PTCOG-AO2025-ABS-0103

Upright Image-guided Positioning System Enables Rapid CBCT Scanning and Reconstruction

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Objectives

In proton therapy, conventional gantry-based cone-beam CT (CBCT) systems face challenges such as prolonged imaging time and significant motion artifacts, which severely limit the efficiency and accuracy of real-time image guidance during radiotherapy. To address these issues, we developed an upright image-guided positioning system that integrates a vertical rotating treatment chair with millisecond-level temporal-controlled CBCT imaging. This system achieves 360° scanning and 3D volumetric reconstruction within 30 seconds, effectively overcoming the imaging efficiency limitations of traditional proton therapy.

Methods

Mechanical System Design: The system employs a vertical rotating treatment chair with a maximum rotation speed of 18°/s, enabling 360° rotation in 20 seconds.

Figure 1: Site layout of upright image-guided positioning system

Imaging Parameter Optimization and Data Synchronization: The X-ray generator is configured with a single-frame exposure time of 8 ms. The flat-panel detector captures images at 30 fps with a 0.8° angular interval, precisely acquiring 450 projection frames of 1536×1536 pixels. The electrical control system synchronously records rotary encoder angles corresponding to X-ray pulse exposure timing. Both projection data and angle information are used as reconstruction inputs to ensure millisecond-level temporal control and high-precision data acquisition.

Parallel Computing Architecture: A GPU-accelerated reconstruction algorithm is triggered simultaneously with the start of scanning, enabling the generation of 512×512×512 voxel 3D images within 5 seconds after scan completion.

Results

Spatial Resolution: Catphan 500 phantom tests demonstrated a high-contrast resolution of 7 lp/cm (based on MTF 10% criterion), sufficient for delineating bone and soft-tissue boundaries in proton dose calculations.

Figure 2: High contrast resolution(7lp/cm)

Clinical Applicability: The 30 seconds full-process scanning time can effectively improve the efficiency of clinical treatment. It can limit each treatment within about 10 minutes and has good clinical application potential.

Figure 3: Millisecond-level exposure timing control (acquiring 449 frames of images in 20.6 seconds)

Conclusions

The upright image-guided positioning system reduces the full-process 3D imaging time to 30 seconds through millisecond-level exposure control and GPU-accelerated reconstruction, significantly improving scanning efficiency and motion artifact management compared to traditional CBCT systems. This study validates the feasibility of rapid imaging and reconstruction in proton therapy and provides technical support for real-time adaptive radiotherapy in future clinical applications.


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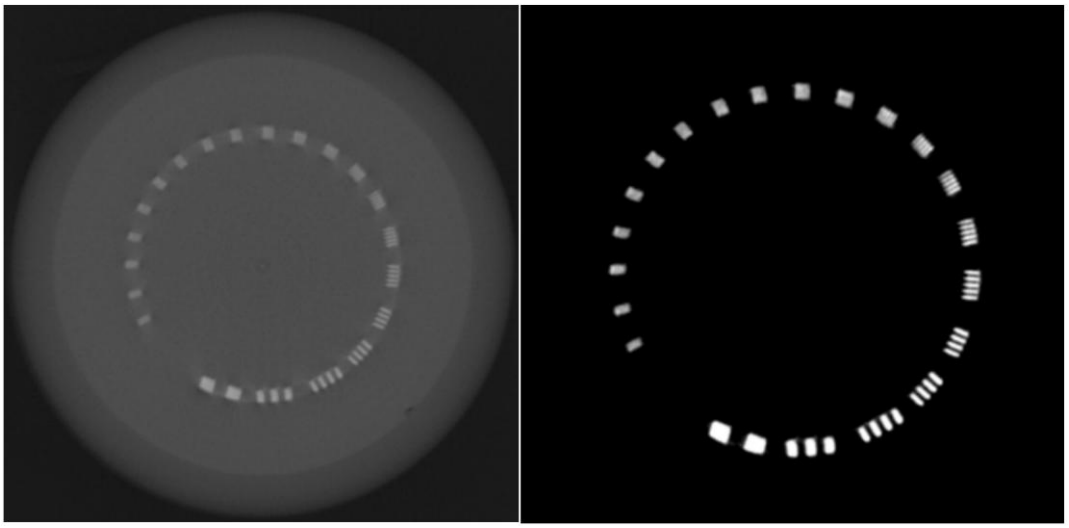


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