911.7). Low-contrast and high-contrast were superior to diagnostic CT.

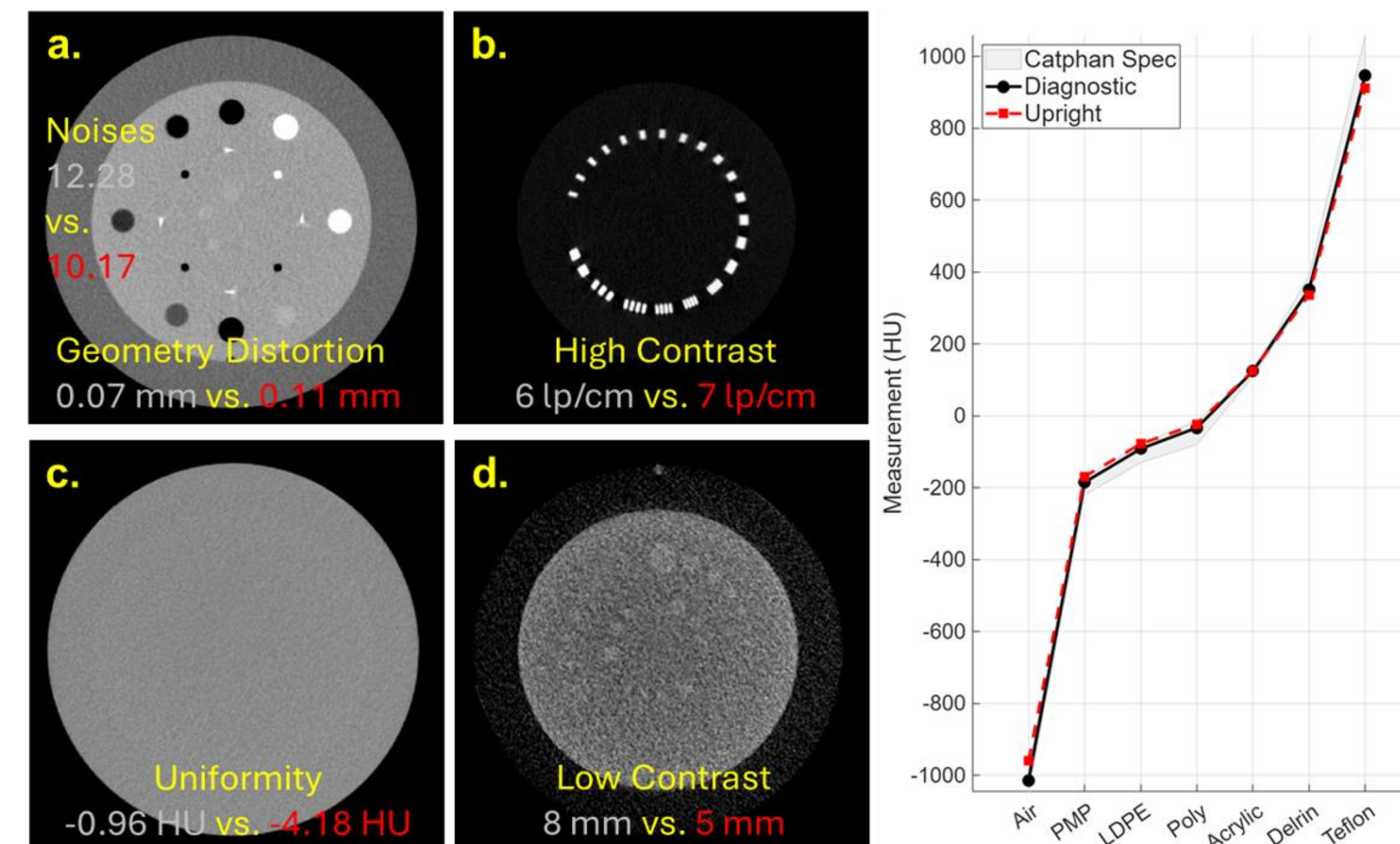


Figure 2: (a-d) Representative slices from upright CT scan of Catphan 504. (FOV: 280mm; 120kVp, 200mAs; Slice Thickness: 1mm). Gray color labels diagnostic CT results, and red color labels upright CT. (e) CT number accuracy.

The CIRS 062M Phantom with tissue-equivalent inserts was used to establish HU look-up table. It was scanned and analyzed following the consensus guidelines. For each of its inserts, HU values were extracted from CT images,

RESULTS

and their corresponding SPRs were calculated theoretically based on elemental composition and mass density. A curve was then fitted between HU and SPR.

