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A Two-Year Retrospective of a Quantitative SPECT Quality Control Program

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ABSTRACT

Introduction
Nuclear medicine is undergoing a paradigm shift to produce images in units of activity concentration, analogous to PET imaging. Quantitative SPECT imaging requires system calibrations. In 2024, we formally incorporated routine quantitative calibrations and verification measurements into our comprehensive SPECT quality assurance (QA) program. Here we present a retrospective evaluation of the quantitative Tc-99m QA program for our eight Siemens Intevo Bold SPECT/CT systems.
Methods
Siemens xSPECT sensitivity calibrations for Tc-99m imaging were performed quarterly using NIST-traceable, long-lived Co-57 point sources. Subsequent verification measurements were performed using our standard ACR Jaszczak phantom preparation and acquisition protocol. Phantom data are reconstructed both quantitatively, to evaluate calibration accuracy, and non-quantitatively, to maintain consistency with existing QA trend analyses. Reported sensitivity values were compared to expected nominal values provided by Siemens, and measured total phantom activities were compared to known input total activities.
Results
A two-year retrospective evaluation of quantitative performance across our fleet demonstrates robust and stable calibration using Siemens xSPECT sources. Across the eight systems, sensitivity calibrations performed with NIST-traceable Co-57 sources remained consistent over time, with only three systems exhibiting sensitivity coefficient of variation (COV) greater than 1%, and a maximum observed COV of 2%.
Although Siemens defines internal trigger limits for sensitivity calibration, our institution implemented a more restrictive +/- 5% acceptance criterion for calibration verification. This threshold was only exceeded 3 times, each on separate systems. In all cases, the issue was resolved through replacement of the calibration source. Across all systems, the average verification error for any individual system did not exceed 4% (minimum average deviation of 1.8% and maximum deviation of 3.8%).
Conclusion
Quantitative SPECT calibration and verification has been successfully integrated into our clinical QA program, supporting reliable longitudinal quantitative performance in a multi-system clinic. Longitudinal evaluation of our Lu-177 QA program is underway.

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INTRODUCTION

BACKGROUND:
Quantitative SPECT imaging is increasingly being adopted into routine clinical practice. Similar to PET, quantitative SPECT images are reconstructed in units of activity concentration (Bq/mL), whereby an objective assessment of radiotracer uptake can be made. As the field of nuclear medicine continues to expand the use of therapeutic radiopharmaceuticals, the need for quantitative imaging and patient-specific dosimetry has grown substantially.

Reliable quantitative performance requires routine calibration and verification procedures to ensure consistency over time and across imaging systems. Despite the rapid expansion of theranostics quantitative imaging applications, limited data exist regarding the long-term performance of quantitative SPECT quality assurance programs.

This work presents a two-year retrospective evaluation of quantitative Tc-99m calibration and verification performance across an eight-system clinical fleet.

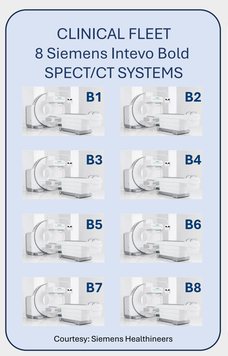
PURPOSE:
In 2024, our institution incorporated routine quantitative Tc-99m SPECT calibration and verification measurements into an established clinical quality assurance program encompassing eight Siemens Intevo Bold SPECT/CT systems. In 2025 we expanded our quantitative QC program to include quantitative Lu-177 on six of our systems.

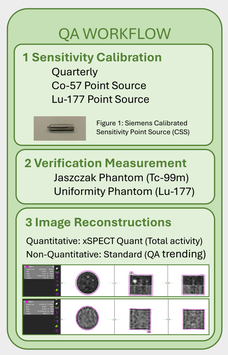
The objectives of this study were to:
- Evaluate long-term calibration stability across all systems
- Assess quantitative verification accuracy using standardized phantom measurements
- Establish institutional performance metrics for quantitative SPECT imaging
- Identify performance trends and potential failure modes requiring corrective action

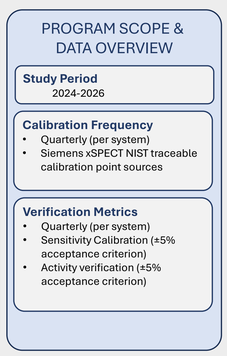
METHODS AND MATERIALS

CLINICAL FLEET:
The quantitative Tc-99m QC program was implemented on :
- Eight Siemens Intevo Bold SPECT/CT systems
- Routine clinical Tc-99m imaging workflows.

The quantitative Lu-177 QC program was implemented on :
- Six Siemens Intevo Bold SPECT/CT systems
- Routine clinical Lu-177 imaging workflows.







