

Feasibility and Challenges of Telemedicine in Delivering Emergency Healthcare in Conflict- Affected Areas of Yemen

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1. Introduction

The ongoing conflict in Yemen has severely damaged the country's healthcare system, leaving millions without access to basic medical services. Hospitals and clinics have been destroyed or rendered non-functional, and healthcare professionals face numerous challenges, including shortages of supplies and security risks [1]. As the traditional healthcare infrastructure struggles to meet the demand, telemedicine emerges as a potential solution to provide emergency healthcare, particularly in conflict-affected and remote regions [2].

Telemedicine has been successfully utilized in various conflict zones and resource-limited settings, such as Syria and Afghanistan, where it has helped bridge gaps in access to medical care by enabling remote consultations and treatment [3]. Similarly, telemedicine has shown significant potential in improving emergency healthcare delivery, particularly where traditional healthcare services are constrained [4]. It allows healthcare providers to remotely offer consultations, diagnoses, and treatments, overcoming geographical barriers that limit access to traditional healthcare facilities. In emergency care, this technology is especially valuable in regions where healthcare services are inaccessible due to conflict or lack of infrastructure [5].

Despite its potential, several challenges influence the feasibility of telemedicine in Yemen. Infrastructure limitations, including unreliable internet access, damaged telecommunications networks, and frequent power outages, pose significant obstacles [1]. Additionally, cultural barriers, low awareness of digital health solutions, and concerns about data privacy hinder the adoption of telemedicine in conflict settings [6]. Yemen has already seen some local experiences with telemedicine, as previous studies have documented its use in specific cases, demonstrating its potential to support healthcare services in underserved areas despite infrastructural and logistical challenges [7]. These challenges are consistent with global difficulties in implementing telemedicine in conflict-affected and resource-limited settings [3].

This study assesses the feasibility of telemedicine in delivering emergency healthcare in Yemen through a cross-sectional survey targeting healthcare professionals and patients. By examining the current landscape, this research will identify key challenges and barriers while providing insights into how telemedicine can be adapted to meet urgent healthcare needs in conflict- affected regions. The findings aim to inform healthcare providers, policymakers, and stakeholders on the necessary steps to improve telemedicine implementation in Yemen's healthcare system.

2. Study Objectives

- Assess the feasibility of telemedicine in delivering emergency healthcare services in Yemen.
- Identify specific challenges and barriers to the successful implementation of telemedicine within the Yemeni healthcare system.
- Evaluate the role of telemedicine in enhancing emergency healthcare delivery under the constraints of ongoing conflict conditions.
- Provide actionable insights for stakeholders, enabling them to overcome obstacles and improve the adoption and effectiveness of telemedicine in conflict-affected regions.

3. Study Design

This study employs a cross-sectional design, utilizing a structured survey to collect both quantitative and qualitative data. The study was conducted between November and December 2024, providing a snapshot assessment of telemedicine adoption, feasibility, and the challenges faced by healthcare providers and patients in Yemen. The inclusion of both numerical and descriptive insights ensures a comprehensive understanding of the current state of telemedicine and its potential impact in conflict-affected areas.

4. Data Collection Procedure 4.1 Survey Instrument

A structured survey was developed to assess various dimensions of telemedicine, including accessibility, usability, satisfaction, and barriers to usage. The survey consisted of close-ended and Likert-scale questions, ensuring a comprehensive understanding of participants' experiences with telemedicine. Key focus areas included demographics, capturing details such as age, gender, location, education level, and role in the healthcare system. The survey also examined access to technology, assessing digital device usage, internet reliability, and awareness of telemedicine services. Additionally, it explored telemedicine usage, capturing the experiences of both healthcare workers (HCWs) and nonhealthcare workers (NHCWs) in using telemedicine services. Participants' perception and satisfaction were measured by evaluating communication effectiveness, trust in telemedicine, and overall satisfaction levels. Finally, the survey identified challenges and barriers to telemedicine adoption, including internet connectivity issues, digital literacy, infrastructure limitations, and cultural barriers.

