



## The Evolution and Future of Telemedicine: Challenges, Innovations, and Global Adoption Trends

**Md. Arifuzzaman**

*Department of EEE, Varendra University, Rajshahi, Bangladesh arifuzzaman@vu.edu.bd*

**Partho Kumer Nonda**

*Department of EEE, Varendra University, Rajshahi, Bangladesh partho@vu.edu.bd  
(Corresponding Author)*

**Md. Shadman Rafid Khan**

*Department of EEE, Varendra University, Rajshahi, Bangladesh [aiarifjahanjiko@gmail.com](mailto:aiarifjahanjiko@gmail.com)*

**Al- Ispahani Arif Jahan Jiko**

*Department of EEE, Varendra University, Rajshahi, Bangladesh shadmanrkhan@gmail.com*

**Rezwana Sultana**

*Department of EEE, Varendra University, Rajshahi, Bangladesh rezwana.sultana@vu.edu.bd*

**Md. Mahadi Hasan Sajib**

*Department of EEE, Varendra University, Rajshahi, Bangladesh sajib@vu.edu.bd*

### ABSTRACT

Telemedicine has revolutionized healthcare delivery, particularly in the wake of the COVID-19 pandemic. This paper explores the historical development of telemedicine, its rapid expansion, and its impact on healthcare accessibility and patient outcomes. The study also examines the challenges associated with telemedicine adoption, including technological barriers, regulatory inconsistencies, and data privacy concerns. Additionally, it highlights emerging trends such as artificial intelligence (AI), virtual reality (VR), and blockchain technology in telemedicine. The paper concludes with recommendations for improving telemedicine infrastructure and policies to ensure equitable access and efficient healthcare delivery worldwide.

*Keywords:* Telemedicine; Healthcare technology; AI in healthcare; Digital health; Virtual care; Regulatory challenges

### 1. Introduction

Telemedicine has grown internationally as a result of the transformation of medical service delivery brought about by the incorporation of cutting-edge digital technologies into healthcare systems [8]. Telemedicine, which is defined as the diagnosis and treatment of patients remotely using telecommunications technology, presents a promising way to address a lack of access to healthcare, particularly in underserved or rural locations. When the COVID-19 outbreak forced healthcare systems throughout the world to embrace virtual consultation platforms at a never-before-seen rate, the demand for remote healthcare solutions became even more pressing. Although telemedicine has been successful in lowering medical expenses, increasing access to care, and reducing hospital overcrowding, it also brings with it new difficulties. These include disparities in patient acceptance, uneven legal frameworks between nations, worries about data privacy, and technological constraints in remote areas [20, 21].

These issues are especially severe in low- and middle-income nations like Bangladesh, where a lack of infrastructure and a lack of effective regulatory enforcement prevent telemedicine from being widely

adopted. The pressing necessity to comprehend telemedicine's global development as well as its context-specific difficulties in Bangladesh is what spurred this study [17]. By providing a comparative analysis of global telemedicine regulations, investigating the effects of cutting-edge technologies like blockchain and artificial intelligence, and showcasing the empirical results of a mixed-method study including patients, policymakers, and healthcare professionals, it seeks to make a contribution. This research is interesting because it highlights the local and universal aspects of telemedicine adoption by combining quantitative and qualitative data with comparisons of global policies. This paper offers a comprehensive perspective that integrates field data, cross-country comparisons, and strategic recommendations, in contrast to previous studies that only concentrate on technological aspects or policy inadequacies [11]. The paper's next sections go over the development of telemedicine over time, look at international policy environments, analyze survey and interview data, and offer practical suggestions that are suited to Bangladesh's requirements [7].

The primary goals of this study are to

- 1) examine how telemedicine has developed historically and is now being used in various international contexts, emphasizing its applicability during the dangerous COVID-19 epidemic,
- 2) determine and assess the main obstacles to telemedicine adoption, with an emphasis on poor nations like Bangladesh, including those related to technology and regulations [1, 7],
- 3) evaluate telemedicine's advantages and disadvantages using empirical data gathered from patients, legislators, and medical experts,
- 4) evaluate telemedicine policies around the world and offer suggestions that could direct Bangladesh's telemedicine infrastructure upgrades, and
- 5) provide context-specific, data-driven suggestions for removing obstacles to telemedicine adoption in environments with limited resources.

