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Evaluating the Diagnostic Accuracy of High-Resolution Computed Tomography in Detecting COVID-19: A Comparative Study Using Polymerase Chain Reaction as the Gold Standard

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ABSTRACT

Pakistan has faced three waves of COVID-19, each intensifying the strain on diagnostic resources. Delayed diagnoses during these waves hindered timely treatment and contributed to disease transmission. **Objective:** To evaluate the diagnostic accuracy of High-Resolution Computed Tomography (HRCT) in detecting COVID-19, using Polymerase Chain Reaction (PCR) as the gold standard. **Methods:** A cross-sectional study was conducted from November 26, 2021, to May 26, 2022, at the Department of Radiology, Northwest General Hospital & Research Centre, Peshawar. The study included 234 clinically suspected COVID-19 patients, aged 20-60 years, of both genders. Chest CT scans were performed, and results were compared with PCR. Data were analyzed using SPSS version 20, with $p<0.05$ considered significant. **Results:** Of the 234 patients, 133 tested positive for COVID-19 via PCR, while 101 were negative. HRCT demonstrated an overall accuracy of 73.9%, sensitivity of 72.9%, specificity of 75.2%, positive predictive value of 79.5%, and negative predictive value of 67.8%. Chi-square analysis revealed significant correlations of HRCT accuracy with BMI ($p=0.004$) and illness duration ($p=0.010$) but not with age ($p=0.956$) or gender ($p=0.113$). **Conclusions:** HRCT shows reasonable sensitivity, specificity, and overall accuracy as a diagnostic tool for COVID-19. Its performance improves in women, those with higher BMI, and longer illness duration but should not replace PCR testing due to its modest negative predictive value.

INTRODUCTION

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the causative agent of COVID-19, a highly contagious and pathogenic viral infection initially identified in Wuhan, China [1]. COVID-19 quickly spread to 213 nations, severely impacting the United States, Italy, Spain, and the United Kingdom. Pakistan reported its first case in Karachi in February 2020, ranking among the top 20 most affected nations [2]. On March 12, 2020, the World Health Organization declared the outbreak a pandemic [3]. By April 20, 2020, over 2.4 million cases had been confirmed in 205 countries [4]. SARS-CoV-2 infections range from asymptomatic to severe, with severe cases associated with high viral loads, inflammation, and immunological dysregulation, often worsened by aging or comorbidities like diabetes and hypertension [5, 6]. Chronic complications such as fatigue and cognitive dysfunction are also recognized [7]. High-Resolution Chest Computed Tomography (HRCT) has demonstrated excellent sensitivity and specificity in detecting lung involvement and diagnosing COVID-19 [8]. With a

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sensitivity of 97% in identifying COVID-19, HRCT aids early detection, especially in cases presenting before clinical symptoms [9]. Its diagnostic patterns, including Ground-Glass Opacities (GGO), consolidation, and pleural effusions, are critical in managing the disease [10, 11]. However, the American College of Radiology advises caution in using HRCT routinely for diagnosis [4]. Pakistan's healthcare system, burdened during COVID-19 waves, faced limited diagnostic resources. While PCR remains the gold standard, HRCT offers quick results, aiding timely clinical decisions [12, 13].

This study evaluated HRCT's diagnostic accuracy using PCR as the gold standard in Peshawar, Khyber Pakhtunkhwa, providing insights for regions with limited PCR access.

