Research Article

Evaluation of the Progress of Coronavirus Disease-19 Pneumonia using the British Society of Thoracic Imaging Reporting Model: A Validation Study

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Abstract: Background: SARS-COV-2 (also known as severe acute respiratory syndrome corona virus-2), emerged as a pandemic and became an overwhelming global concern, causing substantial morbidity and mortality worldwide. Reverse transcription polymerase chain reaction (RT-PCR) is considered a gold standard in detecting clinically symptomatic patients but can have false negative and false positive results. As chest X-Ray (CXR) is considered as a baseline investigation in many hospitals, BSTI reporting model during COVID-19 pandemic has been a useful tool in diagnosis of COVID-19 pneumonia.

Objective: To validate the British Society Thoracic Imaging (BSTI) coding system in the evaluation of the progress of the disease severity in patients with coronavirus disease-2019 (COVID-19) pneumonia.

Materials and Methods: This is a cross sectional observational study. Total 450 CXRs (which included both the baseline and serial CXRs) of 225 COVID positive patients (RT-PCR positive for COVID-19 on nasal swabs) were included. These were retrospectively reviewed and reported by two Radiologists (having experience of at least 5 years in Radiology Reporting) in Corona Ward in Dr. Ruth K M Pfau Civil Hospital Karachi, Pakistan, for the duration of 10 months from 1st March 2020 till 31st December 2020. BSTI coding system was used to classify and interpret the CXR imaging findings as normal, definitive, indeterminate and non-COVID for baseline (CXR on 1st day of admission) and follow up CXRs (done in between 3rd and 7th day of admission). Data was analyzed using SPSS version 25. Numeric data was assessed for distribution using Shapiro-Wilks test. Median and interquartile range (IQR) were reported for numeric variables. Frequencies and percentages were reported for categorical data. Kappa statistics was applied to assess the agreement between BSTI scoring at baseline and follow-up CXRs. A p-value ≤0.05 was considered as statistically significant.

Result: CXRs (including 225 baseline and 225 follow up CXRs) of 225 RT-PCR COVID-19 positive patients were analyzed. Interval change in BSTI coding system was noted, increase in frequency of probable/definitive COVID-19 findings were diagnosed on serial CXRs. The BSTI scoring at baseline and follow-up showed moderate agreement with kappa statistics as 60.3% (p=0.001).

Conclusion: BSTI coding system can be helpful to classify the COVID-19 disease on CXR and filter for the prognosis of disease severity in the serial radiographs. Utilization of BSTI reporting model for reporting CXRs, even before RT-PCR, in future COVID pandemic can be considered as a useful tool.

Keywords: Chest X-ray, COVID-19 pneumonia, RT-PCR, Acute respiratory distress syndrome (ARDS), High resolution computerized tomography (HRCT), British society thoracic imaging (BSTI).

INTRODUCTION

SARS-COV-2 (known as Severe Acute Respiratory Syndrome Corona Virus-2), emerged as a pandemic and became an overwhelming global concern, with its unprecedented nature, causing substantial morbidity and mortality worldwide [1]. SARS-COV-2 belongs to the family of single stranded RNA viruses (+ssRNA) and is transmitted via respiratory droplets or close contact [2, 3]. The gold standard in both asymptomatic and symptomatic patients is made by reverse transcription polymerase chain reaction (RT-PCR) of a nasal and pharyngeal swab [4]. However, false negative and false positive results can be risk factor in both case, with 63% sensitivity with nasal swab and 32% with pharyngeal swab [5, 6]. As COVID-19 pneumonia is an infectious disease and can progress to mild to severe lung injury, its early detection, patient isolation and management are critical. There are four categories for the assessment of the disease according to WHO interim guidance; mild, moderate, severe and critical [3, 7]. In correlation with the clinical and laboratory findings, thoracic imaging including chest radiograph(CXR) and CT-chest plays a pivotal role especially in patients with moderate to severe disease or in those patients with mild illness but are at

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risk of disease progression [8]. A multinational consensus statement published by Fleischner Society in April 2020 negate the use of CXR for screening but recommended CXRs in patients having moderate to severe disease, for the follow-up of patients with increase respiratory dysfunction and for the patients having milder symptoms but are at risk of disease progression [9].

Furthermore, in a rapid advance guide published by WHO, recommended CXR for the symptomatic patients with suspected COVID-19, when RT-PCR is unavailable, RT-PCR results are delayed or RT-PCR is negative but there exists high critical suspicion [10].

