An Automated RayStation Plan-Check System for Error Reduction and Patient Safety

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ABSTRACT

Purpose: To improve consistency and efficiency in radiation therapy plan review through development of a deterministic automated plan-check system integrated within RayStation.

Methods: An automated plan-check framework was developed using the RayStation Python API. The system performs more than 30 checks across multiple clinical domains using predefined pass/fail criteria and generates standardized HTML reports with transparent reporting of measured values.

Results: Applied to over 200 clinical VMAT, SBRT, and 3D plans. The system reliably identified predefined failing conditions including beam-geometry mismatches, isocenter deviations, incorrect prescription inputs, and dose-grid issues. Average runtime was under 3 seconds per plan.

Conclusions: The automated framework improves consistency, reduces reviewer variability, and enhances patient safety through scalable, standardized plan-review automation.

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INTRODUCTION

Manual radiation therapy plan checking is essential for ensuring treatment accuracy and patient safety but can be time-consuming and subject to reviewer variability.
To improve consistency and efficiency, we developed a deterministic, RayStation-integrated automated plan-check system that performs more than 30 checks across multiple clinical domains using predefined acceptance criteria and transparent reporting of measured values. The system aims to reduce reviewer variability, streamline workflow, and enhance patient safety through standardized plan-review automation.

METHODS AND MATERIALS

An automated plan-check system was developed using the RayStation (2024A) Python API. The framework utilizes a modular QA engine in which all checks are implemented using deterministic pass/fail logic with predefined acceptance thresholds. Each check evaluates TPS-accessible parameters and reports both the measured value and the corresponding acceptance criterion within a standardized HTML report.
The system performs more than 30 automated checks across eight major clinical domains:

- CT & Imaging
- Prescription
- Machine & Dose Grid
- Approval
- Structure Validation
- Beam & Geometry
- Plan Quality
- Isocenter & Setup

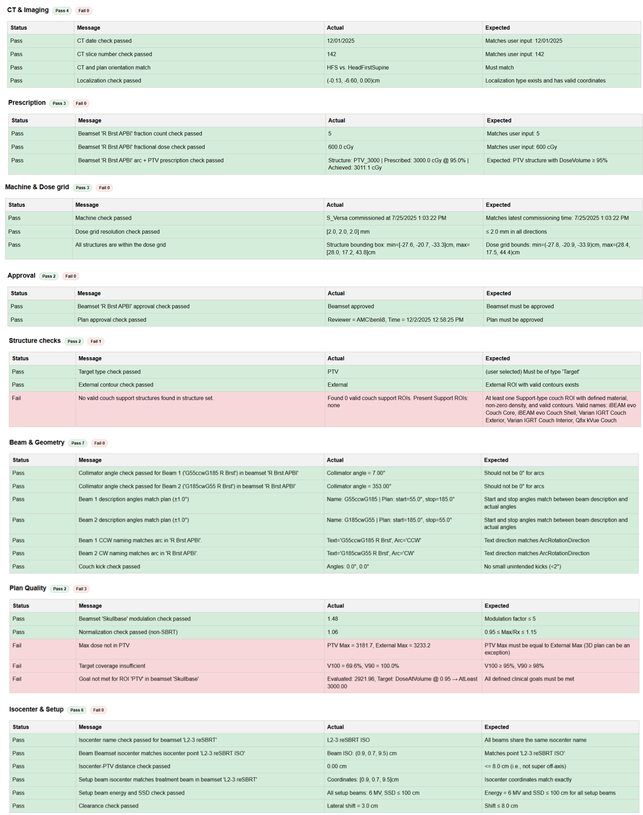
Implemented checks include verification of simulation parameters, slice thickness, CT dataset selection, prescription consistency, beam model assignment, dose-grid resolution, structure-type validation, beam geometry consistency, arc-direction naming, modulation limits, target coverage, hotspot evaluation, clearance checks, setup-beam consistency, and unintended isocenter deviations.
A standardized color-coded HTML report was generated automatically for each plan, displaying pass/fail status, measured values, expected criteria, and summary statistics to support rapid review and QA traceability.

