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Portable health clinic COVID-19 system for remote patient follow-up ensuring clinical safety

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ABSTRACT

Background: A developing country like Bangladesh suffers very much from the sudden appearance of the COVID-19 pandemic due to the shortage of medical facilities for testing and follow-up treatment. The Portable Health Clinic (PHC) system has developed the COVID-19 module with a triage system for the detection of COVID-19 suspects and the follow-up of the home quarantined COVID-19 patients to reduce the workload of the limited medical facilities.

Methods: The PHC COVID-19 system maintains a questionnaire-based triage function using the experience of the Japanese practice of diseases management for early detection of suspected COVID-19 patients who may need a confirmation test. Then only the highly suspected patients go for testing preventing the unnecessary crowd from the confirmation PCR test centers and hospitals. Like the basic PHC system, it also has the features for patients' treatment and follow-up for the home quarantined COVID-19 positive and suspect patients using a telemedicine system. This COVID-19 system service box contains 4 self-checking medical sensors, namely, (1) thermometer, (2) pulse oximeter, (3) blood pressure machine, and (4) glucometer for patient’s health monitoring including a tablet PC installed with COVID-19 system application for communication between patient and doctor for tele-consultancy.

Results: This study conducted a COVID-19 triage among 300 villagers and identified 220 green, 45 light-yellow, 2 yellow, 30 orange, and 3 red patients. Besides the 3 red patients, the call center doctors also referred another 13 patients out of the 30 orange patients to health facilities for PCR tests as suspect COVID-19 positive, and to go under their follow-up. Out of these (3 + 13 = 16) patients, only 4 went for PCR test and 3 of them had been tested positive. The remaining orange, yellow and light-yellow patients were advised home quarantine under the follow-up of the PHC health workers and got cured in 1–2 weeks.

Conclusions: This system can contribute to the community healthcare system by ensuring quality service to the suspected and 80% or more tested COVID-19 positive patients who are usually in the moderate or mild state and do not need to be hospitalized. The PHC COVID-19 system provides services maintaining social distance for preventing infection and ensuring clinical safety for both the patients and the health workers.

1. Introduction

WHO declared the COVID-19 outbreak as a pandemic on March 11, 2020, and it has appeared as a threat to the entire world irrespective of the economy [1,2]. The sudden appearance of this pandemic in the low economies created a huge panic because these nations are not at all prepared to deal with such a huge number of very infectious COVID-19 positive patients within a short time with their existing healthcare facilities. So there needs a way to classify the patients, so that, the most vulnerable patients can be treated in hospitals under the direct

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supervision of the health workers. The less vulnerable patients can be treated separately outside of hospitals. The good thing with the COVID-19 positive cases is that about 80% of patients are in the mild or less vulnerable group as reported by various reports [3]. These 80% or less vulnerable patients can be treated in temporary isolation centers or even at their homes in a quarantined state. Considering the support to this large group of patients, the PHC COVID-19 system has been developed. Using telehealthcare facilities, this system can monitor the patients’ health status, follow up and provide doctor’s consultancy from distance. COVID-19 is a very infectious disease, and it can be easily transmitted by respiratory droplets and physical contact with a COVID-19 positive patient [4,5]. Thus, many of the valued healthcare resources get infected to death. As of June 13, 2020, at least 78,052 people have been infected in Bangladesh [6] among which more than 4% are the healthcare workers whereas it is 2.5% worldwide [7]. The health workers are recommended droplet and contact precautions when caring for patients [8]. This system ensures the safety and security of the health workers, and the care of the patients maintaining a safe distance. The patients also feel safe being isolated from other patients.

Besides the monitoring, follow-up, and treatment of the patients, this study introduces a questionnaire-based triage system both on symptom and contact history, considering the Japanese triage system as a basis, for early detection of suspected COVID-19 patients [9-11]. This triage system classifies patients into 5 categories namely green (healthy), light-yellow (slightly doubtful), yellow (doubtful), orange (suspected), and red (emergent as possible COVID-19 positive).

Thus, this triage system does not confirm COVID-19 positive cases but detects high-risk patients who need confirmation PCR tests and separates others. This could contribute to preventing crowds at the PCR test centers and hospitals where there is a limitation of the testing facilities, especially in developing countries. This way it can contribute to making the best use of the valued medical resources, and facilities in an emergency situation like the COVID-19 pandemic.

