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REVIEW ARTICLE

# A NARRATIVE REVIEW OF THE IMPACT OF TELEMEDICINE ON DIRECT OBSERVED THERAPY IN TUBERCULOSIS

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## ABSTRACT

Tuberculosis (TB) remains a major public health challenge, particularly in low- and middle-income countries (LMICs), where conventional directly observed therapy (DOT) places substantial logistical and resource demands on patients and health systems. Telemedicine, particularly video-observed therapy (VOT), has been increasingly adopted to support tuberculosis treatment supervision; however, existing evidence remains fragmented and insufficiently synthesised from a health system and management perspective. This narrative review synthesised peer-reviewed evidence published between 2013 and 2024 on telemedicine-enhanced DOT for tuberculosis, with a focus on treatment adherence, cost and resource implications, patient acceptability, scalability, and equity across diverse health system contexts. Across study designs and settings, telemedicine-enhanced supervision achieved treatment adherence and completion outcomes comparable to, or exceeding, conventional facility-based DOT. Asynchronous and hybrid VOT models demonstrated advantages in reducing patient burden, improving workforce efficiency, and supporting programme scalability. Economic evaluations indicated consistent cost savings for patients and health systems, while qualitative evidence highlighted high patient acceptability, including increased autonomy and reduced stigma. However, persistent digital inequities related to device access, connectivity, and digital literacy limited universal applicability. Overall, telemedicine-enhanced DOT appears most effective when implemented as a complementary component of differentiated tuberculosis care rather than as a uniform replacement for conventional supervision. This review provides policy-relevant insights for health system leaders and programme managers on the strategic integration of telemedicine to balance effectiveness, efficiency, scalability, and equity in contemporary TB care.

**KEYWORDS**

telemedicine; video-observed therapy; tuberculosis; treatment adherence; health systems; digital equity

## INTRODUCTION

Tuberculosis (TB) remains a major global public health challenge, particularly in low- and middle-income countries (LMICs) where health system constraints continue to undermine effective disease control. Despite sustained international efforts, TB remains one of the leading causes of death from infectious diseases worldwide. The World Health Organization estimated 10.6 million new TB cases and 1.6 million TB-related deaths globally in 2021, highlighting persistent gaps in prevention, diagnosis, and treatment delivery [1]. Ensuring sustained treatment adherence remains central to TB control, given the prolonged duration and complexity of standard treatment regimens.

Directly observed therapy (DOT), a core component of the DOTs strategy, has long been adopted to promote adherence by requiring supervised medication intake [2]. While DOT has contributed to improvements in treatment completion and cure rates, its implementation is associated with substantial logistical and social burdens. Patients are often required to attend health facilities frequently, incurring travel costs, income loss, and time away from work or caregiving responsibilities. From a health system perspective, DOT is labour intensive, resource demanding, and difficult to sustain at scale, particularly in settings with workforce shortages and geographically dispersed populations [3].

Advances in digital health have created opportunities to address these limitations. Over the past decade, telemedicine-enhanced approaches to DOT, particularly Digital Adherence Technologies (DATs) which are digital tools and technologies designed to monitor, support, and improve patients' adherence to prescribed treatment regimens, particularly for diseases that require prolonged therapy such as TB. Hence in TB care, DATs serve as alternatives or complements to traditional DOTs. DATs enable treatment monitoring remotely, reducing the burden on both patients and healthcare providers. A more common type of DAT used for TB patients is video-observed therapy (VOT), while DATs represent the broader category of digital adherence interventions This has gained increasing attention as alternatives to conventional in-person supervision. During VOT sessions, patients record or livestream themselves taking their TB medications using a hand held device. Subsequently, healthcare workers review the videos to confirm adherence to the medications. Evidence from randomised controlled trials, observational studies, and implementation research demonstrates that VOT is non-inferior, and in some settings superior, to traditional DOT in terms of treatment adherence, completion rates, and patient satisfaction.

These findings have informed global normative guidance, including World Health Organization recommendations recognising digital adherence technologies as acceptable alternatives to in-person observation under appropriate programmatic conditions. Studies across economically developed and LMIC settings indicate that VOT can reduce patient burden, mitigate stigma, and lower programme costs while maintaining treatment outcomes comparable to conventional DOT [4].

However, integration of telemedicine into TB care presents important challenges. Digital inequities related to smartphone ownership, internet connectivity, and digital literacy remain significant barriers, particularly among socially and economically marginalised populations [5,6]. Concerns regarding data privacy, confidentiality, and patient trust further complicates implementation. In some contexts, cultural preferences for face-to-face interaction and sustained interpersonal support continue to influence patient acceptance of digitally mediated care [7]. These challenges underscore that telemedicine-enhanced DOT is not a universally applicable solution and must be implemented in ways that are responsive to local health system capacity and population needs.

Although a growing body of literature has examined the effectiveness, feasibility, and acceptability of VOT and other digital adherence technologies, existing reviews have largely focused on clinical outcomes or technological performance in isolation.

Consequently, there is a lack of comprehensive synthesis that evaluates how these dimensions interact within real-world health systems. Questions relating to resource allocation, workforce adaptation, scalability across diverse healthcare

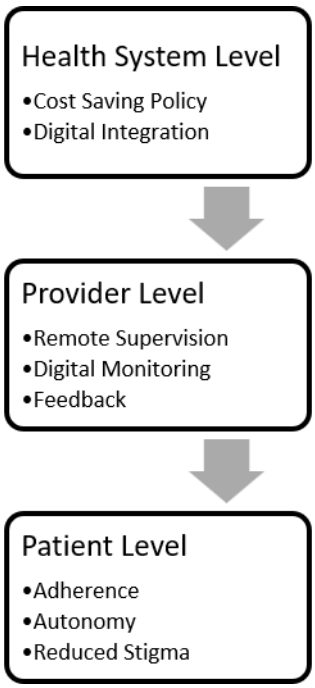
settings, and equitable access to digital services remain insufficiently explored. This gap is particularly important in the post-COVID era, where digital health interventions are increasingly being incorporated into routine TB programmes and require evaluation beyond clinical effectiveness alone.

