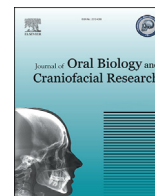




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Internet of Things (IoT) enabled healthcare helps to take the challenges of COVID-19 Pandemic



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ABSTRACT

Background/objectives: The Internet of Things (IoT) can create disruptive innovation in healthcare. Thus, during COVID-19 Pandemic, there is a need to study different applications of IoT enabled healthcare. For this, a brief study is required for research directions.

Methods: Research papers on IoT in healthcare and COVID-19 Pandemic are studied to identify this technology's capabilities. This literature-based study may guide professionals in envisaging solutions to related problems and fighting against the COVID-19 type pandemic.

Results: Briefly studied the significant achievements of IoT with the help of a process chart. Then identifies seven major technologies of IoT that seem helpful for healthcare during COVID-19 Pandemic. Finally, the study identifies sixteen basic IoT applications for the medical field during the COVID-19 Pandemic with a brief description of them.

Conclusions: In the current scenario, advanced information technologies have opened a new door to innovation in our daily lives. Out of these information technologies, the Internet of Things is an emerging technology that provides enhancement and better solutions in the medical field, like proper medical record-keeping, sampling, integration of devices, and causes of diseases. IoT's sensor-based technology provides an excellent capability to reduce the risk of surgery during complicated cases and helpful for COVID-19 type pandemic. In the medical field, IoT's focus is to help perform the treatment of different COVID-19 cases precisely. It makes the surgeon job easier by minimising risks and increasing the overall performance. By using this technology, doctors can easily detect changes in critical parameters of the COVID-19 patient. This information-based service opens up new healthcare opportunities as it moves towards the best way of an information system to adapt world-class results as it enables improvement of treatment systems in the hospital. Medical students can now be better trained for disease detection and well guided for the future course of action. IoT's proper usage can help correctly resolve different medical challenges like speed, price, and complexity. It can easily be customised to monitor calorific intake and treatment like asthma, diabetes, and arthritis of the COVID-19 patient. This digitally controlled health management system can improve the overall performance of healthcare during COVID-19 pandemic days.

1. Introduction

Internet of things (IoT) provides the connectivity of physical objects with the Internet, and information can be sent or received through the Internet. The IoT concept has evolved into and from different technologies like sensors, machine learning, real-time analysis, and embedded systems. It is about the smart hospital concept and other devices controlled by fixed or Wireless Internet. Smart devices can capture data and share it in daily life to accomplish the required task. IoT applications are reaching smart cities, cars, devices, entertainment systems, homes,

and connected healthcare.^{1–3} Various sensors, medical devices, artificial intelligence, diagnostic, and advanced imaging devices are central to IoT implementation in the medical field. These devices improve the productivity and quality of life in both old & new industries and societies.^{4,5}

IoT inter-relates all computing, mechanical and digital technologies to transfer the data through the Internet without any human interaction. This technology is booming in monitoring healthcare during COVID-19 Pandemic. In the current scenario, lots of people die due to improper and untimely information about health.^{6,7} This technology can quickly notify in time the issues related to health through the use of sensors. All

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COVID-19 patient-related information is stored in the cloud, which can further help to provide proper attention. This technology can capture the daily activity of a person and make alerts about health problem.^{8–10}

There is an essential requirement for the proper equipment to make a successful operation in the medical field. IoT has a high capability to make successful operations and also analysis the improvement after the surgery.^{11–14} The application of IoT helps for the better care of the patient during COVID-19 Pandemic. Real-time monitoring is successfully done with IoT and saves lives from different problems like diabetes, heart failure, asthma attack, blood pressure, etc. Smart medical devices are connected via a smartphone to transfer the required health data to the physician smoothly. These devices also collect data on oxygen, blood pressure, weight, sugar level etc.^{15–17}

2. Need for the study

A reliable digital information system is a primary challenge in the medical field during COVID-19 Pandemic, which is quickly undertaken by IoT. There are challenges to studying the technologies being used, their benefits and associated critical applications to fulfil higher efficiency requirements. It can solve various issues due to its extended capability by providing innovative information during COVID-19 Pandemic.

3. IoT implementation in the medical field

IoT has an excellent capability to create high-quality results with the help of innovative technologies. In medical, it becomes a new reality of an innovative concept that provides the best service to COVID-19 patients and performs precise surgery.^{18–21} Complicated cases are easily handled and controlled digitally during ongoing Pandemic. IoT takes new challenges in the medical field to create excellent support systems for doctors, surgeons, and patients. The different process steps are identified systematically for effective IoT implementation. Fig. 1 shows the process chart of IoT in the medical field.

Sensors are used to sense and capture the information regarding patient health/disease and receive necessary data. Here all physical objects are connected to the Internet (networked), and devices display continuous process monitoring. The required medical information is well-provided to specified doctors as per their requirements.

