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PAPER

AT: Asynchronous Teleconsultation for Healthcare Facilities in Rural Areas of Peru

David Mauricio[1](✉), Walter Bendita[1], Ronaldo Flores[1], Pedro Castañeda[1], Robert Chuquimbalqui-Maslucán[2], Leonardo Rojas-Mezarina[2], Nelson Maculan[3]

[1]Universidad Peruana de Ciencias Aplicadas (UPC), Lima, Perú

[2]Universidad Nacional Mayor de San Marcos (UNMSM), Lima, Perú

[3]Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil

pcsidmau@upc.edu.pe

ABSTRACT

Currently, telehealth services in rural regions of Peru primarily rely on telephone and text message communication between rural physicians and specialists based in cities, leading to delays in accessing specialized healthcare services. To overcome this limitation, we propose an information and communication technology (ICT) model for asynchronous teleconsultation in rural areas of Peru. This model, implemented through a system called SITEA, coordinates city-based specialists with treating physicians in rural areas and integrates care phases along with electronic clinical records. A case study conducted in a rural Peruvian healthcare facility, which had limited Internet connectivity and lacked teleconsultation services, revealed significant outcomes. Within 23 days of implementing SITEA, the facility began offering specialized care services, leading to a 60% reduction in patient transfers to specialized urban healthcare facilities. Furthermore, a satisfaction survey conducted with 50 patients resulted in overwhelmingly positive feedback regarding the quality of medical care and future expectations for healthcare services. These positive outcomes can be attributed to the implementation of specialized services, the shift from physical to electronic records, and improved diagnostic accuracy. Importantly, healthcare personnel found the system easy to navigate and highly beneficial, despite the area's connectivity limitations.

KEYWORDS

telemedicine, asynchronous teleconsultation, rural zones

1 INTRODUCTION

Currently, millions of people live in rural areas that are isolated and impoverished, which makes them more vulnerable to various diseases [1]. This vulnerability is exacerbated by inadequate healthcare services, which are often characterized by limited services, physician shortages, a lack of medical equipment, and suboptimal technology utilization [2]. Despite a deficit of over 10,000 doctors in Peru, a staggering

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54% are based in the capital, Lima, leaving rural communities with minimal or no healthcare services [3]. Typically, healthcare services in these rural areas are provided by recent medical graduates who participate in the rural and urban marginal health service programs. These result in the provision of basic, non-specialized care [4]. Accordingly, telemedicine has emerged as a viable solution, enabling the delivery of specialized services in rural areas through remote consultations and thereby garnering high levels of patient satisfaction [5].

The term "telehealth" is gaining prominence due to its impactful applications in clinical settings and the transmission of complex health-related information, including demographics and operational data. In Peru, telehealth is governed by Law No. 30421 (the Telehealth Framework Law) which outlines its guiding principles, implementation measures, and range of services [6]. This regulatory framework is expected to be complemented by a nationwide fiber-optic backbone project, designed to expand Internet services to a substantial number of healthcare facilities across the country [7].

According to the Telehealth Framework Law, Peru's telehealth strategy is organized along four development axes: telemedicine for healthcare service provision; teletraining to enhance the skills of healthcare personnel; teleIEC (teleinformation, education, and communication) to promote a healthy lifestyle and well-being; and telemanagement for the efficient planning, monitoring, and supervision of healthcare services [6].

Telemedicine can be implemented through two distinct approaches: synchronous and asynchronous. In synchronous mode, real-time interaction among multiple participants is facilitated via information and communication technology (ICT). An example is the TCO app, which is designed for remotely monitoring overweight and obesity in pediatric patients. It has shown superior treatment outcomes and lower dropout rates compared to traditional monitoring [8]. Another example is the use of smart glasses, which allow specialists to see patients from a technician's perspective and provide detailed instructions for rehabilitation therapy [9]. The ARTEKMED system uses virtual and augmented reality to generate a three-dimensional reconstruction of the intensive care unit (ICU), enabling real-time communication between medical professions at remote and local locations while reducing the risks of infection spread and personnel traffic [10].

Conversely, asynchronous telemedicine involves the delayed transmission of information, typically when real-time communication with the specialist or physician is not possible due to either a lack of connectivity or specialist availability [9]. This approach is especially relevant in rural and vulnerable areas, such as those found in the Amazon, coastal regions, and the Andean communities of Peru. In several countries, asynchronous telemedicine has been successfully used to expand healthcare services [11]. For instance, the tele-emergency service in the Himalayas aims to alleviate the shortage of healthcare services in mountainous and sparsely populated regions [12]. Similarly, the telepsychiatry system in Colombia is designed to diagnose and treat individuals who choose isolation [13], and the PATH system in the United States facilitates consultations between general practitioners and specialists [14]. Notably, in Albania, teleconsultations represented 63.7% of healthcare services as of 2015 [11].

