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Research Article

Assessment of Disease Activity and Complications in Patients of Pulmonary Tuberculosis by High Resolution Computed Tomography

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Abstract

Background: Tuberculosis (TB) is a global health problem and the second most common infectious cause of death. High-resolution computed tomography (HRCT) is far more superior to chest radiography as well as conventional CT for analyzing the pulmonary parenchyma. This study aimed to evaluate the role of HRCT in pulmonary tuberculosis (PTB) with respect to disease activity and complication after anti-tubercular therapy (ATT).

Methods: This prospective observational study was conducted in the Department of Radiodiagnosis, Teerthanker Mahaveer Medical College & Research Centre (TMMC&RC) for a period of 1.5 years. A total of 50 cases of newly diagnosed TB were included in the study and a standard six-month ATT was given to the patients. Pulmonary involvement was evaluated by HRCT (128 slice multi-detector PHILIPS INGENUITY CT scanner), twice for each patient (first scan after diagnosis and second after treatment completion). The acquired HRCT images were reconstructed on a high-resolution lung algorithm and parenchymal, bronchial, and extra parenchymal findings were recorded systematically.

Results: Out of the 50 patients, 5 died within two months of the initiation of treatment and four were lost to follow-up. Thus, post treatment follow-up sample size was reduced to 41 patients. Ill-defined nodules (96%), tree-in-bud pattern (74%), consolidation (86%), cavitary lesions (98%), and ground glass opacities (58%) were the main imaging features of active cases of TB on HRCT. Resolution to thin-walled cavitary lesions (36.5%), bronchiectasis (41.5%), and fibrotic (parenchymal) bands (66%) were common complications or sequelae which were observed after completion of treatment.

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Conclusion: HRCT thorax is a sensitive modality for evaluation of parenchymal and airway manifestations in cases of PTB and can aid in differentiation of active disease from healed disease. It allows early identification of post-treatment complications and sequelae in patients of PTB.

Keywords: HRCT, lung, tuberculosis, pulmonary, complications

1. Introduction

Tuberculosis (TB) is a global health problem and the second most common infectious cause of death [1]. It is a chronic granulomatous disease caused by mycobacterium tuberculosis (MTB) and characterized by caseating necrosis with remarkable susceptibility for calcification and fibrosis. Tuberculous involvement of lung may occur in variety of ways, for example, local spread, bronchogenic dissemination, or hematogenous route [2].

Timely diagnosis is of paramount importance in the control of TB and is the only efficient measure for stopping the transmission of disease [3]. A number of complication and sequelae can occur in cases of pulmonary tuberculosis (PTB) with or without treatment, and knowledge of radiological signs of these sequelae and complication is vital. Despite clinical recovery, the post-TB sequelae can continue to be identified on imaging which may raise concern regarding disease activity [4].

The characteristic imaging features of active tubercular disease include centrilobular nodules, tree-in-bud configuration, miliary nodules, consolidation, thick-walled- cavitary lesion, and pleural effusion [4]. Imaging features of inactive disease or post-treatment healed TB include thin-walled smooth cavitary lesions, calcifications, and fibrosis [5].

Chest radiography continues to be the front runner for early assessment of individuals with suspicion of PTB; although it may appear entirely normal or inconclusive even in active cases of PTB. Compared to the chest radiography, computed tomography (CT) is way better of diagnosing and analyzing vivid imaging features of PTB [6].

Recent literature shows that high-resolution computed tomography (HRCT) is far more superior to chest radiography as well as conventional CT for analyzing the pulmonary parenchymal diseases. It also offers additional advantage of discerning disease activity and provides crucial information which assists in decision-making for the earliest possible initiation of treatment [7].

The overall diagnostic accuracy of chest radiography in PTB is only 49% (34% for primary and 59% for post-primary cases). Conventional CT, on other hand, gives correct diagnosis in nearly 91% PTB cases and can accurately differentiate between active-type (80%) and inactive-type (89%) diseases. The reported sensitivity and specificity of HRCT in smear positive cases of PTB approaches 90.9% and 96.4%, respectively [7, 8].

With this background, the present study was undertaken to evaluate the role of HRCT in PTB with respect to disease activity and complication after anti-tubercular therapy (ATT).

2. Materials and Methods

This prospective observational and descriptive study was conducted in the Department of Radiodiagnosis of a tertiary care hospital in northern India for a period of 1.5 years (January 2019–June 2020) after obtaining prior clearance from the Institutional Ethics Committee (letter no. TMMC&RC/IEC/18-20/079 dated December 27, 2018). Written informed consent was obtained from all patients or their attendants before enrolment.

