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Post-discharge mortality among SARS-CoV-2-infected adult patients with severe acute respiratory infection in Bangladesh (2020–2023): burden, clinical characteristics, and associated risk factors

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Abstract

Background While global estimates of SARS-CoV-2-infected mortality predominantly focus on in-hospital deaths, post-discharge mortality remains an overlooked contributor to the total disease burden, especially in low- and middle-income countries such as Bangladesh. This study aimed to estimate the 30-day post-discharge mortality rate among adult (≥ 18 years) patients with severe acute respiratory infection (SARI) who were SARS-CoV-2-infected and to identify factors associated with these deaths.

Methods From March 2020–December 2023, we enrolled hospitalised adult meeting the World Health Organization defiend SARI case defination across nine tertiary care hospitals in Bangladesh. We followed-up with patients or their family members 30-day post-discharge to ascertain survival status. We calculated the proportion of post-discharge deaths among SARS-CoV-2-infected patients and compared the demographic and clinical characteristics of decedents versus survivors. Data were summarised using descriptive statistics, *t*-test, Fisher's exact test, and Chi-square tests. We used multivariable Cox's regression models to calculate the adjusted hazard ratio (aHR) to identify factors associated with SARS-CoV-2-infected adult patient's deaths during 30-day post-discharge period.

Results Among 7,816 patients enrolled [mean age 47 years (± 47.7), 62% male], 1,280 (16.4%) were SARS-CoV-2-infected. Of them, 126 (9.8%) died during their hospital stay. Among the 1154 patients discharged alive, 1,108 (96%) were successfully followed up, and 111 (10%) died within 30 days post-discharge. The most frequently reported symptoms among post-discharge decedents included difficulty breathing (105; 94.6%), body ache (55; 49.6%), headache (44; 39.6%), with over half (59; 53.1%) having at least one pre-existing condition. Post-discharge mortality was approximately fourfold higher among prematurely discharged patients (aHR: 4.13; 95% CI 1.52–11.23), nearly fourfold higher in those with difficulty breathing (aHR: 3.69; 95% CI 1.62–8.43), and more than threefold higher among patients with kidney disease (aHR: 3.35; 95% CI 1.34–8.38) compared with their counterparts.

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Conclusions Nearly one in five adult patients with SARS-CoV-2-infected SARI in Bangladesh died either during hospitalisation or within 30-day of post-discharge, with almost half of these deaths occurring after discharge. Study findings underscore the urgent need to strengthen discharge planning, such as developing and implementing standardised discharge guidelines, prioritising high-risk patients such as premature discharge for targeted post-discharge follow-up, and implementing structured post-discharge care interventions to reduce preventable mortality in resource-limited settings.

Keywords SARS-CoV-2, Post-discharge mortality, Severe acute respiratory infection, Surveillance, Bangladesh

Background

SARS-CoV-2, the virus responsible for the coronavirus disease 2019 (COVID-19) pandemic, has emerged as a significant global public health concern due to its high morbidity and mortality [1]. Globally (till July 2025), the mortality rate of patients infected with SARS-CoV-2 was 0.91% (7,098,699/778,417,964), while in Bangladesh, the mortality rate was notably higher at 1.40% (29,500/2,100,000) [2]. However, both global and national mortality estimates are primarily based on in-hospital deaths, suggesting that the exclusion of post-discharge deaths may lead to an underestimation of the true mortality burden associated with SARS-CoV-2 infection [2]. Supporting this concern, a prospective observational study in Bangladesh revealed that nearly two-thirds of deaths related to severe acute respiratory infections (SARI) occurred during the post-discharge period [3].

While in-hospital mortality among SARS-CoV-2-infected patients has been extensively studied, post-discharge mortality remains an underexplored yet critical public health concern. This underscores the need for a comprehensive understanding of mortality beyond the hospital setting. Moreover, there is a lack of data on the factors associated with long-term health consequences of SARS-CoV-2 infection [4]. Identifying these risk factors is crucial for guiding preventive measures and clinical management strategies.

Furthermore, evidence suggests that adults are more vulnerable to severe disease progression and death compared to younger patients, further emphasising the importance of post-discharge monitoring and long-term care strategies for SARS-CoV-2-infected adult patients [5]. Since the emergence of the COVID-19 pandemic, numerous studies have explored the characteristics and risk factors associated with in-hospital mortality [6–10]. However, the factors contributing to post-discharge deaths among SARS-CoV-2-infected patients remain insufficiently characterised, particularly in low- and middle-income countries (LMICs) such as Bangladesh. This knowledge gap is especially concerning given the challenges in healthcare accessibility and the socioeconomic disparities that may influence outcomes following hospital discharge.

A comprehensive understanding of mortality among SARS-CoV-2-infected adult patients with SARI, encompassing both in-hospital and post-discharge deaths over an extended study period, is essential for informing targeted interventions to reduce preventable deaths. This study, therefore, aimed to examine the clinical characteristics of adult SARS-CoV-2-infected SARI patients in Bangladesh who died after hospital discharge and to identify factors associated with post-discharge mortality.

Methods

Study settings, population and study period

We investigated post-discharge deaths associated with SARS-CoV-2-infected adult patients (≥18 years of age) with SARI, identified through the hospital-based influenza surveillance (HBIS) platform in Bangladesh between March 2020 to December 2023. This surveillance system was initiated by the Government of Bangladesh and implemented by icddr,b in collaboration with the Institute of Epidemiology, Disease Control, and Research (IEDCR). Surveillance activities were conducted in nine tertiary care hospitals since 2007, primarily in general medicine wards. However, during the early phase of the COVID-19 pandemic, surveillance activities were extended to specialised isolation wards established for COVID-19 management and in high-dependency units. During this period, some CCUs functioned as high-dependency units for COVID-19 patients rather than exclusively as cardiac units and patients identified with COVID-19 were transferred to specialised isolation wards for clinical management. All enrolments adhered strictly to the WHO SARI case definition, independent of admitting unit [14, 15].

This platform comprises a network of nine tertiary care hospitals in Bangladesh with seven public (free of cost health care) and two private hospitals (with minimal cost for health care) strategically selected to ensure broad nationally representative geographic coverage and representation of both urban and rural populations of Bangladesh (Figure S1) [11]. Collectively, the catchment areas of these hospitals encompass approximately 14% of the national population. Detailed descriptions of catchment area definitions, coverage estimation, and

representativeness have been reported elsewhere [11, 12]. Surveillance remained operational six days a week, excluding one day (Weekend: Friday in eight hospitals, Tuesday at one hospital (JIMCH)) due to weekend day of the hospitals and low patient enrollment. On weekend, outpatient services are closed, general admissions are unavailable, and only emergency admissions occur, with no senior doctors or administrative activities. However, if patients were admitted through the emergency department at the weekend day and their admission on the first working day did not exceed the 24-h timeframe, they were included. However, populations with limited access to emergency care on non-operational days may be slightly underrepresented. Detailed surveillance methods have been published elsewhere [13].

