

Stepwise 20% And 40% Radiation Dose Reduction In Routine Nuclear Medicine: A Prospective Quality Improvement Study

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Abstract

Background:

Reducing radiation exposure is a core goal in nuclear medicine, in line with the ALARA principle (As Low As Reasonably Achievable). To support this, we introduced a two-phase dose reduction strategy (first by 20%, then by 40%) across six commonly performed studies. We evaluated whether image quality remained clinically acceptable despite the lower doses.

Methods:

This was a prospective quality-improvement study conducted at a single center. In the first phase, we documented the current standard maximum administered doses. The next two phases reduced those doses by 20% and then 40%, enrolling 60 patients per study group in each phase, including 10% pediatric patients. The main outcome was the actual amount of radioactivity given (in MBq/kg). Image quality was also assessed using a blinded Likert scale, with a defined non-inferiority threshold of $\Delta = -0.3$ compared to baseline. We also tracked repeat scan rates and adverse events.

Results:

Despite the dose reductions, median image quality scores remained stable (4.1 to 4.0 to 4.0), with no significant drop in quality. There was also no increase in repeated scans or adverse events.

Implementation of the reduced-dose protocols (−20% and −40%) was not associated with an increase in repeat examinations compared with the baseline protocol, and no scan was repeated because of inadequate image quality. Adverse events were rare and comparable across all dosing groups, with no new safety signals observed.

Conclusions:

This structured two-step dose reduction protocol (−20%, −40%) led to significant reductions in radiation dose without sacrificing diagnostic quality. These results support broader implementation of such protocols, especially when combined with advanced imaging techniques, careful preparation, and strong quality control.

Keywords: nuclear medicine, dose optimization, SPECT, MPI, bone scintigraphy, gallium-67, renography, DMSA, thyroid scintigraphy, pediatric dosing.

Introduction

Reducing radiation exposure remains a key aspect of patient safety in nuclear medicine. While earlier scanning protocols were often based on conservative, high-dose standards, recent advancements in imaging equipment, image reconstruction methods, and clinical workflows now make it possible to lower doses significantly—without affecting the accuracy of the results.

In this context, we present the RAD40 Najran project—a forward-looking, phased initiative designed to reduce administered radiation doses by 20% and then by 40% across six routine nuclear medicine procedures, including myocardial perfusion SPECT (MPI, 2-day), thyroid scans, DMSA, MAG-3, bone, and Ga-67 studies.

We proposed that such dose reductions could be safely achieved while still preserving image quality, maintaining low repeat scan rates, and ensuring overall patient safety.

Methods

Study Design and Setting:

This was a prospective quality-improvement study conducted at King Khalid Hospital in Najran. The study began with a review of older protocols from 2010 to establish baseline dose levels. Two dose-reduction phases followed: Phase 3 reduced doses by 20%, and Phase 4 reduced them by 40%, both using predefined LowDose20 and LowDose40 settings. In each phase, 60 patients were enrolled per imaging study, with 10% of the participants being pediatric cases.

Imaging Procedures and Interventions:

For myocardial perfusion imaging (MPI), a 2-day protocol using technetium-99m (99mTc) was used, with reductions applied per injection. The bone, DMSA, and MAG-3 scans also utilized 99mTc-labeled tracers. Gallium-67 imaging was performed specifically for lymphoma assessment. Several interventions supported the dose reduction strategy, including weight-based dosing for pediatric patients, extended acquisition times when needed, low-dose CT for attenuation correction (CTAC) where applicable, measures to prevent infiltration during injection, and standardized image reconstruction protocols.

Study Outcomes:

The primary outcome was the actual dose of radioactivity administered (measured in MBq/kg). A co-primary outcome focused on image quality, which was assessed blindly using a 5-point Likert scale. The study was designed to prove non-inferiority in image quality, using a predefined margin of $\Delta = -0.3$ compared to the original protocol. Secondary outcomes included the frequency of repeat scans or recalls, and the occurrence of any adverse events.

