Permanent Changes in Clinical Engineering Procedures Since COVID-19 in OECD Countries

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Abstract. The COVID-19 pandemic has impacted clinical engineering procedures, including medical technology management, training and technical support, quality risk management, and research and development. This research aims to highlight the permanent changes in clinical engineering practices that emerged due to the pandemic in OECD member countries. By analyzing sources of information, this study examines how the adoption of technologies and digitization of healthcare have been accelerated during the pandemic. The findings are presented in implementations focused on telemedicine, big data, and digital health while also identifying areas of opportunity and challenges for the ongoing adoption of these measures. This abstract provides a succinct summary of the research's focus, objectives, and key findings related to the impact of COVID-19 on clinical engineering procedures and the consequent transformations in healthcare practices.

Keywords: clinical engineering · COVID-19 · OECD

1 Introduction

In December 2019, a cluster of pneumonia cases with an unknown cause was observed in Wuhan, China, leading to an increasing number of reported human infections [1, 2]. It was later confirmed as a novel coronavirus, SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) [1]. On March 11, 2020, the World Health Organization declared the disease caused by SARS-CoV-2 as coronavirus disease 2019 (COVID-19) and classified it as a pandemic [2].

COVID-19 generated significant stress within various healthcare services due to its high contagion rate, leading to an overload of the healthcare system and demanding organizational changes. Throughout the pandemic, healthcare professionals acquired the knowledge and skills required to manage patients infected with COVID-19, utilizing the available resources at the time. These workers faced numerous challenges since the onset of the pandemic, including adapting hospitals for the treatment of SARS-CoV-2-infected patients, limited availability of protective equipment for staff, and inadequate

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clinical protocols [3]. The surge in demand for medical services caused by the pandemic prompted healthcare managers to focus on implementing actions to maximize the efficient utilization of limited resources [4].

Griffin *et al.* [5] list the initial challenges arising from COVID-19 and the corresponding solutions. These include expanding service capacity, ensuring employee well-being, addressing clinical challenges, and providing education on the subject. Based on these issues, contingency plans, ethical recommendations, guidelines on ventilation systems, and resource and patient redistribution strategies were developed [6].

Observing the healthcare system's response to the increased demand for medical care and recognizing the emerging medicolegal and ethical aspects faced by health professionals, consensus documents were developed, incorporating medical criteria and fundamental ethical values [7]. To mitigate the spread of the virus within healthcare facilities, measures such as audits, training, and continuous supervision were implemented [8].

The digitalization of healthcare emerged as a potential solution to transform healthcare delivery during the pandemic [9]. Telehealth, for instance, proved to be a valuable tool for COVID-19 patients, enabling remote assessment and care delivery. Conversely, telehealth provided convenient access to routine care without exposure in crowded hospitals for uninfected individuals at higher risk, such as older adults with pre-existing conditions [10]. The application of intelligent technologies or systems to control and manage SARS-CoV-2 infection offered various advantages, ranging from the rapid production of 3D-printed medical products to the timely assessment of hospital activities using artificial intelligence and machine learning [11].

According to the adaptations, changes, and regulations implemented in hospitals to provide care for COVID-19 patients in member countries of the Organization for Economic Cooperation and Development (OECD), this paper aims to investigate the long-term impact of these measures on clinical engineering procedures.

2 Methods

A comprehensive search was conducted to identify scientific articles, reports, and documents that discussed the implementations resulting from the COVID-19 pandemic and their impact on clinical engineering. These sources were gathered from various databases and subsequently compiled for further analysis. The acquired information was tabulated, and inclusion and exclusion criteria were applied to refine the data.

Inclusion criteria:

- Information collected from scientific articles and reports from OECD member countries.
- The articles had to be published in English or Spanish.
- The articles had to evaluate the impact or permanence of adaptations, changes, and regulations implemented in hospitals to care for patients with COVID-19.
- The timeframe for inclusion was from 2020 to 2022.

Exclusion criteria:

- Information from books and other systematic or state-of-the-art reviews was excluded.

2.1 Document Search

To align with the definition of clinical engineering as the application of engineering knowledge and health technology management to support patient care, a list of relevant terms associated with the topic was generated. These terms created Boolean equations that enhanced the search for relevant information. The search equation was employed in the following databases: EBSCO, PubMed, and ScienceDirect. The University of Ciudad Juarez provided direct access to these databases. The search Eq. (1) used was formulated in English and Spanish.

((coronavirus OR COVID-19 OR SARS-Cov-2 OR pandemic OR post-covid-19) NOT (allergic OR vaccination OR during)) AND (hospitals OR "health facilities" OR "medical equipment" OR healthcare OR "biomedical engineering" OR "clinical engineering") AND ("internet of things" OR telemedicine OR "patient monitoring" OR "electronic health records" OR "medical technology" OR "big data”) (protocols OR normative OR regulations OR "government policy") (1)

2.2 Classification of Information Sources

An Excel file was created to facilitate the organization of the collected information. The file consisted of four different sheets: title, DOI, inclusion/exclusion/revision, and reason. Each sheet corresponded to a specific database where the results were obtained. Documents meeting the inclusion criteria, as determined by the content of their abstracts and titles, were added to the inclusion section of the Excel file. The DOI of each included document was recorded for identification purposes.

