Original Research Article

Role of combined wash-in and wash-out threshold criteria on dynamic multislice CECT for solitary pulmonary nodule characterisation: data from Indian tertiary care hospital

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ABSTRACT

Background: To prospectively assess the accuracy of combined wash-in and washout characteristics at dynamic contrast material–enhanced multi– detector row computed tomography (CT in distinguishing benign from malignant solitary pulmonary nodule (SPN).

Methods: Institutional review board approval and informed consent were obtained. The study included 30 patients (16 men, 14 women; mean age, 52 years; range, 25-80 years) with SPN. After unenhanced CT (1.25mm collimation) scan, dynamic CT was performed (series of images obtained throughout the nodule, with 0.6mm collimation, at 30, 60, 90, and 120 seconds and 4, 5, 9, 12, and 15 minutes) after intravenous injection of contrast medium (120 mL). The HU value of nodule was noted at each of the scans. Data was analyzed for dynamic enhancement characteristics. FNAC from the nodule was done in all patients. The data were correlated with the cytopathological and follow –up results. The significance of various dynamic enhancement features and different threshold criteria for wash-in and wash-out of contrast medium for differentiation between benign and malignant nodules were derived.

Results: There were 16 malignant and 14 benign nodules. When diagnostic criteria for malignancy of both wash-in of 25 HU or greater and washout of 5-34 HU were applied, sensitivity, specificity, and accuracy for malignancy were 100%, 92.8% and 96.7% respectively.

Conclusions: Evaluation of solitary pulmonary nodules by analyzing combined wash-in and washout characteristics at dynamic contrast-enhanced multi– detector row CT showed 96.7% accuracy (p<0.001) for distinguishing benign nodules from malignant nodules.

Keywords: Dynamic contrast enhanced CT, Solitary pulmonary nodule, Peak enhancement, Wash-in, washout

INTRODUCTION

Solitary pulmonary nodule (SPN) is a round or oval opacity smaller than 3 cm in diameter that is completely surrounded by pulmonary parenchyma and is not associated with lymphadenopathy, atelectasis, or pneumonia.[1] This definition is mainly for plain radiographs, the term focal opacity is used for CT.

Widespread use of multislice chest CT imaging has led to exponential rise in detection of pulmonary nodules. Size of the detected nodules is also getting smaller, making characterization difficult. The task is no less daunting for the radiologist stumbling upon an incidental lung nodule on a routine CT chest examination. Most nodules are benign but they may represent early stage of lung cancer. Lung cancer is the leading cause of cancer deaths worldwide with low 5-year survival rate of 14%.[2] Early lung cancer of <3cms (stage 1A) has a survival rate of

70-80%.Therefore, prompt diagnosis and management of lung cancer may be the only chance of cure.[3] While the differential diagnosis for SPN is extensive, most lesions are found to be granulomas, lung cancers, or hamartomas. After initial clinical risk assessment and morphology evaluation, most small nodules will be indeterminate. Approximately 50% of indeterminate lung nodules for which surgery is performed for diagnosis are benign.[4,5] The ultimate goal of SPN evaluation is to detect malignant nodule at the earliest and to avoid unnecessary biopsy of benign nodule. Therefore, the need for noninvasive imaging modalities for the specific diagnosis of indeterminate lung nodules has been raised. Functional imaging options include dynamic MRI, FDG PET-CT, perfusion CT. There is no definite consensus as yet on the most appropriate imaging modality.[6]

The evaluation of tumor vascularity by using contrast-enhanced CT has proved to be useful for differentiating between malignant and benign nodules.[7,8] However, some overlap is found in enhancement characteristics of malignant nodules and active inflammatory nodules or benign vascular tumors if only the peak enhancement is observed.[9,10] Studies have shown higher specificity for malignant nodules if both the wash-in and wash-out characteristics are noted.[11]

Data of SPN imaging is scant from countries like India, where lung tuberculosis is endemic and there are no formal lung cancer screening programs. The cost factor of imaging an incidental nodule and limited availability of advanced imaging like perfusion imaging and PET-CT only add to the dilemma of the Indian radiologist trying to characterize an SPN. In such a scenario, it would be welcome if a readily available imaging modality like CT is found to be accurate enough to distinguish between benign and malignant SPN.

METHODS

The prospective study was conducted in which a total of 30 adult patients meeting the inclusion criteria were part of the study cohort. Informed consent was taken from all patients.

Patients with pulmonary nodules on a Chest x-ray or plain CT scan measuring 5-30 mm, spherical or approximately spherical, with its long and short axis diameter within a factor of 2 of each other and nodules that appear solitary on chest x-ray, but not necessarily on plain CT were included. Patients with nodules with benign pattern of calcification (diffuse, popcorn, laminar, central) and fat were not included. Patients not consenting for the study, with contraindications to intravenous contrast media and those with respiratory insufficiency were also excluded.

