Effect of vaccination on the HRCT profile of COVID-19 patients – A single-center experience

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Abstract

Introduction: Vaccination against the global pandemic coronavirus disease 2019 (COVID-19) is a promising way out of the havoc caused by the disease. The clinico-radiological profile of COVID-19 patients in relation to the vaccination status is depicted in the present study. Materials and Methods: This is a retrospective observational imaging and hospital data-based study performed on 214 confirmed and clinically suspicious patients of COVID-19 who underwent high-resolution computed tomography (HRCT) scan of the thorax at the Department of Radiology of a tertiary medical centre in the Himalayan foothills. The present study aims to evaluate the effect of vaccination on HRCT findings of COVID-19 populations. Results: Forty-three percent of the non-vaccinated population presented with severe HRCT scores (19–25) in comparison to only 11.5% of the study population who had taken both doses of vaccine (P = 0.018). Two doses of vaccination had a negative Pearson correlation coefficient with severe HRCT scores (~0.146). Co-morbidities had a significant correlation with HRCT severity score, with 61.5% diabetics and 63.3% of hypertensive patients showing scores >19 on HRCT. Conclusion: Vaccination proves to be a game changer in the pandemic with two doses of vaccination having a significant negative correlation with COVID-19-induced severe pneumonitis on HRCT of the thorax.

Keywords: COVID-19, pandemic, thoracic imaging

Introduction

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome (SARS) coronavirus 2 after emerging from the Wuhan city of Hubei Province in China in December 2019, has currently spread through the globe. COVID-19 is primarily a respiratory virus, although multi-system involvement is reported in the spectrum of illness caused by it. High-resolution computed tomography (HRCT) scan of the thorax forms the cornerstone of imaging for both diagnosis and assessment of disease severity.[1-4] In late 2020, the world started vaccinating against COVID-19 via a variety of vaccines. India kick-started its vaccination drive in January 2021 with two ingenious vaccines, the ChAdOx1 nCoV-19 coronavirus vaccine (recombinant) known as COVISHIELD produced by the Serum Institute of India and the BBV 152 whole virion (inactivated) vaccine known as COVAXIN produced by BHARAT BIOTECH. Both vaccines were approved for emergency usage in adults by the Government of India. The efficacy of COVISHIELD after 14 days of the second dose was stated as 70.4% (95.8% CI 54.8 to 80.6) in clinical trials.[5] Despite the limited rollout of vaccination drive, India was hit by a massive second wave of the pandemic beginning in middle of March 2021.

The knowledge of HRCT profiles in vaccinated and non-vaccinated COVID-19 patients is absolutely essential for...
treating physicians to understand and guide the course of treatment knowing the disease prognosis.

The present study aims to evaluate the effect of vaccination on HRCT findings of COVID-19 in the Indian population during the second wave of the pandemic in the months of April and May 2021.

**Materials and Methods**

This was a retrospective observational study based on imaging and hospital data of COVID-19 patients in the Department of Radio-Diagnosis of a tertiary hospital in Himalayan foothills performed for the months of April and May 2021.

**Inclusion criteria**

1. All reverse transcription polymerase chain reaction (RT PCR)-positive COVID-19 patients presenting for HRCT of the thorax.
2. All patients with strong clinical suspicion of COVID-19 and positive HRCT changes.
3. Patients whose COVID vaccination data were available.

**Exclusion criteria**

1. Patients showing a negative RT PCR report and negative HRCT changes simultaneously, despite clinical suspicion.

**Study design**

After due clearance from the Institute’s Ethical Committee via reference no. SGRR/IEC/08/21, this study was done on imaging and hospital-based data. A consent waiver was obtained since the patients had already undergone the required investigations for clinical requirements.

“All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.”

Two radiologists with 10 and 11 years of experience in chest radiology independently assessed and documented the HRCT findings of the study population. In case of conflict, the senior radiologist’s opinion presided.

HRCT findings were primarily documented as scoring of lung involvement into mild, moderate, and severe categories. The CT severity score was decided by giving points on the involvement of each of the five lobes, the right upper, middle, and lower lobes and the left upper and lower lobes. One point was given to <5% involvement of the lobe, two points for 6–25% involvement, three points for 26–50% involvement, four points for 51–75% involvement, and five points for more than 75% involvement. A total score of up to eight was demarked as mild disease, nine to eighteen scores were demarked as moderate disease, and 19–25 scores were marked as severe disease.

