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The Association of Chest CT Severity Score (CT-SS) with Vaccination Status Among COVID-19 Patients: A Tertiary Hospital Based Cross Sectional Study

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ABSTRACT
The purpose of this study was to evaluate the effect of vaccination on chest CT severity scores in COVID-19 patients. It was a retrospective observational study carried out in the Departments of Physiology, Radio diagnosis and General Medicine and Medical Records of the Institution. The study was carried out for one year (November 2021–2022). There were 90 confirmed cases of COVID-19 reviewed, of which 51 (56.6%) were male and 39 (43.3%) were female. The average age was 50.17 years (SD = 13.941). Out of the 90, 31 (34.4%) were non-vaccinated, 30 (33.3%) were partially vaccinated and 29 (32.2%) were fully vaccinated. The most common associated comorbidities were diabetes mellitus (41.1%). Fever was the most common presenting symptom (79.5%). The commonly observed CT findings were bilateral (71.7%), peripheral (61.6%) ground glass opacities (71.76%), fibrosis (25%), consolidation (25%), sub-pleural bands (31%) and septal thickening (31.4%). There was a statistically significant association between the chest CT severity score in diabetes mellitus ($p<0.001$), hypertension ($p = 0.013$) and cardiac pathology ($p = 0.011$). There is a significant association between the chest CT-SS and the vaccination status in this study population. This study, conducted in real-world settings, reiterates that full vaccination aids in reducing the severity of lung damage in COVID-19 infections.

INTRODUCTION

SARS-CoV2, initially termed a novel Corona virus belonging to the family Coronaviridae, was first recognized in December 2019 when an outbreak of pneumonia from an unidentified source emanated in Wuhan, China[1]. It typically targets epithelial cells of the respiratory tract, causing lung infiltration, resulting in acute respiratory distress syndrome and later stages of pulmonary fibrosis[2]. The disease was a fast spreader globally, requiring rapid and accurate methods for early recognition, diagnosis and treatment[3]. Due to the high variability in the clinical course of COVID-19, prognostic tools remain necessary for strategic healthcare planning. COVID-19 patients undergo a high-resolution CT scan to determine the extent of lung involvement[4]. The 25-point chest CT severity score serves as a numerical modulus to evaluate the severity of pulmonary involvement quickly and objectively[5].

Various vaccines developed to protect people from virus transmission and adverse effects show high efficacy. But currently, there is a concern that the newly developed strains may impact the efficacy of already-developed vaccines[6]. Furthermore, vaccines do not provide complete immunity against the viral disease, and there have been reports of vaccine-breakthrough infections. Studies comparing the chest CT-SS and vaccination status among South Indian patients with COVID-19 infection are scarce. In this background, this study aims at assessing the correlation between vaccination status and CT severity scores in COVID-19 patients and to understand the effects of vaccination on the body, primarily the lungs. This study is a retrospective, comparative study that utilizes the 25-point chest CT severity score to assess the effect of vaccination on the extent of lung involvement in COVID-19 patients.

Objectives:

- To estimate the severity of lung disease by chest CT severity score
- To compare the chest CT severity scores between different levels of vaccination status among COVID-19 patients

MATERIAL AND METHODS

Study design: This study adopted a retrospective cross-sectional design.

Study setting: The research was conducted at the Departments of Physiology, Radiodiagnosis, General Medicine and Medical Records of the Institution within a one-year duration (November 2021-2022).

Study duration: Spanning one year, from November 2021 to 2022.

Selection of study participants

Inclusion criteria: Encompassed COVID-19 patients aged >18 years who underwent CT scans.

Exclusion criteria: Excluded patients with pre-existing lung diseases.

Sample size: The study comprised 90 subjects meeting the inclusion criteria.

Sampling technique: Employed convenience sampling.

Informed consent: A waiver of consent was obtained for the study.

Study procedure:

Patient groups: Non-vaccinated, partially vaccinated, and fully vaccinated COVID-19 patients (COVISHIELD vaccine recipients) meeting the criteria were retrospectively analyzed.