Furthermore, the rapid expansion of telemedicine during and after the COVID-19 pandemic has reshaped TB service delivery, yet this evolving context is not consistently reflected in earlier reviews. The need for an updated synthesis is further underscored by recent developments in the digital health landscape. Emerging evidence from 2025 has highlighted the growing role of artificial intelligence-assisted VOT systems, updated World Health Organization (WHO) recommendations on DATs, and the expansion of large-scale hybrid care models that combine in-person and remote treatment monitoring. These developments reflect a rapidly evolving telemedicine environment that differs substantially from the early implementation studies that dominate much of the current literature. Despite these advances, there remains a lack of comprehensive narrative reviews that integrate clinical effectiveness, economic considerations, implementation challenges, health-system implications, and equity concerns within the contemporary post-COVID-19 telemedicine era.

In response to this gap, this narrative review synthesises evidence on telemedicine-enhanced DOT for tuberculosis through a health system and programme management lens. Rather than reassessing clinical efficacy, the review examines how telemedicine-supported DOT models have been implemented and integrated within tuberculosis control programmes, with particular attention to treatment adherence, cost and resource implications, patient acceptability, scalability, and digital equity. By identifying cross-cutting patterns, enablers, and contextual constraints across diverse settings, this review aims to provide actionable insights for health system leaders, programme managers, and policymakers on the strategic integration of telemedicine as a complementary component of differentiated TB care.

To support this synthesis, a conceptual framework is presented to illustrate how telemedicine interventions, including VOT and other digital adherence tools, operate across patient, provider, and health system levels to strengthen DOT within tuberculosis programmes. The framework highlights the interdependence of technological capability, workforce readiness, governance structures, and supportive policy environments in determining the effectiveness and sustainability of telemedicine-enhanced TB care.

**FIGURE 1: CONCEPTUAL FRAMEWORK OF TELEMEDICINE INTEGRATION IN TUBERCULOSIS MANAGEMENT**



## METHODOLOGY

This narrative review was guided by the following research question: How have telemedicine-supported directly observed therapy models been implemented across diverse healthcare settings, and what are their impacts on treatment adherence, patient acceptability, service delivery, cost-effectiveness, programme management, scalability, and health equity in TB care?

### REVIEW DESIGN AND RATIONALE

A narrative review approach was selected to synthesise evidence on telemedicine-enhanced DOT for TB treatment supervision, with a focus on health system implementation and programme management considerations. This approach was appropriate given the diversity of study designs, intervention models, and contextual settings represented in the literature, including randomised controlled trials, observational studies, qualitative research, and implementation evaluations [3,7].

### LITERATURE IDENTIFICATION AND SELECTION

A comprehensive literature search was conducted across PubMed, Scopus, ScienceDirect, ProQuest, and JMIR Publications. Searches were supplemented by manual screening of reference lists from key articles and relevant policy documents from international organisations. Peer-reviewed articles published in English between 2013 and 2024 were included to capture early telemedicine applications in TB care and more recent developments following accelerated digital health adoption during the COVID-19 period [8]. Search terms included combinations of "tuberculosis", "directly observed therapy", "video-observed therapy", "telemedicine", "digital technologies", "implementation", "health systems", and "programme management".

The literature selection process was conducted in three stages. First, titles and abstracts were screened for relevance to telemedicine-supported TB treatment and monitoring. Studies focusing solely on diagnostic technologies, non-TB conditions, or interventions unrelated to treatment adherence were excluded. Second, full-text articles were assessed for eligibility based on their relevance to the review objective and research question. Studies reporting clinical outcomes, patient experiences, implementation factors, economic evaluations, health-system implications, or programme management considerations were prioritised. Finally, selected studies were reviewed in detail and grouped according to a thematic synthesis framework.

As this review included a heterogeneous body of evidence comprising quantitative, qualitative, implementation, and policy-focused studies, a formal risk-of-bias assessment tools were not applied. Instead, the credibility of evidence was considered through critical appraisal of study design and methodology, contextual relevance, and consistency of findings across multiple studies. Particular attention was given to recurring trends, implementation experiences, and areas where evidence remained limited or contradictory.

### STUDY SELECTION AND INCLUSION CRITERIA

Studies were included if they examined telemedicine-enhanced approaches to tuberculosis treatment supervision, including synchronous and asynchronous VOT, and reported outcomes or insights relevant to implementation, service delivery, workforce roles, patient acceptability, cost considerations, or health system integration. Both high-income and LMIC settings were included to enable cross-context comparison. Editorials and commentaries without empirical or programme-relevant content were excluded.

### DATA EXTRACTION AND ANALYTICAL APPROACH

Data extraction focused on study characteristics, telemedicine modality, health system context, comparator where applicable, and outcomes relevant to programme management. Outcomes of interest included treatment adherence and completion, patient and provider burden, cost implications, workforce efficiency, scalability, and implementation barriers [11-14,17,18]. Included studies were reviewed iteratively to identify recurring concepts and implementation-related insights. An inductive thematic synthesis was undertaken, grouping findings into domains relevant to health system

performance and programme management, including service delivery models, governance considerations, workforce implications, digital infrastructure, patient equity, and sustainability [3,7,9,10]. Themes were refined through repeated comparison across studies.

### THEMATIC SYNTHESIS FRAMEWORK

Findings were organised into five thematic domains that informed the Results structure:

1. Models of telemedicine-enhanced DOT implementation
2. Programme integration and governance considerations
3. Health workforce roles and operational implications
4. Patient acceptability, access, and equity considerations
5. Cost, sustainability, and scalability considerations

## RESULTS

### MODELS OF TELEMEDICINE-ENHANCED DIRECTLY OBSERVED THERAPY IMPLEMENTATION

Across the reviewed literature, telemedicine-enhanced directly observed therapy for tuberculosis has been implemented through three broad service delivery models: synchronous video-observed therapy, asynchronous video-observed therapy, and hybrid models that combine digital supervision with periodic in-person contact. These models differ substantially in operational design, technological requirements, and levels of integration within existing tuberculosis programme structures, reflecting adaptation to local health system capacity and patient needs. Evidence from both high-income and low- and middle-income country (LMIC) settings indicates that implementation choices are strongly shaped by contextual constraints rather than clinical considerations alone [1,3,7]. To facilitate comparison across diverse study designs and settings, key characteristics of the included studies were extracted and summarised in Table 1. Information extracted included study setting, telemedicine modality, population characteristics, methodological approach, thematic contribution, and key findings relevant to treatment adherence, patient acceptability, implementation, scalability, and health-system implications.

