Trends in health telematics and telemedicine services

ABSTRACT

Telemedicine has experienced a great expansion in recent years, with the inclusion of technological advances achieved on the network communications, artificial intelligence, wireless sensors networks, Internet of things, microprocessors, smartphones, cloud computing, among others novel technological solutions. The deployment of this technological advances converges on dissimilar healthcare telematics services systems, more complex by day, like telemonitoring, metaverse, telesurgery, telestroke, among others that provide more efficient and more close to human interaction solutions. The results of its application in different medical specialties have been excellent, especially during the COVID-19 pandemic. However, there are open paths to research in order to solve the challenges that telemedicine faces in the actual context, to improve the implied technologies, and to continue to penetrate medical services. The exploitation of the advantages that telemedicine offers in the future must consider the correct use of technologies, information secure and reliable management, emerging technologies inclusion, and the development of solutions in the context of each country. This work accosts a bibliographical review regarding telematic services and the different technologies supporting telemedicine in the world in last years, pointing out its strengths, more recent trends and projections.

Key words: Telematics Services; Telemedicine; Health Technologies; Metaverse.

RESUMEN

La telemedicina en los últimos años ha tenido una gran expansión con la inclusión de los adelantos tecnológicos alcanzados en las comunicaciones en red, la inteligencia artificial, las redes de sensores inalámbricos, el Internet de las Cosas, los microprocesadores, los teléfonos inteligentes, la computación en la nube, entre otras soluciones tecnológicas novedosas. El despliegue de estos adelantos tecnológicos converge en sísmiles sistemas de servicios telemáticos de salud cada día más complejos, como el telemontoreo, el metaverso, la telecirugía, el telestroke, entre otros que aportan soluciones más cercanas a la interacción humana y más eficientes. Los resultados de su aplicación en diferentes especialidades médicas han sido excelentes, especialmente durante la pandemia de COVID-19. Sin embargo, existen caminos abiertos a la investigación para solventar los retos que enfrenta la telemedicina en el contexto actual, mejorar las tecnologías implicadas, y seguir penetrado en los servicios médicos. El aprovechamiento de las ventajas que ofrece la telemedicina debe considerar en el futuro cercano el uso correcto de las tecnologías, la gestión segura y confiable de la información, la inclusión de nuevas tecnologías emergentes, y el desarrollo de soluciones en el contexto de cada país. El presente trabajo aborda una revisión bibliográfica respecto a los servicios telemáticos y las diferentes tecnologías que sustentan la telemedicina en el mundo en los últimos años, señalando sus fortalezas, tendencias más recientes y proyecciones.

Palabras claves: Servicios Telemáticos; Telemedicina; Tecnologías de la Salud; Metaverso.
INTRODUCTION

Currently, telematic health services allow permanent access to healthcare professionals through teleconsultations and telecare and telemonitoring systems. Information and Communication Technologies (ICTs) have shown great potential for enabling high-quality, more affordable healthcare services. The World Health Organization (WHO) defines telemedicine as: “The delivery of healthcare services by all healthcare professionals using valid communication and information exchange technologies, both for the diagnosis, treatment or prevention of diseases and injuries”. Telemedicine embodies the fruitful union between medicine and technology put at the service of people, each contributing the best of their advances and knowledge. Telehealth frames an even broader range of possibilities and has been described as a public policy that aims to improve the health conditions of the population through ICTs.

In its origins, telemedicine was an innovative and ingenious tool that was extremely promising for bringing medical care closer to users, overcoming geographical distances, relying on new technologies for the required connectivity, and the development of the necessary interfaces. Before the arrival of COVID-19, telemedicine was increasingly being applied to palliative care in the homes of seriously ill patients. In March 2020, the WHO declared the outbreak of COVID-19 disease a pandemic. In this scenario and in conjunction with the reduction in the cost of telemedicine solutions, high-speed broadband internet, and the massive use of smartphones, telemedicine was promoted and expanded to reduce the risk of transmission.

The advancement of telemedicine has been constant, embracing a series of innovative methods and technologies in medicine: teleconsultation, cooperative work, telemonitoring, telecare, telesurgery, among others. Works in this field include a wide range of research areas seeking to improve the architecture that underpins telematic health services, such as network communications, artificial intelligence (AI) techniques and methods, wearable Internet of Things (IoT) sensors, hardware devices, smartphones, cloud computing, among others. Given the relevance of this topic in the current context, the objectives of this work are defined as follows:

- Describe the main characteristics of the systems and technologies used by telematic health services trending globally.
- Argue the strengths and results of these technologies in the field of telemedicine.
- Identify the challenges currently faced by technology and telematic health services.