Case identification, data collection, and laboratory testing

Surveillance physicians prospectively screened hospital admitted individuals meeting the World Health Organization (WHO) SARI case definition: acute respiratory infection with a history of fever or measured fever $\geq$ 38 °C and cough, with onset within 10 days prior to hospitalisation [14, 15]. After identifying patients with SARI and obtaining written informed consent, surveillance physicians enrolled them and collected data on demographics, clinical signs and symptoms, smoking history, comorbidities, treatment details, and outcome status at initial discharge from the hospital. Nasopharyngeal and oropharyngeal swabs were collected and tested for SARS-CoV-2 virus using real-time reverse transcription polymerase chain reaction (rRT-PCR) in icddr,b virology laboratory. At the beginning of November 2021, the influenza SARS-CoV-2 (Flu SC2) multiplex assay was introduced to simultaneously detect influenza viruses and SARS-CoV-2. During the influenza season in Bangladesh (April–September), all SARI samples were tested for influenza viruses and SARS-CoV-2 using real-time reverse transcription polymerase chain reaction (rRT-PCR). From October to March (non-influenza season in Bangladesh), every second SARI sample per surveillance hospital each week was tested for influenza viruses and SARS-CoV-2 [11].

Hospital discharge

We documented discharge status in four categories: (1) patients had a medical record of being fully recovered; (2) patients or their family member requested early discharge which includes both discharge on request (DOR) and discharge on risk-bond (DORB); (3) physician-advised early discharge [due to high institutional bed occupancy exceeding > 150% at the tertiary care hospitals (2020–2023), where stable patients were transitioned to home care to prioritise more critical admissions [16]; (4) referral to specialised hospital for advanced care [3].

We defined premature discharge as any instance where the patients left the facility before full clinical recovery. This included patients with DOR or DORB or physician-advised early discharge or those transferred upon the physician's recommendation to other specialised healthcare facilities for advanced care.

In the context of Bangladesh, we classified referral or transfer cases as premature discharge when patients were transferred prior to clinical stabilisation. Such transfers frequently occur without accompanying healthcare personnel, with incomplete referral documentation, and in the absence of structured monitoring or follow-up systems [3, 17, 18]. Moreover, prolonged travel times and substantial out-of-pocket expenditures required to reach specialised centres may further delay definitive care. These systemic and logistical barriers place referred patients at a comparable risk of post-discharge adverse events to other groups experiencing premature discharge [17–20].

Post-discharge follow-up

To assess outcomes following discharge, we conducted a mobile phone-based follow-up survey 30-day after hospital discharge (a timeframe commonly adopted in previous studies) [3]. Field staff contacted patients or their family member by phone to inquire about the patient's health status. Data on the place and cause of death were collected through phone interviews based on reports provided by family members. A patient was considered lost to follow-up if they remained unreachable after up to three follow-up phone calls were made. Follow-up interviews were conducted with the patient, or a caregiver if the respondent was 18 years or older and provided verbal consent. We collected information about patient survival status, any further healthcare-seeking behaviour, or instances of hospital readmission related to the illness. In the event of a patient's death, family members or caregivers were interviewed using a structured questionnaire to gather detailed information regarding the date, place of death, and caregiver-reported cause of death. Deaths due to external causes such as road traffic accidents, poisoning, homicide, drowning, and other accidents were excluded from the analysis.

Statistical analysis

We used descriptive statistics to summarise the characteristics of enrolled patients. Continuous variables were presented as mean and standard deviation (SDs), while categorical variables were expressed as frequencies and percentages. Differences between groups were tested using the Chi-square test or Fisher's exact test when

appropriate for categorical variables and the t-test for identifying differences of mean of continuous variables between two groups.

We calculated the proportion of SARS-CoV-2-infected patients with SARI who survived versus who died within 30-day post-discharge, excluding accidental deaths. The case mortality was determined for both in-hospital deaths (in-hospital deaths/total enrolled SARI patients) and post-discharge deaths (post-discharge deaths/total discharged SARI cases after excluding lost of follow-up). Kaplan–Meier curves were used to illustrate time-to-event data and examine 30-day post-discharge mortality.

We used multivariable Cox's regression models to calculate the adjusted hazard ratio (aHR) for factors associated with SARS-CoV-2-infected adult patients' deaths during the post-discharge period. Among adults aged ≥ 18 years, potential risk factors for post-discharge death were assessed by comparing patients who died within 30 days of discharge to those who survived. Factors examined included age, sex, premature discharge difficulty breathing during hospitalisation, duration of symptoms before admission, length of hospital stay, smoking history, and comorbidities (chronic obstructive pulmonary disease (COPD), asthma, diabetes, heart diseases, hypertension, kidney diseases, lung diseases) reported during hospitalisation, as well as co-infection with influenza virus.

Based on previous work and our experience, we classified variables into hierarchical levels for adults aged ≥ 18 years [21, 22]. The hierarchical levels included age, sex, residence, and hospital types as the most distal level variables. The second level included smoking history. The third level included comorbidities (i.e. asthma, kidney diseases, lung diseases) and co-infection with influenza. The fourth level included difficulty breathing, length of hospital stays, duration of symptoms prior to hospital admission, and premature discharge as the most proximal level variables. Adjusted hazard ratios (aHR) with 95% confidence intervals (CIs) were estimated using a multivariable Cox regression model. Initially, all explanatory variables (potential risk factors) of each level were entered into their respective models. Initial risk factors at a 5% level of significance were identified for each level. Selected initial risk factors were jointly included in the model for each level, controlling for all variables retained in previous levels at a 10% level of significance. Variables were progressively excluded at each level, retaining only those statistically significant at a 5% level of significance. In the final model, hazard ratios were simultaneously adjusted for variables in the same hierarchical level and those retained in previous levels (Table S1). Multicollinearity among covariates was assessed using variance inflation factors (VIF). All variables included in the multivariable Cox hazards models demonstrated no significant collinearity (mean VIF range: 1.04–1.17), with no individual VIF exceeding 1.5 (Table S1). Moreover, to assess potential selection bias from CCU inclusion (high-dependency units for COVID-19), we performed sensitivity analyses stratified by admitting unit and excluding CCU patients. Results were consistent with primary findings (Table S2).

The analysis was performed using STATA package, version 15, 2017 (Stata Corp LP, College Station, TX, USA), R software (version 4.4.1) within the RStudio environment (version 2023.06.1 + 524, RStudio, Inc., Boston, MA, USA) utilising "forestplot" package to visualise the forest plot of aHR and map of the study area was created by QGIS (version 3.32, Lima; QGIS Development Team, 2023).

