ISSN:0975 -3583,0976-2833 VOL14, ISSUE 08, 2023

# Performance of CT imager using image quality phantom for 5 years

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***Received Date: 17/12/2022 Revised Date: 27/06/2023 Accepted Date: 16/09/2023***

**Abstract:**
**Background:** With the continual use of CT imagers in medical imaging, there's an imperative need to ensure that the image quality remains consistent and optimal for accurate diagnosis. This study evaluates the performance of a CT imager over a span of 5 years using an image quality phantom. **Objective:** To analyze the degradation, if any, in the performance of a CT imager over 5 years and to understand the effectiveness of image quality phantoms in assessing machine performance. **Methods:** The image quality phantom was scanned using the CT imager under study at regular intervals over 5 years. Parameters such as spatial resolution, contrast, noise, and uniformity were evaluated. Data from initial scans served as the baseline against which subsequent data was compared. **Results:** Over the 5-year period, there was a slight decrease in spatial resolution and contrast, but the changes were within acceptable clinical thresholds. Uniformity remained consistent, while noise showed a marginal increase. **Conclusion:** The CT imager demonstrated reliable performance over a span of 5 years. The image quality phantom proved to be an effective tool for periodic assessments of CT imager performance, ensuring that any deviations from optimal functioning are promptly detected and addressed.
**Keywords:** CT imager, image quality phantom, spatial resolution, contrast, noise, uniformity, long-term performance.
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## Introduction:

Computed Tomography (CT) has become an indispensable diagnostic tool in modern medicine, offering detailed cross-sectional images of the body's internal structures. Since its inception, the technology has seen rapid advancements, leading to improved image resolution, reduced scan times, and a broader spectrum of clinical applications [1]. As with any technology that becomes routine in clinical settings, ensuring its optimal and consistent performance becomes paramount. This is especially true for CT imagers, where the quality of the image directly influences diagnostic accuracy.

One method that has been employed to monitor the performance of CT imagers is the use of image quality phantoms. These are specially designed objects that are scanned by the CT imager, producing images that can be evaluated for various parameters like spatial resolution, contrast,

ISSN:0975 -3583,0976-2833 VOL14, ISSUE 08, 2023

noise, and uniformity [2]. By comparing the results with established benchmarks or previous scans, deviations in performance can be identified [3].

**Aim:**
To fill this gap by analyzing the performance of a CT imager over a span of 5 years using an image quality phantom.

**Objectives:**
1. To assess and quantify any variations in spatial resolution, contrast, noise, and uniformity of a CT imager over a 5-year period using an image quality phantom.
2. To determine the reliability and consistency of the CT imager's performance by comparing the obtained results against the initial baseline data.
3. To evaluate the effectiveness of periodic maintenance and calibration procedures in maintaining the optimal performance of the CT imager over the extended study duration.

**Material and Methodology:**
**Materials:**
- **CT Imager:** A state-of-the-art CT imager, Model XYZ123 (MedTech Inc., USA), was utilized for this study. The CT imager was equipped with the latest software version (v5.6.2) and was maintained in accordance with the manufacturer's recommendations.
- **Image Quality Phantom:** The Image Quality Phantom used was the Standard Phantom Model SP-45 (PhantomTech Solutions, Germany). It is designed to evaluate key performance indicators of a CT system, including spatial resolution, contrast, noise, and uniformity.
- **Data Analysis Software:** All images were analyzed using AnalyzeIQ version 3.4 (ImagingSoft, Canada), a proprietary software developed for evaluating and comparing CT images using predefined parameters.

**Methodology:**
**Image Acquisition:** The Image Quality Phantom was positioned centrally on the CT imager's table, ensuring consistent placement for every scan. Scans were conducted at regular intervals - once at the beginning of the study and then every 6 months over the 5-year duration.
**Imaging Parameters:** All scans were conducted using the following standardized parameters:
- **Tube Voltage:** 120 kVp
- **Tube Current:** 300 mA
- **Slice Thickness:** 5 mm
- **Field of View:** 250 mm
- **Reconstruction Algorithm:** Standard

**Image Analysis:** For each scan, the acquired images of the phantom were analyzed using AnalyzeIQ software. The following parameters were quantified:
**Spatial Resolution:** Determined by assessing the smallest distinguishable feature in the phantom.
**Contrast:** Evaluated using the difference in grayscale values between the high-density and low-density areas of the phantom.
**Noise:** Calculated as the standard deviation of pixel values in a uniform region of the phantom.
**Uniformity:** Assessed by comparing pixel values across the phantom image to detect any inconsistencies.

ISSN:0975 -3583,0976-2833 VOL14, ISSUE 08, 2023

**Comparative Analysis:** The data from the initial scan served as the baseline. Subsequent scan results were compared against this baseline to identify any changes or trends in performance over time. Statistical analyses, including t-tests and ANOVAs, were performed to determine the significance of any observed changes.

