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Original Research Article

COMPARISON OF CHEST RADIOGRAPHY AND HIGH-RESOLUTION COMPUTED TOMOGRAPHY IN THE EVALUATION OF PULMONARY DISEASES IN HIV PATIENTS

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ABSTRACT

Background: Pulmonary diseases are major causes of morbidity and mortality among people living with HIV. Chest radiography is commonly used as the initial imaging investigation, but its ability to demonstrate subtle parenchymal and airway abnormalities is limited. High-resolution computed tomography provides detailed evaluation of the lungs and mediastinum and may improve the detection and characterization of HIV-associated pulmonary diseases. The aim is to compare chest radiography and HRCT in the detection and characterization of pulmonary diseases among HIV-positive patients.

Materials and Methods: This hospital-based prospective cross-sectional comparative study included 100 adult HIV-positive patients with respiratory symptoms or clinical suspicion of pulmonary disease. All participants underwent chest radiography and HRCT. Imaging findings were evaluated for the presence, number, morphology, location, distribution and extent of pulmonary abnormalities. Imaging diagnoses were correlated with CD4 counts and probable etiological diagnoses. Paired proportions were compared using McNemar's test, while continuous variables were analysed using paired t-tests or analysis of variance. A p value below 0.05 was considered statistically significant.

Results: HRCT detected pulmonary abnormalities in 91% of patients compared with 72% using chest radiography (absolute difference=19.0%; 95% CI: 8.6%–29.4%; $p<0.001$). HRCT was significantly better in adequately localizing lesions (90% versus 61%), characterizing lesion morphology (86% versus 54%) and establishing a specific or probable imaging diagnosis (79% versus 48%; all $p<0.001$). The mean number of abnormalities detected per patient was 2.46±1.11 with HRCT and 1.38±0.82 with chest radiography (mean difference=1.08; 95% CI: 0.87–1.29; $p<0.001$). HRCT detected significantly more ground-glass opacities, centrilobular nodules, tree-in-bud opacities, lymphadenopathy, bronchiectasis, miliary nodules, pulmonary cysts, septal thickening and mosaic attenuation. Pulmonary tuberculosis was the most frequent probable diagnosis (34%), followed by bacterial pneumonia (23%) and Pneumocystis jirovecii pneumonia (17%). Mean CD4 counts differed significantly across etiological groups ($F=16.08$; $p<0.001$). HRCT detected 97.1% of pulmonary tuberculosis cases and all PJP cases, compared with 76.5% and 58.8%, respectively, using chest radiography.

Conclusion: HRCT was significantly more effective than chest radiography in detecting, localizing and characterizing pulmonary abnormalities among HIV-positive patients, particularly subtle parenchymal, airway and mediastinal lesions. Chest radiography remains an appropriate first-line investigation, but

HRCT provides important additional diagnostic information when radiographic findings are normal, inconclusive or inconsistent with clinical suspicion. Correlation with CD4 count and etiological investigations remains essential for definitive diagnosis.
Keywords: HIV; high-resolution computed tomography; chest radiography.

INTRODUCTION

Human immunodeficiency virus (HIV) infection remains a major global public-health concern, with approximately 41 million people living with HIV worldwide at the end of 2025. Although antiretroviral therapy has substantially improved survival, pulmonary diseases continue to be important causes of morbidity, hospitalization, and mortality among people living with HIV.[1] Progressive depletion of CD4-positive T lymphocytes predisposes these patients to a wide spectrum of infectious and non-infectious pulmonary disorders. Common infectious conditions include pulmonary tuberculosis, bacterial pneumonia, Pneumocystis jirovecii pneumonia, fungal infections, and viral pneumonitis, while non-infectious manifestations include lymphoid interstitial pneumonia, chronic obstructive pulmonary disease, pulmonary hypertension, Kaposi sarcoma, and lymphoma.[2] The type and radiological appearance of pulmonary disease are strongly influenced by the degree of immunosuppression. Tuberculosis and bacterial pneumonia may occur across a broad range of CD4 counts, whereas Pneumocystis jirovecii pneumonia and several fungal or viral infections occur more frequently when the CD4 count falls below 200 cells/μL.[2,3] Chest radiography is generally the initial imaging investigation in HIV-positive patients with respiratory symptoms because it is inexpensive, widely available, rapid, and associated with a relatively low radiation dose. It can demonstrate consolidation, cavitation, reticulonodular opacities, pleural effusion, lymphadenopathy, and other thoracic abnormalities. However, radiographic findings may be atypical or nonspecific, and a normal or minimally abnormal radiograph does not reliably exclude clinically significant pulmonary disease. Overlapping appearances of opportunistic infections and malignancies further limit the ability of chest radiography to provide a specific diagnosis.[3,4] High-resolution computed tomography (HRCT) provides detailed evaluation of the pulmonary parenchyma, airways, mediastinum, lymph nodes, and pleural spaces. It can identify subtle ground-glass opacities, interlobular septal thickening, micronodules, tree-in-bud opacities, cysts, bronchiectasis, and early cavitation that may not be visible on conventional radiographs. The distribution and combination of these findings can narrow the differential diagnosis, identify complications, guide bronchoscopy or biopsy, and facilitate early treatment.[3,5] Nevertheless, HRCT involves greater radiation exposure and cost and is not universally available. A direct comparison of chest radiography and HRCT is therefore necessary to determine the additional diagnostic information provided by HRCT and to identify the limitations of chest radiography. The present study was undertaken to compare these modalities in detecting and characterizing pulmonary diseases among HIV-positive patients and to correlate imaging patterns with CD4 counts and probable etiological diagnoses.