Ethics

The HBIS surveillance protocol was reviewed and approved by the institutional review board (IRB) of icddr,b (protocol No: 2007-002). All study participants were enrolled following written informed consent obtained from either the participants themselves or their caregivers.

Results

Demographics, SARS-CoV-2 positivity and post-discharge death

From March 2020 to December 2023, a total of 7816 patients were tested for SARS-CoV-2 (Fig. 1). The mean age of the patients was 47 years (± 17.8 years); 4816 (62%) were male. Among them 1280 (16.4%) were laboratory-confirmed SARS-CoV-2. Among the SARS-CoV-2-infected patients, 126 (9.8%) died during their hospital stay. Of the 1154 patients with SARI who were alive at discharge, 46 (4%) were lost to follow-up after discharge. Among the 1108 patients with SARS-CoV-2 who were alive and completed the post-discharge survey, 111 (10%) died within 30 days of initial discharge from the hospital.

Of these post-discharge death patients, 4 (3.6%) were discharged as fully recovered, 81 (73%) had a medical record of physician-advised early discharge, and 26 (23.4%) were referred to specialised hospitals for further treatment. During the study period, the highest enrolment of SARS-CoV-2-positive patients occurred between May and August, with peaks in SARS-CoV-2-associated post-discharge deaths observed between June and August (Fig. 2).

Characteristics of SARS CoV-2-infected SARI patients who died within 30 days post-discharge

Of the 111 SARI patients infected with SARS-CoV-2, who died within 30 days of initial discharge, the median

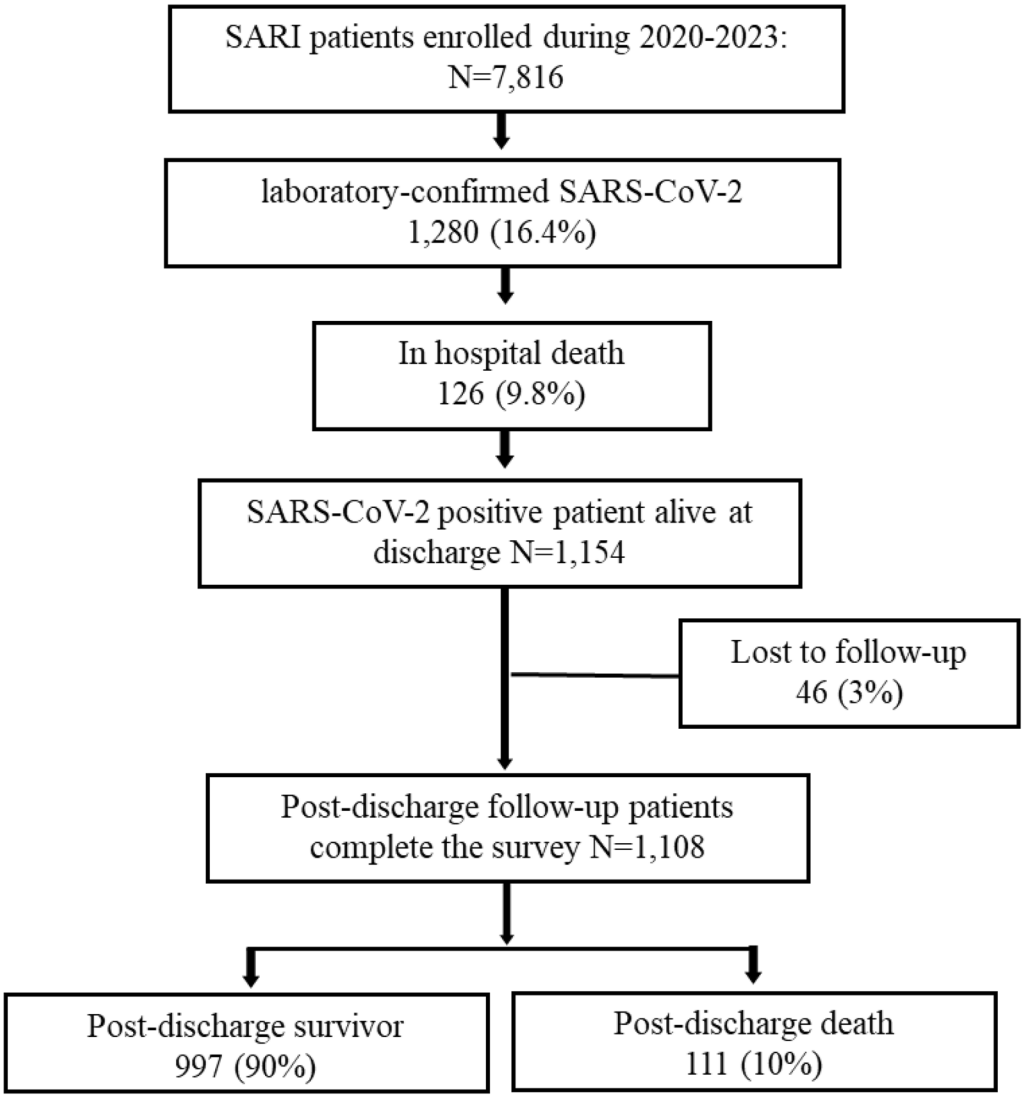

Fig. 1 Flowchart illustrating the severe acute respiratory infection patient enrolment and 30-day post-discharge follow-up of SARS-CoV-2-infected patients

age was 63 years (± 13.6), and 77 (69.4%) were male (Table 1). The mean time between symptom onset and hospitalisation was 4.7 days (± 2.0 days), and the mean length of hospital stay was 4.8 days (± 4.8 days). In addition to SARI-defining symptoms such as cough and fever, the most commonly reported symptoms among the deceased were difficulty breathing (105; 94.6%), body ache (55; 49.6%), and headache (44; 39.6%). Moreover, 59 patients (53.2%) had at least one co-morbid condition. The most commonly reported co-morbid condition was hypertension (36.9%) followed by diabetes (32.4%). Among the SARS-CoV-2-infected patients with SARI who died following discharge, 93.7% received antibiotics during the illness episode, and 92.8% received oxygen during hospitalisation.

