A Validation Study on the Physiological Parameters Recorded by COVIDBEEP - An Indigenous Remote Health Monitoring System Designed for COVID-19 Care in India

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Abstract

Background: COVID-19 pandemic has affected mankind globally. After the three waves since March 2020, the threat continues instilling fear in the minds. Vital parameter monitoring through remote health monitoring system (RHMS) becomes critical for effective disease management and manpower safety and confidence. In a low resource setting like India, a comprehensive, wearable, and remotely operable device that is economical was required to be introduced for COVID-19 care. Present study validated the remote health monitoring device named COVIDBEEP with gold standard equipment. **Materials and Methods:** Six parameters, namely heart rate, SpO2, respiratory rate, temperature, blood pressure, and ECG were acquired in the supine position using the devices. **Result:** Analysis was performed using Graph Pad Prism. Intraclass correlation coefficients were used to measure concurrent validity. Bland–Altman graphs were plotted to know the agreement for each vital parameter. Confidence limits were set at 95%. All the parameters recorded from the devices showed a significant correlation with an "r" value between 0.5 and 0.9 with *P* value between 0.001 and 0.0002. Bland–Altman plots showed a minimum bias of 0.033 for heart rate and maximum of 3.5 for systolic blood pressure and respiratory rate. **Conclusion:** The association between the parameters recorded by the devices strengthened as the time of collection of data increased. Agreement between the two methods in 95% confidence interval was also proven to be significant for the parameters. Therefore, the indigenously developed COVIDBEEP has shown good validity in comparison to standard monitoring device.

Keywords: COVIDBEEP, COVID-care device, remote health monitoring system, IOT, validation

Background

COVID-19 pandemic has drastically affected mankind globally and after the few waves since March 2020, the threat from the disease continues with fear in the community. Many were infected by the virus, admitted to hospitals in different stages of the disease with various outcomes. Monitoring patients during the pandemic was a highly challenging task with constant exposure leading to high risk of transmission of virus to frontline healthcare workers. To minimize the contact, a remote health monitoring system (RHMS) became critical in a hospital setup which would not only minimize physical contact but also reduced the need for manpower and enable implementation of safety precautions among staff.[1] Problems associated with such pandemics were further complicated in a limited resource country like India. Objective and automated approaches have been proposed for syndromic surveillance in the past using statistical algorithms that compared data to non-outbreak trends.[2] COVID-19 pandemic has shown a high fatality rate due to respiratory failure.[3,4] Continuous monitoring of physiological parameters had become critical for SARS-CoV-2-infected

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individuals due to the unpredictable outcome of the disease. Parameters like body temperature, respiratory rate, and oxygen saturation had to be monitored continuously. Clinical manifestations in COVID-19 were found to be heterogenous and many patients infected had co-morbidities like diabetes mellitus, cardiovascular disorders, and hypertension and were immune-compromised leading to complications. Monitoring additional parameters indicative of hemodynamic stability like heart rate, non-invasive blood pressure monitoring (NIBP), and ECG became essential.[5] In addition, various drugs like Hydroxychloroquine and Azithromycin initially used for prophylaxis and management of COVID-19 and were known to have effects on cardiovascular balance in the body.[6-8] Therefore, the objective was to develop a complete comprehensive, accurate, wearable, and remotely operable device that would be economical and safe in a low resource setting as India.

Materials and Methods

Conception of the idea to design a Remote Health Monitoring System (RHMS)

To address the above issue, researchers from the department of Physiology at ESIC Medical College, Hyderabad (under the Ministry of Labour and Employment) and team of engineers from Electronics Corporation of India Limited (ECIL—A Government of India enterprise) came together to design a novel comprehensive remote monitoring system. It was named COVIDBEEP; Continuous Oxygenation and Vital Information Detection Biomed ECIL ESIC Pod which is Internet of Things (IOT)-based versatile indigenous instrument with a mobile app and web browser by which patients could be monitored remotely. Testing and validation was done in the Department of Physiology of the medical college. The idea was to have its utility beyond the pandemic even for routine clinical management of patients living in remotely accessible areas, in radiotherapy units, high risk maternal, and child groups, along with any other group(s) that required constant surveillance.

