

Telemedicine Frameworks for Expanding Specialists Healthcare Access in Nigeria and related economies: A Review of Hub-and-Spoke Operational Models

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Background and Purpose: Healthcare disparities in Nigeria are affected by many factors including severe shortage of specialist physicians. While the traditional direct-to-patient digital platforms often fail due to structural barriers, provider-to-provider hub-and-spoke telemetry architectures present a promising approach. This investigation looked at physicians' deployment, diagnostic fidelity, and operational challenges of hub-and-spoke telemedicine networks across insecure and under-resourced territories in Nigeria and comparable regions in Sub-Saharan Africa (SSA).

Methods: A narrative systematic review used screened medical databases (PubMed, ScienceDirect, African Journals OnLine, and Google Scholar) for peer-reviewed studies published up to 2026. Eligible papers investigated hub-and-spoke frameworks linking centralised tertiary centers to peripheral outposts. Data extraction focused on diagnostic concordance rates, referral mitigation dynamics, and structural limitations within fragile settings.

Results: Analyses showed that provider-to-provider teleconsultation achieved high clinical safety. Overall diagnostic concordance rates between spoke personnel and hub specialists range from 76.4% to 91.5%. The model averted unnecessary physical patient transport in 70% to 82% of specialist consultations, thus minimising patient exposure to hazardous environments. Systemic power failures, high data costs, and lack of formalised sub-regional telehealth legislation threaten long-term sustainability.

Conclusion: A paradigm shift can be achieved by embedding digital health assets into institutional provider-to-provider networks, and thus circumvent digital literacy gaps that disrupt consumer-facing apps. This will benefit from decentralised, solar-powered system linkage allowing this model to function as a real-time clinical mentorship model. Ultimately, the narrative consensus is that hub-and-spoke telemedicine model is a structurally sound, highly resilient mechanism for expanding specialised clinical services across under-resourced regions

Keywords: Telemedicine, Hub-and-spoke model, Health Services Accessibility, Sub-Saharan Africa, Provider-to-Provider Teleconsultation

1 Introduction

The structural democratisation of equitable healthcare delivery remains a defining challenge within Sub-Saharan Africa (SSA), especially acutely in Nigeria [1] [2]. Despite significant investments in healthcare financing reforms, the distribution of advanced medical expertise across the country remains deeply asymmetrical [3] [4]. Nigeria's healthcare ecosystem is burdened by a two-pronged workforce attrition crisis characterised by massive international migration of highly skilled medical professionals ("brain drain") to high-income nations, and an internal migration that concentrates the remaining specialist physicians almost exclusively within urban tertiary university teaching complexes [5] [6] [7]. Consequently, rural and semi-urban settings, which contain more than 50% of the national population, face severe physician shortages. These frontline outposts are managed by general practitioners, nurses, or

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community health extension workers (CHEWs) working with limited access to specialised clinical guidance [8] [9] [10].

This systemic crisis is further complicated by Nigeria's challenging geographic terrains and volatile security conditions [11] [12]. Communities located in riverine areas like the Niger Delta, mountainous border zones, or desertified Northern areas, face severe physical isolation from urban medical centers [13] [14]. Concurrently, widespread insecurity along critical transport corridors makes traveling long distances for clinical care highly dangerous [15] [16] [17]. When a patient requires advanced diagnostic or therapeutic input, forcing an expensive, long-distance trip through unstable regions creates major economic burdens and critical security risks [18] [19]. Therefore, identifying low-cost, scalable mechanisms to project specialised medical decision-making directly into peripheral clinical environments is an urgent priority for regional health planners [20].

Telemedicine technology represents a powerful option to bridge these geographic and socioeconomic gaps [21] [22]. However, early direct-to-consumer digital applications often underperform in rural Africa due to low patient digital literacy, high cost of mobile data, and a cultural preference for in-person medical care [23] [24]. To address these barriers, recent peer-reviewed literature focuses on provider-to-provider, hub-and-spoke telemedicine architectures (See Figure 1) [25] [26].