4. Technologies of IoT for the healthcare during COVID-19 pandemic

IoT connects medical tools, devices, and machines to create intelligent information systems as per individual COVID-19 patient requirements. It takes a different interdisciplinary approach to maximise productivity, quality, and knowledge about upcoming diseases.^{22,23} IoT technologies detect changes in vital patient data to determine relevant information. Table 1 discusses the different technologies of IoT helpful in healthcare during COVID-19 Pandemic.

IoT technologies have a high impact on high-quality medical devices, which help meet the personalised solution during COVID-19 Pandemic. These technologies can capture, store, and analyse the data digitally. All clinical records are maintained digitally, and with the help of internet facilities, patient data and information is easily shared in emergency cases and make doctors job efficiently.⁴⁶ By using smart sensors, we achieve an excellent capability to monitor and control all the essential requirements of medical temperature, sugar level, blood pressure, and information regarding COVID-19 patient health.^{47–49} Software plays an essential role in the best way of communication and monitoring. All records are stored confidentially for the best treatment in the future. Artificial intelligence enhances doctors' and surgeons' performance to achieve accuracy, efficiency, and reliability in treatment. Applying this technology can reduce patient pain and quick identification of bone defects to provide proper medication. Different actuators are introducing

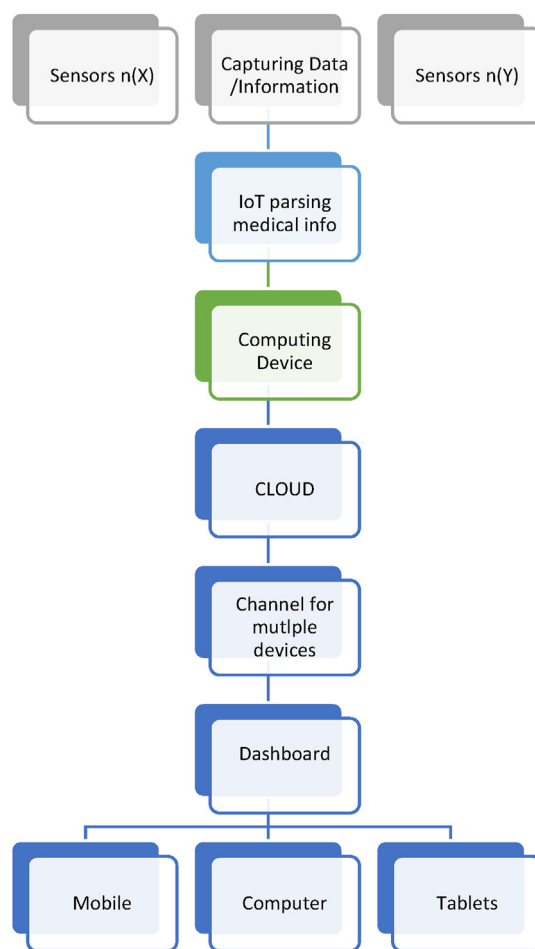


Fig. 1. Process chart of IoT implementation in the medical field.

the motion and control of the physical object.^{50,51} The virtual reality is the best technology of IoT to improve the quality of planning and real-time information.

5. IoT enabled healthcare helpful during COVID-19 pandemic

IoT makes a positive impact on healthcare to improve the lives of millions of peoples. It detects disease and thoroughly monitors the healthcare system. It provides customised attention to the people for their benefits. Technologies used in IoT can remind appointments, exercise check, calorie count, blood pressure, disease condition, and much more information during COVID-19 pandemic.^{52,53} Table 2 discusses some significant applications of IoT in the medical field during COVID-19 pandemic.

In the medical field, IoT has a different application to create innovation during COVID-19 Pandemic. It is the best technique to track patients and staff, thereby reducing the waiting time. It introduces several devices to make the patient comfortable. With smart devices like blood-gas analysers, thermometer, smart bed, glucose meter, ultrasound, and X-rays, there is an improvement in inpatient care. IoT is applicable to replace the biological part or enhance the biological structure.^{100–104} Its applications are in medical equipment such as connected imaging, clinical operations, drug delivery, patient monitoring, laboratory tests, and medication management during COVID-19 Pandemic. IoT helps doctors and health professionals for the best treatment of the patient.^{105–107} It creates a centralised information system in a hospital where all activities are stored digitally, and other Data analytics can also be used to problem-solving during COVID-19 Pandemic. This technology can easily monitor patient health and makes an accurate decision during complex

Table 1
Different technologies of IoT for use in healthcare during COVID-19 Pandemic.