Technical Description of the device COVIDBEEP is shown in Figure 1 with hardware description:

A. **Wearable Device**: It consists of a small box of 85 X 41 X 75 mm (dimensions) mounted on a strap. The strap serves dual purpose used for securing around the wrist and also as the inflatable blood pressure cuff. The device was equipped to measure six parameters, heart rate, SpO_2, respiratory rate, body temperature, blood pressure, and ECG by non-invasive method and transmits information over long range BLE to IOT-based gateway and is designed around a Digital Signal Processor. It also has a built-in GPS and GSM module that was enabled to transmit the parameters directly to cloud/server in the absence of an IOT gateway. Automatic switching facility was created between IOT and GPS and GSM module when one moves toward or away from the range of IOT, respectively. The block diagram of the device is shown in Figure 2.

B. **IOT Gateway**: It was enabled to receive data from a maximum of 20 wearable devices (maximum 20 devices per 1 gateway) to transmit the concatenated data to cloud/private server using GSM. Data were transferred to local LAN or WAN. The Gateway concatenates the data received from different wearable devices (max 20) and pushes to cloud or private server via internet. The internet connectivity to gateway can be accomplished by LAN, WI-FI, or CELLULAR networks. It has provision to use existing GSM network and works with any Indian cellular service provider. These gateways were placed at strategic locations in the hospital wards for good coverage. The data were gathered by Central monitoring server using HTTP web services like REST/JSON/MQTT, etc., and equipped with huge memory for back up during loss of connectivity. The Embedded Linux operating system running on gateway would allow collecting data and push the same to the cloud simultaneously. In case of usage by home-quarantine patients or in remote locations where

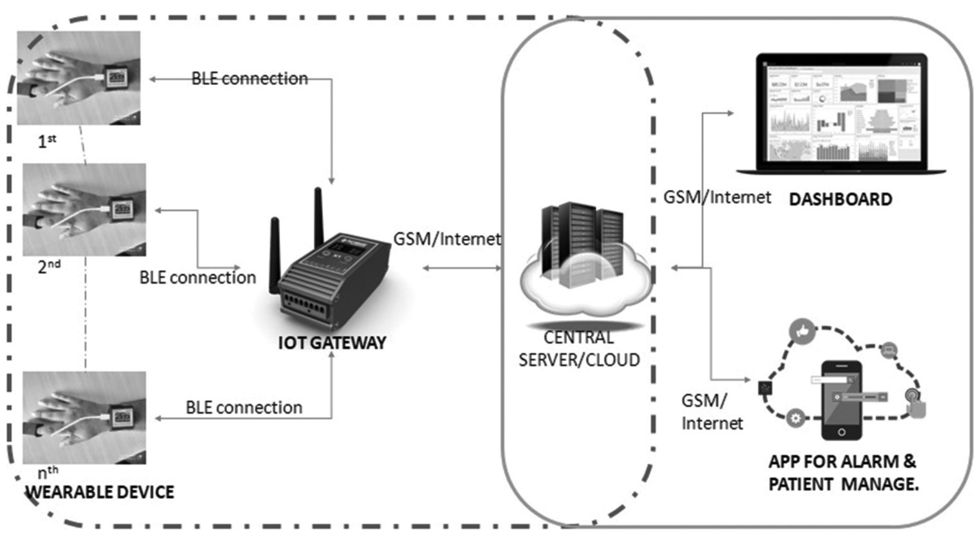

Figure 1: Remote wearable health monitoring system with IOT [Provided by Electronics Corporation of India Limited (ECIL)]

internet was not available, the wearable device itself could communicate to cloud or server with inbuilt GSM/GPRS network without talking to gateway.

C. **Database Management System:** A Cloud/Server with database engine was used to maintain and manage data for facilitating dashboard and various kinds of reports.

D. **Mobile App:** Patients were allocated to doctors and health care workers using this app to monitor the physiological parameters of their COVID-19 patients. Automatic alert signals are generated when parameters cross the preset safety limits. In addition, an SOS button when used by the patient immediately alerts the concerned health professional and ambulance services [Figure 3]

E. **Dashboard:** A web-based application for dashboard provides a summary of all the patients of a particular quarantine room/hospital/districts/states/country. This could be viewed on Mobile/Tablet/Desktop/Large Display [Figure 3].