Data collection: Collected patient history, CT scan reports and chest CT severity scores from the Radiology Department. Baseline data, vaccination status, clinical symptoms and comorbidities were extracted from medical records.

Data handling: Data entry was executed using Excel, and SPSS version 21 facilitated data analysis. Association between chest CT severity scores and vaccination status was assessed.

25-point CT severity score:

Calculation: Assessed for each of the 5 lobes, considering the extent of anatomical involvement.

Scoring criteria:

- 0 = no involvement
- 1 = less than 5% involvement
- 2 = 5-25% involvement
- 3 = 26-50% involvement
- 4 = 51–75% involvement
- 5 = more than 75% involvement

Global CT score: Summation of individual lobar scores (ranging from 0-25).

Severity classification:

- **Mild**: <7
- **Moderate:** 8-17
- **Severe:** 18-25

Statistical analysis

Data summary: Categorical variables were summarized using frequency and percentage, while quantitative variables were summarized using median and IQR [Q1, Q3].

Normality tests: The Kolmogorov-Smirnov and Shapiro tests were employed to assess data normality.

Statistical tests: A one-way ANOVA or Kruskal-Wallis test was utilized due to data violating the normality assumption ($p<0.05$), considering significance.

Software used: SPSS and EZR software facilitated the entire analysis.

RESULTS

Baseline characteristics of study population: There were 90 confirmed cases of COVID-19 reviewed of which 51 (56.6%) were male and 39 (43.3%) were female. The average age was 50.17 years (SD=13.941) with 85 years as the maximum and 20 years as the minimum. Out of the 90, 31 (34.4%) were non vaccinated, 30 (33.3%) were partially vaccinated and 29 (32.2%) were fully vaccinated. The most common associated comorbidities were Diabetes Mellitus (41.1%), Hypertension (28.8%), Cardiac (14.4%), Renal (12.2%) pathologies and others (5.5%). There were 8(8.8%) patients with no comorbidities. Fever was the most common presenting symptom (79.5%) followed by Cough (73.5%) and Dyspnea (55%). Other symptoms were myalgia (24%), anosmia (14%), diarrhoea (11%) and sore throat (11.4%) (Table 1).

Grade of study population based on chest CT severity score: COVID status was graded from mild to severe based on chest CT severity score and there were 40 (44.4%) mild, 25 (27.8) moderate and 25 (27.8%) severe cases (Table 2). Out of the 31 unvaccinated, 15 belonged to severe, 12 belonged to moderate and 4 to mild categories. Out of the 30 partially vaccinated 11 each belonged to mild and moderate, 8 belonged to severe categories. Out of the 29 fully vaccinated, 25 belonged to mild, 2 each belonged to moderate and severe categories (Fig. 1).

CT finding and treatment regimen: The commonly observed CT findings were bilateral (71.7%), peripheral (61.6%) ground glass opacities (71.76%), fibrosis (25%), consolidation (25%), sub-pleural bands (31%) and septal thickening (31.4%). Treatment included Anti-inflammatory (96.5%), Antibiotics (91.8%), Vitamins (93.1%), Bronchodilators (81.4%) and Steroids (64.2%). Remdesivir (48.8%) and Anticoagulants (40.9%). 27.7% patients required ventilation, 56.5% required Oxygen and 29% cases required ICU admissions.

Association of chest CT severity score and vaccination status: Kruskal Wallis test was performed and it was observed that there is a significant difference in the average Chest CT Severity Score between different levels of vaccination status ($p<0.001$). It was also observed from the bonferroni pair wise comparison that there is a significant difference in the Chest CTSS between non-vaccinated and fully vaccinated ($p<0.001$) partially vaccinated and fully vaccinated ($p = 0.001$). There is no significant difference observed in the average CT score between non-vaccinated and partially vaccinated ($p = 0.252$). The average number days after second dose of COVID vaccination after which there was infection was 86 (57,160).