DEVELOPMENT

Systems and Technologies Employed in Telemedicine

Telemedicine is considered a way to provide a health service remotely, in the components of promotion, prevention, diagnosis, treatment, and rehabilitation, by health professionals using ICT. These tools allow medical staff to exchange data with the aim of facilitating access and opportunity in the provision of health services to the population that presents limitations of supply and/or access to services in their geographical area.

According to Ena, telemedicine can be conducted according to the mode of communication: by text (email, Facebook Messenger, WhatsApp), video (Skype, Zoom, Microsoft Team, Facetime, etc.) or audio (telephone), although the last few years have brought more complex new technologies where these categories combine. It is also suggested that telemedicine services can be divided into synchronous (text, video, audio,... in real-time) or asynchronous (email, for example). Technologies that work under Store-and-Forward models are based on the transmission of previously collected medical data (x-rays, video clips, scans, photos), between providers (patients) and medical staff, representing a cost reduction and an improvement in access to health services. This is not the best in all cases, as it may be necessary to maintain real-time contact depending on the application.

Telemedicine can involve several individuals: patient-doctor, doctor-doctor, health worker-patient, or health worker-doctor. In this sense, telemedicine networks can provide services in one-to-one (point-to-point), one-to-many (point-to-multipoint), and many-to-many (multipoint-to-multipoint) models. Figure 1 shows an example of the three models mentioned above.

One of the simplest telematic care services offered during the COVID-19 pandemic was provided by the Faculty of Medicine at the National Autonomous University of Mexico, with the opening of a chat service and telephone care center attended by medical staff for public guidance. In reference Dorsey et al., the authors present experiences in poor countries where smartphones have been used in medical care, exploiting their ubiquity and ability to connect large populations. Examples include the treatment of epilepsy in Nepal, cancer in Botswana, and depression in Jordan.

For some conditions, mobile devices can be used as diagnostic tools (for instance, to access electrocardiograms), or therapeutic (to contact a midwife or obstetrician). For several years, hospitals and national health systems have exploited telemedicine software programs that carry the patient’s medical history. This represents an advantage in managing information in this sector.
Video consultations with health professionals are popular in the field of telemedicine for diagnosis in different specialties.\(^{1(1)}\) A variety of free or low-cost video communication tools can be used, including: Apple FaceTime, Facebook Messenger video chat, Google Hangouts video, and Skype. For this, users must have access to a smartphone, tablet or computer with audio and camera, as well as a data plan or internet connection.\(^{5(1)}\) Videoconferences give doctors real-time interaction with their patients comparable to a traditional consultation, however, streaming audio and video requires fast network equipment with low latency internet access, at both ends.\(^{1(1)}\)

Virtual visits are a way to complement personal care. For instance, the telestroke system exposed in reference Dorsey et al.\(^{10(1)}\) extends the experience of stroke care teams to satellite hospitals to assist in patient care. Germany, Norway, and the United States have mobile stroke care units (ambulances equipped with CT scan scanners and video connections) that allow remote medical teams to assess patients, review images, and provide direct treatment from the patient’s location.

In the case of virtual visits, the computer or system used must have a suitable camera, speakers, and microphone, with enough processor speed to run the required software. Platforms include web applications, computer applications, web systems, mobile apps, video calls, social networks, electronic messaging services, and short message services.\(^{8(1)}\)

Remote surgery or telesurgery combines elements of robotics, high data transmission connections, tactile sensations, and advanced communication technologies. The surgeon carries out the operation using a robot that performs the teleoperation, achieving amazing results and making the expertise of the best professionals much more accessible, in a specialty of traditional medicine that largely depends on the skills of the staff that performs it.\(^{12(1)}\) As posed by Concha-Mora et al.\(^{9(1)}\), its use was increased during the COVID-19 pandemic, however, its future use can benefit from new technologies that are being developed, such as 5G. Pathology has also relied on the treatment and digital transmission of images, including virtual microscopy.\(^{13(1)}\)

**Architectures Employed in Telemonitoring**

Perez-Garcia et al.\(^{8(1)}\) outline telemonitoring as the relationship between health personnel and the user

https://doi.org/10.56294/dm202216
anywhere they are, through a technological infrastructure that collects and remotely transmits clinical data, so that the service provider can track and review clinically, and provide a response accordingly. Telemonitoring includes the transmission of physiological data, as well as other non-invasive ones, and has been boosted by recent advances in sensors, small-sized processors, body area networks, and wireless data transmission technologies, achieving the assessment of environmental, physical, and physiological parameters in different environments, without activity restriction.\(^{(13)}\)

In Ena\(^{(2)}\), the authors expose a case of monitoring carried out by medical staff, who collected telematic information through a smartphone application. Clinical data (temperature and O2 saturation measured by pulse oximetry) were reviewed daily, along with the patient's electronic history for symptomatic treatment or referral to the emergency service in the presence of alarm signs. The program was extraordinarily effective according to the authors.