Post-discharge mortality was significantly higher in patients aged ≥ 60 compared to those < 60 years [21.5% (75/349) vs. 4.7% (36/758); $p < 0.001$] and in males compared to females [12% (77/643) vs. 7.3% (34/464); $p = 0.005$]. Compared to post-discharge death, the survivors had lower rates of difficulty breathing on admission (94.6% vs. 78.5%; $p < 0.001$), oxygen requirement during hospitalisation (92.8% vs. 66.5%; $p < 0.001$), had at least one co-morbid condition (53.2% vs. 43.6%; $p = 0.057$), hypertension (36.9% vs. 24.3%; $p = 0.004$),

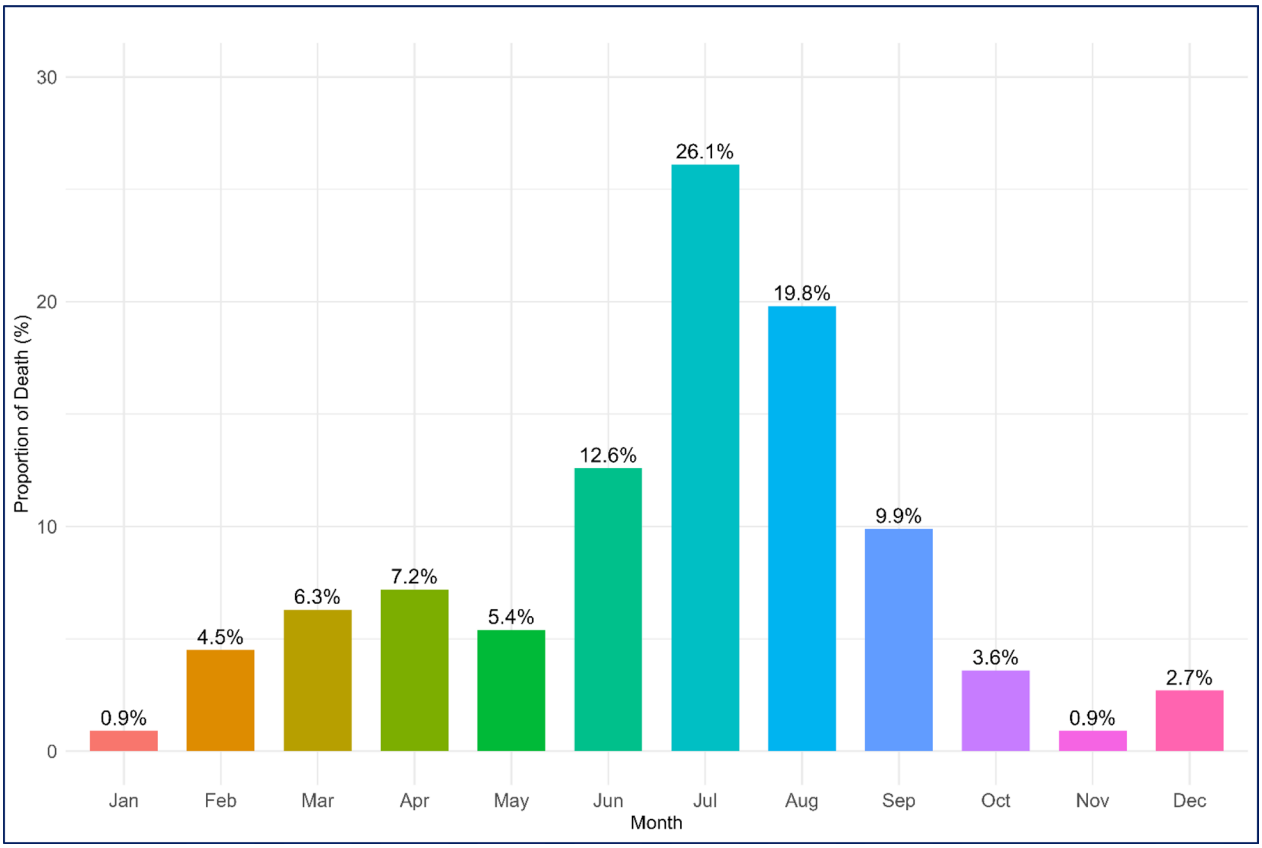

Fig. 2 Month-specific post-discharge deaths among SARS-CoV-2-infected adult patients with severe acute respiratory infection, Bangladesh, 2020–2023

and diabetes (32.4% vs. 23.7%; $p=0.043$) and kidney diseases (4.5% vs. 1%; $p=0.001$) (Table 1).

Place and time of post-discharge death along with discharge note

Among the SARS-CoV-2-infected post-discharge deaths of SARI patients, 67 (60.4%) died in the hospital after readmission, 38 (34.2%) died at their residence, and the remaining 6 (5.4%) died on the way to the hospital (Fig. 3A). Among SARS-CoV-2-infected patients with SARI who died within 30 days post-discharge, 63 (56.8%) died within the first week of discharge, 25 (22.5%) during the second week, 8 (7.2%) in the third week and 15 (13.5%) in the fourth week of initial discharge (Fig. 3B).

Of the patients who died within 2 weeks after initial discharge, only 1 (1%) had a discharge note stating the patient was fully recovered at the time of discharge. The remaining 64 (74.4%) post-discharge deaths had notes stating physician-advised early discharge, and 21 (24.4%) with a referral to specialised hospital (Fig. 3C). Kaplan–Meier survival curve for SARS-CoV-2-infected patients discharged from hospitals showed that most deaths occurred within the first week post-discharge, with survival stabilising after the second week, highlighting the early post-discharge period as the highest-risk timeframe (Fig. 4).

Year-specific distribution of in-hospital and post-discharge deaths

From March 2020 to December 2023, the highest number of SARS-CoV-2-positive patients was recorded in 2021 (728; 26.8%), and the lowest in 2023 (39; 2.1%) (Table 2). Among the yearly SARS-CoV-2-positive patients, predominant number of patients died in hospital during 2021 (87; 12%) while lowest death rate identified in 2022, with no death reported in 2023. In the 30-day discharge period, the highest rate of post-discharge mortality was recorded in 2021 (72; 11.8%), while the lowest occurred in 2022, with no post-discharge deaths reported in 2023. In 2020, among 296 laboratory-confirmed SARS-CoV-2 patients, 30(10.1%) died during hospitalisation and 25 (9.7%) died within 30 days post-discharge. In 2021, of the 728 SARS-CoV-2 patients, 87 (12%) died during hospitalisation and 72 (11.7%) died during post-discharge period. In 2022, among 217 patients, 9 (4.1%) died during

Table 1 Characteristics of SARS-CoV-2-infacted post-discharge deaths and survivors among adult patients with severe acute respiratory infection (SARI), Bangladesh, 2020–2023