METHODS

A cross-sectional study was conducted between November, 2021, and May, 2022, in the Radiology Department of Northwest General Hospital and Research Centre, Peshawar. The sample size was determined to include 234 participants, calculated based on assumptions of HRCT sensitivity at 92%, specificity at 23%, and a prevalence rate of 40.4%, using a 95% confidence level and a 7% margin of error [14]. Non-probability sequential sampling was employed to select participants. Patients aged 20–60 years, irrespective of gender, were eligible if they met the operational definition of COVID-19 infection. Exclusion criteria included individuals who had undergone chest surgery within six months or were unwilling to undergo PCR testing. Approval for the study was granted by the Institutional Review Board of Northwest General Hospital and Research Centre, Peshawar (Ref. No: NWGH/Res/Ethical approval/1724). All participants provided informed written consent after the study's purpose, methods, and data usage were explained to them. A standardized proforma was used to record demographic data such as age and gender. Chest HRCT scans were conducted by a radiologist with over five years of expertise, following international guidelines. Blood samples measuring five microliters were collected post-HRCT and sent for PCR testing to confirm COVID-19 infection. Data analysis was performed using SPSS version 20.0. Descriptive statistics were computed for demographic and clinical variables. Continuous variables such as age, BMI, and symptom duration were expressed as means with standard deviations, while categorical variables including gender, HRCT findings, and PCR results were presented as frequencies and percentages. The diagnostic accuracy of HRCT was calculated using the formula: Accuracy = (a+d)/(a+b+c+d), where "a" represents true positives, "b" false positives, "c" false negatives, and "d" true negatives. Stratification by variables such as age, gender, BMI, and symptom duration was conducted, with correlations assessed through chi-square testing ($p<0.05$ considered statistically significant).

RESULTS

There were 234 people who signed up for the study, and their average age was 52.80 years±5.30 years. The average height of the participants was 170.46 ± 8.00 cm, and their average weight was 71.85 kg±6.45 kg. The BMI was 24.82 kg/m^2 ±2.74 kg/m^2 on average. Furthermore, the illness lasted an average of 5.07 days ±1.03 days. Table 1 provides a summary of the study participants' clinical and demographic traits.

Table 1: Demographic characteristics of the Participants

Variables	Mean ± SD
Age (Years)	52.80 ± 5.298
Weight (Kg)	71.85 ± 6.454
Height (cm)	170.46 ± 8.003
BMI (Kg/m^2)	24.822 ± 2.742
Duration of Disease (Days)	5.07 ± 1.029

According to the age group distribution, 33.3% of the participants (n=78) were over 40, while the majority (66.7%, n=156) were 40 years of age or younger. Women made up 26.5% (n=62) of the sample, while men made up 73.5% (n=172). Of the individuals, 83.8% (n=196) had a BMI of more than 22 kg/m^2, while 16.2% (n=38) had a BMI of less than 22 kg/m^2. In terms of symptom duration, Figure 1 shows that 41.5% (n=97) experienced symptoms that lasted less than five days, whereas 58.5% (n=137) had symptoms that lasted five days or more.

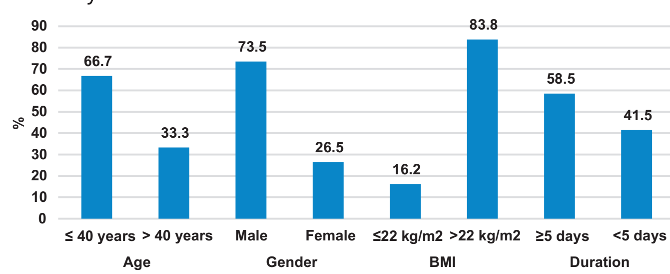

Figure 1: Demographic and Clinical Characteristics of the Participants Distribution

Using Polymerase Chain Reaction (PCR) as the gold standard, table 2 shows the diagnostic performance of High-Resolution Computed Tomography (HRCT) in detecting COVID-19. With a sensitivity of 72.9%, HRCT detected 122 cases as positive out of the 234 participants, 97 of which were true positives. HRCT had a specificity of 75.2%, properly identifying 76 of 101 negative cases. Comparatively speaking, 43.2% of participants were PCR-negative and 56.8% of participants were PCR-positive. Twenty-five percent of HRCT-positive cases were PCR-negative, while 79.5% were PCR-positive. In contrast,

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32.1% and 67.9% of HRCT-negative cases were PCR-positive and PCR-negative, respectively. The probability that a positive HRCT result would translate into a true positive is known as the Positive Predictive Value (PPV), and it was 79.5%. The likelihood that a negative HRCT result is actually negative, or the Negative Predictive Value (NPV), was 67.8%. HRCT has a 73.9% overall diagnostic accuracy.