Telemonitoring systems, like the one for chronic respiratory patients exposed in Angelucci et al.\(^{(13)}\), generally present a two-hop structure, in which data generated by different sensors are transmitted to a gateway, which forwards them to the data management section via cellular technology links. Figure 2 shows a scheme that represents this architecture. The sensors involved in the example system of Angelucci et al.\(^{(13)}\), are divided into: respiratory monitor, pulse oximeter, activity tracker, environmental sensors, and monitors of other physiological variables. The link between the different sensors and gateways in these types of systems is carried out using wireless sensor networks (WSN), with technologies such as Bluetooth, Bluetooth Low Energy (BLE), ANT, ANT+, Z-Wave, ZigBee. In telemonitoring systems, the link between gateways and the cloud or data management center uses technologies such as Wi-Fi and the 4th and 5th generations of cellular communication (4G and 5G), widely known.

**Figure 2.** Telemonitoring system with two-hop transmission architecture\(^{(13)}\)

The Internet of Things (IoT), which has seen significant expansion globally in recent years, aims to create a network of devices that connect anyone, anything, at any time, anywhere, for any service and network, serving as excellent support for remote monitoring. Furthermore, IoT networks offer the opportunity to identify the optimal moment for the supply change in various devices, thereby ensuring their continuous and smooth operation, as well as the efficient distribution of limited resources, ensuring their best use and service for other patients.\(^{(7)}\)

**Telemedicine in Virtual Space and the Metaverse**

Nowadays, we can find examples of complete telemedicine systems developed to achieve independence from technologies external to each country's health systems. Su et al.\(^{(14)}\) shows a system developed in China that supports text, images, voice, video, and other forms of information exchange. This system's architecture is essentially based on three parts: the telemedical service, including teleconsultations, remote image diagnostics, remote electrocardiograms, telesurgery, conferences, etc.; the data center, with basic information (user data, doctor data, department data, etc.) and application data (electronic medical records, follow-up records, databases with patient information, telemedicine files, distance education resource libraries, etc.); and interface service, including hospital information systems, electronic medical record systems, pathological diagnosis systems, among others.

Medical teleconsultations have found a catalyst for their advancement in 3D virtual space. Lo et al.\(^{(15)}\) explains the use of telemedicine in Microsoft's Holoportation communication technology. The system used

https://doi.org/10.56294/dm202216
has an arrangement of 10 Azure Kinect cameras connected to a fusion server, where the depth outputs of each camera are combined to create a 3600 3D model. These cameras also connect to a rendering server that outputs the RGB video model, which is used for patient care in observation rooms, which can be distributed to various remote sites.

The metaverse is a three-dimensional digital environment where Augmented Reality, Virtual Reality, and AI serve as basic visual providers, and where people can have social, financial, and other interactions using personalized digital avatars that mimic real-life experiences. The metaverse constitutes a novel emerging technology in the digital space, with great potential to provide a variety of health services to patients and medical staff with an immersive experience.\(^{(16)}\)

Ali et al.\(^{(16)}\) exploit the possibilities of the metaverse in medical services and propose a service architecture divided into three environments: the patient’s, the doctor’s, and the metaverse’s. Doctors and patients interact during consultations in the metaverse environment, the main environment within the proposed architecture, with the assistance of blockchain technology, which ensures data security and privacy, granting traceability, transparency, and immunity to patient information.

People to access the metaverse environment must register in the blockchain, where all activities, images, texts, videos, etc. generated during the consultation are also collected. This type of information is useful for disease prediction and diagnosis by explainable Artificial Intelligence models (XAI).\(^{(17)}\) The metaverse also opens opportunities for telesurgery with high precision and minimal human error, as well as training in the surgical specialty, with multiple experiences reported worldwide.\(^{(18)}\)

**Strengths and Results of Telemedicine**

According to the consulted literature, telehealth and telemedicine services have successful applications in various branches of medicine, such as cardiology\(^{(19)}\) and stroke care.\(^{(10)}\) It has also been employed in the treatment of epilepsy according to Sánchez-Zapata et al.\(^{(19)}\), involving sending educational material to the patient through text messages, diagnostic videoconferences, medical meetings for the discussion of difficult cases, and even tele-electroencephalogram for prompt interpretation of electroencephalographic studies in clinics that lack a neurophysiology unit.