Nodules fulfilling the inclusion criteria were subjected to targeted thin-section helical CT scanning using PHILIPS BRILLIANCE 40 slice CT scanner. Parameters used

were collimation 0.6mm, 80 mAs, covering the nodule for 40mm along z-axis. Then additional series were taken at 30, 60, 90 and120 seconds and 4, 5, 9, 12 and15 minutes after injecting non-ionic contrast medium at the rate of 3ml/sec by power injector. Immediately after dynamic imaging at 120 seconds helical CT scan was obtained from lung apices to the level of diaphragm to obtain a routine contrast enhanced CT scans of chest. Image data were reconstructed with thickness of 1.25mm for the dynamic series by using a standard algorithm. The technical adequacy of dynamic CT scans was assessed.[12]

Nodules were then evaluated for morphological features including size, margins, satellite lesions, calcification, cavitation and any feeding vessel. For evaluation of dynamic enhancement pattern, selected image was taken as the transverse section with the largest diameter. A circular region of interest was placed that covered about half of the diameter at the equator. The attenuation value was measured in the same area on selected image for each cluster at each time point (i.e. from unenhanced image to image acquired at 15 minutes). Areas of calcification, necrosis and cavitation were excluded. Attenuation values of defined ROI area were recorded. Time-attenuation curves were drawn and analyzed and dynamic characteristics of tumor enhancement were calculated viz. Pre-enhancement HU, peak–enhancement, net–enhancement, time to peak enhancement, absolute loss of enhancement. Net enhancement or wash-in was defined as the difference of the pre-enhancement and peak enhancement attenuation value. Absolute loss or wash out was defined as the difference of the attenuation value at 15 minutes and the peak enhancement value.

CT-guided trans-thoracic FNAC (tissue diagnosis) was done using 22G LP needle for cytopathological correlation in all the nodules as a final reference standard. Cytopathological results were categorised as malignant, non specific benign and specific benign result. Follow up CT scans after 6-9 months were obtained in nodules with non specific benign result on FNAC. Final diagnosis was thus achieved for all the nodules.

Retrospective calculations were used to evaluate the usefulness of contrast medium wash –in as a marker for malignant nodules versus benign nodules. Washout of contrast medium was also calculated for all the nodules. Sensitivity, specificity, accuracy, and positive and negative predictive values were calculated by varying the threshold value for wash-in and wash-out that signified a positive finding (cutoff value). Significance of results for various thresholds of wash-in and wash-out combined together was also calculated. Statistical evaluation was done using SPSS software. Mann-Whitney and Chi-square tests were used to calculate the p-value. P-value of <0.01 was taken as significant.

RESULTS

Clinical and CT findings are summarized in Table 1.

The morphological features are summarized in table below (Table 2). There was significant overlap in the morphological features of benign and malignant nodules.

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Early enhanced CT scan and wash-in of contrast material

Early enhancement characteristics of benign and malignant nodules are summarized in Table 3.

Table 1: Summary of clinical and CT findings.

A/S	Clinical History		Nod. Size	Dynamic Contrast Enhancement Characteristics (HU)					
	Smoker	k/c/o malignancy	(cms)	0 s	peak enhancement	W/I	W/O	Curve. typ	FNAC
61/M	YES	YES(RCC)	0.8 X 0.6	35	98.8	63.8	28	I	M
40/F	YES	NO	2.5 X 2.1	41.1	80	39.5	6.2	I	M
56/F	YES	NO	2.8 X 2.1	53.4	93.5	40.1	10.2	I	M
26/M	YES	NO	1.5 X 1.1	44	66.9	22.9	8.5	II	B
60/M	YES	YES (Maxillary sinus)	2 X 1.1	33.9	68	34.1	8.2	I	M
70/F	YES	YES(CML)	2.2 X 1.8	42.5	107	65.1	18.4	I	M
32/M	NO	NO	2.8 X 2.1	53.2	61.5	8.3	7.2	II	B
35/F	NO	YES(Breast)	2.4 X 1.3	62	103	41.3	14.9	I	M
25/F	NO	NO	0.8 X 0.6	67.9	97.9	30	No WO	III	B
80/M	YES	NO	2.4 X 2.6	68.3	119.5	51.2	17.9	I	M
65/M	YES	NO	2.3 X 1.2	38.9	121	82.1	50.6	IV	B
65/F	YES	NO	1.4 X 1.1	25.9	99.5	73.6	24.6	I	M
26/F	NO	NO	1.2 X 1.1	32.4	42.8	10.1	2.5	II	B
50/F	NO	NO	2.2 X 1.8	55.1	115	48.2	14.6	I	M
53/F	NO	NO	2.5 X 2.1	64.8	102	37.2	24.3	I	B
51/M	YES	YES(Sarcoma)	1.3 X 1.1	33.2	92.3	59.1	33.5	IV	M
43/M	NO	NO	1.3 X 1.2	53.2	59.6	6.4	8.1	II	B
65/F	NO	NO	2.1 X 1.8	52	60.3	8.3	6.1	II	B
65/M	YES	NO	2.5 X 2.2	62.3	93.4	31.1	8.3	I	M
42/F	NO	NO	2.8 X 2.5	76.8	116	39.8	11.4	I	M
48/M	YES	NO	2.8 X 2.5	32.8	66.9	34.1	12.7	I	M
70/F	YES	NO	2.2 X 2	46	148	102.2	32.4	IV	M
52/M	YES	NO	1 X 0.8	27.3	30.8	3.5	3.4	II	B
60/M	YES	NO	2.8 X 2.1	37.3	39.8	2.6	7.8	II	B
62/M	YES	NO	1.5 X 1.2	43.4	49.5	5	3.8	II	B
55/M	YES	YES(Sarcoma)	1.5 X 1.1	43.7	94.2	50.4	24.2	I	M
58/M	YES	NO	2.7 X 2.6	44.4	58	5	3.6	II	B
65/F	NO	NO	1.2 X 1.1	32.2	36.7	4.4	1.3	II	B
52/M	YES	NO	2.8 X 2.5	54.5	83.9	30	8.4	I	M
32/F	NO	NO	1.6 X 1.4	34.4	66.4	32	No WO	III	B

