

ABSTRACT

Purpose: To develop and validate a log file-based patient quality assurance (LFQA) system for intensity modulated proton therapy (IMPT) using a GPU-accelerated pencil beam algorithm for dose reconstruction, permitting rapid log file upload, dose reconstruction, automated Gamma analysis, and report generation, all from a web interface accessible from the treatment machine console, and compare resultant Gamma pass rates and end-to-end workflow times to clinically standard measurement-based QA (MQA).

Methods: We developed a custom LFQA system based on our in-house GPU-accelerated pencil beam algorithm for our Hitachi Probeat system, including a custom DICOM listener that receives plans and reference dose distributions from our clinical treatment planning system (TPS), RayStation 2023B, and a web interface allowing log file upload from the treatment console immediately after beam delivery. File upload triggers dose reconstruction, 3D Gamma analysis, and report generation, which can then be downloaded and entered into our oncology information system (Mosaiq v2.86) immediately. The LFQA approach was tested in 10 IMPT patients who had previously been treated at various sites and verified using MQA with an ion chamber array. Workflow times and Gamma pass rates were recorded and compared between approaches.

Results: The mean±standard deviation (SD) time requirement for MQA was 36.6±12.7 min, including 12.6±10.9 min for beam delivery and 24.0±6.7 min for calculations and analysis. LFQA required 6.3±5.1 min, including 6.2±5.1 min for beam delivery and only 3.2±1.7 s for recalculation and analysis. Both approaches provided Gamma pass rates >95% for all plans at 3%/3 mm criteria.

Conclusions: The GPU-accelerated LFQA approach was developed and validated, significantly reducing the time required for patient QA relative to the clinical standard by accelerating dose calculation, automating steps, and eliminating the need to switch between computers. The LFQA approach holds promise for streamlining clinical operations and enabling faster treatment initiation with adaptive IMPT.

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A patient quality assurance system for intensity modulated proton therapy with automated GPU-accelerated log file-based dose reconstruction and analysis in under 10 seconds

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INTRODUCTION

- Patient-specific QA for intensity modulated proton therapy (IMPT) traditionally relies on measurement-based QA (MQA), which is time-consuming and requires switching between systems.
- Log file-based QA (LFQA) reconstructs delivered dose directly from machine log files, avoiding physical measurement.
- **Purpose:** Develop and validate a GPU-accelerated LFQA system enabling log file upload, dose reconstruction, automated Gamma analysis, and report generation from a web interface at the treatment console — and compare Gamma pass rates and workflow times against clinical MQA.

METHODS AND MATERIALS

- Custom LFQA system built on an in-house GPU-accelerated pencil beam algorithm for the Hitachi Probeat system.
- Custom DICOM listener receives plans and reference dose from the clinical TPS (RayStation 2023B).Web interface allows log file upload from the treatment console immediately after beam delivery.
- Upload automatically triggers dose reconstruction → 3D Gamma analysis → downloadable report, entered directly into the oncology information system (Mosaiq v2.86).
- Validated in 10 previously-treated IMPT patients across various sites; verified against MQA using an ion chamber array.
- Workflow times and Gamma pass rates compared between LFQA and MQA.

RESULTS

Table 1. Mean±standard deviation (SD) seconds required for clinical standard MQA and our novel LFQA approach from 10 previously treated IMPT patients for various treatment sites

	MQA	LFQA
Beam Delivery (s)	756.0±653.1	372.0±305.7
Calculation & Analysis (s)	1440.0±400.0	3.2±1.7
Total (s)	2196.0±763.8	375.2±307.2