S No	Technologies	Description	References
1	Big data	<ul style="list-style-type: none"> • Today Big data seems one the best technique to capture, store and analyse the data of the COVID-19 patient • In medical, data was stored traditionally in hard copy which acquires extra cost • Big data has an excellent capability to store data in digital form • Big data well maintain all patient data, billing system and the clinical record • Data is stored systematically which quickly provides the best solution to health care 	24–27
2	Cloud computing	<ul style="list-style-type: none"> • By using computer system resources, it stores on-demand data storage and describes data with the help of the Internet • It quickly shares COVID-19 patient information in urgent cases • Share proprietary data resources which help doctors and surgeon to do their job efficiently and effectively • It increases data quality and with a reduced cost of data storage 	28–31
3	Smart sensors	<ul style="list-style-type: none"> • In medical, smart sensor has an excellent capability to communicate digital network and produce an accurate and reliable result • It monitors and controls all parameter regarding patient health • Easily monitor blood pressure, temperature, oxygen concentrator, sugar level, infusion and fluid management system of the COVID-19 patient • Helpful to obtain information on health status, defective bone, and surrounding biological tissue 	32–34
4	Software	<ul style="list-style-type: none"> • There are customised software available for the medical field which improves patient care, store patient data, given treatment, associated tests, and diagnosis • Helps to improve communication between patient and doctors • Store medical history of the COVID-19 patient, confidential detail and disease of patient is easily identified and managed by software 	35–37
5	Artificial intelligence	<ul style="list-style-type: none"> • Artificial intelligence helps to perform, evaluate, validate, predict and analyse the data in a predefined environment • Provide excellent capabilities to predict and control infections of the virus • With the help of this technology, doctors and surgeon achieve improved efficiency, accuracy, and effectiveness • It measures the pain of the COVID-19 patient with changes in medication 	38–40
6	Actuators	<ul style="list-style-type: none"> • An actuator is a mechanism which introduces the motion and controls the system to act upon in a given environment • The main applications of the medical actuators are to maintain accuracy and control required parameters 	41,42

Table 1 (continued)

S No	Technologies	Description	References
7	Virtual Reality/ Augmented Reality	<ul style="list-style-type: none"> • Helps to design a hospital bed that can raise or lower its height as per the COVID-19 patients need • The better way to integrate human with electronics systems to provide real-time information • Virtual reality helps to improve the quality of planning, patient safety, and efficiency of COVID-19 patient treatment • Provide needful information to COVID-19 patient and doctors to improve surgical planning quality • Augmented reality also provides digital information of life in digital imagery/sound form 	43–45

cases.^{108–110} By continuously checking the health status, it alerts about any upcoming diseases and provides a solution for its prevention. It is helpful in the detection of an asthma attack and a reminder of medication on time.

6. Discussion

In medical, IoT brings significant changes to improve the facilities and information system during COVID-19 Pandemic. It improves the digitisation of medical processes and proper management in hospitals. IoT opens new applications in medicine when the device/instruments are being connected to the Internet. For patients, internet-connected devices are being introduced in different forms, to monitor patient health more effectively. It alerts about public health problems by tracking climate change. This technology gives way for the proper management of the hospital during COVID-19 Pandemic. It plays a significant role in monitoring the drug by providing validated information. This information can also help the proper distribution process of the right patient’s right equipment/device. With the right information system, this technology is helpful for the reduction of waste in the hospital. With the help of adequately recorded information, it reduces the chance of the hospital’s accidents and controls all the problems. This technology can also prevent the theft of expensive medical devices. IoT delivers superior, relevant, and reliable data with a better technological solution. It allows researchers for human testing with minimum risk. In actual practice, it brings innovation in the medical field to solve a complex problem during COVID-19 Pandemic. It not only produces the facilities but also saves the lives of the individual patient. It provides a critical emergency support service, which helps to reduce the associated losses. There is the fastest adoption in the medical field due to its effectiveness of service.

7. Future scope

In the future, IoT will monitor vital signs of the patient in a real-time environment. This technology will digitally collect all detailed information to prevent ongoing issues regarding treatment of the COVID-19 patient. There will be a major enhancement in healthcare practice, using the latest technologies, and doctors would have to use them. IoT is a sophisticated developing technology with extensive applications in providing precise medical care that opens up an effective way to analyse valuable data, information, and testing. The future has applications in managing inventories used in the medical field and the medical supply chain for getting the right item at the right time and location. IoT intelligent device would be performing autonomously. There will be data storage with private and public cloud, and even software would also be on the cloud, thus disease identification and follow up could be made efficient. This disruptive innovation of the information system will

Table 2
IoT enabled healthcare helpful during COVID-19 Pandemic.