The mean attenuation value of benign nodules on unenhanced scan was not significantly different from that of malignant nodules (p=0.48). In all 16 malignant nodules, peak level of enhancement occurred within 5 minutes of contrast material injection (2 minutes in 6 nodules, 4 minutes in 4 nodules, 90 seconds in 3 nodules, 60 seconds in 2 nodules and 5 minutes in one nodule).

The time to peak enhancement for 14 benign nodules was widely distributed (one each at 30 and 60 seconds, 2, 4, 5, 9 and 12 minutes, 6 at 90 seconds, one at 15 minutes. Time to peak enhancement was not significantly different in benign and malignant nodules (p=0.673). Significantly higher peak enhancement was seen in malignant nodules (mean 92.98HU; range, 68 -149 HU) than in benign

nodules (mean, 69.44HU; range, 38-139HU) (p=0.008). Therefore, the net enhancement for malignant nodules (mean 50.22HU; range, 30-103HU) was significantly greater than that for benign nodules (mean, 24.04HU; range, 2-88 HU) (p=0.002).

Table 2: Morphological characteristics.

Morphological feature	Benign (n=14)	Malignant (n=16)
Size	Mean 17.9	Mean 21.6
(diameter in mm)	Range 8-30	Range 6-30
Margin		
- Smooth	n=11 (71.4%)	n=3 (18.75%)
-Irregular/spiculated	n=3(28.57%)	n=13(81.25%)
Calcification* (eccenteric/coarse)	n=8	n=2
Cavitation**	n=2	n=4
Pleural tag	n=2	n=5
Satellite nodule	n=6	n=1
Feeding vessel sign	n=0	n=1

*nodules with definitely benign pattern of calcification viz. diffuse, laminated, popcorn like or central were excluded from the study
**nodules with predominant cavitatory component which would have precluded the placement of ROI were excluded from the study.

Table 3: Early enhancement characteristics.

Characteristics	Malignant nodule (n=16)	Benign nodule (n =14)	p value†
Pre-enhancement value (HU)			
Mean	47.90±14.53	44.67±12.3	
Median	44.85	43.7	0.48
Range	25-77	20-70	
Peak-enhancement value (HU)			
Mean	92.98±20.35	69.42±33	
Median	96.5	60.55	0.008
Range	68-149	38-139	
Net enhancement value (HU) Mean	50.22±19.04	24.04±28.27	
Median	44.75	9.2	0.002
Range	30-103	2-88	
Time to peak enhancement			
Mean	2.43± 1.3 min	5.07± 5.35 min	
Median	2 min	1.75 min	0.673
Range	60s to 5 min	30s to 15 min	

Three different thresholds i.e. wash-in of more than 20, 25 and 30 HU were assumed as criteria for malignancy. Retrospective calculations were done using the cytopathological and follow up results. Sensitivity, specificity, positive and negative predictive value and accuracy was calculated for each of these threshold values of wash-in (Table 4).

Delayed enhancement CT and washout of contrast material

Malignant nodules showed wash-out in the range of 6.2-33.5 HU. Benign nodules showed wash out in the range of 0-50.6 HU.

Most of the malignant nodules (14 of 16, 87.5%) showed washout of contrast medium within a range of 5-31HU, (Figure 1a and 1b) 1 (6.25%) showed 32.4 HU wash out and 1 (6.25%) showed 33.5HU washout.
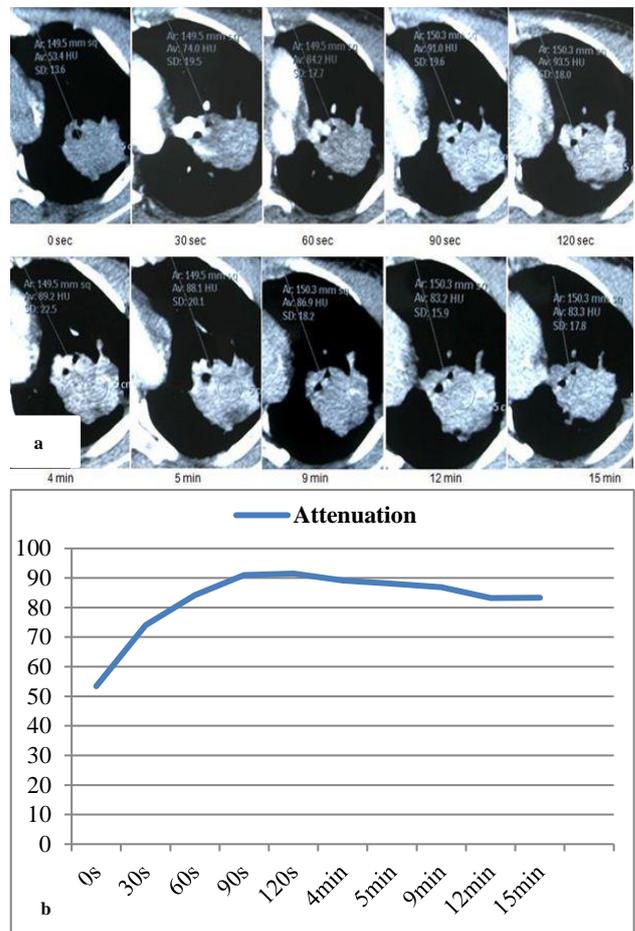
Figure 1: a) Dynamic CECT of SCC (patient no. 3) shows peak enhancement of 93.5 HU at 120s, wash - in of 40.1HU and washout of 10.2 HU; b) Time-attenuation curve plotted showed curve type I.