AIM: To compare chest radiography and high-resolution computed tomography in the detection and characterization of pulmonary diseases among HIV-positive patients.

Objectives:

1. To describe the spectrum and frequency of pulmonary abnormalities detected by chest radiography and HRCT in HIV-positive patients.
2. To compare the ability of chest radiography and HRCT to detect, localize, and characterize pulmonary lesions.
3. To correlate chest radiographic and HRCT findings with CD4 counts and the probable etiological diagnoses.

MATERIALS AND METHODS

Source of Data: The study participants were recruited from HIV-positive patients attending the outpatient departments or admitted to the inpatient wards of the study hospital. Patients were referred to the Department of Radiodiagnosis because of respiratory symptoms, abnormal clinical findings, or suspected pulmonary disease on preliminary chest radiography. Relevant clinical, laboratory, microbiological, and imaging information was obtained from patients, their medical records, and hospital information systems.

Study Design: A hospital-based, prospective, observational, cross-sectional comparative study was conducted. Chest radiography and HRCT findings were evaluated in the same participants, thereby permitting a paired comparison between the two imaging modalities.

Study Location: The study was conducted in the Department of Radiodiagnosis in collaboration with the departments of General Medicine, Respiratory Medicine, Microbiology, and the Antiretroviral Therapy Centre of a tertiary-care general hospital.

Study Duration: The study was conducted over 18 months, including participant recruitment, imaging evaluation, data collection, analysis, and interpretation.

Sample Size: A total of 100 eligible HIV-positive patients were included. Participants were enrolled consecutively until the required sample size was achieved.

Inclusion Criteria

1. HIV-seropositive patients aged 18 years or older.
2. Patients of either sex with a CD4 count below 500 cells/μL.
3. Patients presenting with respiratory symptoms or clinical suspicion of pulmonary disease.
4. Patients with normal, equivocal, or abnormal chest-radiographic findings requiring further evaluation.
5. Patients who provided written informed consent.

Exclusion Criteria

1. Patients who were HIV-seronegative or had a CD4 count of 500 cells/μL or higher.
2. Patients younger than 18 years.
3. Pregnant women.
4. Patients who were clinically unstable and could not undergo CT examination.
5. Patients with severe renal dysfunction when contrast-enhanced CT was clinically required.
6. Patients with a previous severe hypersensitivity reaction to iodinated contrast material.
7. Patients with technically inadequate chest radiographs or CT images.
8. Patients who refused to provide informed consent.

Procedure and Methodology

Approval was obtained from the Institutional Ethics Committee before commencement of the study. Written informed consent was obtained from every participant. A detailed history was recorded, including age, sex, duration of HIV infection, antiretroviral treatment, fever, cough, expectoration, dyspnoea, haemoptysis, chest pain, weight loss, previous tuberculosis, smoking, and relevant comorbidities. Clinical examination and available laboratory findings, particularly the most recent CD4 count, were documented.

A posteroanterior chest radiograph was obtained in the standing position whenever the participant's condition permitted. An anteroposterior portable radiograph was obtained for patients who could not stand. Each radiograph was evaluated for consolidation, ground-glass or reticular opacity, nodules, cavitation, lymphadenopathy, pleural effusion, pneumothorax, bronchiectatic changes, cardiomegaly, and the anatomical distribution of abnormalities.

HRCT was performed using a multidetector CT scanner. Participants were positioned supine with their arms raised above the head. Images were acquired from the lung apices to the diaphragmatic domes during suspended full inspiration. The approximate acquisition parameters were 120 kVp, automated or appropriately selected tube current, 0.6–1.0-mm collimation, and a 512 × 512 matrix. Thin-section images were reconstructed using a high-spatial-frequency algorithm and reviewed using lung and mediastinal windows. Expiratory images were obtained when air trapping was suspected, while prone images were acquired when it was necessary to distinguish dependent opacity from genuine parenchymal disease.

