A CT Quality Control Audit Program Based on Automated Analysis and Alerts

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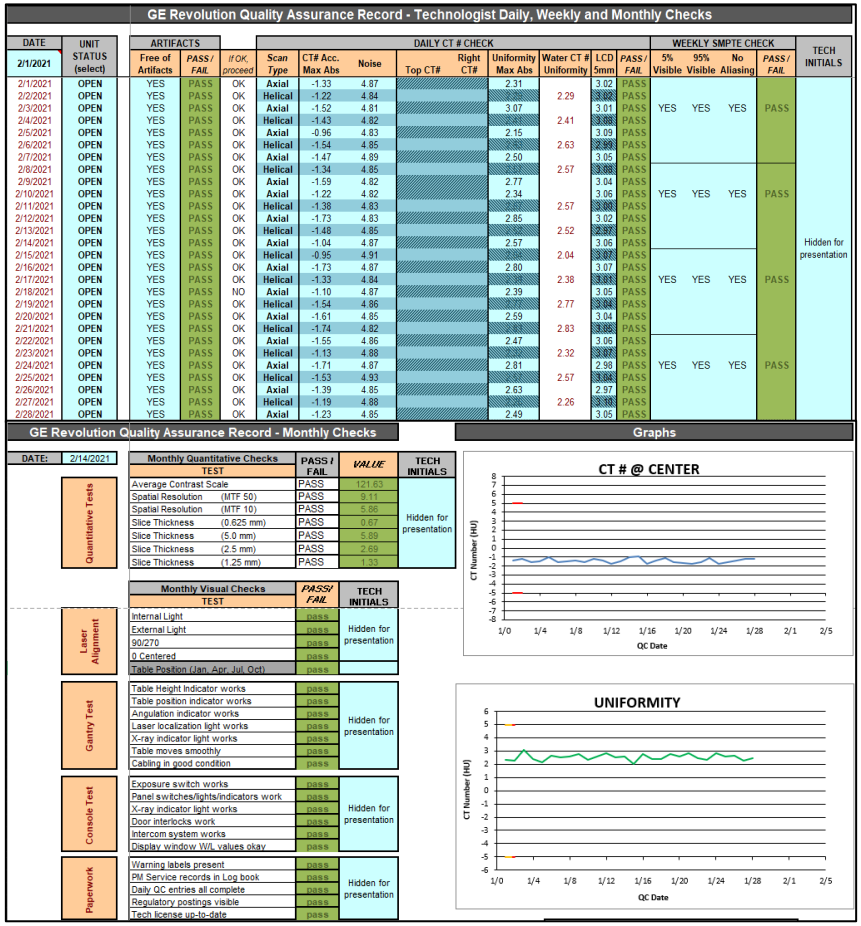
Purpose

- A continuous quality control (QC) program is an essential part of computed tomography (CT) quality assurance to ensure patient safety and consistent clinical performance.
- The American College of Radiology (ACR) requires that the continuous QC program be monitored by a Qualified Medical Physicist (QMP).
- In a clinical setting with multiple sites and scanners, this monitoring activity often entails a constant, detailed, and laborious review of records by a medical physicist.
- The purpose of this study was to minimize the amount of human review time by developing a self-regulating program to monitor CT QC results that can detect and report both missing and out-of-tolerance results.

Methods

1. We created a set of electronic forms using Microsoft Excel for technologists to use to record the QC results.
   - Stored on a cloud drive that both technologists and physicists have access to.
   - Incorporate limits specified by both the vendors and the ACR for each of the QC tests.
   - The daily test includes CT number, noise, the presence of artifacts, and uniformity.
   - The weekly test includes SMPTE pattern check.
   - The monthly test includes visual inspections of the console and gantry, laser alignment, and vendor-recommended quantitative tests such as spatial resolution, contrast scale, slice thickness, and low contrast resolution.



