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RESEARCH

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The role of dynamic-contrast enhanced CT in characterization of solitary solid pulmonary nodules

Dina EL-Metwally[1*], Magda Ali Hany EL-Bakry[1], Mohamed Ali EL-Adalany[1], Shaimaa Adel[2] and Mohamed Mohsen[1]

Abstract

Background: Incidental indeterminate solitary solid pulmonary nodule is a progressively common finding on CT worldwide. Once detected there are a number of imaging modalities that can be done to help in nodule characterization and differentiating benign from malignant nodules. Through these imaging modalities, there are PET CT, SPECT and dynamic CE-CT. Dynamic CE-CT is a functional test that help in assessment of the vascularity of the nodule which reverb the degree of angiogenesis of that nodule so can help in differentiating benign from malignant pulmonary nodules. The purpose of this study was to evaluate the role of Dynamic CE-CT in characterization of solitary pulmonary nodules. Detect what are the important parameters on dynamic CE-CT to differentiate benign from malignant nodules and detect their cut off values.

Results: The pre enhancement value show cut off point of 26.50 HU with sensitivity 93.8% and specificity 75% with accuracy rate 90% in differentiating benign from malignant pulmonary nodules. Peak enhancement value (at 2 min) show cut off point of 40.00 HU with sensitivity 96.9% and specificity 87.5% with accuracy rate 95% in differentiating benign from malignant pulmonary nodules. Net enhancement value show cut off point of 19.00 HU with sensitivity 96.9% and specificity 87.5% with accuracy rate 95% in differentiating benign from malignant pulmonary nodules.

Conclusion: Dynamic CE-CT is a useful tool in differentiating benign from malignant pulmonary nodules. Peak and net enhancement values are important parameters with high sensitivity and specificity in differentiating benign from malignant pulmonary nodules.

Keywords: Solitary, Pulmonary, Nodule, Dynamic CT, Enhancement, Benign, Malignant

Background

Solitary Pulmonary nodule can be seen in many pulmonary disorders, such as bronchogenic carcinoma, pulmonary tuberculoma and other inflammatory and vascular disorders. Thus, pulmonary nodules may be the reverberation of bronchogenic carcinoma and other benign pathologies. It is defined as well marginated rounded opacity that is less than 3 cm in size [1].

Incidental indeterminate solitary pulmonary nodule measuring < 3 cm in size are a progressively common finding on CT worldwide. Once detected there are a number of imaging modalities that can be done to help in nodule characterization and differentiating benign from malignant pulmonary nodules [2–4].

Through the imaging modalities that help in characterization of solitary pulmonary nodules; there are nuclear imaging techniques such as PET and SPECT. The accuracy of these techniques seems similar to dynamic

*Correspondence: elmetwallydina@gmail.com

[1] Faculty of Medicine, Mansoura University, Mansoura, Egypt
Full list of author information is available at the end of the article

CE-CT. Despite the high sensitivity and specificity of PET CT, it still remains an expensive modality with limited access in some countries. In the recent guidelines of the American College of Chest Physicians, dynamic CE-CT is recommended as one of the modalities that is used in assessment of indeterminate solitary pulmonary nodules [5].

Dynamic CE-CT is a functional test that includes the acquisition of a dynamic series of images of a pulmonary nodule before and after intravenous injection of iodinated contrast material [2]. The assessment of the vascularity of the nodule which reverb the degree of angiogenesis of that nodule by using dynamic CE-CT is confirmed to be helpful in distinguishing malignant from benign nodules through different threshold attenuation values across the nodule. Comparing malignant to benign nodules, malignant nodules usually demonstrate high vascularity. Thus, malignant nodules tend to enhance virtually more than benign once [6, 7]. Despite the wide availability and easy technique of dynamic CE-CT, it is not used routinely to differentiate benign from malignant pulmonary nodules. This is may be attributed to lack of data about the most important parameters that used to differentiate benign from malignant nodules and their cut off values.

Aim of the work

The purpose of this study was to evaluate the role of Dynamic CE-CT in characterization of solitary pulmonary nodules. Detect what are the important parameters on dynamic CE-CT to differentiate benign from malignant nodules and detect their cut off values.

Methods

Patient's demographic data

This prospective study was approved by our institution ethics committee and subjects agreed to participate and publicate images in this study with a written consent. The study was performed during the period from March 2020 to April 2022. It included 40 patients with an age range from 20 to 70 years (mean ± SD = 47.72 ± 12.10).

Inclusion criteria

Patients known to have recognized risk factors for lung cancer (e.g. smoking, positive family history, miner's worker, primary malignancy in any other organ). Patients represented by abnormal opacities or pulmonary nodule discovered accidently on CXR. Patients clinically show pulmonary symptoms (e.g. hemoptysis, dyspnea, cough) or clinically deteriorated and their CXRs not correlating.

Exclusion criteria

Patients had contraindication to irradiations as pregnant women. Patients with severe dyspnea or orthopnea (inability to hold breath for 15 s). Patients contraindicated to iodinated contrast media as sever allergy, and renal impairment (serum creatinine level of 1.5 mg/dl). Patients refusing canulation or experiencing panic attacks. Patients with sub solid pulmonary nodules. Patients with nodules < 8 mm.