A total of 50 cases of newly diagnosed smear/Cartridge-based Nucleic Acid Amplification Testing (CBNAAT)-positive PTB were included in the study. Patients with known malignancy, pregnancy, or prior history of ATT intake were excluded from the study. A detailed clinical history, complete physical examination, and routine laboratory investigations were done in all patients and findings were recorded.

All patients received a six-month standard ATT consisting of a two-month initial phase (rifampicin, isoniazid, pyrazinamide, and ethambutol) and a four-month maintenance phase (rifampicin and isoniazid). Pulmonary involvement was evaluated by HRCT which was done twice for each patient. The first scan was obtained after the diagnosis of TB and within 28 days of the initiation of treatment. The second scan was obtained within 30 days after the treatment completion when patient was considered cured as per the clinical criteria. Patients were imaged on 128 slice multi-detector CT scanner (PHILIPS INGENUITY) set to 0.6-mm collimation and a pitch of 1.5. The images were reconstructed with a 1-mm slice thickness in the axial plane using a high spatial frequency bone algorithm. Sagittal and coronal reconstructions were also obtained.

After the acquisition of images, they were systematically analyzed by an experienced radiologist (with eight years of experience in reporting HRCT lung) who was blinded to the clinical details. The various pulmonary, bronchial, and extrapulmonary findings were interpreted as follows: nodule was characterized as “A focal, round opacity, at least moderately well marginated and no greater than 3 cm in maximum diameter” [6];

"Tree-in-bud pattern was recognized by small centrilobular nodules of soft-tissue attenuation connected to multiple branching linear structures of similar caliber originating from a single stalk" [6]; "Homogeneously increased lung opacity with obscuration of underlying vessels" was interpreted as consolidation [6]; "A lucent area within a zone of pulmonary consolidation, or a nodule that may or may not contain a fluid level and that was surrounded by a wall, usually of varied thickness" was labelled as cavitation [9]; "Hazy opacity without obscuration of underlying broncho-vascular structures " was recorded as ground glass opacity [10]; "A linear opacity, 1–3 mm thick and up to 5 cm long which extends to the visceral pleura was considered as parenchymal band" [11]; "Bronchial dilatation (relative to accompanying pulmonary artery) with lack of bronchial tapering was interpreted as bronchiectasis" [11]. "Reduced volume accompanied by increased attenuation in the affected part of lung was considered collapse/atelectasis" [11]; "Homogenous opacification of costophrenic angle and hemidiaphragm was considered as pleural effusion" [12]; "Separation of visceral pleural line from the chest wall by a trans radiant zone devoid of vessels was recorded as pneumothorax" [13]; "Empyema was characterized as "non-dependent elliptical or lenticular shaped opacity having obtuse angle with chest wall with splitting of visceral and parietal pleural surfaces by fluid giving split pleural sign" [14].

2.1. Statistical analysis

Data were entered into the Microsoft excel and the statistical analysis was performed by SPSS (version 21.0). The quantitative variables (numerical variables) were presented in the form of mean and SD and the qualitative variables (categorical variables) were presented in the form of frequency and percentage. The Chi-square test was applied for comparing the categorical variables such as gender and adverse events between the two groups. The sensitivity, specificity, positive, and negative predictive values and accuracy were calculated. The p-value < 0.05 was considered to be significant.

3. Results

This prospective observational study consisted of 50 patients who were enrolled on the basis of the inclusion and exclusion criteria. Out of the 50 patients, 5 died within two months of the initiation of treatment while four were lost to follow-up. Thus, post-treatment follow-up sample size was reduced to 41 patients. Of these, five patients presented showing a relapse in treatment but they were all asymptomatic.

The mean age of the study population was 43.06 ± 17.17 years with the maximum number of patients belonging to the age group of 51–60 years (22%). Out of the 50 patients, 45 were males and rest were females with a M:F ratio of 9:1. Cough (88%), sputum production (68%), fever (60%), hemoptysis (52%), weight loss (52%), and night sweats (24%) constituted most common clinical symptoms.

Ill-defined Nodules were found in 48 (96.0%) cases prior to the initiation of treatment without any zonal predominance. While in 25 out of the 41 patients, the nodules completely disappeared after treatment, 16 patients showed persistent residual nodules, although with reduced nodule burden (Table 1). Tree-in-bud appearance was seen in 37 (74.0%) cases before treatment. It persisted in six patients (14.6%) post-treatment (Table 2), out of which, five were defaulters and were not taking treatment properly (Figure **1**). Prior to the treatment, 43 (86%) cases showed consolidation which persisted in 8 patients (19.5%) after treatment (Table 3). In three out of eight cases, the size of consolidation patch decreased after treatment while the rest of the five patients were simply defaulters **(**Figure **2**).

Table 1: Frequency distribution of ill-defined nodules in pre- and posttreatment cases.