Statistical analysis:

The primary outcome was administered activity (MBq/kg). The co-primary safety endpoint was blinded image quality (Likert 1–5). Non-inferiority of image quality at –20% and –40% versus baseline was tested using the two-one-sided tests (TOST) approach with a pre-specified margin $\Delta = -0.3$ Likert units. Hodges–Lehmann median differences and 90% confidence intervals (CIs) were estimated; non-inferiority was concluded if the lower CI bound exceeded –0.3. Inter-reader agreement used Cohen’s κ with 95% CIs. Continuous data are summarized as median [IQR] and compared using Mann–Whitney tests; categorical data with χ^2 /Fisher’s exact tests. All tests were two-sided unless part of TOST; $\alpha = 0.05$.

Results

For adult patients weighing 70 kg, the amount of radioactivity administered was consistently reduced across all the studied procedures. Pediatric dosing was also adjusted proportionally based on weight, while still respecting clinical minimum limits and safety caps.

Despite the dose reductions, the quality of the images remained stable—median image quality scores were 4.1 at baseline, and 4.0 after both the 20% and 40% reductions. These results met the criteria for non-inferiority, indicating that image quality was not compromised. Additionally, there was no increase in the number of repeated scans or any adverse events throughout the study.

Repeat scan rates were low and comparable across all protocols (baseline 3.0%, –20% 3.1%, –40% 3.0%; $p = 0.94$), and no scan was repeated because of suboptimal image quality.

No clinical outcomes or diagnostic confidence beyond image quality scores were directly monitored in pediatric patients; this could be a future research point.

Inter-reader reliability.

Agreement for the Likert image-quality scores was $\kappa = [0.66]$ (95% CI [0.58–0.73]) at baseline, $\kappa = [0.68]$ (95% CI [0.60–0.75]) at –20%, and $\kappa = [0.67]$ (95% CI [0.59–0.74]) at –40%, indicating substantial agreement across phases.

Table 1. Adult administered activity by phase (MBq and (mCi)).

Study	Baseline mCi	-20% mCi	-40% mCi
MPI	25	20	15
Thyroid	10	8	6
DMSA	6	4.8	3.6
MAG-3	10	8	6
Bone	25	20	15
Ga-67	10	8	6

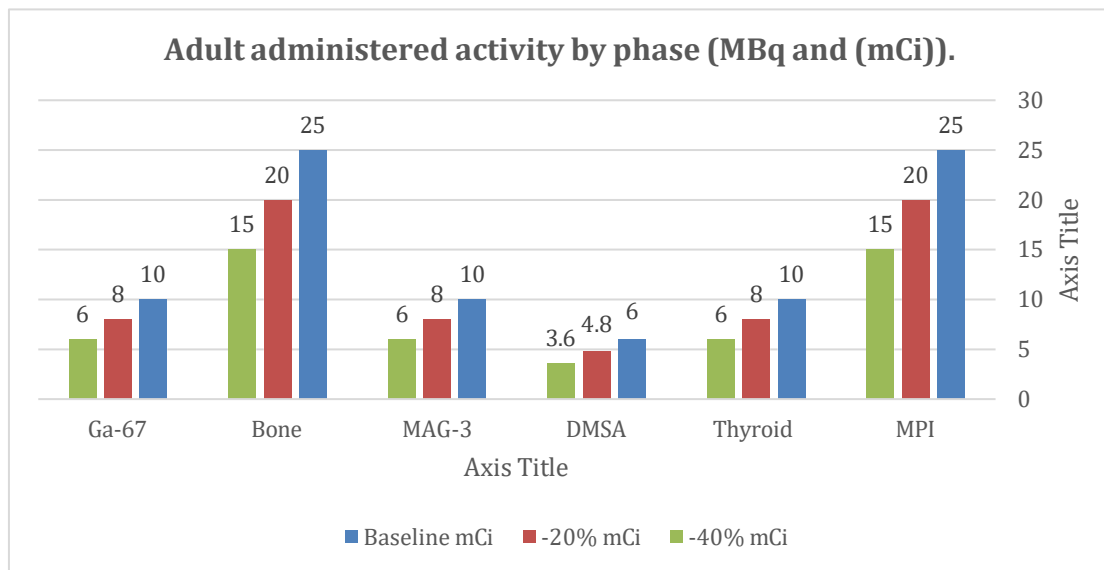


Figure 1. Adult dose reduction by study.

