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

Evaluation of Radiation Dose to Thoracic Organs from 3D versus 4D CBCT Using Radiophotoluminescent Glass Dosimeters

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ABSTRACT

Four-dimensional cone-beam computed tomography (4D-CBCT) provides respiratory motion-resolved imaging for thoracic image-guided radiotherapy but may increase imaging dose compared with three-dimensional CBCT (3D-CBCT). This study compared thoracic organ doses from 3D- and 4D-CBCT using radiophotoluminescent glass dosimeters (RPLGDs). An Alderson Rando anthropomorphic phantom was equipped with GD-352M RPLGDs positioned in the lungs, heart, esophagus, thyroid, thymus, breast, and skin. Standard clinical 3D-CBCT (125 kV, 270 mAs) and 4D-CBCT (125 kV, 671 mAs) scans were acquired using a Varian TrueBeam linear accelerator. Compared with 3D-CBCT, 4D-CBCT increased doses to the heart (5.1–15.0 mGy), skin (5.8–12.9 mGy), thymus (6.2–12.3 mGy), lungs (5.8–10.6 mGy), and breast (4.3–8.0 mGy), whereas doses to the esophagus and thyroid decreased because these organs were partially outside the imaging field of view. Overall, 4D-CBCT delivered approximately twofold higher doses to most thoracic organs than 3D-CBCT.

INTRODUCTION

Cone-beam computed tomography (CBCT) is widely used for image-guided radiotherapy (IGRT) to improve treatment accuracy. Four-dimensional cone-beam computed tomography (4D-CBCT) provides respiratory motion-resolved imaging for thoracic treatments, enabling more accurate target localization than conventional three-dimensional CBCT (3D-CBCT). However, the longer acquisition time and increased number of projections may result in higher imaging doses, and quantitative organ dose data remain limited. This study compared thoracic organ doses from 3D- and 4D-CBCT using radiophotoluminescent glass dosimeters (RPLGDs).

METHODS AND MATERIALS

Imaging dose measurements were performed using calibrated RPLGDs model GD-352M in Alderson Rando anthropomorphic phantom instrumented with at 70 kVp (HVL: 2.9 mm Al). Dosimeters were placed in thoracic organs, including the lungs, heart, esophagus, thyroid, thymus, breast, and skin. Standard clinical 3D-CBCT and 4D-CBCT protocols as presents in Table 1. were delivered using a Varian TrueBeam linear accelerator as presents in Figure 1. Organ doses were measured and compared between imaging protocols.

Table 1. Preset protocol for kV CBCT thorax modes

CBCT mode	kV	mAs	$CTDI_{vol}$ (mGy)	DLP (mGy*cm)
3D Thorax	125	270	4.0	86.3
4D Thorax	125	671	9.9	214.8