Ill-defined Nodule	**Pretreatment**		**Posttreatment**	
	Number	Percentage	Number	Percentage
Absent	2	4%	25	60.97%
Present	48	96%	16	39.02%
Total	50	100%	41	100%
Chi-square value = 10.908, p-value < 0.001*				

Table 2: Frequency distribution of tree-in-bud appearance in pre- and posttreatment cases.

Tree-in-bud appearance	**Pretreatment**		**Posttreatment**	
	Number	**Percentage**	**Number**	**Percentage**
Absent	13	26%	35	85.4%
Present	37	74%	6	14.6%
Total	50	100%	41	100%
Chi-square value = 31.854, p-value < 0.001*				

Cavitary lesions were observed in 98% (49 out of 50) cases before treatment; 96% (48/50) of the patients showed cavitation with smooth internal border and thick external border, 12% (06/50) cases showed thin-walled cavitary lesion, and 6.1% (03/49) showed cavitation with air fluid level. These cavities completely disappeared in 43.9% (18/41) patients after treatment, while 36.5% (15/41) cases showed persistent thin-walled cavitary lesion and 26.8% (11/41) patients had thick-walled cavities (Table 4). Out of these 11 cases

Table 3: Frequency distribution of consolidation in pre- and posttreatment cases.

Consolidation	Pretreatment		Posttreatment	
	Number	Percentage	Number	Percentage
Absent	7	14%	33	80.5%
Present	43	86%	8	19.5%
Total	50	100%	41	100%
Chi-square value = 40.424, p-value < 0.001*				

Table 4: Frequency distribution of cavitation in pre- and posttreatment cases.

	Pretreatment		Posttreatment	
Cavitation	Number	Percentage	Number	Percentage
Absent	1	2%	18	43.9%
Present	49	98%	23	56.1%
Total	46	100%	41	100%
Chi-square value = 23.944, p-value < 0.001*				

Table 5: Frequency distribution ground glass opacification in pre- and posttreatment cases.

Ground Glass Opacity	Pretreatment		Posttreatment	
	Number	Percentage	Number	Percentage
Absent	29	58%	38	92.7%
Present	21	42%	3	7.3%
Total	50	100%	41	100%
Chi-square value = 13.955, p-value < 0.001*				

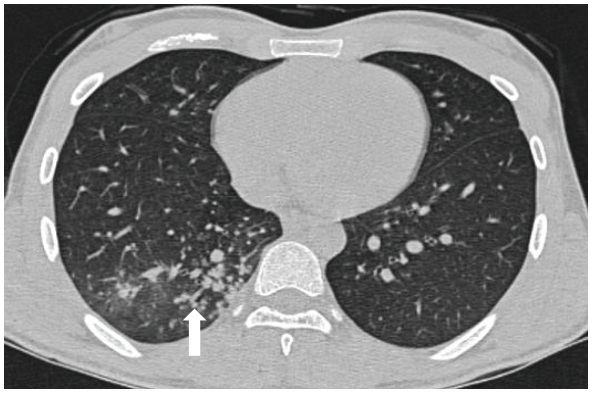
Table 6: Frequency distribution of fibrotic band in pre- and posttreatment cases.

Fibrotic Band	Pretreatment		Posttreatment	
	Number	Percentage	Number	Percentage
Absent	42	84%	14	34.1%
Present	8	16%	27	65.9%
Total	50	100%	41	100%
Chi-square value = 23.655, p-value < 0.001*				

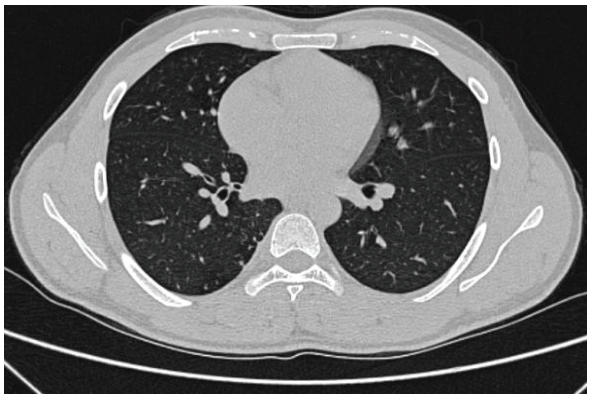
Table 7: Frequency distribution of bronchiectasis in pre- and posttreatment cases.

Bronchiectasis	Pretreatment		Posttreatment	
	Number	Percentage	Number	Percentage
Absent	48	96%	24	58.5%
Present	02	4%	17	41.5%
Total	50	100%	41	100%
Chi-square value = 19.139, p-value < 0.001*				

with persistent thick-walled cavities, 4 were defaulters and in 7 patients, mural thickness was reduced (Figure **3**).