GE Revolution Quality Assurance Record - Technologist Daily, Weekly and Monthly Checks

DATE	UNIT STATUS	ARTIFACTS			DAILY CT # CHECK								WEEKLY SMPTE CHECK				TECH INITIALS
2/1/2021	(select)	Free of Artifacts	PASS / FAIL	If OK, proceed	Scan Type	CT# Acc. Max Abs	Noise	Top CT#	Right CT#	Uniformity Max Abs	Water CT # Uniformity	LCD 5mm	PASS / FAIL	5% Visible	95% Visible	No Aliasing	PASS / FAIL	
2/1/2021	OPEN	YES	PASS	OK	Axial	-1.33	4.87			2.31		3.02	PASS					
2/2/2021	OPEN	YES	PASS	OK	Helical	-1.22	4.84				2.29	3.08	PASS					
2/3/2021	OPEN	YES	PASS	OK	Axial	-1.52	4.81			3.07		3.01	PASS	YES	YES	YES	PASS	
2/4/2021	OPEN	YES	PASS	OK	Helical	-1.43	4.82				2.41	3.08	PASS					
2/5/2021	OPEN	YES	PASS	OK	Axial	-0.96	4.83			2.15		3.09	PASS					
2/6/2021	OPEN	YES	PASS	OK	Helical	-1.54	4.85				2.63	2.99	PASS					
2/7/2021	OPEN	YES	PASS	OK	Axial	-1.47	4.89			2.50		3.05	PASS					
2/8/2021	OPEN	YES	PASS	OK	Helical	-1.34	4.85				2.57	3.08	PASS					
2/9/2021	OPEN	YES	PASS	OK	Axial	-1.59	4.82			2.77		3.04	PASS					
2/10/2021	OPEN	YES	PASS	OK	Axial	-1.22	4.82			2.34		3.06	PASS	YES	YES	YES	PASS	
2/11/2021	OPEN	YES	PASS	OK	Helical	-1.38	4.83				2.57	3.06	PASS					
2/12/2021	OPEN	YES	PASS	OK	Axial	-1.73	4.83			2.85		3.02	PASS					
2/13/2021	OPEN	YES	PASS	OK	Helical	-1.48	4.85				2.52	2.97	PASS					
2/14/2021	OPEN	YES	PASS	OK	Axial	-1.04	4.87			2.57		3.06	PASS					Hidden for presentation
2/15/2021	OPEN	YES	PASS	OK	Helical	-0.95	4.91				2.04	3.07	PASS					
2/16/2021	OPEN	YES	PASS	OK	Axial	-1.73	4.87			2.80		3.07	PASS					
2/17/2021	OPEN	YES	PASS	OK	Helical	-1.33	4.84				2.38	3.03	PASS	YES	YES	YES	PASS	
2/18/2021	OPEN	YES	PASS	NO	Axial	-1.10	4.87			2.39		3.05	PASS					
2/19/2021	OPEN	YES	PASS	OK	Helical	-1.54	4.86				2.77	3.04	PASS					
2/20/2021	OPEN	YES	PASS	OK	Axial	-1.61	4.85			2.59		3.04	PASS					
2/21/2021	OPEN	YES	PASS	OK	Helical	-1.74	4.82				2.83	3.05	PASS					
2/22/2021	OPEN	YES	PASS	OK	Axial	-1.55	4.86			2.47		3.06	PASS					
2/23/2021	OPEN	YES	PASS	OK	Helical	-1.13	4.88				2.32	3.07	PASS					
2/24/2021	OPEN	YES	PASS	OK	Axial	-1.71	4.87			2.81		2.98	PASS	YES	YES	YES	PASS	
2/25/2021	OPEN	YES	PASS	OK	Helical	-1.53	4.93				2.57	3.04	PASS					
2/26/2021	OPEN	YES	PASS	OK	Axial	-1.39	4.85			2.63		2.97	PASS					
2/27/2021	OPEN	YES	PASS	OK	Helical	-1.19	4.88				2.26	3.18	PASS					
2/28/2021	OPEN	YES	PASS	OK	Axial	-1.23	4.85			2.49		3.05	PASS					