In Peru, both the Ministry of Health (Minsa) and the Social Health Insurance (Es-Salud) utilize telemedicine systems for medical care. The most common asynchronous modality relies on text messages or emails, but these often lack essential data, such as medical history, which is crucial for accurate diagnosis and treatment planning [15]. The clinical history (CH) typically includes basic information that helps imitate care processes for each patient and identifies previously involved healthcare professionals. Despite the significance of asynchronous telehealth, and more specifically, asynchronous teleconsultation in rural areas (TAZR), there is limited existing scholarly literature on the subject. The present study introduces a web-based asynchronous teleconsultation solution specifically tailored for rural areas. The solution focuses on multiple medical specialties and integrates clinical histories.

The remainder of this article is organized into four sections. In Section 2, a review of asynchronous telemedicine in rural areas is conducted. The proposed asynchronous telemedicine web system and its validation are presented in Sections 3 and 4, respectively. Finally, the conclusions are summarized in Section 5.

2 ASYNCHRONOUS TELEMEDICINE IN RURAL AREAS

Telemedicine significantly expands access to quality healthcare, particularly benefiting Peru's rural population, which accounts for 20% of the country's total. In such remote and vulnerable regions, access to quality healthcare facilities is extremely limited. These areas suffer from a lack of sanitary infrastructure, equipment, and healthcare professionals, as well as a shortage of specialists capable of addressing community health issues.

In recent years, asynchronous telemedicine has made significant advancements in various domains. For instance, telepsychiatry has shown positive outcomes in treating individuals with mental disorders, especially those in remote areas [13]. Tele-ophthalmology has been proven effective in diagnosing glaucoma, with patient satisfaction levels ranging from satisfied to very satisfied [16]. Tele-obstetrics aims to provide support to expectant mothers throughout their pregnancies by reducing the need for in-person visits and ensuring continuous care [17]. Various barriers to the adoption of telemedicine, such as connectivity, operational hours, and infrastructure, have been identified [18], along with key performance indicators to guide service improvement [19].

Technological platforms play a critical role in the successful implementation of telemedicine, as they allow for seamless application operation without requiring technical expertise from the user. Various platforms have been analyzed in the scholarly literature for their ability to fulfill specific telemedicine requirements. For example, [20] describes platforms that administrative staff evaluate and refer to specialists for remote consultations. The iCanCloud platform has been utilized to simulate the management of asynchronous telecardiology services, demonstrating its ability to customize services for various healthcare facilities [21]. Additionally, the HELP system has been utilized in military settings in Iraq and Syria for teleconsultations [22], while other platforms facilitate collaborative image analysis [23]. In [24], neural networks, fuzzy logic, and neuro-fuzzy logic are used to analyze biomedical images in telemedicine, preserving a greater amount of information such as spectral representation and edges. In [25], a telemedicine system is proposed with an emphasis on the Internet of Medical Things (IoMT). This system enables the connection between the doctor, the patient, and their data through various medical sensors and technologies such as Wi-Fi, Bluetooth, or GSM. In [26], a mobile telehealth prototype was developed using the rational unified process (RUP) methodology. This prototype facilitates remote patient access to mental health care services, addressing their emotional, psychological, and social well-being. A novel tele-echography (teleultrasonography) model has been introduced in several rural areas of Peru. This model utilizes a new image acquisition method involving volumetric protocols, along with comprehensive operator training, user-friendly equipment, and global cloud access for diagnosis [27].

In Peru, the Ministry of Health (Minsa) has implemented an asynchronous/synchronous system called teleatiendo. This system provides guidance, monitoring, and consultation through telephone calls by appointment [28]. Furthermore, the National Institute of Neoplastic Diseases (INEN) uses asynchronous teleconsultation services. In this system, the teleconsultant electronically compiles the patient's data and forwards it to the requesting teleconsultant for further guidance [29].

3 SITEA SYSTEM

3.1 Model

A TAZR model is presented, designed for the diagnosis and treatment of various medical specialties in regions with limited or no internet access. This model is structured into three sequential phases: admission, consultation with the treating physician, and consultation with the specialist physician. Asynchronous teleconsultation is primarily used in the last two phases (see Figure 1).