Synchronous VOT typically involves real-time video interactions between patients and healthcare providers during medication ingestion, closely replicating conventional in-person DOT while removing the need for physical co-location. This model has been most frequently reported in high-income settings with reliable internet connectivity and established telehealth infrastructure [5,14]. Studies implementing synchronous approaches highlight advantages related to real-time clinical oversight and sustained patient-provider interaction but also report higher workforce time requirements and reduced flexibility for patients compared with asynchronous alternatives [5,14]. These characteristics are summarised in Table 2, which outlines key features, implementation contexts, and system requirements associated with synchronous telemedicine-enhanced DOT.

**TABLE 1: SUMMARY OF KEY STUDIES ON TELEMEDICINE AND VIDEO-OBSERVED THERAPY**

| Author (Year) | Country / Setting | Design | Telemedicine Modalities | Sample Size / Population | Primary Thematic Contribution | Synthesized Key Findings |
|---|---|---|---|---|---|---|
| **Story et al., (2019)** | United Kingdom | Multicentre RCT | Asynchronous smartphone VOT | 226 TB patients eligible for DOT | Adherence effectiveness | Asynchronous VOT achieved 70% vs 31% DOT adherence (OR 5.48; 95% CI 3.10-9.68), showing superior effectiveness and patient satisfaction. |
| **Tello-Cajiao et al., (2023)** | Colombia | Quasi-experimental | Synchronous real-time VOT | 78 patients (intensive & continuation phases) | Feasibility and acceptability | Adherence 99.8% (intensive) and 98.2% (continuation) with 100% cure; patients preferred remote contact and flexibility. |
| **Kumwichar et al., (2024)** | Thailand | Protocol for cluster randomised controlled trial | Asynchronous smartphone VOT | 200 patients (urban & rural patients) | Adherence sustainability | Protocol describing planned evaluation of adherence, continuity, and feasibility of smartphone-based asynchronous VOT compared with community-based DOT; outcome data pending. |
| **Abas et al., (2024)** | Malaysia | Single-arm intervention | Gamified real-time VOT app (GRVOTS) | 71 patients (In continuation phase) | Patient motivation and engagement | 90.9% adherence; significant increase in intrinsic motivation (IMI +19.8, $p<0.001$); improved retention and patient satisfaction. |
| **Raj et al., (2024)** | United States | Retrospective cohort | Hybrid synchronous + asynchronous VOT | 548 patients across 20 TB programs | Scalability and system integration | Treatment completion 97.2% vs 92.3% under DOT; reduced median treatment duration and operational costs. |
| **Donahue et al., (2021)** | USA Military Clinics | Implementation case study | Weekly Telemedicine DOT for LTBI | 16 LTBI patients | Access and continuity of care | 100% completion; reduced travel and improved scheduling flexibility for families. |
| **Fekadu et al., (2021)** | Hong Kong | Decision-analytic model | Asynchronous VOT | Simulated 10,000 TB patients | Cost-effectiveness | VOT saved US$1,797 per patient and reduced DALYs by 0.487; 99.4% probability of being cost-effective. |
| **Netto et al., (2024)** | Global (systematic review) | Systematic Review | Mixed VOT modalities | 12 RCTs (2010-2024) | Adherence, cost, satisfaction | VOT non-inferior to DOT for adherence; improved satisfaction and cost reduction up to 60%. |
| **Olawade et al., (2024)** | Multiple LMICs | Narrative review | Telemedicine for MDR-TB | 48 articles reviewed | Scalability in resource-limited settings | Telemedicine improved access to remote diagnosis, follow-up, and specialist care; connectivity and culture remain limiting factors. |

| Author (Year) | Country / Setting | Design | Telemedicine Modalities | Sample Size / Population | Primary Thematic Contribution | Synthesized Key Findings |
|---|---|---|---|---|---|---|
| **Browne et al., (2019)** | USA | Randomised controlled trial | Wirelessly Observed Therapy (WOT) | 77 patients (TB patients in continuation phase) | Precision monitoring | WOT achieved 99.3% positive detection accuracy; confirmed 93% doses vs 63% with DOT; preferred by all participants. |
| **Rabinovich et al., (2020)** | Cambodia | Qualitative study | Mobile VOT perception | 6 focus groups (urban/peri-urban) | Patient acceptability and equity | High willingness to use VOT; barriers include illiteracy and reduced in-person contact. |
| **Adisa et al., (2021)** | Nigeria | Mixed-method cross-sectional | Facility-based DOT (baseline comparator) | 140 patients (Drug-sensitive TB patients) | Baseline adherence constraints | Treatment success 81.9%; major barriers were travelling distance and pill burden; baseline for telemedicine potential. |
| **Cross et al., (2019)** | India | Implementation evaluation | 99DOTS (SMS and phone-call based DOT) | >200,000 TB patients | Scalability in resource-limited settings | 99DOTS achieved large-scale digital DOT coverage with >80% adherence, becoming national standard in India. |

**TABLE 2: IMPLEMENTATION MODELS OF TELEMEDICINE-ENHANCED DIRECTLY OBSERVED THERAPY FOR TUBERCULOSIS**

| Implementation model | Core characteristics | Level of patient flexibility | Health worker involvement | Typical health system context | Illustrative settings |
|---|---|---|---|---|---|
| Synchronous video-observed therapy | Real-time video interaction between patient and health worker during medication ingestion | Low to moderate | High, continuous real-time supervision | Well-resourced systems with stable connectivity and telehealth infrastructure | High-income countries, urban tertiary services |
| Asynchronous video-observed therapy | Patients record and submit videos for later review by health workers | High | Moderate, batch review of videos | Systems prioritising efficiency and flexibility, often with constrained workforce capacity | Low- and middle-income countries, mixed urban–rural settings |
| Hybrid telemedicine-enhanced DOT | Combination of asynchronous video submission with periodic in-person or live video follow-up | Moderate to high | Variable, targeted to patient need | Programmes adapting to heterogeneity in patient risk and system capacity | COVID-19 response settings, decentralised TB programmes |