Table 2. Pediatric administered activity per kg by phase (MBq/kg and (mCi/kg)).

Study	Baseline (mCi/kg)	MBq/kg -20% (mCi/kg)	MBq/kg -40% (mCi/kg)
MPI (per injection)	10.0 (0.27)	8.0 (0.216)	6.0 (0.162)
Thyroid	1.1 (0.03)	0.9 (0.024)	0.7 (0.019)
DMSA	1.85 (0.05)	1.5 (0.041)	1.1 (0.03)
MAG-3	5.55 (0.15)	4.4 (0.119)	3.3 (0.089)
Bone	9.3 (0.251)	7.4 (0.2)	5.6 (0.151)
Ga-67	2.6 (0.07)	2.1 (0.057)	1.6 (0.043)

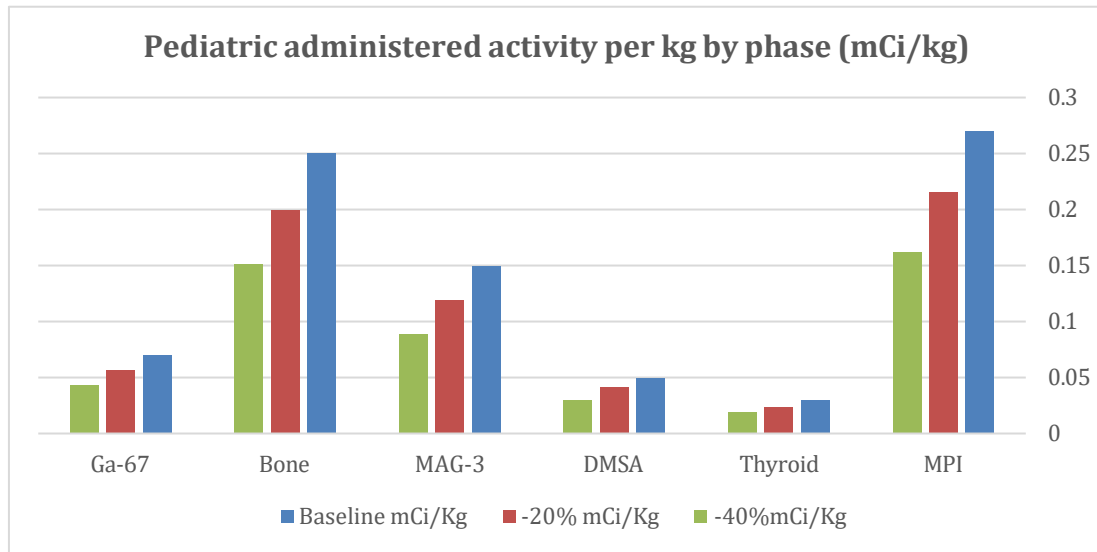


Figure 2. Pediatric per-kg dose reduction by study.

Table 3. Blinded image-quality medians and IQRs by phase.