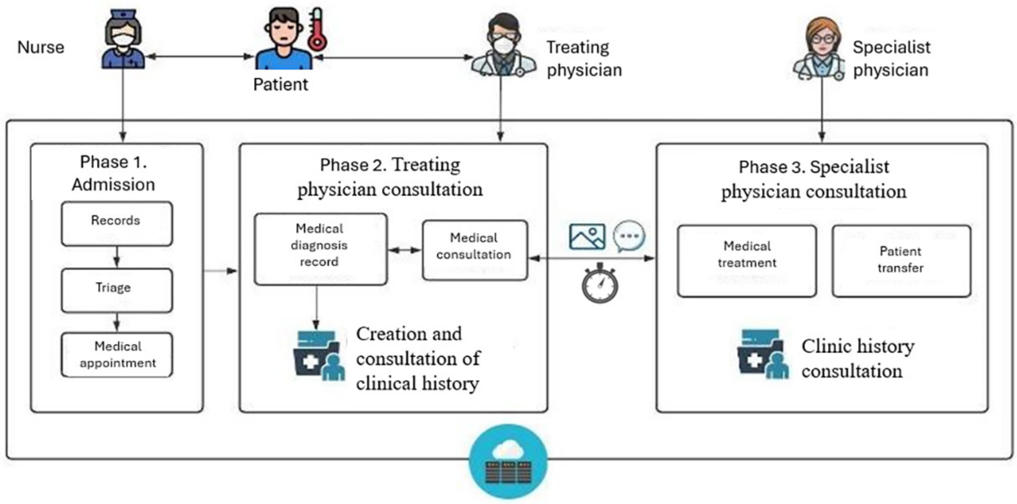

Fig. 1. Asynchronous teleconsultation model for rural areas

The first phase of the model begins when the patient arrives at the healthcare facility, where nursing staff perform a triage and record personal information. If a consultation with the treating physician is deemed necessary, an appointment will be scheduled. During the second phase, the treating physician either establishes or updates the clinical record, conducts a diagnosis, and, if necessary, initiates a specialized medical consultation. In the third phase, the specialist reviews the specialized consultation and provides feedback to the treating physician for appropriate patient care.

The model hosts three types of users (refer to Table 1).

Table 1. Roles involved in model

Roles	Description
Nurse or nursing technician	Health personnel in charge of registering the arrival of the patient, triage, and medical appointment, if required.
Treating physician	Medical personnel who are in charge of attending the medical appointment, recording the diagnosis and medical prescription, and, if required, recording the clinical data, and making the specialized consultation.
Specialist physician	Medical professional of a specific specialty, in charge of issuing a response to the consultation made by the treating physician.

Phase 1: Admission. The model includes three main activities: registration, triage, and appointment scheduling.

- Upon entering the healthcare facility, the patient undergoes data validation to determine if they are new to the system. New patients are required to provide personal data, followed by completing the arrival registration and nursing triage. For existing patients, their electronic clinical records are consulted, and the same registration and triage procedures are applied.
- During the triage stage, the patient's needs are assessed to determine the type of healthcare service required, and then a treating physician is assigned.
- During appointment scheduling, the specific day, time, and physician for the consultation are determined. The appointment may even be scheduled to take place immediately after the triage.

Phase 2: Treating physician consultation. The patient is referred to the treating physician, who provides healthcare services, records the patient's condition in the clinical history, and assesses the need for a specialized medical consultation. For such consultations, the appropriate medical specialty is selected, relevant images are attached, and additional patient information is provided to assist the specialist's evaluation. As outlined in [30], the CH of the patient is either updated or newly created, and the specifics are presented in Table 2.

Table 2. Clinical record data according to Minsa [30]

Stage	Clinical Record
Child	Family data, perinatal, family, and pathological history, vaccinations and growth control, screening, comprehensive care plan, and growth evaluation.
Teenager	Psychosocial, family, and personal history, immunizations, reproductive sexual health problems, health care benefits, and evaluations.
Young Adult	Psychosocial, family, and personal history, reproductive sexual health problems, health care benefits, and preventive control.
Middle-age Adult	Family and personal history, reproductive sexual health problems, health care benefits, and preventive control.
Older Adult	Family and personal history, reproductive sexual health problems, health care benefits, preventive control, and clinical assessment.

Phase 3: Specialist medical consultation. The specialist physician participates in the consultation initiated by the treating physician, usually at a later time. This involves reviewing the patient's current health status, any attached images, and the CH. Subsequently, the specialist decides whether to transfer the patient for emergency or urgent care or recommend a treatment plan. Figure 2 illustrates the

workflow of the specialized medical consultation, showing its different statuses—pending, in process, or attended.

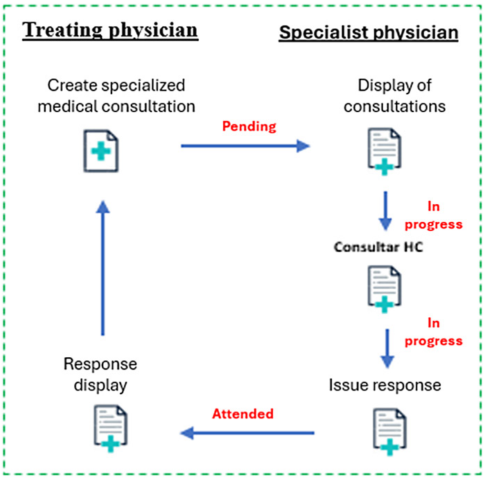

Fig. 2. Flow of specialized physician consultation

3.2 Implementation

The proposed model is implemented through an asynchronous teleconsultation system called SITEA, which utilizes a three-layer architectural framework: business, application, and technology. The business layer includes the main business actors, model phases, and supporting processes. The application layer provides support for the business components through application services and is implemented using the asynchronous teleconsultation web solution. Finally, the technology layer provides the foundational infrastructure services, such as processing, storage, and communication, facilitated by web and database servers, as shown in Figure 3.

