

Novel Coronavirus: Projecting the impact in Rohingya refugee camps and beyond

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Aerial view of Kutupalong camp 4 extension, UNHCR, July 2, 2018

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Executive Summary

Background

There are over 200,000 confirmed cases of COVID-19, the infection caused by the newly emerged severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), globally. Forcibly displaced populations, especially those who reside in settlements with high density, poor access to water and sanitation, and limited health services, are especially vulnerable to a serious outbreak. Bangladesh, where 10 confirmed cases of COVID-19 have been confirmed, hosts almost 1 million Rohingya refugees from Myanmar in Cox's Bazar district. Of these, approximately 600,000 refugees are concentrated in the Kutupalong-Balukhali Expansion Site. The capacity to meet the existing health needs of this population are already limited. An outbreak of COVID-19 within this population threatens to severely disrupt an already fragile situation.

Methods

To explore the potential impact of SARS-CoV-2 virus on the Rohingya refugees in the Kutupalong-Balukhali expansion site, we used a scenario-based approach to model transmission in this population after an introduction of the virus. Using three different assumptions about the transmission potential of SARS-CoV-2 at this site, we estimated the number of infections, hospitalizations, deaths, and health care needs that might be expected.

Results

We found that even in a low transmission scenario, a large-scale outbreak was highly likely after a single introduction of the virus into the camp, with 51% of the simulations leading to an outbreak of at least 1,000 cases and increasing to 75% and 93% in moderate and high transmission scenarios, respectively. On average, in the first 30 days of the outbreak following a single introduction, we expect 119 (95% CI, 105-134), 168 (95% CI, 101-391), and 504 (95% CI, 107-2,070) infections in the low, moderate, and high transmission scenarios, respectively. These rise significantly to 424,798 (95% CI, 382,725-476,302), 543,637 (95% CI, 498,627-570,995) and 591,349 (95% CI, 582,107-596,832) infections at 12 months, respectively. Given the relatively young age distribution in Kutupalong-Balukhali camps, we estimate that the proportion of infections that lead to severe disease and hospitalization will be approximately half of what has been estimated in China (1.8-3.2% vs 4.3-6.2%). However, even in the low transmission scenario, we project that there could be 1,515 (95% CI, 1,285-1,773) deaths at 12 months, rising to 2,109 (95% CI, 1,699-2,571) with the high scenario. In almost all simulations in all scenarios, the hospitalization needs, in terms of beds alone, significantly exceeded capacities.

Discussion

While COVID-19 planning between the government of Bangladesh and international organizations is currently ongoing, such an epidemic in a refugee setting with high population density, poor baseline health status, limited ability to isolate infected individuals, and limited capacity to surge health infrastructure and workforce remains a major challenge. Similar issues exist for the national population

in Cox's Bazar given Bangladesh's limitations in adequately responding to such an epidemic for their own population. A significant amount of medical infrastructure and health capacity will be needed to respond to a COVID-19 outbreak in the camps. Outside support will be challenging to find during a pandemic. Task shifting among existing health personnel will need to be undertaken, requiring enhanced training. Isolation of suspected cases will be difficult given the limited number of hospital beds and available land in Kutupalong-Balukhali Expansion Site. Novel and untested isolation strategies of the elderly and medically vulnerable persons in the site should be considered.

The challenges discussed in this particular setting are not unique to Bangladesh or the Rohingya. Rather, they expose more fundamental issues of how to plan and respond to refugees and internally displaced persons living in high density and unsanitary camp as well as out-of-camp settings globally. During exceptional times, it is not unreasonable for governments to take extraordinary measures to protect their citizens. It is likely that during a pandemic such as this, most if not all countries will restrict their national health services to nationals. This leaves refugees and other non-nationals, such as undocumented migrants, in an extremely precarious position. Sadly, there is no simple recommendation as to how to address this serious issue. Rather, it is important for it to be stated openly, for the international community to acknowledge it and to attempt to come up with some solutions. Finally, refugees generally face discrimination and are often falsely accused of spreading disease. The widespread rise of populism combined with anti-migrant and anti-refugee sentiments that we are observing globally provides a hostile environment that could be exacerbated by a pandemic. We are concerned that the COVID-19 pandemic, while completely unrelated to being a refugee, could be used as an excuse to take retribution against refugees and other vulnerable groups such as IDPs and undocumented migrants. This would jeopardize the effectiveness of all preventive and containment measures, as pandemics require planning and responses that do not discriminate by nationality and protect the health of the global population.

Introduction

The newly emerged severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is responsible for more than 200,000 confirmed cases of the disease known as COVID-19 globally, with local transmission reported in dozens of countries.¹ With growing concern about the global inability to control its spread, rapid preparation and planning are critical, particularly where this virus may have the greatest impact. Forcibly displaced populations, especially those who reside in camps and other temporary settlements with high population density, poor access to water and sanitation, poor health status and limited health services, may be especially vulnerable. The combination of increased transmission potential and limited supplies and capacity to treat cases, particularly those requiring critical care, conspire to produce settings with potentially devastating consequences. Further complicating an already complex situation,

health systems of countries hosting refugees will likely already be stressed from COVID-19 amongst their own populations.