4.2 Sampling Method

A convenience sampling method was employed to recruit healthcare workers (doctors, nurses, paramedics, other supporting staff) and non-healthcare workers (health consumers) who had experience using telemedicine services. Given the challenges of accessing all areas, particularly in conflict-affected regions, participants were recruited through digital platforms, including WhatsApp and social media groups. This approach ensured broader outreach while addressing logistical constraints.

4.3 Survey Distribution

The survey was administered via KoboToolbox, an online data collection platform specifically designed for use in challenging environments. This platform was selected for its ability to facilitate data collection in remote and conflict-affected areas. To maximize participation and overcome accessibility barriers, the survey was distributed through WhatsApp and social media groups, allowing respondents to complete it conveniently and securely.

4.4 Ethical Considerations

Participation in this study was voluntary, with informed consent obtained through an introductory statement in the online survey. Respondents indicated their consent by submitting the survey, signifying their agreement to participate. Data confidentiality and anonymity were strictly maintained, recognizing the sensitive nature of healthcare in conflict-affected regions. Ethical approval for the study was granted by the Research and Ethics Committee of the Faculty of Medicine and Health Sciences, University of Aden, Yemen (Research Code: REC-209-2024). This approval confirms compliance with the International Conference on Harmonization (ICH) – Good Clinical Practice Guidelines, ensuring adherence to established ethical standards.

5. Data Analysis Procedure

The collected survey data (N = 263) was analyzed using IBM

Likert-scale responses were analyzed using measures of central tendency, including mean, median, and mode, to assess perception and satisfaction levels. For inferential statistics, Chi-Square Tests were performed to examine relationships between categorical variables, such as location and awareness of telemedicine. T-tests were used to compare mean scores between two groups, for instance, healthcare workers (HCWs) and non-healthcare workers (NHCWs) regarding satisfaction levels. One-way ANOVA was applied to assess differences across multiple groups, such as education level and perception of telemedicine effectiveness. Binary Logistic Regression was conducted to identify predictors of telemedicine usage, evaluating factors like healthcare role and internet reliability, while Ordinal Logistic Regression was used to model trust in telemedicine based on demographic characteristics. A significance threshold of p < 0.05 was applied to all statistical tests.

To enhance data interpretation, various visualizations were generated, including bar charts, pie charts, histograms, and boxplots, providing a clear representation of key findings.

6. Results

6.1 Participant Characteristics

A total of 263 participants were included in the study, with a mean age of 33.8 years (SD = 10.48, range 15–71 years). The gender distribution was 71.1% male (n = 187) and 28.9% female (n = 76). In terms of location, 74.1% (n = 195) resided in urban areas, 22.4% (n = 59) in rural areas, and 3.4% (n = 9) in conflict zones. The majority of participants were non-healthcare workers (NHCWs) (60.1%, n = 158), while 39.9% (n = 105) were healthcare workers (HCWs).

6.2 Access to Technology and Telemedicine Awareness

Among the participants, 59.3% reported using digital devices very often, while 57.4% had reliable internet access, compared to 41.4% who experienced intermittent connectivity.

Awareness of telemedicine services was relatively low, with only 21.3% of participants being aware of existing services. A Chisquare test revealed a significant association between internet reliability and location ($\chi^2(4) = 19.15$, p = 0.001).

6.3 Telemedicine Usage

Among HCWs, 42.9% reported having delivered healthcare services via telemedicine, with physicians being the primary users, accounting for 58.7% of telemedicine usage. Analysis of multiple response data indicates that among HCWs who utilized telemedicine, pain management (62.5%) was the most commonly provided service, followed by other emergencies (45.8%) and

pediatric emergencies (25.0%). In contrast, telemedicine was used less frequently for trauma emergencies (18.8%), heart attacks (14.6%), stroke emergencies (8.3%), and obstetric emergencies (8.3%). (Figure 1) These findings suggest that telemedicine is primarily leveraged for non-life-threatening and chronic conditions rather than acute and critical emergencies, likely due to limitations in telemedicine infrastructure and the necessity of in-person interventions for severe cases. The overall proportion of HCWs engaged in telemedicine-based medical care was 18.3% (N = 48) of the total 263 participants, reflecting a moderate adoption rate.





