Technical Note

Validation and Efficiency Evaluation of Automated Quality Assurance Software SunCHECK™ Machine for Mechanical and Dosimetric Quality Assurance

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Abstract

Recent decades have witnessed transformative advances in radiation physics and computer technology, revolutionizing the precision of radiation therapy. The adoption of intricate treatment techniques such as three-dimensional conformal radiotherapy, intensity-modulated radiotherapy, volumetric-modulated arc therapy, and image-guided radiotherapy necessitates robust quality assurance (QA) programs. This study introduces the SunCHECK™ Machine (SCM), a web-based QA platform, presenting early results from its integration into a comprehensive QA program. linear accelerators (LINAC) demand QA programs to uphold machine characteristics within accepted tolerances. The increasing treatment complexity underscores the need for streamlined procedures. The selection of QA tools is vital, requiring efficiency, accuracy, and alignment with clinic needs, as per recommendations such as the AAPM task group 142 report. The materials and methods section details SCM implementation in various QA aspects, encompassing daily QA (DQA), imaging QA with Catphan, conventional output assessment with a water phantom, and LINAC isocenter verification through the Winston–Lutz test. Challenges in QA processes, such as manual data transcription and limited device integration, are highlighted. Early results demonstrate SCM's significant reduction in QA time, ensuring accuracy and efficiency. Its automation eliminates interobserver variation and human errors, contributing to time savings and near-immediate result publication. SCM's role in consolidating and storing DQA data within a single platform is emphasized, offering potential in resource optimization, especially in resource-limited settings. In conclusion, SCM shows promise for efficient and accurate mechanical and dosimetric QA in radiation therapy. The study underscores SCM's potential to address contemporary QA challenges, contributing to improved resource utilization without compromising quality and safety standards.

Keywords: Automated QA, output, SunCHECK Machine

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Introduction

In recent decades, remarkable advances in the fields of radiation physics and computer technology have revolutionized the precision and efficacy of radiation therapy in the treatment of various malignancies. These advances have brought about the adoption of more complex treatment techniques such as three-dimensional (3D) conformal radiotherapy, intensity-modulated radiotherapy, volumetric-modulated arc therapy, and image-guided radiotherapy. The rise in the complexity of treatments, individualized treatment strategies, and the use of multiple treatment methods at radiation oncology facilities elevates the requirements and significance of regular quality assurance (QA).[1]

The objective of a QA program for linear accelerators (LINAC) is to maintain machine characteristics within acceptable tolerances, consistent with the initial baseline values established during the acceptance and commissioning processes. Given the various demands to cater to, streamlining procedures and enhancing effectiveness becomes imperative, all the while upholding the utmost standards of quality and safety.[2]

To maintain high levels of quality and safety, it is crucial to consider various factors when choosing the right QA tool, not

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just efficiency. QA platforms should also be evaluated for their accuracy, suitability, and adaptability to the clinic's needs, as well as their alignment with pertinent recommendations and guidelines like the task group 142 report (TG-142). The American Association of Physicists in Medicine (AAPM) TG 142 report, as a point of reference, provides guidance on conducting general QA tests for medical LINAC.[3,4]

QA in radiation therapy encounters several hurdles, such as the requirement for up-to-date equipment and parameters, the creation of multiple machine-specific baselines and tolerances, the absence of automated analysis and consistent tolerance standards, manual data transcription, limited device integration, variable data storage methods, and the generation of reports. Furthermore, challenges exist in terms of training and onboarding new staff, managing IT maintenance and software updates, and the expenses associated with maintaining numerous systems. When selecting a QA platform, it is important to consider additional factors such as user-friendliness, ease of access, and the platform's capabilities for data analysis and trend tracking. These aspects have a direct influence on how effectively the platform can be used.[2]

In this article, we present the early results of an implementation of SunCHECK™ Machine (SCM), a commercially available automated QA software solution provided by Sun Nuclear Inc., Melbourne, FL, USA.