The presence and characters of other associated findings such as lung parenchymal abnormalities, pleural effusion, mediastinal lymphadenopathy, pneumomediastinum, pneumothorax, and pulmonary thromboembolism were also documented.

The clinical and demographic profile of all patients was obtained from the hospital database. Vaccination history was confirmed with the provisional/final vaccination certificate provided by the Government of India.

The primary goal was to evaluate the presence and severity of lung changes on HRCT in association with the vaccination status of patients. Analysis of association of demographic and radiological features was also performed.

**Statistical analysis**

Continuous variables were assessed as mean/median. Categorical variables were studied as percentages. Tests of associations were performed by Chi square test and Fisher exact test. Correlation Regression analysis was performed by Pearson’s correlation coefficient and linear regression. A P value < 0.05 was considered significant. All statistical analyses were performed using Graph Pad 9.1.2 and SPSS Version 27.0.

**Results**

Our study group comprised 214 patients with RT PCR-proven or clinically suspicious COVID-19, who presented for HRCT of the thorax in April and May 2021.

The vaccination status of the study group was assessed and confirmed by the provisional/final vaccination certificate provided by the Government of India. It was observed that 138 patients were not vaccinated for COVID-19. Fifty patients had taken a single dose of the vaccine, and 26 patients had taken two doses of vaccination. All patients had taken the COVISHIELD vaccine, which was available through the Government of India’s vaccination drive.

The study group comprised patients from age 18 to 78 years of age with maximum patients presenting in the sixth decade. The mean age was higher in the vaccinated group as compared to the non-vaccinated group as the vaccination drive was open for health care professionals, frontline workers, and citizens above 60 years of age in the timeline leading up to the study period.

Two thirds of the study group comprised males (n = 144, 67.28%), and one third comprised females (n = 70, 32.71%). There was no significant difference in the vaccination status of both the genders.

While analysing co-morbidities, it was observed that hypertension (n = 60, 28%) and diabetes (n = 52, 24.2%)...
were the most common co-morbidities, possibly due to the higher average mean age of the study group. Interstitial lung disease (ILD) was also a prominent co-morbidity presenting in 9.8% study population (n = 21). Three cases of co-existing tuberculosis (0.05%) were also documented. The demographic profile of the study group is depicted in Table 1 and Figure 1.

On evaluating the clinical history of the study group, it was observed that cough (n = 193, 90.18%), malaise (n = 191, 89.25%), and fever (n = 178, 83.1%) were the most common presenting symptoms. This was followed by dyspnea (n = 74, 43.93%) and gastrointestinal disturbances (n = 19, 13.55%). On assessing the prevalence of symptoms across the study group according to the vaccination status, it was observed that in the non-vaccinated population and in patients who had taken a single dose of the vaccine, cough and malaise were the most common symptoms, followed by fever. However, in patients who had taken both doses of the vaccine, malaise was the single most common presenting feature, followed by cough and fever. Dyspnea was complained by more than half of the non-vaccinated study population, but it was seen in only one fifth of the population that had taken both doses of the vaccine (P = 0.0041).

The duration of illness leading up to HRCT of the thorax was 9.03 days after two doses of vaccination and 7.65 days after a single dose of vaccination. However, the duration of onset of symptoms after vaccination was more in the single-dose vaccination group (11.68 days) in comparison to the double-dose vaccination group (8.87 days). The clinical profile of the study group is detailed in Table 2.

The major observations of this study were in correlating the HRCT severity scores of all patients with their vaccination status. Ground glassing, mainly peripheral and basal, along with interstitial thickening and consolidation was considered as COVID-19-specific lung involvement. The HRCT severity scores were assigned from 0 to 25, and the results were segregated into mild, moderate, and severe categories. The most common HRCT scores were of the moderate group (9–18), seen in 44.4% of the study population (n = 95). However, 20% of the study population (n = 43) showed mild scores (up to 8) on HRCT, and 35.5% (n = 76) patients showed severe scores on HRCT (19–25). The mean HRCT score in the non-vaccinated population was 15.97, whereas that in the vaccinated population with two doses was 8.92. The highlight of this assessment was that 43.4% of the non-vaccinated population presented with severe HRCT scores in comparison to 11.5% of the study population who had taken both doses of the vaccine (P value = 0.018). One fourth of the population who had taken only one dose of the vaccine also showed severe scores on HRCT. This was also a statistically significant difference from the non-vaccinated population.