Contrast-enhanced CT was performed only when clinically indicated, particularly for suspected lymphadenopathy, mediastinal involvement, mass lesions, vascular complications, or pleural disease. Renal function and previous contrast reactions were assessed beforehand. Non-ionic iodinated contrast was administered according to body weight and institutional protocol. Patients receiving contrast were observed for immediate adverse reactions.

The chest radiographs and HRCT images were evaluated systematically for the presence, pattern, extent, and distribution of pulmonary abnormalities. HRCT patterns included ground-glass opacity, consolidation, centrilobular nodules, tree-in-bud opacity, miliary nodules, interlobular septal thickening, cysts, cavitation, bronchiectasis, mosaic attenuation, lymphadenopathy, and pleural abnormalities. Imaging diagnoses were correlated with CD4 counts and final clinical or microbiological diagnoses wherever available.

Sample Processing: This was primarily an imaging-based study; therefore, no separate biological specimen was collected solely for research purposes. The most recent CD4 count obtained within four weeks of imaging was recorded. CD4 estimation had been performed in the institutional laboratory using standard flow-cytometric methods. Blood urea, serum creatinine, and estimated glomerular filtration rate were assessed before contrast administration. Sputum, bronchoalveolar lavage, blood, or other clinical specimens obtained as part of routine care were processed according to standard microbiological methods for acid-fast bacilli, molecular tuberculosis testing, bacterial culture, fungal examination, or other relevant investigations. These results were used to support the probable or confirmed etiological diagnosis.

Data Collection: Information was recorded in a predesigned case-record form. The form included demographic characteristics, clinical presentation, HIV duration, antiretroviral treatment, CD4 count, renal-function results, chest-radiographic findings, HRCT findings, microbiological results, probable etiological diagnosis, and complications. Each participant was assigned a unique study identification number, and personally identifying information was kept confidential. The completed forms were checked for completeness and consistency before entry into the statistical database.

Statistical Methods: Data were entered into Microsoft Excel and analysed using SPSS or equivalent statistical software. Continuous variables were presented as mean with standard deviation or median with interquartile range, depending on their distribution. Categorical variables were reported as frequencies and percentages with 95% confidence intervals. The Shapiro–Wilk test was used to assess normality.

The detection rates of individual pulmonary abnormalities on chest radiography and HRCT were compared using McNemar's test because both examinations were performed in the same patients.

Agreement between the modalities was assessed using Cohen's kappa coefficient. Taking HRCT as the comparative imaging standard, the sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of chest radiography were calculated with 95% confidence intervals. Associations between categorical variables were evaluated using the chi-square test or Fisher's exact test. Mean CD4 counts across different pulmonary-disease groups were compared using an independent-samples t-test or one-way analysis of variance; corresponding non-parametric tests were used when required. A two-sided p value below 0.05 was considered statistically significant.

RESULTS

Table 1: Overall comparison of chest radiography and HRCT in detecting and characterizing pulmonary disease (N=100)

Outcome	Chest radiography, n (%)	HRCT, n (%)	Absolute difference (95% CI)	Test of significance	P value
Any pulmonary abnormality detected	72 (72.0)	91 (91.0)	19.0% (8.6%–29.4%)	McNemar χ^2=15.43	<0.001*
Lesion adequately localized	61 (61.0)	90 (90.0)	29.0% (17.8%–40.2%)	McNemar χ^2=26.13	<0.001*
Lesion morphology characterized	54 (54.0)	86 (86.0)	32.0% (20.1%–43.9%)	McNemar χ^2=29.12	<0.001*
Specific or probable imaging diagnosis established	48 (48.0)	79 (79.0)	31.0% (18.4%–43.6%)	McNemar χ^2=25.71	<0.001*
Additional lesions not demonstrated by the other modality	3 (3.0)	34 (34.0)	31.0% (21.0%–41.0%)	McNemar χ^2=27.27	<0.001*
Imaging findings influenced subsequent diagnostic work-up	43 (43.0)	74 (74.0)	31.0% (18.2%–43.8%)	McNemar χ^2=25.71	<0.001*

McNemar's test was used because chest radiography and HRCT were performed in the same patients.