Characteristics	SARS-CoV-2- infected SARI patients (*N* = 1108)		*p*-value
	Post-discharge survivors *N* = 997 *n* (%)	Post-discharge deaths *N* = 111 *n* (%)	
Demographic characteristics			
Age			
Age 18–40 years	331 (33.2)	3 (2.7)	< 0.001¥
Age 40–60 years	392 (39.2)	33 (29.7)	
Age 60 years and above	274 (27.5)	75 (67.6)	
Mean age (±), years	47 (± 15.8)	63 (± 13.6)	< 0.001#
Sex (male)	567 (56.9)	77 (69.4)	0.012¥
Residence (rural)	715 (71.7)	92 (82.9)	0.011¥
Clinical characteristics			
Difficulty breathing on admission	766 (78.6)	105 (94.6)	< 0.001¥
Runny nose	386 (38.7)	34 (30.6)	0.096¥
Headache	506 (50.8)	44 (39.6)	0.026¥
Sore throat	226 (22.7)	22 (19.8)	0.388¥
Body ache	548 (55.0)	55 (49.6)	0.277¥
Duration of symptoms prior to admission in days; mean (±)	4.5 (± 1.9)	4.7 (± 2.0)	0.799#
Length of hospital stay in days; mean (±)	5.1 (± 4.7)	4.8 (± 4.8)	0.288#
Co-morbid condition			
≥ 1 co-morbid condition	435 (43.6)	59 (53.2)	0.056¥
COPD	23 (2.3)	5 (4.5)	0.190*
Asthma	109 (10.9)	8 (7.2)	0.226¥
Diabetes	236 (23.7)	36 (32.4)	0.042¥
Heart diseases	29 (2.9)	5 (4.5)	0.377*
Hypertension	242 (24.3)	41 (36.9)	0.004¥
Kidney disease	09 (0.9)	5 (4.5)	0.001¥
Treatment received			
Antibiotic	931 (93.4)	104 (93.7)	0.899¥
Oxygen	662 (66.4)	103 (92.8)	< 0.001¥
Initial discharge category			
Fully recovered	131 (13.1)	4 (3.6)	0.005¥
Physician-advised early discharge	730 (73.2)	81 (73.0)	
Discharge with DOR	3 (0.3)	0 (0.0)	
Discharge with DORB	0 (0.0)	0 (0.0)	
Referral to specialised hospital	133 (13.3)	26 (23.4)	

Chronic obstructive pulmonary disease (COPD), inter-quartile range (IQR), discharge on request (DOR); discharge on risk-bond (DORB)

¥ Chi^2 test

*Fisher's exact test where appropriate

t-test for identifying difference between mean

hospitalisation, 14 (7%) died within 30 days following discharge.

Factors associated with post-discharge deaths among SARS-CoV-2-infected SARI patients

After controlling for age, sex, residence and smoking, SARS-CoV-2-infected SARI patients reporting with kidney diseases were more than threefold higher to die within 30 days post-discharge period compared to patients who did not report kidney diseases (aHR: 3.12; 95% CI 1.25–7.78). After controlling for age, sex, residence, smoking, kidney diseases, hypertension, and difficulty of breathing, we found that the post-discharge death among patients with premature discharge was fourfold higher compared with patients discharged with a letter of fully recovered (aHR:4.13; 95% CI 1.52–11.23).

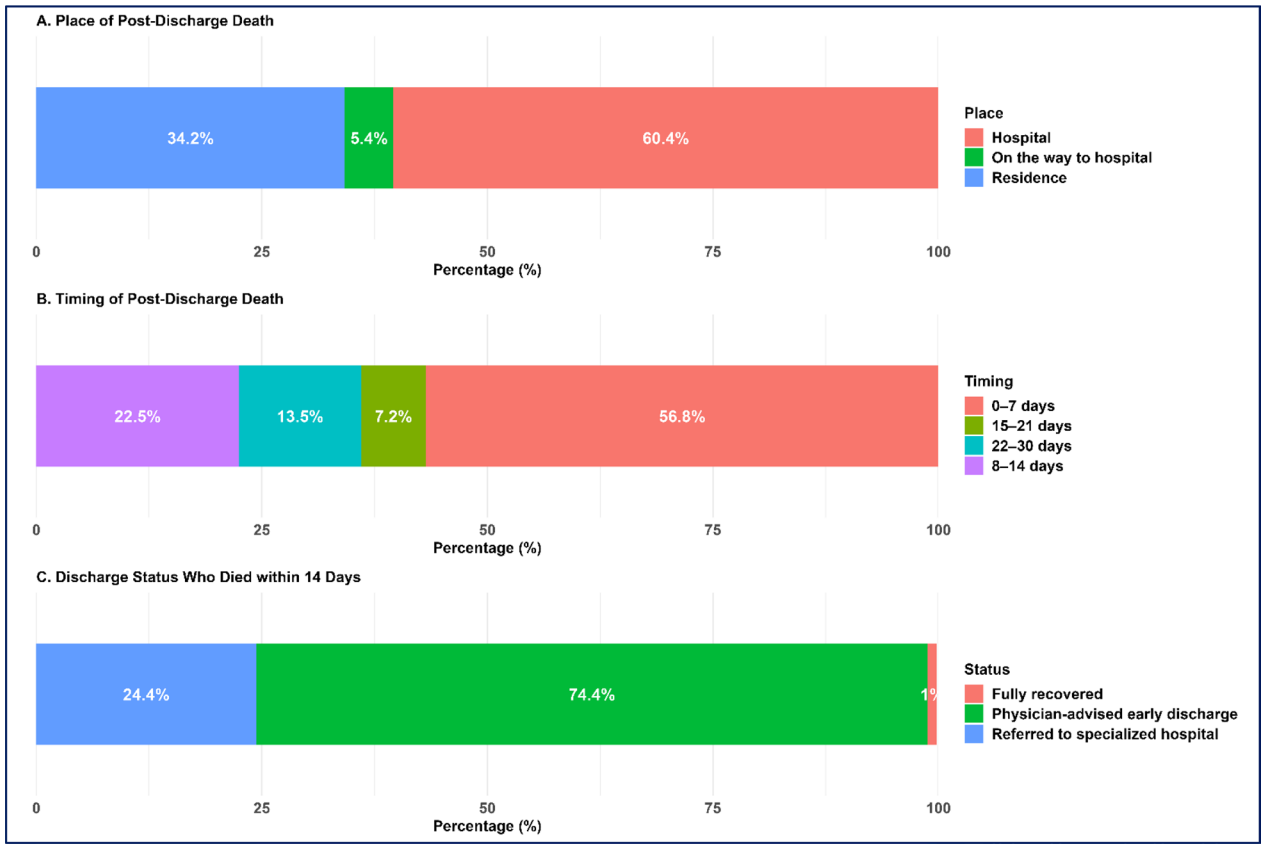

Fig. 3 The place of post-discharge death (**A**), time duration from initial discharge to post-discharge death (**B**), and initial discharge status of patients who died within 14 days of discharge (**C**) among adult patients with severe acute respiratory infection in Bangladesh, 2020–2023. No SARS-CoV-2-infected patients died during the post-discharge period whose initial discharge category was discharge on request (DOR) or discharge on risk-bond (DORB)