Figure 1

Regarding the type of telemedicine tools used, audio calls (68.1%) and text messaging (63.8%) were the most frequently utilized methods for telemedicine services, while video calls (10.6%), telemedicine platforms (8.5%), and other tools (10.6%) were

used less frequently. The reliance on audio-based communication suggests that low internet bandwidth and limited access to video conferencing platforms may be significant factors influencing telemedicine adoption. (Figure 2)





From the patient (NHCW) perspective, 64.3% of non-healthcare workers used telemedicine for medical consultations, while 21.4% used it for obtaining prescriptions, and 14.3% for diagnosis. Telemedicine was used minimally for health monitoring (4.8%) and other services (4.8%). These findings indicate that telemedicine is

primarily serving as a consultation and prescription service rather than a comprehensive remote healthcare solution. (Figure 3) A binary logistic regression indicated that HCWs were 2.14 times more likely to use telemedicine (OR = 2.14, p = 0.005).



6.4 Perception and Satisfaction with Telemedicine

A majority of participants (69.9%) believed that telemedicine could improve healthcare access in Yemen. However, satisfaction levels were mixed, with 39.2% expressing satisfaction, 35.7% remaining neutral, and 9.9% reporting dissatisfaction. A one-way ANOVA revealed that education level significantly influenced belief in telemedicine's effectiveness (F(4, 258) = 3.92, p = 0.004).

6.5 Barriers to Telemedicine Implementation

The most frequently reported barrier to telemedicine implementation was poor internet connectivity (73.0%), followed by a lack of trained staff (43.7%) and insufficient infrastructure (42.2%). Other challenges included privacy concerns (25.9%), limited access to digital devices (23.6%), lack of trust and awareness (49.0%), and unreliable electricity supply (35.0%), all of which contributed to the difficulties in adopting telemedicine services. (**Figure 4**)





6.6 Recommendations for Enhancing Telemedicine

To enhance telemedicine implementation, key recommendations include strengthening infrastructure, particularly by improving internet connectivity and ensuring reliable electricity access. Additionally, comprehensive training programs for healthcare providers are essential to enhance telemedicine competency and digital literacy. Furthermore, public awareness campaigns should be conducted to increase trust in telemedicine services, address social resistance, and educate patients on the benefits and safe use of telemedicine platforms. These measures will collectively contribute to the sustainable adoption and effectiveness of telemedicine in Yemen, especially in conflict-affected and remote areas.

7. Discussion

This study provides a comprehensive analysis of the feasibility, adoption, and challenges of telemedicine in delivering emergency healthcare in Yemen, a conflict-affected and resourcelimited setting. While telemedicine is widely recognized as a potential solution for improving healthcare access, its practical implementation remains hindered by multiple barriers.

Our findings align with existing research on telemedicine in crisis environments, reinforcing the notion that telemedicine can be a feasible intervention in such settings when supported by accessible and cost-effective technologies. A systematic review by Parkes et al. found that telemedicine interventions are viable in conflict-affected regions when leveraging low-cost digital tools [2]. Similarly, Litvak et al. (2022) highlight the importance of integrating telemedicine into disaster preparedness frameworks, enabling its effective use during emergencies [8]. However, both our study and previous literature highlight persistent barriers, including poor internet connectivity, inadequate infrastructure, and a shortage of trained personnel [9]. These challenges mirror those faced in other conflict-affected countries, where infrastructural damage and resource limitations impede telemedicine adoption [10].

Combi et al. (2016) further emphasize that telemedicine adoption in developing countries depends on infrastructure, training, and trust, which align with our findings regarding the challenges in Yemen [11]. Their study suggests that mobile-based telemedicine solutions and simplified digital literacy training programs can enhance adoption, offering potential strategies for improving telemedicine services in Yemen. Additionally, Almathami et al. (2020) highlight technical difficulties, privacy concerns, and lack of digital literacy as key barriers to telemedicine-based consultations, reinforcing the need for targeted training and regulatory safeguards [12].

