Chest CT Performed with 3D and *z*-Axis Automatic Tube Current Modulation Technique:

Breast and Effective Doses[1]

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Rationale and Objectives. Chest computed tomographic (CT) scans are the most effective examinations for detecting lung cancer at an early stage. In chest CT examinations, it is important to consider the reduction of radiation dose, particularly to the mammary gland. The objective of this study was to assess breast doses and effective doses on chest CT examinations between three-dimensional and *z*-axis automatic tube current modulation (ATCM) techniques.

Materials and Methods. Absorbed dose to the breast, lung, mediastinum, and skin was evaluated with an anthropomorphic phantom and radiophotoluminescence glass dosimeters using two different CT scanners. The dosimeters were placed inside and outside the phantom. The phantom was scanned using three-dimensional and *z*-axis ATCM techniques after scanning localizer radiographs from the horizontal and vertical directions. After scanning, each organ dose was calculated. Moreover, the dose-length product recorded in the dose reports was examined, and each effective dose was calculated.

Results. Compared with *z*-axis ATCM, three-dimensional ATCM reduced breast dose by 0.7% to 18.6% and effective dose by 4.9% to 10.2%. In particular, three-dimensional ATCM reduced frontal breast dose. For other organs, three-dimensional ATCM reduced absorbed doses by 3.4% to 13.6% compared to *z*-axis ATCM.

Conclusion. Three-dimensional ATCM can reduce absorbed doses to the breast and other organs, in addition to reducing effective dose, compared to *z*-axis ATCM.

Key Words. Computed tomography; chest; mammary gland; absorbed dose; effective dose.

Computed tomographic (CT) scans are the most effective examinations for detecting lung cancer at an early stage (1,2). With increased numbers of detector rows and faster gantry rotation times, the time required to scan the entire chest has been reduced to less than 5 seconds (3). Although multidetector-row computed tomography has been associated with higher radiation dose than conventional computed tomography, the introduction of automatic tube current modulation (ATCM) has facilitated the effective reduction of patient radiation dose while maintaining optimal image quality (4–7).

In this technique, tube current is automatically adjusted in the *x* and *y* planes (angular ATCM), the *z* plane (*z*-axis ATCM), or both (three-dimensional ATCM) by inputting an appropriate noise value (6,7). Previous studies have shown that three-dimensional ATCM is the most effective in reducing patient radiation dose and could reduce the absorbed dose, particularly in the anterior and posterior parts of the body (8,9). Later, we envisioned the breast as one of the organs located in the anterior or posterior part of the body. The recently recommended tissue weighting factor for the breast reported in an International Commission on Radiological Protection (ICRP) publication is higher than that previously recommended in an earlier ICRP publication (10). This

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implies that overexposure to the breast should be avoided, and three-dimensional ATCM can be used to achieve this objective.

The objective of this study was to assess organ (particularly the breast) and effective doses on chest CT examinations between three-dimensional and *z*-axis ATCM techniques by scanning an anthropomorphic phantom.

MATERIALS AND METHODS

CT Scanners

We performed a phantom study with two 64-section multidetector-row CT scanners: a LightSpeed VCT (GE Healthcare, Milwaukee, WI) installed with 3D mA and Auto mA, and an Aquilion 64 (Toshiba Medical Systems, Tokyo, Japan) installed with Volume EC and Real EC.

Phantom

A female chest RANDO phantom (RAN-110; The Phantom Laboratory, Salem, NY) onto which two breast sections were mounted was used (Fig 1). The phantom, which assumes a woman of 163 cm height and 54 kg in weight, was developed specifically to estimate absorbed dose to specific organs (11).

Dose Calibration

Dose calibration for radiophotoluminescence glass dosimeters (RPLDs) with a tiny filter (GD-352 M, Chiyoda Technol, Tokyo, Japan) was performed against a Ramtec 1000D dosimeter (Toyo Medic, Tokyo, Japan) with a 15-mm^3 ion chamber attached to a 120-kVp (effective energy, 50 keV) diagnostic x-ray beam. The ionization chamber and RPLDs with a tiny filter were placed side by side at the same distance from the x-ray tube in an irradiated field. The ionization dosimeter was calibrated at a laboratory of the Japan Quality Assurance Organization.