Asynchronous VOT emerged as the most frequently described implementation model, particularly in LMICs settings and decentralised tuberculosis programmes [9,11,12,17[. In this approach, patients record and submit videos of medication ingestion for subsequent review by healthcare workers, allowing greater flexibility in dosing schedules and more efficient allocation of staff resources. As shown in Table 2, asynchronous models were consistently associated with reduced patient travel burden and improved convenience, while maintaining acceptable levels of treatment supervision and adherence [3,11-13]. Several studies reported that asynchronous video review enabled healthcare workers to supervise a larger number of patients concurrently, suggesting potential efficiency gains at programme level [12,17].

Hybrid implementation models combine telemedicine-enhanced DOT with periodic in-person contact, either through scheduled facility visits or targeted follow-up for patients identified as having adherence challenges. These models were commonly adopted during the COVID-19 pandemic as adaptive strategies to sustain treatment supervision amid movement restrictions and workforce redeployment [8,15]. As illustrated in Table 3, hybrid approaches were used to balance patient flexibility with clinical oversight, particularly for individuals requiring additional support due to social vulnerability, limited digital literacy, or complex clinical profiles [9,19].

**TABLE 3: OPERATIONAL AND WORKFORCE IMPLICATIONS OF TELEMEDICINE-ENHANCED DIRECTLY OBSERVED THERAPY**

| Operational domain | Synchronous models | Asynchronous models | Hybrid models | Programme-level implications |
|---|---|---|---|---|
| Health worker time use | High time demand per patient | Reduced per-patient time through batch review | Targeted time allocation | Enables redistribution of workforce effort toward higher-risk patients |
| Patient travel and opportunity costs | Minimal travel but fixed dosing times | Minimal travel with flexible dosing | Reduced travel with selective in-person contact | Improves patient-centred care and reduces indirect treatment costs |
| Caseload capacity | Limited scalability due to real-time requirements | Higher scalability with centralised review | Moderate scalability | Supports expansion of treatment supervision without proportional staff increases |
| Training requirements | Moderate, focused on teleconsultation skills | Moderate, focused on video review and digital platforms | Higher, due to blended workflows | Requires structured training and clear standard operating procedures |
| Continuity of care | High continuity through frequent interaction | Variable, dependent on review frequency | High for targeted patients | Highlights need for protocols to prevent reduced patient engagement |

Across all implementation models, the selection of telemedicine modality was strongly influenced by contextual factors including digital infrastructure availability, smartphone access, regulatory frameworks, and workforce capacity. Table 4 synthesises these determinants and highlights how programme-level decisions shaped the adoption and adaptation of telemedicine-enhanced DOT models across settings [6,7,10]. Importantly, no single model was universally optimal. Instead, successful implementation was contingent on alignment between service delivery design and health system readiness, with flexible and differentiated approaches demonstrating greater potential for sustainable integration into routine tuberculosis care.

**TABLE 4: CONTEXTUAL ENABLERS, BARRIERS, AND IMPLICATIONS FOR SCALE-UP OF TELEMEDICINE-ENHANCED DIRECTLY OBSERVED THERAPY**

| Health system domain | Enablers | Barriers | Implications for scale-up |
|---|---|---|---|
| Digital infrastructure | Smartphone availability, mobile network coverage | Poor connectivity, device instability | Asynchronous and hybrid models more feasible in low-connectivity settings |
| Governance and regulation | National endorsement of digital adherence technologies | Unclear data governance and medico-legal frameworks | Clear policy guidance required to institutionalise telemedicine-enhanced DOT |
| Health workforce capacity | Task shifting, centralised monitoring | Resistance to workflow change, digital skill gaps | Workforce engagement and training critical for sustainability |
| Patient equity and access | Reduced travel burden, privacy benefits | Digital literacy gaps, smartphone ownership requirements | Risk of exclusion necessitates complementary non-digital options |
| Financial sustainability | Reduced travel and supervision costs | Upfront technology and maintenance costs | Long-term cost-effectiveness depends on integration into routine services |

Overall, the evidence indicates that telemedicine-enhanced directly observed therapy should be understood not as a single intervention, but as a set of adaptable service delivery models. Programmes that demonstrated flexibility in selecting and modifying implementation approaches were better positioned to integrate telemedicine-enhanced DOT within existing tuberculosis services, underscoring the importance of context-sensitive design in health system innovation [1,3,7].

## INTEGRATION OF TELEMEDICINE-ENHANCED DOT WITHIN TUBERCULOSIS PROGRAMMES AND GOVERNANCE FRAMEWORKS

The integration of telemedicine-enhanced DOT within existing TB programmes varied considerably across settings, reflecting differences in governance structures, regulatory environments, and programme maturity. Across the reviewed studies, successful implementation was most frequently observed when telemedicine-enhanced DOT was embedded within established national or subnational tuberculosis control frameworks rather than introduced as a parallel or standalone intervention [1,3,7]. This integration facilitated alignment with existing treatment protocols, reporting systems, and accountability mechanisms, thereby supporting continuity of care and programme oversight.

In high-income settings, telemedicine-enhanced DOT was commonly integrated through formal policy endorsement and incorporation into routine service delivery workflows, often supported by established telehealth regulations and data governance frameworks [12,14,21]. These settings demonstrated clearer delineation of clinical responsibility, data ownership, and medico-legal accountability, which enabled scale-up beyond pilot phases [12,14]. However, even in these contexts, governance challenges related to data privacy and interoperability with legacy information systems were reported, underscoring the need for ongoing regulatory adaptation as digital adherence technologies evolve [21].

