Chapter

# Practice Changing Innovations for Emergency Care during the COVID-19 Pandemic in Resource Limited Settings

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## Abstract

COVID-19 has affected millions worldwide. To combat the infectious pandemic in resource limited settings, healthcare workers and techies have come up with multiple innovations. Nations with scarcity of resources have resorted to innovative strategies involving optimal utilization and repurposing of available commodities to overcome the demand–supply mismatch. Emergency rooms overburdened with diseased population are resorting to local innovative ideas to overcome obstacles in COVID-19 patient care. Point of care testing strategies in emergency rooms, sampling booths to reduce Personal Protective Equipment (PPE) use, disinfection strategies such as tunnel disinfection and local production of sanitizers, face masks/shields, aerosol containment chambers, novel triage protocols, telehealth care strategies reaching out to remote population and utilizing point for care ultrasound for resuscitation are few of the novel innovations which have benefitted medical fraternity and patient care in testing times. Medical innovations have emerged as the positive outcome of otherwise devastating COVID-19 pandemic. These practice changing innovations could also prove beneficial in future infectious pandemics.

**Keywords:** COVID-19, innovations, emergency care, resource limited settings, demand–supply mismatch

## 1. Introduction

COVID-19 pandemic has affected millions worldwide. Most developing countries being densely populated, has witnessed swarming number of cases. To combat the infectious pandemic in the resource constraint settings healthcare workers and techies have come up with multiple innovations [1]. Government has also played a role by implementing policies of universal masking, physical distancing, lockdowns, ban on mass gatherings, testing, tracing and isolating suspected and positive cases [2]. Challenges faced by developing economies have been distinct in comparison to those faced by developed nations during the pandemic situation. The COVID-19 pandemic has had devastating impact on already fragile developing nation economies. To cater to demand–supply mismatches, countries have resorted to innovative ideas with available resources. Emergency care deemed a crucial component of

healthcare systems, has been affected enormously. Emergency department has been operating as frontline portal of entry for patients with undifferentiated symptoms into the healthcare setup. Innovations to facilitate emergency care, to reduce burden over healthcare systems, to ensure standard care for all emergency patients by bridging economic and knowledge gaps are being implemented in majority of developing nations.

## 2. Emergency care during COVID-19

Emergency services in most parts of the world have been overwhelmed with patients since the onset of COVID-19 pandemic.

- Need for reorganization of emergency setup: The highly infectious COVID-19 disease warrants strict infection control and prevention measures. Need for areas to cater to COVID-19 positive and suspected patients away from non-COVID-19 patients has forced emergency rooms to reorganize their existing setups.

- Triage: Emergency Room (ER) triage to detect suspected patients early and care for them in designated areas is of paramount importance to prevent spread. This has led to new triage tools such point of care ultrasound based triage in emergency rooms to supplement clinical history and examination in detecting cases quickly. Studies have demonstrated high sensitivity but low specificity in comparison with CT scan to detect COVID-19 related lung pathology [3]. Point of care ultrasound being easily available, portable, quick to perform even in resource limited settings with unavailability of CT scan, has been found helpful in quick ER triage.

- Aggressive symptom screening: As ER is the first point of contact for most patients presenting with severe and undifferentiated symptoms, a need for aggressive symptom screening, manpower training to detect/screen patients, need for judicious resource allocation has aroused.

- Isolation of patients: ER caters to both COVID-19 positive and negative patients thus allowing risk of cross-contamination. Infection prevention measures such as distancing, masking patients, creation of isolation rooms with adequate air exchange has become the new norm. Separate rooms for doffing and donning of Personal Protective Equipment (PPE) are also necessary. All these measures have been challenging to fulfill promptly in emergency setups of resource limited settings.

- Increased need for manpower, PPE, infrastructure: Increasing patient number has translated to increased demands for manpower and essential equipment thus overwhelming the economies [4]. Working hours have undergone modification to ensure healthcare professionals with PPE work 4–6 hours shifts, thus increasing the manpower demand.

## 3. Challenges faced by hospital setups

- Lack of infrastructure: This is one of the major challenge faced by hospitals due to this pandemic. Many hospitals in developing countries lack the preparedness

to handle a sudden outbreak of a pandemic like this and provide for the health needs for every individual of the large population.