Of the 14 benign nodules, 10 (71.42%) showed less than 25 HU wash in, 2 (14.28%) showed more than 25 HU wash in with persistent enhancement (Figure 2a and 2b), 1 (7.14%) showed 82.1HU wash in with 50.6 HU wash out (Figure 3a and 3b) and the remaining 1 (7.14%) showed 37.2HU wash in and 24HU wash out.
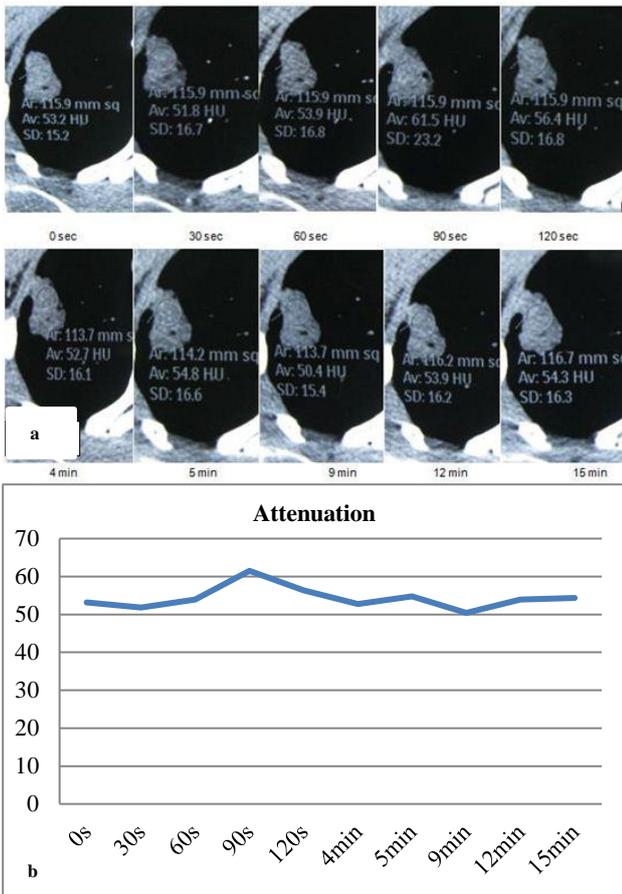
Figure 2: a) Dynamic CECT of patient no.7 shows peak enhancement of 61.5 HU at 90s, wash-in of 8.3HU and washout of 7.2 HU; b) The time-attenuation curve was type II. FNAC yielded inflammatory cells.
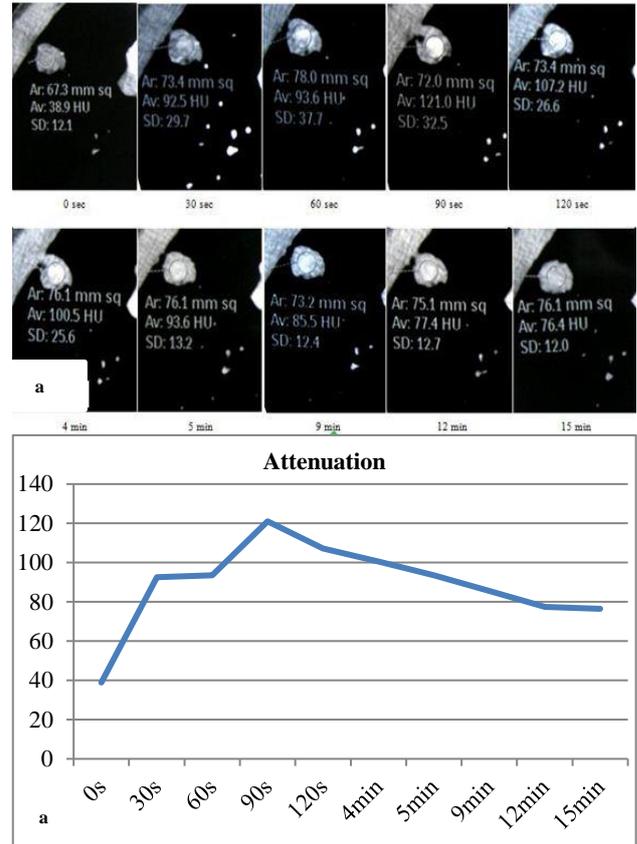
Figure 3: a) Dynamic CECT of pulmonary hamartoma (patient no.11) shows peak enhancement of 121 HU at 90s, wash-in of 82.1 HU and washout of 50.6 HU; b) The time-attenuation curve was of type IV.