RESULTS

The automated plan-check system successfully processed over 200 clinical treatment plans, including VMAT, SBRT, and 3D conformal plans. Average runtime was under 3 seconds per plan, enabling near real-time plan-review support within the clinical workflow.
The system reliably identified predefined failing conditions across multiple QA domains, including:

- beam-geometry inconsistencies,
- isocenter deviations,
- incorrect prescription parameters,
- unintended dose-grid assignments,
- missing support structures,
- normalization inconsistencies,
- excessive modulation factors,
- and target-coverage deficiencies.

The generated HTML reports provided transparent visualization of measured values and acceptance criteria using standardized pass/fail indicators, allowing rapid identification of clinically relevant issues while maintaining QA traceability. Example reports demonstrated successful detection of both geometric and dosimetric plan inconsistencies.
The deterministic framework reduced dependence on reviewer-specific interpretation and improved consistency across plan reviews.



CT & Imaging Pass 4 Fail 0

Status	Message	Actual	Expected
Pass	CT date check passed	12/01/2025	Matches user input: 12/01/2025
Pass	CT slice number check passed	142	Matches user input: 142
Pass	CT and plan orientation match	HFS vs. HeadFirstSupine	Must match
Pass	Localization check passed	(-0.13, -6.60, 0.00)cm	Localization type exists and has valid coordinates

Prescription Pass 3 Fail 0

Status	Message	Actual	Expected
Pass	Beamset 'R Brst APBI' fraction count check passed	5	Matches user input: 5
Pass	Beamset 'R Brst APBI' fractional dose check passed	600.0 cGy	Matches user input: 600 cGy
Pass	Beamset 'R Brst APBI' arc + PTV prescription check passed	Structure: PTV_3000 | Prescribed: 3000.0 cGy @ 95.0% | Achieved: 3011.1 cGy	Expected: PTV structure with DoseVolume ≥ 95%

Machine & Dose grid Pass 3 Fail 0

Status	Message	Actual	Expected
Pass	Machine check passed	S_Versa commissioned at 7/25/2025 1:03:22 PM	Matches latest commissioning time: 7/25/2025 1:03:22 PM
Pass	Dose grid resolution check passed	[2.0, 2.0, 2.0] mm	≤ 2.0 mm in all directions
Pass	All structures are within the dose grid	Structure bounding box: min=[-27.6, -20.7, -33.3]cm, max=[28.0, 17.2, 43.8]cm	Dose grid bounds: min=[-27.8, -20.9, -33.9]cm, max=[28.4, 17.5, 44.4]cm

Approval Pass 2 Fail 0

Status	Message	Actual	Expected
Pass	Beamset 'R Brst APBI' approval check passed	Beamset approved	Beamset must be approved
Pass	Plan approval check passed	Reviewer = AMC\benl8, Time = 12/2/2025 12:58:25 PM	Plan must be approved

Structure checks Pass 2 Fail 1

Status	Message	Actual	Expected
Pass	Target type check passed	PTV	(user selected) Must be of type 'Target'
Pass	External contour check passed	External	External ROI with valid contours exists
Fail	No valid couch support structures found in structure set.	Found 0 valid couch support ROIs. Present Support ROIs: none	At least one Support-type couch ROI with defined material, non-zero density, and valid contours. Valid names: iBEAM evo Couch Core, iBEAM evo Couch Shell, Varian IGRT Couch Exterior, Varian IGRT Couch Interior, Qfix kVue Couch

Beam & Geometry Pass 7 Fail 0

Status	Message	Actual	Expected
Pass	Collimator angle check passed for Beam 1 ('G55ccwG185 R Brst') in beamset 'R Brst APBI'	Collimator angle = 7.00°	Should not be 0° for arcs
Pass	Collimator angle check passed for Beam 2 ('G185cwG55 R Brst') in beamset 'R Brst APBI'	Collimator angle = 353.00°	Should not be 0° for arcs
Pass	Beam 1 description angles match plan (±1.0°)	Name: G55ccwG185 | Plan: start=55.0°, stop=185.0°	Start and stop angles match between beam description and actual angles
Pass	Beam 2 description angles match plan (±1.0°)	Name: G185cwG55 | Plan: start=185.0°, stop=55.0°	Start and stop angles match between beam description and actual angles
Pass	Beam 1 CCW naming matches arc in 'R Brst APBI'	Text='G55ccwG185 R Brst', Arc='CCW'	Text direction matches ArcRotationDirection
Pass	Beam 2 CW naming matches arc in 'R Brst APBI'	Text='G185cwG55 R Brst', Arc='CW'	Text direction matches ArcRotationDirection
Pass	Couch kick check passed	Angles: 0.0°, 0.0°	No small unintended kicks (~2°)