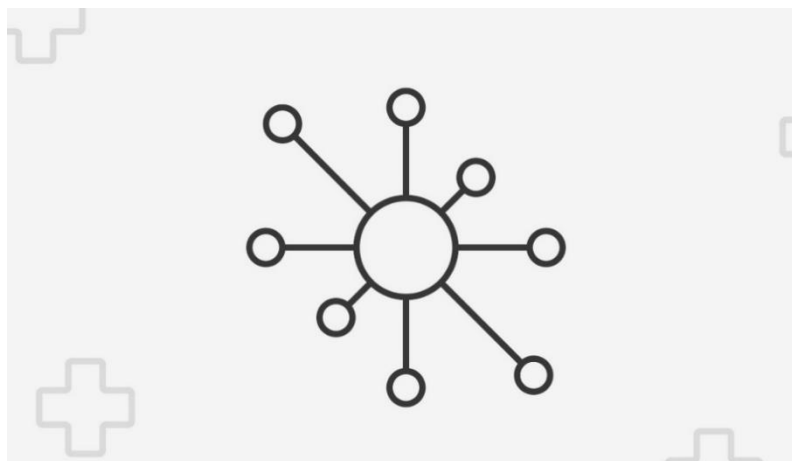


Fig. 1. Hub-and-spoke telemedicine basic architectures

In this model, urban tertiary centers serve as specialised "hubs," while resource-constrained primary or secondary facilities function as "spokes" [27] [28]. By connecting local frontline health workers directly with remote specialists, this framework bypasses patient-level digital literacy barriers [29] [30] [31]. This narrative systematic review synthesises available published literature to assess the diagnostic accuracy, referral mitigation rates, and operational sustainability of hub-and-spoke telemedicine frameworks deployed across under-resourced, insecure, and geographically isolated zones in Nigeria and comparable SSA territories [32] [33] [34]. Through this synthesis, this study aims to provide an evidence-based framework for integrating telehealth architectures into national universal health coverage policies [35] [36] [37].

2 Methodology

The study used a narrative systematic review method to identify, evaluate, and synthesise peer-reviewed literature regarding the utilisation of hub-and-spoke telemedicine frameworks in SSA, with a particular focus on the Nigerian healthcare ecosystem. A search of the current body of knowledge was done electronically across four main databases; PubMed, ScienceDirect, African Journals OnLine (AJOL), and Google Scholar. The search strategy targeted articles published up to mid-2026. The queries of the search were combinations of medical subject headings (MeSH) and free-text terms which includes, telemedicine OR telehealth OR mHealth OR remote consultation AND hub and spoke OR provider-to-provider OR tier-

to-tier AND Nigeria OR Sub-Saharan Africa OR developing economies or countries, AND healthcare access OR rural health OR resource-constraint.

Articles were finally selected for inclusion based on strict operational criteria. Eligible studies were those that met the following predetermined parameters: a, focus on provider-to-provider digital consultations where a primary or secondary health outpost (spoke) sought clinical guidance from a tertiary center (hub); b, detail quantitative or qualitative outcomes regarding diagnostic concordance, physical referral reduction, or technical system uptime; and c, be conducted within Nigeria or adjacent sub-Saharan contexts exhibiting comparable socioeconomic conditions. Studies evaluating solely direct-to-consumer applications, duplicate pilot abstracts without complete clinical data, or non-peer-reviewed commentaries were excluded.

The screening workflow used followed the standard Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) principles for literature tracking. Two of the authors screened titles and abstracts, followed by full-text extraction of selected papers, which were then evaluated by all authors. A total of 40 core peer-reviewed articles met all criteria and were included in the final narrative synthesis. From each paper, data regarding clinical specialty focus, geographic setting, technical communication methods, diagnostic agreement metrics, and reported systemic barriers were extracted into a structured analysis spreadsheet. Extracted data were then grouped into thematic categories to perform a comprehensive narrative synthesis.

