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ORIGINAL ARTICLE

Development of a Telemedicine system for rural areas

Desarrollo de un sistema de Telemedicina para zonas rurales

Guadalupe Esmeralda Rivera García, Juan Carlos Ramírez Vázquez, Ángel Eduardo del Ángel Hernández, José Angel Hernández Santiago*

Abstract

Telemedicine systems are a strategy to provide accessible, high-quality healthcare to communities that face significant barriers to accessing appropriate healthcare services. Through the integration of information and communication technologies (ICT), these initiatives enable residents of remote and disadvantaged areas to access medical consultations, diagnoses and disease monitoring without the need for prolonged travel. This research focuses on the problem of limited access to specialized health services in marginalized regions of northern Veracruz and southern Tamaulipas. In response to these challenges, the development of a telemedicine platform is proposed with the aim of facilitating medical consultations with specialists. The methodology used involves the identification of system requirements, culminating in the creation of a telemedicine web platform that allows remote medical consultations. In conclusion, telemedicine emerges as an innovative opportunity to improve medical care in underserved areas, offering practical and sustainable solutions to overcome existing barriers, and potentially transform the health landscape in these communities.

Keywords: telemedicine; consultations; distance; medicine; telemedicine platform

Resumen

Los sistemas de telemedicina constituyen una estrategia para proporcionar atención médica accesible y de alta calidad a comunidades que enfrentan obstáculos significativos para acceder a servicios médicos adecuados. A través de la integración de tecnologías de la información y comunicación (TIC), estas iniciativas posibilitan que los residentes de áreas remotas y desfavorecidas accedan a consultas médicas, diagnósticos y seguimiento de enfermedades sin necesidad de desplazamientos prolongados. La presente investigación se centra en la problemática del acceso limitado a servicios de salud especializados en regiones marginadas del norte de Veracruz y del sur de Tamaulipas. Como respuesta a estos desafíos, se propone el desarrollo de una plataforma de telemedicina con el objetivo de facilitar consultas médicas con especialistas. La metodología empleada implica la identificación de los requisitos del sistema, culminando en la creación de una plataforma web de telemedicina que permite realizar consultas médicas a distancia. En conclusión, la telemedicina emerge como una oportunidad innovadora para mejorar la atención médica en zonas marginadas, ofreciendo soluciones prácticas y sostenibles para superar las barreras existentes, y potencialmente transformar el panorama de la salud en estas comunidades.

Palabras clave: telemedicina; consultas; distancia; medicina; plataforma de telemedicina

Correspondencia: esmeralda.rivera@itspanuco.edu.mx

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*TecNM. Instituto Tecnológico Superior de Pánuco. Pánuco, Veracruz, México

INTRODUCTION

Telemedicine has established itself as an innovative and revolutionary solution in the field of health care, providing a route to carry medical services to the most neglected and marginalized communities (Mesa & Pérez 2020). In an increasingly digital world, telemedicine uses information and communication technologies (ITCs) to offer remote medical care (Castillo et al., 2022), overcoming the geographical and logistics limitations that traditionally have obstructed access to health in remote and disadvantaged regions. This approach not only improves the accessibility and quality of health care but also has the potential to transform the lives of millions of people who reside in marginalized areas (Saiso et al., 2021).

Marginalized regions, often marked by geographic isolation, lack of infrastructure and shortage of medical resources, face major challenges in the delivery of health services (Santiago,2024). These challenges include the shortage of trained medical personnel, poor infrastructure, and restrictions on the access to medication and medical technologies, resulting in an inadequate health care that undermines the health and well-being of vulnerable populations (Vázquez et al., 2020). In many cases, health centers are hours away, and the lack of appropriate transportation prevents patients from receiving regular and timely health care. Also, unfavorable socio-economic conditions worsen this situation, because many people cannot pay the expenses associated with travel or medical treatment (Sanz & Oliva, 2021).