In contrast, integration within low- and middle-income country programmes was frequently characterised by phased or adaptive approaches, often initiated through pilot projects before gradual incorporation into routine TB services [9,11,19]. In these settings, governance arrangements were less formalised, with programme managers relying on locally developed protocols and discretionary decision-making to balance flexibility with oversight. As summarised in Table 4, enabling factors for integration included national tuberculosis programme endorsement, donor or institutional support, and alignment with broader digital health strategies, while barriers included unclear regulatory guidance and limited institutional capacity for digital governance [6,7,10].

Several studies highlighted the role of telemedicine-enhanced DOT in strengthening programme resilience during periods of system disruption, particularly during the COVID-19 pandemic [8,15]. Temporary policy adjustments allowing remote treatment supervision facilitated rapid adoption of telemedicine-supported models, demonstrating the potential for regulatory flexibility to accelerate innovation when supported by clear governance principles. However, the sustainability of such adaptations beyond emergency contexts remained uncertain, particularly in settings where policy changes were not subsequently formalised [8].

Across settings, the degree of programme integration influenced not only operational feasibility but also equity and accountability. Programmes that embedded telemedicine-enhanced DOT within existing monitoring and evaluation systems were better able to identify patients at risk of non-adherence and to deploy targeted support mechanisms [11,17]. Conversely, fragmented implementation approaches risked creating parallel systems with inconsistent reporting and reduced visibility at programme level. Table 3 illustrates how governance clarity and integration affected workforce coordination and continuity of care across implementation models.

Overall, the findings suggest that telemedicine-enhanced directly observed therapy is most effective when conceptualised as a service delivery adaptation within TB programmes, rather than a purely technological solution. Governance structures that provide clear regulatory guidance, define roles and responsibilities, and support integration with routine programme functions are critical to ensuring that telemedicine-enhanced DOT contributes meaningfully to TB control objectives while maintaining accountability and equity [1,3,7].

## HEALTH WORKFORCE AND OPERATIONAL IMPLICATIONS OF TELEMEDICINE-ENHANCED DOT

The implementation of telemedicine-enhanced DOT has significant implications for health workforce organisation and day-to-day programme operations. Across studies, shifts in supervision modality altered patterns of health worker time use, task allocation, and patient engagement, with effects varying by implementation model and health system context [3,11,12]. These operational changes were central to the perceived feasibility and sustainability of telemedicine-enhanced DOT at programme level.

Synchronous VOT models generally required sustained real-time engagement between healthcare providers and patients, resulting in time commitments comparable to or exceeding those of conventional in-person DOT [5,14]. While this approach preserved direct clinical oversight and continuity of interaction, it limited scalability in resource-constrained settings where workforce capacity was already stretched. Studies from high-income contexts reported that synchronous models were most feasible when integrated into existing telehealth services with protected staff time and clear role delineation [14,21].

In contrast, asynchronous VOT models consistently demonstrated greater operational flexibility and efficiency [11-13,17]. Health workers reviewed recorded medication ingestion videos in batches, allowing supervision of larger patient caseloads without proportional increases in staffing. This redistribution of effort enabled programmes to prioritise follow-up and counselling for patients identified as having adherence challenges, rather than applying uniform supervision intensity across all patients [11,17]. As summarised in Table 3, asynchronous approaches were associated with reduced travel requirements, improved workflow efficiency, and enhanced capacity for differentiated care.

Hybrid implementation models combined elements of digital supervision with targeted in-person contact, offering a pragmatic balance between efficiency and clinical oversight [9,19]. These models were particularly valuable for managing patients with complex social needs, limited digital literacy, or unstable treatment engagement. Health workers reported that hybrid approaches allowed more judicious allocation of face-to-face interactions, reserving in-person supervision for patients most likely to benefit from additional support [9]. Table 3 illustrates how such models supported continuity of care while mitigating the operational burden associated with universal in-person DOT.

Across all models, the transition to telemedicine-enhanced DOT required new competencies among health workers, including digital literacy, remote patient engagement skills, and familiarity with data platforms [6,7]. Training and change

management emerged as critical enablers of successful implementation, particularly in settings where digital health tools were not previously embedded within routine service delivery. Conversely, resistance to workflow change and concerns regarding increased administrative burden were identified as barriers to adoption in some programmes [19].
Overall, the findings indicate that telemedicine-enhanced directly observed therapy reshapes workforce roles rather than reducing the need for human resources. Programmes that approached implementation as an opportunity to redesign supervision workflows, rather than simply digitising existing practices, were better positioned to achieve operational efficiencies while maintaining patient-centred care. These workforce and operational considerations underscore the importance of aligning telemedicine-enhanced DOT models with broader health system capacity and programme management strategies to support sustainable scale-up [1,3,7].

## PATIENT ACCEPTABILITY, ACCESS, AND EQUITY CONSIDERATIONS

Patient acceptability emerged as a key determinant of the effectiveness and sustainability of telemedicine-enhanced DOTs across diverse settings. Overall, studies consistently reported high levels of patient satisfaction with telemedicine-supported supervision, particularly due to reduced travel requirements, increased convenience, and greater autonomy in medication intake [9,11,13,14]. These benefits were especially pronounced among working adults and individuals facing logistical barriers to daily facility-based supervision.

Asynchronous VOT was frequently associated with higher acceptability compared with synchronous models, owing to its flexibility and reduced disruption to daily routines [11-13,17]. Patients valued the ability to record medication ingestion at convenient times without the need to synchronise schedules with healthcare providers. Hybrid models further enhanced acceptability by maintaining periodic in-person contact, which some patients perceived as important for reassurance, relationship-building, and clinical support [9,19]. As reflected in Table 3, acceptability was closely linked to how well implementation models balanced flexibility with ongoing human interaction.

Despite these positive findings, access to telemedicine-enhanced DOT was unevenly distributed, raising important equity concerns. Several studies highlighted the risk of exclusion among populations lacking access to smartphones, stable internet connectivity, or adequate digital literacy [6,10]. Requirements for personal device ownership disproportionately affected older adults, individuals with lower socioeconomic status, and those living in remote or marginalised communities. As summarised in Table 4, digital access constraints and varying levels of technological familiarity were recurrent barriers to equitable implementation across settings.