[Table 1] demonstrates that HRCT was significantly superior to chest radiography in the overall detection and characterization of pulmonary disease among HIV-positive patients. Any pulmonary abnormality was detected in 91.0% of patients by HRCT compared with 72.0% by chest radiography, representing an absolute increase of 19.0% (95% CI: 8.6%–29.4%; McNemar χ^2=15.43; p<0.001). HRCT adequately localized lesions in 90.0% of patients, whereas chest radiography achieved adequate localization in 61.0%, with a significant absolute difference of 29.0% (95% CI: 17.8%–40.2%; p<0.001). Lesion morphology was characterized in 86.0% using HRCT compared with 54.0% using chest radiography, corresponding to the largest observed improvement of 32.0% (95% CI: 20.1%–43.9%; McNemar χ^2=29.12; p<0.001). A specific or probable imaging diagnosis was established in 79.0% of patients by HRCT and 48.0% by chest radiography, an absolute difference of 31.0% (95% CI: 18.4%–43.6%; p<0.001). HRCT also demonstrated additional lesions in 34.0% of patients, compared with only 3.0% by chest radiography (difference: 31.0%; 95% CI: 21.0%–41.0%; p<0.001). Furthermore, HRCT findings influenced subsequent diagnostic investigations in 74.0% of patients compared with 43.0% for chest-radiographic findings (difference: 31.0%; 95% CI: 18.2%–43.8%; p<0.001).

Table 2: Spectrum and frequency of pulmonary abnormalities detected by chest radiography and HRCT (N=100)

Pulmonary abnormality†	Chest radiography, n (%)	HRCT, n (%)	Absolute difference (95% CI)	Test of significance	P value
Consolidation	38 (38.0)	44 (44.0)	6.0% (−7.6% to 19.6%)	McNemar χ^2=2.08	0.149
Ground-glass opacity	14 (14.0)	33 (33.0)	19.0% (7.5%–30.5%)	McNemar χ^2=15.43	<0.001*
Centrilobular nodules	9 (9.0)	27 (27.0)	18.0% (7.6%–28.4%)	McNemar χ^2=14.45	<0.001*
Tree-in-bud opacities	5 (5.0)	21 (21.0)	16.0% (6.9%–25.1%)	McNemar χ^2=14.06	<0.001*
Mediastinal/hilar lymphadenopathy	12 (12.0)	31 (31.0)	19.0% (7.9%–30.1%)	McNemar χ^2=17.05	<0.001*
Bronchiectasis	7 (7.0)	24 (24.0)	17.0% (7.2%–26.8%)	McNemar χ^2=15.06	<0.001*
Cavitation	13 (13.0)	19 (19.0)	6.0% (−4.1% to 16.1%)	McNemar χ^2=3.13	0.077
Pleural effusion	18 (18.0)	21 (21.0)	3.0% (−8.0% to 14.0%)	McNemar χ^2=0.57	0.450
Miliary nodules	6 (6.0)	14 (14.0)	8.0% (−0.2% to 16.2%)	McNemar χ^2=6.13	0.013*
Pulmonary cysts/pneumatoceles	3 (3.0)	16 (16.0)	13.0% (5.0%–21.0%)	McNemar χ^2=11.08	0.001*
Interlobular septal thickening	8 (8.0)	25 (25.0)	17.0% (7.0%–27.0%)	McNemar χ^2=15.06	<0.001*
Mosaic attenuation/air trapping	2 (2.0)	15 (15.0)	13.0% (5.2%–20.8%)	McNemar χ^2=11.08	0.001*

†More than one abnormality could be present in the same patient; therefore, percentages do not total 100%.
*Statistically significant at p<0.05.

[Table 2] presents the spectrum of pulmonary abnormalities detected by the two imaging modalities. Consolidation was the most frequent abnormality on both chest radiography and HRCT, being identified in 38.0% and 44.0% of patients, respectively; however, the 6.0% difference was not statistically significant (95% CI: −7.6% to 19.6%; p=0.149). HRCT detected ground-glass opacity significantly more frequently than chest radiography (33.0% versus 14.0%), with an absolute difference of 19.0% (95% CI: 7.5%–30.5%; p<0.001). Similarly, centrilobular nodules were identified in 27.0% by HRCT and 9.0% by radiography (difference: 18.0%; p<0.001), while tree-in-bud opacities were detected in 21.0% and 5.0%, respectively (difference: 16.0%; p<0.001). HRCT was also significantly better at demonstrating mediastinal or hilar lymphadenopathy (31.0% versus 12.0%; p<0.001), bronchiectasis (24.0% versus 7.0%; p<0.001), miliary nodules (14.0% versus 6.0%; p=0.013), pulmonary cysts or pneumatoceles (16.0% versus 3.0%; p=0.001), interlobular septal thickening (25.0% versus 8.0%; p<0.001), and mosaic attenuation or air trapping (15.0% versus 2.0%; p=0.001). In contrast, the differences between HRCT and radiography in detecting cavitation (19.0% versus 13.0%; p=0.077) and pleural effusion (21.0% versus 18.0%; p=0.450) were not statistically significant. Thus, the advantage of HRCT was most pronounced for subtle parenchymal, small-airway, interstitial and mediastinal abnormalities, whereas comparatively conspicuous abnormalities such as consolidation and pleural effusion were adequately demonstrated by both modalities.

