2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

CBCT Imaging Optimization, Towards Establishment of Dose Reference Levels

Parham Alaei, PhD[1]; Sebastien Gros, PhD[2]
[1]University of Minnesota, Minneapolis, MN; [2]Loyola University, Chicago, IL

ABSTRACT

Despite widespread use of kilovoltage cone beam computed tomography (CBCT), variations in clinical implementation of CBCT exist, and default imaging protocols are often used for patient imaging, irrespective of patient size or imaging intent.

Imaging protocol optimization, however, is essential to ensure adherence to ALARA principles without compromising patient positioning accuracy.

This work summarizes preliminary CBCT protocol optimization efforts as a necessary step before meaningful development of radiotherapy-specific dose reference levels (DRL_RT).

These optimization efforts help ensure that future reference levels reflect optimized, task-specific imaging practices rather than default or non-optimized protocols.

CONTACT

Parham Alaei
alaei001@umn.edu

INTRODUCTION

Imaging dose optimization in radiation therapy remains inconsistently implemented despite recommendations from AAPM TG-180, ESTRO Physics Workshop IGRT working group (Wilson et al. 2025), and the ICRP TG-116 guidance supporting the establishment of dose reference levels (DRL_RT) for radiotherapy imaging. A key limitation for this has been the lack of practical workflows linking phantom-based optimization, quantitative image quality assessment, and clinical validation.

This work addresses this gap through real-world CBCT optimization case studies that demonstrate how radiological protection principles can be applied in routine clinical practice and how local, task-specific, optimization can serve as a prerequisite to meaningful DRL_RT development. The emphasis is placed on imaging intent, patient-specific considerations, and the role of physicists in guiding protocol selection and standardization, providing a practical framework to support local optimization efforts, or to compare against future DRL_RT values.

METHODS AND MATERIALS

Kilovoltage CBCT imaging optimization studies from two institutions are presented. Imaging protocols were modified by reducing the current–time product (mAs) and/or the number of projection frames. Image quality was evaluated using both qualitative and quantitative assessments, followed by clinical image review from multidisciplinary teams composed of medical physicists, radiation oncologists and radiation therapists. Qualitative analysis examined the visibility of targets and anatomical landmarks, while quantitative metrics included image noise, contrast, visibility, and registration accuracy.

For pelvis and extremity imaging, progressive reductions in mAs and/or projection number were assessed using phantom measurements alongside clinical image review, allowing protocol changes to be anchored to specific imaging tasks rather than image quality metrics alone.

RESULTS

Optimization examples illustrate how CBCT protocol modifications were evaluated and selected in routine clinical practice.

Qualitative image assessments revealed increased noise with mAs reduction, and streaking and aliasing artifacts with frame number reduction. However, these did not necessarily render the lower dose protocols unusable, particularly when the intent of imaging was alignment based on bony or external anatomy.

Quantitative analyses showed degradation of certain image quality metrics, such as noise, low contrast resolution, and visibility, with minimal effect on high contrast resolution and geometric fidelity. The impact of dose reduction on image registration accuracy remained within clinically acceptable limits across optimized protocols as shown in Table 1. Figures 1 and 2 illustrate CBCT image optimization for pelvic and extremity imaging.

	Lat.	Post.	Long.	Yaw	Pitch	Roll
Default Protocol	1.4	0.6	0.8	0.8	0.1	0.1
25% Dose Reduction	1.4	0.5	0.8	0.8	0.1	0.2
40% Dose Reduction	1.4	0.6	0.8	0.8	0.1	0.2
60% Dose Reduction	1.4	0.6	0.8	0.8	0.1	0.2

Table 1: Image registration shifts for default and reduced-dose protocols determined using Rando phantom (translations in cm, rotations in degrees)