Refugee camps and settlements are home to more than 7.2 million people, a majority of which reside in nine countries globally.^{2,3} Between 2009-2017, there were 364 disease outbreaks in 108 refugee camps.⁴ To date, 34 countries that host more than 20,000 refugees have reported local transmission of SARS-CoV-2. While refugees have not yet been reported to be affected, the United Nations High Commissioner for Refugees (UNHCR) has appealed for US\$33 million to prevent, prepare, and respond to their public health needs.⁵ To understand how SARS-CoV-2 might impact refugee camp populations, we conducted a case study focused on the Rohingya refugees living in the Kutupalong-Balukhali Expansion Site in Cox's Bazar, Bangladesh.

In this study, we explore three potential scenarios using current available global data on COVID-19 combined with specific characteristics of the Rohingya refugees living in Kutupalong-Balukhali Expansion Site in Cox's Bazar, Bangladesh to estimate the number of infections, hospitalizations, and deaths that might be expected in each scenario. The primary aims of these analyses are to: 1) develop a baseline expectation of the possible infection burden, speed, and hospitalization capacity needed to respond to a COVID-19 epidemic; 2) use these findings to provide some recommendations to support ongoing preparedness planning by the Bangladesh government, United Nations agencies and other actors for a COVID-19 outbreak; and 3) apply lessons from this case study to refugees and other forcibly displaced persons globally.

Context

Over 900,000 Rohingya refugees have sought refuge in Cox's Bazar, Bangladesh; 744,000 of whom arrived after 2017 fleeing ongoing violence and widespread persecution in Myanmar.⁶ Prior to the refugee influx, Cox's Bazar District had a population of close to 2.3 million.⁷ Refugees are now estimated to constitute more than one-third of the total district population.⁸ These refugees reside in 34 congested settlements in eastern Bangladesh, 23 of which constitute the Kutupalong-Balukhali Expansion Site.⁹ This site includes the Kutupalong refugee camp as well as adjacent makeshift settlements under UNHCR management and is home to approximately 600,000 Rohingya refugees.¹⁰

The Kutupalong-Balukhali Expansion Site has specific characteristics that make it a high-risk setting for both the introduction and transmission of SARS-CoV-2. With 10 confirmed COVID-19 cases in Bangladesh (as of March 17th) due to local transmission and ongoing transmission in neighboring countries, the introduction of the virus into the site is likely. With a population of nearly 600,000, 75% of families share their shelters, and 93% live below the UNHCR emergency standard of 45m² per person. The population density of over 46,000 persons per km², with space as low as 8m² per person in some

areas, this site could qualify as one of the densest cities on earth. The population is also at high risk for epidemics given the above characteristics, as exemplified by the previous diphtheria and measles outbreaks.

The health status of refugees is improving but remains fragile. Mortality has decreased since 2017 and is now well below emergency thresholds. The latest crude mortality rates were estimated in November 2019 at 0.12 and 0.2/ 10,000/day in Kutupalong refugee camp and in all makeshift settlements in Cox's Bazar, respectively; under 5 mortality rates were reported at 0.0 and 0.68/10,000/day, respectively.¹¹ In the same surveys, the prevalence of global acute malnutrition (GAM) and severe acute malnutrition (SAM) were estimated at 12.1% & 1.3% and 10.9% & 0.9%, respectively, considered a high prevalence per World Health Organization (WHO)-UN Children Fund (UNICEF) newly revised prevalence thresholds (prevalence of GAM between 10 and 15%).¹² One-third of the children under five years are stunted and almost 60% of children under 2 years are anemic in both the camp and the settlements.¹³ Measles vaccination coverage for children 6 months to under five years is 84% in Kutupalong camp and 25% in the makeshift settlements, below the target 95% coverage set by humanitarian response plans and the Sphere standards.^{13,14}

The site is served by seven hospitals run by non-governmental organizations (NGOs) and foreign governments with a total of 342¹ hospital beds (5.7 beds per 10,000 population) and up to 630 hospital beds when needed (10.5 per 10,000 population).¹⁵ There are 24 primary health care centers (1 PHC/25,000 persons) with numerous health posts, though the total number of functioning PHCs varies.^{16,17} Outside of the refugee site, there are 910 beds available in Cox's Bazar district, including government, private, and NGO facilities for both the host community and refugees.^{18,19} The district hospital, with a 250 bed capacity, typically treats between 400-600 inpatients daily; 50-60 of whom are estimated to be refugees.^{19,20} It suffers from overcrowding with a bed occupancy rate over 200%, poor infection control, and inadequate hygiene protocol and waste management.^{19,20} Furthermore, it lacks one-third of the human resources needed to be fully functional.^{19,20} While it has six intensive care unit (ICU) beds available, the ICU is reportedly not functional.²¹ There are an estimated 0.31 physicians and 0.12 nurses per 1,000 population²² in Bangladesh, far below the 4.5 skilled health workers per 1,000 population recommended by WHO.²³

¹ Includes adult inpatient beds, obstetric beds, and pediatric beds.