In recent years, a range of categories within telemedicine have emerged, responding to different branches of traditional medicine into which technology has penetrated. As outlined Chaudhary\(^{(12)}\), terms such as telepharmacy, teleneurology, teleneuropsychology, telerauma, telerehabilitation, telenutrition, telecardiology, teleradiology, telepathology, and telenursing are now managed. The report from the WHO’s Third Global eHealth Survey on the implementation of Telemedicine programs in different countries informs that 75 % of the implemented programs are teleradiology, 50 % are telepathology, teledermatology, and chronic disease monitoring, and 33 % are telepsychiatry, with teleradiology being the program with the greatest stability over time.\(^{(20)}\)

During the COVID-19 pandemic, the use of telemedicine allowed many countries to slow the spread of the virus in the population by limiting person-to-person contact. Patients who identified with symptoms had a triage that prevented infection of health personnel, and those who were not infected could receive their routine care without exposure to the virus. This demonstrated the effectiveness of telemedicine and telehealth in managing communicable diseases as explain Smith et al.\(^{(11)}\)

According to Ena\(^{(2)}\), telemedicine was equivalent to the conventional medical visit in both diagnostic and therapeutic facets. Teleconsultations lead to a higher frequency of contact between doctor and patient, albeit of shorter duration. The feedback received from patients in Lo et al.\(^{(15)}\) has suggested a preference for the use of real-time 3D teleconsultations, feeling that they align better with traditional in-person care, which is the fundamental goal of telemedicine.

Patients who receive palliative care through telemedicine are typically very satisfied with the convenience and time-saving of care through video consultation. Telemedicine also saves valuable driving time for home visits of palliative care clinicians and increases care capacity in physical clinics.\(^{(5)}\) The use of broadcast and communication tools for telemedicine on mobile devices opens the possibility for population education in the treatment and prevention of diseases.\(^{(10)}\)

Lovo\(^{(3)}\) argued how telemedicine is especially beneficial for primary care, considering the high number of patients and the heterogeneity of actions that the family doctor must carry out in their usual practice. The use of virtual interfaces in this area can help reach those groups that otherwise lack medical attention, optimizing traditional care, offering a more efficient and higher quality service, regulating costs, and generating greater satisfaction in users.

Telemedicine has been shown to reduce hospitalization rates when applied to anticoagulation consultations or malnutrition in elderly patients.\(^{(21)}\) Telemonitoring has had a significant impact on preventing hospitalizations, improving self-care, and raising health-related quality of life.\(^{(13)}\) Cost analyses conducted in countries like Canada, presented by Sánchez-Zapata et al.\(^{(4)}\), show how telemedicine consultations in patient follow-up with

https://doi.org/10.56294/dm202216
epilepsy represent significant capital savings.

**Challenges to Telemedicine**

Telemedicine faces several challenges in perfecting its outcomes and being seen as a regular practice of health systems worldwide. Most countries lack a regulatory framework for the practice of telemedicine and the provision of telehealth services, leaving open space for the different problems that inadequate implementations can bring. The free technological solutions that are most known to medical personnel may not respect the security and privacy requirements of the country’s health-related data. Since they belong to third parties and are not integrated with national health systems, they do not share the information obtained with public health authorities or epidemiological surveillance, representing a risk to patient privacy. Telemedicine activities must be recorded in the user's medical history for their control and medical evolution.

The technological infrastructure used for information exchange in telehealth services must guarantee the confidentiality and security of the data, with the service provider being responsible for this. The use of appropriate technological tools is fundamental, with specific platforms that allow encrypting the information exchanged being used. The network connection must be secure, with bandwidth that allows stable connectivity. Efforts must continue to eradicate significant limiting factors, such as speed, latency, and reliability in the case of telesurgery, especially over considerable distances, like from one continent to another, as outlined by Chaudhary. In the long and medium term, researchers must take telemedicine to an expansion of the areas it covers, the applications it has, and the population sectors it anticipates. Each country’s health systems face the challenge of including telehealth services in their regular practice, thus better expanding and validating the results obtained in the cited literature.

**CONCLUSIONS**

Telemedicine can be considered one of the greatest innovations in health services, not only from a technological standpoint but also from a cultural and social perspective. The constant development of new technologies is reflected in it, with the adoption of new tools and solutions, such as AI, wearable medical sensors and devices, IoT, installable medical devices, augmented and virtual reality, 5G, the metaverse, among others. The deployment of these technological advancements converges in increasingly complex telehealth service systems, providing solutions that are closer to human interaction and more efficient, in different areas of medicine.

Telemedicine and telehealth services in the contexts of the pandemic and post-pandemic COVID-19 have been shown to favor access to medical care services, reduce costs, free up capacities in clinics and hospitals, prevent the spread of diseases, expand prevention and diagnosis, improve care quality and organizational efficiency. Despite the significant expansion that telehealth services have had in recent years, there are still new applications to be carried forward focused on covering all sectors of society and areas of medicine that have not yet been explored. The exploitation of the multiple advantages presented by telemedicine must be paired in the near future with the correct use of technologies, the secure, reliable, and transparent management of patient information, the assimilation of new technologies, and the development of proprietary solutions that are appropriate to the characteristics of each country.

**REFERENCES**


FINANCING
No external funding.

CONFLICT OF INTEREST
AUTHORSHIP CONTRIBUTION

Conceptualization: Marcos A Gil Oloriz.
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