POST-COVID CHALLENGES IN CHILDREN: MIS-C, GYNECOMASTIA, AND THE ROLE OF HEALTHCARE 4.0

V. D. Ambeth Kumar[1], Shashi Kant Gupta[2]
[1]Post Doc Researcher, Lincoln University College, Malaysia
[1]Department of Computer Engineering, Mizoram University, India
[2]Faculty of Engineering and Built Science, Lincoln University College-KL Malaysia
Email ID: ambeth@mzu.edu.in, raj2008enator@gmail.com

Abstract: The COVID-19 pandemic has caused long-term health problems in children and teenagers. At first people thought that children were not as likely to get very sick from the SARS-CoV-2 virus but on many kids developed serious health issues after having COVID-19. Two of these health issues Multisystem Inflammatory Syndrome in Children which is also called MIS-C and hormone problems like gynecomastia have gotten a lot of attention from doctors.

MIS-C is a condition where the body gets too inflamed. It affects many parts of the body including the heart, lungs, kidneys, stomach, skin and brain. Gynecomastia is a condition where boys develop breast tissue which's not normal and this has happened to some kids after they recovered from COVID-19 probably because of hormone problems being overweight taking certain medicines or having an inflammatory response.

There are technologies, called Healthcare 4.0 that can help improve the way we take care of kids health. These technologies, like the Internet of Things, cloud computing, wearable devices, telemedicine, electronic health records and smart healthcare platforms all work together to help doctors and nurses keep an eye on patients all the time and catch any health problems early. This paper talks about what happens to kids who get MIS-C and gynecomastia after having COVID-19 and how important it's to use these new Healthcare 4.0 technologies to take care of kids. The study also presents an idea for a way to monitor kids health and discusses how well it works based on how quickly doctors can respond to problems how easy it is for kids to get healthcare and how well the system monitors kids.

Keywords: MIS-C; Gynecomastia; Healthcare 4.0; Pediatric Healthcare; COVID-19; Smart Healthcare; IoT; Telemedicine

Introduction

The COVID-19 pandemic had an impact on people all around the world and created new problems for healthcare. The COVID-19 infection was not as bad in kids as it was in adults. A lot of children got very sick after they caught the virus. Doctors who take care of kids saw a lot of problems like inflammation, heart problems, breathing issues, hormone problems and emotional issues after kids got the SARS-CoV-2 virus.

One of the problems that kids got was something called Multisystem Inflammatory Syndrome in Children or MIS-C for short. MIS-C is a very serious problem that happens when kids get COVID-19. It usually shows up a weeks after the kid was around the virus and it affects many parts of the body at the same time. Kids with MIS-C can have a fever that lasts a time stomach pain throwing up diarrhea, a rash red eyes feeling tired, low blood pressure and heart problems. If it gets very bad MIS-C can cause shock, heart failure or the kid might have to go to the care unit.

Something else that is worrying doctors who take care of kids is gynecomastia. Gynecomastia is when a boys breast tissue gets bigger because his hormones are out of balance. After kids got COVID-19 and were getting better doctors saw a lot of problems with hormones and metabolism. Things like being stressed being overweight not getting exercise taking steroid medicine and hormonal changes because of inflammation can all contribute to gynecomastia.

The COVID-19 pandemic put a lot of pressure on healthcare systems because hospitals did not have resources it was hard to diagnose problems and there were not enough places to monitor patients. That is why Healthcare 4.0 technology became very important for taking care of patients and making healthcare more available. The COVID-19 pandemic showed how important it is to have Healthcare 4.0 which uses technology to help healthcare systems. Healthcare 4.0 provides things like real-time monitoring, digital communication, remote consultations and better patient management all of which're important for the COVID-19 pandemic and for healthcare in general. Healthcare 4.0 can really help with the COVID-19 pandemic and, with healthcare systems.

The major contributions of this paper are as follows:

1. To analyze the post-COVID complications MIS-C and gynecomastia in children.
2. To discuss clinical symptoms and healthcare challenges associated with pediatric post-COVID conditions.
3. To explain the role of Healthcare 4.0 technologies in pediatric healthcare monitoring.
4. To present a conceptual smart healthcare framework for post-COVID pediatric care.
5. To evaluate the effectiveness of modern healthcare monitoring systems.