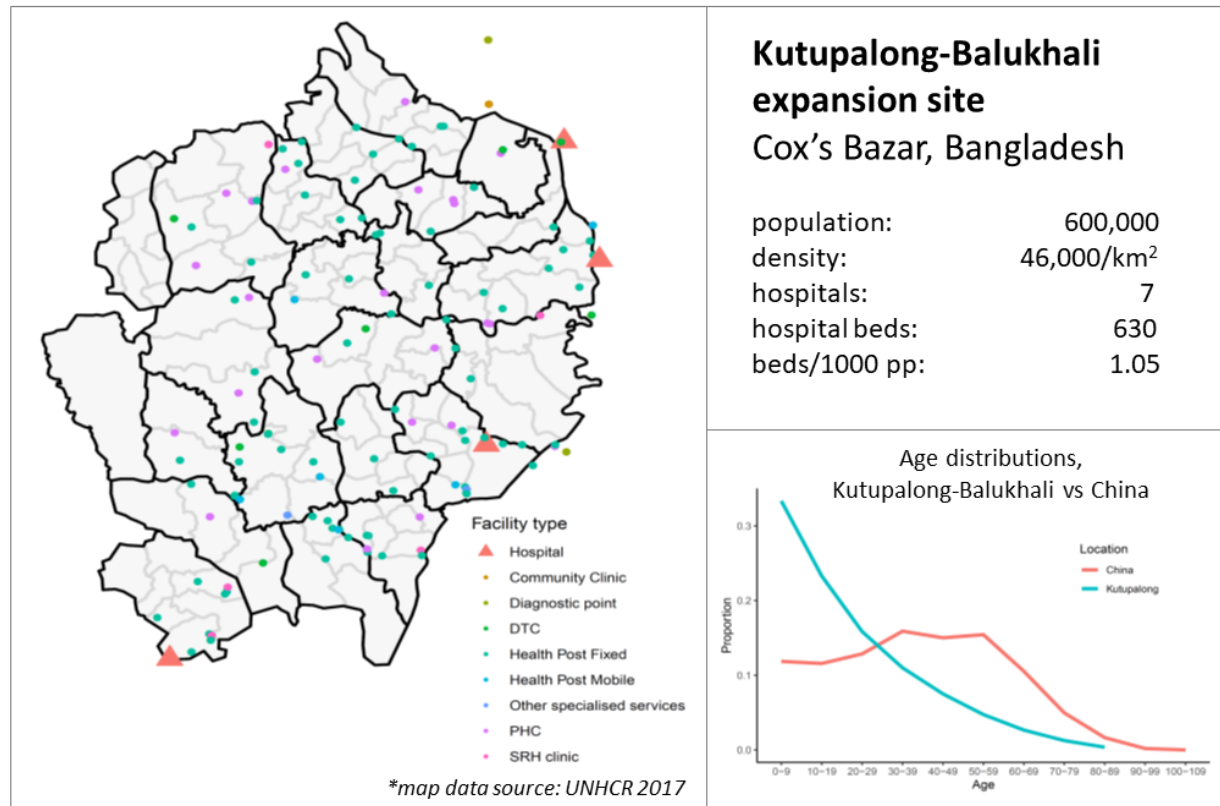


Figure 1. The Kutupalong-Balukhali Expansion Site: map (on the left); key figures (top right panel) and population age distributions in Kutupalong-Balukhali Expansion Site and China (bottom right panel).

Methods

Transmission scenarios

One of the primary drivers of our epidemic simulations is the transmission potential characterized by the basic reproductive number (R_0), or the average number of people each infected individual is expected to transmit to assuming no immunity. We considered three potential scenarios with different values of R_0 : 1) a **low transmission scenario** based on transmission levels in many of the Chinese provinces with elevated isolation and control practices and an R_0 similar to influenza ($R_0=1.5-2.0$)²⁴; 2) a **moderate transmission scenario** that mirrors estimates in early stages of the outbreak in Wuhan, China ($R_0=2.0-3.0$)²⁵; and, 3) a **high transmission scenario** where we assume that R_0 is increased by a factor of 1.65 ($R_0=3.3-5.0$) compared to estimates from open community settings as observed during the 2017 diphtheria outbreak.²⁶ The R_0 in each of these scenarios falls within the 95% confidence interval of the current range of estimates for COVID-19.²⁷ We assumed an Erlang distributed serial interval (time

between the onset of symptoms in infector-infectee pairs) with a mean of 6 days (standard deviation = 4.2),²⁸ and used a stochastic SEIR model to simulate transmission in this population.

Hospitalization and mortality

We assume that in this setting hospitalization would be limited to those with severe disease (defined as tachypnea (≥ 30 breaths/min) or oxygen saturation $\leq 93\%$ at rest, or $\text{PaO}_2/\text{FIO}_2 < 300$, and/or lung infiltrates $> 50\%$ of the lung field within 24-48 hours)²⁹, and not used as a means of isolation. Thus, we assumed the hospitalization rate was equivalent to the severe disease rate. Using estimates based on data from Shenzhen, China, we estimated an age-adjusted rate of severe disease, accounting for the age distribution of Kutupalong-Balukhali, and applied this severe disease rate to incident infections from the model simulations.²⁸ We estimated deaths assuming a 10% case fatality risk rate among hospitalizations/severe disease. We assumed hospitalization occurs a median of 3.42 days after symptom onset (lognormally distributed, $\text{sd}=0.79$), hospitalized cases are discharged after a mean of 11.5 days (95% CI, 8.0-17.3), and deaths occur after a mean of 11.2 days (95% CI, 8.7-14.9).²⁴ Additionally, early reports from the outbreak in China indicate that mechanical ventilation was required by approximately 25% of patients with severe disease, while the remaining 75% required only oxygen supplementation.²⁹

In summary, the model uses three reproductive numbers for the virus, with severe cases requiring hospitalizations and a 10% severe case fatality risk. The estimates of infections and deaths do not take into consideration possible interventions and behavior changes. We assume that all hospital beds are used to treat severe COVID-19 cases and not used for other conditions nor isolation.