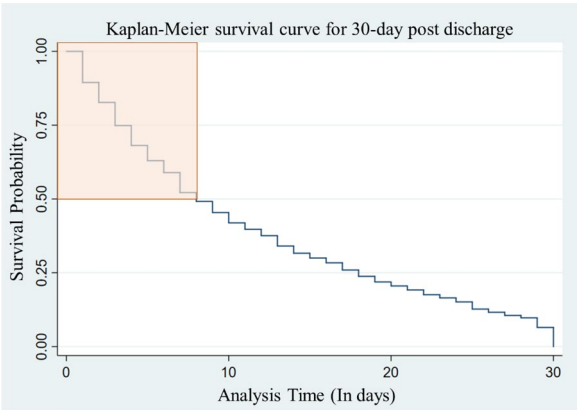

Fig. 4 Kaplan–Meier survival curve of SARS-CoV-2-infected patients following discharge in Bangladesh, 2020–2023

Moreover, after controlling for age, sex, residence, smoking, kidney diseases, hypertension, and premature discharge, patients with difficulty breathing were more than threefold higher to die within 30 days post-discharge than cases not reporting difficulty breathing (aHR: 3.69; 95% CI 1.62–8.43) (Fig. 5, Table S1).

Discussion

This 4-year prospective observational study underscores the critical importance of including post-discharge outcomes when assessing the full burden of SARS-CoV-2. Notably, the proportion of post-discharge deaths was nearly equivalent to in-hospital deaths, suggesting that nearly half of all deaths in this cohort of SARS-CoV-2 confirmed respiratory patients occurred after patients left the hospital. This underscores a critical limitation of conventional surveillance systems that focus solely on in-hospital mortality, especially in low-resource settings where continuity of care is often disrupted after discharge. By capturing both phases of mortality, our study presents a more comprehensive picture of COVID-19 outcomes and emphasises the urgent need for improved discharge protocols and structured post-hospital care systems.

Table 2 Year-specific distribution of in-hospital and post-discharge deaths among SARS-CoV-2-infected adult patients with severe acute respiratory infection, Bangladesh, 2020–2023

Year	Total number of SARI patients	SARS-CoV-2- infected patients *n* (%)	SARS-CoV-2- infected in-hospital deaths *n* (%)	Lost to follow-up (%)	SARS-CoV-2- infected post-discharge deaths *n* (%)
2020 (March–December)	1328	296 (22.3)	30 (10.1)	8 (3)	25 (9.7)
2021	2716	728 (26.8)	87 (12)	28 (4.4)	72 (11.8)
2022	1942	217 (11.2)	9 (4.1)	8 (3.8)	14 (7)
2023	1830	39 (2.1)	0 (0)	2 (5.3)	0 (0)

The rate of post-discharge mortality among SARS-CoV-2-infected patients in our study (10%) was comparable to findings from a study conducted in Denmark (10.2%), which reported similar outcomes during the 2020–2021 period [23]. Notably, this aligns with the timeframe of our highest post-discharge mortality rates, further documenting the WHO's report identifying 2020–2021 as the peak period of global SARS-CoV-2 circulation and associated mortality [2]. However, the SARS-CoV-2-infected post-discharge death of SARI patients was higher in our study (10%) compared to a systematic review of 43 studies (8.9%), as well as individual studies conducted in a study in the United States (5.9%) and India (6.5%) [22, 24, 25]. This disparity likely reflects healthcare system-associated challenges prevalent in LMICs, such as inadequate follow-up systems, weak referral networks, poor discharge planning, and limited communication between hospitals and primary care providers [26]. In addition, access to essential medications remains a challenge in rural areas due to financial constraints and limited availability in local pharmacies, further compromising patient recovery [27].

We found that the most commonly reported symptoms among SARS-CoV-2-infected patients were difficulty breathing, body ache, and headache in addition to fever and cough, both of which are the defining symptoms in the SARI case definition. These symptoms are also the most frequently reported in SARS-CoV-2 infections and deaths globally [4–7, 9]. Moreover, over half of the patients who died post-discharge had at least one pre-existing co-morbid condition, received antibiotics and oxygen therapy during hospitalisation, which is consistent with findings from another study on SARI patients in Bangladesh conducted before the COVID-19 pandemic and a meta-analysis [3, 22, 28]. Moreover, we found that length of hospital stay was similar among post-discharge survivors and non-survivors, which contrasts with conventional clinical expectations and therefore merits careful interpretation. This result also mirrors the pre COVID-19 pandemic situation of Bangladesh [3]. Rapid clinical deterioration leading to early in-hospital death among some non-survivors, together with health-system constraints during pandemic surges including bed shortages, limited intensive care capacity, and early discharge in extremis or against medical advice may partly explain this finding [11, 29–31]. Residual confounding by unmeasured factors such as severity at presentation and treatment intensity cannot be excluded. Nonetheless, this pattern underscores the importance of post-discharge surveillance and highlights post-discharge mortality as an under-recognised component of the COVID-19 burden in resource-constrained settings. Our study also identified several key predictors of post-discharge mortality. Male patients, those with premature discharge from the hospitals, had difficulty breathing, and kidney disease were at significantly greater risk, consistent with existing literature [22, 23, 25, 32]. We observed that elderly patients aged ≥ 60 years were at significantly higher risk of death within 30 days after hospital discharge compared to younger patients (18–40 years). This age-related vulnerability has similarly been documented in studies conducted in Brazil, Estonia, and Spain, as well as in a meta-analysis [33–35].

Moreover, our study also observed that patients who were prematurely discharged posed a higher risk of post-discharge death compared with patients discharged with a letter of fully recovery. A study conducted before the Covid-19 pandemic among SARI patients also underscored a high rate of premature discharge among those who died within 30-day post-discharge [3]. Previous research suggests that premature discharge in developing countries such as Bangladesh may occur to free bed space in the overcrowded hospitals [29, 30] and due to patient's preference to die at home rather than in the hospital [31]. To reduce premature discharge and preventable deaths; physician training, development of hospital discharge and referral guidelines could be effective strategies to reduce the preventable deaths [36]. In addition, formative studies could help to understand the causes of premature