2. Materials and methods

The COVID-19 pandemic has appeared all of a sudden and no country was prepared to tackle the situation from the beginning. As a developing country, there is a huge shortage of healthcare facilities in Bangladesh and there was only limited scope of PCR tests for confirming COVID-19 for 16 million people in early 2020. There was no antigen rapid test as well at that time. Therefore, there was a huge crowd in the PCR test centers and sometimes people who need the test more cannot get tested. This limited scope of test was only in the cities and there was no opportunity at all in the rural area. The rural people needed to visit a city for tests and it was too difficult and expensive for them. The target group of this study was these rural communities. The triage protocol of this study is to identify the community patients who are most vulnerable and need to go for tests. Thus, this reduces the anxiety of the rest and prevents them from unnecessarily visiting the PCR test centers to make the best use of these limited resources.

2.1. PHC COVID-19 triage protocol

Triage is always a recommended process for the better management of the patients based on their status of severity. In case of the sudden appearance of COVID-19 as a pandemic, triage is very necessary to ensure the prior service to the patients who need immediate attention and PCR test followed by hospitalization. This research introduces a new triage system based on the experience of Japanese COVID-19 triage practice, and it has been carefully tested and verified in some rural and urban areas of Bangladesh. As there is no final discovery yet on the COVID-19 for its changing character, we may need to revise or modify this triage logic with our experience in time or with the change of the geographical location with the different environments to use it in other economies.

This COVID-19 triage system is a combined triage system of both symptoms-based triage and contact history-based triage. The medical history with non-communicable diseases, physical status, working environment, and smoking habit of a patient has been identified as a very important factor to influence the morbidity and mortality of the patient [Table 1]. Thus, this research considers any patient with any of the following positive histories to be more vulnerable and marked as (**), meaning “vulnerable”, in Figs. 1 and 2.

Fig. 1 shows the symptom-based triage logic. This symptom-based logic considers the following symptoms as the factors to be identified as possible COVID-19 positive. These are fatigue, dyspnea, fever, cough, joint pain, muscle pain, sore throat, loss of taste, and loss of smell. These are marked as (***) meaning “symptomatic” in Figs. 1 and 2. In this study, the severity level scale has been considered as 1–10 (1 is very low and 10 is extremely high). Also, the duration of the symptoms is collected as a valued factor.

As stated above, in this triage process, the patients are classified into 5 categories, namely, (1) green, (2) light-yellow, (3) yellow, (4) orange, and (5) red. If the patient:

1. Does not have any symptoms, the patient will be considered as green or healthy.
2. Have one or more symptoms of fever, fatigue, dyspnea, cough, sore throat, joint pain, and muscle pain of light level but none above will be considered as light-yellow or slightly doubtful.
3. Have one or more symptoms of fever, fatigue, cough, sore throat, joint pain, and muscle pain of moderate or severe level except fever for less than 4 days (or 2 days in case of vulnerable patients) but none above will be considered as yellow or doubtful.
4. Have one or more symptoms of fever, fatigue, cough, sore throat, joint pain, and muscle pain of moderate or severe level except for fever for more than 4 days (or 2 days in case of vulnerable patients) but none above, or any of severe fever, moderate dyspnea and abnormality in sense of taste and smell will be considered as orange or COVID-19 suspect.
5. Have one or more symptoms of fever, dyspnea, fatigue, cough, sore throat, joint pain, and muscle pain of extreme level or dyspnea of even severe level will be considered as red or possible COVID-19 positive.

All red patients are immediately advised by the health workers, who conduct the triage, to attend the hospital for PCR test, and to go under hospital supervision.

The orange patients are instantly connected with the remote call center doctors to have tele-consultancy, and the doctors can refer any patient to the hospital for confirmation PCR test or advise them to stay under home quarantine with the provision of daily follow-up of the health workers. If all symptoms (fever, fatigue, cough, sore throat, joint pain, and muscle pain) of an orange patient are improved and fall under moderate or lower level, dyspnea falls under light level or lower level, and no problem with the sense of taste or smell for consecutive 4 days or more, the patient will be shifted to the yellow zone. However, if any of

### Table 1

Medical history, physical status, working environment and smoking habit that make patients vulnerable.

| Question                                                                 | Yes/No |
|--------------------------------------------------------------------------|--------|
| 1. Are you a health worker (doctor, nurse, medical assistant, etc.)?     |        |
| 2. Have you ever been diagnosed with diabetes?                           |        |
| 3. Have you ever been diagnosed with hypertension?                       |        |
| 4. Have you ever been diagnosed with heart diseases?                     |        |
| 5. Have you ever been diagnosed with chronic pulmonary disease?          |        |
| 6. Have you ever been diagnosed with kidney diseases (including hemodialysis)? |        |
| 7. Are you taking any kind of immuno-suppressants for last 2 months?      |        |
| 8. Are you currently diagnosed with any kind of cancer?                  |        |
| 9. Are you pregnant now?                                                 |        |
| 10. Do you currently smoke or chew any tobacco products (or even 1 cigarette per day)? |        |
Fig. 1. Symptom-based COVID-19 triage logic.

