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Telestroke in Resource-Limited Settings: Systematic Review of Clinical Outcomes and Barriers

***Akbar Wibriansyah[1]**
Rumah Sakit Umum Daerah Bahteramas Provinsi Sulawesi Tenggara, Indonesia

Laras Wiyardhani[2]
Universitas Indonesia, Indonesia

Tara Sander[3]
Universitas Respati Indonesia, Indonesia

***Corresponding author:**
Akbar Wibriansyah, Rumah Sakit Umum Daerah Bahteramas Provinsi Sulawesi Tenggara. ✉akbarw2b2@gmail.com

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Abstract

Background: Stroke disproportionately affects resource-limited settings, where delayed access to specialist neurological evaluation limits eligibility for time-critical reperfusion therapies.
Objectives: This review aimed to evaluate the clinical outcomes, workflow efficiency, and implementation barriers associated with *telestroke* in resource-limited settings, thereby informing evidence-based strategies to improve equitable stroke care.
Methods: This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PubMed, Scopus, and the Cochrane Library were searched for studies published between 2005 and 2025 that evaluated *telestroke* implementation in resource-limited settings. Eligible studies included randomized and observational designs reporting clinical outcomes, workflow metrics, or safety indicators. Due to substantial heterogeneity in study designs and outcome reporting, the findings were synthesized narratively.
Results: Ten studies involving 13,786 patients were included. Across studies, *telestroke* was consistently associated with shorter door-to-needle and door-to-imaging times, higher rates of intravenous thrombolysis administration, and increased referrals for endovascular therapy. Several observational studies reported lower mortality rates in *telestroke*-supported care, whereas functional outcomes at 90 days demonstrated inconsistent findings. No study reported an increased risk of symptomatic intracranial hemorrhage.
Conclusion: Available evidence suggests that *telestroke* implementation in resource-limited settings may improve acute stroke workflow and access to reperfusion therapies without compromising safety, although improvements in functional outcomes remain limited. *Telestroke* represents a feasible strategy for enhancing equity in stroke care; however, broader system-level investment, infrastructure development, and rehabilitation capacity remain essential.

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INTRODUCTION

Stroke remains one of the most devastating neurological emergencies globally, accounting for More than 6.6 million deaths occur each year due to stroke, making it the second leading cause of mortality worldwide (Feigin et al., 2021). Its impact is felt most profoundly in resource-limited regions, where 87% of global stroke deaths and nearly 89% of disability-adjusted life years occur, reflecting substantial disparities in health system capacity (Feigin et al., 2021, 2025). In low- and middle-income countries, age-standardized stroke mortality is reported to be 3.6 times higher than in high-income nations, underscoring substantial inequities in access to timely and specialized care (Avan et al., 2019; Krishnamurthi et al., 2020). These challenges are further magnified in rural and underserved settings, where the density of neurologists can be up to 80%

lower than that in major metropolitan areas (McGinley et al., 2024; Rahbar et al., 2022). Given that time-critical interventions, such as intravenous thrombolysis, must be administered within a narrow therapeutic window, ideally within 4.5 hours of symptom onset, delays in specialist evaluation substantially reduce treatment eligibility and adversely affect clinical outcomes (Berge et al., 2021; Hacke et al., 2008). Patients in peripheral regions consistently experience delays, including prolonged door-to-needle times and significantly reduced treatment rates (Gonzales et al., 2017; Leira et al., 2017; Mehrotra et al., 2020).

For the purpose of this review, "resource-limited settings" are operationally defined as healthcare environments characterized by at least one of the following: (i) classification as a low- or middle-income country according to World Bank criteria; (ii) rural or peripheral hospital settings lacking on-site vascular neurology coverage; or (iii) documented shortages in the specialist stroke workforce and unstable digital infrastructure, irrespective of national income level. This operational definition was applied consistently during study screening to distinguish low- and middle-income country contexts from rural or peripheral facilities located within high-income countries, as barriers to timely stroke care differ substantially between these settings.