Results

Infections

We found that a large-scale outbreak is highly likely in this population, even under the low transmission scenario, with 65% of the simulations producing an outbreak of at least 1,000 cases with a single introduction (Table 1) and increasing to 75% and 93% in the moderate and high transmission scenarios, respectively. On average, in the first 30 days of an outbreak following a single introduction, we expect 119 (95% CI, 105-134), 168 (95% CI, 101-391), and 504 (95% CI, 107-2070) infections cases in the low, moderate, and high transmission scenarios, respectively. One year after the start of an outbreak, and in the absence of any effective interventions (e.g., vaccination, quarantine) or behavior change, we expect 71% (95% CI, 64-79%) of the population to have been infected under the low scenario, 91% (83-95%) in the moderate scenario, and 99% (97-99%) in the high transmission scenario (Table 1).

We found that in all scenarios, epidemic growth is likely to remain relatively slow at the beginning of an outbreak in this population, with limited numbers of infections and few, if any, hospitalizations and

deaths during the first three months (Table 2). However, this quickly changes once sufficient infections are in the population, with rapid increases and culmination of the outbreak within the year (Table 2, Figure 2).

By the time the first hospitalization occurs, we expect 50 (95% CI, 1-197) individuals to be infected in the population under the low scenario. This increases to 72 (95% CI, 2-289) and 141 (95% CI, 3-502) in the moderate and high scenarios, respectively. Similarly, we would expect the virus to have been circulating in this population for an average of 38, 30, and 23 days under the low, moderate, and high transmission scenarios, respectively.

Hospitalization and mortality

Adjusted for the age-distribution in the Kutupalong-Balukhali expansion site, we estimated that 3.6% (1.2-9.3%) of infections in this population would result in severe disease and hospitalization. The maximum daily hospitalization capacity needed in the low, moderate, and high scenarios was 4,192 (95% CI, 2391-6143), 7,264 (95% CI, 4760-10315), and 11,567 (95% CI, 8228-15865) beds, respectively (Table 1). Under the low transmission scenario, hospitalization needs exceeded the hospitalization capacity of 630 beds after 84 days (95% CI, 57-131) while in the high transmission scenario, this occurred after only 38 days (95% CI, 26-57; Table 1, Figure 3).

Assuming that 10% of severe cases result in death, which puts the infection fatality rate at 0.36 (95% CI, 0.12-0.93%), we estimated a total of 1,647 (95% CI, 1,331-1,951), 1,945 (95% CI, 1,699-2,571), and 2,109 (95% CI, 1,699-2,571) deaths in the low, moderate, and high transmission scenarios, respectively (Table 1). In the high transmission scenario, the maximum number of daily deaths is reached on day 179, compared to day 121 and day 79 on average in the low and moderate scenarios, respectively (Figure 2).

Table 1. Outbreak results in Kutupalong-Balukhali Expansion Site, assuming no effective novel interventions or behavior change.

Transmission Scenario	Probability of outbreak of >1000 cases after a single introduction	Total Infections <i>Mean</i> (95% CI)	Total Hospitalizations <i>Mean</i> (95% CI)	Total Deaths <i>Mean</i> (95% CI)	Maximum daily Infections <i>Mean</i> (95% CI)	Maximum daily Hospitalizations <i>Mean</i> (95% CI)	Maximum daily Hospitalization Capacity needed* <i>Mean</i> (95% CI)	Day Hospitalization Need exceeds capacity <i>Mean</i> (95% CI)
Low ($R_0=1.5-2.0$)	65%	459,968 (383,938-496,943)	16,481 (13,449-19,452)	1,647 (1,331-1,951)	8,873 (5,145-11,223)	700 (375-1,123)	4,192 (2,391-6,143)	83 (57-131)
Moderate ($R_0=2.0-3.0$)	82%	543,637 (498,627-570,995)	19,424 (16,529-22,659)	1,945 (1,637-2,287)	16,509 (11,319-20,959)	1,200 (716-1,967)	7,264 (4760-10,315)	58 (38-89)
High ($R_0=3.3-5.0$)	93%	591,349 (582,107-596,832)	21,099 (17,166-25,534)	2,109 (1,699-2,571)	28,890 (24,093-33,266)	1,931 (1,207-3,135)	11,567 (8,228-15,865)	38 (26-57)

* Maximum daily hospitalization capacity needed, among simulations that resulted in outbreaks.

Table 2. Infections, hospitalizations, intensive care unit admissions, and deaths in 3, 6, and 12 months.