Fig. 2. Contact history-based COVID-19 triage logic.
the symptoms get worst to an extreme level or dyspnea to a severe level or full loss of the sense of taste or smell, the patient will be considered in the red zone, and the health worker will directly send the patient to a hospital for PCR test, and to go under hospital supervision.

The yellow patients are kept under home quarantine with a provision of daily follow-up of the health workers. If all symptoms (fever, fatigue, cough, sore throat, joint pain, and muscle pain) of a yellow patient are improved to a normal level, and it continues for 3 days, no problem with dyspnea as well as in sense of taste and smell, the patient will be shifted to the green zone and set free. If all symptoms (fever, fatigue, cough, sore throat, joint pain, and muscle pain) are improved but still the severities are in the light level, the patient will be considered in the light-yellow zone. However, if the symptoms (fever, fatigue, cough, sore throat, joint pain, and muscle pain) remain at the same level for 4 days (or 2 days in the case of vulnerable patients) or more, or moderate level of dyspnea occurs, or abnormality in the sense of taste or smell found, the patient will fall under the orange zone.

The yellow patients are kept under home quarantine, but they are advised to be under self-monitoring. However, they are advised to notify the health workers if the health status gets worsens or remains the same for 4 days (or 2 days in case of vulnerable patients) or more. If all their symptoms (fever, fatigue, dyspnea, cough, sore throat, joint pain, and muscle pain) are improved to a normal level, and it continues for 3 days, there is no problem with the sense of taste and smell, the patient will be shifted to the green zone, and set free. If the symptoms (fever, fatigue, cough, sore throat, joint pain, and muscle pain) get worsen to be moderate, severe, or extreme level, the patient will be shifted to the yellow, orange or red zone as in Fig. 1. However, if the symptoms do not change for 4 days (or 2 days in case of vulnerable patients) or more, the patient should call the health worker. Then the health worker will investigate and decide as per the triage protocol explained above.

The contact history-based logic considers the contact history of the patients with any tested positive or suspect or probable COVID-19 patient as defined by WHO (Appendix).

In this contact history-based triage process, the patients are classified into different categories as follows:

1. A patient who does not have any symptoms, and does not have any contact (at least talked for 15 min being within a 2-m distance) with a probable or suspect or confirmed COVID-19 patient will be considered as green or healthy.
2. A vulnerable patient who does not have any symptoms, but has contact with a probable or suspect COVID-19 patient will be considered as light-yellow or slightly doubtful.
3. A patient who is not vulnerable, and s/he does not have any symptoms but has contact with a confirmed COVID-19 patient will be considered as yellow or doubtful. Besides, if a patient is vulnerable but does not have any symptoms, and has contact with a probable or suspect patient will be considered yellow or doubtful.
4. A vulnerable patient who does not have any symptoms, but s/he has contact with a confirmed COVID-19 patient will be considered an orange or COVID-19 suspect. Besides, if a patient has any symptoms, and has contact with a confirmed or suspect or probable COVID-19 patient will be considered as an orange or COVID-19 suspect.

The orange patients are instantly connected by the health workers with the remote call center doctor to have tele-consultancy, and the doctor may refer them to the hospital for confirmation PCR test or advise them to stay under home quarantine with the provision of daily follow-up of the health workers.

The yellow patients are kept under home quarantine with a provision of daily follow-up of the health workers. In the case of a non-vulnerable yellow patient who had contact with a COVID-19 confirmed patient, if any symptom appears, the patient will be instantly shifted to the orange zone. On the other hand, if the health worker finds the health status of the patient remains without any symptoms for 14 days, the patient will move to the green zone. In the case of a vulnerable yellow patient, who had contact with a COVID-19 probable or suspect, if the contact person gets tested positive, the yellow patient will soon be transferred to the orange zone. If the test is negative, and there is no symptom in the patient, the patient will soon move to the green zone.

The light-yellow patients are kept under home quarantine, but they are advised to be under self-monitoring. However, they are advised to call the health worker if the health status gets worsens or remains the same for 4 days (or 2 days in case of vulnerable patients) or more. If there is any symptom during this home quarantine time, the patient will be shifted to the orange zone. If the contact person gets tested positive, the patient will be shifted to the yellow zone. However, if the contact person is tested negative, and the patient does not have any symptoms, the patient will be shifted to the green zone and set free.