(A)



(B)

Figure 1: Axial section of HRCT lung in a case of tuberculosis before and after treatment. (A) Pretreatment scan shows multiple centrilobular nodules getting confluent at places and giving tree-in-bud appearance (white arrow) in posterior segment of right lower lobe. (B) Posttreatment HRCT scan shows complete disappearance of tree-in-bud appearance.

Ground glass opacity was found in 21 (42%) pretreatment cases and persisted in 3 patients after treatment (Table 5). Collapse/volume loss was seen in one patient before treatment and three patients posttreatment. Pleural effusion was found in nine (18%) cases before treatment. It resolved completely in all nine patients. However, in one patient who had no sign of pleural effusion at the time of the initiation of therapy, pleural effusion was detected posttreatment (Figure **4**). Lung cyst was found in seven (14%) cases before treatment and persisted in only one of them after treatment. Nine (18%) cases showed emphysematous changes before treatment which increased to eleven posttreatment. Majority of the patients showed paraseptal emphysematous changes.

Pretreatment, fibrotic band was found in eight (16%) cases, which increased to 27 cases after treatment (Table 6) and (Figure **5**). Bronchiectasis was noted in two (4%) patients, calcification in one (2%), and pneumothorax in two (4%) patients before treatment. Posttreatment, bronchiectasis changes and calcification were observed in 17 and

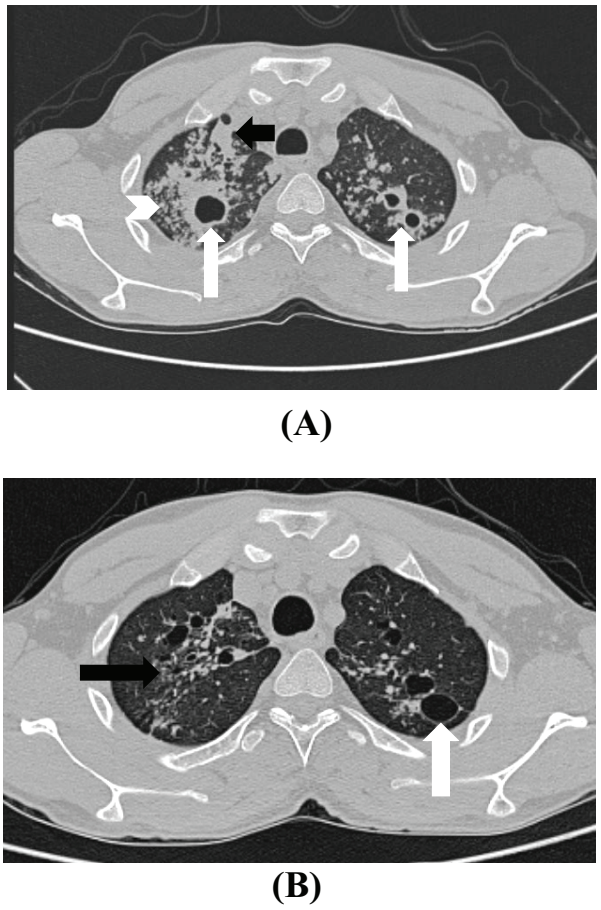


Figure 2: Axial section of HRCT lung in case of tuberculosis at the subapical level. (A) HRCT scan acquired at the time of diagnosis showed multiple nodules with tree-in-bud appearance at places (arrowhead) and three large thick-walled cavities (white arrow) in bilateral upper lobes with patchy areas of consolidation (black arrow) in right upper lobe. (B) Follow-up HRCT obtained after six months of anti-tuberculous chemotherapy shows marked thinning of the wall of cavities (white arrow) with near complete resolution of nodules and consolidation. Fibrotic changes and focal areas of emphysema (black arrow) can also be noted.

3 cases, respectively (Table 7). There was no case of pneumothorax in posttreatment follow-up.

4. Discussion

PTB can mimic a myriad of diseases in clinical and laboratory findings. Sputum smear examination cannot be relied solely on as it has many limitations. The smear may be false negative in cases with mild disease. Bacilli load in the sputum sample may be low and instead of sputum, saliva may be examined. The smear-negative PTB suspects pose an important diagnostic dilemma in daily clinical practice [15].