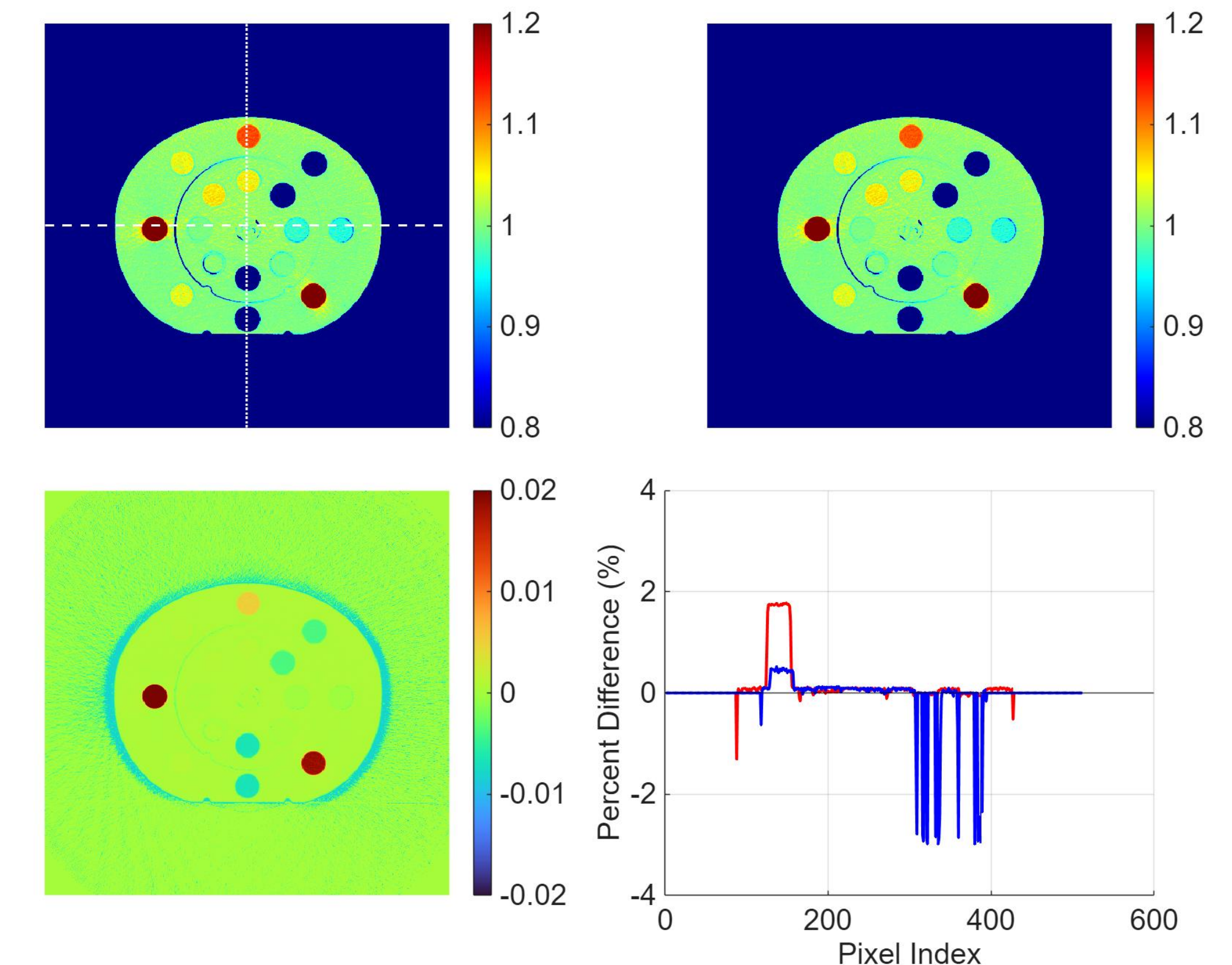


Figure 3: Stopping power ratios (SPRs) derived using (a) diagnostic CT-based calibration and (b) upright CT-based calibration. The resulting SPR difference map is shown in (c), with percentage SPR difference profiles along the vertical and horizontal midlines presented in (d).

The difference in SPR values derived using upright CT-based and diagnostic CT-based calibrations (Figure 3) was 0.00081 ± 0.0034 , corresponding to a percentage difference of $0.47\% \pm 0.52\%$ within the phantom.

SUMMARY AND CONCLUSIONS

The clinical upright CT integrated into the Mevion S250-FIT system demonstrates satisfactory performance in both image quality and HU-to-SPR calibration when compared with a state-of-the-art diagnostic CT. Future work will focus on improving CT number accuracy to further enhance image-guided upright proton therapy.