Materials and Methods

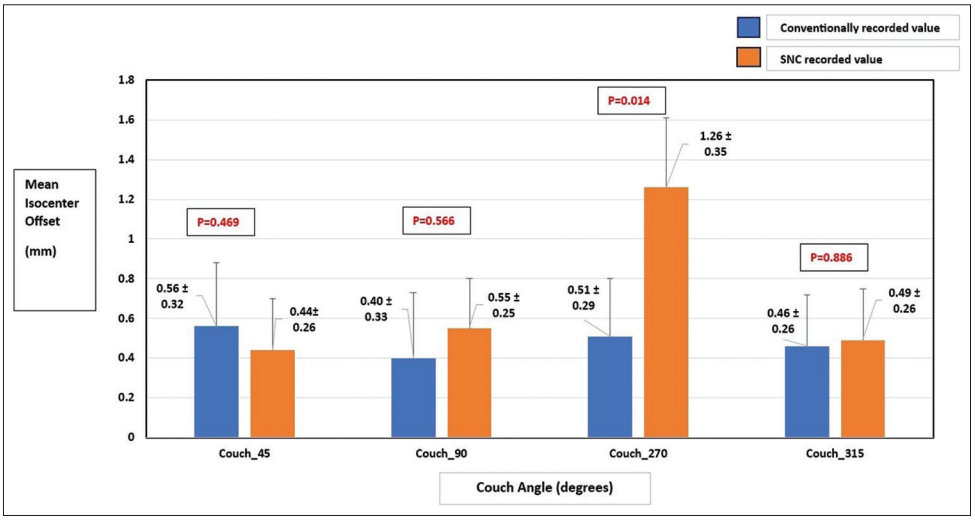
SCM is a web-based QA platform designed to gather, identify, evaluate, and store QA data. This platform includes prebuilt templates for conducting the recommended daily QA (DQA) tests outlined in TG-142, and these templates can be adjusted to suit the specific requirements of the clinic. While SCM is versatile and applicable to all machine QA tasks, the primary focus of this work is on DQA. SCM streamlines the process by employing the DQA3 system from Sun Nuclear Inc., which fully automates beam constancy assessments.

In our institute, we implement a comprehensive QA program covering various aspects of radiotherapy. For DQA, our DQA3 is equipped with 12 diodes to verify the alignment of light and radiation fields, four ion chambers for photon energy checks, another four for electron energy verification, and five for assessing flatness and symmetry. The DQA3 compiles beam parameters during startup, and our software, SCM, automatically analyses the results.

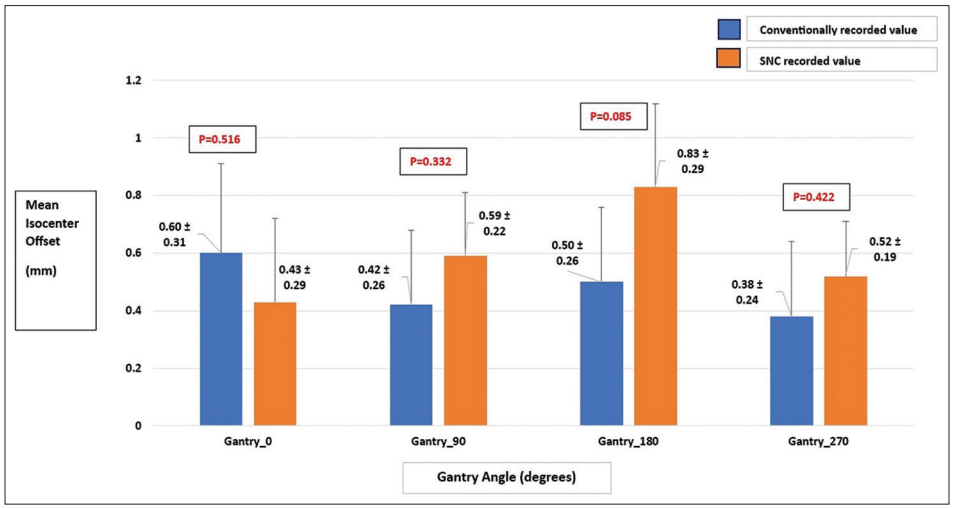
In the imaging QA process, we rely on the Catphan, conducting measurements that evaluate different aspects of Kilo-Voltage (KV) imaging performance, including sensitometry, uniformity, geometry, and low contrast sensitivity. To ensure slice geometry accuracy, we utilize opposed 23° wire ramps, assessing the phantom position, patient alignment, and scanner table incrementation. Sensitometry measurements involving materials such as Teflon, acrylic, LDPE, and air help us evaluate computed tomography number linearity, while high-resolution line pairs aid in characterizing the Modulation Transfer Function (MTF) curve.