F. **Bhuvan Maps:** The real time location tracking of COVID-19 patients and Red, Green, and Orange Zones of COVID-19 pandemic are shown on maps using Bhuvan on-line portal mapping service with active support from NRSC, Hyderabad, ISRO [Figure 3].

The following are the salient features of the application:

- Hospital/Home/Cluster-based health monitoring.
- A real-time Database Management System for pandemics like COVID-19

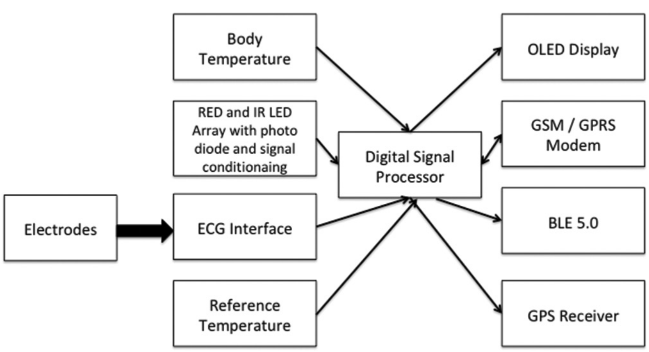

Figure 2: Block diagram of wearable device

- Location tracking through indigenous Bhuvan on-line mapping Portal of ISRO [Department of Space, Government of India].
- Display of geographical distribution of suspected or infected cases like those of COVID-19 pandemic.
- Real time monitoring of patients.
- Real time alerts when the monitored patient parameters exceed the pre-set threshold level.
- Real time display of six physiological parameters including heart rate, SpO_2, respiratory rate, body temperature, blood pressure, and ECG.

Communication

The wearable device communicates the six physiological parameters of the patients to remote distances in the following two configurations:

a. The device sends the data to IoT gateway over a long range BLE. The gateway has the communication features to connect to hospital LAN/WAN or dedicated PCs for monitoring, database, etc. The gate way also has GSM/GPRS feature to communicate with cloud/private servers over mobile network communications.

b. The device directly sends the data to cloud/server using GSM/GPRS over mobile network communications. No gateway is required in this mode. However, mobile network should be available.

Testing and validation methods: The prototype of the device (DEVICE-A) was made and compared with the standard device (DEVICE-B). After obtaining clearance from Institutional Ethics Committee of ESIC Medical College and Hospital, Hyderabad (ESICMC/SNR/IEC-F0179/04/2020), this validation study was performed in the department of physiology. 30 healthy volunteers belonging to both sexes between 20 and 60 years of age were included in the study after taking informed consent from the subjects or their guardians. COVIDBEEP display unit **(DEVICE-A)** mounted on the BP cuff was attached snugly to the left forearm 5 cm above the wrist crease. The finger sensor also incorporated with the IR sensor to record temperature was clipped to the index finger of the left hand and its wire connected to the display unit. ECG electrodes were attached to the chest/trunk and the lead