CT technique:

CT examinations were done for all patients using multi detector CT (Philips, CT 128 slices). Before CT examination serum creatinine of patients was rechecked, good intravenous line for contrast injection was established. Breath-hold training was done before each exam.

Patients were in supine position with head first and elevated arms, in order to avoid beam hardening artifacts overlaps in the abdomen. The patients were asked to hold breath at the end of inspiration as long as possible. At first thin-section unenhanced CT scan images were obtained with the following parameters; slice thickness: 5 mm, Tube voltage: 120KVp and Tube current: 350 mA. The aim of unenhanced CT images was to confirm the presence of solitary pulmonary nodule that is suitable for dynamic CE-CT examination (Solid nodule > 8 mm in diameter and visible on mediastinal window). After confirming the suitability of the nodule on unenhanced CT images, 100 ml of contrast medium (350 mg/ml) was injected from antecubital vein, with injection rate of 4 ml/sec by using an automatic injector and then dynamic and delayed enhanced CT scans were obtained with the following parameter; Tube voltage: 120 KVp, tube current: 350 mA and slice thickness: 3 mm. Dynamic images were obtained at 60,120,180,240 s after contrast injection, delayed CT scanning was done approximately 15 min after the injection of contrast material.

Image analysis

After scanning, images were reconstructed, all images were then transferred to the workstation for further evaluation. The nodule should be analyzed in mediastinal window (width 400 HU, level 40HU) on the axial plane and in maximum size and the closest to the nodule equator. Assessment was done first for the morphological nodule characteristics: well-defined or ill defined, Lobulated, speculated or irregular margins and presence or absence of calcification and macroscopic fat. Then a circular or ovoid region of interest (ROI) was placed in the nodule at both dynamic and delayed scans. The section with the largest surface area of tissue was selected. Then, the mean attenuation value was calculated by detecting the mean Hounsfield unit value in each ROI of the pulmonary nodules on the dynamic and delayed CT scans, dynamic characteristics of tumor enhancement were calculated and assessed. Pre enhancement

is non contrast attenuation HU, peak enhancement is maximum attenuation value after contrast injection &it was detected at 120 s when the aorta is full with contrast material. Net enhancement was calculated by subtracting the pre-enhancement attenuation value from the peak enhancement attenuation value. Delayed enhancement is attenuation value on HU obtained on delayed CT scan (obtained 15 min after contrast injection). Absolute loss of enhancement (washout) was calculated by subtracting the delayed enhancement attenuation value from the peak enhancement attenuation value.

Standard of reference

Diagnosis were confirmed with histopathologic examination of specimens obtained with CT guided transthoracic needle biopsy in 20 cases, transbronchial lung biopsy in 9 cases and surgical resection in 5 cases.

Follow up for two years was done for cases with pulmonary nodules less than 1.5 cm in maximum diameter and had benign criteria on dynamic CE-CT and this was done in 6 cases.

Statistical analysis and data interpretation

Data were analyzed using the Statistical Package of Social Science (SPSS) program for Windows (Standard version 21). The normality of data was first tested with one-sample Kolmogorov-Smirnov test. Qualitative data were described using number and percent. Continuous variables were presented as mean ± SD (standard deviation) for normally distributed data and median (min-max) for non-normal data. The two medians were compared with Mann Whitney test. The two paired groups were compared with paired t test while more than two groups were compared with repeated measured ANOVA test. Sensitivity and specificity at different cut off point were tested by ROC curve. Level of significance: For all above mentioned statistical tests done, the threshold of significance is fixed at 5% level. The results was considered significant when $p \leq 0.05$. The smaller the p-value obtained, the more significant are the results.

Results

This Prospective study conducted on 40 adult patients with age range from 20 to 70 years (mean ± SD =47.72±12.10). 20 cases (50%) out of the patients were males while the other 20 cases (50%) were females, 21cases (52.5%) were smokers and 19 cases (47.5%) were non smokers.

According to our standard of reference, we had 32 malignant neoplastic nodules including (15 primary malignant and 17 secondary malignant pulmonary nodules) and 8 benign nodules including (inflammatory nodules in 6 cases, hamartoma in one case and granulometous nodule in one case) (Table 1).

Table 1 Final diagnosis of studied pulmonary nodules according to our standard of reference

Pathology	The study group (n = 40)
Benign nodules	
TB	2 (5.0%)
Septic pulmonary embolism	1 (2.5%)
Non-specific inflammatory nodule	2 (5.0%)
Wagner granulomatosis	1 (2.5%)
AML with fungal infection	1 (2.5%)
Hamartoma	1 (2.5%)
Malignant nodules	
Bronchogenic carcinoma	5 (12.5%)
Adenocarcinoma	11 (27.5%)
Primary	5 (12.5%)
Secondary	6 (15%)
Small cell lung cancer	3 (7.5%)
Large cell lung cancer	2 (5.0%)
Multiple myloma with pulmonary mets	1 (2.5%)
Ovarian cancer with pulmonary mets	2 (5.0%)
Nephrogenic tumor with pulmonary mets	2 (5.0%)
NHL with pulmonary mets	2 (5.0%)
Infiltrating duct carcinoma with pulmonary mets	2 (5.0%)
High grade sarcoma (leiomyosarcoma) with pulmonary mets	1 (2.5%)
Synovial sarcoma (liposarcoma) with pulmonary mets	1 (2.5%)