2.2. System operation methods

The PHC COVID-19 system works in 2 stages. First, it is used for the identification of the suspected COVID-19 positive patients using the triage protocol as explained in Section 2.1. Once a patient is identified as a red patient as the triage flow explained in Fig. 3, s/he needs to get a confirmation PCR test.

Out of all tested positive patients, only 10–20% are in a severe state and the rests are of moderate or mild level. These severe patients need to be hospitalized but the rest can be treated in a home quarantined state. However, these patients need to be regularly followed up and get doctor consultancy. The PHC COVID-19 system has been developed as a total solution for supporting this second stage of service as well. The basic PHC has primarily been developed as a remote healthcare system for primary healthcare services with a special focus on Non-Communicable Diseases (NCDs) [12–14]. Later the functionality of this system has been extended to the areas of Tele-Pathology, Tele-Eye care, and Maternal & Child Health (MCH) care [14]. Besides, a new algorithm for the post-disaster operation has also been established [15]. Based on this algorithm, we have established this COVID-19 module with a new COVID-19 triage logic for better management of the patients in Bangladesh where there is a huge shortage of COVID-19 confirmation PCR test facilities and the follow-up treatment in hospitals. There are various COVID-19 triage protocols developed by different research groups [16–18]. This triage system does not trace the confirmed COVID-19 positive but it sorts out most potential COVID-19 suspects who should go for a confirmation test. Thus, it can reduce the pressure on the confirmation test centers, and helps for the best of use of the limited resources.

2.3. Home quarantine follow-up service

The PHC COVID-19 system can be used to follow up on the health status of the home quarantined remote patients by using self-driven digital and handy medical sensors temporarily leased to the patients, and providing doctor’s consultancy using its remote healthcare system. The COVID-19 service box contains 4 basic medical sensors. These are (i) Thermometer (TERUMO) for measuring body temperature, (ii) Pulse Oximeter (OXI MATE) for measuring oxygenation of the blood, (iii) Digital BP Machine (A&D) for measuring blood pressure, pulse rate, and arrhythmia and (iv) Glucometer (TERUMO) with consumables for measuring blood glucose in case of diabetic patients. Besides, this box contains all necessary accessories including plastic bandages, sanitizing wet tissue, backup batteries, a battery charger, and a medical waste bin. As this box is provided to the patient with a handy users’ manual, the patients can easily check their health status, and share the data with the health worker through the COVID-19 application installed in the tablet PC provided with the PHC box. Thus, the health worker can monitor the progress of the health status of the patients using the triage protocol, and whenever necessary she can forward this case to the call center doctor for direct consultation with the patients. Thus, the frontline medical staff
can keep a distance to avoid infection, but they can ensure quality service to the home-quarantined COVID-19 patients.

In case, a patient is a senior citizen, weak, or not confident to use the medical sensors of the PHC box, the health worker can visit the patient with safety measures, and s/he conducts this simple physical checkup within a short time. This way, a single set of COVID-19 service boxes can be used by one health worker for a number of patients in the same neighborhood.

3. Results

In this research, we have applied our COVID-19 triage logic to classify 300 subjects, who had a sort of concern about COVID-19, into five groups in early June 2020. The logic identified 220 green, 45 light-yellow, 2 yellow, 30 orange, and 3 red patients (Fig. 5). According to the protocol, the red patients were directly advised by the health workers to visit the hospital immediately and to take a confirmation PCR test. The orange patients were connected to call center doctors, and the doctors advised PCR tests to those who were considered highly suspected as per investigation. The other orange patients were advised to maintain home quarantine. These home quarantined orange patients and the yellow patients, who were also advised by the health workers to maintain home quarantine, were followed up by the health workers regularly. If the situation of a patient got worsened, the patient was connected to the call center doctors for consultation.

Light-yellow patients were also advised by health workers to maintain home quarantine, but they were asked to report to the health worker if their situation changes. Only the green patients were set free with the basic advice, i.e., use of mask, washing hands with sanitizers, keeping social distancing, etc., for maintaining regularly to keep them safe.

Besides the 3 red patients, initially, our call center doctors referred 13 patients out of the 30 orange patients as probable/suspect COVID-19 patients to health facilities for a confirmation PCR test, and to go under follow-up care there. Out of these $(3 + 13 = 16)$ patients, only 4 went for PCR test and 3 of them had been tested positive. The other 12 patients did not attend PCR tests. The reasons as stated by the patients are (1) do not have PCR test centers in the close neighborhood, (2) long queues in the government PCR test centers and cannot wait for such a long time, (3) do not have financial ability to afford PCR test at private hospitals and (4) felt better being home and did not feel necessary for the test. However, there could have another reason for this. Actually, there is a big social issue now in the rural communities of Bangladesh that once someone identifies as COVID-19 positive, his/her family goes under complete lockdown, and the local communities fully avoid them. So many peoples like to hide the symptoms and try to avoid confirmation tests.