Despite these obstacles, successful telemedicine models exist in comparable contexts. For example, in Afghanistan, remote consultations have facilitated the provision of medical expertise despite geographical and security constraints [13,14]. Similarly, in Syria, telemedicine has enabled local healthcare workers to access international medical expertise, particularly in emergency and trauma care [1]. Although telemedicine has been effectively deployed for acute emergency care in other conflict zones, our study found that its utilization in Yemen remains predominantly limited to non-emergency consultations. Specifically, telemedicine was most frequently used for pain management (62.5%), general emergencies (45.8%), and pediatric emergencies (25.0%), while its application in trauma (18.8%), stroke (8.3%), and obstetric emergencies (8.3%) was significantly lower.

In addition to these models, Healey (2024) highlights the potential of health technology in mitigating the adverse effects of war on healthcare systems. Telemedicine, AI chatbots, and electronic health records have proven valuable in maintaining healthcare delivery, particularly in settings where physical infrastructure is compromised. These technologies enable remote consultations, mental health support, and efficient patient data management, which are critical for sustaining healthcare services in conflict zones [15). However, Healey also emphasizes that successful implementation requires robust cybersecurity measures and reliable internet connectivity—factors that remain significant challenges in Yemen. Addressing these digital security concerns, alongside infrastructural improvements, could enhance the effectiveness of telemedicine in such settings.

This contrasts with reports from other regions where telemedicine has been effectively integrated into critical emergency services, such as tele-triage and tele-ICU support [16,17]. Litvak et al. (2022) suggest that telemedicine in disaster settings is underutilized for real-time emergency response, often due to a lack of infrastructure and preparedness, which may explain its limited role in critical care settings in Yemen [11]. Furthermore, emergency cases often require on-site interventions, further constraining telemedicine's role in acute scenarios. However, as Combi et al. (2016) and Almathami et al. (2020) suggest, expanding mobile-based telemedicine services, strengthening digital literacy, and improving regulatory frameworks could enhance real-time telemedicine adoption even in home-based or resource-limited settings. These insights reinforce the need for targeted policy interventions, capacitybuilding initiatives, and infrastructure development to maximize telemedicine's impact in Yemen.

Healey (2024) also discusses how health technology can help address disruptions in routine care, such as cancer treatments, by enabling remote monitoring and consultations [15]. These insights are particularly relevant to our findings, which indicate that telemedicine in Yemen is predominantly utilized for nonemergency consultations rather than critical emergency services. Expanding telemedicine services to include chronic disease management could alleviate the burden on local healthcare facilities and ensure continuity of care for patients with longterm health needs. Moreover, Healey emphasizes the need for infrastructure investment, improved internet access, and stronger cybersecurity measures to enhance telemedicine's viability in conflict settings. These recommendations align with our study's findings and highlight crucial areas for development in Yemen's telemedicine ecosystem.

Hadian et al. (2024) conducted a systematized review identifying further challenges that hinder telemedicine implementation. Their findings emphasize the absence of standardized technical protocols, complicating the integration of telemedicine into existing healthcare systems.

Moreover, unclear or inadequate financing mechanisms limit the sustainability of telemedicine services. Ambiguities in defining patient-physician interaction guidelines also affect trust and the overall quality of telemedicine consultations [18]. These insights align with our study's findings on infrastructure challenges, digital illiteracy, and lack of trust in remote healthcare but further emphasize the need for structured guidelines and sustainable funding models.

Several barriers must be addressed to enhance telemedicine's effectiveness in Yemen. Infrastructure limitations pose significant challenges, with 41.4% of participants reporting intermittent internet connectivity, making video consultations and real-time data sharing unreliable. Frequent power outages further disrupt both service delivery and patient access, while limited access to digital devices, particularly in rural areas, restricts telemedicine adoption.