Radiographic (CXR) findings may show multifocal small patchy shadows with interstitial changes in early course of disease. These may progress to multifocal ground glass opacities (having peripheral predominance) and pulmonary consolidation. However, pleural effusion appears to be a rare finding [11]. In critical patients, chest radiographs may show features of acute respiratory distress syndrome (ARDS) [12].

Definite CXR findings may negate the use of High Resolution Computerized Tomography scan (HRCT) in patients with high suspicion of COVID-19 [13]. However, HRCT can be preferred for suspected COVID-19 patients as second line approach, when chest X-rays are equivocal or uncertain. Furthermore, performing CT is very difficult in critically ill patients in ICU, where portable X-rays may serve as an alternative tool. Portable CXRs not only reduce the risk of cross infection but also limit the radiation exposure to the patients on follow-up CT examinations [14].

British Society of Thoracic Imaging (BSTI) proposed the CXR report proforma, to ensure uniformity in the CXR reporting in COVID-19 pandemic [15]. This proforma includes coding system for reporting COVID 19 radiographic findings in order to achieve simplified Radiology Information System (RIS) searching. It is to utilize CXR report proforma not only in initial CXR reporting but also in reporting of the follow-up CXR to assess the progress and outcome in known COVID-19 RT-PCR positive patients. The aim of our study is to validate the British Society Thoracic Imaging (BSTI) coding system in the evaluation of the progress of the disease severity in patients with COVID-19 pneumonia.

MATERIALS AND METHODS

This retrospective study of chest x-rays of COVID-19 patients, admitted in Corona Ward in Dr. Ruth K M Pfau, Civil Hospital Karachi, Pakistan, was reviewed and reported by two consultant Radiologists having 3 to 5 years' experience in Radiology reporting. Exemption was taken for this retrospective study from Institutional Review Board (IRB).

The review included Chest Radiographs carried out in between from 1st March 2020 till 31st December 2020. The adult patients admitted with positive RT-PCR pharyngeal swab for COVID-19 were included in the study and those adults with concomitant known lung pathologies were excluded.

CXR findings on initial (baseline CXR) and follow up CXRs were assigned codes according to BSTI coding system and correlated with the clinical examination, laboratory status and Oxygen saturation from the clinical record. Oxygen saturation, leukocyte count and Serum CRP levels were used to assess the progression of COVID-19 in admitted patients.

The initial CXRs were coded according to BSTI coding system and on follow up CXRs, which were done upon clinical instigation. Change in coding was noted for every category.

The BSTI coding system for reporting COVID-19 radiographic findings in order to achieve simplified Radiology Information System (RIS) searching is displayed in Table **1** and Figs. (**1-3**).

Table 1. The BSTI coding system for classifying COVID-19 CXR findings [15].

Code	Classification	Findings
CVCX0	Normal	COVID-19 not excluded. Correlated with RT-PCR(Fig.**1**).
CVCX1	Classic/probable COVID-19	Lower lobe and peripheral predominant multiple opacities that are bilateral (>> unilateral) (Fig. **2**).
CVCX2	Indeterminate for COVID-19	Does not fit Classic or Non-COVID-19 descriptors (Fig. **3**).
CVCX3	Non-COVID-19	Pneumothorax/Lobar pneumonia/Pleural effusion(s)/Pulmonary oedema.

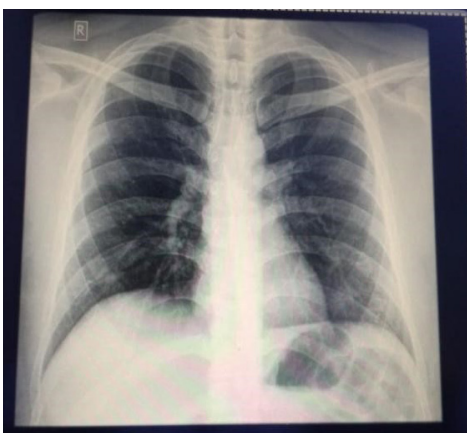

Fig. (1). Normal CXR; COVID-19 not Excluded; Correlate with RT-PCR.

STATISTICAL ANALYSIS

Data was analyzed using SPSS version 25. Numeric data was assessed for distribution using Shapiro-Wilks test. Median and interquartile range (IQR) were reported for numeric variables. Frequencies and percentages were reported for categorical data. Kappa statistics was applied to assess the agreement between BSTI scoring at baseline and follow-up CXRs. A p-value ≤ 0.05 was considered as statistically significant.