In this context, telemedicine emerges as an essential tool to close the gap in health care, offering sustainable and accessible solutions. Through digital platforms and mobile devices, telemedicine provides a way to overcome these barriers (Aizenberg, 2023), offering specialized and uninterrupted medical care to those that need it most. This has a significative impact on these regions by allowing remote medical appointments, reducing the need for expensive and often prohibiting trips to receive attention, which is particularly relevant in rural and remote areas where health centers could be far and away (Vanegas, 2020). Also, telemedicine eases the follow up and management of chronic diseases, allowing patients to receive constant monitoring and orientation without leaving their communities, which is crucial for the management of conditions such as diabetes, hypertension, and cardiac diseases, which require regular monitoring and treatment adjustments (López et al., 2021).

Telemedicine covers a wide range of services, from online medical medical consultation and remote patient monitoring, to continuing education for health care professionals. Through digital platforms, patients can contact specialists and medicine doctors without the need to travel, which is beneficial for those with reduced mobility or chronic conditions that require constant supervision (Bustamante, 2023). Connected medical devices, like blood pressure monitors and glucose meters, allow real time transmission of vital data to health care providers, facilitating continuous monitoring and effective

disease management. These advances not only improve the quality of life of patients but also optimize the use fo health care resources and the associated costs from the medical attention (Gómez, Salas & Fernández, 2023).

The successful implementation of telemedicine systems in marginalized areas requires careful planning and close collaboration between various actors, including the government, non-governmental organizations, health care providers and the private sector (López et al., 2023). In addition, it has the potential to improve the education and training of local health care professionals. Through webinars, online conferences and remote training programs, doctors and nurses can access up-to-date information to develop their skills without the need to travel to urban centers, thus contributing to strengthening local capacities to address health challenges and improve the quality of care provided to the community (Castaño, García & Medina, 2022).

However, it is essential to assess the specific needs of the community and design a system that is accessible and easy to use for patients and health care professionals. Technological infrastructure, such as internet connectivity and availability of adequate devices, is a critical component that must be developed and maintained (Barbosa & Sanjuan, 2023). In addition, the education and training of health care providers in the use of telemedicine tools is essential to ensure a successful and sustainable implementation (Rodriguez et al., 2023).

The development of telemedicine also poses several challenges, especially in terms of privacy and security of the patient's personal information (Pico & Aparicio, 2020). It is crucial that government initiatives and collaboration with non-governmental organizations and the private sector develop adequate and accessible technological infrastructures. Furthermore, it is essential to consider the privacy and security of medical data, as well as the protection of patient information against unauthorized access (Quispe, 2021).

Local regulations and laws must be enforced rigorously to protect the patient's rights and maintain confidence in the health care system (Gianfelici,2022). Also, digital literacy in communities needs to be addressed, ensuring that patients and their families learn how to use telemedicine platforms and feel comfortable doing so. Internet connectivity and the availability of suitable devices are also critical factors that must be addressed to ensure the effectiveness of these systems (Zambrano et al., 2023).

Education and awareness emerge as crucial elements in the adoption of telemedicine, highlighting the importance of the patient's understanding of the benefits of this modality and how it can be integrated into their daily lives. Awareness campaigns and community education programs have the potential to overcome cultural and social barriers that could hinder the acceptance of new health technologies. Testimonials from other patients and endorsements from community leaders can act as powerful catalysts

for change, promoting a favorable attitude toward telemedicine (Fernandez, 2022).

Globally, telemedicine has proven its effectiveness in a variety of circumstances, from health crisis to chronic disease management. The COVID-19 pandemic highlighted the relevance of telemedicine by enabling the continuity of care in times of physical constraints. This experience has accelerated the adoption of digital health technologies and underscored the need to invest in robust and accessible telemedicine systems. For the marginalized areas, this transition may represent an unprecedented opportunity to improve the health and well-being of their residents (Carbonel et al., 2024).

This study presents the design and development of a telemedicine system, conceived through interfaces that facilitate its use by physicians, swiftly providing the resources and tools they might need.

METHODS, TECHNIQUES, AND INSTRUMENTS

For the design of the platform interfaces, the programming language was HTML, while JavaScript and PHP were used for the internal operation of the system and its integration with real-time video call services, allowing physicians to visualize and examine the patient in real time.