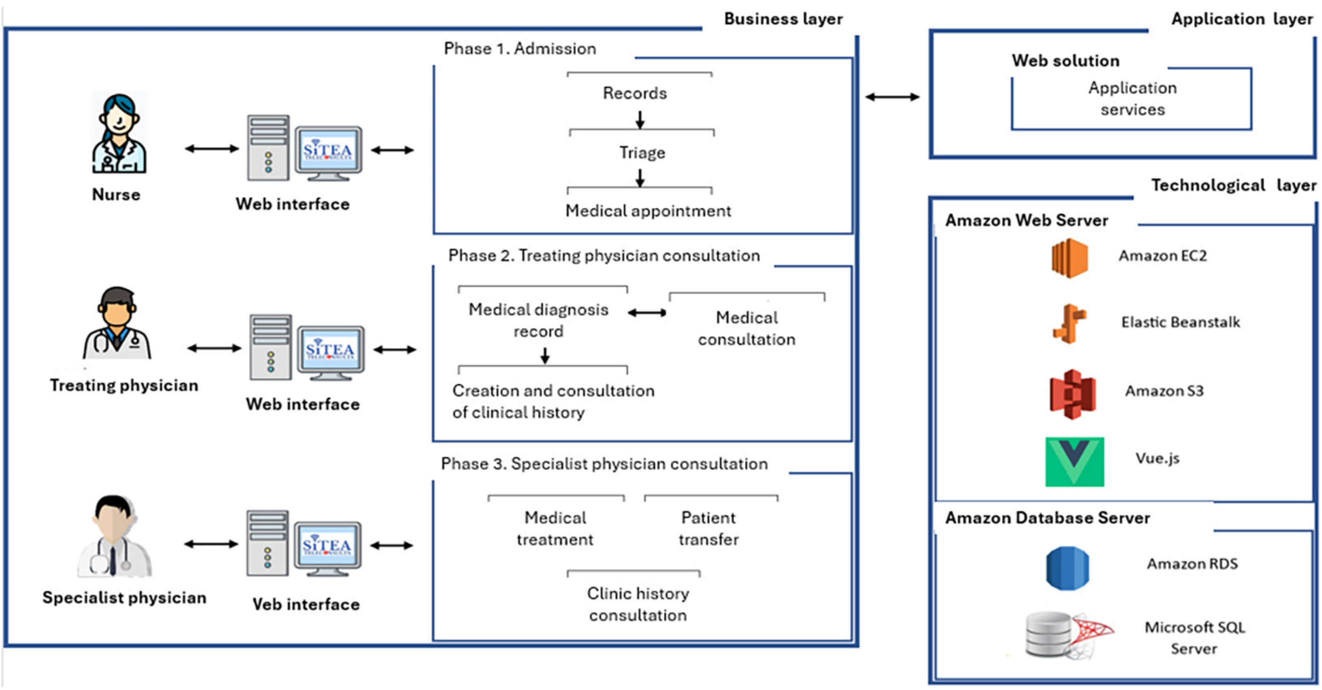

Fig. 3. SITEA architecture

For front-end development, the open-source JavaScript framework Vue.js was utilized to reduce code duplication and enable the reusability of web components [31]. Similarly, the Spring framework was used in the backend for superior component management [32]. The database used was SQL Server, and Amazon services included AWS Elastic Beanstalk, Amazon S3, Amazon RDS, and Amazon EC2.

SITEA comprises four modules, each with specific functionalities:

- Management: This module enables user registration and profile creation, including roles such as nurse or nursing technician, treating physician, and specialist physician.
- Nursing: This module supports patient registration, nursing triage documentation, medical appointment scheduling, and CH review.
- Treating Physician: This module allows for the recording of medical diagnoses, the creation and updating of clinical histories, the initiation of specialized medical consultations, and the display of responses. Figure 4 illustrates the interface for creating a specialized medical consultation, showing a section for providing details about the consultation and the related specialty. File attachments are allowed with a maximum size limit of 5 MB. Additionally, the time and date of the consultation are shown.