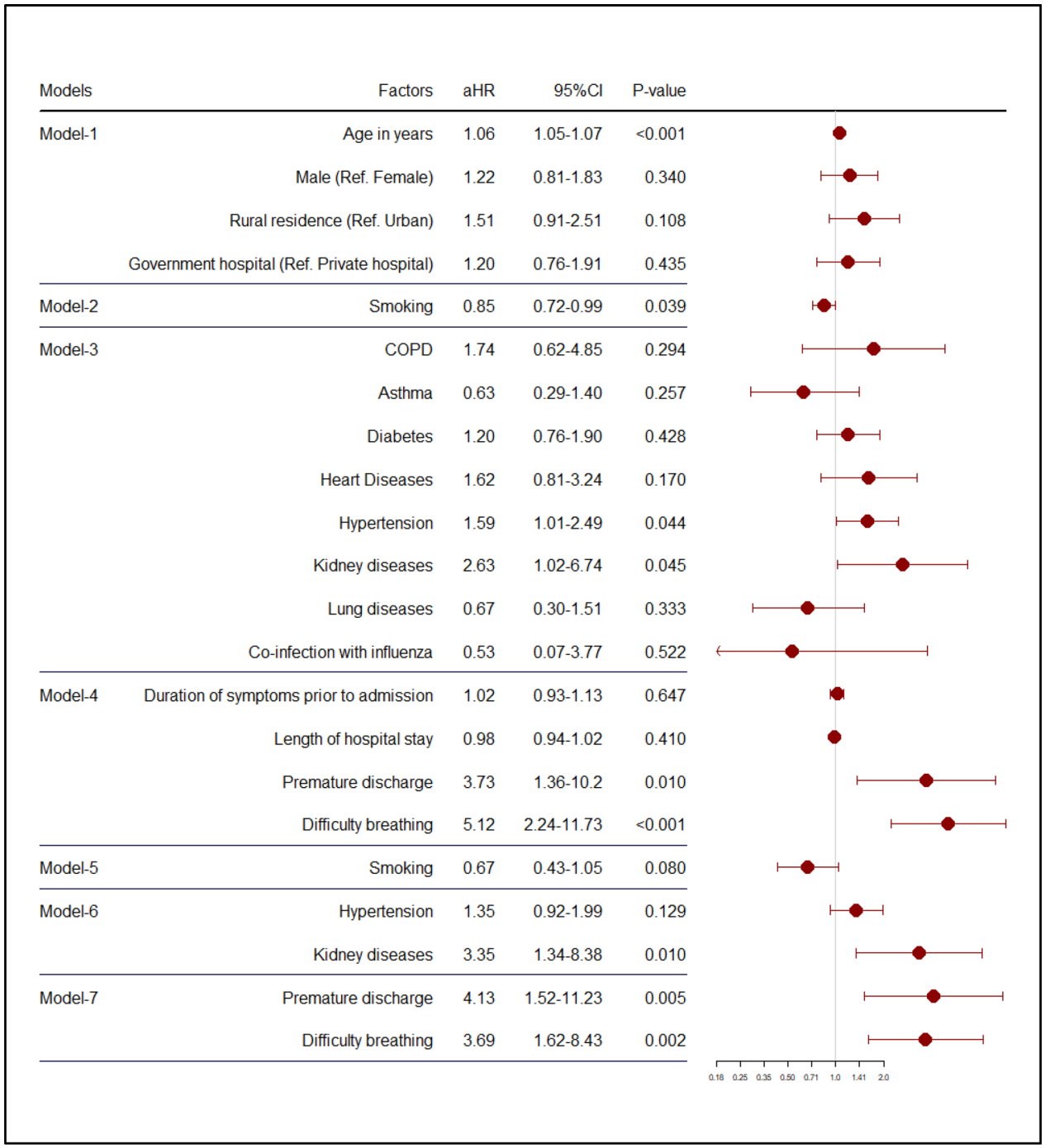

Fig. 5 Factors associated with SARS-CoV-2-infected SARI deaths among adult patients with severe acute respiratory infection in Bangladesh ($N = 1108$), 2020–2023. Adjusted hazard ratio (aHR), confidence interval (CI). In Models 1–4, we presented the direct relationship between the outcome and explanatory variables/potential predictors at each level without adjusting for variables from other levels. Model 5 incorporated smoking history along with age, sex, and residence variables as covariates. In Model 6, the covariates included hypertension and kidney diseases, along with the covariates age, sex, rural residence, and smoking. In Model 7, the covariates included premature discharge and difficulty breathing, along with the covariates age, sex, rural residence, smoking, hypertension, and kidney diseases

discharge in Bangladesh and to identify ways to prevent adverse health outcomes among SARS-CoV-2-infected patients during the post-discharge period. Data suggest that many patients may have been discharged before achieving full clinical recovery or were unable to access timely follow-up care. Notably, only 3.6% of those who died post-discharge had been documented as "fully recovered" at the time of discharge, whereas 73% were prematurely discharged, often at the request of the patient or their family members. These findings raise important concerns about the adequacy of discharge decision-making and the effectiveness of post-discharge care planning, underscoring the need for more rigorous clinical assessment and support systems prior to discharge. Moreover, the lower post-discharge mortality observed among patients with asthma (aHR = 0.63) supports growing evidence that asthma does not increase and may even reduce the risk of COVID-19–related death compared with conditions such as hypertension and diabetes. This finding suggests that asthma may be an independent protective factor against fatal outcomes in COVID-19 patients [37]. Although the exact mechanisms linking asthma to a lower risk of COVID-19 mortality are not fully understood, several explanations have been suggested. First, patients with asthma may receive earlier and more intensive medical care [37]. Second, common asthma treatments, such as inhaled corticosteroids and biological therapies, may help reduce viral replication and airway inflammation [38]. Third, the type 2 immune response seen in asthma may partially counteract the excessive inflammation triggered by SARS-CoV-2 infection [39]. Further studies are needed to clarify how pre-existing asthma may reduce the risk of fatal COVID-19 outcomes. We also found that patients with co-infection with influenza disease had higher survival than those with hypertension or diabetes contradicts, consistent with findings in Bangladeshi SARI cohorts where co-infected cases had no recorded mortality [4]. Moreover, robust meta-analyses show mixed severity but reported lower mortality in some regional contexts [40, 41]. A mechanistic study suggest that viral co-infection can alter pathogen virulence and, consequently, influence disease severity [42]. Furthermore, mathematical modelling of viral co-infection dynamics indicates that interactions between viral species and their respective growth rates may modulate replication efficiency [43]. Moreover, observational studies have reported heterogeneous associations between co-infection and clinical outcomes, ranging from protective effects to worsened prognosis or no observable impact [40]. This inconsistency highlights the complex biological interplay underlying co-infection and underscores the need for further investigation to clarify its effects on mortality and severe outcomes.