Regarding the telemedicine system requirements, provided by the physicians from the Facultad de Medicina of the Universidad Autónoma de Tamaulipas, the following aspects are included: the management of the patient medical records to access data such as X-rays and laboratory results, the possibility of scheduling appointments with other physicians from different clinics through the platform, the management of patients at a clinical level to restrict their access only to authorized physicians, and the integration of real time video calls.

The telemedicine system represents a solution to address the problem of difficult access to specialized health services in certain marginalized areas of northern Veracruz and southern Tamaulipas. Four main actors are involved in the operation of the system: the system administrator, clinic managers, social service students and medical interns, as well as specialists. To access the system, you must enter the link www.telemesys.net and use the access credentials provided, allowing you to start working on the platform.

The telemedicine system, through video calls, promises to be highly beneficial, easing the consultation between a specialist doctor, the clinic administrator and a social service student who interacts directly with the patient. This will make it possible to track medical records including data such as X-rays and laboratory results, as well as to schedule appointments with other physicians in different clinics. For the patients of rural clinics, the chance to receive prescriptions issued by specialists will be opened and will be authorized and signed by the clinic administrator. The availability of medical

appointments with specialists through telemedicine can have a decisive impact on the preservation of lives.

The system is structured in four main sections: Appointments, Patients, Clinics and Doctors in the Clinics section, it is possible to create new clinics with basic data such as the person in charge, address and working hours. In the Doctors section, the registration of new physicians is allowed, requesting general information from both the head of the clinic and the undergraduate students.

In the Patients section, individuals coming from the clinics can be added, identified by their CURP (Unique Population Registry Code) to avoid duplications, and their clinical record must be completed. Once this process is completed, the patient's appointment history, clinical record, and a specific space for uploading laboratory files can be accessed. Under Appointments, there are four subdivisions: a record of previous appointments, the possibility of scheduling new appointments and a space for sending invitations to appointments with other doctors.

When creating a new appointment, the clinic administrator or the undergraduate medicine student can invite a specialist from a list, who must confirm or decline the invitation. Once the appointment is confirmed, it will appear in the upcoming appointments section. The specialist will have access to the patient's contact information, medical records, and clinical documents. Also, minutes before the appointment, the undergraduate medicine student must record general patient data, such as temperature, height, weight, blood pressure, heart rate and body mass index, which must be entered into the system to enable the video call.

RESULTS AND DISCUSSION

Once the essential elements of the system have been taken into account, the process of designing its visual structure begins, using a web design tool known as Figma. This platform, available for free, allows us to create user interfaces, as illustrated in the figure 1.

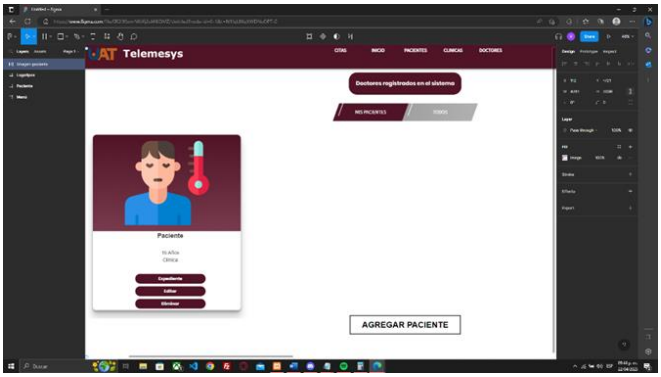

Figure 1. *Interface design by the Figma platform*

Once the interface has been designed, we move on to the actual implementation of the platform, which involves coding both these interfaces and their respective functionalities. For this purpose, the programming languages used are PHP, JavaScript y HTML, addressing the individual requirements in each section of the system. Initially, the development of a system of clinics within the platform has been launched. The purpose of this function is to manage and categorize patients according to the health center

in which they are affiliated, thus allowing better organization by areas for the students. Figure 2.