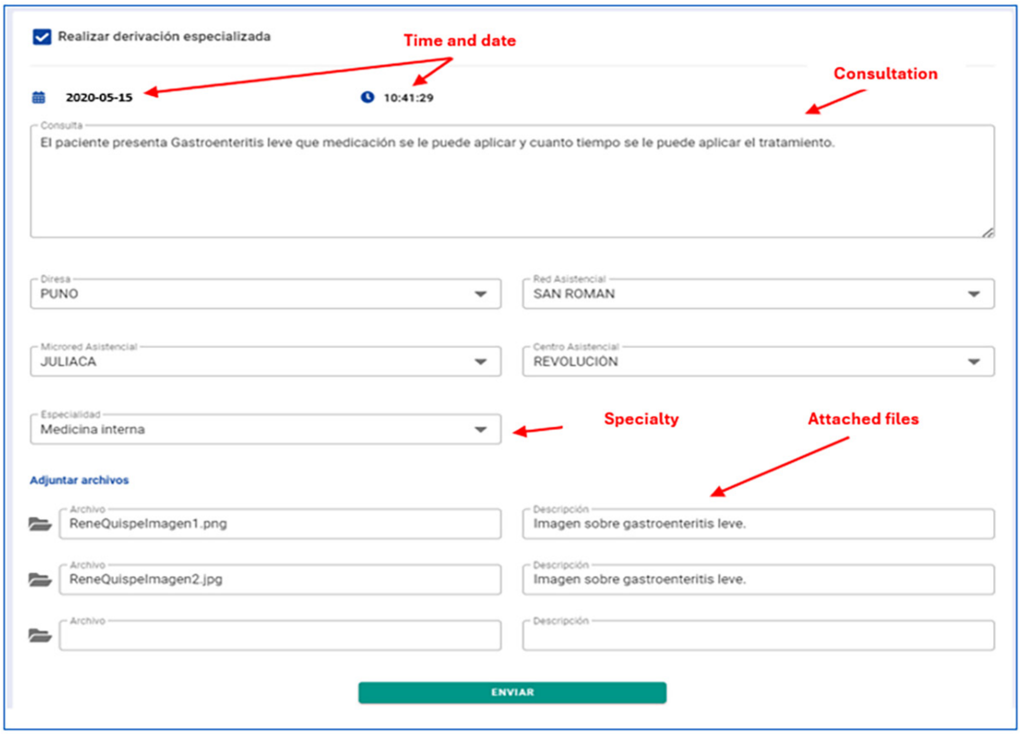

Fig. 4. Treating physician module, functionality creation of specialized medical consultation

After the specialized medical consultation and review by the specialist physician, the treating physician can access the specialist's response through the treating physician module.

- Specialist physician: This module includes functionalities such as reviewing medical consultations (initiated by the treating physician), consulting clinical histories (see Figure 5), and issuing specialized responses. The specialist physician can provide feedback by conducting individual medical consultations (see Figure 6) and reviewing any attached files or images.