Table 4: Statistical significance of wash-in threshold values for malignancy.

Wash-in threshold for malignancy	Sensitivity	Specificity	PPV	NPV	Accuracy	p-value
>20HU	100%	57%	72.72%	100%	80%	<0.001
>25HU	100%	64.28%	76.19%	100%	83.3%	<0.001
>30HU	93.75	73.3%	78.9%	90.9%	83.3%	<0.001

Table 5: Statistical significance of wash-out threshold values for malignancy.

Wash-out (HU)	Sensitivity(%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy	p-value (chi-square test)
5-31HU	87.5	92.8	93.33	86.66	90	<0.001
5-33HU	93.75	92.8	93.7	92.8	93.33	<0.001
5-34HU	100	92.8	94.1	100	96.67	<0.001

Considering the nodule dynamics of both early and delayed enhancement CT, several diagnostic rates were retrospectively calculated at different cutoff values (Table 5).

Considering the nodule dynamics of both early and delayed enhancement on CECT, four kinds of enhancement pattern were observed (Figure 4).
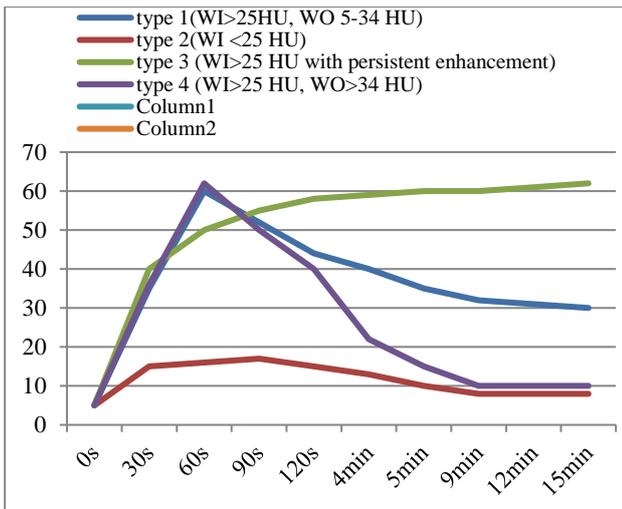
Figure 4: Time attenuation curve.
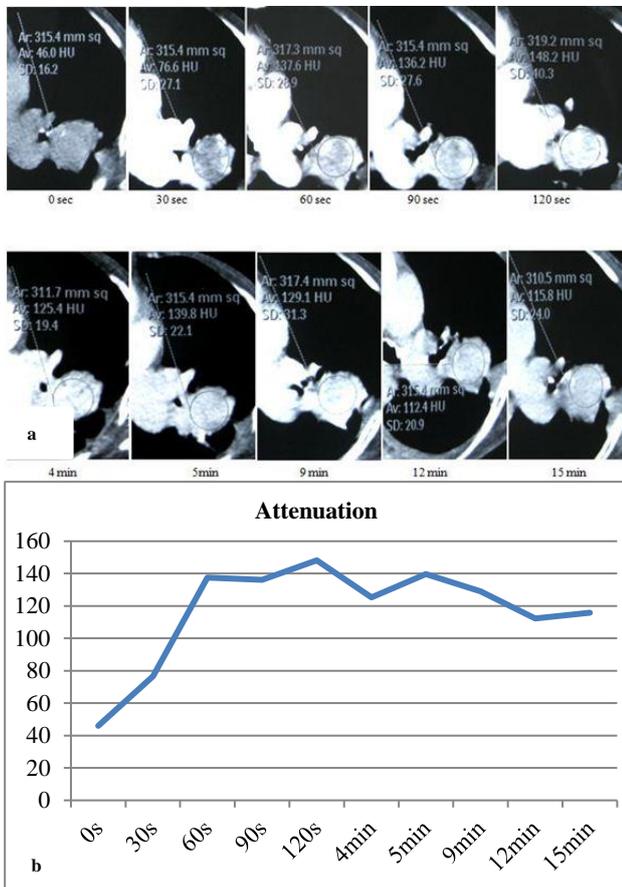
Figure 5: a) Dynamic CECT of patient no. 22 shows peak enhancement is 148.2HU at 120s, wash-in of 102.2 HU and washout of 32.4 HU; b) The time-attenuation curve was of type IV. FNAC yielded adenocarcinoma. This was a false-negative case.