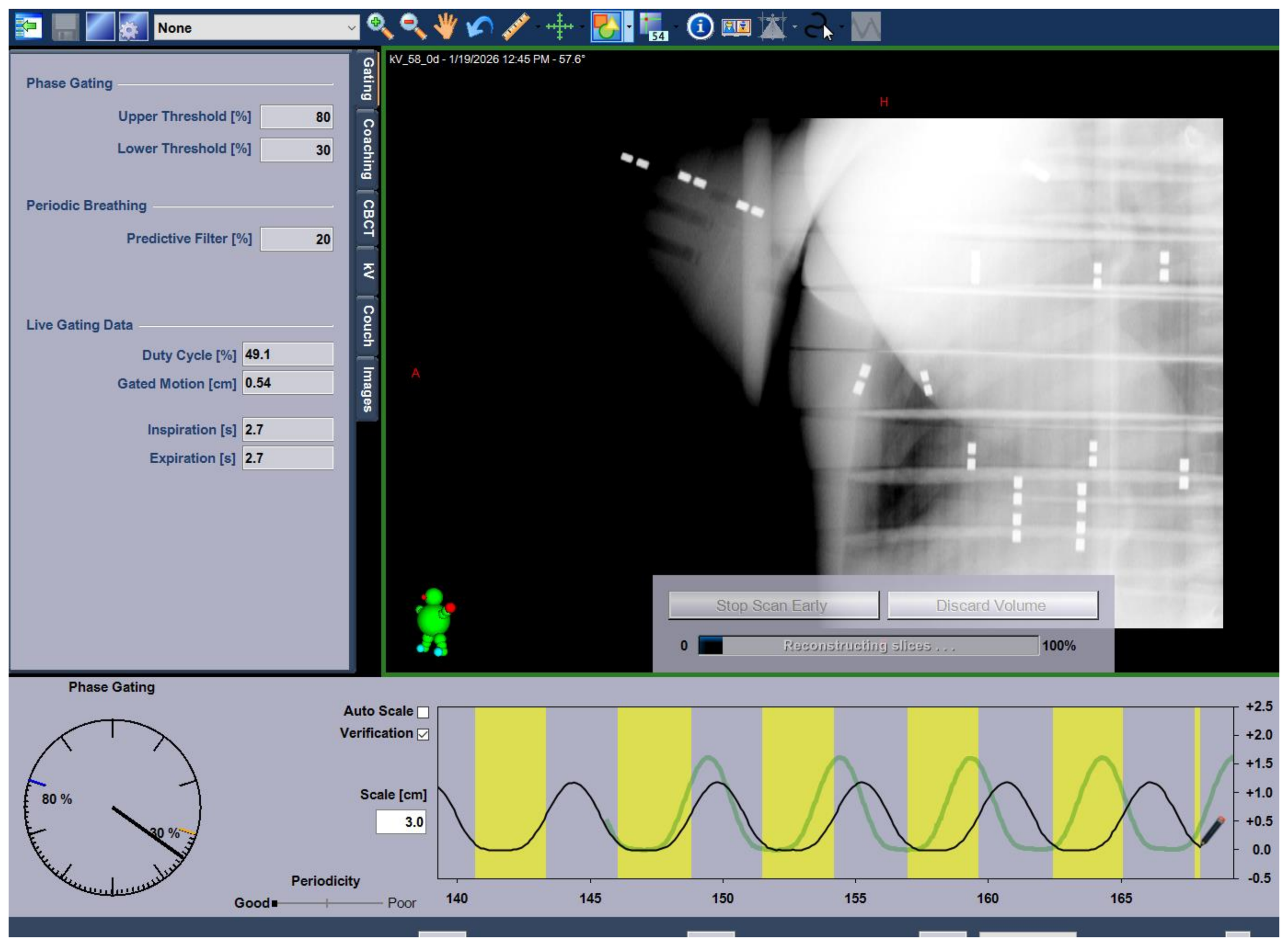

Figure 1. 4D-CBCT acquisition using a Rando phantom with GD-352M dosimeters

RESULTS

For 3D-CBCT, organ doses ranged from 2.4 to 6.2 mGy, whereas 4D-CBCT yielded doses of 1.8–15.0 mGy, with higher doses observed in most thoracic organs except the esophagus and thyroid as presents in chart 1.