Regarding morphological criteria of studied pulmonary nodules, Regarding nodules margin, 3 nodules out of the 8 benign nodules showing regular borders while the remaining 5 nodules showing irregular borders, 14 nodules out of the 15 primary malignant nodules showing irregular margins (Fig. 1) while, the remaining one primary malignant nodule showing regular borders, 14 nodules out of the 17 secondary malignant nodules showing regular margins while the remaining 3 nodules showing irregular margins (p value ≤ 0.001). Also nodule speculation is more common in malignant nodules (p value $= \leq 0.001$). There was no statistically significant difference regarding the size of the nodules where, the mean size of benign nodules was 1.40 ± 0.48, mean size of primary malignant nodules was 1.89 ± 0.78 and the mean size of secondary malignant nodules was1.45 ± 0.59 (p value $= 0.118$). Regarding nodule lobulation, cavitation and calcifications, there was no statistically significant difference between benign and malignant nodules (p value > 0.5) (Table 2).

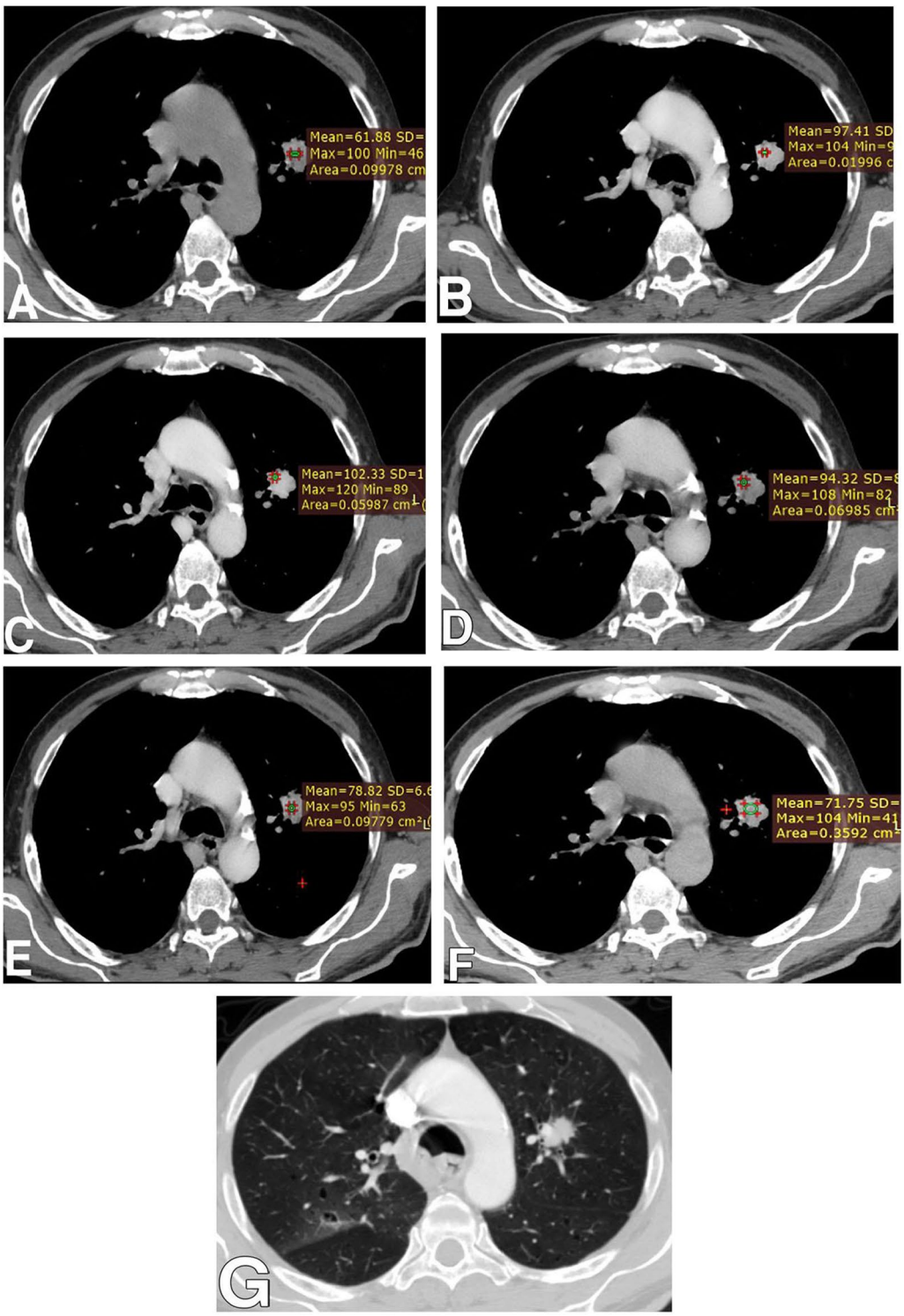

Fig. 1 Dynamic CE-CT study **A** Pre contrast axial CT scan of the chest on mediastinal window, **B–F** contrast enhanced axial CT scans of the chest on mediastinal window obtained 1,2,3,4 &15 min respectively after contrast injection: All figures showed: Well defined pulmonary nodule with irregular speculated border in left upper lung lobe measured 2.5 cm shows mean pre contrast enhancement of 61 HU, mean peak enhancement (after 2 min) of 102 HU and net enhancement = 41HU. **G** Axial CT scan of chest in pulmonary window showing the same pulmonary nodule with irregular speculated borders in left upper lung lobe. Pathological diagnosis: Moderately differentiated adenocarcinoma

Table 2 CT morphological characterization of benign, primary and secondary malignant pulmonary nodules

	Benign nodule (n = 8)	Primary malignant (n = 15)	Secondary malignant (n = 17)	Test of significance *p* (value)
Margin				≤ 0.001*
Regular	3(37.5%)	1(6.7%)	14(82.4%)	
Irregular	5(62.5%)	14(93.3%)	3(17.6%)	
Size	1.40 ± 0.48	1.89 ± 0.78	1.45 ± 0.59	$p = 0.118$
Speculation				≤ 0.001*
No	8(100%)	1(6.7%)	16(94.1%)	
Speculated	0(0%)	14(93.3%)	1(5.9%)	
Lobulation				0.851
Yes	1 (12.5%)	3 (20.0%)	2 (11.8%)	
No	7 (87.5%)	12 (80.0%)	15 (88.2%)	
Calcification				0.671
Yes	1 (12.5%)	0 (0%)	1(5.9%)	
No	7 (87.5%)	15 (100%)	16(94.1%)	
Cavitation				0.206
Yes	3(37.5%)	1(6.7%)	3(17.6%)	
No	5(62.5%)	14(93.3%)	14 (82.4%)	