Other associated findings included interstitial lung disease (n = 25, 11.68%), cardiomegaly (n = 8, 3.7%), and cavitation seen in the case of co-existing tuberculosis (n = 2, 0.9%). The most common complications seen on HRCT were pleural effusion (n = 12, 5.6%) and mediastinal lymphadenopathy (n = 12, 5.6%). Pneumomediastinum was seen in ten patients (4.6%), and pneumothorax was seen in four patients (1.8%). The radiological profile of the study group is depicted in Table 3.

The above results were analyzed by correlation-regression analysis to assess the association between vaccination status and scores on HRCT of the thorax. The Pearson correlation coefficient showed a negative correlation between two doses of vaccination and a severe score on HRCT (R = -0.146) and a positive correlation between non-vaccination and severe scores (R = 0.224), both of which were found to be statistically significant (P < 0.05). Although a weak positive correlation was found between the single-dose-vaccinated population and severe HRCT scores (R = 0.0932), this association was not found to be statistically significant (P = 0.20). Correlation regression analytical results and graphs are depicted in Table 4 and Figure 2, respectively.

While considering the distribution of disease severity along the demographic group on the whole and vaccinated populations, it was observed that the mean age of patients presenting as severe CT scores in the entire disease population was 58.4 years, whereas it was 59.8 years in the vaccinated population. A significant difference was found in gender distribution with 38.89% (n = 56) males in the group presenting as severe CT scores. On the contrary, only 28.5% (n = 20) females in the study group presented as severe CT scores. However, in the vaccinated population,
there was no significant difference in the prevalence of CT presentation among both genders (P = 0.1857) as depicted in Figure 3. On further assessing the CT scoring in vaccinated versus non-vaccinated sub-groups based on gender, it was observed that there was a statistically significant difference in both genders after vaccination. (P value for males = 0.001, P value for females = 0.01). Sub-groups based on co-morbidities were also assessed for CT scoring. There was a significant association of common co-morbidities Diabetes and hypertension with a HRCT profile with 61.5% of diabetic patients and 63.34% of hypertensive patients present with severe scores on HRCT. No significant difference was seen in CT scores of vaccinated versus non-vaccinated diabetics and hypertensive patients in the present study. The demographic profile of the study group in relation to disease severity is depicted in Tables 5 and 6.

Few representative cases are shown in in Figures 4 and 5.

Discussion

The coronavirus pandemic is a wreaking havoc across the globe after originating in the Hubei province of China in December 2019. Although vaccination is available in most countries now, multiple waves of the pandemic continue to hit across various nations causing morbidity and mortality to unprecedented extents.1-3 It is vital to understand the utility and absolute necessity of vaccination in bringing this vicious circle of disease to an end along with robust public health measures. India began its nationwide vaccination drive in January 2021, with phase one open to health care workers, followed by frontline workers and then senior citizens above 60 years of age. By the time the vaccination umbrella could cover a wider group of population, India was hit by a massive second wave of the pandemic beginning from March 2021.

SARS coronavirus 2 (SARS CoV2) is primarily a respiratory vaccine, and its effects on the lung on HRCT thorax imaging are
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now well documented in numerous studies. Predominant HRCT features include ground glassing, interstitial thickening, and consolidations. Although CT is not recommended as screening modality, its major advantages remain in RT PCR-proven COVID cases with moderate to severe disease to assess the severity of pulmonary involvement, RT PCR-negative disease with strong clinical suspicion, non-availability of RT PCR tests, and pre-existing pulmonary disease.\cite{7,8} This study comprised 214 patients of COVID-19, both vaccinated and non-vaccinated, who underwent HRCT of the thorax for various clinical indications.

Out of the 214 patients, 65% were non-vaccinated and 35% were vaccinated by one or two doses of COVISHIELD. Most cases presented in the sixth decade with a higher mean age in the vaccinated population. No significant difference was seen in gender distribution within the vaccination population.\cite{7,8} However, within the vaccinated population, females showed a better response with significantly less cases of severe HRCT scoring. Although fever, cough, and dyspnea are known common presentations of COVID, a significant difference was noted in the distribution of presenting features across vaccinated and non-vaccinated populations with a drastic reduction in dyspnea in the vaccinated population. This was an indicator of reduced disease severity in this study group as dyspnea correlates to significant pulmonary involvement.\cite{1,3}

Co-morbidities, especially diabetes and hypertension, had a substantial prevalence and statistically significant association with severe pulmonary involvement in our study; however, among co-morbid patients, no significant difference could be established in relation to their vaccination status.\cite{3}