Privacy and confidentiality considerations also influenced patient acceptability. While some patients reported increased privacy due to reduced clinic visits and avoidance of TB-related stigma, others expressed concerns regarding video recording, data security, and unintended disclosure within shared living environments [9,19]. These concerns were particularly salient in densely populated households and informal settlements, underscoring the need for context-sensitive implementation and clear communication regarding data protection measures.

Across settings, programmes that proactively addressed equity considerations through flexible eligibility criteria, alternative supervision options, and patient support mechanisms demonstrated higher overall acceptability and engagement [6,9,19]. Table 4 highlights how equity-oriented design choices, such as offering non-digital alternatives or providing devices and technical support, mitigated exclusion risks and enhanced inclusivity. These findings suggest that patient-centred and equity-informed approaches are essential to ensuring that telemedicine-enhanced DOT strengthens, rather than inadvertently exacerbates, disparities in tuberculosis care.

## COST, SUSTAINABILITY, AND SCALABILITY OF TELEMEDICINE-ENHANCED DOT MODELS

Cost considerations were a central driver of interest in telemedicine-enhanced DOT, particularly in contexts where conventional in-person DOT imposed substantial recurrent expenses related to staff time, patient travel, and facility utilisation. Across studies, telemedicine-supported models were consistently associated with reductions in indirect costs for patients and operational efficiencies for tuberculosis programmes, although the magnitude and distribution of savings varied by implementation model and health system context [3,8,12].

Asynchronous VOT demonstrated the greatest potential for cost savings at programme level, primarily through reduced staff time per patient and the ability to supervise larger caseloads without proportional workforce expansion [12,17]. Studies from both high-income and middle-income settings reported that savings accrued from decreased travel requirements and more efficient supervision workflows outweighed the costs associated with platform maintenance and staff training over time [8,12]. These efficiency gains are reflected in Table 3, which summarises operational implications linked to different telemedicine-enhanced DOT models.

Synchronous VOT, while effective in maintaining close clinical oversight, was generally associated with higher recurrent staffing costs due to real-time supervision requirements [5,14]. As a result, its scalability was more limited in resource-constrained settings unless integrated within existing telehealth infrastructure with protected staffing and funding streams. Hybrid models offered a pragmatic alternative by concentrating resource-intensive in-person or real-time interactions on patients with greater support needs, thereby improving cost efficiency without compromising care quality [9,15].

Sustainability of telemedicine-enhanced DOT depended not only on immediate cost considerations but also on long-term integration within health system financing and governance structures. Several studies highlighted that pilot projects supported by short-term funding or emergency policy adjustments, particularly during the COVID-19 pandemic, faced challenges in transitioning to routine service delivery once external support diminished [8,15]. As summarised in Table 4, sustainable scale-up was more likely when telemedicine-enhanced DOT was embedded within national tuberculosis programme budgets and aligned with broader digital health strategies [1,7].

Scalability was further influenced by equity-related cost considerations. Programmes that required patients to bear the cost of smartphones or data connectivity risked excluding socioeconomically disadvantaged populations, thereby limiting both reach and effectiveness [6,10]. Conversely, models that incorporated device provision, low-bandwidth solutions, or complementary non-digital supervision options demonstrated greater scalability across diverse populations [6,9]. These findings underscore that cost-effectiveness at programme level must be assessed alongside affordability and access at patient level.

Overall, the evidence suggests that telemedicine-enhanced directly observed therapy can offer meaningful cost and efficiency advantages, particularly when implemented through flexible, asynchronous, or hybrid models. However, realising these benefits at scale requires deliberate attention to financing mechanisms, governance integration, and equity safeguards. Telemedicine-enhanced DOT is most likely to be sustainable when positioned as a long-term service delivery strategy within tuberculosis programmes rather than as a time-limited technological innovation [1,3,7].

## DISCUSSION

Unlike previous reviews that have predominantly focused on adherence outcomes and technological effectiveness, this review synthesises evidence through a health management and policy lens, highlighting the governance, workforce, scalability, sustainability, and equity factors that determine successful implementation of telemedicine-enhanced DOT within contemporary tuberculosis programmes. Across the reviewed literature, telemedicine-enhanced DOT demonstrated high patient acceptability and considerable potential for scalable implementation, particularly through asynchronous and hybrid models. Nevertheless, persistent challenges relating to digital exclusion, programme integration, and long-term sustainability highlight the need for context-sensitive implementation strategies.

This review highlights five principal findings of relevance to health system management and programme design. First, telemedicine-enhanced DOT has been implemented through diverse service delivery models, including synchronous, asynchronous, and hybrid approaches, with no single model demonstrating universal superiority. Instead, feasibility and effectiveness are strongly shaped by alignment with local health system capacity, digital readiness, and patient needs. Second, successful adoption depends on supportive governance arrangements and regulatory clarity, particularly in relation to data governance, clinical accountability, and integration with existing tuberculosis programme structures.

Third, telemedicine-enhanced DOT reshapes health workforce roles and operational workflows. Rather than reducing workforce requirements, it enables more efficient allocation of staff time when models support differentiated supervision. Fourth, while patient acceptability is generally high due to reduced treatment burden and increased flexibility, access and equity concerns persist, particularly for populations with limited digital access or literacy. Finally, telemedicine-enhanced DOT demonstrates potential for cost savings and scalable implementation, especially through asynchronous and hybrid models, but long-term sustainability requires integration into routine financing and programme planning.

## COMPARATIVE INTERPRETATION OF FINDINGS

These findings are broadly consistent with previous systematic reviews demonstrating that video-observed therapy is non-inferior to conventional DOT in terms of adherence and patient satisfaction, while offering operational efficiencies in selected contexts. However, this review extends existing evidence by shifting the analytical focus from efficacy to implementation as a health system intervention. The variability observed across settings underscores that telemedicine-enhanced DOT should not be conceptualised as a standardised technological solution, but rather as a set of adaptable service delivery options that must be matched to programme objectives and system constraints.