Table 2: Diagnostic Accuracy of High-resolution Computed Tomography vs PCR as Gold Standard

Variables	HRCT Result	PCR Positive Frequency (%)	PCR Negative Frequency (%)	Total	Diagnostic Metrics
Overall	Positive	97 (79.5%)	25 (20.5%)	122	Sensitivity: 72.9% (65.5–79.4%)
	Negative	36 (32.1%)	76 (67.9%)	112	Specificity: 75.2% (66.5–82.6%)
	Total	133	101	234	PPV: 79.5% (71.7–85.8%)

Across various age ranges, the diagnostic accuracy of HRCT in identifying COVID-19 was evaluated. HRCT had a sensitivity of 73.6%, specificity of 70.7%, positive predictive value (PPV) of 77.9%, Negative Predictive Value (NPV) of 65.7%, and overall accuracy of 72.4% in patients aged 40 years or younger (n=156). Of the people who tested positive for HRCT, 22.1% were false positives and 77.9% were real positives. Of those who tested negative for HRCT, 65.7% were real negatives and 34.3% were false negatives. HRCT showed a sensitivity of 71.4%, specificity of 83.3%, PPV of 83.3%, NPV of 71.4%, and accuracy of 76.9% in people over 40 (n=78). 83.3% of those who tested positive for HRCT were true positives, whereas 16.7% were false positives. Of those who tested negative for HRCT, 71.4% were real negatives and 28.6% were false negatives. Male and female HRCT diagnostic accuracy in identifying COVID-19 was assessed independently. The HRCT's sensitivity, specificity, and positive predictive value (PPV) were 69.2%, 69.1%, 77.4%, and 59.5%, respectively, for males (n=172). In males, the overall accuracy was 69.2%. 22.6% of the male HRCT-positive individuals were false positives, whereas 77.4% were real positives. Of the guys who tested negative for HRCT, 40.5% had true negative results and 59.5% had false negative results. The HRCT demonstrated superior diagnostic performance in females (n=62), with 86.2% sensitivity, 87.9% specificity, 86.2% PPV, and 87.9% NPV. For females, the overall accuracy was 87.1%. Of the females who tested positive for HRCT, 13.8% were false positives and 86.2% were real positives. Among HRCT-negative females, 12.1% were true positives, andwere true negatives. A chi-square test was performed to evaluate the association between HRCT diagnostic outcomes and the variables of age and gender. For age, the analysis yielded a p-value of 0.956, indicating no statistically significant correlation between age groups (≤40 years and >40 years) and HRCT results. Similarly, for gender, the p-value was 0.113, suggesting no statistically significant relationship between gender (male and female) and HRCT results. These findings imply that neither age nor gender had a significant impact on the diagnostic performance of HRCT in this study, as shown in table 3.

Table 3: Comparative Analysis of Diagnostic accuracy of HR-CT among the Age and Gender Groups

Variables		HRCT	PCR				p-Value
			Positive Frequency (%)	Negative Frequency (%)	Total Frequency (%)	Diagnostic Performance Metrics	
Age	≤40 Years	Positive	67 (77.9%)	19 (22.1%)	86 (100%)	Sensitivity= 73.6% Specificity = 70.7%	0.956
		Negative	24 (34.3%)	46 (65.7%)	70 (100%)	PPV= 77.9%	
		Total	91 (58.3%)	65 (41.7%)	156 (100%)	NPV= 65.7% Accuracy=72.4%	
	>40 Years	Positive	30 (83.3%)	6 (16.7%)	36 (100%)	Sensitivity= 71.4% Specificity = 83.3%	
		Negative	12 (28.6%)	30 (71.4%)	42 (100%)	PPV= 83.3%	
		Total	42 (53.8%)	36 (46.2%)	78 (100%)	NPV= 71.4% Accuracy= 76.9%	
Gender	Male	Positive	72 (77.4%)	21 (22.6%)	93 (100%)	Sensitivity= 69.2% Specificity =69.1%	0.113
		Negative	32 (40.5%)	47 (59.5%)	79 (100%)	PPV= 77.4% NPV=59.5% Accuracy=69.2%	
		Total	104 (60.5%)	68 (39.5%)	172 (100%)	Sensitivity= 86.2%	
	Female	Positive	25 (86.2%)	4 (13.8%)	29 (100%)	Specificity =87.9%	
		Negative	4 (12.1%)	29 (87.9%)	33 (100%)	PPV= 86.2%	
		Total	29 (46.8%)	33 (53.2%)	62 (100%)	NPV=87.9% Accuracy=87.1%	