Fig. 5. Clinic history consultation

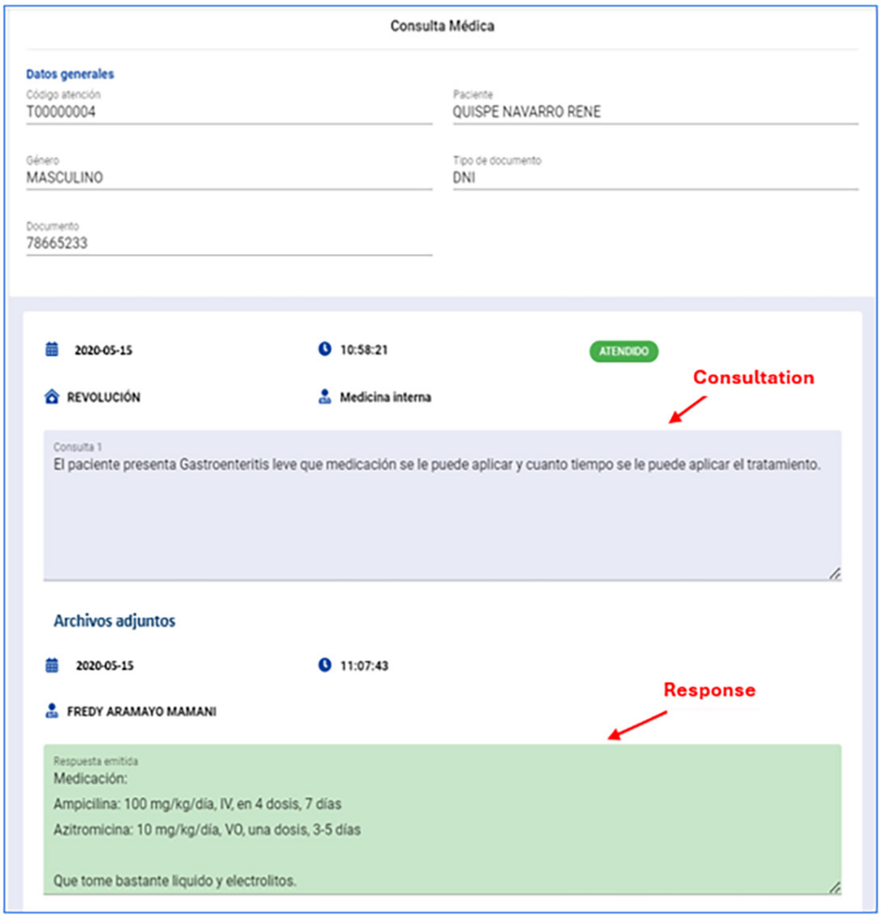

Fig. 6. Response to specialized medical consultation

4 VALIDATION

The SITEA model was validated through a case study at a health facility in rural Peru.

4.1 Rural healthcare facilities

Peru has around 8,377 rural healthcare facilities (RHF), most of which are situated far from urban centers and frequently lack reliable connectivity [33].

The case study under consideration focuses on a RHF situated in the province of Huancane, within the Puno department, designated as T-RHF. This facility is staffed by two attending physicians, one nurse, and two nursing assistants. Additionally, it is equipped with a single computer, limited internet connectivity, and provides both primary and secondary healthcare services to a rural community of 13,193 residents. First-level services include screening tests, diagnosis of parasitic infections, comprehensive guidance, nutritional counseling, immunizations, and monitoring of child growth, among others. Second-tier services include dental care, endodontics, treatments, tooth extractions, obstetric examinations, laboratory tests, and visual acuity evaluations. The patient care processes at T-RHF generally align with those at most RHFs. Upon the patient's arrival, personal data is recorded, and triage is conducted by a nurse or nursing technician. This information is documented on a medical form, and the attending physician then records the patient's CH in physical files. In the absence of specialist physicians to address serious conditions, a reference sheet is prepared detailing the ailment. This facilitates the patient's transfer to a nearby hospital for specialized care, along with their medical history and the reference sheet.

4.2 Deployment

Following discussions with T-RHF, the healthcare personnel involved in this study were enrolled in the SITEA system: a nurse, a treating physician, and a specialist physician located in Lima. Unique usernames and passwords were generated for each staff member. A two-hour remote training session was then conducted to explain the functionalities of SITEA in a practical manner. Simultaneously, customized digital user manuals were distributed to each role, explaining all functionalities and offering guidance on smooth interaction within the system. Following that, SITEA was activated, and a follow-up was conducted over a period of 23 days to monitor the administration of medical care using the SITEA platform and to address any queries related to its registration or consultation functionalities.

4.3 Participants

A nursing technician, a treating physician from the T-CSR, and a specialist based in Lima participated. The qualifications of these healthcare professionals are outlined in Table 3.

Table 3. Profile of health personnel

Medical Staff	Age	Years' Experience	Specialization
Nursing technician	25	5	Family and Community Nursing
Treating physician	33	7	General Medicine
Specialist doctor	59	35	General Medicine

A total of 123 patients participated in the study, with 50 receiving treatment with SITEA and 73 receiving treatments without SITEA. The profiles of the groups are described in Table 4.

Table 4. Profile of the 123 patients

SITEA	Patient	Age	Male	Female	Total	Diagnosis
With	Child	3 months–10 years	2 (4%)	3 (6%)	5 (10%)	Cold, discomfort due to parasites from undisinfected food and gastroenteritis.
	Teen	12–18 years	2 (4%)	1 (2%)	3 (6%)	Urinary infection and eating disorder.
	Young	20–26 years	14 (28%)	6 (12%)	20 (40%)	Accidents, communicable diseases, urinarytract infection, flu and gastritis.
	Adult	29–57 years	6 (12%)	5 (10%)	11 (22%)	Urinary infection, flu and gastritis.
	Elderly	65–81 years	5 (10%)	6 (12%)	11 (22%)	Hypertension, diabetes, osteoporosis, arthritis and Alzheimer's.
	Total		29 (58%)	21 (42%)	50 (100%)	
Without	Child	3 months–10 years	2 (3%)	6 (8%)	8 (11%)	Cold, discomfort due to parasites from undisinfected food and gastro-enteritis.
	Teen	12–18 years	7 (9.5%)	5 (7%)	12 (16.5%)	Urinary infection and eating disorder.
	Young	20–26 years	9 (12%)	7 (9.5%)	16 (21.5%)	Accidents, communicable diseases, urinary tract infection, flu and gastritis.
	Adult	29–57 years	13 (18%)	5 (7%)	18 (25%)	Urinary infection, flu and gastritis.
	Elderly	65–81 years	10 (14%)	9 (12%)	19 (26%)	Hypertension, diabetes, osteoporosis, arthritis and Alzheimer's.
	Total		41 (56.5%)	32 (43.5%)	73 (100%)	

4.4 Experiment

Experiments were conducted to evaluate the impact and user satisfaction of SITEA in a healthcare setting. Two metrics were used: a) to measure the impact, the number of specialized healthcare services provided and patient transfers were compared over a 23-day working period, with and without SITEA; b) surveys were given to healthcare personnel (refer to Table 5) and patients (refer to Table 6) to gather their views on usability and satisfaction.