For conventional output assessment, we use a water phantom, specifically the Tissue Phantom Ratio (TPR) 20/10 phantom, with a setup involving a 0.6cc ionization chamber, wires, and an electrometer. The electrometer provides charge readings from the ion chamber, adjusted for various factors such as temperature pressure, polarity, leakage, saturation, and Dose to Water correction Factor (NDW) corrections to obtain the output for each beam.

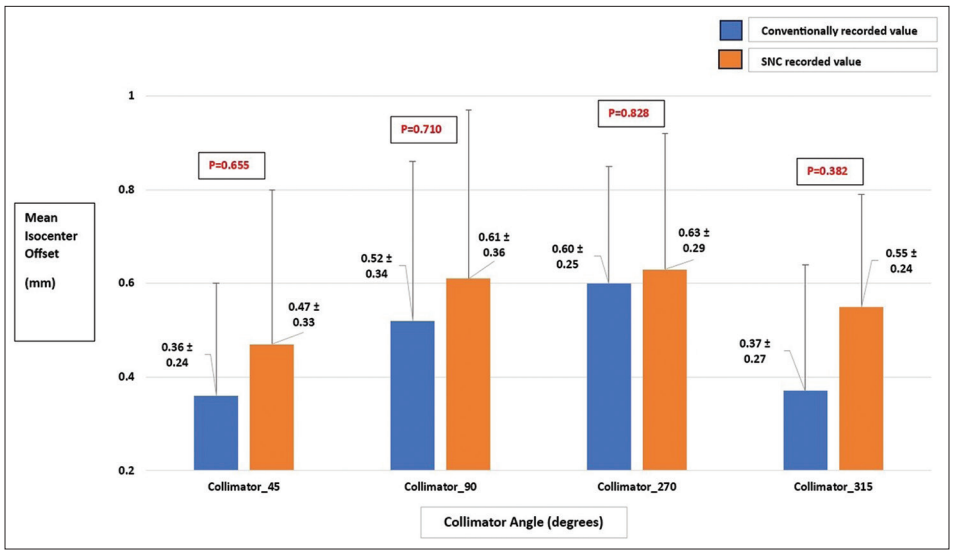
To verify the LINAC isocenter, we conduct the Winston–Lutz test, a well-established procedure involving a cube phantom with a lead ball. By exposing the phantom at different gantry, couch, and collimator angles and comparing the resulting images with a reference image, we ensure the accuracy of the LINAC's isocenter.



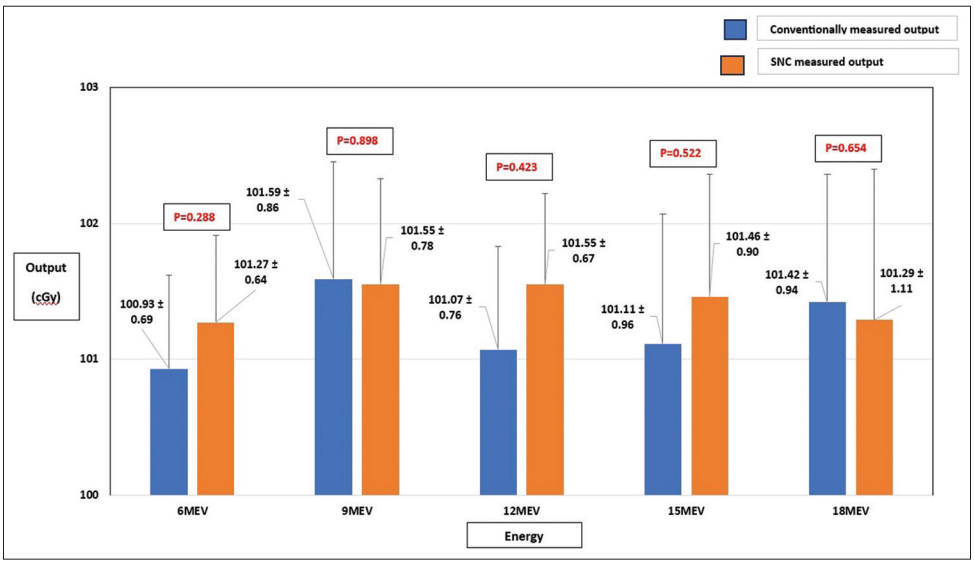
Graph 1: Winston–Lutz test: Couch (observations = 5). SNC: Sun Nuclear Corporation