GE Revolution Quality Assurance Record - Monthly Checks

DATE: 2/14/2021

	Monthly Quantitative Checks TEST	PASS / FAIL	VALUE	TECH INITIALS
Quantitative Tests	Average Contrast Scale	PASS	121.63	Hidden for presentation
	Spatial Resolution (MTF 50)	PASS	9.11	
	Spatial Resolution (MTF 10)	PASS	5.86	
	Slice Thickness (0.625 mm)	PASS	0.67	
	Slice Thickness (5.0 mm)	PASS	5.89	
	Slice Thickness (2.5 mm)	PASS	2.69	
	Slice Thickness (1.25 mm)	PASS	1.33	

	Monthly Visual Checks TEST	PASS / FAIL	TECH INITIALS
Laser Alignment	Internal Light	pass	Hidden for presentation
	External Light	pass	
	90/270	pass	
	0 Centered	pass	
	Table Position (Jan, Apr, Jul, Oct)	pass	
Gantry Test	Table Height Indicator works	pass	Hidden for presentation
	Table position indicator works	pass	
	Angulation indicator works	pass	
	Laser localization light works	pass	
	X-ray indicator light works	pass	
	Table moves smoothly	pass	
	Cabling in good condition	pass	
Console Test	Exposure switch works	pass	Hidden for presentation
	Panel switches/lights/indicators work	pass	
	X-ray indicator light works	pass	
	Door interlocks work	pass	
	Intercom system works	pass	
	Display window W/L values okay	pass	
Paperwork	Warning labels present	pass	Hidden for presentation
	PM Service records in Log book	pass	
	Daily QC entries all complete	pass	
	Regulatory postings visible	pass	
	Tech license up-to-date	pass	

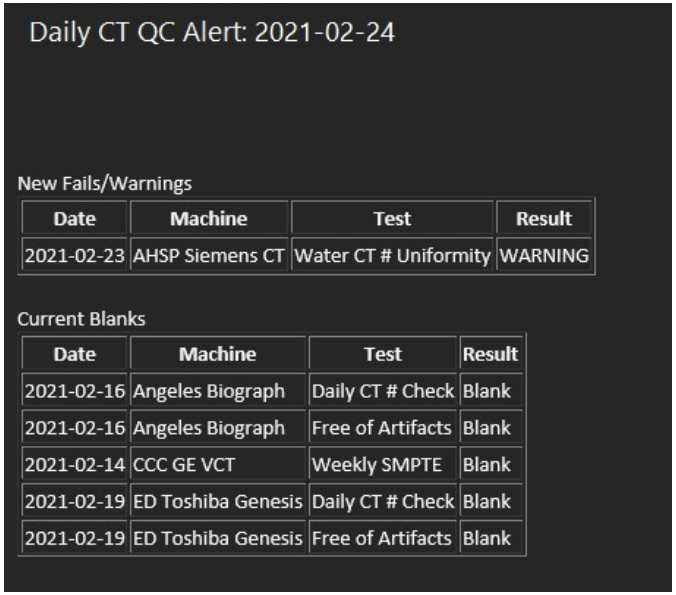
Graphs

Methods

2. These digital forms are reviewed automatically by a Python-based program at a user-defined frequency.
   - Our institution uses the program:
     - **Daily** to search the forms for out of tolerance results—either a warning or failure depending on the specified upper and lower limits
     - **Weekly** to identify missing entries
   - The program also maintains a record of all out-of-tolerance results detected throughout the month in a separate file.
   - The Pandas library was used for all data manipulation and Pywin32 was used to create copies of the original files for our records

Methods

3. When an out-of-tolerance result is detected, the program sends an email alert to a group of defined users.
   - The Pywin32 library was used to send out email alerts.
   - The program automatically runs at our defined frequency using Windows Task Scheduler on a desktop computer.