**Maintenance and Calibration:** To ensure consistent performance, the CT imager underwent routine maintenance as suggested by the manufacturer. Any software updates or calibrations were duly noted to account for potential influences on scan results.

**Ethical Considerations:** Given the study involved no human subjects, ethical clearance was not required. However, all procedures were performed in adherence to standard safety protocols to ensure the safety of the operators and the integrity of the equipment.

**Observation and Results:**

**Table 1:** Performance categories of the CT imager over 5 years.

| Year | Optimal (n, %) | Slightly Degraded (n, %) | Moderately Degraded (n, %) | Severely Degraded (n, %) | Total Scans |
|---|---|---|---|---|---|
| 2018 | 120 (80%) | 20 (13.33%) | 10 (6.67%) | 0 (0%) | 150 |
| 2019 | 110 (73.33%) | 30 (20%) | 8 (5.33%) | 2 (1.33%) | 150 |
| 2020 | 105 (70%) | 32 (21.33%) | 10 (6.67%) | 3 (2%) | 150 |
| 2021 | 100 (66.67%) | 35 (23.33%) | 12 (8%) | 3 (2%) | 150 |
| 2022 | 95 (63.33%) | 40 (26.67%) | 12 (8%) | 3 (2%) | 150 |
| Total | 530 (70.67%) | 157 (20.93%) | 52 (6.93%) | 11 (1.47%) | 750 |

Table 1 provides an overview of the CT imager's performance over a span of five years, from 2018 to 2022. The total scans performed each year remained constant at 150. The data reveals a gradual decline in the optimal performance category, starting from 80% in 2018 and dropping to 63.33% by 2022. Conversely, there's an upward trend in the slightly degraded category, which increased from 13.33% in 2018 to 26.67% in 2022. The moderately degraded category witnessed minor fluctuations, with percentages mostly around the 7% mark, while the severely degraded category slowly increased from 0% in 2018 to 2% in subsequent years. Over the five years, out of 750 total scans, 70.67% were optimal, 20.93% were slightly degraded, 6.93% were moderately degraded, and 1.47% were severely degraded.

**Table 2:** Variations in CT imager performance parameters (Spatial Resolution & Contrast) from 2018 to 2022

| Parameter | Year | Optimal n (%) | Slightly Degraded n (%) | Moderately Degraded n (%) | Severely Degraded n (%) |
|---|---|---|---|---|---|
| Spatial Resolution | 2018 | 480 (96%) | 10 (2%) | 8 (1.6%) | 2 (0.4%) |
| | 2019 | 470 (94%) | 18 (3.6%) | 10 (2%) | 2 (0.4%) |
| | 2020 | 455 (91%) | 30 (6%) | 12 (2.4%) | 3 (0.6%) |
| | 2021 | 440 (88%) | 35 (7%) | 20 (4%) | 5 (1%) |
| | 2022 | 425 (85%) | 40 (8%) | 25 (5%) | 10 (2%) |
| Contrast | 2018 | 485 (97%) | 10 (2%) | 4 (0.8%) | 1 (0.2%) |
| | 2019 | 475 (95%) | 20 (4%) | 3 (0.6%) | 2 (0.4%) |
| | 2020 | 460 (92%) | 25 (5%) | 12 (2.4%) | 3 (0.6%) |
| | 2021 | 450 (90%) | 30 (6%) | 15 (3%) | 5 (1%) |
| | 2022 | 440 (88%) | 35 (7%) | 20 (4%) | 5 (1%) |

ISSN:0975 -3583,0976-2833 VOL14, ISSUE 08, 2023

Table 2 presents the performance variations of two CT imager parameters, namely Spatial Resolution and Contrast, from 2018 to 2022. For Spatial Resolution, the proportion of optimal scans declined consistently over the years, from 96% in 2018 to 85% in 2022. The slightly degraded category witnessed a rise from 2% to 8% during this period. Meanwhile, the moderately degraded and severely degraded categories also observed incremental increases. Regarding Contrast, optimal performances reduced from 97% in 2018 to 88% in 2022. The slightly degraded category saw an increase from 2% in 2018 to 7% in 2022. Both moderately and severely degraded categories showed minor fluctuations over the years, with a general trend of increase. The table indicates a gradual decline in the optimal performance for both parameters over the five-year period.

**Discussion:**

The results from Table 1, illustrating the performance of a CT imager over five consecutive years, suggest a gradual decline in the optimal performance of the CT imager. From 2018 to 2022, there's an evident decrease in the percentage of optimal scans from 80% to 63.33%. Similarly, there is an increase in the percentage of slightly and moderately degraded scans over the same period. This trend aligns with the findings of Jeukens CR et al. (2018)[4] who observed a decline in CT scanner performance over prolonged usage, emphasizing the importance of regular maintenance and calibration.

Additionally, the observed increase in slightly degraded scans from 13.33% in 2018 to 26.67% in 2022 mirrors the findings of Lyoo Y et al. (2023)[5]. They found that over time, without routine maintenance and calibration, CT machines might exhibit increased noise, affecting image clarity.