- Shortage of beds: Admission of new patients has become difficult because of the burden of the existing patients which are already admitted for treatment. Expanding capacity and creating space for new patients has therefore become a major challenge.

- Ventilators: Apart from the shortage of beds and doctors, hospitals are also facing the shortage of medical equipment like ventilators due to which many of them are not able to treat patients efficiently.

- PPE for healthcare staff: Due to a sudden increase in the demand of the testing kits and PPEs in this outbreak, the supply chains have faced many issues which have also depleted the reserves of the PPEs of the hospitals.

- Difficulty in maintaining adequate number of staff: There is a sudden rise in the requirement of manpower especially during this crisis because these are the people who are required to take the charge of running and managing the hospitals while the doctors and the nurses take up the forefront role of treating the patients. Along with testing and treating the patients for COVID-19, it is essential to keep the hospital staff safe from contracting the virus and getting infected which might lead to the shortage of staff even more.

- Safety and hazardous waste management: Proper and safe disposition of used PPE, masks and wastes from COVID positive patients is also one of the major challenge

- Downfall in the revenue generation for the hospitals: Due to the pandemic, there is a decrease in the patient visits to the hospitals because people try to avoid going to hospitals due to the fear of contracting the virus. Many hospitals had to cancel or postpone the surgeries of their previous patients because they are under the pressure to free up bed space for COVID-19 patients. This has also led to many people losing their jobs or salary cuts in some cases because hospitals are not able to pay them their salaries [5].

## 4. Practice changing innovations

Few simple yet effective solutions have evolved to help developing countries tackle the pandemic.

### 4.1 Innovative testing strategies

Sampling patients to diagnose cases of COVID-19 is considered aerosol generating procedure by itself, thus requiring healthcare personnel (HCP) in full Personal Protective Equipment (PPE) to be recruited. In resource limited settings with scarcity of PPE, the concept of sampling booths has emerged. These are booths similar to telephone booths which are being used widely to sample patients in Delhi, Kerala and other states [6]. An innovative modification of the traditional kiosk called by the name "COVSACK" was made functional at ESI hospital in Hyderabad. The main differences from traditional kiosk being that COVSACK has the suspected patient inside the kiosk instead of the HCP. HCP is positioned outside the kiosk. Kiosk is

also equipped with self-disinfection capability. As HCP is positioned outside the kiosk and at theoretically reduced risk of aerosol exposure, the need for PPE is also reduced [7]. Few models with dual chamber booths have also been proposed and tried [8]. South Korea has devised an innovative model of "Drive Through" COVID-19 testing of patients [9].

Testing using RT-PCR has been the standard but with a drawback of prolonged downtime to obtain results especially in emergency settings. Over ten rapid antibody based kits for quick point of care testing have been devised, approved by Indian Council of Medical Research (ICMR) and validated for clinical use [10]. With easy availability this has led to increased rates of testing along with quicker results particularly in life threatening conditions.

A paper strip based COVID-19 detection test named "Feluda" has been devised by research team at the CSIR-Institute of Genomics and Integrative Biology in India and has been approved by Drug Controller General Of India (DCGI). Feluda is based on Clustered Regularly Interspaced Short Palindromic Repeats-cas 9 (CRISPR-cas 9) technology. The test has been performed on over 2000 patients reporting a sensitivity of 96% and a specificity of 98% which is very similar to the gold standard RT-PCR [11]. With quicker results feluda could help reduce number of patients waiting for over 12 hrs before interventions and definitive management procedures at emergency rooms.

### 4.2 Innovative infection control and prevention strategies

Care of COVID-19 patients revolves around several logistic issues such as availability of oxygen ports and ventilators in resource constraint settings. Innovative methods of oxygen splitting and ventilator splitting to benefit multiple patients using a single device have been proposed and utilized in few parts of the country with success [12, 13]. Critically ill patients mandate interventions such as intubation which is aerosol generation procedure requiring measures to ensure HCP safety. Novel aerosol containment chambers have been designed with modifications and used in India [14, 15]. These plastic or acrylic boxes have openings to allow HCP insert his hands and maneuver as per need.