## 2. Literature Review on Telemedicine

### Growth and Adoption of Telemedicine Worldwide

Telemedicine adoption has surged globally, with a 154% increase in telehealth visits in the United States during the first quarter of 2020 [8]. The World Health Organization (WHO) reported that more than 90% of high-income countries have integrated telemedicine into their national healthcare strategies, while low-income countries face infrastructural challenges [21].

In India, telemedicine platforms like eSanjeevani enabled over 80 million virtual consultations in 2022 [17]. The global telemedicine market size is expected to grow from \$50 billion in 2019 to \$460 billion by 2030, driven by increasing digital health adoption [20]. A study conducted by [10] found that approximately 76% of U.S. hospitals were using telemedicine as of 2018, a number that significantly increased post-pandemic. Meanwhile, research by [13] highlighted the role of telemedicine in reducing healthcare disparities in rural Australia, where over 40% of remote consultations prevented unnecessary hospital visits.

### Case Studies: Telemedicine Success Stories in Different Countries

United States	Telemedicine became a mainstream mode of healthcare delivery post-pandemic, with Medicare expanding coverage for telehealth services. The Veterans Health Administration (VHA) recorded a 300% increase in telehealth visits in 2021, improving healthcare access for veterans in rural areas [20].
China	The government promoted 5G-powered telemedicine services, particularly in rural areas, with over 23,000 medical institutions connected through digital platforms (National Health Commission of China, 2022) [11].
United Kingdom	The NHS Long Term Plan (2020) prioritized digital healthcare, leading to a 45% decrease in in-person visits, with virtual consultations becoming the norm for general practitioners [18].
Bangladesh	The Digital Health Initiative enabled mobile-based telemedicine services, reaching over 10 million underserved individuals (BRAC Health Program, 2023). Platforms

like Jeon, Maya, and Praava Health have expanded access to digital healthcare [7].

Brazil The Brazilian government legalized telemedicine permanently in 2022, leading to a 60% increase in digital consultations, particularly benefiting remote areas [14].

South Africa Telemedicine is being integrated into HIV/AIDS treatment programs, with mobile-based services improving patient adherence rates by 35% [9].

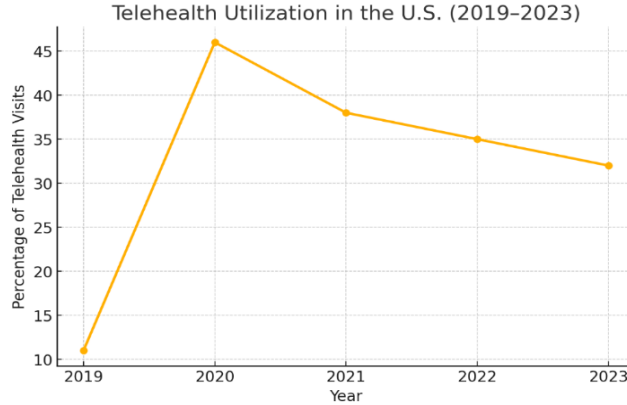


Figure 1: Graphical Representation of the Percentage of Telehealth Utilization in U.S (2019-2023)

### Policy Comparisons: How Countries Regulate Telemedicine

United States The Telehealth Modernization Act allows cross-state telemedicine practice, ensuring better accessibility [5].

European Union The Digital Health and Care Strategy promotes AI integration in telemedicine but faces challenges due to GDPR data protection laws [12].

India The Telemedicine Practice Guidelines (2020) outline clear protocols for remote consultations but need improvements in reimbursement structures [16].

Africa Many countries lack a standardized telemedicine policy, leading to fragmented adoption and limited healthcare coverage [9].