CBNAAT is a rapid diagnostic test recommended by WHO for TB and is a simple, useful, and reliable test especially when culture is unfeasible. However, it has a few

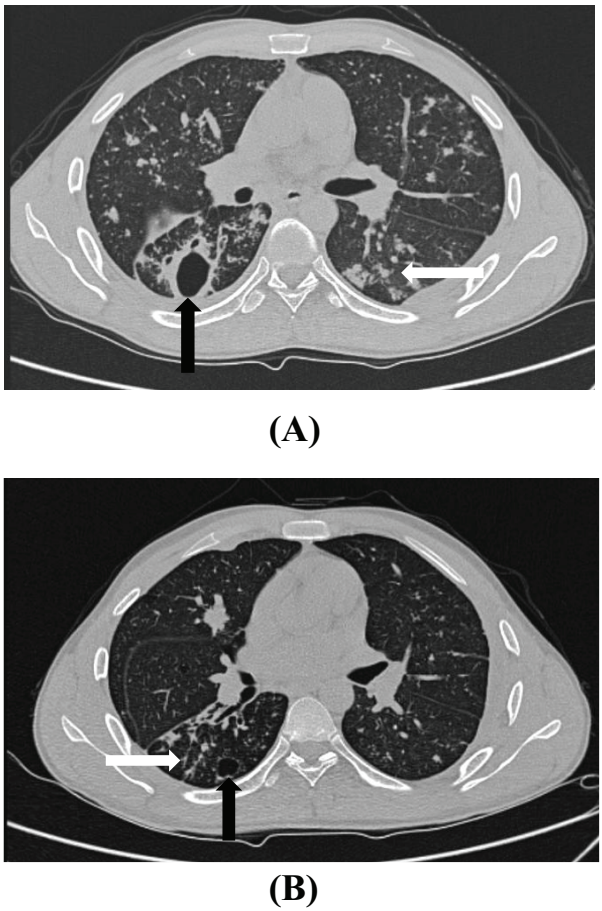


Figure 3: Axial section of HRCT lung in case of tuberculosis at subcarinal level. (A) HRCT scan acquired before starting the treatment showed multiple nodules (white arrow) in both lungs with a thick-walled cavity (black arrow) in superior segment of right lower lobe. (B) Follow-up scan after anti-tuberculous treatment shows marked thinning of the cavity wall (black arrow) with significant reduction in nodule burden. Note is also made of fibrotic changes (white arrow).

disadvantages too. The threshold values for the detection of MTB are high (130–150 cfu/ml) as compared to bacterial culture. Secondly, CBNAAT is Polymerase Chain Reaction-based test and can provide false positive results as it amplifies DNA in both live and dead bacilli and thus it cannot be utilized to monitor TB treatment [16]. These limitations of CBNAAT can be surpassed by using HRCT lung.

HRCT is a useful technique for imaging evaluation of both lung parenchyma and airways. Patients who are clinically suspicious for PTB but are sputum smear negative can be best assessed by HRCT [13]. HRCT can easily detect complications after the completion of treatment and can also predict risk of complications [6]. The present study was undertaken to identify the HRCT findings of sputum-positive cases of PTB and assess the role of HRCT in disease activity and complications.

Majority of our patients belonged to the age group of 51–60 years (22%) followed by 41–50 years (18%), which matches with the previous studies [17, 18]. The mean age

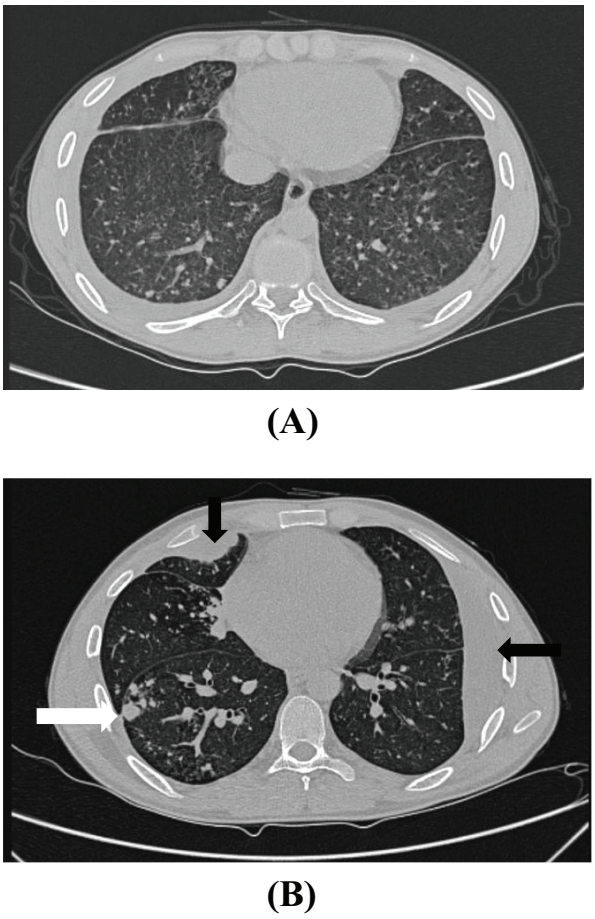


Figure 4: (A) Axial section of HRCT lung in a case of tuberculosis before treatment shows no significant parenchymal findings. (B) Posttreatment HRCT scan shows pleural collection/empyema (black arrow) along the right anterior and left lateral chest wall with ill-defined nodules (white arrow) in right lower lobe.