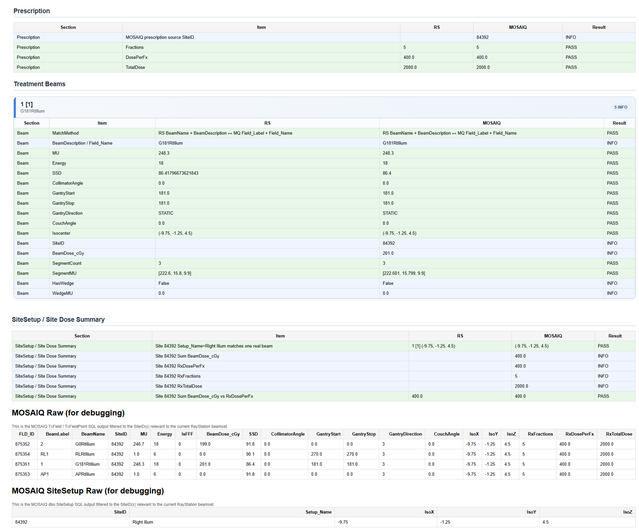
Plan Quality Pass 2 Fail 3

Status	Message	Actual	Expected
Pass	Beamset 'Skullbase' modulation check passed	1.48	Modulation factor ≤ 5
Pass	Normalization check passed (non-SBRT)	1.06	0.95 ≤ Max/Rx ≤ 1.15
Fail	Max dose not in PTV	PTV Max = 3181.7, External Max = 3233.2	PTV Max must be equal to External Max (3D plan can be an exception)
Fail	Target coverage insufficient	V100 = 69.6%, V90 = 100.0%	V100 ≥ 95%, V90 ≥ 98%
Fail	Goal not met for ROI 'PTV' in beamset 'Skullbase'	Evaluated: 2921.96, Target: DoseAtVolume @ 0.95 → AtLeast 3000.00	All defined clinical goals must be met

Isocenter & Setup Pass 6 Fail 0

Status	Message	Actual	Expected
Pass	Isocenter name check passed for beamset 'L2-3 reSBRT'	L2-3 reSBRT ISO	All beams share the same isocenter name
Pass	Beam Beamset isocenter matches isocenter point 'L2-3 reSBRT ISO'	Beam ISO: (0.9, 0.7, 9.5) cm	Matches point 'L2-3 reSBRT ISO'
Pass	Isocenter-PTV distance check passed	0.00 cm	<= 8.0 cm (i.e., not super off-axis)
Pass	Setup beam isocenter matches treatment beam in beamset 'L2-3 reSBRT'	Coordinates: [0.9, 0.7, 9.5]cm	Isocenter coordinates match exactly
Pass	Setup beam energy and SSD check passed	All setup beams: 6 MV, SSD ≤ 100 cm	Energy = 6 MV and SSD ≤ 100 cm for all setup beams
Pass	Clearance check passed	Lateral shift = 3.0 cm	Shift ≤ 8.0 cm

Figure 1. Example Plan Check Report. Demonstrates consistent, reviewer-independent error detection across **eight key domains**: CT & imaging, prescription, machine & dose grid, approvals, structure validation, beam geometry, plan quality, and isocenter setup.



Prescription

Section	Item	R/S	MOSAIQ	Result
Prescription	MOSAIQ prescription source SiteID		84392	INFO
Prescription	Fractions	5	5	PASS
Prescription	DosePerFx	400.0	400.0	PASS
Prescription	TotalDose	2000.0	2000.0	PASS

