Evaluation of Computed Tomography Scan Ability in Detecting Chest Nodules Using Tissue Equivalent Phantom

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Abstract:

Aim of Study: The lung cancer is noted at the end stages of disease, the morbidity and mortality rate related to is higher than others. To minimize this rate, early diagnosis of lung solitary nodules before spreading metastases to lymph nodes and other organs is of consideration. At the moment, Computerized Tomography is one of the most important modalities in diagnosing lung solitary nodules, however the CT exposure rates are much higher than diagnostic radiology field. Therefore it is necessary to do evaluation of CT. Scan ability in detecting chest nodules for preventing unnecessary radiation dose to patient.

Materials and Methods: In this study, a chest phantom including different nodules of sizes and types was designed. Imaging of phantom was performed by TOSHIBA spiral CT of Imam Khomeini medical complex and GE spiral CT of Fayyazbaksh hospital with 5,3,1 mm slices and 80, 120 kVp and 50,60,80,100 mA.

Results: This study revealed, 4 mm width nodules were noted both in slices with 120 kV and 50, 100 mA and 3, 5 mm thickness and in 80 kV and 60 mA with 3 mm thickness. The calcium carbonated particles were noted in 6, 8, and 10 mm whitish but not in smaller nodules; however a low density of carbonated calcium was noted just in 10 mm width nodules.

Conclusion: CT.scan is a useful technique for detection of lung tumor with sizes more than 4mm.

Keywords: Chest nodules, CT.Scan, Chest Phantom.

INTRODUCTION

Lung is known as a common place for metastases of primary tumors originated extra pulmonary, thus primary lung cancers and lung metastases early diagnosis is of importance in therapy protocols. As the lung cancer is noted at the end stages of disease, the morbidity and mortality rate related to is higher than others. To minimize this rate, early diagnosis of lung solitary nodules before spreading metastases to lymph nodes and other organs is of consideration. Although chest X-ray makes these solitary nodules be detected, the noise - based pitfalls play the barrier role [1].

The lung nodule is a small round mass which enlarges intrapulmonary and can be noted by the physician in a chest X-ray graph or CT.Scan images. These nodules being smaller than a green pea or as big as a golf ball or even bigger are detected while the patient is being examined for other reasons (e.g. chest X-ray for pneumonia). Having seen the chest X-ray and lung CT.Scan images, the physician observes the lung solitary nodules, follows the enlargement through the sequential imagings in 3, 6 or 12 months later and diagnoses the probability of malignancy.

About 500 CT.Scan cases of 60000 done for the children under 15 years old causes cancer. In chest imagings of children with primary cancers, diagnosis of lung nodules is of importance, because in these patients the probability of changing the benign stage of a nodule with diameter less than 5 mm to malignant stage exits. Exposing even low amounts of radiation can increase cancers or other genetic disorders risk, therefore in children with longer life and much more sensitivity to radiation in childhood the malignancy risk is higher. In children, even the low doses of radiation can increase the risk of cancer quantitatively. Based on the BEIR health ministry report (2005), being exposed by even very low doses of radiation must be considered cancerogenous so minimizing exposure has been recommended. For evaluating the relationship between the dose rate and the CT images noises and the effect of the noise in lung nodules diagnosis, chest X-ray is used. The increment of image noise effects diagnosing of nodules [2].

Computerized Tomography which is being introduced in 1972, is the most important exposure source nowadays. One of the protection attempts in this field has been minimizing the patients’ exposure, so in clinical cases such as monitoring for lung cancer, CT is applied with low doses of X-ray exposure. To obtain an acceptable CT image the following notations have to be considered:

1) Shortening the total exposure time
2) mA and Kv [3].

In the last decade, new CT scanners have been sophisticatedly improved because of the image processing methods development and spiral CT introduction; however the CT exposure rates are much higher than diagnostic radiology...
field. Furthermore, in recent years most of the monitoring researches have been done using low doses of exposure which lead to the low image quality [4].

