

Suitability of Simulated X-rays for Optimizing Imaging Settings for Positioning and Monitoring in Radiotherapy

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Purpose

Patient positioning and monitoring in radiotherapy is often based on in-room X-rays, usually acquired using indication-specific default imaging settings. Personalizing imaging settings prior to treatment, e.g., via simulated X-rays (sX-rays), could optimize the workflow and reduce the imaging dose. The aim of this study was to evaluate the quality of sX-rays, generatable on-the-fly, for lung, brain and pelvis.

Materials and Methods

- Computed tomography (CT) scans and X-rays acquired with 3 anthropomorphic phantoms (Lungman (Kyoto Kagaku, Japan), head and pelvis verification phantoms (Brainlab SE, Germany)) and 57 patients (13 lung, 20 brain, 24 prostate)
- sX-rays created from CT data with pilot software (Brainlab SE, Germany) using default imaging settings (lung: 110kV 16mAs, brain: 90kV 10mAs, prostate: 120kV 20mAs)
- sX-ray computation algorithm based on Beer-Lambert law (incident intensities estimated from empty ExacTrac Dynamic (Brainlab SE, Germany) images and linear attenuation coefficients estimated from CT Hounsfield units)
- Evaluation: Structural Similarity Index (SSIM), Normalized Cross Correlation (NCC), Normalized Mean Absolute Error (NMAE), average patient histogram and line profile comparison

Conclusion

The sX-rays investigated in this study demonstrated promising accuracy, highlighting their potential for patient-specific optimization of imaging settings for positioning and monitoring.

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Results

sX-rays were visually similar to X-rays for both phantoms and patients (Figure 1). Phantom evaluation yielded high-fidelity metrics, superior to average patient metrics by up to 65% (Table 1). Patient NCC for lung and NMAE for prostate yielded only moderate results. Peak values of average sX-ray histograms for the patients were shifted by less than 2.2% of the entire pixel value range compared to the corresponding average X-ray histograms. Line profiles showed similar trends, especially for brain and pelvis, with some discrepancies in absolute values (Figure 3).

Indication	Phantoms			Patient mean $\pm$ STD		
	SSIM	NCC	NMAE (%)	SSIM	NCC	NMAE (%)
Lung	0.87	0.99	4.1	0.80 $\pm$ 0.05	0.89 $\pm$ 0.07	10.7 $\pm$ 6.4
Head	0.94	0.99	2.6	0.88 $\pm$ 0.02	0.99 $\pm$ 0.02	3.2 $\pm$ 1.5
Pelvis	0.85	0.99	2.6	0.79 $\pm$ 0.08	0.60 $\pm$ 0.17	4.0 $\pm$ 2.2

Table 1: Image quality metrics for phantoms and an average ($\pm$ STD) over all patients using the default settings

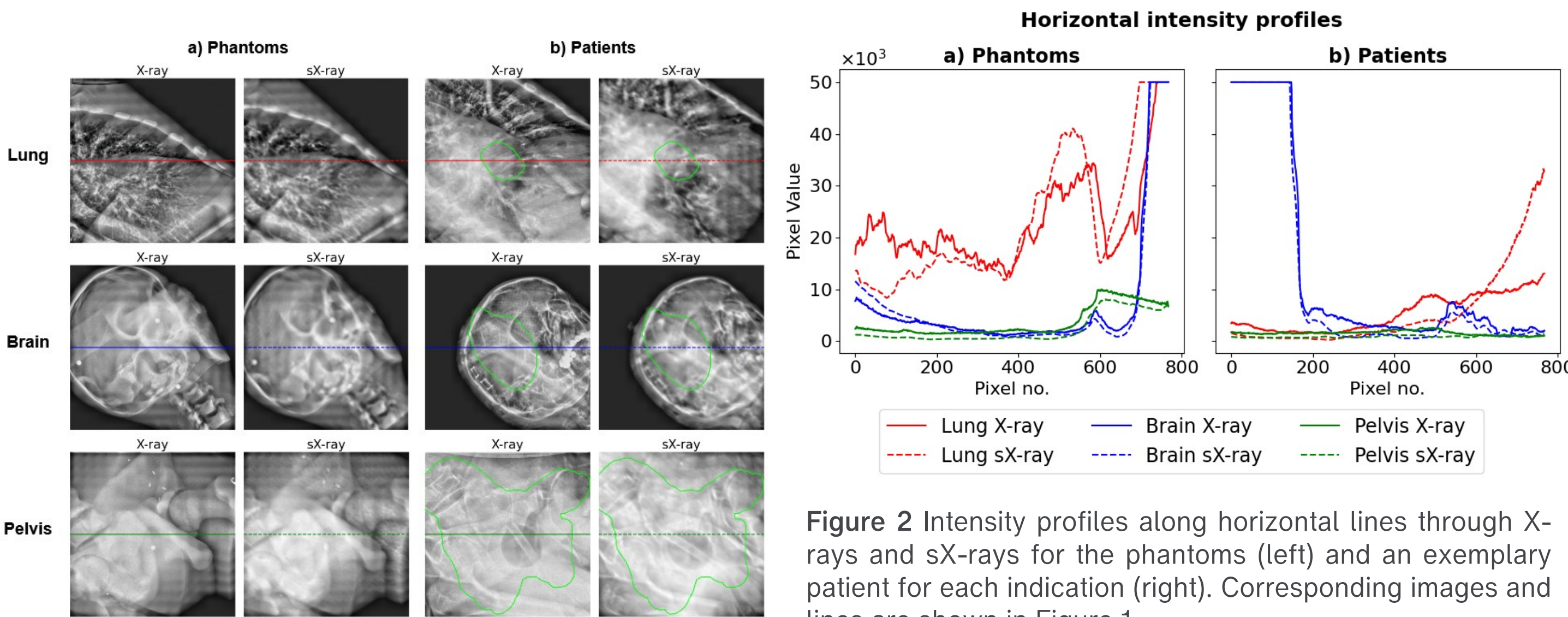


Figure 1 X-rays and corresponding sX-rays for phantoms (a) and exemplary patients (b) with indicated planning target volume (PTV) in green. Lines for intensity profile comparison are indicated as well.