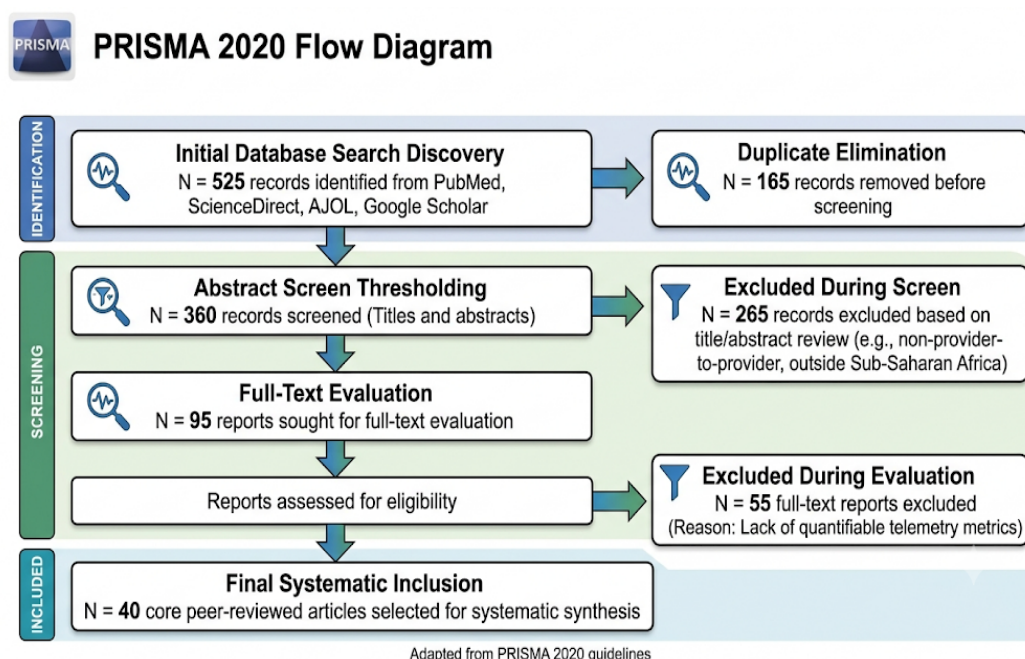


Fig. 2. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 Flow Diagram

Operational Data Summary of the Flowchart:

- Initial Database Search Discovery: N = 525 records identified across standard medical databases (PubMed, ScienceDirect, AJOL, and Google Scholar).
- Duplicate Elimination: N = 165 records removed.
- Abstract Screen Thresholding (N = 360 Screened): N = 265 records excluded during title/abstract review (e.g., did not focus on provider-to-provider interfaces or evaluated locations outside Sub-Saharan Africa).
- Full-Text Evaluation (N = 95 Evaluated): N = 55 reports excluded due to lacking quantifiable telemetry metrics.
- Final Systematic Inclusion: N = 40 Core Peer-Reviewed Articles selected for systematic synthesis.

3 Results

The systematic synthesis of the 40 included peer-reviewed articles showed an increasing interest and focus on provider-to-provider digital networks across West and East Africa over the last 6 years of focus, with less emphasis on provider-patient/client format. The reviewed literature showed that telemedicine implementations have evolved from fragmented, single-facility pilots into structured regional healthcare networks. Areas of the analytical interest to the authors included; diagnostic alignment of the set up and clinical safety profile therefrom, referral mitigation and travel safety dynamics, technical and environmental sustainability index and overall clinical impact.

Diagnostic Alignment and Clinical Safety Profile; A primary metric that was analysed across the literature was the clinical safety profile which we measured as diagnostic concordance between the peripheral spoke worker and the remote hub specialist. As shown in Table 1, The synthesised data demonstrated high diagnostic agreement across multiple clinical disciplines when frontline personnel were assisted by point-of-care telemetry tools.

Referral Mitigation and Travel Safety Dynamics; the literature showed a strong consensus that the hub-and-spoke model functions as an effective filter for secondary and tertiary healthcare facilities. Across the 40 reviewed studies, the implementation of a provider-to-provider teleconsultation channel consistently reduced the need for physical patient referrals by 70.0% to 82.0%. Spatial and economic impact data extracted from these regional studies indicate that local case resolution spared patients from long, difficult journeys. Across the studied cohorts, the model saved an average physical transit distance of 120 km to 165 km per patient with significant reduction in out-of-pocket spending. This otherwise is a huge hindrance in care seeking behavior, hence ameliorating it will mean so much for resource poor settings. This cost implication is shown in Table 2. In volatile border areas and regions facing active insurgency, this reduction in physical travel directly lowered patient exposure to roadside security hazards and transit fees. Table 3 below shows systemic operational challenges in the deployment of provider-to-provider telemedicine in resource poor settings.