of our study population was 43.06 ± 17.17 years which is similar to the studies by Bolla *et al.* [17] (average age 44.15 ± 22.6 years) and Capone *et al.* [19] (mean age 47.5 years). Most previous studies [10, 18, 20] have reported a male preponderance of disease, a finding which we also observed in the present study (M:F ratio 9:1). Male predominance is mainly due to behavioral and epidemiological factors. Males are more socially active and travel frequently from one place to another which may increase the transmission of infection. Further, consumption of alcohol and smoking also makes the male gender vulnerable to TB [20]. The clinical symptomatology of our patients closely matches previous literature [17, 18].

4.1. HRCT findings in pre- and posttreatment cases

Ill-defined nodules are mostly found in the initial stages of TB and appear 5–6 mm in diameter with fuzzy margins with a tendency to coalesce. These nodules are usually not

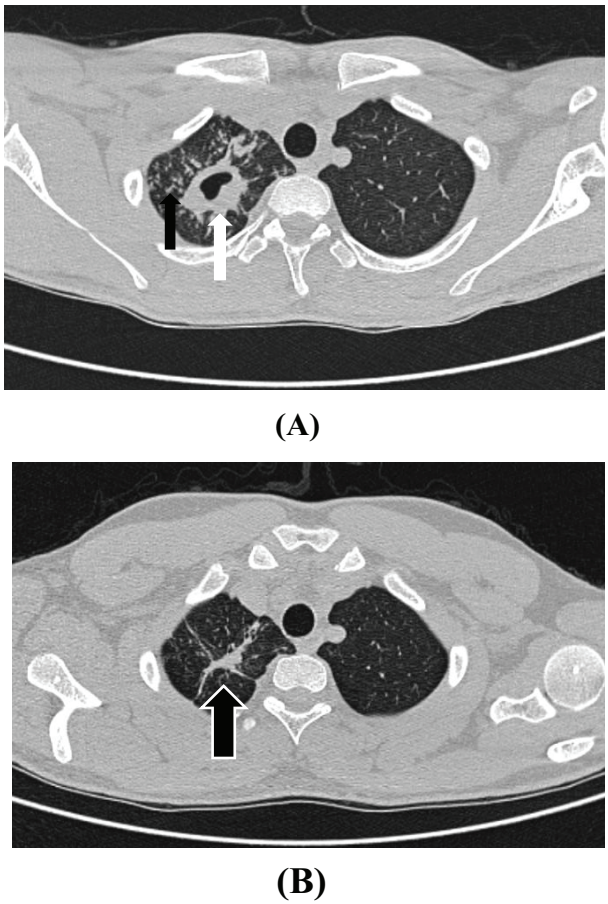


Figure 5: Axial section of HRCT lung in a patient of tuberculosis at the level of apical segment of lung. (A) HRCT scan obtained at the time of diagnosis shows thick-walled cavity (white arrows) and micronodules (black arrow) on right side. (B) Follow-up HRCT scan obtained after six months of ATT shows cicatricial changes in form of fibrotic parenchymal band (black arrow). There is complete resolution of cavity and micronodules.

detectable on chest radiograph and the presence of nodules on HRCT is an early sign of active TB [6]. Im *et al.* [21] stated that TB progresses primarily in respiratory bronchioles followed by focal inflammation, and that these pathological processes are reflected in form of nodules seen on HRCT thorax. Pathologically, these micronodules represent solid caseous material within or around the terminal or respiratory bronchioles [9]. In the present study, ill-defined nodules were seen in 96% of the patients before treatment and persisted in 39% of them posttreatment, although the burden of nodules appeared to be reduced. These findings are in accordance with Lee *et al*. [6] who found ill-defined nodules in 88% pretreatment cases and 56% posttreatment cases. Capone *et al.* [19] also reported that 86.4% of their patients showed nodules in active cases of TB which persisted in 48.6% patients after treatment.

Tree-in-bud pattern is most commonly due to the presence of caseation necrosis and granulomatous inflammation within and surrounding the terminal and respiratory

bronchioles and alveolar ducts, and reflects endobronchial spread of TB [22]. Rossi *et al.* [23] also stated that tree-in-bud appearance occurs generally in cases with endobronchial spread of MTB and is found it to be an indicator of active TB. However, the opinion of Im *et al.* [21] differs and according to them, “tree-in-bud” pattern is not pathognomonic for active PTB as it can also be recognized in many other entities like infections (bacterial, viral, parasitic, and fungal), congenital disorder, inhalation of foreign body, and vascular diseases. In the present study, tree-in-bud configuration was detected in 74% of patients before treatment which persisted in 14.6% posttreatment. However, five patients were defaulters who were not taking treatment properly. Our results nearly match with Lee *et al.* [6] who reported tree-in-bud sign in 87% patients before treatment and in none of the cases posttreatment. Bombarda *et al.* [4] also observed tree-in-budsign in 60% of their patients before treatment and 5% patients posttreatment.