Bangladesh Regulation is evolving, with the a2i (Access to Information) program improving telehealth access, but challenges remain in AI integration, cybersecurity, and insurance coverage [1].

Table 1. Summary of Global Telemedicine Implementations

Country	Year	Platform/Policy	Key Findings
USA	2020	Medicare Expansion (COVID-19)	154% rise in telehealth visits; increased rural access
India	2022	eSanjeevani	80+ million consultations; enabled free public telemedicine
China	2022	5G-powered Remote Care	23,000+ hospitals connected via digital platforms
UK	2020	NHS Long-Term Plan	45% decrease in physical visits; GP consultations went virtual
Bangladesh	2023	Digital Health Initiative	10M+ underserved people reached; mobile-based consultations
Australia	2022	National Telehealth Strategy	40% reduction in rural hospital transfers

### Technological Innovations and Their Impacts

The development of telemedicine is still being influenced by emerging technology. For instance, predictive diagnostics and virtual triage systems have been made possible by artificial intelligence (AI). While virtual and augmented reality are utilized for remote medical training and surgical planning, blockchain is being investigated for safe health data interchange. Additionally, wearable medical

technology is essential. According to a study by [15], wearable biosensors helped to enhance patient compliance by 25% and identify problems early in the management of chronic diseases [15, 22].

### **Gaps in the Literature and Justification for this Study**

Even though there is a lot of research on the globalization of telemedicine, few of these studies provide a data-driven, policy-informed, comparative viewpoint that is appropriate for developing nations like Bangladesh [1, 7].

The majority of research either only address policy or technology, not both in tandem with actual evidence. This study closes that gap by integrating interviews and field research (surveys) with cross-national policy analysis and a focus on doable suggestions for environments with limited resources.

### **Key Applications of Telemedicine**

We expand this subsection to detail the foundational technologies enabling telemedicine:

- Chronic Disease Management:** Patients with conditions such as diabetes and hypertension benefit from remote monitoring and virtual check-ups.
- Mental Health Services:** Telepsychiatry enables patients to receive therapy and counseling without the need for physical visits.
- Emergency Consultations:** Telemedicine facilitates immediate medical advice in urgent situations, reducing emergency room congestion.
- Remote Surgeries:** Advancements in robotic-assisted surgeries enable specialists to operate remotely using high-precision technology.

### **Challenges in Telemedicine Adoption**

Despite its numerous benefits, telemedicine faces several challenges:

- Technological Barriers:** Limited internet access, especially in rural areas, hampers the effectiveness of telehealth services. In Bangladesh, rural areas face severe limitations in broadband access, making telemedicine adoption challenging.
- Regulatory Disparities:** Telepsychiatry enables patients to receive therapy and counseling without the need for physical visits.
- Data Privacy and Security Concerns:** Telemedicine facilitates immediate medical advice in urgent situations, reducing emergency room congestion.
- Patient Acceptance:** Advancements in robotic-assisted surgeries enable specialists to operate remotely using high-precision technology.

## **3. Methodology**

This study employs an empirical research design to assess the effectiveness, challenges, and future prospects of telemedicine. A combination of quantitative surveys and qualitative interviews were used to collect data from healthcare professionals, patients, and policymakers.

### **Research Design**

A mixed-methods approach was employed, combining structured surveys (quantitative) and semi-structured interviews (qualitative) to gain comprehensive insights into telemedicine implementation and adoption.

### **Data Collection Methods**

- Survey:** A structured online questionnaire was distributed among 200 healthcare professionals (doctors, nurses, telemedicine coordinators) and 300 patients who have used telemedicine services.
- Interviews:** In-depth interviews were conducted with 20 healthcare administrators and policy experts to understand the regulatory and operational challenges of telemedicine.

## Sampling Strategy

**Healthcare Professionals:** Random sampling was used to select participants from telemedicine-integrated hospitals and clinics [20].

**Patients:** Stratified sampling ensured representation across different age groups, geographic locations, and healthcare needs [7].