In the fully adjusted Cox proportional hazards model, smoking history was associated with a lower hazard of 30-day post-discharge mortality; however, this association did not reach statistical significance. Similar paradoxical and insignificant associations were also found in several studies [3, 44]. The observed inverse association between smoking history and post-discharge mortality should be interpreted with extreme caution. This finding is consistent with the well-described "smoker's paradox", which has been attributed to residual confounding, selection or survivor bias, and incomplete adjustment for smoking intensity, duration, or cessation status [44–46]. Despite rigorous multivariable adjustment and low multicollinearity across models, unmeasured clinical and socioeconomic factors may persist. Importantly, this result does not imply a protective effect of smoking, which remains a well-established risk factor for severe respiratory disease and mortality. Future studies with detailed smoking exposure data are required to clarify this association.

Importantly, our findings showed that almost half of the post-discharge deaths occurred within the first week, and most within the first 14 days, indicating a critical window of vulnerability for patients during the initial seven days after discharge. Similar trends have been observed in Denmark [23]. Many of these deaths occurred either at home or en route to a hospital, while 60% died after being readmitted in the hospital.

Geographically, most post-discharge decedents lived in rural areas, where healthcare access remains a persistent barrier. These regions often faces lack of adequate infrastructure, medical personnel, and essential equipment, leading to compromised post-discharge care and an increased risk of adverse health outcomes, including preventable morbidity and mortality [29, 47]. Moreover, according to a cohort study, the primary reason for the poor post-discharge outcomes among rural population is their limited geographic access to healthcare providers, particularly medical specialists, and their heavy reliance on generalists [48]. In this context, educating patients and caregivers about symptom monitoring, medication adherence, and recognising danger signs could substantially improve outcomes [49].

To reduce post-discharge mortality, it is essential to strengthen follow-up care systems, including scheduled post-discharge visits and proactive monitoring for patients with SARI [3]. In addition, conducting qualitative studies to explore the factors contributing to premature discharge, the underlying causes of post-discharge mortality, and potential preventable strategies to reduce

preventable post-discharge death could be a crucial attempt to reduce preventable deaths. Insights from such findings could help guide resource utilisation and develop effective post-discharge care in Bangladesh, improving recovery for patients with SARS-CoV-2–infected SARI and offering lessons for other LMICs.

There are a few limitations that should be considered before interpreting this study. First, we could not follow up with about 4% of patients after discharge, which means the actual number of post-discharge deaths may be slightly higher than what we reported. However, the vast majority of patients were successfully reached, giving us confidence in the overall findings. Second, all follow-ups were conducted over the phone which may cause recall bias. However, this phone-based follow-up was practical during the pandemic and allowed us to reach many people; it limited our ability to gather detailed clinical information and may have missed some complications. We also did not collect data on some potentially important factors, such as patients' anthropometric data, socioeconomic status, or detailed lab results such as kidney or liver function and inflammatory markers. This limited our ability to explore all the possible reasons behind post-discharge deaths. Although inclusion of CCU-admitted patients (high dependency unit for Covid-19) may reflect greater illness severity, sensitivity analyses excluding these patients generated similar estimates, suggesting minimal influence of CCU-related selection bias. Finally, we were not able to confirm the exact cause of death for those who died after leaving the hospital. In the future, using tools such as WHO's verbal autopsy could help healthcare providers a clearer picture of what was driving these deaths, especially in settings such as Bangladesh, where conducting autopsies is extremely challenging.

However, this study assessed the 30-day post-discharge mortality rate among adult patients (≥18 years) hospitalised with SARI and confirmed SARS-CoV-2 infection, identifying risk factors associated with mortality, including premature discharge, having difficulty breathing, and underlying kidney disease. To reduce preventable post-discharge mortality, standardised discharge protocols should be developed and implemented at least for high-risk patients, and targeted post-discharge telephone follow-up should be initiated.

Conclusion

Nearly one in five adult SARS-CoV-2-infected patients with SARI in Bangladesh died either during hospital stay or within 30-day of post-discharge, with almost half of these deaths occurring after discharge, suggesting that post-discharge mortality might be an overlooked contributor to the actual SARI-related mortality burden in Bangladesh. Adult SARS-CoV-2-infected SARI patients who experienced premature discharge, residence in rural areas, had difficulty breathing, or had kidney diseases were at a significantly higher risk of post-discharge mortality. Strengthening discharge planning, prioritising high-risk patients for post-discharge monitoring, and implementing post-discharge followed up care may reduce preventable post-discharge deaths. Future studies are warranted to explore the underlying causes of post-discharge SARI deaths.

Authorship

All authors meet the ICMJE authorship criteria.

Abbreviations

aHR	Adjusted hazard ratio
CCU	Coronary care units
CDC	Centers for Disease Control and Prevention
Cis	Confidence intervals
CMCH	Chattogram Medical College Hospital, Chattogram
COPD	Chronic obstructive pulmonary disease
CuMCH	Cumilla Medical College Hospital, Cumilla
HBIS	Hospital-based influenza surveillance
HR	Hazard ratio
IEDCR	Institute of Epidemiology, Disease Control, and Research
IRB	Institutional review board
JGH	Jashore 250 bed General Hospital, Jashore
JIMCH	Jahurul Islam Medical College Hospital, Kishoregonj
JRRMCH	Jalalabad Ragib-Rabeya Medical College Hospital, Sylhet
KMCH	Khulna Medical College Hospital, Khulna
LMICs	Low- and middle-income countries
MARMCH	M Abdur Rahim Medical College Hospital, Dinajpur
RMCH	Rajshahi Medical College Hospital, Rajshahi
rRT-PCR	Real-time reverse transcription polymerase chain reaction
SARI	Severe acute respiratory infection
SBMCH	Sher-e-Bangla Medical College Hospital, Barishal
SD	Standard deviation
WHO	World Health Organization

Supplementary Information

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Additional file1 (DOCX 253 KB)

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Author contributions

Conceptualisation, S.B and M.A.I; methodology, S.B, M.A.I, and F.C.; software, S.B.; validation, S.B. and M.A.I; formal analysis, S.B. M.A.I, M.A.A. and MZH; investigation, S.B., M.AI, and F.C.; resources MAI, MZH and FC; data curation, S.B, M.A.I.; writing—original, draft preparation, S.B; writing—review and editing, S.B., M.A.I, T.A.S., M.A.A., A, M.Z.H, and F.C.; visualisation, S.B.; supervision, M.A.I. and F.C.; project administration, S.B, M.A.I. and F.C.; funding acquisition, F.C. All authors have read and agreed to the published version of the manuscript.

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Data availability
According to data policies of the contributing institutions, to protect intellectual property rights the primary data cannot be made publicly available by the authors. The data may be made available upon reasonable request to the Institutional Data Access Committees of the contributing institutions.

Declarations

Ethics approval and consent to participate
The icddr,b Institutional Review Board (IRB) approved the HBIS protocol (PR-2007-002). Informed written consent to participate in the study was obtained from the participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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