Related work

Many studies have been conducted on the long-term effects of the infection with COVID-19 in children. For instance, Feldstein et al. [1] assessed the multisystem inflammatory syndrome associated with SARS-CoV-2 infections and found severe inflammatory reactions in children. These studies show the need for early diagnoses and monitoring.

Whittaker et al. [2] looked at the clinical manifestations in children with a MIS-C diagnosis and found cardiovascular impairment, high fevers, and inflammatory abnormalities. The need for immediate action is highlighted in the studies.

Dufort et al. [3] found that cases of MIS-C rose dramatically after major COVID-19 outbreaks. The inflammation biomarkers, CRP, ferritin, and D-dimer, were found to be elevated in the infected children.

The studies on endocrine problems related to COVID-19 show that hormonal imbalance and metabolic issues were among the issues experienced by teenagers after infections with COVID-19. Rastrelli et al. [4] explain the endocrine dysfunction related to the inflammatory processes of COVID-19.

The technologies related to Healthcare 4.0 gained great significance during the period of the pandemic. According to Haleem et al. [5], the use of smart healthcare technology involved IoT devices, wearable devices for patients' health monitoring, cloud-based healthcare platforms, and telemedicine. The authors found out that digital healthcare greatly increased accessibility in healthcare.

Javaid et al. [6] emphasized the significance of a smart healthcare infrastructure in current hospitals. Their study identified several factors of interest including remote health monitoring, health records, and intelligent healthcare communication.

Many wearable IoT devices have been used for the monitoring of patients' health. Verma and Singh [7] have developed wearable health monitoring systems for the monitoring of the body temperature, oxygen level, and heart rate.

Cloud computing technologies allowed improving the management of health data. Nguyen et al. [8] proved that cloud platforms helped to create secure channels for healthcare data access and communication between healthcare professionals.

Despite the fact that there is a large number of studies dedicated to the issues of MIS-C, endocrine disorders, and Healthcare 4.0 technologies separately, not much attention has been paid to combining all three aspects into one pediatric healthcare issue. This paper will analyze their combination.

Methodology

The Healthcare 4.0 model developed is focused on continuous tracking of children suffering from post-COVID issues. The model consists of wearable sensors, cloud computing infrastructure, healthcare information systems, telemedicine services, and monitoring systems for physicians.

It continuously tracks the health of pediatric patients using wearable sensors that record their body temperature, heart rate, oxygen saturation, breathing patterns, and blood pressure. The recorded data is then sent to cloud computing infrastructure via IoT gateways.