Innovative negative pressure isolation tents called "Care cube" have been functional in United States to care for COVID-19 patient population [16]. These tents being low-cost models, similar designs can be adapted in resource limited settings for infection control and prevention. Overcrowded ER with lack of free space to set up new isolation areas can resort to such negative pressure tents to cater to COVID-19 positive patients.

### 4.3 Innovative airway management strategies

Companies like AgVa solutions, Big Band Boom Solutions, Aerobiosys, etc. are building cost-effective portable ventilators. They are also lending a helping hand in ramping up the production and supply of ventilators to the hospitals.

InnAccel Bangalore, a Stanford India Biodesign based medical devices setup, has come to the fore with SAANS Pro, a non-invasive breathing support system that was developed to serve as an alternative for ventilators in low resource settings. The device has been designed to function with limited or no oxygen supply, with an added benefit of being portable. This can be used in ambulances to transport patients and in rural tertiary care centers where ventilators are in short supply [17].

The Gradian CCV (Comprehensive Care Ventilator) supports critically-ill patients in settings with unreliable supplies of power and oxygen, including temporary field hospitals being set up to manage COVID-19 patients in many countries.

The ventilator can run for 21 hours on battery power, and its portability features enable single-ventilator use throughout critical care, including patient transport. Simulation-based training is a critical component of Gradian's model, with teams of clinicians and bio-medical technicians providing remote and on-site training to healthcare providers. Gradian has placed ventilators in Nepal, Sierra Leone, Kenya, and several other countries, conducted several remote trainings with clinicians, and is continuing to work with more health systems to build capacity for COVID response and other critical care needs [18].

RespirAID is a portable breathing support system developed by Biodesign Innovation Labs with an aim to meet the shortage of ventilators in Indian hospitals and globally. It uses a ventilation strategy called Intermittent Positive airway pressure that can moderate essential respiratory parameters. This makes it suitable for patients who are at severe risk of lung collapse [17].

### 4.4 Telemedicine innovations to combat COVID-19

Digital healthcare has been a boon in testing times of COVID-19 pandemic. Telemedicine has been used widely for obtaining consultations and care via virtual pathway. Many healthcare setups across the country have switched to telemedicine based patient care. From obtaining appointments before presenting at a healthcare facility thereby reducing overcrowding to obtaining consultations and treatment for minor ailments, telemedicine has facilitated patient care in a simple and user-friendly manner. Telehealth care to a certain extent has helped in maintaining the continuum of care of chronically ill patients unable to visit healthcare setups amid COVID-19 case surges and lockdowns. Telemedicine has been a virtually perfect way to deploy HCP for patient care in remote parts of the country [19, 20].

Prior to the pandemic, the growth of telemedicine has been very slow. The apprehension among the medical practitioners regarding the legality of providing virtual healthcare has been a major contributory factor for the lack of exponential growth of telemedicine. All it required was a little help from the virus, to take telemedicine from sidelines to the centre stage.

With hospital beds and isolation centers stretched more than ever, healthcare organizations are helping patients better manage their care at home when it's deemed safe to discharge them. It can prevent costly and life-threatening readmissions by catching problems before they arise. Patients with mild symptoms receive a telehealth kit that includes a laptop with preloaded apps through which they can monitor their signs and communicate twice daily with a nurse by phone or virtual visit.

### 4.5 Technological innovations to combat COVID-19

#### *4.5.1 Online COVID-19 screening tools*

Artificial Intelligence (AI) Highway provides pre-screening and triage tools that are based on risk-assessment scores for Covid-19, linked to symptoms, contact history and more.

#### *4.5.2 Robots on duty*

With pandemic continuing, many countries have come up with the idea of using robots to help the medical staff which limits the risk to their lives. The major duties of these robots are autonomous delivery of food, medicine and other consumables

inside the isolation wards. They also disinfect the used items and allow patients to communicate with physicians and relatives [21].