2.3 Content Analysis and Identification of Adaptations

The selected information sources from the initial stage were subjected to a detailed content analysis based on the established guidelines. A table was created to identify the title of each article, provide a summary of its content, specify the implemented change or adaptation, describe how the implementation was carried out, identify the specific area where it was implemented, and include an inclusion/exclusion condition section to filter further and categorize the obtained results effectively.

2.4 Categorization of Identified Changes

To ensure a structured view of the identified implementations or adaptations, the search terms associated with clinical engineering were utilized to define categories for classifying the selected information sources. This categorization process aimed to present the gathered information clearly and organized. The articles and reports were categorized into the following fields: telemedicine, microdata, and eHealth. Once the categories were established, the obtained information was presented through tables, focusing on visualizing the implemented actions and their applications in various medical areas rather than sorting them by specific medical fields.

3 Results

This section presents the findings, synthesizes, and discusses the identified areas of opportunity or challenges associated with the obtained results.

3.1 Document Search

Equation 1 was utilized in the search engines to retrieve relevant information. However, the search conducted using the equations in Spanish did not yield significant results. As a result, only the equations in English were applied. Figure 1 shows the PRISMA 2020 flow diagram for identifiying of studies via databases and registers.

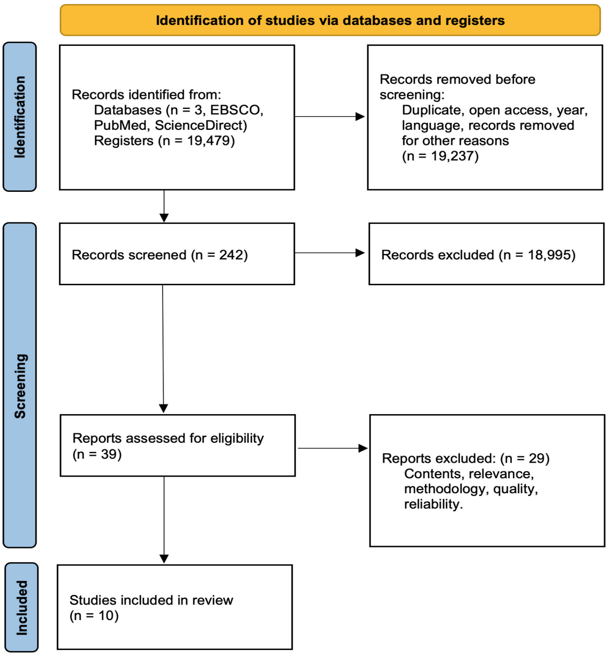

Fig. 1. Prisma 2020 flow diagram.

3.2 Summary of Selected Sources

Out of the initial 39 documents, a final selection of 10 documents was made as information sources. This reduction was made with the specific aim of highlighting real-world project implementations. The following tables present the categorization of the identified implementations. Table 1 showcases implementations centered around telemedicine; Table 2 focuses on implementations related to big data, and Table 3 highlights implementations in the realm of digital health.

Table 1. Implementations focused on telemedicine.

Article	Health area	Situation to be addressed	Summary of contents
[12]	Neurology	Amyotrophic Lateral Sclerosis Clinical Trials	Telemedicine requirements for supporting clinical trials in recruitment, consent, screening, and evaluation, such as investigator compliance with FDA-1572. Remote tests, like the ALSFRS-R, are performed for ALS treatment
[13]	Orthopedics	Remote patient care in surgical orthopedics	Identifying the benefits and challenges of remote care became necessary during the COVID-19 pandemic. Benefits include increased access to healthcare and decreased provider spending. The challenge to address: Cost management for technology implementation and maintenance
[14]	General Practice	Two-way communication systems linked to the patient's medical record	Existing patient portals are being improved to allow online interfaces for patients to monitor certain aspects of their health remotely, such as blood sugar levels or blood pressure
[15]	Otolaryngology	Digital assessment and care	Shift towards using virtual platforms for patient care that comply with HIPAA requirements, including platforms like "Skype for Business," "Zoom for Healthcare," "Google G Suite Hangouts Meet," "Doxy.me," "Updox," and "Vsee"
[16]	Neurology / Neurophysiology	Development of guidelines in Italy for clinical teleneurophysiology	Use of secure VPN connections and remote desktop programs to establish both in-hospital and out-of-hospital computer networks, ensuring compliance with patient privacy legislation

Table 2. Implementations focused on big data.