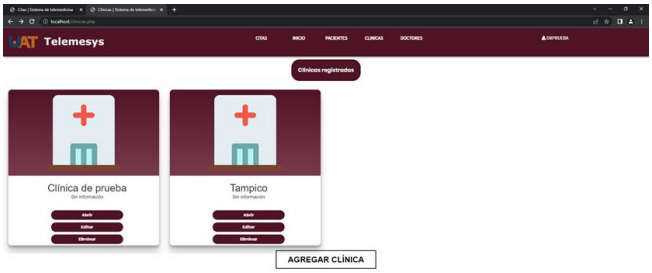

Figure 2. *Clinics sections in the platform*

Following the segmentation of the system into clinic units, patient administration is simplified, thus incorporating a patient registration form that includes clinical questioning. This form will then make it easier for doctors to create clinical records, which will be generated and stored on the platform. Once registered, these records cannot be modified or altered, guaranteeing the preservation of the patient's dignity, and ensuring ethical integrity in all procedures performed. Figure 3.

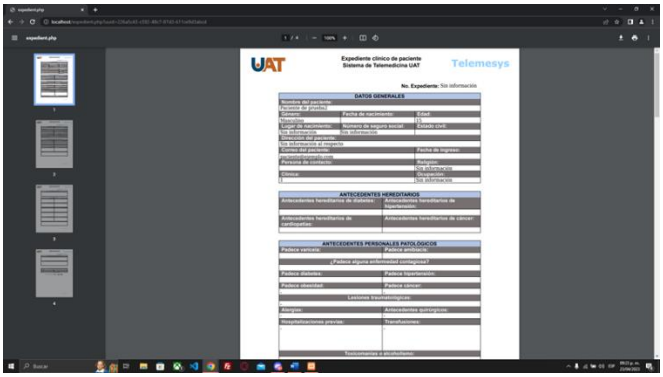

Figure 3. *Clinical record format generated by the system*

Appointment management aims to facilitate the physician's connection with specialists from different clinics and medical areas. Through the system, the doctor can request a medical appointment, which must be previously confirmed by the specialist. The latter receives an invitation within the platform, which can accept or decline according to their availability and professional criteria.

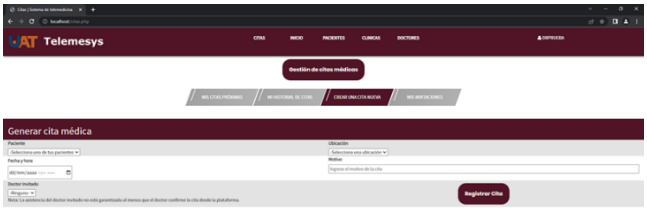

Figure 3. *Medical appointments management section*

The teleconsultation is performed through a video call generated within the platform itself, which, when the consultation is initiated, triggers a conference in the Jitsi Meet API. This API provides secure and encrypted videoconferencing with the DTLS-SRTP security protocol, ensuring privacy and ethics in the medical process. In addition, the doctor who is present with the patient has to enter preliminary patient data, such as symptoms, temperature, weight, height, among others. This data not only streamlines the process for the specialist doctor, but is also permanently recorded on the platform, forming part of the patient's clinical history, which is immutable and securely stored. Figure 5.

At the end of the teleconsultation, the physician can generate a prescription directly through the system. This prescription includes information such as the name of the doctor, his/her medical professional license number, home institution, as well as the

details of the treatment prescribed, in accordance with the legal requirements demanded by Mexican legislation for this type of documents.

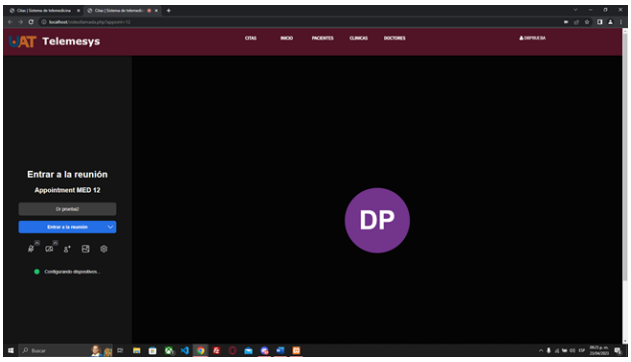

Figure 5. *Video call generated on the platform for patient care*

Finally, there is a test program is scheduled to start soon, in order to test the functionality of the system, implementing it in several health care centers in the city of Tampico, Tamaulipas, Mexico. This project will be carried out in collaboration with students of the Surgeon Physician Degree from the Universidad Autónoma de Tamaulipas that are currently doing their social service internships. The implementation of the platform aims to provide families in the region with access to consultations with medical specialists without the need to travel to other cities or hospitals, allowing them to attend exclusively to their nearest health center.