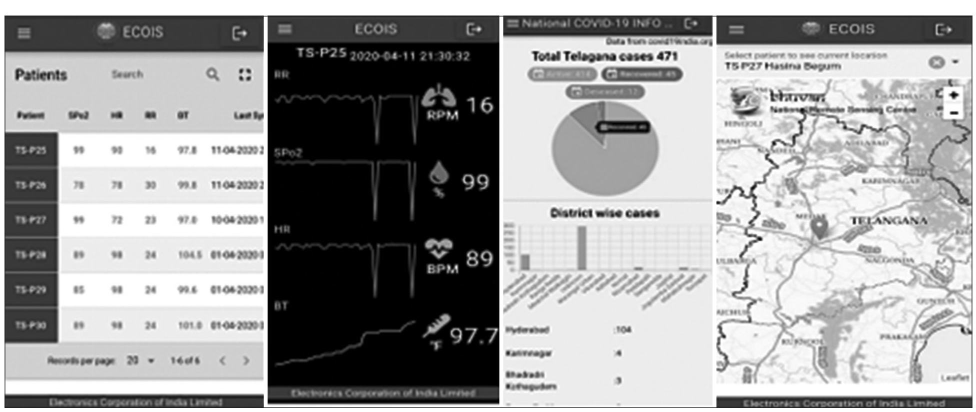

Figure 3: Mobile app display: Parameters, statistics, Bhuvan maps

wire connected to the display unit. Physiological parameters, i.e., heart rate, spO2, respiratory rate, digital temperature, blood pressure, and ECG were acquired in the supine position. The standard ICU monitor **(DEVICE-B)** of model number and make AQUA-15 manufactured by Shenzhen Unicare Electronic Co., Ltd. routinely used in the Intensive Care Unit (ICU) of the hospital was used for validation purpose. SpO2 sensor, temperature sensor, NIBP, and ECG lead wires of the ICU monitor were simultaneously connected to the right side of the subject. Once connected to both the systems, the subject was made to rest for 5 minutes. The parameters were then periodically noted down at the end of 1, 3, and 5 minutes after the resting period. The data were instantly entered in an MS-Excel sheet.

Measurement philosophy/parameters

a. *Oxygen Saturation Level (SpO_2):*The finger sensor having Red and Infrared light sources measures the Oxygen saturation (*SpO_2*). By measuring the intensity of Red and Infrared light passing through capillary blood of finger, the *SpO_2* is measured. The data collected from these reflected lights are digitized and processed in Digital Signal Processor of the device.
b. *Blood Pressure:* Oscillometric method is used for measurement of blood pressure. In this method, a cuff is wrapped around the patient's lower part of forearm, just above the wrist. The Oscillometric method is based on the principle of occluding the artery of the patient by inflating the tourniquet above systolic pressure; this compresses the artery against the underlying bone and shuts off the flow of blood in the vessel. The pressure is slowly released by deflating the tourniquet in gauged intervals till the pressure falls slightly below the systole. As soon as pressure falls to systolic value, blood breaks through the occlusion and flows turbulently through the artery. This causes the artery walls to vibrate or oscillate and they create a counter pressure against the tourniquet. A piezoelectric pressure transducer continuously monitoring the tourniquet pressure detects these vibrations. The onset of pressure oscillations correlates with the systolic pressure. The diastolic pressure is marked by the sudden change in slope of decreasing amplitude. The pressure is continuously reduced till the tourniquet is fully deflated, the blood flow returns to normal, and oscillations cease.
c. *Heart Rate:* The heart rate is taken from ECG. In the case of regular cardiac rhythm, the heart rate can be determined by calculating the interval between two successive QRS complexes.
d. *Body Temperature sensor:* The body temperature sensor, incorporated into the finger sensor, is based on semiconductor sensing with clinically approved standards: ASTM E1112 and ISO 80601-2-56.
e. *Respiratory Rate:* Impedance plethysmography technique is used to measure respiration with the help of two current injecting electrodes placed across the chest. The voltage across the electrodes and current is measured to calculate changes in trans-thoracic impedance which represents the respiratory rate. In case of non-connectivity of the chest electrodes, the respiratory rate is delivered from the photo-plethysmography signal from the finger sensor.
f. *Electrocardiogram (ECG):*

Bio-potential sensing method with four surface mounted electrodes is used for ECG. The electrodes are placed according to the standard protocol. Einthoven triangle concept is used for selection of location for placement of electrodes.

Device specifications (DEVICE-A):

Parameter	Range	Accuracy
Body temperature (Fahrenheit)	95-110	<0.5%
Heart rate (Beats/min)	30-200	<2%
Oxygen saturation (SpO_2%)	30-100%	<2%
Respiratory rate (Breaths/min) Using Infra/ECG probe	5-40	<4%
Blood pressure	Systolic and diastolic pressures	<2%
ECG	3 leads waveform	<2%

Statistical Analysis: The data entered into MS-Excel sheet were calculated for Mean and Standard Deviation of each parameter recorded by both the devices. Further analysis was performed using Graph Pad Prism Version 9.2.0 (332) software. To know the concurrent validity, Intraclass correlation coefficients were used. To know the agreement for each vital parameter, Bland–Altman graphs were plotted. Confidence limits were set at 95%.