Treatment Beams

1 [1] G185cwG55 3 INFO

Section	Item	R/S	MOSAIQ	Result
Beam	MatchMethod	R/S BeamName + BeamDescription == MQ Field_Label + Field_Name	R/S BeamName + BeamDescription == MQ Field_Label + Field_Name	PASS
Beam	BeamDescription / Field_Name	G185cwG55	G185cwG55	INFO
Beam	MU	248.3	248.3	PASS
Beam	Energy	10	10	PASS
Beam	SSD	86.4179667362164 3	86.4	PASS
Beam	CollimatorAngle	0.0	0.0	PASS
Beam	GantryStart	181.0	181.0	PASS
Beam	GantryStop	181.0	181.0	PASS
Beam	GantryDirection	STATIC	STATIC	PASS
Beam	CouchAngle	0.0	0.0	PASS
Beam	Isocenter	(-9.75, -1.25, 4.5)	(-9.75, -1.25, 4.5)	PASS
Beam	SiteID		84392	INFO
Beam	BeamDose_cGy		201.0	INFO
Beam	SegmentCount	3	3	PASS
Beam	SegmentMU	[222.6, 15.8, 9.9]	[222.681, 15.799, 9.9]	PASS
Beam	HasWedge	False	False	INFO
Beam	WedgeMU	0.0	0.0	INFO

SiteSetup / Site Dose Summary

Section	Item	R/S	MOSAIQ	Result
SiteSetup / Site Dose Summary	Site 84392 Setup_Name='Right Bum matches one real beam		1 [1] (-9.75, -1.25, 4.5)	PASS
SiteSetup / Site Dose Summary	Site 84392 Sum BeamDose_cGy		400.0	INFO
SiteSetup / Site Dose Summary	Site 84392 RxDosePerFx		400.0	INFO
SiteSetup / Site Dose Summary	Site 84392 RxFractions		5	INFO
SiteSetup / Site Dose Summary	Site 84392 RxTotalDose		2000.0	INFO
SiteSetup / Site Dose Summary	Site 84392 Sum BeamDose_cGy vs RxDosePerFx	400.0	400.0	PASS

MOSAIQ Raw (for debugging)

This is the MOSAIQ FxFeed / FxFeedPrest SQL output filtered to the SiteID(s) relevant to the current RayStation beamset.

FLD_ID	BeamLabel	BeamName	SiteID	MU	Energy	IsFFF	BeamDose_cGy	SSD	CollimatorAngle	GantryStart	GantryStop	GantryDirection	CouchAngle	IsoX	IsoY	IsoZ	RxFractions	RxDosePerFx	RxTotalDose
875352	2	G185Bum	84392	248.7	10	0	199.0	91.8	0.0	0.0	0.0	3	0.0	-9.75	-1.25	4.5	5	400.0	2000.0
875354	RL1	RLRtBum	84392	1.0	6	0	0.0	90.1	0.0	270.0	270.0	3	0.0	-9.75	-1.25	4.5	5	400.0	2000.0
875361	1	G181RtBum	84392	248.3	10	0	201.0	86.4	0.0	181.0	181.0	3	0.0	-9.75	-1.25	4.5	5	400.0	2000.0
875363	AP1	APRtBum	84392	1.0	6	0	0.0	91.8	0.0	0.0	0.0	3	0.0	-9.75	-1.25	4.5	5	400.0	2000.0

MOSAIQ SiteSetup Raw (for debugging)

This is the MOSAIQ dbo.SiteSetup SQL output filtered to the SiteID(s) relevant to the current RayStation beamset.

SiteID	Setup_Name	IsoX	IsoY	IsoZ
84392	Right Bum	-9.75	-1.25	4.5

Figure 2. Prototype MOSAIQ reconciliation workflow integrated into the automated plan-check framework for end-to-end treatment workflow verification.

DISCUSSION

This work demonstrates the feasibility of a deterministic TPS-integrated automated plan-check framework for radiation therapy plan verification. By using standardized pass/fail criteria and transparent reporting, the system reduces reviewer variability and cognitive burden while providing rapid, reproducible QA directly within the TPS environment.
The automated checks are intended to augment clinical physicist review by improving clinical efficiency, consistency, and plan accuracy.

CONCLUSIONS

A deterministic automated plan-check system was developed within RayStation using the Python API. The framework performs more than 30 automated checks across multiple clinical domains and generates standardized HTML reports with transparent pass/fail reporting.
The system demonstrated robust performance across more than 200 clinical treatment plans, reliably identifying predefined failure conditions with average runtimes under 3 seconds per plan.
This framework improves consistency, reduces reviewer variability, and enhances patient safety through scalable, standardized plan-review automation.

REFERENCES

Ford EC, et al. Strategies for effective physics plan and chart review in radiation therapy: Report of AAPM Task Group 275. Medical Physics. 2020;47(6):e236-e272.