Transm- ission Scenario	1 month				3 months				12 months			
	<i>Infections</i>	<i>Hospital- izations</i>	<i>Intensive Care Unit</i>	<i>Deaths</i>	<i>Infections</i>	<i>Hospital- izations</i>	<i>Intensive Care Unit</i>	<i>Deaths</i>	<i>Infections</i>	<i>Hospital- izations</i>	<i>Intensive Care Unit</i>	<i>Deaths</i>
<i>Low (R=1.5- 2.0)</i>	119 (105-134)	3 (2-4)	0 (0-1)	0 (0-0)	3,014 (153- 13,692)	84 (3-364)	16 (0-69)	3 (0-15)	424,798 (382,725- 476,302)	15,150 (13,014- 17,551)	3,721 (3,198- 4,317)	1,515 (1,285- 1,773)
<i>Moderate (R=2.0- 3.0)</i>	168 (101-391)	4 (0-11)	1 (0-3)	0 (0-1)	99,359 (975- 419,741)	2,775 (20- 13,442)	526 (4-2,737)	92 (0-567)	543,637 (498,627- 570,995)	19,424 (16,529- 22,659)	4,775 (4,040- 5,585)	1,945 (1,637- 2,287)
<i>High (R=3.3- 5.0)</i>	504 (107-2070)	9 (1-38)	1 (0-5)	0 (0-1)	547,083 (289,130- 595,983)	18,931 (7,184- 24,990)	4,469 (1,182- 6,101)	1,498 (137-2,412)	591,349 (582,107- 596,832)	21,099 (17,166- 25,534)	5,193 (4,246- 6,325)	2,109 (1,699- 2,571)

Table 3. Comparison of selected indicators of health status and health service availability in Kutupalong-Balukhali extension site and Bangladesh

Indicators	Comparison		Standards	
	Kutupalong-Balukhali Extension Site (KB)	Bangladesh: National (N) or Chittagong Division (C) Cox's Bazar (CB) (acc. to data availability)	WHO standards/ recommendations	Emergency Minimum Standards ^a
Crude mortality rate¹ (same value converted for ease of comparison)	KC ^{2, b} : 0.12/10,000/day MS ^{3, a} : 0.2/10,000/day KC: 4.32/1,000/year MS: 7.2/1,000/year	0.13/10,000/day 0.14/10,000/day 4.7/1,000/year (C) ^c 5.1/1,000/year (N) ^c	Not applicable	1/10,000/day 36/1,000/year
Community health workers per 10,000 population	23.6 ^f	2.13 ^d (N)	Does not exist	10 - 20
Primary Health Care facility per population	1 per 25,000 ^g	1 per 39,394 (CB) ^h	1 per 50,000 ^a (rural areas)	1 per 10,000
Hospital beds per 10,000 population	5.7 ^{l, 5} 10.5 (surge capacity)	8 (N) ^j	Does not exist	18 ⁶
District/ rural/ referral hospital per population	1 per 84,707 (7 hospitals in KB site) ⁱ Tertiary: None available	Secondary hospitals (C): 1 per 320,000 (89 in division) 1 per 386,000 (421 nationwide) ^k Tertiary: 1 per 2,500,000 (C) 11 tertiary hospitals ^k 1 per 2,600,000 (N) 62 tertiary hospitals ^k	Does not exist	District/ rural hospital: 1 per 250,000
Number of liters of water per person per day	17.9 l/p/d collected at HH level ^l	Not available	50 – 100 ^m	15

Notes:

- ¹ Mortality rates in emergency settings are calculated per 10,000/day, while in stable settings, they are calculated in 1,000/year. We presented the same mortality rate expressed in the two measures for ease of comparison with Bangladesh estimates.
- ² KC: Kutupalong Camp
- ³ Makeshift Settlements (MS) include the Kutupalong MS, Balukhali MS and Expansion Zones, (which are part of the Kutupalong–Balukhali extension site together with KC) as well as Hakimpura, Jamtoli, Potibonia, Chakmarkul, Unchiprang, Shamlapur, Leda, Ali Khali, Jadimura Shamlapur, and Nayapara Expansion (that are not part of the Kutupalong-Balukhali extension site).
- ⁴ An aggregated estimate of the skilled health worker density needed to achieve 80% coverage of 12 selected Sustainable Development Goals’ tracer indicators.
- ⁵ This includes all hospital beds: adult inpatient beds, obstetric beds, and pediatric beds.
- ⁶ Standard excludes maternity beds.