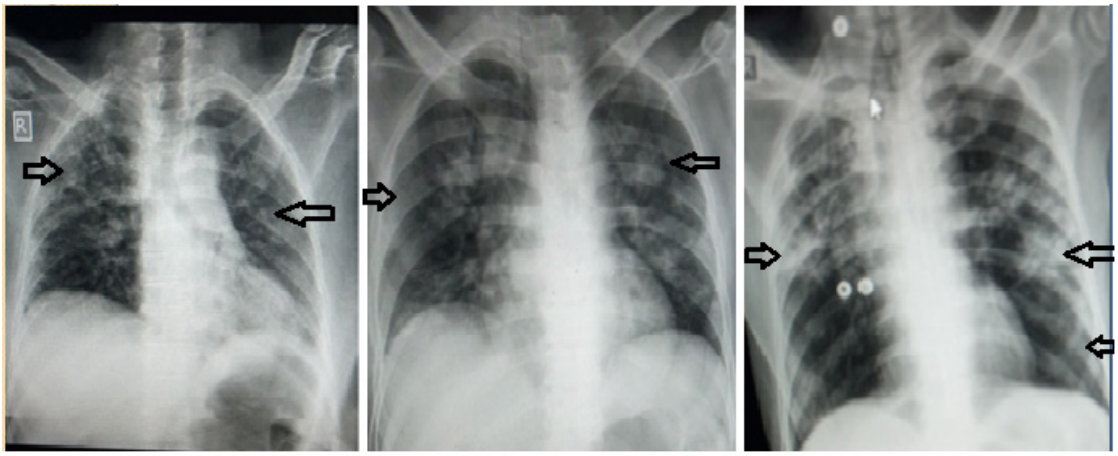

Fig. (2). CVCX1(Classic/Probable COVID-19 Findings) i.e Bilateral Multifocal Ground Glass Opacities/Consolidation with Lower Lobe and Peripheral Predominance; Bilateral (>> Unilateral).

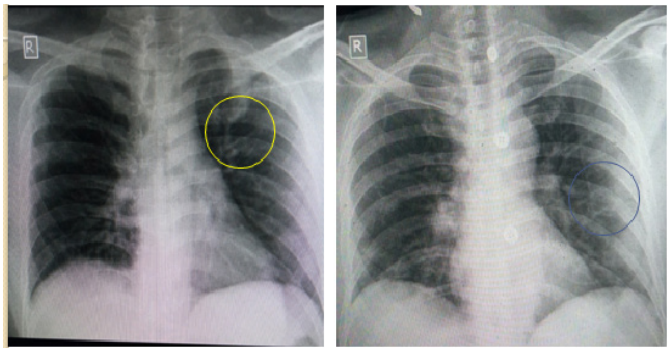

Fig. (3). CVCX2 (Indeterminate) i.e Does not Fit Classic or Non-COVID-19 Descriptors; For Example Peribronchial Cuffing (yellow circle), Linear/Reticular Opacities (Blue Circle), Unilateral Lung Involvement (Left >>Right).

RESULT

Total 225 patients diagnosed with COVID-19 were included in the analysis. The median age was estimated as 52 years (IQR=45-62 years). Of 225 patients, most of the patients were males (72.9%) and 27.1% were females. At presentation, median oxygen saturation was 94% (IQR=89-97), with median lymphocyte count of 15.89 (IQR=11-20) and median TLC was 13.34 (IQR=10-18). About 82.7% of the patients had elevated CRP (≥10 mg/L) and 65.3% had elevated D-Dimer level (≥0.5) (Table **2**). Most of the patients showed moderate and severe form of disease (31.6% and 36.9%), whereas, 61 patients had mild form of disease and 10 patients were critical and shifted to HDU.

Table 2. Baseline Characteristics of 225 Patients Diagnosed with COVID-19.

Variable	Statistics
Age in years	52 (45-62)
Gender	
Male	164 (72.9)
Female	61 (27.1)
Oxygen Saturation (%)	94 (89-97)
Lymphocyte Count (%)	15.89 (11-20)
TLC	13.34 (10-18)
CRP	
<10 (mg/L)	39 (17.3)
≥ 10 (mg/L)	186 (82.7)
D-dimer	
<0.5	78 (34.7)
≥0.5	147 (65.3)
Data expressed as Median (IQR) or n (%).	

According to BSTI coding system at baseline, 80 patients were identified as normal (CVCX0), 93 patients had probable/classic COVID-19 (CVCX1), 48 were classified as indeterminate for COVID-19 (CVCX2) and 4 patients were labeled as non-COVID-19 (CVCX3) (Fig **4**).