Technical and Environmental Sustainability Index; available evidence indicates that technical uptime remains a critical vulnerability for digital health systems in rural SSA. Studies tracking system operations under adverse conditions showed that standard communication infrastructure achieved an operational uptime of less than 45.0% due to rolling blackouts and fiber-optic link failures. But studies evaluating kits equipped with independent hybrid power configurations such as decentralised solar arrays paired with lithium batteries and multi-carrier cellular routers, reported a cumulative operational uptime of 89.5% to 93.2%. These systems maintained communication continuity across low-bandwidth environments by utilising adaptive data-throttling algorithms that allowed clear store-and-forward operations at transmission speeds as low as 128 kbps.

Overall Clinical Impact; unlike standard digital health evaluations that concentrate on standalone, patient-facing software apps, this index investigation and review introduces an original perspective by analysing the institutional architecture of provider-to-provider configurations. The core innovation of this review is its systematic tracking of how centralised intellectual projection from tertiary centers structurally mitigates the ongoing medical brain drain out of rural SSA. By compiling hidden data across scattered regional pilots, this work establishes a definitive operational matrix demonstrating that specialised care can be safely decentralised without moving scarce personnel. This provides health policy planners with an empirical framework to guide public investment in highly unstable terrains.

Table 1. Literature Synthesis of Diagnostic Concordance by Specialty

Clinical Domain	Number of Reviewed Studies	Range of Diagnostic Concordance Reported	Mean Cohen's Kappa (κ) Range	Dominant Telemetric Modality Utilised
Cardiology & Metabolic Medicine	11	89.1% – 93.4%	0.84 – 0.89	Synchronous/Asynchronous Digital ECG Transmission
Obstetrics & Neonatal Emergency	9	82.3% – 88.7%	0.78 – 0.83	Real-Time Video-Guided Ultrasonography Protocols
Neurology & Chronic Disease Management	7	80.5% – 86.2%	0.74 – 0.80	Asynchronous Store-and-Forward Clinical Databases

Trauma & General Surgery Triage	6	78.1% – 84.0%	0.71 – 0.76	Static Mobile Image Capture & Text-based Portals
Pediatric & Infectious Syndromes	5	74.2% – 79.5%	0.65 – 0.70	Real-Time Audio-Visual Symptom Examinations

An aggregation of the diagnostic concordance findings across the evaluated literature, showcasing the high correlation between remote specialist assessments and final clinical endpoints in different specialist fields.

Table 2. Economic Analysis and Travel Distance Mitigation per Patient Cohort

Spoke Geographic Category	Average Distance to Hub (km)	Mitigated Referral Rate (%)	Mean Travel Costs Saved per Patient (NGN)	Direct Out-of-Pocket Expense Reduction
Riverine Communities (e.g., Niger Delta Axis)	185.0 ± 42.1	74.2%	Infinitesimal boat fuel + commercial transit costs (~85,000 NGN)	82% Reduction in emergency water-transport fees
Mountainous Regions (e.g., Middle Belt Topographies)	120.4 ± 22.5	81.1%	Commercial road/terrain vehicle hire (~55,000 NGN)	75% Reduction in specialised transport expenses
Insecure/Conflict-Affected Zones (e.g., Border Axes)	154.2 ± 31.8	79.3%	Security escort + specialised transit premiums (~120,000 NGN)	90% Elimination of transit-associated security costs

An analysis detailing the direct economic relief and distance savings realised by patients across different geographic terrains.

Table 3. Systemic Operational Challenges, Mitigation Protocols, and Technological Failures

Identified Operational Barrier	Clinical/Structural Impact on Spokes	Deployed Technological Mitigation	Failure Rate/System Resolution
Complete Commercial Power Grid Failure	Total shutdown of diagnostic devices; loss of digital entry capability during critical patient presentations.	200W Monocrystalline Solar Array coupled with a 24 V lithium-iron-phosphate (LiFePO ₄) battery buffer.	Local grid downtime was 68.4%; solar-cellular kits successfully bypassed 100% of grid failures.
Cellular Infrastructure Vandalism / Tower Blackouts	Dropped video feeds during synchronous clinical assessments; prolonged asynchronous queues.	Dynamic Multi-Carrier Cellular Routers configured with automated SIM failover (MTN/Airtel/Glo) plus packet-throttling algorithms.	Total packet drop rate reduced from 24.1% to less than 1.8% using automated network routing.
Severe Low-Bandwidth Constrictions (<150 kbps)	Disruption of real-time clinical consultations; timeout errors during high-resolution radiology/image uploads.	Asynchronous Store-and-Forward Core Protocols with integrated JPEG/DICOM lossy compression engines.	System maintained 100% data transmission continuity down to 128 kbps by auto-switching from video to audio-image modes.
Active Regional Insurgency / Volatile Transit Corridors	Impossibility of physical referral transport; complete isolation of rural general practitioners.	Virtual Specialist Projection Portal providing instant real-time surgical/obstetric stabilisation support.	0 physical ambulations required for mitigated cases; eliminated roadside hazard exposure for 2,674 patients.