Result: Table 1 shows the distribution of the Mean and Standard Deviation values for the physiological parameters recorded from both the devices. It can be observed that the difference in mean values of respiratory rate recorded by both the devices is narrowed down by the end of 5 minutes. Intra-class correlation coefficient between the 2 devices for all parameters was analyzed Pearson's correlation coefficient revealed a good association between the parameters recorded by both the devices which only strengthened as the time of collection of data points increased. Agreement between the two methods in 95% confidence interval was also proven to be significant for the parameters. As Fever is one of the important symptoms for COVID-19, recording of temperature was a mandatory requirement. The digital temperatures recorded from both the devices showed a significant correlation with an "r" value of 0.64 and "*P*" value of 0.0002 [Table 2]. The strength of relationship between the parameters recorded by both instruments was established by Bland–Altman comparison showing no consistent bias [Table 3, Figures 4 and 5]. When data on heart rate and blood pressure were collected from both devices and subjected to statistical analysis, a significant correlation was found with "r" values of 0.9792, 0.9814 and 0.9847 for heart rate, SBP and DBP, respectively. "*P*" values for all these parameters were found to be <0.0001. Respiratory system was one of the

Table 1: Distribution of mean and standard deviation values

Time	Parameter tested	Device	Mean	SD
1 Minute	HR	Device-A	74.33	8.46
		Device-B	74.10	7.75
	SpO2	Device-A	97.10	0.91
		Device-B	97.43	1.15
	RR	Device-A	13.60	3.21
		Device-B	18.57	3.21
	Temperature	Device-A	96.68	1.06
		Device-B	98.29	0.34
3 Minutes	HR	Device-A	74.53	7.20
		Device-B	74.73	7.09
	SpO2	Device-A	97.03	0.75
		Device-B	97.27	0.89
	RR	Device-A	14.43	3.27
		Device-B	18.23	3.29
	Temperature	Device-A	98.05	0.56
		Device-B	98.31	0.43
5 Minutes	HR	Device-A	73.97	8.00
		Device-B	74.00	7.15
	SpO_2	Device-A	96.77	1.09
		Device-B	97.00	1.06
	RR	Device-A	14.17	3.45
		Device-B	17.67	3.28
	Temperature	Device-A	98.10	0.52
		Device-B	98.24	0.43
	SBP	Device-A	112.97	7.52
		Device-B	116.47	7.07
	DBP	Device-A	71.33	6.65
		Device-B	73.20	6.75

Table 2: Intra-class correlation coefficient between the 2 devices for all parameters

Parameter	Statistic	1 Min	3 Min	5 Min
Heart rate	R	0.9923	0.9816	0.9792
	P	<0.0001	<0.0001	<0.0001
SpO2	R	0.5035	0.3346	0.6344
	P	0.0046	0.0707 (ns)	0.0002
Respiratory rate	R	0.8432	0.9338	0.9813
	P	<0.0001	<0.0001	<0.0001
Temperature	R	0.3764	0.5923	0.6370
	P	0.0404	0.0006	0.0002
SBP	R	-	-	0.9814
	P	-	-	<0.0001
DBP	R	-	-	0.9847
	P	-	-	<0.0001

earliest systems to have been involved in the patho-physiology of this disease. Alteration of respiratory rate was prognostic of the course of disease. Monitoring respiratory rate was crucial. COVIDBEEP was designed to extract respiratory rate values from both finger sensor as well as from the ECG electrodes. Analysis of the data on the respiratory rate from both the devices showed a significant correlation between the two

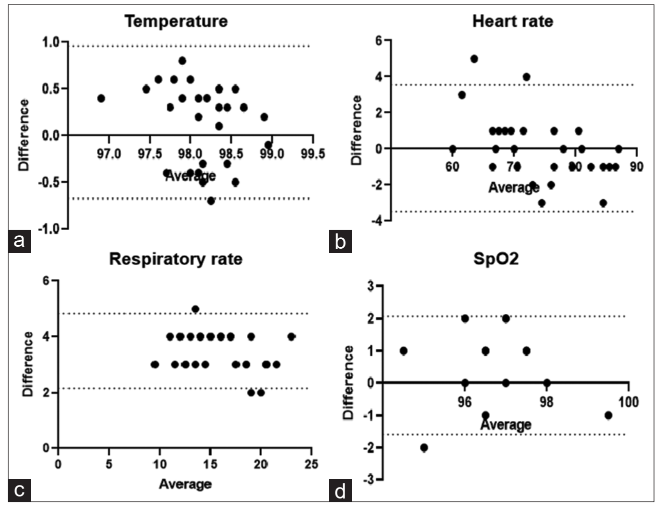

Figure 4: Bland–Altman comparison plots for the physiological parameters—(a) temperature (b) heart rate (c) respiratory rate (d) SpO2 recorded using both devices. X-axis in each plot corresponds to the mean values of a particular parameter. Y-axis corresponds to difference in the mean values (bias) to the mean values of a particular parameter