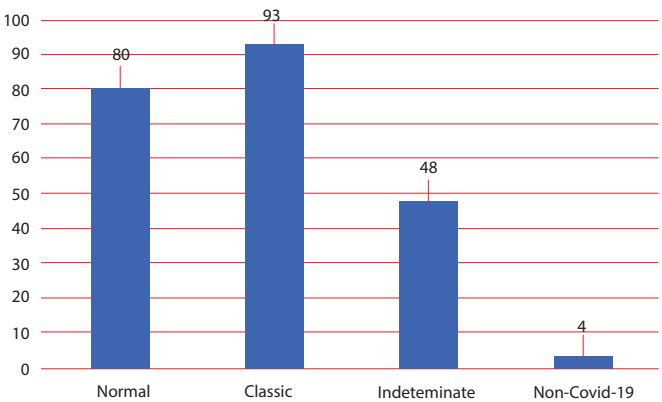

Fig. (4). BSTI Scoring at Baseline of Included Patients (n=225).

Among 93 patients with CVCX1 findings, 54 patients had ground glass opacities, 13 patients had consolidation, 13 patients had reticular opacities and 2 patients had linear opacities. Of 93 patients with CVCX1 findings, 83 patients had bilateral multifo-

cal involvement, 6 patients had unilateral right lung involvement and 4 patients had unilateral left lung involvement respectively.

According to final classification of follow up chest x-rays according to BSTI scoring, 64 patients had CVCX0, 140 had CVCX1, 15 had CVCX2 and 6 patients were CVCX3 (Fig. **5**).

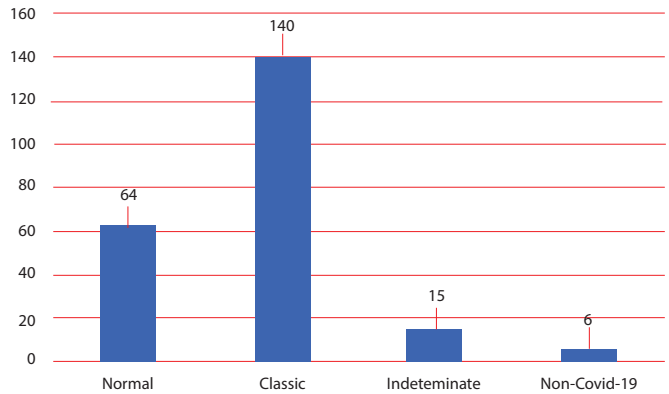

Fig. (5). BSTI Scoring at Follow-Up of Included Patients (n=225).

The BSTI scoring at baseline and follow-up showed moderate agreement with kappa statistics as 60.3% (p=0.001) (Table **3**).

Table 3. Agreement of BSTI Scoring at Baseline and Follow-Up (n=225).

BSTI Scoring at Baseline	BSTI Scoring at Follow-up				K-statistics	p-value
	CVCX0	CVCX1	CVCX2	CVCX3		
CVCX0	63 (78.8)	15 (18.8)	2 (2.5)	0	0.603	0.001*
CVCX1	1 (1.1)	90 (96.8)	1 (1.1)	1 (1.1)		
CVCX2	0	35 (72.9)	12 (25)	1 (2.1)		
CVCX3	0	0	0	4 (100)		

* Statistically Significant.

DISCUSSION

The results of this study highlights the significance of follow up chest X-rays, which were carried upon to assess the prognosis of the disease in COVID-19 positive patients especially in those COVID 19 positive patients who showed Normal baseline CXRs on initial presentation but presented with clinical symptoms. It was found that baseline chest x-rays were categorized normal in relatively more number of patients when compared with the follow up chest x-rays, thus depicting better BSTI coding for classical/definite COVID findings on follow up CXRs (in between 3rd and 7th day of admission). Similarly, CXRs which were coded indeterminate on baseline evaluation also showed reduction in number, and demonstrated classical/definite COVID findings on follow up CXRs.

Our study show concordance with the results of the study by Yasin R. [16] in which they observed change in the findings during the course of the disease. They found that 37.1 % baseline CXR were normal in COVID 19 positive patients, but 13.7 % of the normal CXRs show positive COVID findings on the follow up CXRS. They classified as normal and abnormal findings only and BSTI coding was not specified for CXRs. In our study out of 35.6 % normal baseline CXRs, nearly 7 % showed classic findings on follow up.

Our results in determining Classic COVID findings are very close to the study carried by Harre SS, *et al*. but differ in categorizing Normal CXRS among COVID positive patients [17]. Similarly our study shows the change in code from CVCX0 to CVCX1 in significant number of patients, which reinforce the category for CVCX0 which specifies it Normal but RT-PCR is mandatory.

Kerpel A, *et al*. evaluated the Radiographic Assessment of Lung Edema (RALE) score and assigned scoring to CXRs of both PCR positive and PCR negative patients. They concluded that CXR on the initial presentation cannot be used as a sufficient diagnostic tool as pulmonary opacities increase during the course of the disease [18]. This study also favors our results that classic COVID findings are better established in follow up CXRs.