A notable strength across the reviewed studies was the consistent demonstration of favourable adherence outcomes and high patient acceptability. Patients frequently reported reduced travel requirements, increased flexibility, and lower treatment burden, while programmes reported improved efficiency in treatment monitoring and supervision. Several studies also demonstrated the feasibility of scaling telemedicine-enhanced DOT within routine tuberculosis programmes, particularly through asynchronous monitoring approaches. However, important limitations were also evident. Many studies were conducted as pilot projects, implementation evaluations, or within relatively well-resourced settings, limiting the generalisability of findings to routine practice. Sample sizes varied substantially, and long-term sustainability outcomes were rarely evaluated. Furthermore, while studies conducted in high-income settings often benefited from established telehealth infrastructure and supportive regulatory frameworks, studies from low- and middle-income settings highlighted ongoing challenges related to internet connectivity, digital literacy, device access, and financing mechanisms. These contrasting findings suggest that implementation success depends not only on intervention design but also on the broader organisational, economic, and policy environment.

Differences between high-income and low- and middle-income settings were particularly evident in governance and integration processes. While high-income settings often benefited from established telehealth regulations and digital infrastructure, lower-resource settings relied more heavily on adaptive, phased implementation approaches. Importantly, several studies demonstrated that flexibility and incremental integration, rather than technological sophistication, were key to sustaining telemedicine-enhanced DOT in resource-constrained environments. These observations reinforce the need to prioritise system readiness and managerial capacity alongside technological considerations.

## CONTRIBUTIONS AND IMPLICATIONS FOR POLICY AND HEALTH MANAGEMENT

This review contributes to the literature by explicitly framing telemedicine-enhanced DOT as a programme management and health system innovation, rather than solely a digital adherence tool. By synthesising evidence across implementation models, governance contexts, workforce implications, equity considerations, and sustainability, the review clarifies why outcomes vary across settings and how these variations can be anticipated and managed.

Several practical implications emerge for policymakers, programme managers, and healthcare systems. First, telemedicine-enhanced DOT should be positioned as a complementary component of differentiated tuberculosis care rather than a universal replacement for conventional DOT, allowing supervision intensity to be tailored according to patient risk, treatment phase, and programme capacity. Second, successful implementation requires investment not only in digital platforms but also in workforce training, change management, governance mechanisms, and integration with existing health information systems to maintain accountability and continuity of care. Third, equity considerations should be incorporated into programme design from the outset through the provision of alternative non-digital pathways and targeted support for populations at risk of digital exclusion. Fourth, hybrid models that combine in-person and remote monitoring may provide the greatest flexibility by balancing patient-centred care with programme oversight. Finally, long-

term sustainability depends on embedding telemedicine-enhanced DOT within routine financing arrangements, national digital health strategies, and tuberculosis programme planning rather than relying on short-term pilot projects or emergency-driven implementation.

Unlike earlier reviews that primarily evaluated the effectiveness of video-observed therapy, the present review situates telemedicine-enhanced DOT within the broader 2025 digital health landscape characterised by expanding use of Digital Adherence Technologies, artificial intelligence-supported monitoring systems, hybrid care delivery models, and increasing emphasis on health system integration and digital equity.

### FUTURE DIRECTIONS

Looking ahead, further research is needed to examine long-term outcomes of telemedicine-enhanced DOT beyond pilot phases, particularly in low-resource and decentralised health systems also focusing on optimising implementation within rapidly evolving digital health ecosystems. Emerging developments in digital health, including artificial intelligence–supported adherence monitoring and evolving global guidance, warrant careful evaluation to determine how they can be integrated responsibly into tuberculosis programmes without exacerbating inequities. Comparative implementation research focusing on governance models, workforce adaptation, and patient stratification strategies would be particularly valuable in informing scalable and context-sensitive approaches. Additional research is also needed to explore governance frameworks, workforce adaptation, interoperability with national health information systems, and financing mechanisms that support sustainable implementation. Given the increasing emphasis on equitable digital health transformation, future studies should prioritise strategies to reduce disparities in access among rural populations, socioeconomically disadvantaged groups, older adults, and individuals with limited digital literacy. Such work will be critical to ensuring that telemedicine-enhanced DOT contributes to both effective tuberculosis control and equitable healthcare delivery.

### LIMITATIONS

This review has several limitations. As a narrative review, it does not employ formal systematic methods or meta-analysis, which may limit reproducibility and introduce selection bias. However, this approach was intentionally adopted to accommodate heterogeneous study designs and to support interpretation through a health system and management lens. The evidence base remains uneven across regions, with limited long-term data from some low-resource settings. In addition, many studies were conducted during periods of system disruption, such as the COVID-19 pandemic, which may affect generalisability. Rapid evolution in digital adherence technologies also means that evidence will continue to develop beyond the scope of this review. As tuberculosis programmes increasingly embrace digital transformation, telemedicine-enhanced DOT is likely to become an integral component of differentiated, patient-centred care. The challenge facing policymakers in 2025 is no longer whether telemedicine can support tuberculosis treatment, but how digital innovations can be implemented sustainably, equitably, and at scale within diverse health system contexts.

## CONCLUSION

Telemedicine-enhanced DOT represents a pragmatic evolution in tuberculosis treatment supervision, offering health systems greater flexibility to balance patient-centred care with programme efficiency. This review demonstrates that the value of telemedicine-enhanced DOT lies not in the technology itself, but in how it is governed, integrated, and operationalised within existing tuberculosis programmes. Implementation outcomes vary widely according to health system readiness, workforce capacity, and equity considerations, underscoring the need for differentiated and context-sensitive approaches. For policymakers and programme managers, telemedicine-enhanced DOT should be positioned as a complementary strategy within routine TB care, supported by clear governance frameworks, sustained financing, and inclusive design. When aligned with broader health system priorities, telemedicine-enhanced DOT has the potential to strengthen treatment supervision, enhance resilience to service disruptions, and advance equitable tuberculosis care across diverse settings.

## CONFLICTS OF INTERESTS

The authors have no conflicts of interest to declare.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## DATA AVAILABILITY STATEMENTS

No datasets were generated or analyzed during the current study. This article is a narrative review based primarily on previously published literature.