Association of chest CT severity score and comorbidity status: Mann Whitney U test was performed as data violates normality assumption to check the association between CT-SS and comorbidity status and it was observed that there was a statistically significant association in diabetes Mellitus ($p<0.001$), Hypertension ($p = 0.013$) and cardiac pathology ($p = 0.011$) (Table 5).

DISCUSSIONS

SARS-CoV-2 primarily infects the human respiratory system, leading to pneumonia and respiratory failure in severe cases. Fever and cough were the dominant symptoms, whereas gastrointestinal symptoms were rare, suggesting a viral tropism compared with SARS-CoV, MERS-CoV and influenza. (14) In this study, fever was the most common presenting symptom (79.5%), followed by cough (73.5%) and dyspnea (55%). Other symptoms were myalgia (24%), anosmia (14%), diarrhea (11%), and a sore throat (11.4%). The mean age of the study population was 50.17 years (SD = 13.941), with 85 years as the maximum and 20 years as the minimum. Men had a 56.6% incidence rate, while women had a 43.3% rate. The biological differences in immune systems between men and women impact the

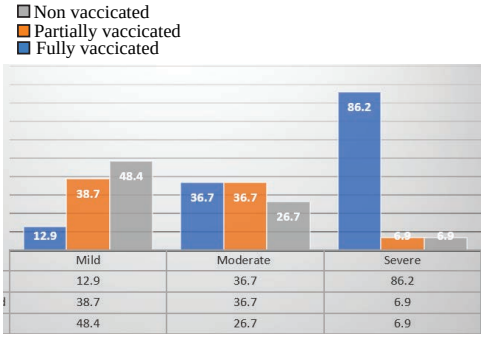

Fig. 1: Vaccination-Grade Cross tabulation

Table 1: Characteristics of study population

Variable	Characteristics	Frequency	Percentage
Gender	Male	51	56.6
	Female	39	43.3
Vaccination status	Non vaccinated	31	34.4
	Partially vaccinated	30	33.3
	Fully vaccinated	29	32.2
Comorbidity	Diabetes mellitus	37	41.1
	Hypertension	26	28.8
	Cardiac	13	14.4
	Renal	11	12.2
	Others	5	5.5
	No comorbidity	8	8.8
Symptoms	Fever	71	79.5
	Cough	66	73.5
	Dyspnea	49	55
	Myalgia	22	24
	Anosmia	13	14
	Diarrhoea	10	11
	Sore Throat	11	11.4

Table 2 Grade of study population based on chest CT severity score

Grade	Frequency	Percentage
Mild	40	44.4
Moderate	25	27.8
Severe	25	27.8
Total	90	100

Table 4: Association of chest CT severity score and vaccination status

Vaccination status	CT-SS Median Q1, Q3	kruskal wallis statistic	p-value
0	16 (10,21)	30.47	<0.001*
1	11 (4,18)		*Significant
(p<0.05)			
2	0 (0,4)		

Table 5: Association of Chest CT severity score and comorbidity status

Comorbidity	CT-SS Median Q1,Q3	U-value	p-value
Diabetes mellitus	18 (13,20)	1553	<0.001
Hypertension	16 (7,20)	1092	0.013
Cardiac pathology	18 (12,20)	702	0.011

ability to fight COVID-19, making women more resistant to infections than men and this is possibly mediated by factors like sex hormones and a higher expression of ACE receptors in men. A higher incidence of smoking and alcoholism among men is an added cause[15].

In this study, significantly higher frequencies of cases were observed in patients with diabetes (41.1%) and hypertension (28.8%). Diabetics infected with SARS-CoV-2 have been found to have a higher rate of hospital admission, severe pneumonia and a higher mortality rate compared to non-diabetic subjects. This is primarily because chronic hyperglycemia compromises innate and humoral immunity. Furthermore, diabetics with a low-grade inflammatory state favor the development of an exaggerated inflammatory response, thereby resulting in acute respiratory distress syndrome[16].

There was a statistically significant association between the chest CT severity score in diabetes mellitus ($p<0.001$), hypertension ($p = 0.013$) and cardiac pathology ($p = 0.011$).