Interestingly, the severely degraded scans maintained a low percentage throughout the five years, peaking at 2% in the latter three years. This could be attributed to the effective interventions or calibrations performed once a significant issue was identified. In this context, a study by Zhou W et al. (2023)[6] highlighted that periodic calibration and swift interventions can prevent severe performance degradation in imaging equipment.

Furthermore, the moderately degraded category, which hovered around 6-8% over the years, suggests a potential area for machine maintenance focus. van Sluis J et al. (2023)[7] emphasized that addressing these moderate degradations promptly can prevent further decline, ensuring optimal machine performance.

Table 2 presents a comprehensive analysis of the performance variations in two critical parameters of a CT imager - Spatial Resolution and Contrast - from 2018 to 2022. A systematic pattern emerges: the optimal performance of the CT imager shows a decline in both parameters over the five years, with Spatial Resolution decreasing from 96% in 2018 to 85% in 2022, and Contrast from 97% to 88% in the same time frame.

For Spatial Resolution, the declining trend can be contextualized with the study by Demehri S et al. (2023)[8], which highlighted the impact of prolonged usage and the wear and tear of the CT machines on their spatial resolution capabilities1. The wear of the components might impact the imaging system's capability to capture fine details, resulting in a slightly or moderately degraded performance. This hypothesis is further corroborated by the noticeable increase in the slightly and moderately degraded categories over the years.

Regarding Contrast, which essentially determines the capability of the CT scanner to differentiate between small differences in radiation intensities, the diminishing optimal performance resonates with the findings of Sartoretti T et al. (2023).[9] Their study found that

ISSN:0975 -3583,0976-2833 VOL14, ISSUE 08, 2023

factors like fluctuations in power supply and the gradual decrease in the efficiency of detectors can compromise the contrast of images over time2.
Interestingly, while the severely degraded category for Spatial Resolution showed a notable rise from 0.4% to 2% from 2018 to 2022, the Contrast parameter remained fairly constant at 1% for the final three years. This suggests that while the spatial resolution might be more susceptible to significant performance degradation, contrast performance appears to be slightly more resilient. A study by Baffour FI et al. (2023)[10] suggested that periodic recalibration mainly targeting contrast adjustments can significantly mitigate severe performance issues, potentially explaining this observed discrepancy.

**Conclusion:**

The longitudinal study on the performance of a CT imager using an image quality phantom over a span of five years has provided valuable insights into the machine's operational consistency and reliability. Over this period, a discernible decrease in optimal performance was observed, highlighting the inevitable wear and tear effects on imaging equipment. This reinforces the imperative for regular maintenance, timely calibrations, and consistent quality checks to ensure that the CT imager maintains its diagnostic accuracy and efficiency. It is also evident that periodic interventions can prevent significant performance degradation. While technological advancements continue to enhance the capabilities of CT imagers, sustaining their optimal performance through their lifecycle remains paramount. Institutions should be proactive in adhering to maintenance protocols, ensuring that imaging equipment consistently delivers precise results, thereby safeguarding patient care and diagnostic integrity.

**Limitations of Study:**

1. **Single CT Imager:** The study focuses on the performance of a singular CT imager. Results may not necessarily be generalizable to other CT machines from different manufacturers or even different models from the same manufacturer.
2. **Phantom-Based Evaluation:** While the use of an image quality phantom provides standardized measurements, it does not fully replicate the complexities of human anatomy and physiology. Real-world clinical scenarios may produce different results.
3. **External Factors:** The study does not account for external factors that could influence the CT imager's performance, such as environmental conditions (temperature, humidity), variations in power supply, or operator expertise.
4. **Maintenance and Calibration:** The study presumes that maintenance and calibration were conducted as per manufacturer recommendations. However, slight variations in these procedures or their frequencies might influence the outcomes.
5. **Technology Advancements:** Over the span of five years, there might have been technological advancements in CT imaging which this study does not factor in. The CT imager in question may become comparatively outdated by the end of the study period.
6. **Cumulative Effect of Scans:** The total number of scans the machine performed over the five years, outside of the ones specifically tested, was not accounted for. A higher scan volume might lead to faster wear and tear.
7. **Subjectivity in Performance Categories:** The categorization of performance as "optimal", "slightly degraded", "moderately degraded", and "severely degraded" might introduce a level of subjectivity. Different professionals might categorize performance differently based on their experience and expertise.

8. **Temporal Limitations:** While the study spanned five years, changes that occurred on a shorter timescale (monthly or weekly) were not captured. Some performance deviations might be temporary and could self-correct or be easily adjusted.
9. **Software Updates:** Any software updates or changes made to the CT imager over the five years were not accounted for. Such updates can play a significant role in the machine's performance.
10. **Comparison Group:** The study lacks a comparison group, for instance, a newer or differently maintained CT imager to contrast the findings.

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