Regarding the enhancement criteria on dynamic CE-CT images, we found that the Mean pre, peak net and delayed enhancement were higher in malignant nodules compared to benign nodules as they were 43.80 ± 9.95 100.66 ± 25.98, 44 (35–131) and 53.60 ± 8.05 respectively for primary malignant nodules (Fig. 1), 34.35 ± 9.53, 73.64 ± 12.24, 34 (24–78) and 40.88 ± 7.50 respectively for secondary malignant nodules (Fig. 2) versus 25(20–37), 33(30–45), 7.50 (5–14) and 28.12 ± 4.29 respectively for benign nodules (Fig. 3) with significant high *p* value ≤ 0.001. Regarding the washout of contrast we also found that malignant nodules showed higher values for contrast washout when compared to benign nodules. The mean contrast washout values was 47 (23–70) for primary malignant nodules and 32 (15–48) for secondary malignant nodules versus 6 (2–9) for benign nodules (Table 3).

According to ROC curve analysis, we found that the pre enhancement value show cut off point of 26.50 with sensitivity 93.8% and specificity 75% with accuracy rate 90% in differentiating benign from malignant pulmonary nodules. Peak enhancement value (at 2 min) show cut off point of 40.00 with sensitivity 96.9% and specificity 87.5% with accuracy rate 95% in differentiating benign from malignant pulmonary nodules. Net enhancement value show cut off point of 19.00 with sensitivity 96.9% and specificity 87.5% with accuracy rate 95% in differentiating benign from malignant pulmonary nodules (Table 4) (Fig. 4).

Discussion

The aim of the work was to evaluate the role of Dynamic CE-CT in characterization of nature of solitary pulmonary nodules through assessment of both nodule morphological criteria and enhancement criteria.

In the present study the size of pulmonary nodule is not predictive of benignity or malignancy ($p = 0.118$) and this is in agreement with Swensen et al. [8], Hou et al. [9], Yang et al. [10] who reported that there is no formative size guideline to determine the nature of a nodule and there was no statistically significant difference between benign and malignant pulmonary nodules regarding their size.

Regarding nodule margin in this study we found that there was statistically significant difference between benign and malignant nodules ($p \leq 0.001$). This agreed with the results of Hou et al. [9] and Yang et al. [10] who found that the margin of the lesion able to differentiate between benign and malignant nodules where benign nodules usually show well defined margins and smooth counters while malignant nodules usually show spiculated margins and irregular cotour and there was statistically significant difference between bening and malignant nodules regarding their margin.