Article	Health area	Situation to be addressed	Summary of contents
[17]	N/A	Secure informed consent of personal data provided by individuals	Research on synthetic data, generated by artificial intelligence algorithms trained on real-world data, aiming to address the issue of miscommunication regarding informed consent and the abuse of personal data
[18]	Oncology, General Medicine, Gynecology, and Obstetrics	Measuring the performance of healthcare innovations	Use of dashboards to present key performance indicators and enable performance management in hospitals. Example applications in pilot projects include deploying a tracking interface for locating medical equipment and utilizing big data to identify workflow bottlenecks within the hospital
[19]	N/A	Unfalsifiability and anonymity of patient information	Proposing a secure and privacy-preserving authentication system, known as SEAPA, based on Lattice's approach, to meet the data security requirements of cyber-physical healthcare systems

3.3 Summary of Findings

Although the articles were classified based on the primary implementation identified, they have a close relationship. Telemedicine in clinical engineering is connected to managing big data, and digital health is linked to artificial intelligence, cybersecurity, and big data. An example of this relationship is in reference [22], where inter-societal recommendations by the Italian Society of Neurophysiology and the Italian Society of Telemedicine are mentioned. These recommendations involve using computer networks, secure VPN connections, and remote desktop software to enable remote control of electro-medical equipment by physicians.

Table 3. Implementations focused on digital health.

Article	Health area	Situation to be addressed	Summary of contents
[20]	N/A	Investing in new information and communication technologies, such as artificial intelligence, cybersecurity, and high-performance computing	The new European interoperability framework was announced in 2017, and research work has been conducted to implement it as a strategy within the timeframe of 2020–2025
[21]	N/A	Modernize the information system with the purpose of guaranteeing reliable information that anticipates the needs of the population and favors the National Health System	Policy guidelines related to e-health are mentioned, including coordinating measures to prevent and combat diseases, particularly during pandemics, focusin on utilizing digital media. Emphasis is placed on improving communication, databases, and digitizing records in the healthcare sector

Compliance with General Data Protection Regulation (GDPR) requirements, such as appointing a data protection officer, maintaining a register of processing activities, obtaining signed consent, and conducting data protection impact assessments, is necessary for health institutions.

Critical data management and control are often outsourced to external providers. Patient rights regarding access, deletion, and transfer of personal data should be respected.

During the COVID-19 crisis, big data technology was used to support virus control, and it continues to be used for performance management in hospitals. Integrated management tables and pilot projects were utilized to analyze their functionality.

The pandemic has led to the adoption of medical technologies in most of the OCDE countries, particularly in private health institutions. Digital health has been incorporated to improve administrative management, with logic/benefit measures applied to laboratory information systems and medical imaging. Laboratory chains are more advanced in medical technology and telemedicine services, allowing for experience and quality to be gained before implementing them in more extensive settings like hospitals.

3.4 Limitations and Future Areas of Opportunity

Although the benefits of clinical engineering strategies during the pandemic have been discussed, there are also areas of opportunity for further improvement and their continued implementation in clinical practices.

Reference [17] highlights a limitation related to users not always limiting the use of their personal data to the original purpose for which consent was given. In one example, private information collected for tracking purposes during the pandemic was used in a murder investigation, indicating a need to address mishandling of patient data.

Other limitations identified in the investigation include the time range of the search, with many articles focusing on pandemic mitigation strategies rather than future applications or potential long-term implementation in clinical engineering.

Member countries face various limitations in achieving permanent implementations, such as the absence of interoperable platforms, inadequate regulatory frameworks for digital health, limited budgets, and operational capabilities.

The Mexican Health Sector Program proposes six action plans to address these limitations and promote digital health:

1. Create a Health Intelligence Center to standardize information recording and storage.
2. Utilize existing information systems to create platforms and databases.
3. Digitize records or promote interoperability across different levels of care.
4. Strengthen mechanisms for recording personal data to avoid duplication.
5. Implement telemedicine in marginalized populations.
6. Improve the evaluation and management of Information and Communication Technologies in healthcare to enhance service quality.

4 Conclusions

The investigated implementations played a significant role in mitigating the spread of the SARS-CoV-2 virus and have found additional applications in healthcare and health management practices, leading to their permanent use.

The categorized applications and changes highlight the interconnectedness between different functions, such as the need for interoperability to support patient information management, closely related to digital health.

While the adoption of technologies for risk management during the pandemic was accelerated, the permanent implementation of these technologies in clinical engineering procedures requires careful consideration of various factors, including technology costs, legal agreements, the appointment of data protection officers, and ongoing data protection assessments.

The research needs to be more transparent regarding whether healthcare managers comply with the necessary agreements, training, regulations, and standards to establish the permanence of technologies in different healthcare areas officially. The need for written agreements, training, and regulatory frameworks is discussed, as well as the potential reliance on temporary consents and permits, which may indicate the current state of the permanence of these technologies in clinical engineering procedures.

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