Daily CT QC Alert: 2021-02-24

New Fails/Warnings

Date	Machine	Test	Result
2021-02-23	AHSP Siemens CT	Water CT # Uniformity	WARNING

Current Blanks

Date	Machine	Test	Result
2021-02-16	Angeles Biograph	Daily CT # Check	Blank
2021-02-16	Angeles Biograph	Free of Artifacts	Blank
2021-02-14	CCC GE VCT	Weekly SMPTE	Blank
2021-02-19	ED Toshiba Genesis	Daily CT # Check	Blank
2021-02-19	ED Toshiba Genesis	Free of Artifacts	Blank

The email alert sent when the program detects an out-of-tolerance or blank result.

Results

The accuracy of the program was evaluated for 16 weeks, and the results were compared to human performance of the same task. In addition, the total number of missing records were compared before and after the implementation of the automated QC program to evaluate the behavior change of the technologists performing the QC.

- The results of a manual review of the QC records agreed with the results reported in the email alerts with the accuracy of 100%.
- For our enterprise health system with 16 CT scanners, implementing the automated program saves 60 minutes of a medical physicist's time per week, or 50 hours per year.
- The program detected missing entries that the human review did not capture.

Results

- After the first two weeks of implementation, the number of missing QC results detected each week decreased from 12 and 14 in the first and second week, respectively, to a median of 2 each week for the following 14 weeks.
- The continuous and detailed monitoring by the program in combination with the routine, weekly follow-up by the physicists led to more timely QC entries by the technologists and an overall decline in missing QC records.

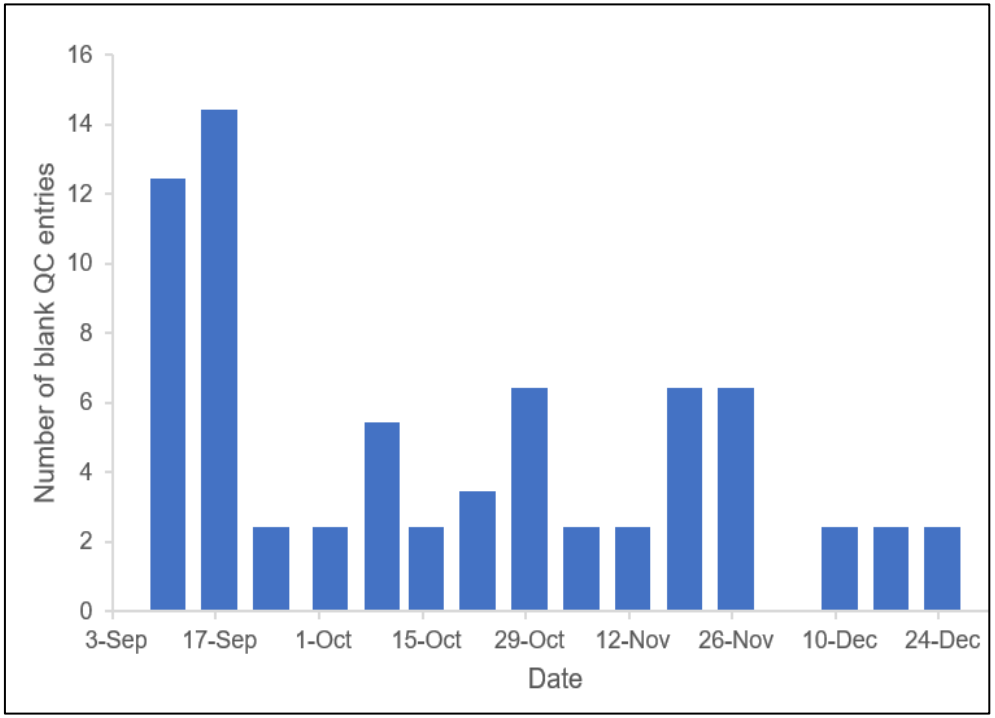


Figure C. The number of missing QC records reported each week.

Conclusions

We successfully implemented an automated method for CT QC documentation and review. This method not only increased the productivity of medical physicists by saving a significant amount of time and avoided human errors, but also drove behavioral changes of technologists which led to significantly reduced missing records.