Also in this present study speculation of a nodule showed high significant statistical value in differentiating benign from malignant nodules as most of malignant nodules showed speculation especially in cases

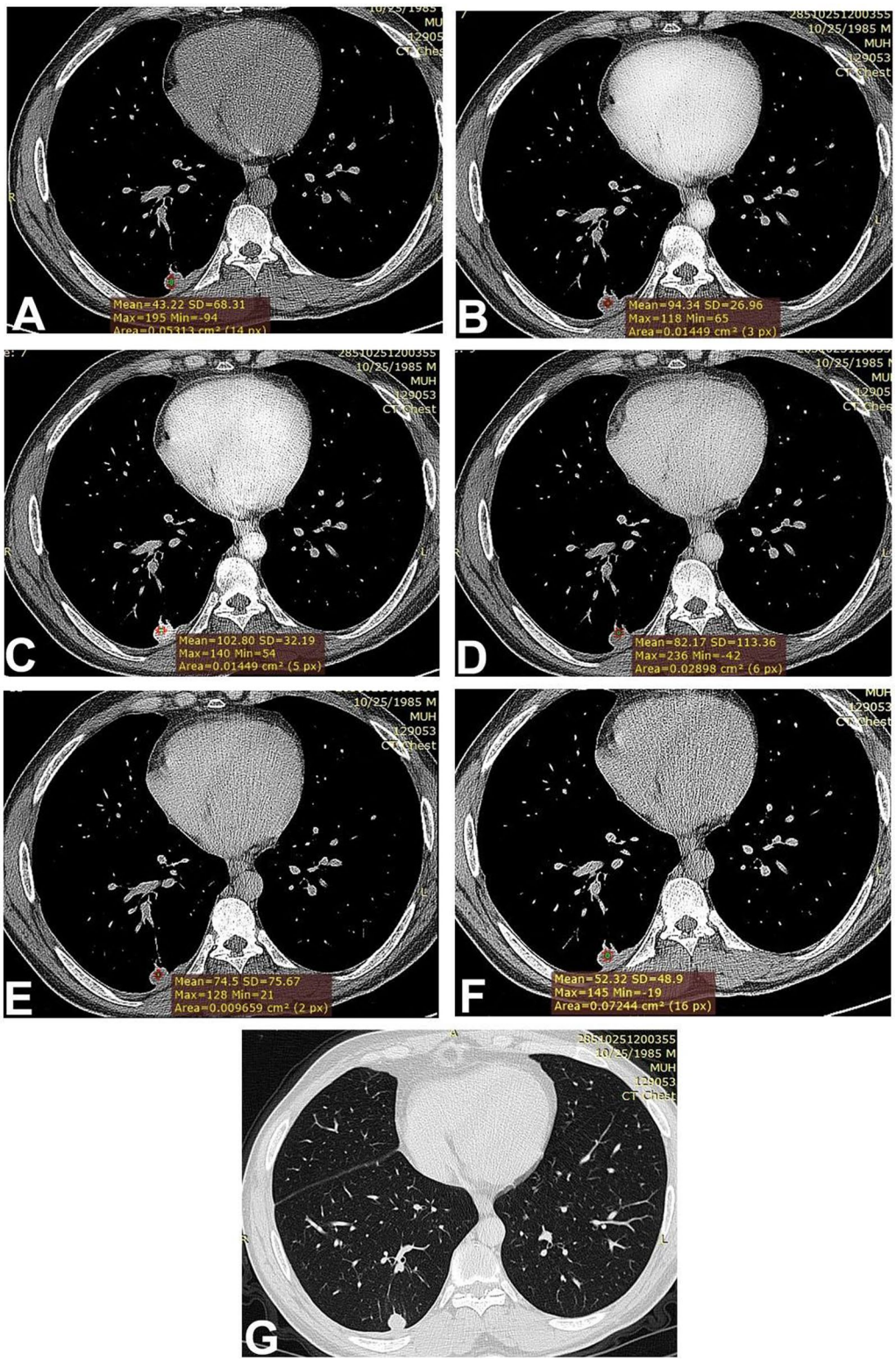

Fig. 2 Dynamic CE-CT study **A** Pre contrast axial CT scan of the chest on mediastinal window, **B–F** contrast enhanced axial CT scans of the chest on mediastinal window obtained 1,2,3,4 &15 min respectively after contrast injection: All figures showed: Well defined pulmonary nodule with regular margin in right lower lung lobe measured 1.2 cm shows mean pre contrast enhancement of 43 HU, mean peak enhancement (after 2 min) of 102 HU and net enhancement of 59 HU. **G** Axial CT scan of chest in pulmonary window showing the same pulmonary nodule with regular borders in right lower lung lobe. Pathological diagnosis: Metastatic nodule from ovarian carcinoma

with primary malignant nodules ($p=0.001$) and this fitted with Xu et al. [11] who reported that spiculated or irregularly marginated nodule signifying uneven growth, is often associated with malignant nodules ($p=0.001$). Also our results agreed with Alexander et al. [12] who reported that, the speculated edge has a positive predictive value (PPV) range of 88–94% for malignant pulmonary nodule. Moreover Hou et al. [9] demonstrated that speculation showed statistically significant difference in differentiation between benign and malignant nodules ($p=0.001$). Winer-Muram [13] stated that spiculated margin which is often described as a sunburst or corona radiata sign is highly predictive of malignancy, with a positive predictive value of 90%.

In contrary to our work, Yang et al. [10] reported that speculation isn't a good sign in differentiation between benign and malignant nodules ($p=0.88$). Also Park et al. [14] Reported that up to 20% of primary malignant nodules and many metastatic lesions, have smooth margins, therefore, the presence of a smooth contour is not a reliable sign ($p>0.05$), and also Cruickshank et al. [15] found that nodule margins and contours can be classified as smooth, lobulated, irregular, or spiculated. Although most nodules with smooth, well-defined margins are benign, these features are not diagnostic for a benign cause as 21% of malignant nodules have well-defined margins ($p>0.05$).