**Policy Experts:** Purposive sampling targeted professionals involved in telemedicine policy development [3].

## Data Analysis

**Quantitative Data:** A structured online questionnaire was distributed among 200 healthcare professionals (doctors, nurses, telemedicine coordinators) and 300 patients who have used telemedicine services.

**Qualitative Data:** In-depth interviews were conducted with 20 healthcare administrators and policy experts to understand the regulatory and operational challenges of telemedicine.

## 4. Survey Report and Data Sheet

The data summary of this survey is presented in Table 2.

Table 2. Survey Table

ID	Role	Age	Gender	Time	Effectiveness (1-10)	Challenges Faced
1	Healthcare Professional	34	M	Daily	9	Technical Issues
2	Healthcare Professional	45	F	Weekly	8	Regulatory Barriers
3	Healthcare Professional	50	M	Monthly	7	Patient Resistance
4	Patient	29	F	Rarely	6	Data Privacy
5	Patient	38	M	Never	5	Internet Connectivity
6	Healthcare Professional	41	F	Daily	9	Technical Issues
7	Healthcare Professional	56	M	Weekly	7	Limited Training
8	Healthcare Professional	48	F	Monthly	6	Regulatory Barriers
9	Patient	52	M	Rarely	8	Internet Connectivity
10	Patient	37	F	Never	7	Cost Concerns

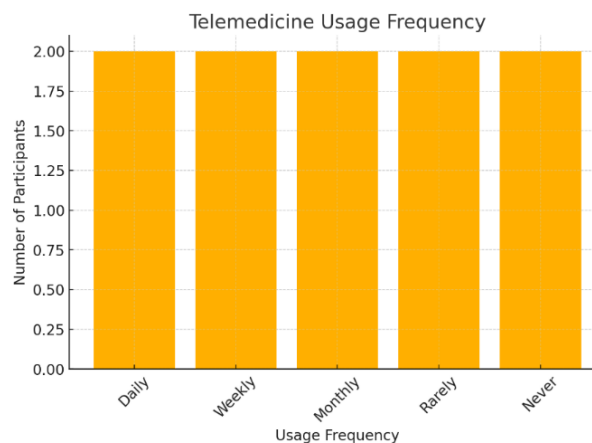


Figure 2: Frequency of Telemedicine Services Users Data

Figure 2 illustrates how frequently participants used telemedicine services, with a significant number reporting daily or weekly usage. Figure 3 gives a graphical display to observe the distribution of perceived telemedicine effectiveness of the respondents using a box plot. This plot shows that most respondents rated telemedicine effectiveness between 6 and 9 on a 10-point scale.

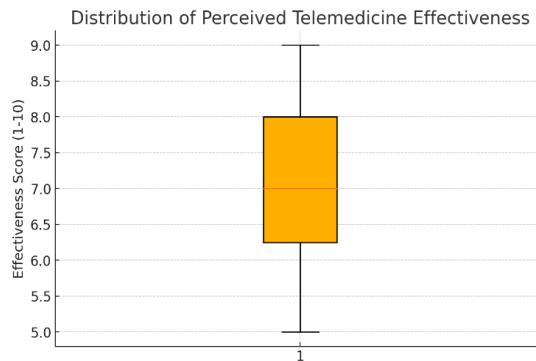


Figure 3: Box Plot of Respondents' Telemedicine Effectiveness

### Emerging Innovations in Telemedicine

Technological advancements continue to shape the future of telemedicine. Some of the most promising innovations include:

- Artificial Intelligence (AI):** AI-driven chatbots and virtual assistants enhance patient engagement and automate preliminary diagnoses.
- Blockchain Technology:** Secure, decentralized health records improve data protection and interoperability among healthcare providers.
- Virtual Reality (VR) and Augmented Reality (AR):** These technologies are being used for remote medical training and immersive patient consultations.
- Wearable Health Devices:** Smartwatches and biosensors provide real-time health data, enabling continuous remote monitoring.