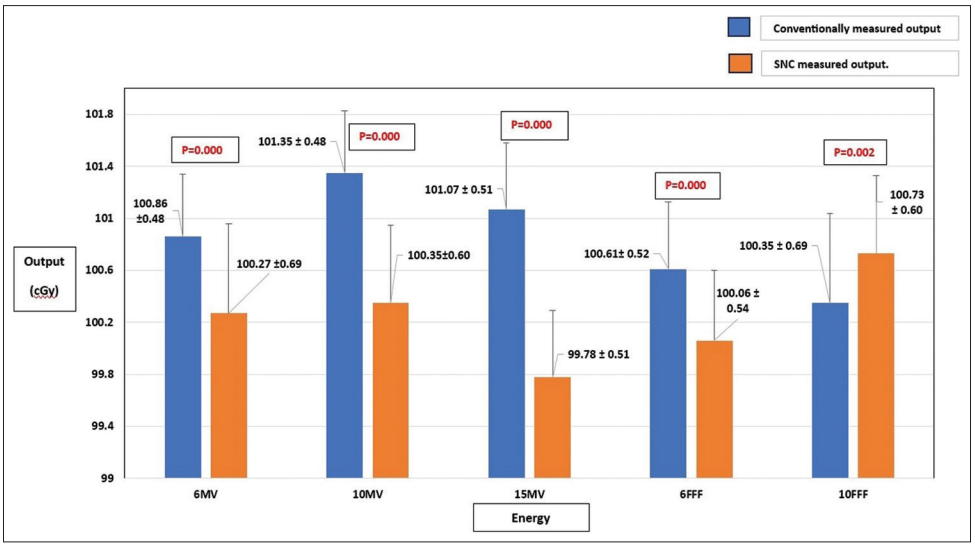
Graph 2: Winston–Lutz test: Gantry (observations = 5). SNC: Sun Nuclear Corporation



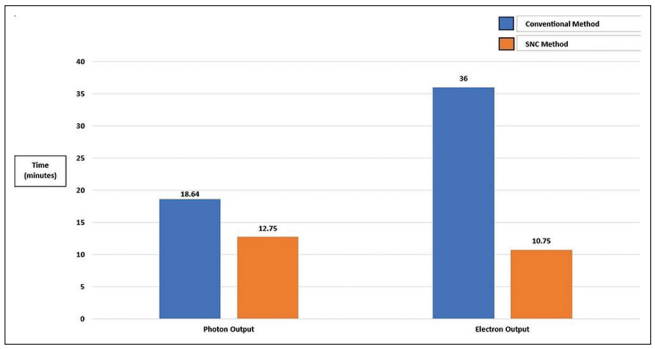
Graph 3: Winston–Lutz test: Collimator (observations = 5). SNC: Sun Nuclear Corporation



Graph 4: Electron output (observations = 4). SNC: Sun Nuclear Corporation



Graph 5: Photon output (observations = 18). SNC: Sun Nuclear Corporation



Graph 6: Average time for calculating output. SNC: Sun Nuclear Corporation

Table 1: Imaging quality assurance: Conventional versus SNC (observations=5)

Parameters	SNC		Manual		*P*
	Mean	SD	Mean	SD	
Geometric distortion (mm)	0.08	0.02	0.04	0.02	0.016
Spatial resolution (lp/mm)	0.41	0.05	0.13	0.00	0.000
Uniformity (HU)	9.63	4.57	12.37	0.21	0.244
Contrast (units)	0.89	0.01			
Noise (units)	34.60	3.26			
Air (HU)	−995.16	5.00	−999.80	0.45	0.116
Teflon (HU)	1080.80	51.92	1013.64	45.62	0.028
Delrin (HU)	394.38	24.25	362.20	17.60	0.083
Acrylic (HU)	153.25	9.80	135.20	4.55	0.004
Polystyrene (HU)	−25.54	6.92	−37.80	13.33	0.101
Low-density polyethylene (HU)	−91.22	5.82	−101.60	4.51	0.030
Polymethylpentene (HU)	−188.81	4.91	−176.00	16.08	0.145
Slice thickness (mm)	1.91	0.15	0.97	0.04	0.000
Low contrast (mm)	15.00	0.00	6.80	0.45	0.000