The Chest CT Severity Score (CTSS), a semi-quantitative assessment of pulmonary involvement in COVID-19 patients, is positively correlated with inflammatory laboratory markers and hence can work as an indicator of disease severity and outcome. CT chest imaging can play a vital role in the management plan for COVID-19 pneumonia and should be used for a comprehensive evaluation, combined with the results of nucleic acid tests and epidemiological data[17].

CT-SS describes ground glass patches, consolidation, vascular dilatation, crazy paving, subpleural bands and architectural distortions in correlation with clinical and laboratory parameters in patients with COVID-19, with 83.3% sensitivity and 94% specificity[9]. There is a more predominant bilateral and peripheral distribution[9].

In this study, the commonly observed CT findings were bilateral (71.7%), peripheral (61.6%) ground glass opacities (71.76%), fibrosis (25%), consolidation (25%), sub-pleural bands (31%) and septal thickening (31.4%). India's COVID vaccination drive began on January 16, 2021, as a part of the global effort to abate the onslaught of the pandemic. India initially approved Covisheild's Covaxin for use, and Covisheild's data has been used for this study. Out of the 90 study participants, 31 (34.4%) were non-vaccinated, 30 (33.3%) were partially vaccinated, and 29 (32.2%) were fully vaccinated. The primary objective of vaccination is to prevent the severity of disease rather than infection. According to a study published by Watson et al. in the Lancet, the COVID-19 vaccination prevented 19.8 million deaths globally by the end of the first year

of vaccine rollout. Even so, there are breakthrough post-vaccination infections attributable to the newly emerging strains of the virus. (15)

COVID status was graded from mild to severe based on the chest CT severity score, and there were 40 (44.4%) mild, 25 (27.8%) moderate, and 25 (27.8%) severe cases. COVID status was graded from mild to severe based on the chest CT severity score and there were 40 (44.4%) mild, 25 (27.8%) moderate and 25 (27.8%) severe cases. Out of the 31 unvaccinated, 15 belonged to severe, 12 belonged to moderate and 4 to mild categories. Out of the 30 partially vaccinated, 11 each belonged to the mild and moderate categories and 8 belonged to the severe categories. Out of the 29 fully vaccinated, 25 belonged to the mild category and 2 each belonged to the moderate and severe categories. The average number of days after the second dose of the COVID vaccination, after which there was an infection, was 86 (57,160).

In these settings, the present study assessed the association between CT-SS and the vaccination status of RT-PCR-confirmed, symptomatic COVID-19 patients, and it was observed that there is a significant difference in the average chest CT severity score between different levels of vaccination status ($p<0.001$). It was also noted from the comparison that there is a significant difference in the chest CTSS between non-vaccinated and fully vaccinated ($p<0.001$), partially vaccinated and fully vaccinated ($p = 0.001$). The findings were consistent with those of previous studies on the association between CT severity and COVID-19 vaccination status. However, there was no significant difference observed in the average CT score between non-vaccinated and partially vaccinated people ($p = 0.252$).

It is noteworthy that there was a fall in the number of COVID-19 patients who had to take a CT scan following a reduction in the severity of the disease in the post-vaccination period. In this study, CT-SS was used as an objective tool to grade the severity of disease and study the effect of vaccination, from which we can conclude that vaccination resulted in a significant reduction in the severity of disease seen on HRCT chest scans. There is a significant decrease in the incidence of severe COVID-19 pneumonia among vaccinated individuals.

CONCLUSION

There are various vaccines developed to protect people from transmission and adverse effects of the SARS CoV2 virus that show a high percentage of efficacy but the emerging COVID-19 variants challenge the effect of available vaccines. Researchers employed CTSS as a numerical modulus to study the severity of the disease and the impact of vaccination. Vaccination resulted in a significant reduction in chest CT-SS seen on HRCT chest scans and the severity of pneumonia, thereby reducing the indication for a CT scan in the post-vaccination period. There is a significant association between the chest CT-SS and the vaccination status in this study population. This study, conducted in real-world settings, reiterates that full vaccination aids in reducing the severity of lung damage in COVID-19 infections.

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