with an "r" value of 0.9813 and a "*P*" value of <0.0001. The data were also subjected to Bland–Altman analysis, a tool to know the degree of agreement between 2 methods within the given confidence interval. The mean difference was found to be 0.14, 0.03, 3.5, 0.2, 3.5, and 1.8 for temperature, heart rate, respiratory rate, SpO2, SBP, and DBP, respectively, with 95% confidence interval.

Discussion

The need for comprehensive remote health monitoring of patients has been immensely felt during the ongoing COVID-19 pandemic due to the critical requirement of continuous surveillance of patients as well as protection of the healthcare givers. The pathophysiology of the disease and the medication used in the management of COVID-19 patients was expected to affect the heart rate, blood pressure and ECG, and any co-morbidities resulting out of the above needed to be monitored carefully. To make the monitoring system comprehensive, the blood pressure and ECG recording were incorporated into it. COVIDBEEP was designed to record forearm blood pressure and 6 lead ECG. Though the display unit shows single lead ECG, the physician can monitor the six lead ECG through the server. The configuration of the device is shown in Table 4. Therefore, the indigenously developed COVIDBEEP has shown good validity in comparison with standard monitoring device. With judicious usage of COVIDBEEP, the following benefits can be seen.

I. Beneficiaries/Target population:

a. COVID patients both symptomatic and asymptomatic.
b. Patients in isolation who cannot visit hospital frequently.
c. Vulnerable population: Heart Disease, Metabolic Disorders (Diabetes mellitus), Cancers, Immune

compromised patients, etc.

Utility in Resource Crunch Situations:

The country needed doctors, nurses, and technicians, etc., more than ever during the COVID-19 pandemic. To protect the healthcare workers was vital to serve the community. Not to forget that many healthcare workers/professionals themselves could be associated co-morbidities and immune compromised conditions. Long leave due to ill health and fear among the staff lead to manpower crunch. In such a situation, the remote health monitoring system would help the hospitals in overcoming these deficiencies. The device was expected to strongly supplement and support the existing model of healthcare facilities.

Table 3: Bland–Altman comparison between the 2 devices

Parameter	Bland–Altman values	
Heart rate	Bias	0.0333
	SD	1.79
	Confidence Interval (95%)	-3.476, +3.543
SpO2	Bias	0.2333
	SD	0.9353
	Confidence Interval (95%)	-1.6, +2.066
Respiratory rate	Bias	3.500
	SD	0.6823
	Confidence Interval (95%)	+2.163, +4.837
Temperature	Bias	0.1433
	SD	0.4166
	Confidence Interval (95%)	-0.6732, +0.9599
SBP	Bias	3.5
	SD	1.5
	Confidence Interval (95%)	+0.5544, +6.446
DBP	Bias	1.867
	SD	1.196
	Confidence Interval (95%)	-0.477, +4.210

Table 4: Configuration of the device

Parameters	Specifications
Monitoring Interval	Configurable between range of 1 sec to 1hour
Alerts to gateway	Beyond threshold settings
Wireless Communication	Long Range BLE (~300-400 m)
Built in GPS receiver	Tracking through Bhuvan map/Google
Built in Display	Graphics Display
GSM/GPRS interface	Connect to cloud/server patient tracking
Battery Life	12 Hours
Operating temperature	0 – 50 deg centigrade
Unique ID	10 Alphanumeric string
Communication	Secure Communication through https://

II. Advantages of the COVIDBEEP:

The device has mltiple advantages for COVID-19 and non-COVID-19 care.