SD: Standard deviation, SNC: Sun Nuclear Corporation

Statistical analysis

After testing the normality of the data using the Shapiro–Wilk test, continuous variables are expressed as mean and amp; standard deviation. Furthermore, the difference between the mean manual and the SunCHECK Machine (SCM) values is compared using the paired *t*-test. For all analyses, a two-tailed *P* value of less than or equal to 0.05 was considered statistically significant. All statistical analyses are performed using STATA 17 (StataCorp. 2021. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC).

Results

The initial 5 months of employing the SCM software yielded the following outcomes. The Winston–Lutz test demonstrated strong agreement in results. For the 45-, 90-, 270-, and 315° angles involving the couch, gantry, and collimator, both SCM and manual computations displayed no statistically significant disparities, except at the 270° couch angle, but the result of 270° couch angle is well within the accepted tolerance of 2 mm [Graphs 1-3]. The mean time taken to manually analyze the test and record the results was 20 min (range: 18–22 min).

Manual analysis of imaging QA elapsed a mean time of 35 min (range: 30–40 min) to complete and record. The parameters of uniformity, air, Delrin, polystyrene, and polymethylpentene did not show a statistically significant difference between the manual analysis and SCM readings. For the SCM, the generated results adhered to AAPM-TG 142 requirements [Table 1].

Electron output was documented monthly, while photon output was recorded weekly. Electron output was in alignment with the prespecified cutoff criteria, with no statistically significant difference between manual and SCM [Graph 4]. A statistically

significant difference was recorded between manual and SCM findings for photon output, though in both modalities the value was within the prespecified cutoff criteria and was in alignment [Graph 5]. The manual recording meantime for electron output was 36 min (range: 30–45 min), whereas, for SCM, it was reduced to mean 11 min (range: 9–13 min). Similarly, the manual recording time for photon output mean was 19 min (range: 15–24 min), while SCM further streamlined the process to mean 13 min (range: 12–16 min) [Graph 6].

Discussion and Conclusion

Based on this study's findings, SCM can substantially reduce the time required for QA checks.

Bonanno *et al.* evaluated the use of DoseLab provided by Varian Medical Systems A, a commercially available AutoQA solution with the conventionally conducted single test mode for monthly QA. They found that the AutoQA solution was able to complete the monthly QA in 90 min while the conventional single test mode required 190 min.[5]

Stambaugh *et al*. illustrated the development of a thorough TG-142 DQA, incorporating SCM as the primary tool and introducing Machine Performance Check (MPC) as a valuable tool and backup for output verification, ensuring an effective DQA process. In their study, the SCM method required 22 min, displaying a standard deviation of 6 min, while the MPC approach reduced the time to 15 min with a standard deviation of 3 min. Notably, although some tests overlapped, the SCM tests were more closely aligned with TG-142 requirements, emphasizing relevance.[6]

This study represents data generated in the initial 6 months of starting to use the SCM on a single linear accelerator which explains the relatively small sample size. A wider application of this technology may help us to further understand the nuances of the benefits and challenges.

The authors do acknowledge certain limitations as well as challenges encountered. Initial setup of the SCM is time-consuming, however, once the setup is done, further utilization is very easy and saves time. It is important that the team involved in the installation is well-trained for the SCM. The initial investment cost for purchasing SunCHECK software and hardware can be a deterrent, but it is compensated in terms of time and manpower saved during the QA. The generation of large amounts of data from QA measurements and analyses by SunCHECK required efficient data management practices to ensure traceability, accessibility, and security.

The automated QA software allows for accurate calculation and eliminates interobserver variation and human errors. With the near-immediate publication of results, it is a time-saving modality. Utilizing SCM facilitates the consolidation and storage of all pertinent DQA data within a single platform. Evaluations of efficiency, like the one conducted here, enable the allocation of sufficient staffing and time resources, ultimately minimizing time and resource wastage. This is an indispensable aspect of modern practice, especially in a progressively resource-limited setting.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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