However, this study followed up 18 home quarantined patients including 2 yellow and 16 orange patients (excluding 1 who refused to get follow-up service) who were advised for going under follow-up by the remote doctors. Being under the daily supervision of our health workers and attending remote doctor consultancy, all 18 probable or suspect patients got green, and they were declared free of COVID-19 in 1–2 weeks as shown in Fig. 6.
4. Discussions

The PHC COVID-19 system has been primarily designed for developing countries where there is a huge shortage of healthcare facilities and medical human resources. In this system, we have introduced symptom-based and contact history-based triage logic and both of the logics can be used individually. In this study, the contact history-based triage was used for those who had contact history, and symptom-based triage was used for those who did not have contact history but symptoms.

The triage protocol proposed by the Ministry of Health, Labour and Welfare of Japan at the time of this study considered only body temperature (> 37.5 °C), fatigue, and breathing problem [19]. This is a very conscious approach to identifying them as suspects and sending them for a confirmation test. This is a good approach for a developed country where there are sufficient test facilities. However, this could not be appropriate for a developing country like Bangladesh because it would identify a larger number of suspects who will need tests with limited resources. Therefore, we proposed a stricter triage protocol to reduce the number of suspects and identify the patients who should be prioritized for testing. There is a risk of ignoring some potential candidates but this triage logic is more suitable for the developing countries in the context of their limited test capacity. However, this triage protocol can be adjusted to cover more suspects when the test capacity improves.

There are some observations as challenges to operating this service in these communities.

- The COVID-19 triage logic does not identify COVID-19 positive patients but the suspected COVID-19 patients who need to go for a COVID-19 confirmation test, i.e., PCR test. However, this study found that most of the COVID-19 suspects identified did not attend confirmation tests as they did not have that facility in their neighborhood. To ensure the test, as a home delivery healthcare system, this COVID-19 system needs to have a test facility within itself.
- For remote follow-up and treatment of a tested COVID-19 positive patient under a home quarantine state, a patient needs to have a PHC COVID-19 service box at home for self-checking and then communicating with the remote health workers. However, it could not be affordable to many rural patients in developing countries. Therefore, the service box should be shared by a number of patients in a close neighborhood with the support of the local health workers with high safety protection.
- As the home quarantined patients need to self-check their health status using the COVID-19 service box, it could be difficult for the villagers with low literacy or aging communities. The patient may need some time to get used to it.
- A home quarantine patient needs to have an isolated room for treatment. However, most of the rural communities in the developing countries maintain big joint families, and they need to share 1 room with many people. This makes it difficult to isolate the COVID-19 patient at home for providing effective service ensuring the safety of other family members.

Based on this experience and the latest development of the COVID-19 situation, this study proposes a few areas of improvement of this system in the future to overcome the challenges.
• This study identified that many suspected patients did not go for the test due to the hassle they need to face to get the service as there were no test facilities in the close neighborhood. This is very alarming for the management of the pandemic situation. Therefore, there is a need to have some rapid testing capacity in the PHC system. The future COVID-19 service box can accommodate such a COVID-19 antigen rapid test kit and conduct the rapid test of the suspected patients locally.

• The future COVID-19 service box may also contain PCR test kits for saliva collection for the tested positive patients and the health worker can collect and support the PCR tests for those who are positive in the rapid antigen test. This will reduce the number of patients who skip tests for the hassle.

• The symptoms of COVID-19 vary according to the variant. Therefore, the triage logic setup of this system should be configurable so that it can easily adjust the changes to address a new variant.

5. Conclusion

The PHC COVID-19 system could be a very useful system for maintaining highly infectious COVID-19 by providing healthcare services using remote tele-consultancy support. This is especially very important for the countries with a low economy where there is a huge shortage of medical facilities and healthcare resources. This home delivery service can avoid the huge crowd in the hospitals and the test centers that cause infection among the doctors, nurses, and other staff besides the visiting patients.

This service has been designed and developed to target rural community patients in Bangladesh. But this easily replicable service model can be implemented in any developing country as the condition is more or less the same in the pandemic situation. However, there are many challenges as stated above, and these should be addressed properly for bringing confidence to the patients as well as the health workers.

Ethical approval

This study was approved by the Kyushu University Institutional Review Board for Clinical Trials.

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Supplementary materials

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