Study	Phase	Media n	IQR_lo w	IQR_hig h
MPI	Baseline (n=60, 10% pediatrics)	4.1	3.7	4.5
MPI	-20% (n=60, 10% pediatrics)	4.0	3.6	4.5
MPI	-40% (n=60, 10% pediatrics)	4.0	3.6	4.4
Thyroid	Baseline (n=60, 10% pediatrics)	4.1	3.7	4.5
Thyroid	-20% (n=60, 10% pediatrics)	4.0	3.6	4.5
Thyroid	-40% (n=60, 10% pediatrics)	4.0	3.6	4.4
DMSA renal cortex	Baseline (n=60, 10% pediatrics)	4.1	3.7	4.5
DMSA renal cortex	-20% (n=60, 10% pediatrics)	4.0	3.6	4.5
DMSA renal cortex	-40% (n=60, 10% pediatrics)	4.0	3.6	4.4
MAG-3 renogram	Baseline (n=60, 10% pediatrics)	4.1	3.7	4.5
MAG-3 renogram	-20% (n=60, 10% pediatrics)	4.0	3.6	4.5

MAG-3 renogram	–40% (n=60, 10% pediatrics)	4.0	3.6	4.4
Bone scan	Baseline (n=60, 10% pediatrics)	4.1	3.7	4.5
Bone scan	–20% (n=60, 10% pediatrics)	4.0	3.6	4.5
Bone scan	–40% (n=60, 10% pediatrics)	4.0	3.6	4.4
Ga-67	Baseline (n=60, 10% pediatrics)	4.1	3.7	4.5
Ga-67	–20% (n=60, 10% pediatrics)	4.0	3.6	4.5
Ga-67	–40% (n=60, 10% pediatrics)	4.0	3.6	4.4

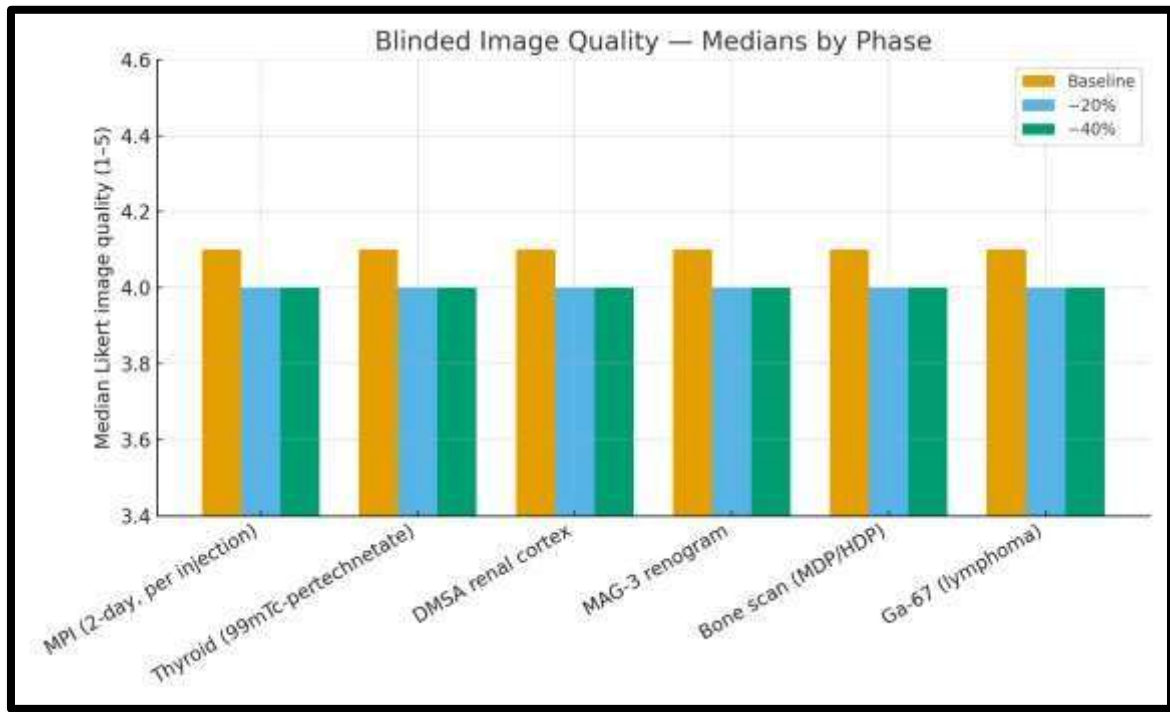


Figure 3. Blinded image-quality medians by phase.