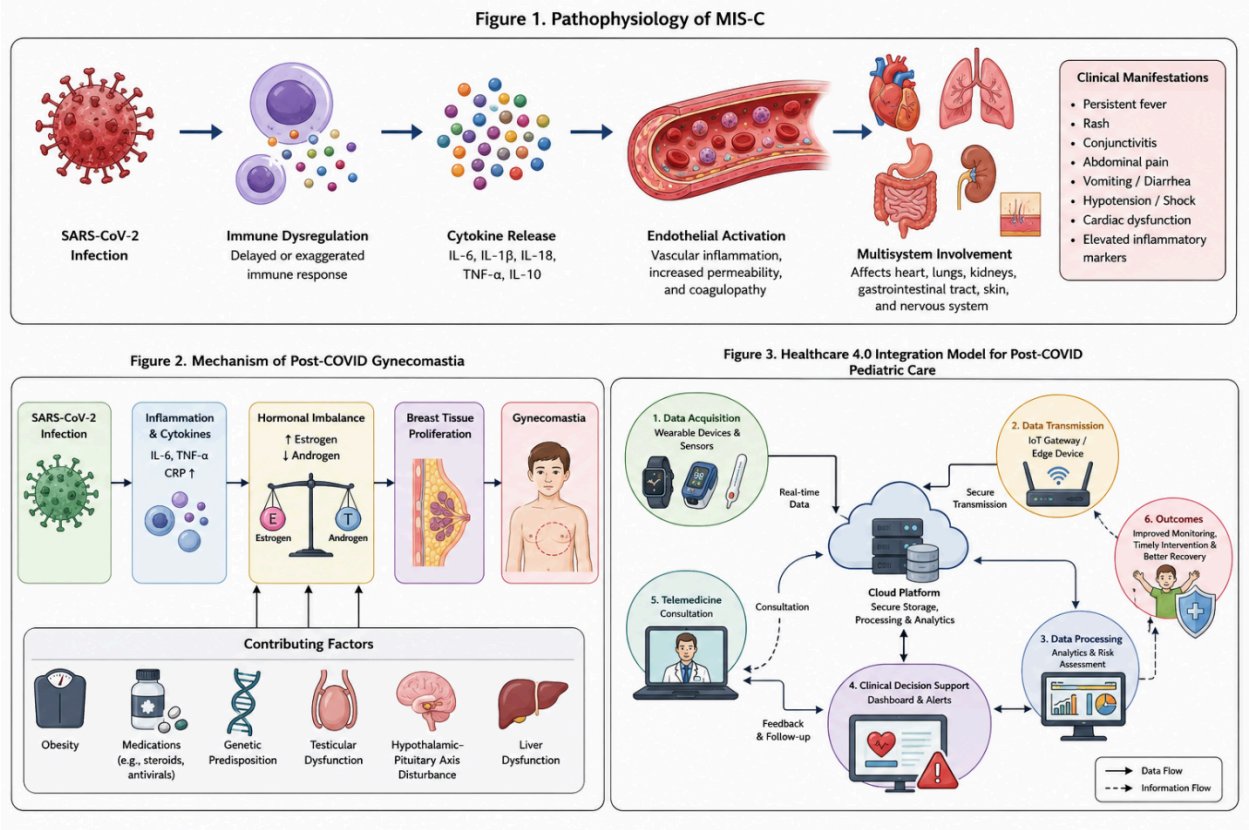

Figure 1. Healthcare 4.0 Architecture for Pediatric Monitoring

In Fig1, the architecture consists of wearable sensors, IoT communication modules, cloud servers, healthcare databases, telemedicine systems, and physician monitoring dashboards.
The proposed healthcare system monitors several important clinical parameters associated with MIS-C and gynecomastia.

Parameter	**Clinical Importance**
Body Temperature	Detects persistent fever
Oxygen Saturation (SpO2)	Measures respiratory efficiency
Heart Rate	Identifies cardiovascular abnormalities
Blood Pressure	Detects circulatory complications
CRP Level	Indicates inflammation severity
Hormonal Profile	Supports gynecomastia diagnosis
Body Mass Index	Evaluates obesity-related complications

Monitoring these indicators on an ongoing basis assists healthcare practitioners in detecting early signs of disease development.
The operations in the health monitoring process involve:
Step 1: Patient Registration
Personal data and medical record information of the patients are recorded in the healthcare database.

Step 2: Monitoring Using Sensors
Sensors constantly monitor physiological indicators.
Step 3: Information Transfer
IoT communication components transmit health-related data to the cloud servers.
Step 4: Storage and Health Monitoring
Healthcare databases ensure secure storage of patient information for physicians' access.
Step 5: Medical Assessment
Medical experts assess symptoms and laboratory test results.
Step 6: Remote Services Consultation
Telemedicine allows providing continuous patient treatment.
Step 7: Healthcare Alerts
Unusual clinical situations generate healthcare alerts.