In the present study, cavitary lesions were observed in 98% cases before treatment. Of them, 96% patients showed cavitation with smooth internal border and thick external border, 12% showed thin-walled cavitary lesion, and 6% showed cavitation with air fluid level. These cavities completely disappeared in 43.9% patients posttreatment. About 36.5% cases showed persistent thin-walled cavitary lesion, while 26.8% (11 out of 41) patients had thick-walled cavities. Out of these 11 cases with persistent thick-walled cavities, 4 were defaulters and in 7 patients mural thickness was reduced. Our findings correlate with the previous work of Lee *et al.* [6] and Bombarda *et al.* [4]. Lee *et al.* [6] found cavitary lesion in 73% cases which persisted in 35% cases after treatment. In addition, 25% cases in the study by Bombarda *et al.* [4] showed persistent thin-walled cavitary lesions after treatment. Im *et al.* [21] also reported persist cavities in 42% cases. The cavitary lesions are independently related with increased time for acid-fast smears to become negative in patients receiving ATT and their persistence increases risk of relapse after completion of treatment [24].

Ground glass opacity was noted in 42% of our study cases before treatment and 7.3% after treatment. These findings are consistent with the studies of Capone *et al.* and Lee *et al.* [6, 19,]. Capone *et al.* [19] noted ground glass opacities in 37.8% cases before treatment which persisted in 4% patients. In the study of Lee *et al.* [6] it persisted in 2% patients. However, these findings do not match with the Raj *et al.* [25] who reported lower percentage of ground glass opacities in their study (20%). Ground glass opacities on HRCT can result from trauma, inflammation, focal interstitial fibrosis, hemorrhage, and malignancy [10]. The higher proportion of patients with hemoptysis in this study could be the possible reason for this discrepancy.

Pleural effusion was seen in nine (18%) patients before treatment and it resolved completely in all these patients, although one patient was diagnosed with empyema after treatment who had no signs of pleural effusion before treatment. Our findings are in line with previous studies. Nachiappan *et al.* [26] found pleural effusion in only 25% patients with primary TB. Only 10% of the cases in the study by Lee *et al.* [6] showed pleural effusion before treatment which resolved after treatment in all the patients.

We found emphysematous changes in nine (18%) cases before treatment and eleven (26.8%) cases after treatment. Emphysematous changes were mainly paraseptal type. These findings are similar to Im *et al.* [21] who found emphysema in 24% of pretreatment cases.

In this study, fibrosis was found in 8 (16%) pretreatment cases and this number rose to 27 (66%) after treatment. Our findings match with Lee *et al.* [6] who noted an increase in fibrosis in TB patients after treatment from 42 to 92%. Bombardo *et al.* [4] in their study also reported increase in fibrotic changes posttreatment from 10 to 70%. Healing of TB lesions is usually followed by development of a fibrotic scar and dystrophic calcification with loss of lung volume. Rarely, if a lesion heals without development of necrosis, no residual fibrotic changes may occur [27].

In the present study, bronchiectasis was found in two cases (4%) before treatment. It significantly increased to 17 cases (41%) after treatment. Our findings match with Bombarda *et al.* [4] who also found increase in bronchiectasis in posttreatment cases (35%). Lee *et al.* [6] encountered increase in bronchiectasis from 29 to 44% in posttreatment cases. Im *et al.* [21] reported cicatricial changes in the areas of cavitation, which on follow-up CT scans were characterized by increase in fibrotic bands, emphysema, or bronchiectasis. Fibrosis and bronchiectasis are common sequelae of TB. While fibrosis occurs primarily due to scarring of pleura spaces, bronchiectasis occurs due to fibrosis and damage of the lung parenchyma with irreversible dilatation of secondary bronchus [28].

Collapse (volume loss) was seen in only one of our cases before treatment while after treatment it was observed in three patients. Bronchial wall thickening was seen in five cases after the treatment of PTB. Hatipoglu *et al.* [29] found bronchial wall thickening adjoining to areas of fibrotic changes in few of their patients with inactive disease. Thus, the collapse and bronchial wall thickening represents sequelae to post-tubercular cicatrization.