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## AUTHORS' CONTRIBUTIONS

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## References


1. World Health Organization. Global tuberculosis report 2022 (Internet). 2022. Geneva. Available from: https://www.who.int/publications/i/item/9789240061729
2. Elangovan R, Arulchelvan S. A study on the role of mobile phone communication in tuberculosis DOTS treatment. Indian Journal of Community Medicine. 2013 Oct;38(4):229-33.
3. Netto TAL, Diniz BD, Odutola P, Dantas CR, de Freitas MCFLC, Hefford PM, et al. Video-observed therapy (VOT) vs directly observed therapy (DOT) for tuberculosis treatment: A systematic review on adherence, cost of treatment observation, time spent observing treatment and patient satisfaction. PLoS Negl Trop Dis. 2024 Oct 1;2024-October 2024.
4. Cross A, Gupta N, Liu B, Nair V, Kumar A, Kuttan R, et al. 99DOTS: A low-cost approach to monitoring and improving medication adherence. In: ACM International Conference Proceeding Series. Association for Computing Machinery; 2019.
5. Tello-Cajiao ME, Mosquera-Hernández JC, Ardila-Giraldo S, Romero-Rosas N, Parra-Lara LG, Niño-Ramírez Y, et al. Synchronous video-supported treatment for tuberculosis in Cali, Colombia: An implementation study. Health Policy Technol. 2023 Jun 1;12(2).
6. Bommakanti KK, Smith LL, Liu L, Do D, Cuevas-Mota J, Collins K, et al. Requiring smartphone ownership for mHealth interventions: Who could be left out? BMC Public Health. 2020 Jan 20;20(1).
7. Olawade DB, Eberhardt J, David-Olawade AC, Balogun MA, Bolarinwa OA, Esan DT. Transforming multidrug-resistant tuberculosis care: The potentials of telemedicine in resource-limited settings. Health Sciences Review. 2024 Sep;12:100185.
8. Fekadu G, Jiang X, Yao J, You JHS. Cost-effectiveness of video-observed therapy for ambulatory management of active tuberculosis during the COVID-19 pandemic in a high-income country. International Journal of Infectious Diseases. 2021 Dec 1;113:271-8.
9. Rabinovich L, Molton JS, Ooi WT, Paton NI, Batra S, Yoong J. Perceptions and acceptability of digital interventions among tuberculosis patients in Cambodia: Qualitative study of video-based directly observed therapy. J Med Internet Res. 2020 Jul 1;22(7).
10. Adisa R, Ayandokun TT, Ige OM. Knowledge about tuberculosis, treatment adherence and outcome among ambulatory patients with drug-sensitive tuberculosis in two directly-observed treatment centres in Southwest Nigeria. BMC Public Health. 2021 Dec 1;21(1).
11. Garfein RS, Collins K, Muñoz F, Moser K, Cerecer-Callu P, Raab F, et al. Feasibility of tuberculosis treatment monitoring by video directly observed therapy: A binational pilot study. International Journal of Tuberculosis and Lung Disease. 2015 Sep 1;19(9):1057-64.

12. Lam CK, Fluegge K, Macaraig M, Burzynski J. Cost savings associated with video directly observed therapy for treatment of tuberculosis. International Journal of Tuberculosis and Lung Disease. 2019 Nov 1;23(11):1149-54.
13. Ravenscroft L, Kettle S, Persian R, Ruda S, Severin L, Doltu S, et al. Video-observed therapy and medication adherence for tuberculosis patients: Randomised controlled trial in Moldova. European Respiratory Journal. 2020 Aug 1;56(2).
14. Story A, Aldridge RW, Smith CM, Garber E, Hall J, Ferenando G, et al. Smartphone-enabled video-observed versus directly observed treatment for tuberculosis: a multicentre, analyst-blinded, randomised, controlled superiority trial. The Lancet. 2019 Mar 23;393(10177):1216-24.
15. Donahue ML, Eberly MD, Rajnik M. Tele-TB: Using TeleMedicine to Increase Access to Directly Observed Therapy for Latent Tuberculosis Infection. Mil Med. 2021 Jan 1;186:25-31.
16. Kumwichar P, Chongsuvivatwong V, Prappre T. Tuberculosis Treatment Compliance Under Smartphone-Based Video-Observed Therapy Versus Community-Based Directly Observed Therapy: Protocol for a Cluster Randomized Controlled Trial. JMIR Res Protoc. 2022 Jul 1;11(7).
17. Raj A, Khakoo NS, Ashkin AA, Green MT, Tresgallo RR. Investigating the efficacy of integrating video-directly observed therapy (VDOT) in the treatment of tuberculosis (TB): A statewide analysis from Florida. J Clin Tuberc Other Mycobact Dis. 2024 Dec 1;37.
18. Abas SA, Ismail N, Zakaria Y, Yasin SM, Ibrahim K, Ismail I, et al. Enhancing tuberculosis treatment adherence and motivation through gamified real-time mobile app utilization: a single-arm intervention study. BMC Public Health. 2024 Dec 1;24(1).
19. Sekandi JN, Kasiita V, Onuoha NA, Zalwango S, Nakkonde D, Kaawa-Mafigiri D, et al. Stakeholders' perceptions of benefits of and barriers to using video-observed treatment for monitoring patients with tuberculosis in Uganda: Exploratory qualitative study. JMIR Mhealth Uhealth. 2021 Oct 1;9(10).
20. Al Daajani MM, Alsahafi AJ, Algarni AM, Moawwad AL, Osman AA, Algaali KY, et al. Use of Smartphone-Based Video Directly Observed Therapy to Increase Tuberculosis Medication Adherence: An Interventional Study. Galen Medical Journal 12:2023; Available from: https://doi.org/10.31661/gmj.v12i.3067
21. Holzman SB, Perry A, Saleeb P, Pyan A, Keh C, Salcedo K, et al. Evaluation of the Latent Tuberculosis Care Cascade among Public Health Clinics in the United States. Clinical Infectious Diseases. 2022 Nov 15;75(10):1792-9.
22. Browne SH, Umlauf A, Tucker AJ, Low J, Moser K, Garcia JG, et al. Wirelessly observed therapy compared to directly observed therapy to confirm and support tuberculosis treatment adherence: A randomized controlled trial. PLoS Med. 2019;16(10).