Human resource constraints also hinder implementation, as only 18.3% of healthcare workers (HCWs) reported using telemedicine for patient care, reflecting a lack of training and familiarity with

digital healthcare tools. The absence of dedicated telemedicine platforms has forced reliance on basic communication tools, such as audio calls (68.1%) and text messaging (63.8%), which are less effective for complex medical consultations. Cultural and social barriers further impede adoption, with low public awareness (21.3%) of telemedicine services and concerns about data privacy (25.9%) leading to distrust in remote healthcare. Additionally, conflict-related challenges exacerbate logistical and operational difficulties, making it harder to establish reliable telemedicine infrastructure, while security risks prevent healthcare professionals from actively participating in telemedicine programs, particularly in high-risk regions. Addressing these barriers through targeted interventions is crucial to maximizing telemedicine's impact in Yemen.

Despite these challenges, several opportunities exist to enhance telemedicine adoption in Yemen. Leveraging existing technologies, such as the widespread use of audio calls (68.1%) and text messaging (63.8%), presents a practical foundation for expanding low-bandwidth telemedicine solutions. International collaboration with global health organizations can provide essential technical expertise, funding, and training to strengthen Yemen's telemedicine infrastructure.

Furthermore, targeted interventions for rural areas, where telemedicine adoption remains low, could focus on deploying mobile health clinics equipped with telemedicine capabilities. Developing clear policies and regulations is also critical to

ensuring data security, patient confidentiality, and overall trust in remote healthcare services.

To ensure the sustainable expansion of telemedicine in Yemen, a multi-pronged approach is necessary. Investing in infrastructure, including expanding internet coverage through satellite- based networks and implementing solar-powered solutions, can mitigate connectivity and power challenges. Capacity building through healthcare worker training in digital literacy and telemedicine best practices is vital for improving adoption and service quality. Community awareness campaigns should also be prioritized to educate the public about telemedicine's benefits while addressing cultural reservations about remote care. Additionally, ongoing research and evaluation are essential to explore financial constraints, legal frameworks, and provider- patient dynamics influencing telemedicine adoption. By addressing these factors, Yemen can strengthen its telemedicine landscape and enhance healthcare delivery in conflict-affected and remote areas.

8. Limitation

Despite providing valuable insights into the feasibility and challenges of telemedicine in Yemen, this study has several limitations that should be acknowledged.

One key limitation is the sampling bias associated with the use of convenience sampling. Participants were recruited through digital platforms such as WhatsApp and social media groups, which may have excluded individuals without internet access or digital literacy skills. As a result, the sample may not fully represent hard-to-reach populations, particularly those in rural and conflict-affected areas with limited connectivity. Additionally, the study relied on self-reported data, which introduces the risk of recall bias and social desirability bias, as respondents may have either overestimated or underestimated their telemedicine usage and satisfaction levels. Another limitation is the limited generalizability of the findings. The study primarily included participants who were already aware of or had access to telemedicine services, which may not reflect the experiences of the broader Yemeni population. The study's sample also had a low representation of individuals from conflict zones (3.4%) and rural areas (22.4%), limiting the ability to fully assess the urban-rural divide in telemedicine accessibility.

Finally, while the study identified major barriers to telemedicine implementation, some contextual and policy-related factors were not deeply explored. Issues such as government regulations, legal frameworks, healthcare provider resistance, and financial constraints could play a crucial role in the scalability of telemedicine services. Addressing these gaps requires further research into policy-level barriers, cost implications for patients and providers, and potential telemedicine reimbursement models.

9. Conclusion

This study underscores both the potential and challenges of telemedicine in Yemen. While telemedicine is perceived positively and used frequently, several barriers hinder its widespread adoption, including poor network connectivity, insufficient training, inadequate infrastructure, social resistance, and lack of trust in telemedicine services. Additionally, low digital literacy among both healthcare providers and patients further limits engagement with telemedicine platforms.

To ensure effective and sustainable integration of telemedicine, targeted policy interventions, capacity-building initiatives, and infrastructure development are essential. Addressing technological limitations, improving digital literacy, and fostering public trust through awareness campaigns and training programs will be key to overcoming these barriers. Strengthening regulatory frameworks and privacy safeguards may also help mitigate concerns related to data security and confidentiality, thereby enhancing telemedicine adoption across Yemen, particularly in conflict-affected and remote areas.

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