Original Investigation

Association of Focal Radiation Dose Adjusted on Cross Sections with Subsolid Nodule Visibility and Quantification on Computed Tomography Images Using AIDR 3D: Comparison Among Scanning at 84, 42, and 7 mAs

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Abbreviations and Acronyms

AIDR 3D
adaptive iterative dose reduction using three-dimensional processing

CT
computed tomography

CTDIvol
computed tomography dose index volume

FOV
field of view

Rationale and Objectives: The objectives of this study were to compare the visibility and quantification of subsolid nodules (SSNs) on computed tomography (CT) using adaptive iterative dose reduction using three-dimensional processing between 7 and 42 mAs and to assess the association of size-specific dose estimate (SSDE) with relative measured value change between 7 and 84 mAs ($RMVC_{7–84}$) and relative measured value change between 42 and 84 mAs ($RMVC_{42–84}$).

Materials and Methods: As a Japanese multicenter research project (Area-detector Computed Tomography for the Investigation of Thoracic Diseases [ACTIve] study), 50 subjects underwent chest CT with 120 kV, 0.35 second per location and three tube currents: 240 mA (84 mAs), 120 mA (42 mAs), and 20 mA (7 mAs). Axial CT images were reconstructed using adaptive iterative dose reduction using three-dimensional processing. SSN visibility was assessed with three grades (1, obscure, to 3, definitely visible) using CT at 84 mAs as reference standard and compared between 7 and 42 mAs using *t* test. Dimension, mean CT density, and particular SSDE to the nodular center of 71 SSNs and volume of 58 SSNs (diameter >5 mm) were measured. Measured values (MVs) were compared using Wilcoxon signed-rank tests among CTs at three doses. Pearson correlation analyses were performed to assess the association of SSDE with $RMVC_{7–84}$: $100 \times$ (MV at 7 mAs – MV at 84 mAs)/MV at 84 mAs and $RMVC_{42–84}$.

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LDCT
low-dose computed tomography
RMVC
relative measured value change
SDCT
standard dose computed tomography
SSDE
size-specific dose estimate

Results: SSN visibilities were similar between 7 and 42 mAs (2.76 ± 0.45 vs 2.78 ± 0.40) (P = .67). For larger SSNs (>8 mm), MVs were similar among CTs at three doses (P > .05). For smaller SSNs (<8 mm), dimensions and volumes on CT at 7 mAs were larger and the mean CT density was smaller than 42 and 84 mAs, and SSDE had mild negative correlations with $RMVC_{7–84}$ (P < .05).

Conclusions: Comparable quantification was demonstrated irrespective of doses for larger SSNs. For smaller SSNs, nodular exaggerating effect associated with decreased SSDE on CT at 7 mAs compared to 84 mAs could result in comparable visibilities to CT at 42 mAs.

Key Words: Computed tomography; subsolid nodule quantification; iterative reconstruction; size-specific dose estimate; reduced radiation dose.

INTRODUCTION

Persistent subsolid nodules (SSNs) are often an early sign of lung cancer (1), and pure ground-glass nodules should be followed up at 6–12 months to confirm their persistence and every 2 years until 5 years; part-solid nodules should be followed up at 3–6 months to confirm their persistence and annually for 5 years, if unchanged and solid component size remain less than 6 mm by chest computed tomography (CT) from their initial detections in cases with a diameter of 6 mm or more according to the latest management guidelines by the Fleischner Society (2). Dependable quantitative assessment of changes in SSN volume or density on CT images supports the feasibility of subjective visual inspection of changes in SSN size, which is typically applicable in routine clinical settings, and could be useful to determine an appropriate choice of treatment (3). The accuracy of the volume measurement of lung nodules, including SSNs, is influenced by some mutually related factors, such as characteristics of the nodular margin, algorithm of the measurement tool, data acquisition, and reconstruction parameters (4,5). Among these factors, radiation dose has a considerable effect on SSN quantification and should be as low as possible for CT to be applicable as the follow-up tool in terms of the exaggerating influence of radiation dose on carcinogenesis probability (6,7).

In combination with an iterative reconstruction (IR) algorithm, ultra–low-dose CT (0.16–0.29 mSv) has recently demonstrated comparable detection performance of lung nodules to low-dose computed tomography (LDCT) (0.92–1.74 mSv) regardless of the different IR techniques developed by different manufacturers (8–11). Furthermore, in addition to lung nodule detectability, simulated SSNs placed in an anthropomorphic phantom have been shown to be measured on ultra–low-dose CT images obtained with an IR algorithm as reliably as on LDCT images obtained with an IR algorithm despite the different acquisition and reconstruction techniques (12,13). However, simulated nodules in an anthropomorphic phantom lack the diversity and complexity of clinical nodules and background lung fields modified by dependent effects and respiratory levels. In contrast, the size-specific dose estimate (SSDE) corresponding to an individual image plane has been recently introduced as one of the more practicable dose adjustments on body cross sections (14–16), and SSDEs in the transaxial plane, including SSNs, can vary among nodular locations even in an individual patient and have an association with SSN detection performance.

The purpose of the present study was to compare the visibility, dimension, density, and volume of SSNs on CT images using adaptive iterative dose reduction using three-dimensional processing (AIDR 3D) between 7 and 42 mAs and to assess the association of SSDE with difference in the measured values between 7 and 42 mAs, and between 7 and 84 mAs.

MATERIALS AND METHODS

The present study was conducted as part of the Area-detector Computed Tomography for the Investigation of Thoracic Diseases (ACTIve) study, an ongoing multicenter research project in Japan. The research committee of the study project outlined and approved our study protocols. The institutional review board of each institution approved the present study, and written informed consent was obtained from all participants. This study was planned as a supplementary analysis after our previous research (9), which did not include any quantitative measurements of SSNs.

Patients' Populations

In addition to 112 subjects who were initially enrolled in our previous study between December 2012 and March 2013 at six institutions for the assessment of detection performance for both pulmonary solid nodules and SSNs (9), 33 patients were enrolled from April to July 2013 at two institutions for our other previous study evaluating SSN detectability and its association with SSDE (17). Among the 145 subjects, 50 patients having SSNs with the longest diameter of 5 mm or more were identified as the final study population after reviewing the CT images of all the subjects (35 women and 15 men, with a mean age of 69.6 ± 11.3 years). The subjects' body mass indices were 22.7 ± 3.0.

Image Data Acquisition and Reconstruction

In each single visit, the 50 subjects underwent plain chest CT (64-row helical mode) using identical 320-row