Considering >25HU wash-in and 5-31 HU washout as threshold value for malignancy false-positive result for malignancy was obtained in only one patient which proved out to be a tubercular consolidation (Figure 6a

and 6b). False-negative result was seen in only one patient which turned out to be an adenocarcinoma. Considering >25HU wash-in and 5-34 HU washout as threshold value for malignancy false-positive result for malignancy was obtained in only one patient which proved out to be a tubercular consolidation (Figure 5a and 5b) and there was no false-negative case.
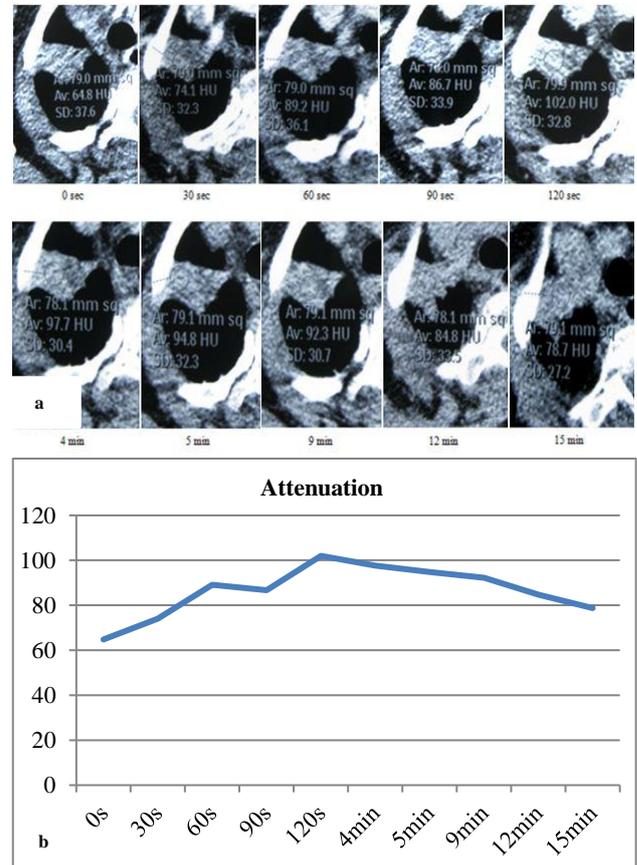
Figure 6: a) Dynamic enhancement of patient no. 15 shows peak enhancement of 102 HU at 120s, wash-in of 37.2 HU and washout of 24.3 HU; b) The time-attenuation curve was of type I. FNAC yielded granulaomatous. this was a false-positive case.

DISCUSSION

Of 30 nodules, 16 (53.33%) proved to be malignant and 14 (46.67%) proved to be benign. Larger number of malignant nodules can be explained by the inherent selection bias in the study because nodules with definitely benign pattern of calcification were excluded.

Malignant nodules (mean size 21.6mm, range 8-30mm) were comparatively larger than benign nodules (mean 17.9mm, range 6-30mm) (Figure 7a and 7b).

Malignant nodules usually had irregular and spiculated margins (81.25%) while benign nodules usually had smooth margins (71.4%) (Figure 8a and 8b).
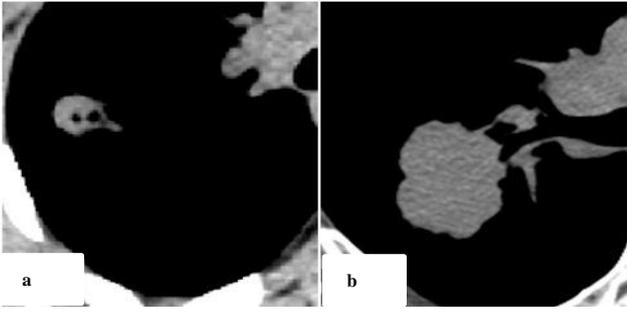
Figure 7: a) A small (measuring 1.1cm) solitary pulmonary nodule which proved out to be of benign nature; b) A larger (measuring 2.8cm) solitary pulmonary nodule which proved out to be of malignant nature.
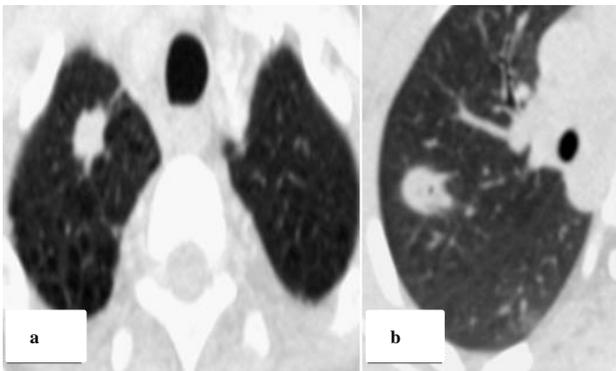
Figure 8: a) Irregular spiculated margin in a proven malignant SPN; b) Well defined and smooth margin in a proven benign SPN. A small area of cavitation is also seen.
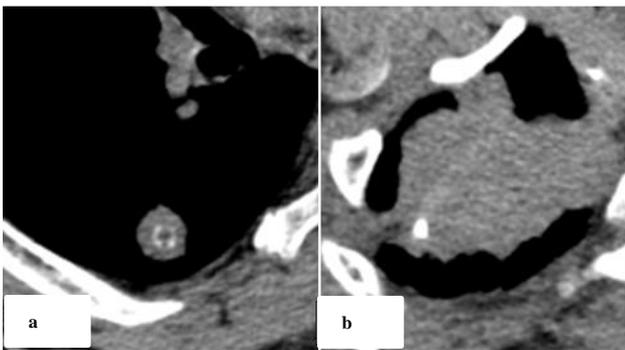
Figure 9: a) Central calcification in a benign SPN (proven case of benign pulmonary hamartoma); b) a malignant nodule with eccentric calcification and associated pleural tag.

