Aims and objectives

Computer tomography (CT) examinations are commonly associated with high individual patient doses (up to 50-100 mSv), composing up to 50% of the collective dose from medical exposure. Hence it is important to reduce the exposure of the patients through the optimization of the CT examinations. That can be achieved by reducing tube current (mA) and time of scans (sec) as well as applying the iterative reconstruction algorithms. However, these parameters have a significant impact on the CT image quality. According to the data available [1-2], the differences in the density of the nodule can be used for estimating the possibility of the malignancy. Unfortunately, precise and objective estimation of the nodule size and density is challenging due to the differences in the equipment, scan parameters and experience of the radiologist.

The aim of this study was to evaluate the impact of the CT reconstruction algorithms and tube current reduction on the density of solid, calcified and ground-glass (GG) nodules.
Methods and materials

The study was conducted using the anthropomorphic chest phantom Multipurpose Chest Phantom N1 "Lungman" (Japan). This phantom corresponds to the chest of a healthy male (40 years old, 174 cm height, 75 kg weight), representing the normal anatomy of the chest (Fig. 1). The construction of a phantom allows positioning of the nodules inside the lung parenchyma.

1 calcified, 2 solid and 2 ground glass nodules were randomly positioned inside the phantom. Density of the artificial nodules corresponded to the data available [2-8]. Overall data on the nodules is presented in Table 1; layout and the comparison of the nodules as well as the examples on the CT scans are presented in Fig. 2-3.

Table 1. Data on the nodule size and material

<table>
<thead>
<tr>
<th>Size, mm</th>
<th>Material</th>
<th>Calcified nodules</th>
<th>Solid nodules</th>
<th>Ground glass nodules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>5-7</td>
<td>5-7</td>
</tr>
<tr>
<td>Material</td>
<td>Chalk</td>
<td>Frozen wax</td>
<td>Medical bandage</td>
<td></td>
</tr>
</tbody>
</table>

Five different loads of the phantom with different random nodule locations were prepared. Each load was scanned on a 64-row CT scanner in a CT department of National Medical Almazov Research Center. Prior to the study, QA was performed on a CT allowing accurate estimation of CTDI and DLP. The examples of the protocols and the corresponding DLP and effective dose values are presented in Table 2. The effective dose was determined using conversion coefficient from DLP, 0,017 mSv/(mGy·cm) [Jessen KA, Panzer W, Shrimpton PC, et al. European Guidelines on quality criteria for computed tomography. Brussels, Belgium: European Commission, 2000:EUR 16262].

Table 2. Examples of the CT protocols

<table>
<thead>
<tr>
<th>Protocol #</th>
<th>Tube current, mA</th>
<th>Tube voltage, kV</th>
<th>Scan mode</th>
<th>Rotation time, s</th>
<th>Collimation Pitch</th>
<th>DLP, mGy·cm</th>
<th>Effective dose, mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>142</td>
<td>100</td>
<td>Helical</td>
<td>0.4</td>
<td>64x0.625 1.048</td>
<td>209</td>
<td>3.5</td>
</tr>
<tr>
<td>2</td>
<td>71</td>
<td>100</td>
<td>Helical</td>
<td>0.4</td>
<td>64x0.625 1.048</td>
<td>104</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
<td>100</td>
<td>Helical</td>
<td>0.4</td>
<td>64x0.625 1.048</td>
<td>52</td>
<td>0.9</td>
</tr>
</tbody>
</table>
The tube current modulation was disabled to allow investigating the effect of tube current on a nodule density. Image reconstruction was performed using three algorithms, such as FBP (filtered back projection), iDose level 4 (hybrid statistical reconstruction) and IMR level 2 (model-based reconstruction). The following parameters were used: slice thickness of 1 mm, an increment of 1mm, standard (B) filter for iDose and FBP and routine filter for IMR, field of view (FoV) of 375 mm and image matrix of 768×768 pixels.

Each phantom load was scanned on each of the presented CT protocols, reconstructed using all three algorithms and then presented to the radiologist for the estimation of the density of the nodules. A total of 5 radiologists with more than 5 years of CT experience participated in the study. Nodule density was estimated using Philips IntelliSpace Portal software. The ROI size was estimated as at least 50% of nodule area. ROI were positioned based on the experience of the radiologists and the visibility of the nodule. Data from the radiologists was merged into a joint sample for each tube current value and reconstruction algorithm.

A statistical evaluation of differences in the nodule density for different reconstruction algorithms and mA settings was performed using Kruskell-Wallis ANOVA analysis and median test in Statistica 10 software. Differences were considered to be significant with p<0.05.
Fig. 1: Chest phantom N1 "Lungman": external view, insert with the heart and lung parenchyma, example of a CT scan in a frontal axis.

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
Fig. 2: Layout and the comparison of the nodules.

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
**Fig. 3:** Nodule appearance on the CT scans

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
Results

It is visible from Fig. 4-6, that the estimation of size, area and density was most complicated for the ground glass nodules, due to their uneven shape and inhomogeneity.

Data on the resulting range of HU values for the investigated reconstruction algorithms and mA settings for the joint sample for solid, calcified and ground glass nodules is presented on Figure 7-9 respectively.

It is visible from Fig. 7-9 that the increase in mA has no significant impact on the estimated density of the nodules for all three investigated reconstruction algorithms. However, the density of calcinated and solid nodules for IMR algorithm was significantly (p<0.05) higher compared to the FBP and iDose algorithms. Mean values and ranges of HU densities were comparable with the available data on solid and ground glass nodules [2-8].

Significant variation of HU values (up to ±50%) for each mA setting and reconstruction algorithm can be explained by the differences in the selection of a CT slice for the ROI positioning, differences in shape, area and inhomogeneity of the nodules. However, the use of IMR reconstruction algorithm corresponded to the lowest variation in the solid and calcified nodule density compared to other algorithms. Hence, prediction of the malignancy, based only on the module density, would lead to a bias (false-positive or false-negative results).
Images for this section:

![SOLID NODULE](image)

<table>
<thead>
<tr>
<th>mAs</th>
<th>142</th>
<th>71</th>
<th>35</th>
<th>17</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBP</td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
</tr>
<tr>
<td>iDose</td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
</tr>
<tr>
<td>IMR</td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
</tr>
</tbody>
</table>

**Fig. 4:** Examples of the solid nodules for the different tube current values and reconstruction algorithms.

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
Fig. 5: Examples of the ground glass nodules for the different tube current values and reconstruction algorithms.

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
**Fig. 6:** Examples of the calcified nodules for the different tube current values and reconstruction algorithms.

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
Fig. 7: HU values for the calcified nodules for FBP, iDose and IMR reconstruction for the joint sample.

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
Fig. 8: HU values for the ground glass nodules for FBP, iDose and IMR reconstruction for the joint sample.

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
**Fig. 9:** HU values for the solid nodules for FBP, iDose and IMR reconstruction for the joint sample.

© CT, Almazov National Medical Research Centre - St. Petersburg/RU
Conclusion

It is necessary to develop a unified method of estimating the HU density in a CT department to be used for the evaluation of the dynamics of the nodule morphology. To estimate the changes in a nodule structure it is suggested to consider type of equipment, protocol settings and the reconstruction algorithms.
Personal information

G.Berkovich, MD

Almazov National Medical Research Centre
Saint-Petersburg, Russia, 194156
Prospect Parchomenko 15
Phone: +79046147650
e-mail: glebberkovich@gmail.com
References


