



# Cone beam computed tomography—the need for future guidance

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Cone beam computed tomography (CBCT) represents an important radiologic advancement for generating volumetric images through a process of tomographic reconstruction (1,2). Increasingly, this technique is being used in on-line image guidance during radiation treatment delivery, and for diagnosis and treatment in interventional radiology (3,4).

In contrast to traditional CT scans, which uses a fan-shaped, anode X-ray beam, CBCT employs a round or rectangular cone-shaped beam with an area detector (versus a linear group of detectors) (5). The cone-beam method has relatively short scan times (~1 min) yet yields high quality images with sub-millimeter resolution and high dimensional accuracy (i.e., 3D volumetric data in axial, sagittal, and coronal planes). While radiation emanating from a standard CBCT is considerably lower (on the order of 10-fold less) than conventional CT scans, the levels are not inconsequential and well-exceed daily background amounts of radiation in the natural environment (~8.2 µSv per day in the United States) (5,6). Furthermore, some CBCT scanners use intensified X-ray sources that output substantially higher levels of radiation. Accordingly, clinicians and technical staff should err on the side of caution when routinely performing CBCT scans.

This minimally invasive imaging technique provides several benefits, including guidance for radiation therapy and as an important alternative to open surgery and biopsy in many applications. When administering radiation therapy, a key challenge is identifying disease volume while

avoiding nearby normal tissue (7). Owing to the relatively short acquisition time of CBCT, this imaging modality is ideal for efficiently monitoring ongoing tumor volume changes over the course of treatment and is routinely used during radiation treatment delivery. The use of CBCT in such settings is even more important for a highly mobile target like lung cancer to make radiation treatment delivery more accurate. The use of CBCT has shown promise as a prognostic tool for assessing gradual tumor regression and consequently better outcomes for patients presenting with locally advanced, unresectable non-small cell lung cancer and undergoing definitive chemoradiation (7-10). Nonetheless, the prognostic value needs to be further explored in future studies.

In a recent preliminary study of small pulmonary nodule localization, CBCT and augmented fluoroscopy was successfully used to interactively guide lung resection during video-assisted thoracic surgery (11). The outcome of this study highlights the potential of CBCT as a non-invasive method to improve the perception of targeted small tumors. In past practice, precisely locating these lesions represented a significant surgical challenge, often requiring an invasive preoperative procedure under CT-fluoroscopic guidance involving metal hook-wire placement and coils.

The current study by Saito and colleagues (12) further improved on the intraoperative localization of small peripheral pulmonary tumors by using a sandwich marking technique in combination with CBCT. In this pilot

investigation, metal clips were placed in several places of visceral pleura, where the target lesion was sandwiched by marking clips. The detection rate of this arrangement was 100% effective, without any marking-related complication. Furthermore, radiation exposure to skin with CBCT was comparable to that with multidetector computed tomography and less than that of the Lipiodol marking method if the number of CBCT scans was less than four (but higher for four or more scans).

Radiation exposure is cumulative. According to the linear no-threshold model used by the US Environmental Protection Agency, there is no safe dose of ionizing radiation (13). Controversy exists regarding whether or not the radiation dose attributable to CBCT scans, although seemingly inconsequential, poses an immediate or long-term health risk. While efforts to decrease scattered radiation (generated by the interaction of the main radiation beam with the jaws and collimators, airborne particles, objects in the treatment field, and the patient during transit from the focal spot to detector) and reduce scan times have been suggested, the practical aspects of such recommendations remain challenging (14). A certain level of radiation is needed within the field of view to maintain image quality and accordingly, there are functional limits on lowering scattered radiation by adjusting the radiation output (15). To date, no standardized guidance exists for reducing scattered radiation dose for CBCT imaging (15).

Radiation safety implies keeping the dose “as low as reasonably achievable (ALARA)” by adhering to the three basic protective measures of “time, distance, and shielding” (16,17). A prudent strategy is to minimize radiation dosing to a patient when feasible, even if the radiation dose for CBCT is relatively low in comparison with therapeutic doses. Shielding alone decreases the absorption of non-scattered radiation by up to 95% (17). As suggested in the Saito manuscript, more clinical experience could facilitate the identification of target lesions with fewer scans, and thereby reduce the radiation exposure of patients (12). The authors also recommend additional research to compare radiation exposure among the different marking methods for CBCT.

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