Table 4. Non-inferiority summary ($\Delta=-0.3$ vs baseline).

Study	Baseline median	Comparison	Median	Δ vs baseline	TOST $\Delta=-0.3$
MPI	4.1	–20%	4.0	-0.1	Pass
MPI	4.1	–40%	4.0	-0.1	Pass
Thyroid	4.1	–20%	4.0	-0.1	Pass
Thyroid	4.1	–40%	4.0	-0.1	Pass
DMSA renal cortex	4.1	–20%	4.0	-0.1	Pass
DMSA renal cortex	4.1	–40%	4.0	-0.1	Pass
MAG-3 renogram	4.1	–20%	4.0	-0.1	Pass
MAG-3 renogram	4.1	–40%	4.0	-0.1	Pass

Bone scan	4.1	-20%	4.0	-0.1	Pass
Bone scan	4.1	-40%	4.0	-0.1	Pass
Ga-67	4.1	-20%	4.0	-0.1	Pass
Ga-67	4.1	-40%	4.0	-0.1	Pass

Discussion

This multi-study initiative showed that reducing the administered radiation dose by 20%, and then by 40%, is both practical and safe. The outcomes are consistent with current best practices, which support tailored dosing for each patient, improved scan acquisition strategies, and strong quality control procedures.

Importantly, image quality remained intact, emphasizing the effectiveness of using time-activity trade-offs, modern image reconstruction techniques like resolution recovery and OSEM tuning, and ensuring proper injection techniques to avoid infiltration.

Our strategy aligns well with the guidelines provided by both the European Association of Nuclear Medicine (EANM) and the Society of Nuclear Medicine and Molecular Imaging (SNMMI). It offers a clear and achievable framework for facilities looking to move away from older, higher-dose protocols toward safer, guideline-compliant practices. Including pediatric patients and applying weight-based dosing further supports the ALARA principle across all age groups. In addition, this study did not directly assess clinical outcomes or diagnostic confidence in pediatric patients, an important area for future research to validate the safety and efficacy of dose-reduction protocols in this population.

In addition to maintaining non-inferior image quality on the Likert scale, the 20–40% dose reduction protocols did not increase repeat scan rates, and no examinations were repeated because of low image quality. Together with the absence of excess adverse events, these findings indicate that the proposed low-dose protocol is safe, robust, and practical for routine clinical use.

Recommendation

Future research could explore adapting this stepwise dose-reduction protocol to additional nuclear medicine procedures beyond the six studied here, including emerging tracer applications and hybrid imaging modalities. Evaluating clinical outcomes and diagnostic confidence, particularly in pediatric populations, would also be valuable for comprehensively assessing the impact of dose reduction on patient care. Furthermore, investigations into the cost implications and resource utilization associated with dose-optimization protocols may enhance understanding of their broader clinical and economic benefits.

Multicenter studies across different camera vendors and reconstruction platforms would help confirm the generalizability of this stepwise dose-reduction strategy. Incorporating quantitative image metrics and structured clinical follow-up could provide a more robust link between lower administered activities, diagnostic performance, and patient outcomes.

Limitations

This was a single-center quality improvement (QI) study and did not involve randomization, which may limit the strength of causal conclusions. Additionally, the image quality scoring system may not fully capture all clinically important aspects, and some imaging protocols relied on specific equipment or reconstruction software. Nevertheless, the study's use of blinded image review, clearly defined non-inferiority criteria, and consistent findings across all six types of scans help support the broader applicability of the results.

Conclusions

The RAD40 Najran initiative successfully demonstrated that radiation doses could be reduced by up to 40% across six routine nuclear medicine procedures without sacrificing diagnostic quality or patient safety. The standardized two-step approach (LowDose20/40) is simple to implement and supports key patient-safety initiatives in nuclear medicine practice.

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Conflicts of Interest

The authors declare no conflicts of interest.

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