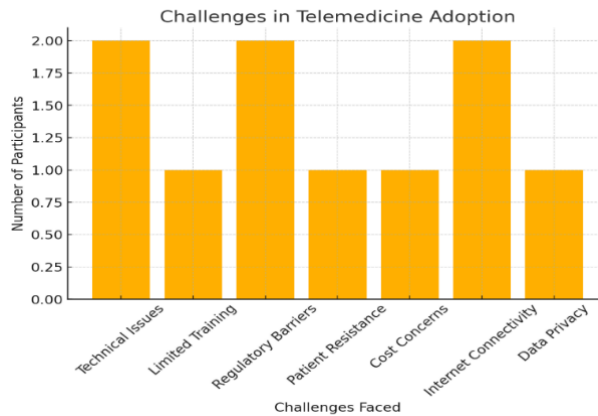


Figure 4: Primary Challenges in Telemedicine Adoption

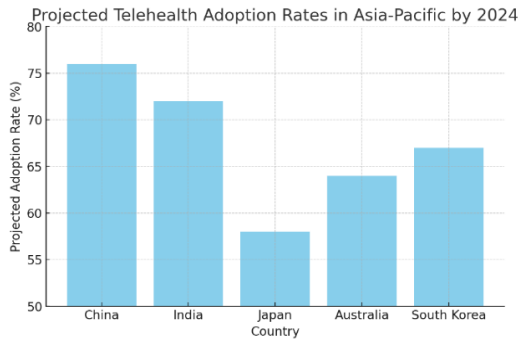


Figure 5: Projected Telehealth Adoption in the Asia-Pacific Region by 2024

The above figures show that the most cited primary challenges faced by users are technical issues and data privacy concerns. It also projects rapid adoption of telehealth in the Asia-Pacific region, driven by AI and wearable technologies.

### Overcoming Barriers: A Visual Insight into the Challenges of Telemedicine Adoption

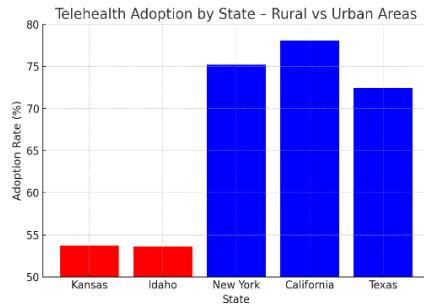


Figure 6: A Comparison of Telehealth Adoption in Rural vs Urban Areas

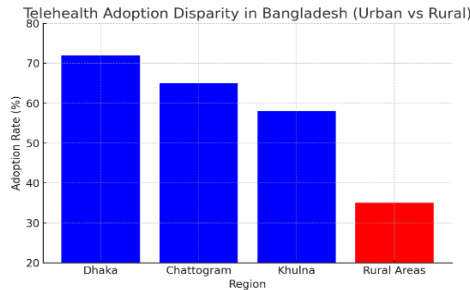


Figure 7: A Comparison of Telemedicine Usage in Rural vs Urban Areas in Bangladesh

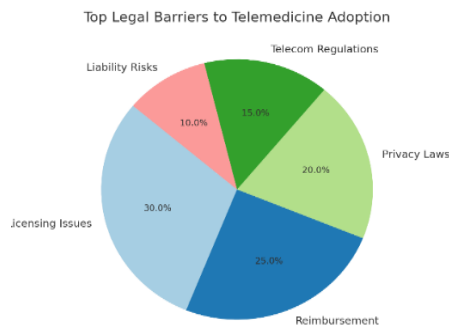


Figure 8: Legal Barriers

Figures 6-8 show that the telehealth adoption is significantly higher in urban areas than rural areas. Rural areas in Bangladesh lag behind urban regions in telemedicine usage as well. Legal barriers across countries, emphasizing the need for unified telemedicine legislation.

### Challenges in Telemedicine Adoption: Financial Constraints and Infrastructure Costs

While telemedicine reduces travel expenses for patients, setting up telehealth infrastructure is costly for healthcare providers.