The mean duration of onset of illness was lower in the non-vaccinated group (6.04 days), signifying faster disease progression in comparison to the vaccinated population (9.03 days). However, it was observed that the mean time of onset of symptoms after the last dose of vaccination was less after two doses (8.87 days) in comparison to a single dose (11.68 days). In various clinical trials, the efficacy of vaccination is measured after

| Variable       | Mild | Moderate | Severe | P         |
|----------------|------|----------|--------|-----------|
| Mean age (in years) | 49.04 | 56.12 | 58.44 |           |
| Gender          |      |          |        |           |
| Male            | 21   | 67       | 56     | 0.0248    |
| Female          | 21   | 29       | 20     |           |
| Co-morbidities  |      |          |        |           |
| Diabetes        | 5    | 15       | 32     | <0.000034 |
| Hypertension    | 6    | 16       | 38     | <0.00001  |
| Tuberculosis    | 0    | 0        | 3      |           |
| ILD             | 6    | 7        | 12     | 0.2048    |

Figure 2: Graph plotting of correlation regression analysis of vaccination status with severe disease on HRCT. (Slope of the graph: non-vaccinated: 0.2243+/-0.06693, single-dose vaccine: 0.1052 +/- 0.08238, two doses of the vaccine: -0.20384 +/-0.09479)

Figure 3: Graph showing demographic distribution of disease severity on HRCT in the vaccinated population

Figure 4: Axial sections of HRCT of the thorax of two vaccinated patients (a and b) show peripherally placed ground glass opacities with interstitial thickening. Mild HRCT scores of both patients (<8)

Figure 5: Axial sections of HRCT of the thorax of two non-vaccinated patients (a and b) show extensive diffuse ground glass opacities with interstitial thickening and peripheral basal consolidations. Associated Pneumomediastinum and subcutaneous emphysema seen in image b

Table 5: Demographic profile of the study group in relation to disease severity

Figure 5: Axial sections of HRCT of the thorax of two non-vaccinated patients (a and b) show extensive diffuse ground glass opacities with interstitial thickening and peripheral basal consolidations. Associated Pneumomediastinum and subcutaneous emphysema seen in image b
2 weeks of the second dose of the vaccine, and the presentation of illness within the first 10 days of the second dose suggests that either the disease was in the incubation period when the vaccine was given or exposure occurred before vaccine-induced immunity could take over.

The evaluation of correlation between HRCT features of disease and the vaccination status revealed a definite protective effect against severe pulmonary involvement after two doses of vaccination, with 11.53% of the vaccinated population showing severe HRCT scores in comparison to 43.47% of the non-vaccinated population. A negative Pearson correlation coefficient (R = -0.146) was also suggestive of less probability of severe pulmonary involvement on imaging after completion of vaccination. Although a single dose of vaccination could not elicit a significant protective effect with a weak positive correlation with severe HRCT scores (R = 0.0932), the correlation was weaker than the effect of non-vaccination (R = 0.224). This gives a clear indication that although vaccination may not prevent infection, it can surely modify the disease process and prevent significant morbidity and mortality.

Overall, there was a significant difference in severe pulmonary involvement on HRCT in vaccinated and non-vaccinated subjects, irrespective of vaccination dosage. This signifies a definite assurance that vaccination is a major positive resource in prevention of severe morbidity and mortality in COVID-19 patients.

**Conclusion**

Two doses of vaccination have a significant protective effect against severe HRCT scores for pulmonary involvement. Irrespective of age and gender, vaccination is an effective tool against the radiological effects of COVID-19.

## Limitations and Recommendations

This is a retrospective study performed on a relatively small study group. Larger prospective studies will be required to address the exact effects of vaccination on COVID-19. Being a radiological study, clinical parameters were not assessed in detail, hence preventing the evaluation of both the disease and vaccination on clinical parameters and the overall disease process. The HRCT scoring system followed in this study is a subjective tool which is susceptible to inter-observer variability. To the best of our knowledge, there is not much literature reference available on similar research at the time of writing of this study.

A larger prospective study with a follow-up protocol will help validate the results of this study and generalize it to the external population.

## Disclaimer

This is an observational study done solely for academic interest of medical professionals. Neither the manufacturers of the vaccine COVISHIELD nor the Government of India has any participation or influence over this study.

## Research quality and ethics statement

This study was approved by the Institutional Ethics Committee (Registration No. ECR/710/Inst/UK/2015/RR-21) with approval number SGR/IEC/08/21. The authors followed applicable EQUATOR network guidelines during the conduct of this research project.

We also certify that none of the authors is a member of the Editorial board of the Journal of Emergencies, Trauma and Shock.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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