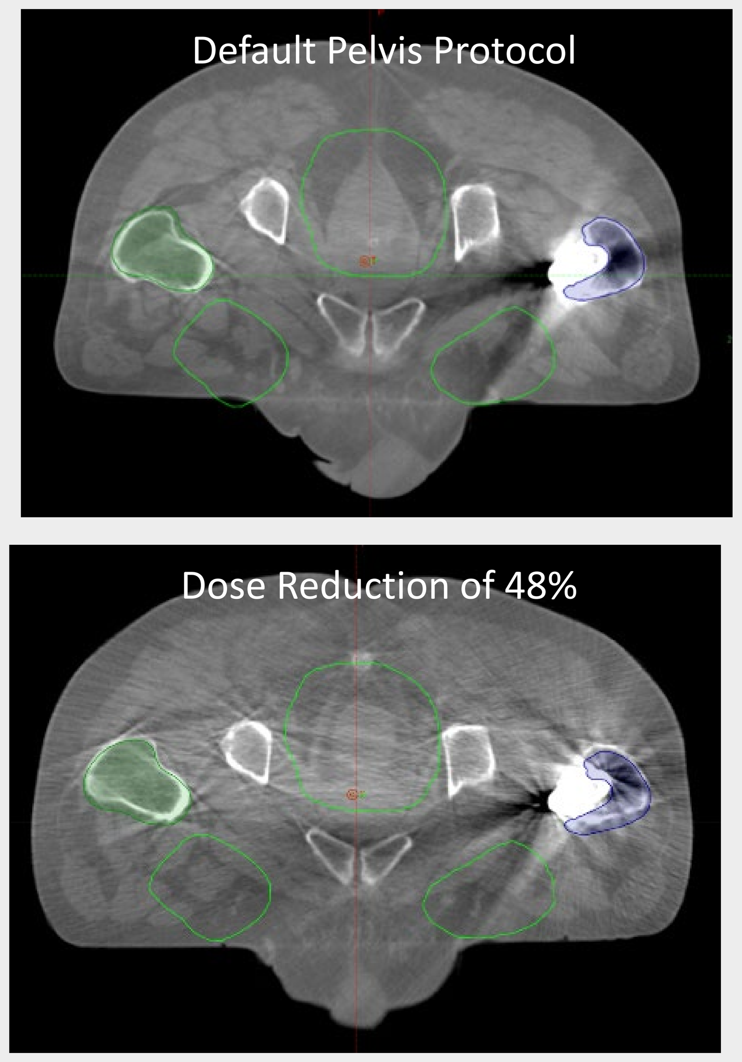

Figure 1: An example of optimization of CBCT protocol for the treatment of pelvis on a Varian Truebeam. In this case the intent of the imaging was soft tissue and bony alignment and using a low-dose protocol provided appropriate shifts as well as acceptable image quality for the clinicians. Phantom study of the same protocols indicated a noise increase of 63%.

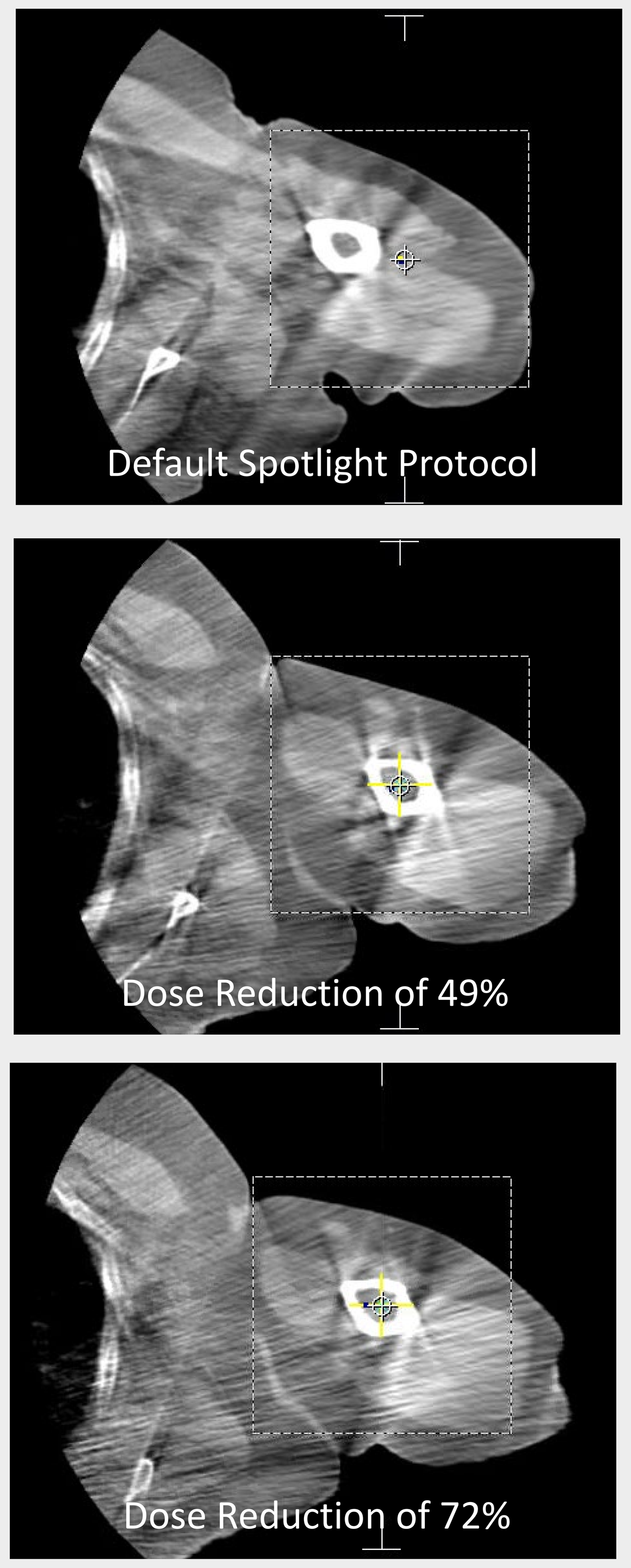

Figure 2: An example of optimization of CBCT protocol for the treatment of left arm on a Varian Truebeam. In this case the intent of the imaging was alignment of humerus and external surface of the arm, and using low dose protocols provided appropriate shifts as well as acceptable image quality for the clinicians. Phantom study of the same protocols indicated a noise increase of ~36% and 86%, for the two low dose protocols, respectively.

CONCLUSIONS

CBCT protocol optimization is warranted where low contrast resolution is not critical, and for smaller patients. Phantom studies can serve as a foundation for evaluating altered protocols, but patient-based validation is essential to develop clinically relevant protocols. Quantitative image quality and registration accuracy metrics can guide optimization and assess protocol performance; however, imaging intent often dictates the balance between dose, image quality and clinical utility. These studies provide a necessary first step toward clinically meaningful DRL_RT development for CBCT imaging.

References:

AAPM TG-180: doi: 10.1002/mp.12824

Wilson et al.: doi.org/10.1016/j.radonc.2025.110958