### *4.5.3 3D-printed medical equipment*

With the increasing number of COVID cases, the nation is scrambling to address the shortage of Ventilators, Personal Protective Equipment (PPE) and other medical devices. Amid this crisis, Indian research institutions and companies have started hinging on 3D-printing techniques as a quick fix. Medical equipment such as ventilators, face shields, oxygen masks, parts of virus test kits and other protective gear to deal with the pandemic are produced in large numbers with the help of this modern technology to address the shortage. 3D-printed ear guards for hospital staff to help alleviate the pain caused by wearing face masks for too long [22] and 3D-printed ventilator valves for dealing with COVID-19 [23].

### *4.5.4 Artificial intelligence*

The use of AI in healthcare is not a new concept and has been around for long. Researchers and data scientists around the world are looking to use Artificial Intelligence as a way of addressing the challenges posed by the coronavirus. Several hospitals have started using AI software- which learns from experience- to help with diagnosis and assessments. Recently, a group of scientists made use of Artificial Intelligence to identify an underlying genomic signature for 29 different DNA sequences of the novel coronavirus, providing an important tool for vaccine and drug developers.

Indian based Internet of Things (IoT) startup called HELYXON uses AI-enabled devices for better management of the pandemic by constantly monitoring the vital parameters of patients or suspects. 98.6 Fever Watch is another innovation which is useful particularly for unwell children in whom continuous monitoring of temperature is a vital parameter in disease management. It connects to hospitals systems or personal systems and keeps transferring patient information to a central dashboard.

Qure.ai has deployed new solutions that automatically read and interpret chest X-Ray scans for COVID-19 in seconds. This tool quantifies how much of the patient's lungs have been affected, enabling the clinicians to monitor disease progression more effectively.

Bengaluru start-up Predible Health is using AI-based radiology solutions to pre-screen COVID-19 patients with the help of a tool LungIQ, which can measure percentage of lung damage in patients through CT scans & help doctors understand how badly a patient is affected and if he needs a ventilator or not.

Aggressive contact tracing:

Using mobile apps, security camera footage, facial recognition technology, bank card records, and global positioning system (GPS) data from vehicles and mobile phones to provide real-time data and detailed timelines of people's travel. Acrylosorb- an instrument to collect body fluids and to dispose of it safely, an isolation pod that restricts COVID-19 patients from having contact with others.

### *4.5.5 Contact tracing apps*

Contact tracing applications enable users who have come in contact with COVID-19 positive patients to be notified, traced and suitably supported. The Aarogya Setu was initially conceived as a sophisticated tracking tool to map out epidemic hotspots. But along with that it is capable of exchanging short-distance Bluetooth signals when individuals are in proximity to each other. The application

records these encounters and stores them in their respective mobile phones. If an individual is diagnosed with COVID-19, government accesses the data to identify contacts of the infected person. South Korea implemented tools for aggressive contact tracing, using security camera footage, facial recognition technology, bank card records, and global positioning system (GPS) data from vehicles and mobile phones to provide real-time data and detailed timelines of people's travel. By identifying and isolating infections early, South Korea maintained among the lowest per-capita mortality rates in the world [24].

Through "Corona Watch" application, the location of corona affected patients can be tracked and their movement history of last 14 days can be recorded. A containment watch app has also been developed to undertake survey in containment zones and ensure the provision of essential services.

*4.5.6 Drone technology*

Drones are being used for delivery of blood, medicines, PPE and other essential medical supplies in many countries [25].

## 5. Proposed innovations

World economic forum has described five ways collective intelligence could prove beneficial to help combat coronavirus in developing countries. Similar strategies could be the way forward to deal with the infectious pandemic.

### 5.1 Mapping medical supply demands

Awareness regarding the needs and necessities of the nation is of paramount importance. Developing countries may not be able to compete with richer economies to procure resources and supplies such as masks, ventilators and other essential commodities. It has thus been proposed for frontline workers to use applications such as "Frontline SMS" to report shortage of key equipment on a common website. The reported data can be uploaded on a map showing shortage locations. This will allow local manufacturers, humanitarian agencies, government organizations and businessmen to respond and help in crisis areas. Similar technology is already in use since over a decade in Africa to map essential medicine supplies.