In the present study the mean pre enhancement value was 25.12 ± 5.54 for benign nodules versus 43.80 ± 9.95 for primary malignant nodule and 34.35 ± 9.53 for secondary malignant nodules ($p\leq0.001$). This is in line with Ye et al. [6] who reported that the mean pre enhancement value of benign nodules was significantly different from that of malignant nodules $p\leq0.001$.

In the present study the mean peak enhancement (2 min after contrast administration) was 34.12 ± 4.64 for benign nodules versus 100.66 ± 25.98 for primary malignant nodule and 73.64 ± 12.24 for secondary malignant nodules ($p\leq0.001$). This is in agreement with the results of Li et al. [1] who reported that benign nodules showed a maximal enhancement (peak enhancement) at 2 min after contrast administration, and it was 57.31 ± 21.44 for benign nodules versus 79.63 ± 16.38 for malignant nodules ($p\leq0.001$). Also in agreement with Khanduri et al. [7] who reported that, the mean peak enhancement of benign nodules was 61.29 ± 6.94 HU (range from 52 to 75 HU) and the mean peak enhancement of the malignant nodules was 69.94 ± 10.88 HU (range from 58 to 84 HU) ($p<0.001$).

In the present study the mean enhancement on delayed CT scans (15 min after contrast injection) was higher on malignant pulmonary nodules when compared to benign nodules. It was 28.12 ± 4.29 for benign nodules versus 53.60 ± 8.05 for primary malignant nodule and 40.88 ± 7.50 for secondary malignant nodules ($p<0.001$). This is in line with Ye et al. [16] who found that the mean enhancement value on delayed CE-CT for malignant nodules was higher than benign nodules. It was 48 ± 16.8 HU for benign nodules versus 62 ± 11.7 HU for malignant nodules ($p<0.001$).

Regarding the mean net enhancement, we found that net enhancement were higher in malignant nodules compared to benign nodules. It was 7.50 (5–14) for benign nodules versus 44 (35–131) for primary malignant nodules and 34 (24–78) for secondary malignant nodules ($p<0.001$). This is in agreement with Khanduri et al. [7] who stated that the net enhancement attenuation (wash in) was 22.29 ± 7.60 HU (range 7–40) for benign nodules versus 30.96 ± 5.95 HU (range 20–42) for malignant nodules ($p<0.001$).

Regarding washout of contrast on delayed CT images, we found malignant nodules showed higher contrast washout compared to benign nodules ($p<0.001$). This is in agreement with Choi et al. [16] who found that benign nodules showed persistent enhancement < 15 HU and no wash-out or washout < 25 HU, while malignant nodules showed early enhancement > 15 HU and early wash-out of 5–25 HU. Also our results agreed with Jeong et al. [17] who stated that Malignant nodules showed greater washout of contrast (15 HU (0–34 HU) in absolute loss or 15% in relative loss) than did benign nodules (14 HU (0–90 HU) in absolute loss or 14% in relative loss) (P 0.001 and 0.035, respectively). In their study most of the malignant nodules (94%) showed 5–31 HU washout out of contrast.

(See figure on next page.)

Fig. 3 Dynamic CE-CT study **A** Pre contrast axial CT scan of the chest on mediastinal window, **B–F** contrast enhanced axial CT scans of the chest on mediastinal window obtained 1,2,3,4 &15 min respectively after contrast injection: All figures showed: Well defined pulmonary nodule with smooth border measured 2.2 cm in apeco posterior segment of left upper lobe and mean pre contrast enhancement of 37 HU and mean peak enhancement (after 2 min) of 45 HU and net enhancement of 8HU. **G** Axial CT scan of chest in pulmonary window showing the same pulmonary nodule with regular smooth borders in apeco posterior segment of left upper lung lobe. Pathological diagnosis: pulmonary tuberculoma