At the moment, Computerized Tomography is one of the most important modalities in diagnosing lung solitary nodules, also its calibration in the lung equivalent tissue can be used with higher sensitivity, so evaluating the sensitivity rate is of necessity. To this reason, nodule diagnosis tests are done in the lung equivalent tissue with CT scanners to determine the procedure sensitivity rate and to prevent useless exposures and repetitious observations.

MATERIALS AND METHODS

In this study, a phantom was designed on the basis of chest phantoms recommended by Capintec, INC including 4, 2.54*25*25 cm transparent acrylic planes and one 0.2*25*25 mm pure aluminum 110 plane and a 0.1*25*25 mm pure aluminum 1100 plane.

For designing nodules, nodules with the diameters of 1, 2, 4, 6, 8, 10 mm and 3 rows parallel were located. The height of those with the diameter of 1, 2, and 4 mm was 4 mm and of those with the diameter of 6 mm, 6 mm of those

Fig. (1). Cylinder-shaped nodules drew out of the acrylic plane with different diameters (up-side view).

Fig. (2). Cylinder-shaped nodules drew out of the acrylic plane with different diameters and height (lateral view).
with the diameter of 8 mm, 8 mm and of those with diameter of 10 was 10 mm (Figs. 1-3).

Designing the nodules, the phantom’s pieces were assembled and the completed phantom was used for imaging with spiral CT.Scan.

Imaging of phantom was performed by TOSHIBA spiral CT of Imam Khomaini medical complex and GE spiral CT of Fayyazbakhsh hospital with 5, 3, 1 mm slices and 80, 120 kVp and 50, 60, 80, 100 mA.

RESULTS

This study revealed 1 mm width nodules were seen in none of the images (Fig. 4). 2 mm width nodules were noted in slices with 120 kV and 50, 60, 100 mA (Fig. 5). 4 mm width nodules were noted both in slices with 120 kV and 50, 100 mA and 3, 5 mm thickness and in 80 kV and 60 mA with 3 mm thickness (Fig. 6).

The 6 mm width nodules were noted in slices with 120 kV and 50, 100 mA and 3, 5 mm thickness. The nodules

Fig. (3). The nodules of the first row were filled with pure epoxy, the second row with epoxy mixed with carbonated calcium with density of 50 mg/cc and the third row with epoxy mixed with carbonated calcium with density of 100 mg/cc.

Fig. (4). 1 mm width nodules were seen in none of the images.
Fig. (5). Nodules with diameter of 2 mm were seen in slices with 120 kV and 50, 60, 100 mA.

Fig. (6). Images with the 4 mm width nodules.

larger than 6 mm were noted in all slices with 120 kV. The calcium carbonated particles were noted in 6, 8, and 10 mm whitish but not in smaller nodules; however a low density of carbonated calcium was noted just in 10 mm width nodules (Figs. 7-9).

DISCUSSION

Based on Siegel’s research et al., [5] the photon’s energy affects the dose rate directly and voltage reduction causes dose reduction in all forms and sizes of designed phantoms. In this study, the 2 mm width nodules were not notable in images with 80 kV and in fact in this voltage just the 4 mm width nodules were noted.

According to the mentioned issues, to recognize the 2 mm width nodules the voltage reduction from 120 kV to 80 kV can’t apply, so generally speaking for specifically recognition of 2 mm width nodules, voltage reduction can’t be used for dose reduction but for 4 mm width or larger nodules we can reduce the absorbed dose with reducing voltage from 120 kV to 80 kV.
Based on Heyer et al. study [6], modern CT scanner use 120 and 140 kV to obtain high quality and standard images. Reducing electric power from 120 kV to 80 kV leads to exposure dose reduction but to increase the image noise causing image resolution to decrease incrementally. Our study represented low amount of image resolution reduction related to voltage reduction which highly affected 2 mm width nodules recognition, in other words although voltage reduction is not considered as an effective factor on image quality reduction but is of importance for the less than 4 mm width nodules, so in cases which these small nodules are to be observed specifically, the voltage should not be reduced and 120 kV and 140 kV should be applied.