Measurement of Organ Dose

We scanned the phantom positioned head first using three-dimensional ATCM (3D mA and Volume EC) and *z*-axis ATCM (Auto mA and Real EC) techniques, after scanning localizer radiographs (anteroposterior and lateral projections) and placing the RPLDs with a tiny filter at the breast (32 dosimeters), lung (eight dosimeters), mediastinum (two dosimeters), and skin (six dosimeters). Two RPLDs were used to measure background radiation. The exposure parameters used are shown in Table 1. The parameters were based on protocols used in our facility, and the noise value was selected on the basis of the manufacturer's recommendations. The minimum and maximum tube current values were set widely so that ATCM could function appropriately according to the set noise value. The RPLDs were annealed at 400°C for 20 minutes beforehand, and their initial values were read using an FGD-1000 reader (Chiyoda Technol) according to the manufacturer's recommended protocol. Moreover, we scanned the same phantom positioned feet first using three-dimensional ATCM (3D mA and Volume EC) and *z*-axis ATCM (Auto mA and Real EC) techniques, after placing RPLDs with a tiny filter at the breast (32 dosimeters), with identical exposure parameters as shown in Table 1.

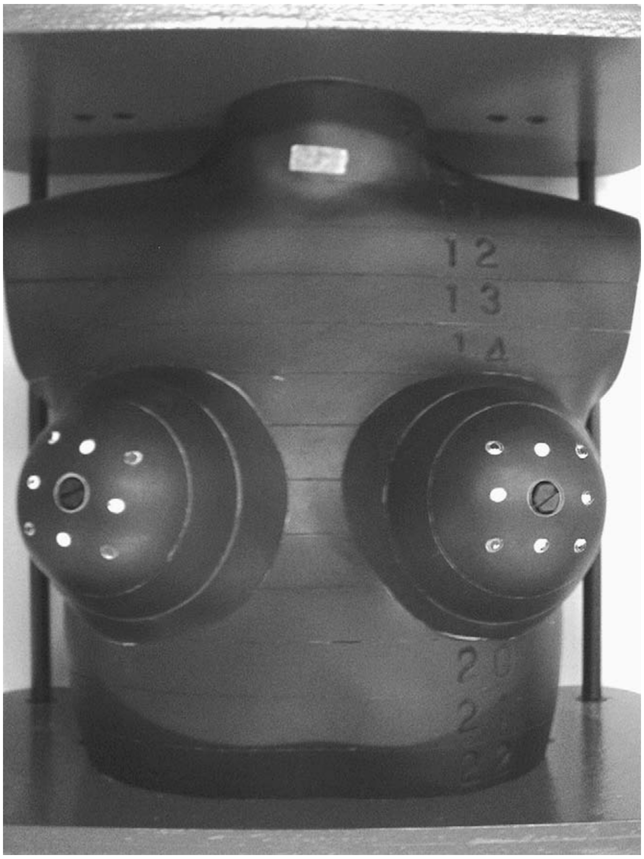

Figure 1. Female anthropomorphic chest phantom. The phantom was sliced into 14 pieces of 25 mm thickness, and each slice was drilled with holes to enable the insertion of the dosimeters in the position of each organ. The phantom was equipped with standard, close-fitting Mix D plugs and inserted in the holes. Each breast was molded into 20-mm-thick sections, and each slice was drilled with holes to enable the insertion of dosimeters or close-fitting Mix D plugs.

After exposure, RPLDs were heated at 70°C for 30 minutes and were read using the FGD-1000 reader 24 hours later. Subsequently, each organ dose was calculated by multiplying obtained dose values by the mass energy coefficient ratio of each organ to air (12).

Effective Dose Estimation

An estimate of effective dose can easily be derived from dose-length product (DLP) using a suitable effective dose conversion coefficient (13). Therefore, we examined each