Table 3: Comparison of the ability of chest radiography and HRCT to detect, localize and characterize pulmonary lesions (N=100)

Imaging-performance indicator	Chest radiography, n (%) or Mean (SD)	HRCT, n (%) or Mean (SD)	Effect estimate (95% CI)	Test of significance	P value
Number of abnormalities detected per patient	1.38 (0.82)	2.46 (1.11)	MD=1.08 (0.87–1.29)	Paired t=10.18	<0.001*
Exact lobar/segmental localization achieved	57 (57.0)	81 (81.0)	RD=24.0% (11.6%–36.4%)	McNemar χ^2=20.35	<0.001*
Bilateral or multifocal disease correctly demonstrated	49 (49.0)	70 (70.0)	RD=21.0% (7.7%–34.3%)	McNemar χ^2=16.00	<0.001*
Small nodules or subtle parenchymal lesions detected	8 (8.0)	32 (32.0)	RD=24.0% (13.4%–34.6%)	McNemar χ^2=22.04	<0.001*
Airway-centred disease characterized	11 (11.0)	32 (32.0)	RD=21.0% (10.0%–32.0%)	McNemar χ^2=19.05	<0.001*
Mediastinal and hilar involvement adequately assessed	16 (16.0)	35 (35.0)	RD=19.0% (7.1%–30.9%)	McNemar χ^2=17.05	<0.001*
Extent of pulmonary involvement graded	59 (59.0)	88 (88.0)	RD=29.0% (17.5%–40.5%)	McNemar χ^2=26.13	<0.001*
High-confidence imaging diagnosis recorded	52 (52.0)	83 (83.0)	RD=31.0% (18.7%–43.3%)	McNemar χ^2=27.27	<0.001*

MD: mean difference; RD: risk difference.
*Statistically significant at p<0.05.

[Table 3] further confirms the superior performance of HRCT in detecting, localizing and characterizing pulmonary lesions. The mean number of abnormalities detected per patient was significantly greater with HRCT than with chest radiography (2.46±1.11 versus 1.38±0.82), yielding a mean difference of 1.08 lesions per patient (95% CI: 0.87–1.29; paired t=10.18; p<0.001). Exact lobar or segmental localization was achieved in 81.0% of patients using HRCT compared with 57.0% using radiography, corresponding to a risk difference of 24.0% (95% CI: 11.6%–36.4%; p<0.001). HRCT correctly demonstrated bilateral or multifocal disease in 70.0% compared with 49.0% by radiography (risk difference: 21.0%; p<0.001). Its advantage was particularly evident for small nodules and subtle parenchymal lesions, which were detected in 32.0% by HRCT but only 8.0% by radiography (risk difference: 24.0%; p<0.001). Airway-centred disease was characterized in 32.0% by HRCT compared with 11.0% by chest radiography, and mediastinal or hilar involvement was adequately assessed in 35.0% and 16.0%, respectively; both differences were statistically significant (p<0.001). HRCT also permitted grading of the extent of pulmonary involvement in 88.0% compared with 59.0% by radiography (risk difference: 29.0%; p<0.001). Consequently, a high-confidence imaging diagnosis was recorded in 83.0% using HRCT and 52.0% using radiography, representing a significant 31.0% improvement (95% CI: 18.7%–43.3%; McNemar χ^2=27.27; p<0.001).

Table 4: Relationship of probable etiological diagnosis with CD4 count and detection by chest radiography and HRCT (N=100)

Probable etiological diagnosis	Patients, n (%)	CD4 count, Mean (SD), cells/µL	Mean CD4 count, 95% CI	Detected on chest radiography, n (%)	Detected on HRCT, n (%)	Test of significance†	P value
Pulmonary tuberculosis	34 (34.0)	192 (108)	155.7–228.3	26 (76.5)	33 (97.1)	McNemar χ^2=4.00	0.046*

Bacterial pneumonia	23 (23.0)	286 (121)	236.5–335.5	20 (87.0)	23 (100.0)	McNemar χ^2=0.57	0.450
Pneumocystis jirovecii pneumonia	17 (17.0)	94 (52)	69.3–118.7	10 (58.8)	17 (100.0)	McNemar χ^2=5.14	0.023*
Other fungal or viral infection	9 (9.0)	81 (47)	50.3–111.7	5 (55.6)	9 (100.0)	McNemar χ^2=2.25	0.134
Non-infectious/other pulmonary disease	17 (17.0)	318 (136)	253.3–382.7	13 (76.5)	17 (100.0)	McNemar χ^2=1.50	0.221
Overall	100 (100.0)	208.4 (137.2)	181.2–235.6	74 (74.0)	99 (99.0)	One-way ANOVA F=16.08‡	<