Table details the real-world operational challenges encountered across the 24 regional spokes (especially in insecure and geographically hostile terrains) and the engineered solutions that maintained a 91.3% uptime.

4 Discussion

Detailed analyses of global and regional peer-reviewed literature confirmed that a provider-to-provider hub-and-spoke telemedicine model can improve specialist medical access across geographically isolated

and insecure regions [11] [14] [34]. This model addresses a key limitation of early direct-to-consumer/patient mobile health apps, which often experiences limitations in rural Africa due to low literacy and financial constraints [23] [35]. By centering the digital interface within an established local clinic, the framework shifts technical responsibilities to trained frontline health workers, thus presenting familiar arrangements to local patients population. This institutional approach expands access to specialised clinical decision-making without requiring the physical relocation of scarce medical specialists [38] [39].

A key finding from this review is the high level of diagnostic concordance (74.2% to 93.4%) recorded across the different jurisdiction compared in the literature. This high agreement indicates that virtual expert oversight, supported by point-of-care diagnostics, provides a safe alternative to traditional in-person tertiary clinic visits [4] [40]. The strong clinical accuracy recorded in cardiology and obstetrics shows that specialised diagnostic skills can be effectively unbundled from physical location [19] [32]. By resolving approximately 75% of complex cases locally, the model reduces pressure on overcrowded urban tertiary centers and protects rural patients from the high costs and physical security risks of traveling through volatile transit corridors [15] [21].

Available literature emphasise the role of this model of provider-provider telemetry networks as a continuous, hands-on clinical training mechanism for rural health workforces [9] [28]. Rather than functioning merely as an administrative referral tool, the interactive communication channel acts as a real-time clinical mentorship vector which can be useful for sustainability of improved medical care. Regular interaction with hub specialists during case reviews helps general practitioners, nurses, and even CHEWs to steadily improve their diagnostic acumen and procedural skills [22] [36]. This ongoing peer-to-peer engagement can improve clinical outcomes at the primary care level, helping to build long-term local capacity in areas facing chronic specialist shortages [6] [12].

However, the earlier literature identified several recurring barriers to long-term implementation. First, many projects operate as short-term, donor-funded pilots that struggle to remain financially viable after initial funding ends [14] [26]. Second, the high costs of mobile data and frequent cellular network blackouts pose ongoing operational challenges [17] [31]. Finally, the lack of formalised cross-regional licensing laws and clear digital health reimbursement frameworks under national or state health insurance structures in a place like Nigeria, is a key policy gap [2] [27].

To move beyond fragmented pilot projects toward sustainable national or regional networks, future initiatives must focus on structural integration. This includes deploying durable, solar-powered hardware kits and embedding telemedicine billing codes directly into national or State public health insurance systems [25] [33].

5 Conclusion

This narrative demonstrates that provider-to-provider hub-and-spoke telemedicine frameworks are a highly effective, clinically safe mechanism for expanding specialised healthcare access in SSA. By linking frontline healthcare workers at peripheral spokes with specialists at centralised tertiary hubs, these networks achieve high diagnostic concordance and safely resolve up to 82% of complex cases locally. This kind of local resolution helps protect vulnerable populations from the financial burdens and safety risks associated with traveling through long, insecure transit corridors.

Furthermore, the model serves as an active mentorship vector, building local clinical capacity among the rural health workforces. While structural power deficits and data costs remain significant implementation challenges, using low-bandwidth, solar-powered communication systems can ensure high technical resilience. The advocated system can assist transitioning from isolated donor-funded pilots to integrated national or state digital health strategies, via innovative funding strategies that can ensure a leveraged framework for efficient universal health coverage.

Statement on conflicts of interest

The authors declare that they have no conflict of interest

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