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When stratified by BMI, the diagnostic accuracy of HRCT varied significantly. For individuals with a BMI of ≤22.0 kg/m^2 (n=38), HRCT demonstrated a sensitivity of 33.3%, specificity of 100.0%, PPV of 100.0%, and NPV of 76.5%, with an overall accuracy of 78.9%. In this group, all HRCT-positive individuals were true positives (100%), while 23.5% of HRCT-negative individuals were false negatives. In contrast, for individuals with a BMI >22.0 kg/m^2 (n=196), HRCT sensitivity increased to 76.8%, and specificity was 66.7%, with a PPV of 78.8% and NPV of 64.1%. The overall accuracy was slightly lower at 72.9%, with 78.8% of HRCT-positive individuals being true positives and 21.2% being false positives. Among HRCT-negative individuals, 35.9% were false negatives, and 64.1% were true negatives. Similarly, disease duration influenced HRCT diagnostic performance. For individuals with a disease duration ≤5 days (n=137), HRCT sensitivity was 65.5%, specificity was 82.9%, with a PPV of 88.0% and an NPV of 55.7%. Overall accuracy in this group was 71.5%. Among HRCT-positive individuals, 88.1% were true positives, and 11.9% were false positives, while 44.3% of HRCT-negative individuals were false negatives, and 55.7% were true negatives. For disease duration >5 days (n=97), HRCT sensitivity increased to 88.4%, while specificity decreased to 68.5%. The PPV was 69.1%, and the NPV was 88.0%, with an overall accuracy of 77.3%. In this group, 69.1% of HRCT-positive individuals were true positives, and 30.9% were false positives. Among HRCT-negative individuals, 11.9% were false negatives, and 88.1% were true negatives. A chi-square test revealed statistically significant associations between HRCT diagnostic outcomes and BMI categories (p=0.004) as well as disease duration (p=0.010). These findings suggest that BMI and disease duration are important factors influencing HRCT's diagnostic efficacy in detecting COVID-19 (Table 4).

Table 4: Comparative Evaluation of HR-CT Diagnostic accuracy across BMI and Disease Duration

Variables		Diagnostic Performance Metrics	HRCT	PCR			p-Value
				Positive Frequency (%)	Negative Frequency (%)	Total Frequency (%)	
BMI (kg/m^2)	≤22.0	Sensitivity= 33.3%	Positive	4 (100%)	0 (0.0%)	4 (100%)	0.004
		Specificity=100.0%	Negative	8 (23.5%)	26 (76.5%)	34 (100%)	
		PPV=100.0% NPV= 76.5% Accuracy=78.9%	Total	12 (31.6%)	26 (68.4%)	38 (100%)	
	>22.0	Sensitivity =76.8%	Positive	93 (78.8%)	25 (21.2%)	118 (100%)	
		Specificity= 66.7% PPV= 78.8%	Negative	28 (35.9%)	50 (64.1%)	78 (100%)	
		NPV= 64.1% Accuracy= 72.9%	Total	75 (38.3%)	196 (100%)	75 (38.3%)	
Duration of Disease	≤5 Days	Sensitivity= 65.5%	Positive	59 (88.1%)	8 (11.9%)	67 (100%)	0.010
		Specificity= 82.9% PPV= 88.0%	Negative	31 (44.3%)	39 (55.7%)	70 (100%)	
		NPV= 55.7% Accuracy=71.5%	Total	90 (65.7%)	47 (34.3%)	137 (100%)	
	>5 Days	Sensitivity= 88.4%	Positive	38 (69.1%)	17 (30.9%)	55 (100%)	
		Specificity= 68.5% PPV= 69.1%	Negative	5 (11.9%)	37 (88.1%)	42 (100%)	
		NPV= 88.0%, Accuracy= 77.3%	Total	43 (44.3%)	(55.7%)	97 (100%)	