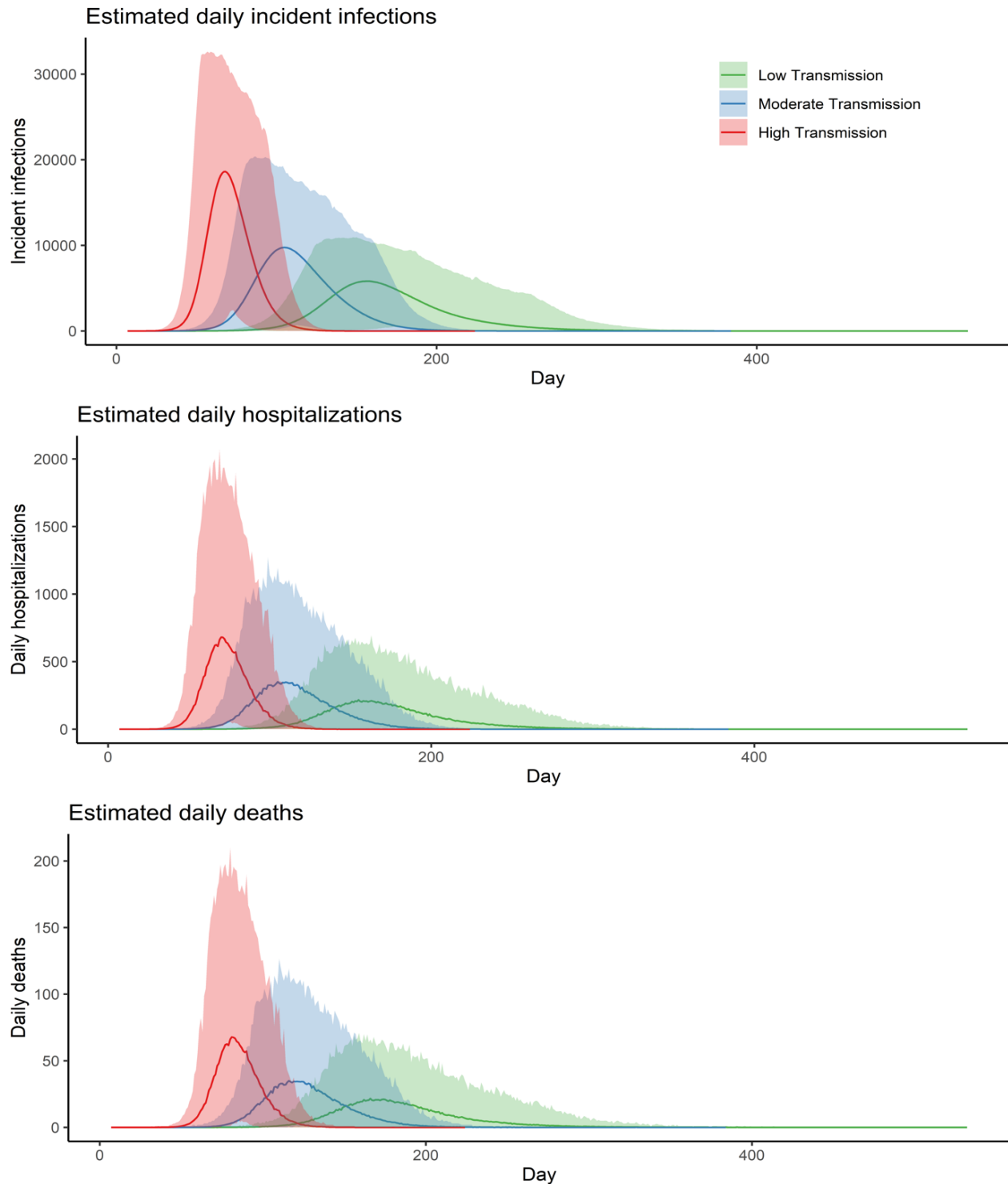


Figure 2. Simulated outbreak trajectories for Kutupalong-Balukhali camps under three transmission scenarios: low transmission ($R_0=1.5-2.0$), moderate transmission ($R_0=2.0-3.0$), and high transmission ($R_0=3.3-5.0$). (A) daily incident infections of COVID-19, (B) daily incident hospitalizations, and (C) daily hospital capacity needed under the three scenarios.

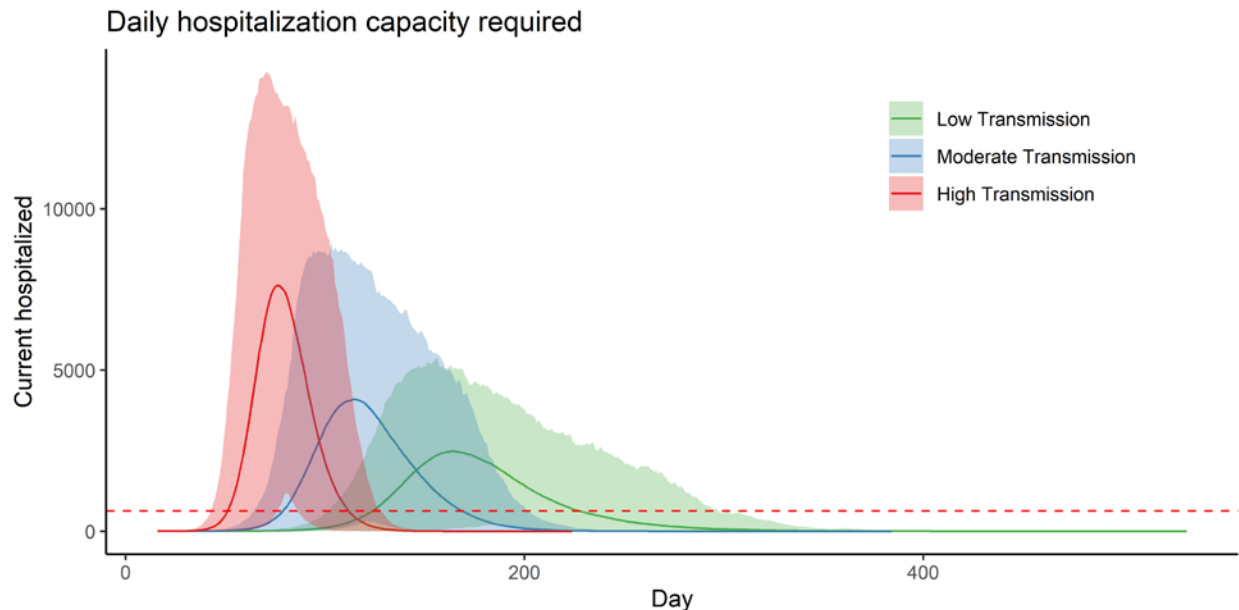


Figure 3. Hospitalization capacity requirements for an outbreak of SARS-CoV-2 in the Kutupalong-Balukhali camps, under three transmission scenarios: low transmission ($R_0=1.5-2.0$), moderate transmission ($R_0=2.0-3.0$), and high transmission ($R_0=3.3-5.0$). The dashed red line represents the 630-bed surge capacity currently believed to exist in the population.

