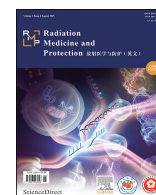




Contents lists available at ScienceDirect

Radiation Medicine and Protection

journal homepage: www.radmp.org

Original article

Technical performance and quality assurance of the CyberKnife® S7™ system



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ARTICLE INFO

Managing Editor: Chen Li

Keywords:

Stereotactic radiotherapy
CyberKnife
Acceptance test
Iris
Multileaf collimator

ABSTRACT

Objective: To analyze the acceptance testing items of the CyberKnife® S7™ system and evaluate its technical performance and quality assurance (QA).

Methods: A comprehensive test was conducted on the CyberKnife® S7™ system, which is equipped with a linear accelerator, X-ray imaging, a fixed collimator, an Iris™ collimator, an InCise2™ multileaf collimator (MLC), iDMS® data management system, and the Accuray Precision® treatment planning system (TPS) and safety mechanisms. End-to-end (E2E) testing was conducted to assess the overall projection accuracy of the CyberKnife S7 system, with relevant parameters recorded. In addition, quality control during clinical application was analyzed, including the verification results of 72 patients obtained using SRS MapCHECK®.

Results: The 6 MV X-ray beam exhibited radiation quality and off-axis ratio curves within normal ranges, dose stability and linearity deviations both were below 1.0%. The transmission factors of the fixed and Iris collimators were <0.2%. Repeatability tests for the 5 mm and 60 mm apertures of the Iris collimator met acceptance criteria. The alignment deviation between the laser and radiation beam centers fell within the standard of <1 mm. The maximum leakage of the MLC complied with the ≤0.5% standard. All three criteria for the leaf positioning accuracy tests were satisfied. The maximum deviation in overall projection accuracy for the fixed, Iris, and MLC collimators was 0.90 mm. Across 83 automated quality assurance (AQA) tests, the average deviation was 0.42 mm. Regarding tracking methods, E2E testing for Xsight lung tracking using fixed and Iris collimators showed the maximum deviations, with averages of 0.59 mm and 0.74 mm, respectively. In contrast, the MLC system showed the highest deviation for Xsight spine tracking, with an average of 0.7 mm. Based on the 2%/2 mm γ analysis criteria with a threshold of 10%, the γ pass rate for quality control results of 72 patients was $97.65\% \pm 2.36\%$. **Conclusion:** All acceptance testing results of the CyberKnife® S7™ system met the established standards, confirming its reliability and readiness for clinical deployment. Rigorous quality control during clinical application is importance to ensuring the system's ability to deliver precise and effective treatments. This will safeguard patient outcomes and advance the standardization of patients care in radiotherapy.

1. Introduction

Radiotherapy represents one of the most crucial therapeutic modalities in oncology. In recent years, stereotactic radiotherapy has evolved rapidly, becoming a major modality for tumors. The CyberKnife® system, a frameless stereotactic radiosurgery platform, has advantage in the field of stereotactic radiotherapy technology.¹ Unlike conventional Linacs, the CyberKnife employs a six-axis robotic arm to deliver focused radiation beams to tumors with sub-millimetric spatial accuracy.² Recent iteration, the CyberKnife® S7™ system, integrates artificial

intelligence-driven motion tracking and real-time adaptive delivery. This system employs the advanced KUKA robotic platform (KR 300 Ultra), enabling over 6000 non-coplanar beam angles. Compared to the M6 system, the S7 system represents software advancement. It incorporates the Precision® TPS (version 3.2.0.0), featuring the Graphics Processing Unit (GPU)-accelerated voxel-less optimization (VOLO) algorithm. This algorithm has a demonstrated capability to reduce plan complexity^{3,4} and improve treatment efficiency while maintaining or enhancing plan quality.^{5,6} The S7 system supports multiple dose calculation algorithms, including ray tracing, finite-size pencil beam (FSPB),

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<https://doi.org/10.1016/j.radmp.2025.06.001>

Received 28 February 2025; Received in revised form 11 April 2025; Accepted 3 June 2025

Available online 4 June 2025

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