Malignant nodules with smooth margins were metastasis from extra-pulmonary malignancy. Benign nodules with irregular margins were fibrotic due to the surrounding cicatrisation. Satellite nodules were associated more with benign nodules. Pleural tag was more common in malignant nodules which signify the infiltration of underlying pleura. All these findings were similar to the

study of 486 nodules by Lee et al. Out of 30 nodules, 10 (33.33%) showed calcification which was predominantly eccentric and coarse. 8 out of these nodules were benign (Figure 9a) and remaining two were malignant (Figure 9b).

Although benign and malignant lung nodules tend to show some morphological patterns more frequently, there is considerable overlap in the findings (Figure 10a and 10b).
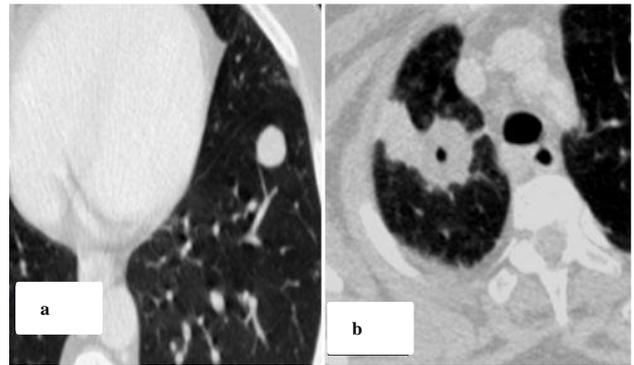
Figure 10: a) A SPN with smooth margin but it proved out to be a malignant lesion (metastasis from a case of primary lower limb sarcoma); b) A SPN with irregular spiculated appearing margin but it proved out to be of benign etiology (tubercular in nature).

Most of the features are found in both types of nodules and cannot be reliably used for differentiation. Our findings are in concordance with literature in this regard.[13-15]

Contrast enhancement values obtained at CT are a summation of the intra- and extra vascular concentrations of contrast medium. Transport of contrast medium through the lung involves the intravascular and interstitial spaces. The vascular supply of most malignant pulmonary nodules is from the bronchial arterial system, while outflow is through the bronchial veins. Lymphatic blockade leads to substantial reduction of clearance of contrast medium from the interstitial space in malignant tumors. In most inflammatory pulmonary processes, because of diffuse thrombosis at the arterioles of the pulmonary circulation, the vascular supply is actually from the hypertrophied bronchial arteries. Outflow of contrast medium (washout) through the intravascular space in an inflammatory situation is taking place through relatively straight vessels with a normal configuration, and washout of contrast medium from the interstitial space is accelerated by active lymphatic flow. In the inflammatory nodules, the time-attenuation curve declines after reaching peak height because of normal washout. In malignant nodules, the curve changes little after reaching peak height because of the retarded flow in the washout phase.[12]

The mean pre-enhancement attenuation value of benign nodules 44.66 HU (range 20-70HU) and malignant nodules was 47.90 HU (range 25-77HU). The difference was not statistically significant (p = 0.48).

Significantly higher peak enhancement was seen in malignant nodules (mean 92.98HU; range, 68 -149 HU) than in benign nodules (mean, 69.44HU; range, 38 - 139HU) (p = 0.008) and the net enhancement for malignant nodules (mean 50.22HU; range, 30-103HU) was significantly greater than that for benign nodules (mean, 24.04HU; range, 2-88 HU) (p = 0.02). This was in concordance with previous studies.[16-21]

The mean time for peak enhancement in malignant nodule was 2.43minutes. The mean time for peak enhancement in benign nodules was 5.07 minutes. The time taken for peak enhancement was non-significant (p = 0.673) which was in concordance with previous study by Lee et al.[12] In this study, 5 nodules showed peak enhancement after 5minutes which was in concordance with Yamashita et al, who observed that some lung carcinomas reached peak enhancement late, at 5 minutes which reflects the fact that some lung carcinomas have a wide extra vascular fluid pool.[22] The distribution of contrast material approaches a balance at 5 minutes after injection, being directly related to the volume of the extracellular space, with more than 80% of the contrast medium remaining outside blood vessels.[23]

Different threshold wash-in values viz. >20HU, >25HU and >30HU were studied for positive finding (i.e. indicator of malignancy). In general, malignant nodules tend to enhance substantially more than benign nodules. Yamashita et al reported that a maximum attenuation of 20–60 HU appears to be a good predictor of malignancy.[22] A report by Swensen et al, in 2000 is also noteworthy, in that the authors reported a threshold value of 15 HU produced a sensitivity of 98%, a specificity of 58%, and an accuracy of 77% for malignant nodules.[20] Cutoff values for the differentiation between benign and malignant nodules have since been set at 15 or 20 HU. However, in a dynamic study with multi–detector row CT, higher peak enhancement was obtained in comparison with that in previous studies performed with conventional or single– detector row helical CT because of higher temporal and spatial resolution due to thinner collimation and faster scanning and thus higher attenuation cutoff values could be used for differentiation.[18]

Previous dynamic CT studies were focused on the early phase of dynamic CT scanning, and results showed low specificities that ranged from 54% to 77%, due to overlap with active granulomas and benign vascular tumors.[16-20]

Most of the malignant nodules (14 of 16, 87.5%) showed more than 25 HU wash-in and 5-31 HU washout of contrast medium, 1 (6.25%) showed more than 25 HU wash in with 5-33 HU wash out and 1 (6.25%) showed

more than 25HU wash in and 5-34 HU washout. Keeping the washout threshold of 5-34 HU, all the malignant nodules were diagnosed correctly. Therefore, we propose the washout threshold as 5-34 HU and type I curve as wash-in of >25HU and washout of 5-34HU for malignant nodules.