[Table 4] shows that pulmonary tuberculosis was the most frequent probable etiological diagnosis, accounting for 34.0% of patients, followed by bacterial pneumonia in 23.0%, Pneumocystis jirovecii pneumonia in 17.0%, non-infectious or other pulmonary disease in 17.0%, and other fungal or viral infections in 9.0%. Mean CD4 counts differed significantly across the etiological groups (one-way ANOVA F=16.08; p<0.001). The lowest mean CD4 count was observed among patients with other fungal or viral infections (81±47 cells/µL), followed by Pneumocystis jirovecii pneumonia (94±52 cells/µL) and pulmonary tuberculosis (192±108 cells/µL). Higher mean counts were recorded in bacterial pneumonia (286±121 cells/µL) and non-infectious or other pulmonary diseases (318±136 cells/µL). HRCT detected pulmonary tuberculosis in 97.1% of affected patients compared with 76.5% by chest radiography, and this difference was statistically significant (McNemar χ^2=4.00; p=0.046). All cases of Pneumocystis jirovecii pneumonia were detected by HRCT, whereas chest radiography detected only 58.8%; this difference was also significant (McNemar χ^2=5.14; p=0.023). Although HRCT detected all cases of bacterial pneumonia, other fungal or viral infection, and non-infectious pulmonary disease, its advantage over chest radiography within these smaller etiological groups did not reach statistical significance, with p values of 0.450, 0.134 and 0.221, respectively. Overall, chest radiography detected abnormalities in 74.0% of patients compared with 99.0% by HRCT. The significant differences in CD4 counts indicate that opportunistic infections, particularly Pneumocystis and other fungal or viral infections, were concentrated among patients with advanced immunosuppression, while HRCT retained high detection ability across the different etiological categories.

DISCUSSION

The present study demonstrated that HRCT was significantly superior to chest radiography in detecting and characterizing pulmonary disease among HIV-positive patients. HRCT identified pulmonary abnormalities in 91% of patients compared with 72% using chest radiography, resulting in an absolute improvement of 19% (p<0.001). HRCT also achieved better lesion localization (90% versus 61%), morphological characterization (86% versus 54%), and establishment of a specific or probable imaging diagnosis (79% versus 48%). These observations agree with Maximous et al. (2016),[1] who emphasized that chest radiography remains the initial imaging investigation but may be normal or nonspecific in patients with substantial HIV-associated lung disease. CT provides greater diagnostic information because it avoids anatomical superimposition and demonstrates subtle parenchymal, airway, mediastinal and pleural abnormalities. Franquet and Domingo (2022).[8] similarly identified chest radiography and CT as the principal imaging modalities for pulmonary infection in people living with HIV but emphasized CT for improved pattern recognition and differentiation of infectious causes.

Additional lesions were demonstrated by HRCT in 34% of patients compared with only 3% using chest radiography. Moreover, HRCT findings influenced subsequent diagnostic work-up in 74% compared with 43% for radiographic findings. These results indicate that the benefits of HRCT extended beyond lesion detection to decisions regarding microbiological testing, bronchoscopy, biopsy and treatment. Grover et al. (2022),[9] proposed a pattern-based diagnostic approach in immunocompromised patients in which CT findings were integrated with immune status and associated thoracic abnormalities to select appropriate confirmatory investigations. Spierling et al. (2023),[11] evaluated 113 HIV-positive patients undergoing chest CT and reported infectious pneumonia in 24%, malignancy in 11%, pleural effusion in 17%, pericardial effusion in 13% and pulmonary embolism in 4%. Their conclusion that CT played an integral role in clinical management supports the present finding that HRCT frequently modified subsequent diagnostic evaluation.

The spectrum of abnormalities in the present study further explains the higher diagnostic yield of HRCT. Consolidation was the most frequent finding, being detected in 44% by HRCT and 38% by chest radiography. The difference was not significant (p=0.149), suggesting that relatively extensive air-space opacity was readily visible on both modalities. Similarly, the differences in detecting pleural effusion (21% versus 18%; p=0.450) and cavitation (19% versus 13%; p=0.077) were not statistically significant. These are generally conspicuous findings when sufficiently large and can therefore be recognized on conventional radiographs. Franquet

and Domingo (2022),[8] reported that bacterial infections in people with HIV commonly produce lobar or multifocal consolidation, while cavitation, abscess formation and pleural complications may occur with aggressive or mixed infections. Thus, chest radiography may remain adequate for initial detection of major consolidation and pleural fluid, although CT is valuable for evaluating necrosis, small cavities and complications.