QUANTITATIVE CALIBRATION

SENSITIVITY CALIBRATION:
Quarterly Tc-99m and Lu-177 xSPECT sensitivity calibrations were performed using:
- NIST-traceable Co-57 (Tc-99m) and Se-75 (Lu-177) point sources
- Siemens xSPECT calibration workflow
- Manufacturer-recommended acquisition protocols

Measured sensitivity coefficients were compared with Siemens nominal sensitivity values to evaluate longitudinal stability and inter-system consistency

CALIBRATION VERIFICATION:
Tc-99m Verification
- Standard ACR Jaszczak phantom
- ACR-recommended phantom preparation and acquisition protocol
- Quantitative reconstruction using xSPECT Quant
- Standard clinical reconstruction to maintain consistency with existing QA trending analysis

Lu-177 Verification
- Uniformity phantom (6 L and 1 L) with known Lu-177 activity
- Clinical Lu-177 acquisition protocol
- Quantitative reconstruction using our clinical Lu-177 xSPECT Quant reconstruction protocol

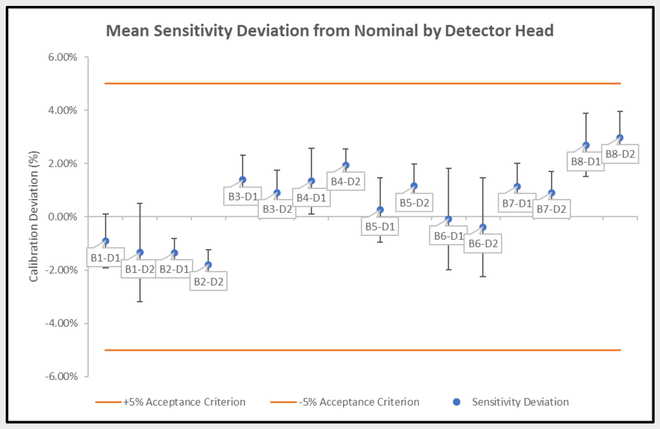


Figure 2:
Sensitivity calibration performance across sixteen detector heads from eight Siemens Intevo Bold SPECT/CT systems. Values represent mean percent deviation from the nominal sensitivity coefficient for each detector head over 2 years of quarterly calibrations. Error bars represent ±1 standard deviation across the calibration measurements orange lines indicate our institutional ±5% acceptance criteria.

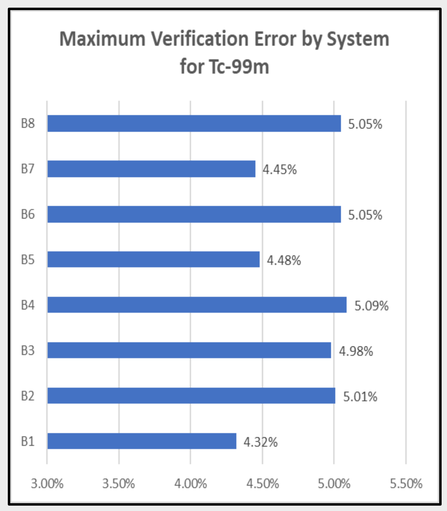


Figure 3:
Maximum absolute verification error observed for each SPECT/CT system during the two-year evaluation period. The largest observed deviation was 5.09%

DISCUSSION

The successful implementation of quantitative SPECT imaging requires routine calibration and verification procedures to ensure consistent activity quantification and support of high-quality patient care. Although quantitative SPECT imaging has been rapidly adopted in recent years, longitudinal evaluations of quantitative performance remain limited. Such evaluations are essential for understanding system stability, identifying performance drift, and ensuring quantitative accuracy over time.

Over the two-year evaluation period, all eight Siemens Intevo Bold SPECT/CT systems demonstrated stable quantitative performance. Sensitivity calibration measurements remained highly reproducible, as shown in Figure 2, with the mean sensitivity deviations remaining within our internal ±5% action limit for all scanners. These findings demonstrate the long-term stability of the Siemens xSPECT calibration workflow across a large clinical fleet.

Verification measurements further demonstrated excellent agreement between measured and known phantom activity. Although five measurements marginally exceeded our institutional ±5% acceptance criterion, the maximum observed deviation was only 5.09%. Although these exceedences were infrequent and small in magnitude, they were flagged. No corrective action was implemented, but they offered additional data points for assessing long term stability of the quantitative calibration and verification process.

Building on the success of our quantitative Tc-99m SPECT program, routine quarterly Lu-177 quantitative calibrations and verification measurements were incorporated into the institutional quality assurance program in 2024/2025. Preliminary results demonstrate similar quantitative stability and support the continued expansion of quantitative imaging workflows.
Lu-177 Quantitative Verification Summary:
- Only one verification measurement exceeded our institutional ±5% acceptance criterion.
- The maximum observed verification error 5.6%.
- Recently in 2026, an internal study was conducted assessing the performance equivalence of switching from the 6 L uniformity phantom to a simple 1 L plastic bottle for quantitative calibration accuracy, which demonstrated comparable performance between both phantoms. These findings suggest a simple 1 L bottle phantom may provide a simpler and practical alternative for routine Lu-177 quantitative verification.

CONCLUSIONS

The integration of quantitative calibration utilizing the Siemens xSPECT NIST traceable calibration sources into an established QA program provides a robust framework for emerging quantitative SPECT applications. Over two years of evaluation, stable quantitative SPECT performance was maintained across our fleet, demonstrating that quantitative SPECT can be successfully implemented and sustained across multiple systems within a large clinical enterprise. These findings support the continued expansion of quantitative nuclear medicine imaging for routine clinical practice.

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