Of the 14 benign nodules, 10 (71.42%) showed less than 25 HU wash in, 2 (14.28%) showed more than 25 HU wash in with persistent enhancement, 1 (7.14%) showed more than 25 HU wash in with >34 HU wash out and the remaining 1 (7.14%) showed a malignant pattern with >25 HU wash in and 5-34HU wash out which proved out to be tubercular consolidation. This false positive case can be explained by the active granulomatous lesion which is endemic in this country.

This was nearly concordant with study by Jeong et al, in which majority of malignant nodules showed type I and majority of benign nodules showed type II curve. Persistent enhancement without washout on dynamic contrast-enhanced CT scans may be related to the amount and degree of fibrosis.[12] The slight discordance in washout threshold can be explained by our higher detector (40 slice CT scanner) and lower collimation (0.6mm).
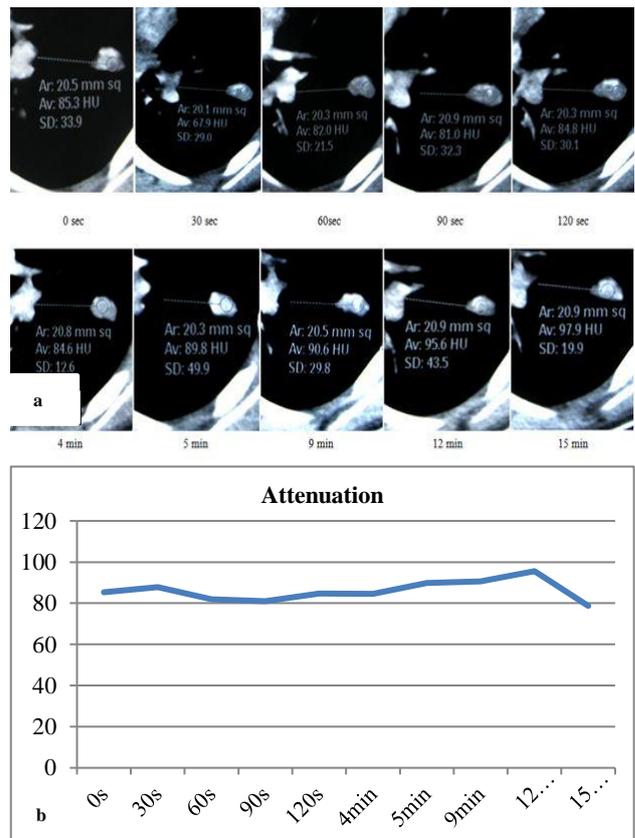
Figure 11: a) Dynamic CECT of patient no.9 shows peak enhancement of 97.9 HU at 15 minutes, wash-in of 30HU with no washout; b) The time- attenuation curve was of type III. FNAC yielded showed tubercular granuloma.

By analyzing the wash-in phase only, the false-positive rates for malignancy was 35% (5 out of 14 benign nodules). The use of the washout characteristics of dynamic enhancement allowed us to correctly diagnose 4 out of 14 benign nodules, and false-positive rates were reduced to 7% (1 out of 14 benign nodules). This was in concordance with the study by Jeong et al. in which false-positive rate was 52% (30 of 58 benign nodules). On use of washout characteristics 24 of these 30 benign nodules were correctly diagnosed.[12]

Radiation levels in dynamic study have been previously described and similar results were obtained in this study. Authors performed FNAC in all the patients in contrast to previous study where follow-up of nodules was done in many nodules. Small nodules <1cm (two nodules were 6 and 8 mm in size) were also accurately analyzed (Figure 11a and 11b) by dynamic study due to better spatial and temporal resolution of multi-detector computed tomography.

No history of smoking or any known primary malignancy. Figure 11a) Serial images of dynamic CECT shows peak enhancement of 97.9 HU achieved at 15 minutes, wash-in (net enhancement) of 30HU (>25 HU), with no washout; suggestive of persistent enhancement. Figure 11b) The time- attenuation curve was plotted which showed type III curve (wash in >25HU with persistent enhancement and no wash out) suggesting benign etiology. FNAC showed inflammatory cells of granulomatous etiology; likely tubercular.

There was some selection bias in this study, since many of the nodules picked up on radiographs had substantial calcification and thus were excluded from the study. Most of the nodules were selected from NCCT study. Since our institution is a tertiary center, some of our patients were known case of extra-pulmonary malignancy.

CONCLUSION

Evaluation of solitary pulmonary nodules by analyzing combined wash-in and washout characteristics at dynamic contrast-enhanced multi-detector row CT showed 96.7% accuracy (p <0.001) for distinguishing benign nodules from malignant nodules.

ACKNOWLEDGEMENTS

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