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Computer-aided detection (CAD) of solid pulmonary nodules in chest x-ray equivalent ultralow dose chest CT - first in-vivo results at dose levels of 0.13 mSv

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ABSTRACT

Objectives: To determine the value of computer-aided detection (CAD) for solid pulmonary nodules in ultralow radiation dose single-energy computed tomography (CT) of the chest using third-generation dual-source CT at 100 kV and fixed tube current at 70 mAs with tin filtration.

Methods: 202 consecutive patients undergoing clinically indicated standard dose chest CT (1.8 ± 0.7 mSv) were prospectively included and scanned with an additional ultralow dose CT (0.13 ± 0.01 mSv) in the same session. Standard of reference (SOR) was established by consensus reading of standard dose CT by two radiologists. CAD was performed in standard dose and ultralow dose CT with two different reconstruction kernels. CAD detection rate of nodules was evaluated including subgroups of different nodule sizes (<5, 5–7, >7 mm). Sensitivity was further analysed in multivariable mixed effects logistic regression.

Results: The SOR included 279 solid nodules (mean diameter 4.3 ± 3.4 mm, range 1–24 mm). There was no significant difference in per–nodule sensitivity of CAD in standard dose with 70% compared to 68% in ultralow dose CT both overall and in different size subgroups (all $p > 0.05$). CAD led to a significant increase of sensitivity for both radiologists reading the ultralow dose CT scans (all $p < 0.001$). In multivariable analysis, the use of CAD ($p < 0.001$), and nodule size ($p < 0.0001$) were independent predictors for nodule detection, but not BMI ($p = 0.933$) and the use of contrast agents ($p = 0.176$).

Conclusions: Computer-aided detection of solid pulmonary nodules using ultralow dose CT with chest X-ray equivalent radiation dose has similar sensitivities to those from standard dose CT. Adding CAD in ultralow dose CT significantly improves the sensitivity of radiologists.

1. Introduction

Early detection of lung cancer is crucial for improving clinical outcomes given the relative survival rate for non-small cell lung cancer of 80% without recurrence when detected in a local stage [1,2]. However, 60% of the estimated 224′390 new cases of patients with lung cancer that are predicted to occur in 2016 in the United States are expected to be in a distant stage [3]. The National Lung Screening Trial (NLST) has suggested a reduced mortality from lung cancer among people at high risk that underwent low-dose computed tomography (CT) [4]. Although many aspects remain to be studied about the impact of implementing widespread CT screening for lung cancer on economics and health, it is likely that CT will gain access to official screening programs for certain risk groups in the near future.

A fundamental role to the success and effectiveness of a CT screening program will be played by the radiologists who are in charge of detecting suspicious lesions (i.e. pulmonary nodules) in CT. A retrospective analysis from the International Early Lung Can-

Abbrevations: ADMIRE, advanced modelled iterative reconstruction; CAD, Computer-aided detection; CT, computed tomography; NLST, the National Lung Screening Trial; IR, iterative reconstruction.

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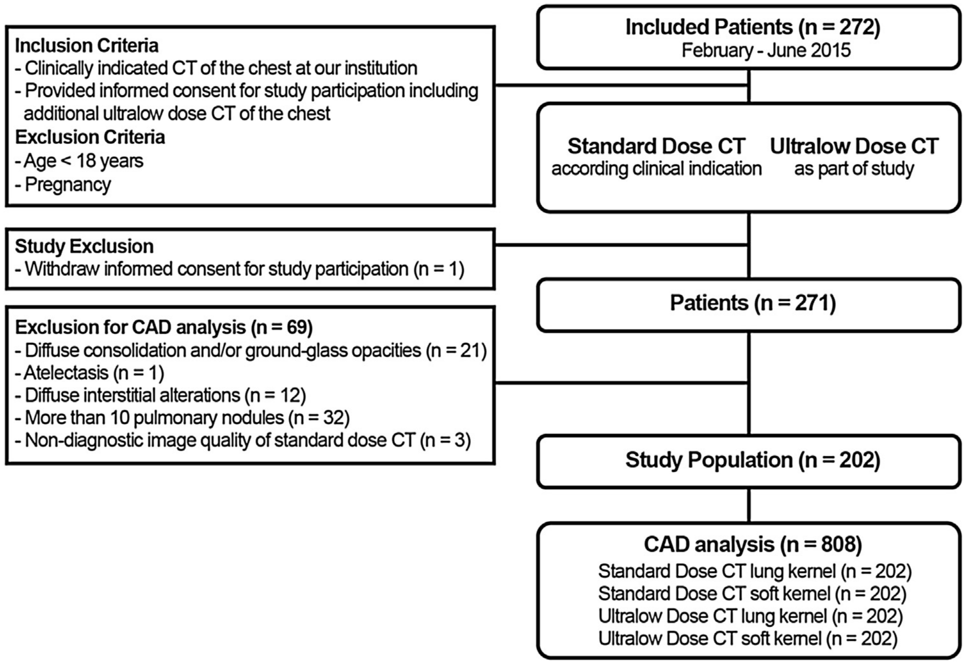