Punwani et al. concluded that dose rate reduction is possible in recognition of 4 mm width lung nodules. Our study which showed the possibility of using power of 80 kV for nodules larger than 4 mm width verified their conclusion. In

**Fig. (7).** Carbonate calcium can be seen in nodules of 6 mm with concentration of 100 mg/cc.

**Fig. (8).** 8 mm width nodules with noted carbonated calcium particles in the one at the right side (density 100 mg/cc).
their work, the recognition rate of 2 mm width nodules was 33% and of 1 mm width was 25%. In our study, 2 mm width nodules were not observed in 80 kV but in 120 kV, and none of the 1 mm width nodules were noted in the whole study. The main constraint in Punwani et al.’s study was applying just one slice which caused decreasing nodules recognition sensitivity, but our study represented that sequential slices lead to increase in ability of small nodules recognition. Punwani et al. showed that existence of more than one nodule causes the first nodule is noted by the second one. This fact was verified in our research because locating the nodules in 3 parallel rows caused them to be noted beside each other and help be diagnosed clinically. In Punwani’s research the nodules’ location was not of importance in its observation but the nodules in our survey were all located inside the phantom which can be the continuant of Punwani’s research.

The low rate of diagnosing of small nodules (1-3 mm) in Punwani’s research caused using multislice modality and multinodule sets with various size, location, number and density be proposed. Thus we tried to provide better nodule diagnosis and complete the previous procedures with applying variation in number, size, location and type of nodules.

In Goodsite et al.’s survey, the man-made nodules were of carbonated calcium and epoxy with definite density located in a man-made phantom [7], but we used phantom of acrylic-aluminum planes with cylinder-shaped nodules having different diameters inside the planes which were filled with carbonated calcium and definite density of epoxy. To obtain higher resolution, they have suggested to apply tiny slices with a little space between in detecting large nodules. Following the recommendation, we observed that using ti-nier slices with a little space between has no significant effect on CT image resolution in large nodules (8-10 mm).

To reduce image noise in CT, Hiltz and Duzenli have recommended to maximize the X-ray tube voltage, and increase the mean current, time and image number which adversely cause the heating of X-ray tube during imaging [8].

Applying the recommended method and using different mAs and a great number of images, we observed that high mA (100 mA) comparing to low mA (50 mA) has no considerable effect on image noise and resolution but on increase in X-ray tube heat.

CONCLUSION

Based on our observing, detecting of small nodules was possible using high voltages, in other words voltage increasing was more effective than mA increasing in detecting of small nodules.

We concluded that increasing mA in high voltages had no significant effect on image quality and nodule detection but would considerably increase absorbed dose in patients, so while using high voltage to obtain better resolution and more precise nodule diagnosis, we can decrease absorbed dose with decreasing mA.

In our survey, the slice thickness was of little degree in nodule diagnosis as in detecting small nodules (less than 4 mm); no significant difference was observed in slices with thicknesses of 1, 3 and 5 mm. So we can prevent obtaining slices with low thicknesses which increase the patient, speaking generally choosing proper slice thickness, regarding to the imaging goal being nodule detection, can play an important role in patient absorbed dose reduction.

We observed that small calcified nodules (smaller than 4 mm) are not detectable in different kV and mA and carbon-
ated calcium is noted just in 6 mm width nodules or the larger ones. Identifying the density of carbonated calcium depends on the nodule size because high densities of carbonated calcium are noted in 6-8 mm width nodules but the 10 mm width nodules show different densities. In this study, large nodules (8 mm) were noted in several images, so in following imaging, which cause of pervious detection of these nodules there is no need to focus on detection procedure, to decrease patient dose we can obtain images with high thickness and mA reduction.

Considering all the mentioned issues related to dose rates, can be of importance in preventing unwanted and risky effects of exposure such as the probability of lung tumor formation or changing their state from benign to malignant.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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REFERENCE