S No	Applications	Description	References
1	Treatment of COVID-19 patient	<ul style="list-style-type: none"> IoT having real-time location service used for the best treatment of the COVID-19 patient Different medical devices and apparatus like nebulisers, scales, wheelchair, pumps, and other devices are used for monitoring in the context of IoT Also check, monitor and control the environmental condition like temperature, humidity, etc 	54–56
2	Smart Hospital	<ul style="list-style-type: none"> IoT provides a smart hospital using a connected dedicated network and automation Software provides proper information regarding ongoing abnormalities of the patient The smart hospital provides all information with a complete digitisation of the system; thus, reducing the waiting time of the patient It provides an analysis of records for the process & patient Data analysis help daily operation to improve the care of the COVID-19 patient 	57–60
3	Storage of COVID-19 patient data	<ul style="list-style-type: none"> IoT devices can transmit, efficiently store and analyse data of COVID-19 patient for better treatment in the future Increase awareness about the cause of this virus Helpful to check and analyse the recovered of the patient 	61–63
4	Originate multiple sources and devices	<ul style="list-style-type: none"> In healthcare, IoT provides multiple sources and device which can be automatically be analysed IoT device automatically collects, reports and store the required data of the COVID-19 patients It helps to decide complex cases, as a result, reduce error in surgeries and medicine 	64–67
5	Accurate decision making	<ul style="list-style-type: none"> Due to different communication required for accurate surgery, this technology record data and make an accurate and quality decision Helpful in an accurate recording of COVID-19 patient data which was previously difficult to capture by the doctors 	68–70
6	Monitor status of the COVID-19 patient	<ul style="list-style-type: none"> It predicts the arrival of the COVID-19 patient and monitors the status of support facilities Helps in monitoring cleanliness and infection in hospital and support areas Access information of the COVID-19 patient and stores other details 	71–73
7	Alert about the COVID-19 disease	<ul style="list-style-type: none"> In life-threatening circumstances, this technology alerts the human for COVID-19 disease with real-time tracking It quickly notifies people via linked devices Report and correctly gives an opinion about the condition of human health Provide real-time alerting, on-time treatment and monitoring with better accuracy 	74–76
8	Information to the healthcare worker		77–79

Table 2 (continued)

S No	Applications	Description	References
		<ul style="list-style-type: none"> The proper information to healthcare worker, location, time identification, and database Proper lightening through personal control and intimate about the patient need Best way to communicate doctors with the patient and their family member 	
9	Proper medication	<ul style="list-style-type: none"> It monitors proper medication to the body as well as intake of proper protein and diet for the COVID-19 patient 	80–82
10	Proper facilities	<ul style="list-style-type: none"> Check and monitor the improvement of the patient in daily life The patient workflow can easily automate by IoT to provide proper facilities in healthcare during COVID-19 Pandemic It exchanges information to make healthcare service effective It seems the best technique for better utilising quality resources, which improves the planning of complex surgery 	83,84
11	Check level of glucose	<ul style="list-style-type: none"> Check the level and flow of glucose as per the requirement of the patient Automatically adjust the insulin amount within the safe range 	85–87
12	Assist in remote areas	<ul style="list-style-type: none"> For villages far away from hospitals, IoT can help remotely located patients, contact doctors, via smart mobile phone applications Helpful in checkup of a COVID-19 patient and identify the cause of the infection It will improve patient care and increase digitisation in the hospital 	88–90
13	Detection of an asthma attack	<ul style="list-style-type: none"> It quickly detects the symptoms of asthma before an attack can occur Notified about the attack and information related its prevention 	91,92
14	Reminder about medication time	<ul style="list-style-type: none"> The main application of this technology is to remind patient about to take their medication During missing of does, it alerts the patient to take in the required time 	93–95
15	Emergency case	<ul style="list-style-type: none"> In an emergency case, IoT analyse the distance and access patient profile before reaching nearby facility/hospital This result to improve emergency care and reduced the associated losses 	96,97
16	Smart bed	<ul style="list-style-type: none"> IoT applications are attempting towards making a smart bed which can change height as per the COVID-19 patient's requirements This smart bed can automatically adjust the appropriate pressure and support to the patient 	98,99

facilitate intelligent healthcare service in the Medical 4.0 environment.

8. Conclusion

IoT is for better managing chronic disease, medical emergencies, better patient-care, fitness, blood pressure monitoring, health check system, measurement & control system, heart rate checking system, and hearing aids. It can continuously & reliably monitor COVID-19 patients and provide a better personalisation experience in the medical field. IoT-enabled devices can facilitate digital storing of COVID-19 patients'

personal health information and connect to different databases. This technology can help to minimise the manual record keeping. With the help of a well-informed decision, it reduces errors and provides results on time. By using this technology, healthcare devices and networks become smarter and efficient during COVID-19 Pandemic. Thus, these technologies give immediate information and extend communication to improve the patient's quality of life. In the future, this technology will create advancement for the better treatment of the patient to stay healthy and will used to any COVID-19 type pandemic.

Declaration of competing interest

None.

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