A. In COVID-19 care:

1. The country needed a strategic plan to attend to the disease at multiple levels of health care like in Primary Health Care, Secondary Health Care, and Tertiary Health Care. For effective utilization of oxygen beds, monitoring played a vital role to decide the further course of management. The following points will elaborate on this issue.
   a. At Primary Health Care level (**L1**): When a case is identified with potential risk of COVID-19 disease with symptoms, a preliminary monitoring was essential to know the physiological stability of the patient. However, for the fear of contracting the disease patients were kept at distance from the time symptoms appeared. COVIDBEEP helped in monitoring patients throughout the period from sample collection, RT-PCR testing to consultation and treatment. A decision could be taken based on parameters whether to refer patients to secondary level care (L2 Level). This constituted an effective triaging based on the saturation and other vital information.

Triaging of the cases: All COVID-19 suspected and confirmed cases could be triaged using the baseline parameters and appropriately allotted to groups such as 1) Asymptomatic 2) Symptomatic stable; 3) Symptomatic requiring Oxygen bed; 4) Symptomatic requiring HDU bed; and 5) Symptomatic requiring ICU bed

   b. The feasibility of the device being carried by the patient to home and still be monitored by the doctor/nurse made COVIDBEEP a novel robust gadget.

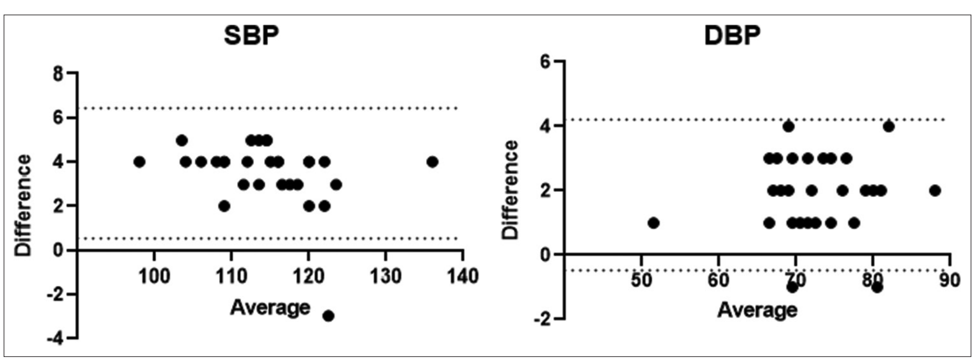

Figure 5: Bland–Altman comparison plots for physiological parameters

c. At Secondary Health Care level (**L2**): Suitable Oxygen support along with continuous monitoring of parameters.
d. At tertiary Health Care level (**L3**): All tertiary health care centers may be equipped with a COVID COMMAND ROOM (CCR) to monitor the data of the patients at primary and secondary levels under the tertiary Centre. The CCR of a tertiary hospital can supply the devices to its secondary and primary centers with the device IDs and their locations. The data of the patients who were connected to the devices will be continuously monitored by dedicated personnel in the CCR. This triage is required for suitable allocation of hospital beds, which is especially essential owing to the current condition of scarcity of resources for patient care. In case of admission, the CCR alerts the Oxygenation and vital support units and allocates bed to the patient. If the CCR is already aware that all the beds are occupied in their Centre, the command room can allot the patient to another hospital.
e. The technological advantages in the device will help the treating physician/nurse in proper management of a COVID-19 patient:
   i. Blood Pressure is one of the vital parameters that requires to be monitored in these patients may be due to pre-existing Hypertension or secondary to drug side effects which may produce cardiovascular or hemodynamic instability. COVIDBEEP was incorporated with a forearm cuff which easily worn by the patients themselves and the BP icon touched to start NIBP recording.
   ii. Heart rate was extracted from PPG signal from finger pulse as well as from the RR interval of the ECG. This ensures, recording of vital data even during connection issues.
   iii. Respiratory rate was also extracted from both PPG signal from finger pulse and via impedance plethysmography from chest ECG electrodes.
   iv. This robustness in the data acquisition helped doctor/nurse take timely decisions such as continuing isolation/quarantine or shifting the patient to ward/ICU/HDU or continue to monitor even after discharge.