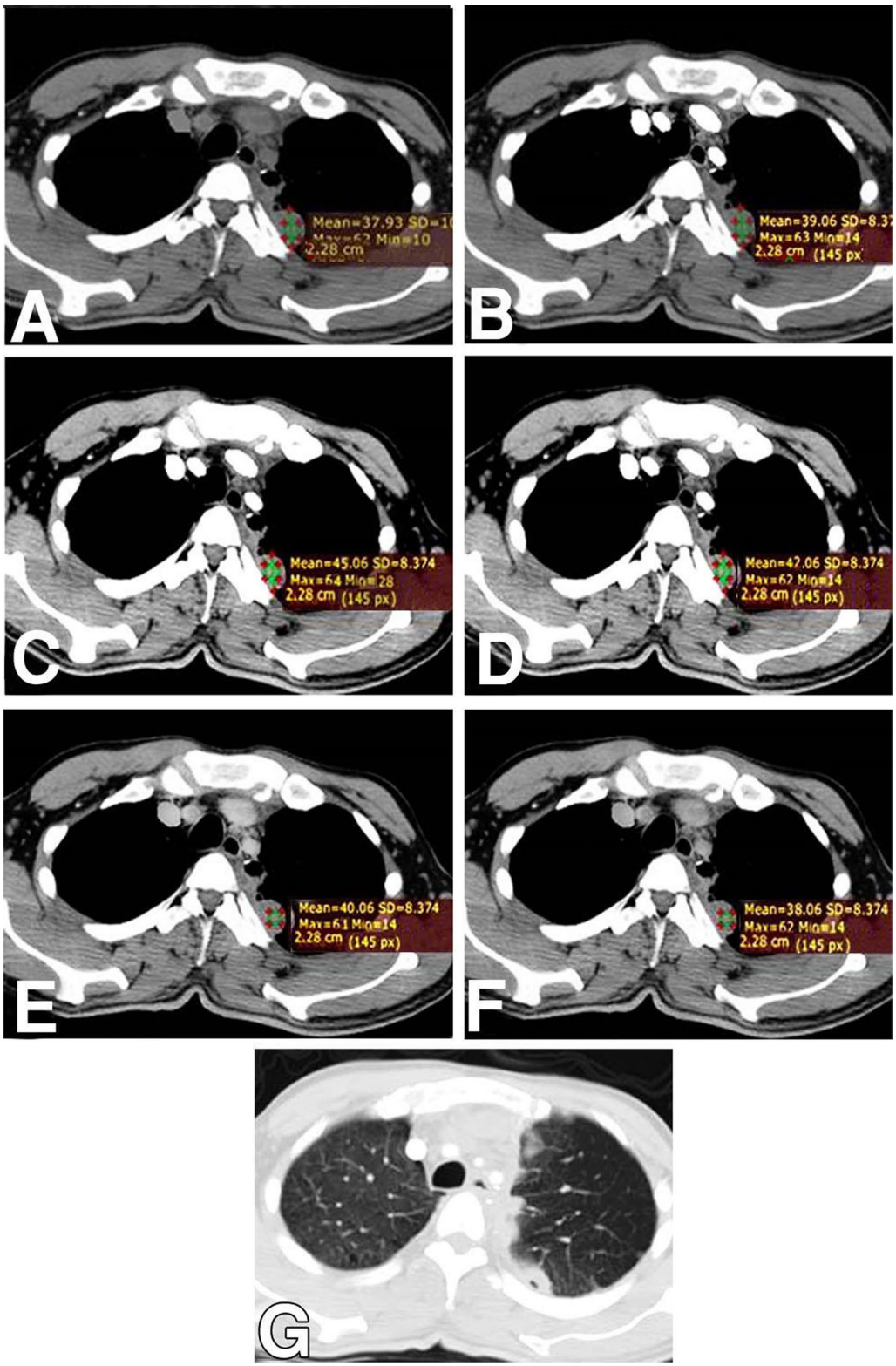

Fig. 3 (See legend on previous page.)

Table 3 The mean pre, peak & net enhancement among the studied pulmonary nodules

	Benign nodule (n = 8)	Primary malignant (n = 15)	Secondary malignant (n = 17)	Test of significance *p* (value)
Pre	25.12 ± 5.54	43.80 ± 9.95	34.35 ± 9.53	$F = 11.526$ $p \leq 0.001$*
After 1 min	31.50 ± 3.50	80.86 ± 18.10	60.64 ± 10.91	$F = 36.007$ $p \leq 0.001$*
After 2 min (peak)	34.12 ± 4.64	100.66 ± 25.98	73.64 ± 12.24	$F = 35.835$ $p \leq 0.001$*
After 3 min	32.25 ± 4.71	75.53 ± 14.25	58.00 ± 9.77	$F = 40.170$ $p \leq 0.001$*
After 4 min	29.75 ± 4.43	65.33 ± 10.56	50.82 ± 7.98	$F = 45.212$ $p \leq 0.001$*
After 15 min	28.12 ± 4.29	53.60 ± 8.05	40.88 ± 7.50	$F = 33.706$ $p \leq 0.001$*
Net enhancement	7.5 (5–14)	44. (35–131)	34 (24–78)	KW = 22.697 $p \leq 0.001$*
Washout of contrast	6 (2–9)	47 (23–70)	32 (15–48)	KW = 20.587 $p \leq 0.001$*

KW, Kruskil wallis test

Table 4 Receiver operating characteristics curve (ROC) curve for prediction of malignant nodules by pre, peak & net enhancement

	AUC	95% CI	Cutoff	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Pre	0.898	0.77–1.02	26.50	93.8	75	93.7	75	90
After 2 min (peak)	0.990	0.97–1.01	40.00	96.9	87.5	96.9	87.5	95
Net	0.986	0.96–1.01	19.00	96.9	87.5	96.9	87.5	95

AUC: area under the curve, CI: confidence interval, PPV: positive predictive value, NPV: Negative predictive value