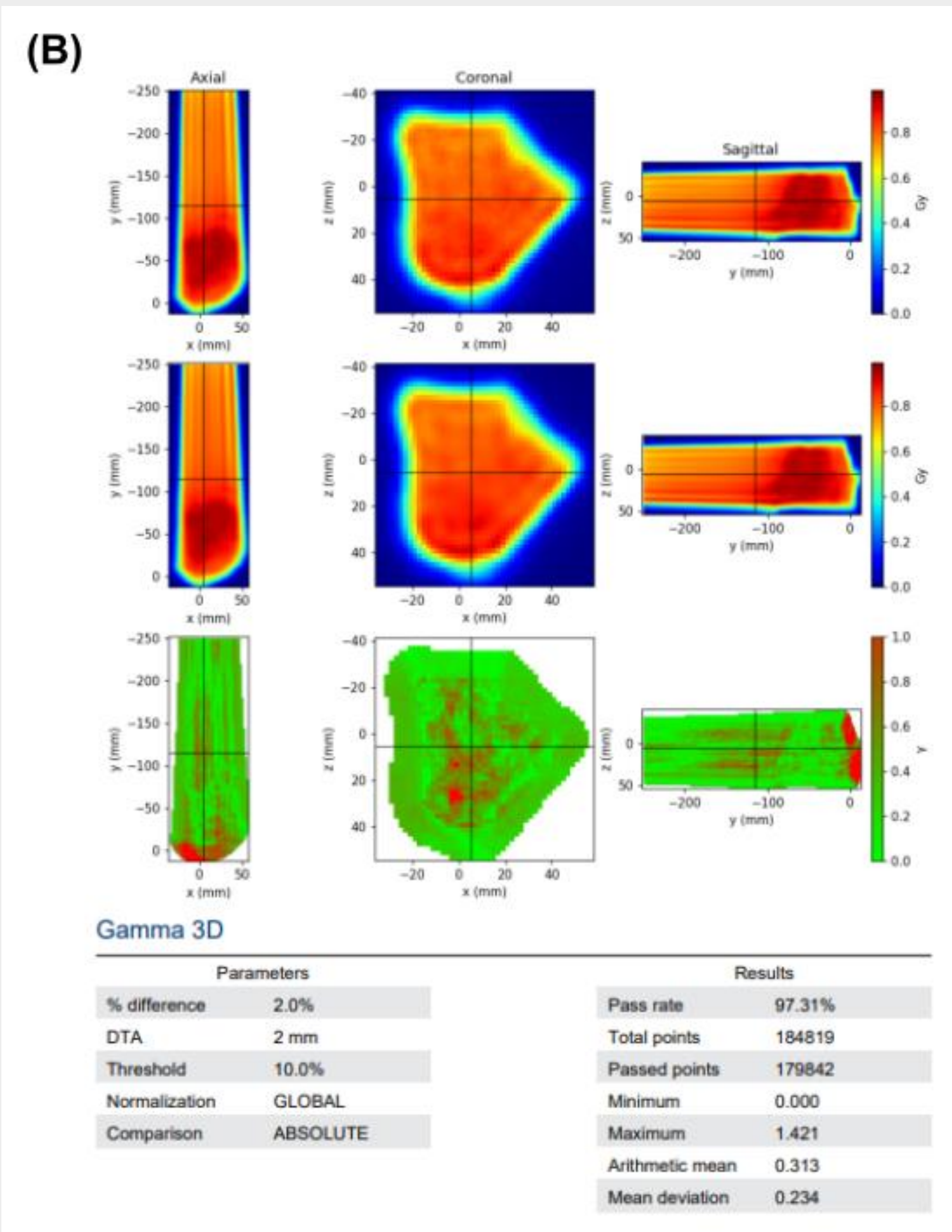
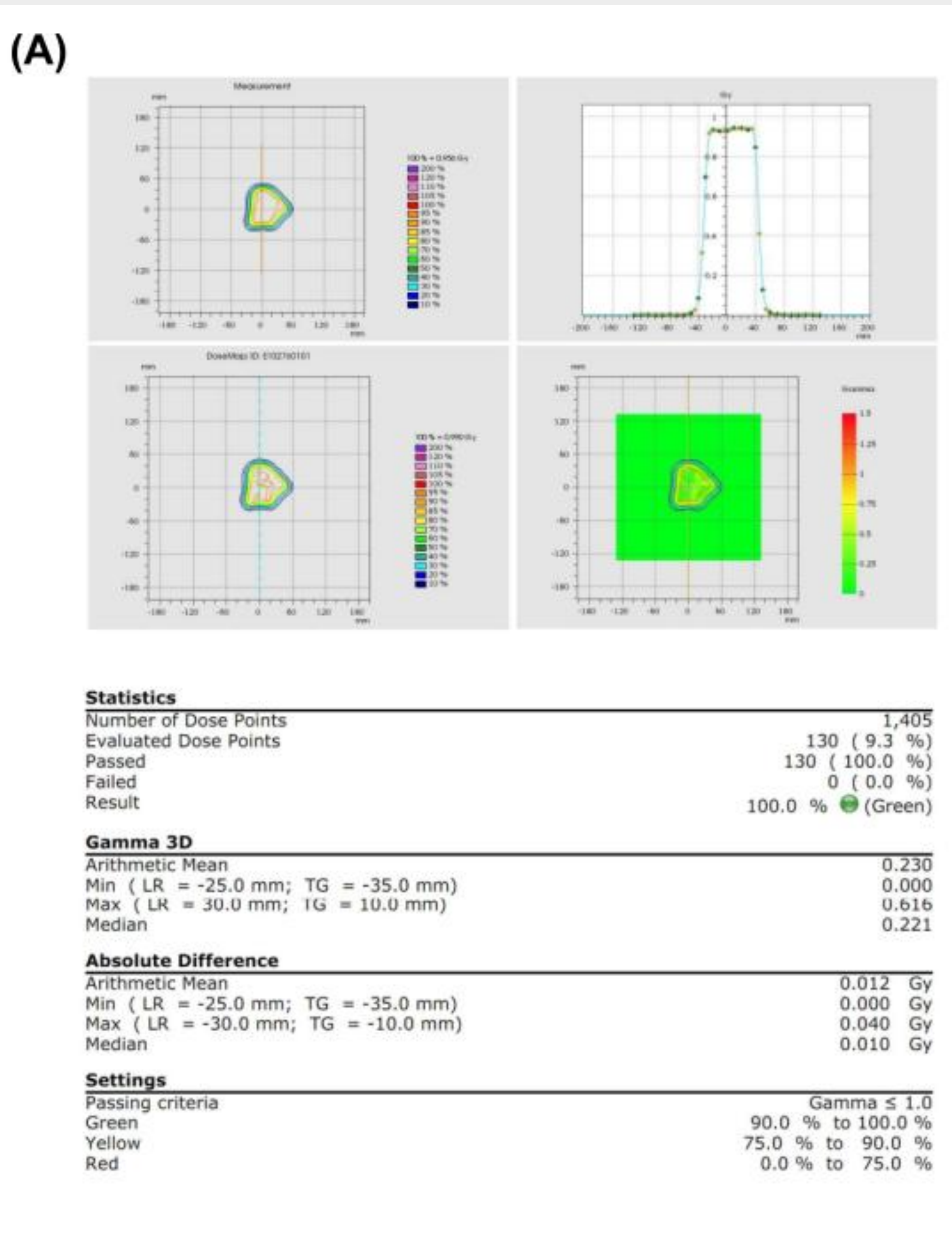


Figure 1 (A) Example screenshot from the MQA analysis report and (B) example of our automatically-generated LFQA report for the same IMPT beam from a prostate plan.

RESULTS (Cont'd)

- MQA total time: 36.6 ± 12.7 min (12.6 ± 10.9 min delivery; 24.0 ± 6.7 min calculation/analysis).
- LFQA total time: 6.3 ± 5.1 min (6.2 ± 5.1 min delivery; only 3.2 ± 1.7 s recalculation/analysis).
- Both approaches achieved Gamma pass rates >95% for all plans at 3%/3 mm.

DISCUSSION

- LFQA reduced total QA time ~6-fold, driven by GPU-accelerated calculation (sub-4-second analysis), automation of manual steps, and elimination of computer switching.
- Comparable Gamma agreement confirms LFQA is a valid alternative to MQA.
- Console-based web workflow integrates cleanly into existing clinical systems.

CONCLUSIONS

- GPU-accelerated LFQA was developed and validated, significantly reducing patient QA time versus the clinical standard while maintaining equivalent accuracy.
- Promising for streamlining clinical operations and enabling faster treatment initiation, particularly for adaptive IMPT.