DISCUSSION

The gold standard for evaluating the diagnostic precision of High-Resolution Computed Tomography (HRCT) in identifying COVID-19 is Polymerase Chain Reaction (PCR). HRCT showed sensitivity, specificity, PPV, NPV, and accuracy of 72.9%, 75.2%, 79.5%, 67.8%, and 73.9%, respectively. These results suggest HRCT is a reliable diagnostic tool, especially where PCR testing is unavailable. Most participants were middle-aged, with a mean age of 52.8 ± 5.3 years, BMI of 24.8 ± 2.7 kg/m^2, and illness duration of 5.1 ± 1.0 days [15]. A total of 74% of patients showed the crazy-paving pattern on HRCT scans, consistent with prevalence rates of 12.5–36% reported in the literature [16, 17]. Pleural and pericardial effusions were observed in 10% and 5% of cases, aligning with reported rates of 4.8–8.4% [16, 18]. The posterior segments of the right upper lobe and posterior basal segments of both lungs were most affected, consistent with findings from previous studies [14, 16, 19]. Comparisons with studies by Hanif N *et*

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al., revealed similarities and discrepancies in diagnostic performance. Hanif N *et al.,* reported lower specificity (23%) but higher sensitivity (92%) compared to these findings [2]. This may have indicated challenges in distinguishing COVID-19 from other conditions, leading to more false positives in their study [20]. Fang Y *et al.,* reported higher sensitivity (97%) but lower specificity (25%) than these results, indicating HRCT's strong detection capabilities but limited specificity in their study [8]. Deng *et al.,* reported sensitivity, specificity, and accuracy of 85.71%, 60.94%, and 65.38%, respectively, showing variability in diagnostic metrics [21]. These findings demonstrated that females had higher diagnostic accuracy (87.1%) than males (69.2%), with females showing greater sensitivity (86.2%) and specificity (87.9%). Hanif N *et al.,* reported higher sensitivity (100%) in males, highlighting demographic differences [2]. We observed significant associations between HRCT accuracy and BMI (p=0.004) and disease duration (p=0.010), which Hanif N *et al.,* did not address [2]. The sensitivity (72.9%) and PPV (79.5%) in this study highlight HRCT's utility in identifying true positives but were lower than metrics reported by Ali *et al.,* (91% sensitivity, 83% PPV) [22]. Ali *et al.,* also reported higher specificity (90%) and NPV (84%), surpassing these findings of 75.2% and 67.8%, respectively [22]. Differences in population demographics, imaging protocols, and diagnostic criteria likely contribute to these variations [22]. This study underscored HRCT's value as a complementary diagnostic tool for COVID-19, particularly in resource-constrained settings. However, the lower specificity and NPV emphasize the importance of confirmatory PCR testing. Limitations include the single-center design, small sample size, and potential observer bias. Future research with larger multicenter cohorts and multiple radiologists could enhance generalizability and reliability. Additionally, studies exploring HRCT's role in predicting disease severity and outcomes could further establish its clinical utility.

CONCLUSIONS

With an overall accuracy of 73.9%, a sensitivity of 72.9%, and a specificity of 75.2%, HRCT proves to be a valuable diagnostic tool for COVID-19. Its diagnostic performance is significantly influenced by gender, BMI, and disease duration. Higher accuracy was observed in females, individuals with a BMI over 22 kg/m^2, and those with a disease duration longer than five days, while age showed no significant impact. HRCT plays a complementary role in resource-limited settings, particularly when PCR testing is unavailable. However, confirmatory PCR testing remains essential due to HRCT's moderate negative predictive value. Future studies with larger and more diverse populations are needed to validate these findings and explore additional factors affecting diagnostic performance.

Authors Contribution

Conceptualization: RS
Methodology: RS, SK, N, SLS, MS
Formal analysis: RS, SK, N, RS, MS
Writing, review and editing: RS, SK, N, SLS, RS, MS

All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

The authors declare no conflict of interest.

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