The experiment was conducted from May 13 to June 8, 2020, spanning 23 working days. It took place during T-CSR's business hours, which are Monday to Friday from 8:00 a.m. to 5:00 p.m. and Saturdays from 8:00 a.m. to 12:00 p.m. The specialist doctor was available Monday to Friday from 1:00 p.m. to 8:00 p.m. The survey presented in Table 6 was administered to all patients who received treatment using the SITEA system. Therefore, questions Q5–Q7 pertain to the use of the system (current care) compared to not using the system (previous care).

Table 5. Usability and usefulness perception questions for medical personnel

Id	Questions
Q1	Did you understand the functionalities properly?
Q2	How useful do you think the system is?
Q3	How would you rate the response time?
Q4	How would you rate the clinical record in the system?

Table 6. Healthcare satisfaction questions

Id	Questions
Q5	How would you rate the medical care provided compared to your most recent visit?
Q6	How would you rate the response provided by the physician who treated you?
Q7	How do you think the medical care you receive at this health facility will change in the coming year?

The response options for all questions in Tables 5 and 6 followed a Likert scale ranging from 1 to 5 (1: very low, 2: low, 3: intermediate, 4: high, 5: very high). For example, the response options for question Q7 are: very bad (1), bad (2), neither bad nor good (3), good (4), and very good (5).

4.5 Results

The impact of SITEA on the rural community is shown in Table 7. Notably, the use of SITEA enabled the delivery of specialized healthcare services at T-RHF that were previously unavailable. Additionally, there was a 60% reduction in the number of patient transfers. This decrease can be attributed to the availability of specialized consultations, suggesting an improvement in the quality of medical care provided.

Table 7. Medical care at T-RHF before and after SITEA

Type of Care	Without SITEA	SITEA
Non-specialized	73	15
Specialized	0	35
Transfers	23	9

Table 8 presents the medical personnel's opinions on the usability and usefulness of SITEA. Utilizing intervals of 0.8 for each Likert scale score—categorized as follows: [1.0, 1.8): very low; [1.8, 2.6): low; [2.6, 3.4]: intermediate; (3.4, 4.2]: high; (4.2, 5.0]: very high—the data indicate a very high rating for the comprehension of functionalities (Q1), the system's usefulness (Q2), and the maintenance of CH records (Q4). Conversely, the response time (Q3) received a high rating, bordering on intermediate. The latter can be attributed to the limited and sometimes non-existent connectivity in the area.

Table 8. Medical personnel's perception of usability and usefulness

Medical Staff	Questions			
	Q1	Q2	Q3	Q4
Nurse	4	4	3	4
Treating physician	5	5	3	5
Specialist physician	5	5	5	5
Average	4.7	4.7	3.7	4.7

Table 9 summarizes patients' satisfaction with the medical care provided. For example, in response to question Q5, a score of 14 indicates that 14 patients rated it as 4. The results reveal that all responses averaged a very high rating according to the Likert scale, covering the quality of medical care provided (Q5), the perception of the physician's responses (Q6), and future expectations of the health service. These high ratings can be attributed to three key factors: 1) the introduction of previously unavailable specialized health services; 2) the transition from physical to digital documentation, which has improved both the speed and quality of service; and 3) more accurate diagnoses, resulting in a significant reduction in patient transfers to urban healthcare facilities.

Table 9. Healthcare satisfaction results

Questions	Answers					Average
	1	2	3	4	5	
Q5	0	2	4	14	30	4.44
Q6	0	1	5	13	30	4.38
Q7	0	3	7	11	29	4.32

5 CONCLUSIONS

In the present study, we propose an ICT model for asynchronous teleconsultation in rural regions of Peru. This model integrates medical specialists to offer specialized consultations and is designed for areas with limited or no internet connectivity. The system, known as SITEA (asynchronous teleconsultation system), was validated through a case study, yielding promising results. Unlike current models, the proposed framework facilities improved communication between primary care physicians and specialists by enabling the asynchronous transmission of clinical histories, consultations, and responses.