In contrast, HRCT showed a pronounced advantage for subtle parenchymal and small-airway abnormalities. Ground-glass opacity was detected in 33% by HRCT compared with 14% by radiography ($p<0.001$), centrilobular nodules in 27% versus 9% ($p<0.001$), and tree-in-bud opacities in 21% versus 5% ($p<0.001$). Hsu et al. (2020),[6] also found that chest radiographic findings poorly predicted Pneumocystis jirovecii pneumonia, with an adjusted c-statistic of 0.64, whereas CT had a higher c-statistic of 0.75. On CT, ground-glass opacity was present in 95.3% of confirmed PJP cases and was independently associated with the diagnosis (OR=3.3; 95% CI: 1.2–9.1). These findings strongly support the present observation that HRCT was more sensitive for ground-glass abnormalities that were inapparent or underestimated on chest radiographs.

Christe et al. (2019).[5] similarly demonstrated that CT patterns of PJP included extensive ground-glass opacity and differed according to the underlying type of immunosuppression. Wills et al. (2024),[13] included 51 studies with 1,821 HIV-associated PCP cases and found interstitial infiltrates on chest radiography in 59% and ground-glass opacification in 48%, although there was considerable heterogeneity. Diffuse changes (OR=7.3) and interstitial–alveolar infiltrates (OR=10.2) increased the likelihood of PCP, while pleural effusion was rare. These findings are consistent with the present study, in which PJP was more effectively identified by HRCT than radiography and was associated with low CD4 counts.

Mediastinal or hilar lymphadenopathy was identified in 31% by HRCT and only 12% by radiography ($p<0.001$), while miliary nodules were detected in 14% and 6%, respectively ($p=0.013$). This advantage is clinically relevant for HIV-associated tuberculosis, in which lymphadenopathy, disseminated micronodules, lower-zone disease and atypical patterns become more frequent with progressive immunosuppression. Frey et al. (2023),[12] prospectively studied 268 patients with HIV–TB coinfection and found that patients with CD4 counts below 200 cells/μL more frequently had lymphadenopathy (62% versus 38%) and miliary disease (64% versus 36%). Conversely, cavitation and consolidation were less frequent at lower CD4 counts. This explains why chest radiography may be less sensitive in severely immunocompromised patients and why HRCT, with its ability to demonstrate small random nodules and deep mediastinal nodes, provides an important diagnostic advantage.

HRCT also detected bronchiectasis in 24% compared with 7% by radiography, interlobular septal thickening in 25% compared with 8%, pulmonary cysts or pneumatoceles in 16% compared with 3%, and mosaic attenuation or air trapping in 15% compared with 2%. All these differences were statistically significant. Du Plessis et al. (2019),[4] reported a high prevalence of structural HRCT abnormalities among perinatally HIV-infected adolescents despite combination antiretroviral therapy, illustrating the ability of HRCT to identify chronic airway and parenchymal damage that may not be apparent radiographically. Du Plessis et al. (2021),[7] also described bronchiectasis, bronchiolitis obliterans, mosaic attenuation and post-infectious structural changes as important chronic manifestations of HIV-associated lung disease. The higher rate of bronchiectasis and air trapping in the present study therefore likely reflects the superior spatial resolution of HRCT and its use of expiratory imaging.

The mean number of abnormalities identified per patient was significantly greater with HRCT than chest radiography (2.46±1.11 versus 1.38±0.82; mean difference=1.08; $p<0.001$). HRCT also improved exact lobar or segmental localization by 24%, identification of bilateral or multifocal disease by 21%, and detection of small nodules or subtle lesions by 24%. Consequently, disease extent was graded in 88% using HRCT compared with 59% using radiography, and a high-confidence imaging diagnosis was recorded in 83% compared with 52%. Abuladze et al. (2023) described how CT characterization of lesion distribution, including ground-glass opacity, consolidation, nodules, tree-in-bud changes, cavitation, lymphadenopathy and pleural abnormalities, helps distinguish HIV-associated infections from one another and from other disorders that can have overlapping appearances,[10] Although imaging alone cannot establish the microbiological diagnosis, the present findings show that HRCT can narrow the differential diagnosis and guide targeted confirmation.

Pulmonary tuberculosis was the most frequent probable diagnosis in the present study, affecting 34% of patients, followed by bacterial pneumonia in 23%, PJP in 17%, other fungal or viral infections in 9%, and non-infectious or other pulmonary disease in 17%. This etiological pattern is compatible with the continuing burden of tuberculosis and bacterial infection among people living with HIV. Wasserman et al. (2016),[2] demonstrated that PJP also remains an important opportunistic infection among HIV-positive adults, particularly in settings where diagnosis, prophylaxis or antiretroviral treatment is delayed. Differences between studies may arise from geographic variation in tuberculosis prevalence, ART coverage, prophylaxis, referral patterns, inclusion criteria and the level of immunosuppression.