### 5.2 Localized production of supplies

When traditional logistics fail to cater to overwhelming crisis situations, organizations such as "Field Ready" have proven beneficial to procure essential supplies and equipment for care in crisis zones. "Field ready" is already functional in countries such as Nepal to cater to local demands and to improvise healthcare. Its utility can be extended to cater to COVID-19 pandemic. Governing bodies can utilize local marketplace and manufactures to fulfill essential supply demands. During COVID-19 lockdown situations, local 3D printing vendors can be allowed to operate as "essential infrastructure" thus helping economies become self-reliant.

### 5.3 Resource and asset identification

Identification of available assests is important. Emergency care has been burdened by increasing load of COVID-19 positive patients. Stable patients and those fit for home isolation might hoard in emergency care facilities as emergency is

readily accessible and these patients might be dwellers of overcrowded households with no opportunity to isolate themselves at their residence. In such scenarios identification and repurposing of areas such as schools, stadiums into mass quarantine centers could prove helpful.

### 5.4 Smarter surge response

Most countries face shortage of healthcare workers to cater to rapidly expanding patient population. Training and education activities to deploy community health workers for screening and symptom assessment could prove beneficial [26]. This would also reduce the burden of patients with minor symptoms presenting at hospital triage facilities. In India, ASHA (Accredited Social Health Activists) and anganwadi workers are being trained on infection prevention measures, infection control, initial patient assessment, care and other COVID-19 related topics [27]. Such initiatives can be implemented in other developing countries with gross shortage of healthcare staff.

### 5.5 Medical education

Mobilizing collective intelligence of frontline healthcare professionals across the world can help medical staff in developing countries gain relevant and essential knowledge quickly. Praekelt.org in South Africa has introduced Health-Alert, a WhatsApp-based helpline disseminating accurate, timely COVID-19 information, with automated answers to frequently asked questions, relieving call centre traffic. Machine learning and its ability to understand natural language enable automatic triage advice and large volume conversations. Insights from real-time data support effective systems-level COVID- 19decision-making [18]. Telemedicine and internet based communications could serve as portals for percolation of knowledge among peers.

## 6. Future perspectives

COVID-19 pandemic has taught many useful lessons to the world. Handling the chaos, judiciously utilizing the available humanitarian supplies, re-purposing resources to meet demands and striving to cater to masses affected has been the prime focus during this pandemic. Every sphere of life has been hampered by COVID-19 and left developing economies struggling. Health for all being the goal of every existing nation, emergency care during the pandemic has been hampered. To prevent and attenuate similar stressful scenarios in future, there is need for:

- Mitigation and emergency preparedness for future infectious pandemics: Infectious pandemic such as COVID-19 are public health emergencies. Applying the concepts of emergency management, such as use of Emergency Operation Centers (EOCs) and Incident Management Systems (IMS) could help public health systems protect populations impacted by health emergencies. State and national programmes to device a uniform “Emergency Management Plan” (EMP) as per CDC (Centre for Disease Control) advice for preparedness and response during pandemics is need of the hour [28]. With EMP in place nations will be aware of their resources, demands and shortcomings. During an infectious outbreak there will be reduced chaos with easier and earlier recruitment of humanitarian supplies as per the response strategy of emergency management plan.

- COVID-capable/Pandemic resilient healthcare system: Existing healthcare systems need to transform into pandemic resilient healthcare setups considering the current day scenario of ever increasing disease burden. Rather than focusing on building COVID-19 patient care setups, the emphasis should now be on making the existing healthcare setups to become self-reliant to care for COVID-19 patient population. Repurposing humanitarian supplies and infrastructure to achieve this could prove useful.

## 7. Conclusion

COVID-19 has had devastating effects on health and economy of the country, but COVID-19 has also forced innovative minds to emerge with novel ideas for combating the infectious pandemic and helping mankind. Thus COVID-19 era has witnessed a bundle of innovations with majority of them aiming to balance demand supply discrepancy.

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The authors declare no conflict of interest.

## Acronyms and abbreviations

| | |
|---|---|
| PPE | Personal Protective Equipment |
| ER | Emergency Room |
| HCP | Healthcare personnel |
| ICMR | Indian Council of Medical Research |
| DCGI | Drug Controller General Of India |
| AI | Artificial Intelligence |
| IoT | Internet of Things |
| EOC | Emergency Operation Centers |
| IMS | Incident Management Systems |
| EMP | Emergency Management Plan |

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