4.2. HRCT findings in active cases of TB

Ill-defined nodules (96%), tree-in-bud pattern (74%), consolidation (86%), cavitary lesions (98%), and ground glass opacities (58%) were the main imaging features of active cases of TB on HRCT in our study. These results are in close agreement with the previous literature. Lee *et al.* [6] observed exactly similar imaging features in the active cases of TB in their research. Air space nodules, consolidation, thick-walled cavity, bilateral hilar lymphadenopathy, and bilateral pleural effusion were typical imaging findings in the active cases in the study by Bhalla *et al.* [1]. Bombarda *et al.* [4] found centrilobular nodules, thick-walled cavities, tree-in-bud appearance, and consolidation in majority of patients before starting anti-tuberculous drugs. The imaging pattern in pretreatment active cases in the study by Capone *et al.* [19] comprised of nodules (1–3 cm in diameter), tree-in-bud pattern, consolidations with air bronchograms, architectural distortions, and cavitary lesions. Hatipoglu *et al.* [26] reported centrilobular nodules with tree-in-bud pattern, consolidation, and cavitation as main features of active TB. Centrilobular nodules with branching linear lesion, tree-in-bud appearance, poorly defined nodules, and lobular consolidation were the main features of primary TB on HRCT in the study by Im *et al.* [21]. Naseem *et al.* [30] also reported centrilobular nodules, lobular consolidation, tree-in-bud appearance, and cavitation as most frequent imaging features in newly diagnosed PTB cases.

4.3. HRCT imaging feature after completion of treatment

Resolution to thin-walled cavitary lesions (36.5%), bronchiectasis (41.5%), and fibrotic (parenchymal) bands (66%) were common complications or sequelae which were observed after completion of treatment in our patients. We also observed decrease in nodule burden, disappearance of consolidation, tree-in-bud pattern, pleural effusion, and parenchymal cyst after treatment which indicates effectiveness of the treatment. These findings are in accordance with previous studies. Lee *et al.* [6] found increase in fibrotic bands in patients after treatment. Bombarda *et al.* [4] reported thin-walled cavities, fibrotic bands, and traction bronchiectasis in their patients posttreatment. Skoura *et al.* [31] stated that the appearance of fibrosis and resolution to thin-walled smooth cavitary lesions are main features of inactive PTB. Our findings, however, differ from Khan *et al.* [28] as they reported aspergilloma, bronchogenic carcinoma, and tracheobronchial stenosis as post-TB sequelae. These are mostly rare and late

complication of TB and require long-term follow-up. Also, most of these findings require contrast study for optimal evaluation which was not done in the present study.

Thus, this study exhibited that HRCT lung significantly aids in detection of parenchymal and airway lesions of PTB. It can accurately identify features of active TB and can easily differentiate active cases from inactive ones. HRCT not only permits assessment of treatment progress but also allows early diagnosis and management of posttreatment complications thereby reducing mortality and morbidity in these cases.

Limitations

The small sample size of the study may limit statistical relevance. Due to problem of attrition and high mortality in TB, the follow-up patient sample size was even lower. Some of the patients relapsed after treatment which may have affected the results in posttreatment follow-up category. MDR (multi-drug resistance) and XDR (extensively drug resistant) TB cases were not included in the study and findings in those cases may differ. Some of the post-tubercular sequelae like aspergilloma, bronchogenic carcinoma, and tracheobronchial stenosis were not observed in this study due to short-term follow-up and lack of contrast imaging. Mediastinal imaging features of TB in pre- and posttreatment cases were not analyzed due to lack of contrast study.

5. Conclusion

HRCT thorax is a sensitive modality for evaluation of parenchymal and airway manifestations in cases of PTB and the most frequent pretreatment HRCT findings include Ill-defined nodules, tree-in-bud appearance, thick-walled cavitary lesions, consolidation, ground glass opacities, and pleural effusion. Ill-defined nodules, tree-in-bud pattern, consolidation, cavitary lesions (thick walled), and ground glass opacities are the main predictors of active disease in TB on HRCT. Based on these imaging features, HRCT can aid in differentiation of active disease from healed disease. Disappearance of consolidation, tree-in-bud pattern, pleural effusion, and decrease in nodule burden on follow-up HRCT are indicators of successful completion of treatment, and thus, HRCT permits accurate assessment of treatment efficacy. HRCT allows early identification of posttreatment complications and sequelae in patients of PTB which most commonly include thin-walled cavitary lesions, bronchiectasis, and fibrotic (parenchymal) bands.

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Ethical Considerations

Prior ethical approval was taken from the Institutional Ethics Committee (IEC), Teerthanker Mahaveer Medical College & Research Centre (TMMC&RC), Moradabad vide letter no. TMMC&RC/IEC/18-19/079 dated December 27, 2018.

Competing Interests

The authors declare hereby that there are no conflicts of interest.

Availability of Data and Material

The raw data used during the current study is available from the corresponding author on reasonable request.

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