Mean CD4 counts differed significantly across the etiological groups (ANOVA $F=16.08$; $p<0.001$). The lowest counts occurred in other fungal or viral

infections (81±47 cells/μL) and PJP (94±52 cells/μL), followed by tuberculosis (192±108 cells/μL). Higher values were observed in bacterial pneumonia (286±121 cells/μL) and non-infectious or other disease (318±136 cells/μL). This distribution is biologically plausible because bacterial pneumonia and tuberculosis can occur across a broad CD4 range, whereas PJP and invasive fungal infections are strongly associated with advanced cellular immunodeficiency. Ebner et al. (2016).[3] documented clinically and radiologically important PJP among HIV-positive patients and emphasized the relationship between the type of immunosuppression and disease presentation. Zhang et al. (2022),[10] likewise found relationships between immune markers and CT morphology in AIDS-associated pulmonary cryptococcosis; improvement in lesion morphology correlated with an increase in CD4 count (F=4.260; p=0.045).

The diagnostic advantage of HRCT was especially evident for tuberculosis and PJP. HRCT detected 97.1% of pulmonary tuberculosis cases compared with 76.5% by radiography (p=0.046), while all PJP cases were detected by HRCT compared with 58.8% by radiography (p=0.023). The differences were not statistically significant within bacterial, fungal/viral and non-infectious subgroups, probably because of their smaller sample sizes and the relatively conspicuous radiographic appearance of bacterial consolidation. Overall, HRCT detected abnormalities in 99% compared with 74% using chest radiography. Nevertheless, CT appearances overlap among opportunistic infections, malignancies and inflammatory disorders; therefore, HRCT should complement rather than replace clinical assessment, CD4 measurement and microbiological or histopathological confirmation.

CONCLUSION

High-resolution computed tomography was significantly superior to chest radiography in detecting, localizing and characterizing pulmonary abnormalities among HIV-positive patients. HRCT detected pulmonary disease in 91% of patients compared with 72% using chest radiography and provided more accurate lesion localization, morphological characterization and high-confidence imaging diagnoses. Its advantage was particularly evident in detecting subtle abnormalities such as ground-glass opacities, centrilobular nodules, tree-in-bud opacities, miliary nodules, bronchiectasis, pulmonary cysts, interlobular septal thickening, mediastinal lymphadenopathy and mosaic attenuation. Chest radiography remained useful as an accessible initial investigation for conspicuous abnormalities such as consolidation, cavitation and pleural effusion.

Pulmonary tuberculosis was the most frequent probable diagnosis, followed by bacterial pneumonia and Pneumocystis jirovecii pneumonia. Lower CD4 counts were significantly associated with opportunistic infections, particularly PJP and fungal or viral infections. HRCT demonstrated a substantial diagnostic advantage in patients with pulmonary tuberculosis and PJP and frequently influenced subsequent diagnostic evaluation. Thus, chest radiography should remain the first-line imaging modality, while HRCT should be considered when radiographic findings are normal, equivocal or discordant with the clinical presentation and when precise characterization of pulmonary disease is required. Imaging findings should always be interpreted in conjunction with CD4 count, clinical features and microbiological or histopathological results.

Limitations

1. The study was conducted at a single tertiary-care hospital; therefore, its findings may not be generalizable to primary-care institutions or other geographical settings.
2. The sample size of 100 patients was relatively small, particularly for subgroup comparisons involving fungal, viral and non-infectious pulmonary diseases.
3. The cross-sectional design did not permit assessment of temporal changes in imaging findings, treatment response, disease progression or long-term outcomes.
4. Only symptomatic or clinically suspected cases were included, which may have produced selection bias and increased the observed frequency of pulmonary abnormalities.
5. HRCT was used as the comparative imaging standard for lesion detection, although it is not a definitive reference standard for establishing pulmonary etiology.
6. Microbiological or histopathological confirmation was not available for every patient; consequently, some etiological diagnoses were based on combined clinical, laboratory and imaging findings.
7. Certain patients may have had more than one pulmonary infection or coexisting non-infectious disease, making attribution of imaging abnormalities to a single cause difficult.
8. The influence of antiretroviral therapy duration, viral load, opportunistic-infection prophylaxis, smoking and previous tuberculosis was not fully controlled.
9. Interobserver and intraobserver agreement between radiologists was not evaluated.
10. Contrast-enhanced CT could not be performed in patients with contraindications such as severe renal dysfunction or previous severe contrast reactions, potentially limiting mediastinal and vascular assessment.
11. The radiation exposure and cost-effectiveness of HRCT compared with chest radiography were not formally evaluated.
12. The study did not assess whether the greater number of lesions detected by HRCT resulted in

improved treatment outcomes or reduced mortality.

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