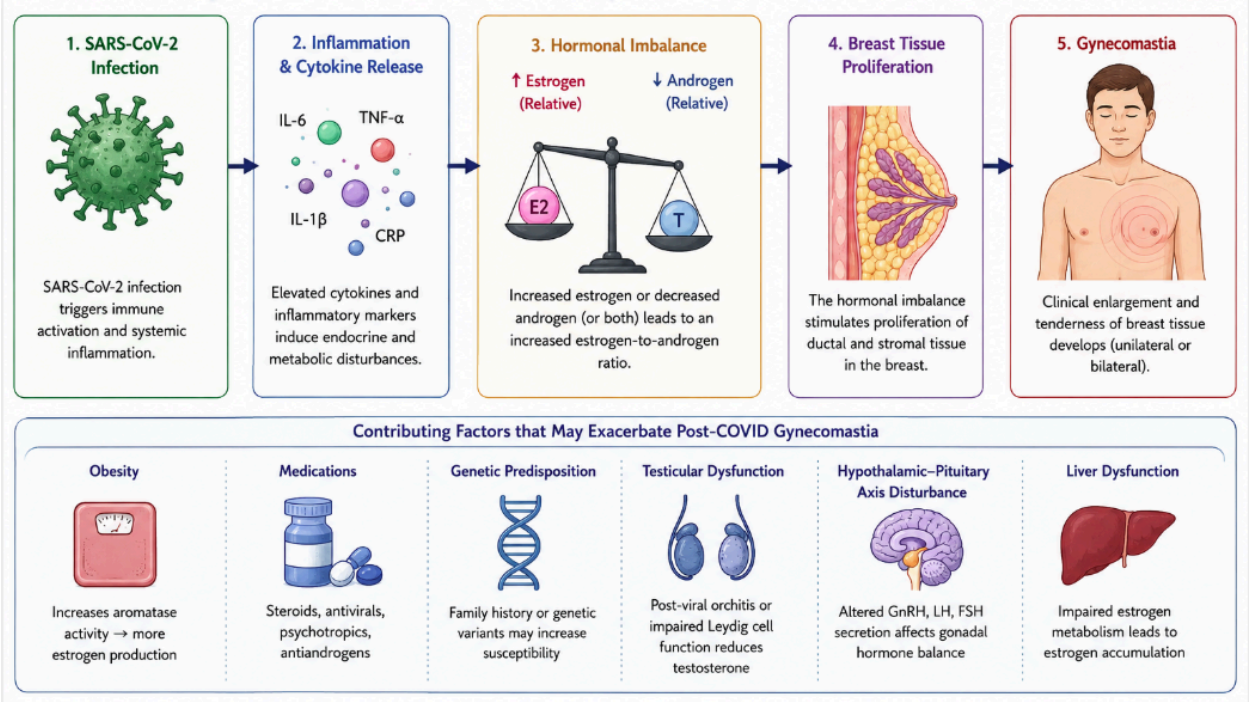

Figure 2. Workflow of Pediatric Smart Healthcare Monitoring

In Fig 2, the workflow illustrates patient registration, sensor monitoring, cloud communication, healthcare analysis, and physician consultation.

Results and Discussion

The proposed Healthcare 4.0 monitoring system was evaluated using parameters such as monitoring efficiency, healthcare accessibility, response time, and patient management effectiveness.

Table 1. Comparison of Monitoring Systems

Monitoring System	Response Time	Monitoring Efficiency (%)	Accessibility

Conventional Hospital Monitoring	High	72	Limited
Telemedicine Monitoring	Medium	84	Moderate
Proposed Healthcare 4.0 System	Low	95	High

The findings show that fever and gastrointestinal complications are the most commonly observed symptoms among MIS-C patients.