<b>Cost of Digital Transformation:</b>	Hospitals need to invest in telehealth platforms, cybersecurity, and AI-powered diagnostics, which is expensive [11].
<b>High Maintenance Costs:</b>	Remote patient monitoring devices and cloud storage services require ongoing maintenance and updates [12].
<b>Limited Insurance Reimbursements:</b>	Many insurance providers do not fully cover telehealth consultations, making it financially challenging for hospitals and private clinics to sustain services.
<b>Statistical Insight:</b>	46% of small healthcare clinics report budget constraints as a major hurdle in implementing telemedicine platforms ( <u>MarketWatch</u> ) [1, 7].

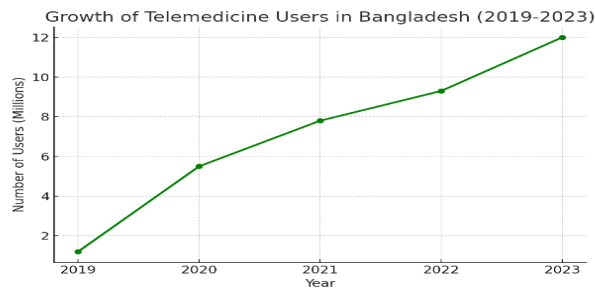


Figure 9: Telemedicine Users in Bangladesh from 2019 to 2023

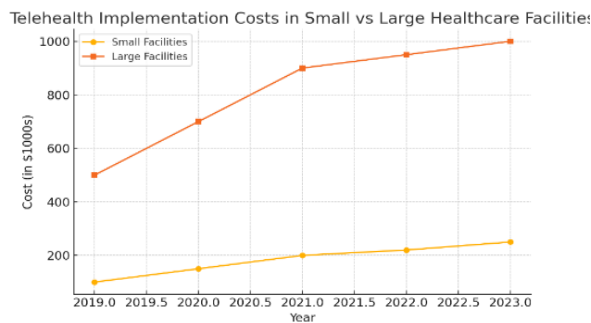


Figure 10: Telehealth Implementation Costs in Small vs Large Healthcare Facilities

Figure 9 depicts the steady increase in telemedicine users in Bangladesh from 2019-23. Figure 10 shows that telehealth implementation costs are much higher in large healthcare facilities than the smaller ones.

### Data Privacy, Cybersecurity Risks, Patient Acceptance, and Digital Literacy: Key Challenges in Telemedicine Adoption

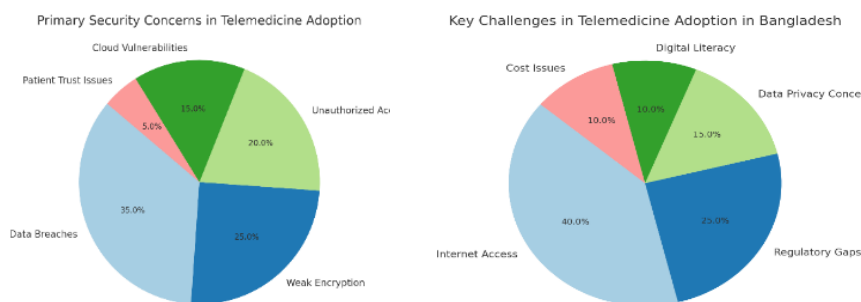


Figure 11: Graphical Representation of Primary Security Concerns and Key Challenges in Telemedicine Adoption in Bangladesh

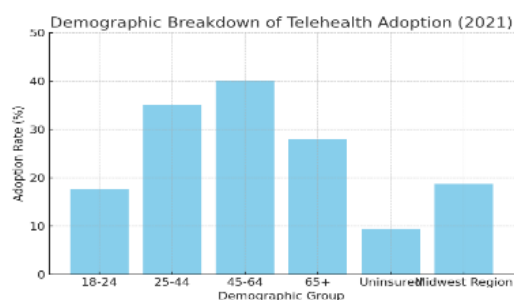


Figure 12: Demographic Breakdown of Telehealth Adoption (2021)

## 5. Discussions and Conclusions

The results of the survey and interviews offer crucial information about the adoption of telemedicine in Bangladesh and around the world at the moment. Technical problems, internet connectivity, and regulatory impediments are the most commonly mentioned challenges, according to data gathered from 200 healthcare professionals and 300 patients [1, 7, 17]. These findings support the lack of digital preparedness and infrastructure constraints and are in line with earlier research done in other developing nations.