B. **In non-COVID-19 care:** COVIDBEEP devices are designed with a future utility to function beyond the pandemic in certain conditions:
1. High risk pregnant mothers—to monitor their BP, Oxygenation, heart rate, etc., to know the cardiovascular stability. As they cannot be frequently mobilized, such monitoring at home in a user-friendly manner.
2. General health monitoring of seriously ill patients in a geographically isolated or secluded zones like in flooded areas, earthquake affected zones, dense forests, soldiers, etc., and guide local staff in management of patients.
3. For patients with leukemia (blood cancers), cancer therapy, etc., to monitor the changes which arise due to the drug dosage or disease progression *per se*.
4. In people who are immuno-compromised where patient is kept in isolation.
5. For patients in radiotherapy units or chemotherapy units who need isolation.
6. For geriatric age groups patients to monitor general well-being, remotely.
7. In children or adults with sleep apnea or other sleep disorders.

Unique features of the device make it robust and user-friendly:

a. An SOS alarm button for use by patient or attender to call for immediate help. SOS buttons address such grave situations like washroom syncope, hypoxia, sleep apnea, etc.
b. GPS tracking of the device and hence the patient who received the device will enable the Hospital personnel to reach out to the patient through dedicated ambulances and Oxygen cylinders.
c. The wearable device on the wrist of the patient is robust enough to bear the temperature or physical pressures of the immediate environment. The interference from adjacent electronic devices is also very minimal not affecting the signal acquisition by the device.
d. Blood pressure recording is also a unique feature of the device which forms an important factor in the management of a COVID-19 patient. Whether due to side effect of drug or as an associated risk factor, BP needs prompt monitoring to identify any deviations. Unique feature was that the BP cuff could be operated/inflated remotely by the Physician when needed.
e. Device is user friendly.
f. Relevance of such RHMS device as a mitigation plan to address manpower issues:
g. To address the manpower issue, usage of such devices especially in a government run hospital with huge numbers of cases, would help mitigate the deficiency of health care personnel and promise continued monitoring of patients for health outcomes.

Conclusion

COVIDBEEP is an indigenous, low-cost, effective, user-friendly, and comprehensive remote health monitoring device with a robust technology that has tremendous application especially in the present pandemic and beyond. As it is the first of its kind, validation was done against a standard recording device for the physiological parameters like temperature, heart rate, respiratory rate, SpO2, and blood pressure. A significant correlation between the two devices has proved that the device is a valid tool. In future, it can be utilized in ICUs, HDUs, and Isolation wards for other diseases like leukemia, bone marrow transplantation, HIV patient wards, immune disorders, and all of whom require to be strictly monitored in an aseptic environment. Another area where its use will immensely benefit is in maternal and fetal health monitoring during pregnancy. Geriatric patients can be closely observed using this device. It may find an important place in pulmonology for monitoring patients with sleep apnea. COVIDBEEP has tremendous applications especially in the present pandemic and even beyond.

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Conflicts of interest

There are no conflicts of interest.

References

1. Mirza MB, Hamid G. Smart health monitoring systems: An overview of design and modeling. J Med Syst 2013;37:1–14.
2. Chretien J-P, Burkom HS, Sedyaningsih ER, Larasati RP, Lescano AG, Mundaca CC, *et al*. Syndromic surveillance: Adapting innovations to developing settings. PLoS Med 2008;5:e72.
3. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, *et al*. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA 2020;323:1061-9.
4. Tian S, Hu W, Niu L, Liu H, Xu H, Xiao S-Y. Pulmonary pathology of early-phase 2019 novel coronavirus (COVID-19) pneumonia in two patients with lung cancer. J Thorac Oncol 2020;15:700-4.
5. Sardu C, D'Onofrio N, Balestrieri ML, Barbieri M, Rizzo MR, Messina V, *et al*. Outcomes in hyperglycemic patients affected by COVID-19: Can we do more on glycemic control? Diabetes Care 2020;43:1408–15.
6. Giustino G, Croft LB, Stefanini GG, Bragato R, Silbiger JJ, Vicenzi M, *et al*. Characterization of myocardial injury in patients with COVID-19. J Am Coll Cardiol 2020;76:2043-55.
7. Sandoval Y, Januzzi JL, Jaffe AS. Cardiac troponin for assessment of myocardial injury in COVID-19: JACC review topic of the week. J Am Coll Cardiol 2020;76:1244-58.
8. The Novel Coronavirus Pneumonia Emergency Response Epidemiology Team. The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) — China, 2020. China CDC Wkly 2020;2:113–22.