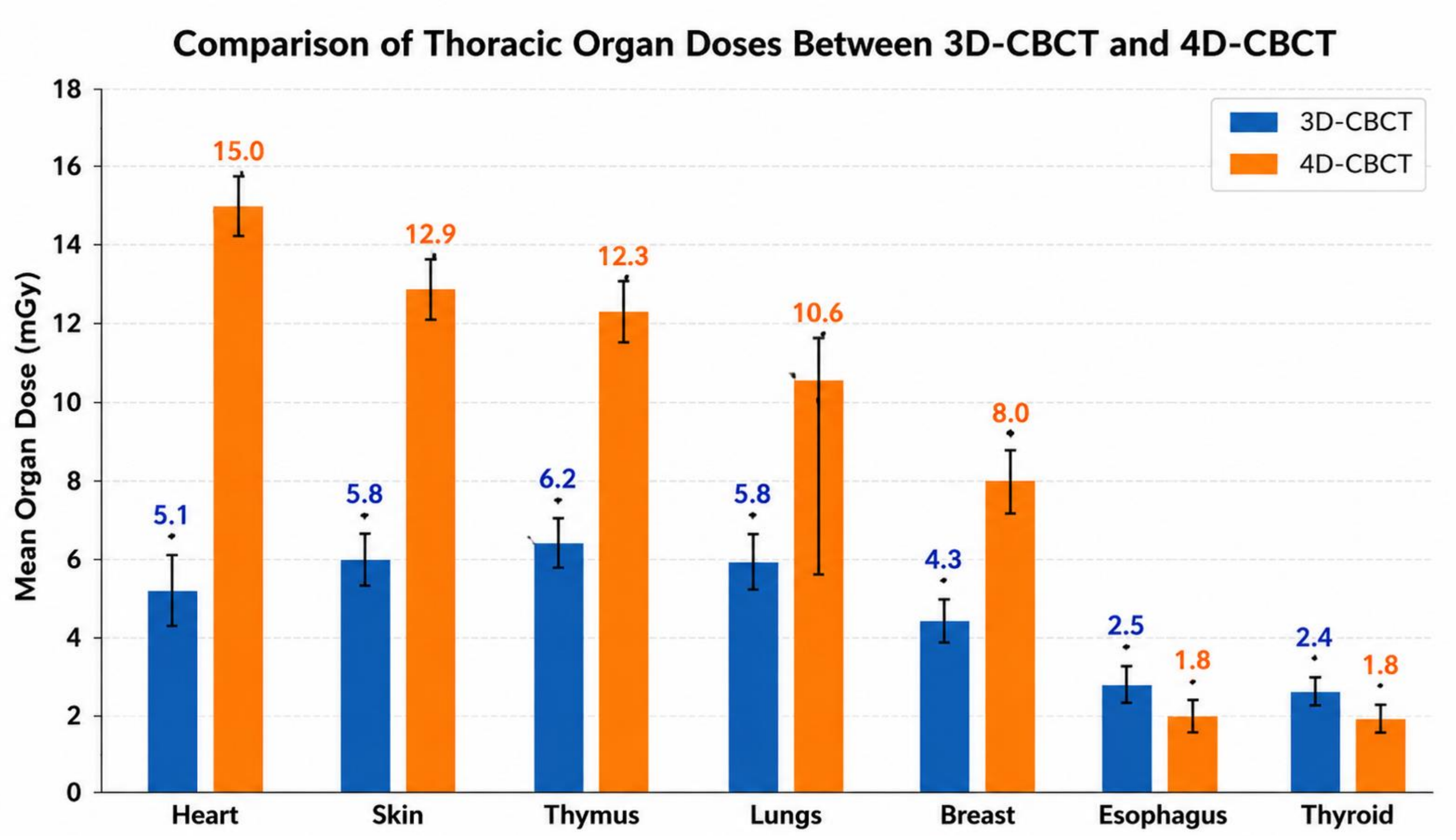

Chart 1. Comparison of thoracic organ doses between 3D-CBCT and 4D-CBCT

DISCUSSION

Our study demonstrated that 4D-CBCT delivered higher radiation doses to most thoracic organs than conventional 3D-CBCT, particularly in the heart, lungs, thymus, skin, and breast. These findings are consistent with those reported by Wu et al.[1], who demonstrated that respiratory-correlated 4D-CBCT results in higher concomitant imaging doses because of prolonged acquisition time, increased projection numbers, and higher exposure. The measured lung dose of 5.8 mGy for 3D-CBCT is comparable with values reported in previous phantom studies using kilovoltage CBCT systems [2–4]. For 4D-CBCT, the lung dose increased to 10.6 mGy, consistent with the findings of Wu et al. Similarly, the heart dose reached 15.0 mGy, representing the greatest increase among the evaluated organs and reflecting its central position within the imaging field. Unlike most thoracic organs, the esophagus and thyroid received lower doses during 4D-CBCT than during 3D-CBCT. This observation differs from the general trend reported by Wu et al. and is most likely explained by differences in imaging field of view, scan length, and phantom positioning.

CONCLUSIONS

4D-CBCT imaging doses are approximately twofold higher than 3D-CBCT, this increase may be clinically justified by improved image quality and respiratory motion information. These findings highlight the importance of imaging protocol optimization to balance IGRT accuracy and patient dose and support the use of RPLGDs as a reliable tool for CBCT dose assessment in thoracic radiotherapy.

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