Discussion

The introduction of SARS-CoV-2 into the Kutupalong-Balukhali expansion site or any other large refugee or internally displaced persons (IDPs) camp or settlement is very likely to have serious consequences and overwhelm existing health systems. Even when transmission rates were assumed to be similar to that of influenza (low scenario), the necessary hospitalization capacities far exceeded the available capacities for the refugees in the Kutupalong-Balukhali expansion site in most simulations. Recent experience with other infectious disease outbreaks shows that the transmission of SARS-CoV-2 will likely be more intense in settings such as Kutupalong-Balukhali expansion site that has high population density, inadequate water and soap to maintain hygiene, limited ability to isolate infected individuals, and large household sizes.²⁶ Such increased transmissibility was observed in the Rohingya population during the diphtheria outbreak in 2017, where R_0 was estimated to be more than 65% higher than in diphtheria outbreaks in out of camp settings.²⁶

The younger demographic profile of the Rohingya camp population could reduce the overall rate of severe cases as compared with China or other upper-middle and high-income countries that have older populations. After adjusting for age, we found the overall severe disease rate in this population (3.6%) to be approximately half that estimated for China (6.6% [95% CI, 3.7-10.4]).²⁸ However, it is unclear

whether other co-morbidities such as malnutrition and poor overall health status could modify the virulence of the virus among children and younger age groups, and consequently their clinical outcomes.

Even though the severity of illness and hospitalization rates could be lower in this setting than other parts of the world solely due to demographic characteristics, the existing inpatient facilities in the camps are already operating close to full bed occupancy, and all scenarios show that they will be overwhelmed. Under current conditions, we expect this to occur within 1-3 months of the first introduction of the virus, depending on the transmission rate, where hospitalizations will range from 84 to 18,931 at 3 months depending upon the scenario; these numbers dramatically rise by 12 months. Even in relatively well-resourced contexts such as China and Italy, a massive amount of additional hospitalization capacity and human resources were needed to respond to the COVID-19 outbreak. For example, in Hubei province, China, there were 3.2 registered nurses and 2.6 licensed physicians per 1,000 population before the COVID-19 pandemic;³⁰ this was just above the WHO standard, and close to 10 times the available human resources in Bangladesh.²² Nevertheless, Hubei was rapidly overwhelmed by cases, necessitating the building of two 1,000-person hospitals in the span of 10 days and 16 total temporary hospitals to contain the virus.³¹

We were not able to find an accurate estimate of the human resources currently available in the camps (e.g., number of doctors, nurses, midwives), and thus, we are unable to estimate the number of health care workers that would be needed as surge capacity during a COVID-19 outbreak. However, given the limited availability of skilled health workers and hospital beds in Cox's Bazar combined with human resource ratios that are below standards for meeting the universal health coverage goals in Bangladesh, it is unlikely that additional health care professionals within Bangladesh would be available, as they would be needed for the national response. A surge of international health care workers could be considered, but this will be difficult given the high demands worldwide for them during the pandemic. Furthermore, issues of introduction of the virus from expatriates into Bangladesh would need to be considered. A more likely strategy would be task shifting among existing health care workers, where doctors will be treating the most severe cases, nurses the less severe cases, and community health workers addressing mild infections. Such task shifting would require intensive training immediately.

Given the limited number of beds for treating the predicted large number of severe COVID-19 cases in Kutupalong-Balukhali expansion site, isolation through hospitalization, as is being done in other settings, will likely be very difficult. Alternative plans for the isolation of mild symptomatic infections are needed and are currently being discussed with the government of Bangladesh to help control such an outbreak, as was done during the 2017 diphtheria outbreak. During that outbreak, bed occupancy rates in MSF facilities were over 100% for several weeks as both mild and severe cases were hospitalized.³² This outbreak will be much larger. Setting up inclusive and accessible temporary hospitals to triage mild cases in these populations will require significant support and coordination by the government, UN agencies and NGOs. The physical availability of land is a specific constraint in this setting. Therefore, detailed advanced planning of healthcare capacities, triage procedures, and isolation strategies need to

be finalized and shared widely as soon as possible. Given the gravity of the pandemic, different and previously untried strategies for social distancing and isolation need to be considered. While culturally difficult and requiring a large amount of socialization, isolating people over 60 years of age as well as those who are medically vulnerable together in certain designated sections of the camp may need to be considered. Consistent monitoring of fever and other symptoms combined with appropriate testing, if tests become available will be an integral part of this strategy. In the future, the use of people who have recovered from COVID-19 infections will need to be considered after more data become available as to their ability to become re-infected and transmit to others. Such a strategy was used to strong effect among Ebola survivors in the socialization of messages and treating patients in Ebola Treatment Units.