The SITEA platform was developed using JavaScript, the Spring framework, and SQL Server. It also utilizes services such as AWS Elastic Beanstalk, Amazon S3, Amazon RDS, and Amazon EC2. The system was tested in a remote health facility with limited internet connectivity and without prior teleconsultation services. Following the implementation and staff training, the 23-day evaluation showed a significant positive impact. Specifically, specialized care services were introduced to the rural community, resulting in a 60% decrease in patient referrals. Additionally, healthcare personnel rated their understanding of the system's functionalities (Q1), its usefulness (Q2), and the management of clinical histories (Q4) as "very high." The "high" rating for response time (Q3) was attributed to the facility's limited connectivity.

The survey results from 50 patients indicated a "very high" level of satisfaction with the quality of medical care provided (Q5), the physician's responses (Q6), and future expectations of the health service. These positive results can be attributed to three main factors: a) the introduction of specialized services that were previously unavailable; b) the use of digital documentation, which speeds up and improves services; and c) improved diagnostic accuracy, significantly reducing the need to transfer patients to urban healthcare facilities.

For future initiatives, the proposal is to integrate SITEA into Peru's national health system to expand teleconsultation services to rural areas nationwide, particularly those facing internet connectivity challenges.

6 ACKNOWLEDGMENT

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8 AUTHORS

David Mauricio has a PhD in Computer and Systems Engineering and a Master's degree in Applied Mathematics from the Federal University of Rio de Janeiro (Brazil).

He has been a professor at the Universidad Estadual Norte Fluminense in Brazil (1994–1998), and since 1998 he is a full professor at the Universidad Nacional Mayor de San Marcos in Peru. Areas of interest: Mathematical Programming, Artificial Intelligence, Software Engineering, and Entrepreneurship (E-mail: pcsidmau@upc.edu.pe; ORCID: https://orcid.org/0000-0001-9262-626X).

Walter Bendita is a graduate of the Information Systems Engineering program at the Universidad Peruana de Ciencias Aplicadas (UPC). He is currently working in Coltantech E.I.R.L. (E-mail: u201310797@upc.edu.pe).

Ronaldo Flores is a graduate of the Information Systems Engineering program at the Universidad Peruana de Ciencias Aplicadas (UPC). He is currently working in Stinville Peru S.A.C. (E-mail: u201312582@upc.edu.pe).

Pedro Castañeda has a PhD in Systems Engineering – UNMSM, a Master's Degree in Management and Information Technology Management – UNMSM and a Master's Degree in Business Administration (MBA) – ESAN. He currently leads projects of electronic brokering, software development and process improvement, using agile and traditional methodologies. He has the following certifications: Project Management Professional (PMP), Scrum Certified Developer (CSD), IBM Certified Professional in Rational Unified Process, ORACLE Certifications. Teacher of Project Management Methodologies and Software Development in public and private universities. Areas of Interest: Software Productivity, Business Intelligence, Machine Learning, and Software Engineering (E-mail: pcsipcas@upc.edu.pe; ORCID: https://orcid.org/0000-0003-1865-1293).

Robert Chuquimbalqui-Maslucán is surgeon, Master in Project Management and Social Programs, Professor at the Faculty of Medicine of the Universidad Nacional Mayor de San Marcos. Extensive experience in Management and Direction of Research, Development and Innovation projects. He is currently coordinator of Innovation and Business of the Center for Technological, Biomedical and Environmental Research – CITBM "First Center of Excellence of Peru" certified by CONCYTEC and linked to national companies and international centers of excellence such as the University of Washington (USA), Federal University of Minas Gerais (Brazil), National Institute of Health (INS-Ministry of Health of Peru) (E-mail: rchuquimbalqui@citbm.pe).

Leonardo Rojas-Mezarina is surgeon from the Universidad Nacional Mayor de San Marcos (UNMSM), specialist in Health Administration and Management (UPCH), Master (c) in Health Management (UPCH), RENACYT Researcher, Coordinator of the Health Information and Innovation Technologies research group and Associate Professor of the Academic Department of Preventive Medicine and Public Health (UNMSM). Former General Director of the General Office of Information and Systems of the National Institute of Health. He is currently Executive Director of the Telemedicine Directorate of the Peruvian Ministry of Health and Head of the Telehealth Unit of the UNMSM (E-mail: leonardo.rojas@unmsm.edu.pe).

Nelson Maculan is a Professor Emeritus, Dept. of Systems Engineering and Computer Science, Graduate School of Engineering (COPPE) and Dept. of Applied Mathematics, Institute of Mathematics, Federal University of Rio de Janeiro (UFRJ). He is a Full Member of the Brazilian Academy of Sciences, a Full Member of the National Academy of Engineering (Brazil), a Full Member of the European Academy of Arts, Sciences and Humanities (Paris), a Fellow of the TWAS – the Academy of Sciences for the Developing World, INFORMS, and IFORS. To his credit he has published 10 textbooks in Optimization, more than 120 articles published in indexed scientific journalsm and 78 supervised doctoral theses (E-mail: maculan@cos.ufrj.br).