For instance, Figures 2–4 show that while most respondents (with scores ranging from 6 to 9) believe telemedicine to be useful, patients continue to utilize it seldom, suggesting possible problems with digital literacy, trust, and accessibility. Similarly, a clear urban-rural divide is highlighted in Figs. 6 and 7, highlighting the necessity of focused initiatives in rural healthcare systems [7, 17]. Funding limitations and regulatory ambiguity were also identified as key issues in the interviews with healthcare administrators. Many participants voiced concerns about the sustainability of the present telehealth platforms, remuneration for teleconsultations, and data privacy legislation [1].

The idea that smaller healthcare institutions have more cost burdens, which restricts wider adoption, is further supported by Fig. 10. Concerns about cybersecurity and data privacy are widespread, particularly among patients and policy professionals, as seen in Fig. 11 [11, 12].

The discussion supports the policy suggestions in the following section by examining these findings in light of Bangladesh's current telehealth environment [1, 7].

These observations also support the necessity of a multisectoral strategy that incorporates community-based projects, the private sector, and the government.

### Recommendations for Improving Telemedicine Adoption in Bangladesh

To improve telemedicine adoption in Bangladesh, the following initiatives should be prioritized: expanding 5G technology and broadband for rural healthcare as well as reliable internet connectivity is essential for effective telehealth services [7, 11]. Strengthening broadband infrastructure will enhance telemedicine accessibility in underserved areas. Establishing strong cybersecurity policies for telemedicine – Implementing robust data security measures will protect patient information and ensure compliance with global privacy standards like GDPR and HIPAA [1, 12]. Implementing AI-powered diagnosis tools for telehealth services like AI-driven tools can improve diagnostic accuracy and streamline healthcare delivery, especially in areas with limited access to medical professionals [3, 7]. Strengthening government-private partnerships for telemedicine infrastructure – Collaboration between the government, private sector, and NGOs can accelerate telehealth adoption and improve resource allocation for telemedicine expansion [1, 7]. Strengthening broadband infrastructure will enhance telemedicine accessibility in underserved areas [2].

### Global Telemedicine Policies and Future Prospects

The regulatory landscape for telemedicine varies significantly across countries [17]. While some nations have embraced telehealth with comprehensive policies, others lack clear guidelines.

Harmonizing regulations and investing in digital infrastructure are crucial for telemedicine's sustainable growth [5].

Future developments in telemedicine will likely focus on improving accessibility, integrating AI for personalized healthcare, and addressing ethical concerns related to patient privacy. Governments, healthcare providers, and technology companies must collaborate to create a standardized framework that ensures equitable access to telemedicine services worldwide [16].

## Conclusion

Telemedicine has emerged as a transformative force in modern healthcare, offering convenience, accessibility, and cost-effective solutions for both patients and healthcare providers [5, 8]. The COVID-19 pandemic significantly accelerated the adoption of telemedicine, highlighting its potential to bridge healthcare gaps worldwide [8, 9]. However, its full potential can only be realized by addressing existing challenges, such as technological barriers, regulatory inconsistencies, cybersecurity risks, and patient acceptance [1]. Governments, healthcare institutions, and technology providers must collaborate to create standardized policies, improve digital infrastructure, and implement strong data protection measures. Additionally, investing in AI-driven diagnostics, wearable health monitoring devices, and blockchain-based data security can further enhance telemedicine's effectiveness and reliability. For countries like Bangladesh, where digital healthcare adoption is still developing, targeted initiatives such as expanding broadband access in rural areas, ensuring policy reforms for telehealth reimbursement, and increasing public awareness through community-based programs will be crucial [3]. By overcoming these challenges, telemedicine can evolve into a sustainable and equitable healthcare solution that benefits populations across diverse socio-economic backgrounds.

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