ROC curve analysis in this study revealed that the cutoff point of mean net enhancement (19.00 HU) had sensitivity of 96.9%, specificity of 87.5% and accuracy of 95% in differentiating benign from malignant pulmonary nodules. This is in agreement with Khanduri et al. [7] who stated that the results of the ROC curve analysis showed that a threshold net enhancement value of 22.5 HU has a sensitivity of 88.5% and specificity of 57.1% to diagnose malignant pulmonary nodule. Qureshi et al. [2] also reported that, typically a pulmonary nodule that demonstrates an overall net enhancement > 15 HU is usually suggestive of being malignant nodule whereas nodule enhancement of < 15HU are strongly predictive of benign nodules. Also Ye et al. [18] reported that a threshold net enhancement value of 15 HU or more produced sensitivity of 98%, specificity of 58%, and an accuracy of 77% for malignant nodules. Dabrowska et al. [5] stated that applying 15 HU as the cutoff level between benign and malignant nodules demonstrate 100% sensitivity, 41% specificity and 75% diagnostic accuracy.

There are few limitations for this study which are the small number of patients and inter observer agreement about the patient's data was not performed.

Conclusions

Dynamic CE-CT is a useful tool in differentiating benign from malignant pulmonary nodules. Peak and net enhancement values are important parameters with high sensitivity and specificity in differentiating benign from malignant pulmonary nodules.

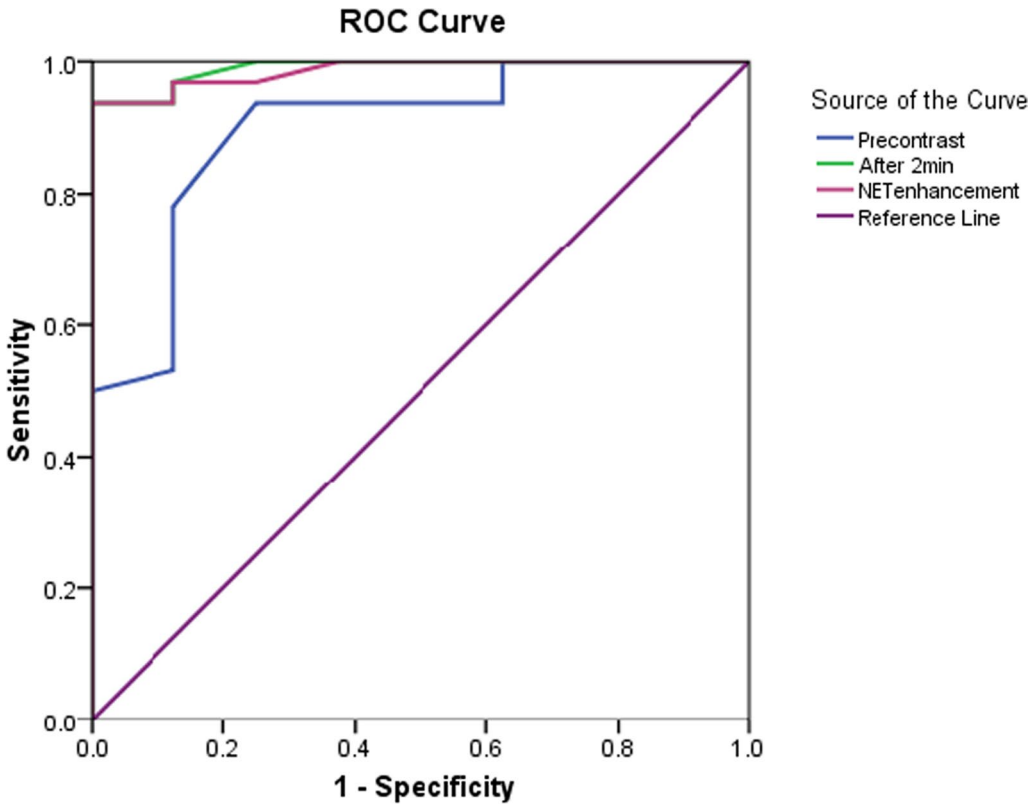

Fig. 4 ROC curve showing the cutoff point, sensitivity, specificity and accuracy of the pre enhancement, peak enhancement and net enhancement values in differentiating benign from malignant pulmonary nodules

Abbreviations
CE-CT: Contrast enhanced computed tomography; CT: Computed tomography; PET: Positron emission tomography; FDG: Fluorodeoxyglucose; SPECT: Single photon emission computed tomography; HU: House field unit; CXRs: Chest X-ray; mA: Milliampere; KVp: Kilo volt; SD: Standard deviation; mm: Millimeter; ROI: Region of interest; ROC: Receiver operating curve.

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Author contributions
ME revised the collected data and the manuscript. SA & DM analyzed the CT images of all patients. MM & DM wrote the manuscript. MA performed the statistical analysis. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by our institution's ethics committee (Mansoura Faculty of Medicine Institutional Research Board) (ethics committee reference number is MS/17.07.61) and all patients gave their written informed consent before inclusion in the study.

Consent for publication
Written informed consent for the publication of this data was taken from the patients.

Competing interests
The authors declare that they have no competing interests**.**

Author details
[1]Faculty of Medicine, Mansoura University, Mansoura, Egypt. [2]Ministry of Health, Cairo, Egypt.

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