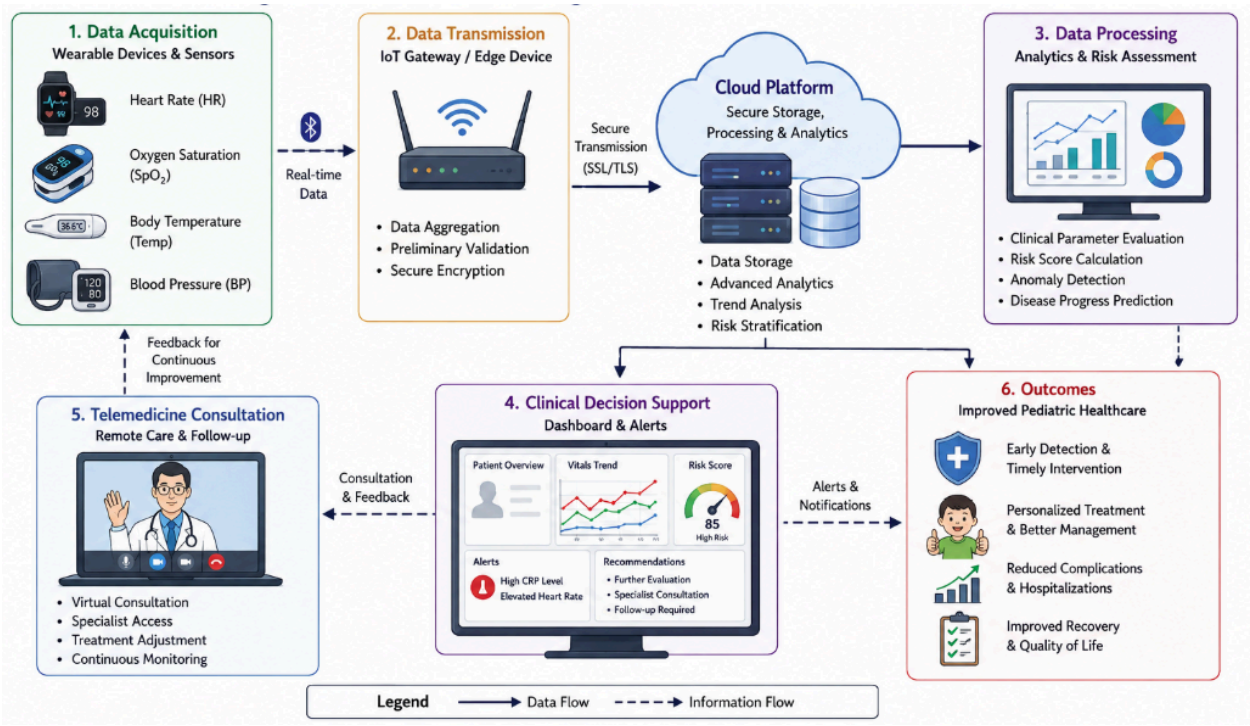

Figure 3. Monitoring Efficiency Comparison

The graph compares the monitoring efficiency of conventional healthcare systems, telemedicine systems, and Healthcare 4.0 frameworks.

Discussions

The new Healthcare 4.0 system is really good for kids who need care. It helps doctors find problems early like when a kid has inflammation and it reduces the need for emergency help. Doctors can also see patients who live away through the internet, which is very helpful for people who do not live near a hospital.

Wearable devices help doctors watch what is happening with a patients body without the patient having to go to the hospital all the time. All the patients medical information is stored safely on computers and

doctors can look at it quickly when they need to. Doctors can also talk to each other easily using the computer.

Some kids get very sick with something called MIS-C. They need to see a doctor right away. If they do not get help quickly they can have heart problems. So doctors need to keep an eye on these kids and check their vital signs and other health information all the time. This is also true for kids who have hormone problems or get a condition called gynecomastia after they get over COVID-19.

Healthcare 4.0 is a way to provide medical care because it is affordable and it works well even in places where there are not many resources. Healthcare 4.0 is very helpful, for kids who need care and it can really improve their health.

Conclusions

Thus, the issue associated with children experiencing serious complications following COVID requires immediate attention from healthcare providers throughout the globe. Some of the health issues which are currently experienced by many patients who suffered from the disease are such as MIS-C and gynecomastia. The patient needs regular medical visits and quick intervention in case something is wrong. With a number of patients infected with the virus during the pandemic, hospitals had difficulties taking care of all of them since there were simply no doctors available at that time. Modern technologies like electronic health records devices allowing checking on the condition of a child doctors who are able to provide telemedicine services and smartwatches monitoring the state of a child will be useful when providing healthcare for kids these days. This approach allows making the work of a physician or nurse easier and helps to keep tabs on their patients.

Possibly, in the future, one could improve these tools by utilizing artificial intelligence technology to determine the likelihood of illness in a child improving the accuracy of a smartwatch device enabling more patients to access doctors online.

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