The Bangladesh government, UN agencies, and NGOs have done a remarkable job in addressing the health of the Rohingya refugees in Cox's Bazar since their recent large-scale exodus in 2017 from Myanmar. Unlike in other mass displacements from conflict into large refugee camps, the mortality rates among the refugees have been remarkably low.^{33,34} Despite the elevated transmission rate during the 2017 diphtheria outbreak, the mortality was low with a case fatality of only 0.5%, much less than observed elsewhere in other diphtheria outbreaks.³⁵ This success was likely in part due to rapid case identification and early treatment with antibiotics and antitoxin and prophylactic treatment of contacts, both of which limited onward transmission and reduced the severity of disease.²⁸ Unfortunately, however, COVID-19 is not the *Corynebacterium Diphtheriae* bacterium, and as described above, the transmission rates and severity of illness will overwhelm health systems in most countries, never mind relatively poorly resourced refugee settings.

The three scenarios show varying degrees of increased mortality. Mortality due to COVID-19 is dependent upon various factors, particularly access to hospitals with ICUs and ventilators. Currently, there is only one facility with few mechanical ventilators in the camps and one facility with less than 10 ICU beds and no ventilators. Therefore, it is likely that mortality rates due to COVID-19 will be significantly higher here than in settings where nationals or refugees have such access. Reportedly, the ICUs and ventilators are not functioning in the district hospital in Cox's Bazar, and thus similar challenges in terms of access to health care facilities to treat severe cases of COVID-19 may be equally challenging for nationals in Cox's Bazar. Mortality in Kutupalong-Balukhali expansion site is currently comparable to estimates for Chittagong division and nationwide, and are below emergency levels. However, the scenarios show a significant increase in mortality, ranging from 1,515 deaths (2.6/1,000/year) to 2,109 deaths (3.6/1,000/year at 12 months due to COVID-19 alone; this does not take into account expected deaths that would have occurred during this time as well as increased deaths due to other illnesses that are untreated due to the outbreak.

As in other major epidemics where healthcare capacity and access to it is already limited, major outbreaks like this can easily disrupt an already precarious health system.³⁶ Diversion of these limited health resources from existing health services, including vaccination, obstetrical care, and emergency care, may cause an increase in mortality due to disease that could normally be treated by the health

system; this occurred in the Ebola outbreak in West Africa where more people died from malaria than Ebola, and in Eastern DRC, where more people died from measles than Ebola.^{37,38}

This analysis does have limitations. Specifically, we are using a mass-action model, which tends to overestimate the size of outbreaks since populations are generally not closed and well mixed. However, due to population density and often closed nature of refugee camps, transmission in these settings has been shown to act more closely to theory. Additionally, the current evidence on the natural history and key epidemiological properties of COVID-19 reflect the interactions of the SARS-CoV-2 virus with non-displaced populations. Population structure and population health can lead to widely different burden of disease with no modifications to the virus. With the particular demographic characteristics and health status of refugee populations, like this one in Cox's Bazaar, we need to be cautious when developing guidance based on previously estimated properties of SARS-CoV-2/COVID-19. Clinical surveillance, laboratory confirmation, and documentation are key to generating new evidence specific to this population and potentially generalizable to other refugee settings. Finally, the situation in the camps is fluid, and we were not able to gather accurate data regarding total numbers and types of health care workers, nor were we able to confirm the exact number of current hospital beds. Thus, we used the existing data that were available from documents and personal communications.

While we are focused here on the possible impact of SARS-CoV-2 on the Kutupalong-Balukhali expansion site, most of these findings are applicable to other refugee and IDP camp-like situations. While governments' preparedness and response plans for COVID-19 may mention these populations, it is the details or lack of, that must be examined. The Inter-Agency Standing Committee has recently released interim guidance for scaling up the COVID-19 response in camps and camp-like settings that highlights inclusion, protection, and readiness.³⁹ This guidance, which applies the WHO guidance on COVID-19 preparedness and response⁴⁰ to populations in humanitarian crises, should be acknowledged in government and humanitarian agency decision-making. We assume that in the case of a large-scale COVID-19 epidemic in Cox's Bazar, the government would limit access to hospitals only for nationals. During exceptional times, it is not unreasonable for governments to take extraordinary measures to protect their citizens; in fact, that is what is expected of governments. Nevertheless, this likelihood in most if not all countries leaves refugees and other non-nationals, such as undocumented migrants, in an extremely precarious position globally. During a pandemic, there will be limited support by countries to establish field hospitals with ICU capabilities for refugees, as they will be occupied with addressing their own capacity issues nationally. Sadly, there is no simple recommendation as to how to address this serious issue. Rather, it is important for it to be stated openly, for the international community to acknowledge it and to attempt to come up with some solutions.

The scenarios presented in this study focus on camp-like settings where refugee populations are relatively accessible, and health services are available and generally free. However, the majority of refugees reside outside of camps and often in urban contexts; the latter is often very congested with multiple families sharing crowded dwellings.² For these populations, availability, access, cost and quality

of health services vary by host government policies. These refugee populations are also particularly vulnerable to the serious consequences of pandemics as targeted responses among a dispersed group of refugees, and equity in health service delivery is very difficult to achieve.

Refugees generally face discrimination and are often falsely accused of spreading disease. The widespread rise of populism combined with anti-migrant and anti-refugee sentiments that we are observing globally provides a hostile environment that could be exacerbated by a pandemic. We are concerned that the COVID-19 pandemic, while completely unrelated to being a refugee, could be used as an excuse to take retribution against refugees and other vulnerable groups such as IDPs and undocumented migrants. This would jeopardize the effectiveness of all preventive and containment measures, as pandemics require planning and responses that do not discriminate by nationality and protect the health of the global population.

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