Durrani M, *et al*. found only 7% normal baseline CXRs in contrast to 23 % classic findings for COVID 19 pneumonia. Our study contradicts with this study as we noticed higher percentage of normal CXRs. This could be due to the small sample size of the study which was conducted in initial days of COVID pandemic [19].

Hui TCH, *et al*. assessed the utility of CXRs in predicting the course of COVID-19 disease and concluded that CXRs in between 6th and 10th day from the onset of disease provided better clinical prognosis than those CXRs which were conducted at the early onset [20]. Studies have shown that chest imaging findings may be obscure in early course of disease specifically between 0-2 days with increasing rate of chest findings in between 3rd to 5th day of illness [21], which was also experienced in our study.

As recent studies have demonstrated that characteristic CT findings for COVID-19 pneumonia can also be visualized on CXRs, thus follow up CXR in symptomatic patients may negate the use of CT chest for all the patients [22].

Results of baseline CXRs in our study slightly corresponds with the study by Yates A, *et al*, in which they categorized 37.8 % (54/143) CXRs as normal, 10.5 % (15/143) as non-COVID, 15.4 % (22/143) as indeterminate and 24.5 % (35/143) as highly suspicion and 11.9 % (17/143) as characteristic for COVID-19 in positive RT-PCR patients. Thus concluding that CXRs have high specificity and high predictive values of 98% (95 % CI 96–99 %) and 88 % (95 % CI 80–96 %) if a structured template reporting system is used. The difference in their template from BSTI model was that they divided Classic COVID 19 findings (CVCX1) into characteristic pattern (mentioned as bilateral

symmetric sub pleural pulmonary opacities) and high suspicion pattern (i.e unilateral sub pleural opacities or bilateral large volume patchy or ill-defined opacities) [23].

In our study few number of CXRs initially categorized as indeterminate and as non COVID show change in the coding and classified as Classic COVID-19 findings on follow up CXRs. These results of our study favor the idea of amalgamation of "Indeterminate findings" and "Non-COVID findings" into single category i.e "not classic for COVID-19" as suggested by Harre SS, *et al*. in a retrospective study conducted for validation of BSTI guidelines for COVID-19 CXR reporting [24].

RT-PCR may be negative in consecutive nasal/pharyngeal swab sampling and may take more than 7 days' time to become true positive. Our study may help in this dilemma by repeating the CXR after 3 to 5 days after the onset of symptoms, when repeated PCR show negative result, as RT-PCR may remain negative in clinically symptomatic patients [25].

For the definite diagnosis of COVID-19 pneumonia, pathogen detection by RT-PCR may be hindered by several factors as well as isolated imaging findings may be nonspecific. Clinical history, laboratory tests and chest imaging may aid in specific diagnosis when etiologic detection is uncertain. However, combination of nucleic acid detection may warrantees final diagnosis [26].

With the onset of COVID-19 pandemic, various scoring systems were established for early identification and management of COVID-19 disease, with each system having its own merits. Comparison between various systems has not been studied so far as per our literature search, but we tried to implement and validate the BSTI scoring system in our study.

LIMITATIONS

Our study has some limitations. (i) It was a retrospective study and therefore only symptomatic COVID-19 patients were included, excluding asymptomatic COVID-19 positive patients. Therefore course of illness of asymptomatic patients was not followed upon. (ii) Although follow up CXRs in between 3rd and 7th day of admission were included but this may not represent the same day of illness in all patients. (iii) Portable CXRs were carried out on follow up, which may obscure subtle findings due to positioning.

CONCLUSION

Chest X-rays are considered an effective imaging tool for screening patients in triage units of COVID-19, and BSTI coding system for COVID-19 pneumonia has filtered out COVID-19 patients quite efficiently. Besides its better results in screening of the patients, it is anticipated that this tool can pave further prognosis of disease severity.

AUTHORS' CONTRIBUTION

- **Javerya Sattar**: Conception and Study design, Literature research, Data analysis, Drafting, Final approval, Accountable.
- **Azizullah Khan Dhiloo**: Data acquisition, Study design, Revision, Final approval, Accountable.
- **Saba Sohail**: Conception and Study design, Critical revision, Final approval, Accountable.
- **Mukhtiar A. Memon and Rashid Qadeer**: Data acquisition, Revision, Final approval, Accountable.
- **Nasreen Naz**: Conception and Study design, Revision, Final approval, Accountable.

CONFLICT OF INTEREST

Declared none.

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