Fig. 1. Flow chart of study.

cer Action Program (I-ELCAP) including 104 patients with newly diagnosed lung cancer revealed that pulmonary lesions were visible in 54% of the cases but were not identified in prior CT scans [5]. Among other factors, the detection of nodules by radiologists depends on nodule size [6]. Meanwhile, 35% of lung cancers in the National Lung Screening Trial (NLST) had a diameter of 10 mm or less at the time of detection on incidence screens [7] which calls for techniques to ensure high sensitivity and time-efficient nodule detection.

Computer-aided detection (CAD) has been developed to improve detection of pulmonary nodules and numerous previous studies in standard dose CT showed that CAD used as a second reader significantly improved detection rate of pulmonary nodules [8–10]. Furthermore, a recent study showed a high sensitivity of CAD for the detection of lung cancers that were initially missed by radiologists in a screening setting [11].

Using CT for screening purposes and interval follow-up studies implies substantial radiation burden for the screened population [12]. A recently introduced dual-source CT scanner allows for single-energy scanning with tin filtration (TF). Combining this technique with new generation iterative reconstruction (IR) allows for drastic dose reduction [13,14]. In a preliminary phantom study, radiation dose levels of 0.06 mSv were achieved for chest CT while producing diagnostic image quality, high sensitivity and good diagnostic confidence for nodule detection [15].

The purpose of this study was to determine the value of CAD for detection of solid pulmonary nodules with the introduced single-energy TF ultralow dose CT protocol in combination with latest generation IR at a radiation dose equivalent to chest X-ray.

Table 1
Demographics of study patients (n = 202).

Female/male	72 (36%)/130 (64%)
Age, years	60 ± 14 (18–89)
Weight, kg	77 ± 18 (40–150)
Height, m	1.71 ± 0.1 (1.49–1.92)
BMI, kg/m^2	26.2 ± 5.3 (15.9–49)
Clinical indications for CT	
Known or suspected tumor	132 (65%)
Infection	4 (2%)
Work up or follow up of pulmonary nodule	19 (9%)
Work up or follow up of pulmonary disease	31 (15%)
Abnormal chest X-ray findings	8 (4%)
Vascular	6 (3%)
Thoracic skeleton assessment	3 (1%)
Conducted CT study	
Contrast enhanced CT	169 (84%)
Non-enhanced CT	33 (16%)

BMI body mass index, CT computed tomography, presented as n (%) and mean ± SD (range).

2. Materials and methods

2.1. Study design

The evaluated patients are part of an ongoing prospective clinical single-center study (clinicaltrials.gov identifier NCT0246860) on ultralow radiation dose CT of the chest (flow chart in Fig. 1). The local ethics committee approved the study. All patients gave written informed consent for an ultralow radiation dose CT that was conducted additionally to the clinical CT performed with institutional standard dose settings in the same session. No funding was received for this study. One author (R.W.B.) who is on the speakers' bureau of Siemens Healthcare was not in control of the study data. The study was conducted in compliance with ICH-GCP-rules and the declaration of Helsinki.

2.2. Patients

Between February and June 2015, 272 consecutive patients (176 male, 96 female; mean age 62 years; range 18–90 years) who were referred to our department for a CT of the chest were included. In 228 patients a contrast-enhanced CT and in 44 patients a non-enhanced CT was performed.

Exclusion criteria for the study were (a) pregnancy and/or (b) age <18 years. One patient withdrew the informed consent a few days after the scan and was therefore excluded. Prior to CAD analysis CT studies were excluded from reading by a radiologist not involved in any other image evaluation (5th year radiology