One of the main benefits of telemedicine in marginalized areas lies in its ability to overcome geographic limitations and improved access to medical care. A study by Guerra (2018) explored how telemedicine has made remote medical consultations more accessible in rural areas of the United States, thereby reducing the need for patients to make long trips to access specialty care. In a similar case, Shewamene et al. (2021) conducted research to assess access and utilization of health services through telemedicine in remote areas of sub-Saharan Africa. The results indicated that the use of telemedicine significantly increased medical care, especially among vulnerable groups such as pregnant woman and children.

In addition, telemedicine can improve early detection and management of chronic diseases in these communities. A study by Huaiquián, Espinoza & Ríos (2022) highlighted how telemedicine has enabled a more effective monitoring of patients with chronic diseases such as diabetes and hypertension, which facilitates early interventions and reduces associated complications. Williams & Shang (2024) examined the effectiveness of a telemedicine system in the management of chronic diseases such as diabetes and hypertension in a rural community, obtaining results that showed a significant improvement in the control of blood glucose and blood pressure levels, as well as increased adherence to treatment among participants.

On the other side, a longitudinal study by Pont et al. (2021) investigated the impact of telemedicine on early detection and prevention of disease in an Indigenous community in South America. The results revealed a significant improvement in the early detection of chronic diseases and an increase in participation in health promotion and preventive care activities.

Even though telemedicine has significant benefits, its application in marginalized areas faces several challenges. A Word Health Organization (WHO) report (WHO,2020) identified the lack of technological infrastructure and a shortage of trained medical personnel such as the main obstacles to the adoption of telemedicine in developing countries. A case study by Ziegler et al. (2020) identified technological and infrastructural challenges affecting telemedicine implementation in rural areas of North America, including limited internet connectivity and lack of technical training among health care providers.

In addition, privacy and security of patient data are important concerns in telemedicine environments. Fernandez (2020), in his research, highlighted the need to address concerns about the confidentiality of medical information transmitted through electronic channels, especially in regions where data protection regulations are less rigorous. In a similar context, Reino (2023) conducted an analysis of the legal and ethical implications of telemedicine use in rural areas of Latin America, identifying concerns about health data privacy, informed consent, and medical liability. This highlights the importance of establishing clear regulatory frameworks and data security policies..

CONCLUSIONS

In front of the social challenges Mexico faces, telemedicine emerges as one of the most viable alternatives to address and counteract the difficulties in accessing specialized medical services in marginalized areas. The development of this platform presents itself as a totally feasible option, with multiple doctors willing to provide medical care through remote consultations, while being assisted in person by colleagues or medicine doctors in their social service internship. The application of this platform could contribute to counteract the worrying statistics related to medical accessibility in Mexico, and with it, potentially save human lives.

The development of implementation strategies and infrastructure for the use of the platform presents itself as a challenge but represents a more viable alternative to the various obstacles that prevent society from going to specialized medical units. One of the main challenges faced by the platform lies in the constant need for the presence of medical students or medicine doctors in their social service internship to carry out an adequate examination of the patient and evaluate their symptomatology, which leads to the need of employing human resources in the areas where the platform is planned to be used, which is in itself a challenge for implementation. Another crucial aspect to consider is the importance of providing training to the personnel who will use the platform, in order to guarantee its correct use and optimize time. However, the intuitive designed interfaces make the website easy to understand, doctors can easily grasp the functionality of each section of the system.

The telemedicine system represents a revolutionary opportunity to improve medical care in marginalized

areas, offering practical and sustainable solutions to overcome existing barriers. By leveraging modern technologies and fostering collaboration among diverse actors, it is possible to transform the health landscape in these communities, ensuring that all individuals, regardless of location, have access to quality medical services.

Successful implementation of a telemedicine system requires a comprehensive strategy that considers local needs, technology infrastructure, health care providers training, and patient education. With these elements in place, telemedicine can become a powerful tool to promote health and improve the lives of people in the most disadvantaged areas of the world.

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