Original Investigation

Radiation Dose to the Breast by 64-slice CT: Effects of Scanner Model and Study Protocol

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Rationale and Objectives: This work aimed to study the effects of scanner model and study protocol on radiation dose received by breast tissues from 64-slice computed tomography (CT) studies.

Materials and Methods: Four scanner models and three study protocols were used in scanning an anthropomorphic phantom with breast modules. Each protocol follows recommendations or guidelines from the American Association of Physicists in Medicine and the American College of Radiology. Twenty thermoluminescent dosimeters were placed inside the breast modules to measure breast tissue doses. Both the absolute and the normalized breast tissue doses were analyzed.

Results: The mean glandular doses of a lung cancer screening CT, a chest/abdomen/pelvis CT, and a virtual colonoscopy CT are equivalent to less than 1, 5–7, and 1–3 two-view digital mammograms, respectively, for a standard-sized patient. The normalized breast dose differs significantly ($P < 0.01$) between lung cancer screening CT and chest/abdomen/pelvis CT; however, it shows less than ±10% variation among scanner models for the same protocol. In virtual colonoscopy CT, breast tissue dose decreases with the distance between local tissues to the edge of the x-ray field, although the decreasing trend varies for different scanner models and protocol settings.

Conclusions: When breasts are entirely included in the primary x-ray field, breast dose by 64-slice CT is mainly protocol dependent, with the normalized breast dose about 15% lower for protocols with modulated mA than for those with constant mA; when breasts are only partially included in the primary beam field, breast dose by 64-slice CT is dependent on both the scanner model and the protocol settings.

Key Words: Computed tomography; radiation dosimetry; breast dose.

INTRODUCTION

In recent years, public concerns over computed tomography (CT) radiation dose and its associated risks have spurred efforts to understand, manage, and optimize patient dose from CT studies (1–4). Among these efforts, the recording and reporting of patient dose play an important role for patient management in clinical practice. Although CT dose index (CTDI), a metric directly available from scanners, has long been used in reporting scanner radiation output, its practical value is limited because of its inability to account for patient variation. Organ dose has been considered a more valuable and suitable metric to meet clinical needs; it gives physical characterization of patient-specific radiation dose and forms the basis for risk estimates.

The determination of organ dose is a challenging task. The organ is affected not only by the scanner radiation output level, usually characterized by CTDI, but also by various other factors, such as patient size, study protocol, scanner model, and x-ray energy spectrum. A number of studies have been conducted with the aim of developing a robust yet simple method with acceptable accuracy for organ dose estimation (5–18). These studies employed either experimental methods using physical phantoms or numerical methods using validated Monte Carlo programs, although the majority of them were based on the latter because of the flexibility of simulation.

This paper attempts to characterize CT-induced breast dose with a phantom-based experimental study. In recently published International Commission on Radiological Protection Publication 103 (19), the weighting factor for breast tissue in calculating patient risks was increased from 0.005 to 0.12, which puts an emphasis on breast dose in estimating radiation-induced patient risk. Although the dependence of breast dose

Acad Radiol 2016; ■:■■–■■

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http://dx.doi.org/10.1016/j.acra.2016.03.022

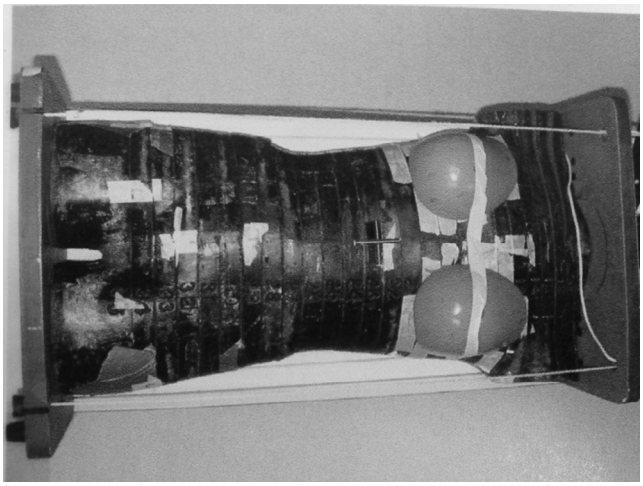

Figure 1. The Rando-Alderson phantom with breast modules attached to simulate a standard-sized female patient.

on patient size has been studied in the past (18), this paper focuses on the effects of scanner model and study protocol on breast dose, with the goal of providing guidance on how to effectively account for these two factors in the determination of breast dose from commonly performed CT studies.

MATERIALS AND METHODS

Phantom and CT Scan Protocols

The Rando-Alderson anthropomorphic phantom (The Phantom Laboratory, Salem, NY, USA) with breast modules (Fig 1) was scanned on four 64-slice CT scanner models, including GE LightSpeed VCT, Siemens SOMATOM Sensation 64, Philips Brilliance 64, and Toshiba Aquilion 64. The breast modules have a typical anatomically relevant relaxed shape.

Three types of CT studies were investigated in this study, including:

(1) Lung cancer screening CT—this commonly used low-dose screening study represents those that typically use constant mA in scanning the chest region;
(2) Chest/abdomen/pelvis CT—this most commonly used body CT study represents those that typically use tube current modulation technique in optimizing patient dose; and
(3) Virtual colonoscopy CT—this study represents those in which breast tissues are in close vicinity of the scan coverage to receive nonnegligible x-ray scatter and may be partially included in the scan coverage to get direct exposure.

The acquisition parameters of the protocols used in the study are summarized in Tables 1–3. They were primarily based on

TABLE 1. Acquisition Parameters for the Lung Screening CT Protocols Used on Different Systems

	GE LightSpeed VCT	Siemens SOMATOM Sensation 64	Philips Brilliance 64	Toshiba Aquilion 64
kVp	120	120	120	120
mAs	20	25	18	15
Rotation time (s)	0.5	0.5	0.75	0.5
Pitch	0.969	1.0	0.673	0.828
Detector configuration	32 × 0.625 mm	64 × 0.6 mm*	64 × 0.625 mm	64 × 0.5 mm
Bow-tie filter	Large body	Body	Body	Large
$CTDI_{vol}$ (mGy)	1.9	1.8	1.7	2.1

CT, computed tomography; $CTDI_{vol}$, volume CT dose index.
* The physical beam width is 32 × 0.6 mm. The flying focal spot technology is used to produce 64 slices per rotation.

TABLE 2. Acquisition Parameters for the Chest/Abdomen/Pelvis CT Protocols Used on Different Systems

	GE LightSpeed VCT	Siemens SOMATOM Sensation 64	Philips Brilliance 64	Toshiba Aquilion 64
kVp	120	120	120	120
Tube current modulation technique	Auto mA and Smart mA	Care Dose 4D	D-DOM and Z-DOM	Sure Exposure
Rotation time (s)	0.4	0.5	0.75	0.5
Pitch	0.984	0.9	0.891	0.828
Detector configuration	64 × 0.625 mm	64 × 0.6 mm*	64 × 0.625 mm	64 × 0.5 mm
Bow-tie filter	Large body	Body	Body	Large
CTDIvol (mGy)	20.0	20.0	20.0	20.0

CT, computed tomography; $CTDI_{vol}$, volume CT dose index.
* The physical beam width is 32 × 0.6 mm. The flying focal spot technology is used to produce 64 slices per rotation.