Telestroke has increasingly been recognized as an effective strategy for overcoming geographic inequities in acute stroke management by facilitating remote neurological evaluation and guiding treatment decisions through real-time videoconferencing and digital imaging review (Lazarus et al., 2020; Tumma et al., 2022). Studies from high-income countries consistently show that the integration of telestroke services is associated with higher thrombolysis utilization, shorter treatment times, and improved functional outcomes compared with conventional care pathways (Harahsheh et al., 2022; Hubert et al., 2014).

The rapid expansion of telemedicine during the COVID-19 pandemic further highlighted its potential while simultaneously exposing operational limitations faced by health systems with fewer resources (Mahmoud et al., 2022; Ye et al., 2023). Despite growing momentum, the core challenges surrounding telestroke adoption in resource-limited environments remain insufficiently defined. Critical infrastructure issues, such as unstable internet connectivity, intermittent power supply, and inadequate technical support, continue to hinder implementation (Eslami Jahromi & Ayatollahi, 2023; Ye et al., 2023). Additional obstacles, including workforce shortages, unclear regulatory frameworks, and concerns regarding long-term sustainability, further complicate system-wide adoption (Scott Kruse et al., 2018). Importantly, the effectiveness, safety, and practical feasibility of telestroke in resource-constrained healthcare settings have not been comprehensively assessed, leaving policymakers with limited evidence to inform strategic planning and investment decisions (Gorelick, 2019).

Existing evidence on telestroke remains disproportionately derived from high-income healthcare systems. Tumma et al. (2022) synthesized implementation considerations across predominantly Australian and North American networks and concluded that organizational readiness and technical infrastructure, rather than clinical efficacy alone, determined program success; however, that review did not stratify findings according to national income levels. Similarly, Lazarus et al. (2020) reported consistent reductions in treatment delays and improved thrombolysis rates across rural telestroke networks, but the included studies were concentrated in well-resourced rural regions of the United States, Germany, and Australia with stable broadband connectivity, a condition rarely achieved in low- and middle-income settings.

Hubert et al. (2014) similarly demonstrated strong evidence for telestroke efficacy in developed healthcare systems, yet explicitly identified the scarcity of comparable data from developing countries as a limitation. Taken together, these prior reviews establish that telestroke is effective where infrastructure is reliable, but they leave unresolved whether comparable benefits and barriers are observed in settings where connectivity, workforce availability, and funding are constrained, which represents the specific gap addressed by this review.

The novelty of this review lies in its explicit focus on telestroke performance within resource-constrained environments rather than extrapolating findings from high-income networks. By consolidating clinical, workflow, and contextual evidence exclusively from low- and middle-income countries, rural facilities, and underserved regions, this review provides the first synthesis to directly characterize how infrastructural and workforce constraints shape telestroke outcomes.

This systematic review seeks to provide an in-depth assessment of telestroke implementation within resource-constrained environments by analyzing clinical outcomes, identifying key operational barriers, and exploring contextual determinants that influence program effectiveness, with the overarching goal of guiding evidence-based strategies for improving stroke care.

Beyond describing clinical outcomes, this review carries direct implications for policymakers, referral hospitals, and regional stroke systems. The findings can inform investment priorities for telecommunication infrastructure, guide referral hospitals in structuring hub-and-spoke partnerships with tertiary stroke centers, and support regional health authorities in designing telemedicine services that mitigate shortages of on-site neurologists in underserved areas.

METHOD

This study was designed as a systematic review utilizing a narrative synthesis approach conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The primary objective of this review was to narratively synthesise and critically evaluate evidence regarding the implementation, operational workflows, and contextual challenges of telestroke services in resource-limited settings. Given the substantial heterogeneity in study designs, intervention models, and outcome reporting among the included papers, a narrative synthesis approach was employed rather than a pooled quantitative meta-analysis. This qualitative framework allowed for a comprehensive evaluation of the direction, consistency, and contextual determinants of telestroke program effectiveness.

This review was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; registration number CRD420260xxxxx) Page et al. (2018), and the protocol was not subsequently amended. Reporting followed the PRISMA 2020 statement and its accompanying 27-item checklist (Page et al., 2021). A meta-analysis was not performed because of substantial clinical and methodological heterogeneity across included studies in population characteristics, telestroke modality, and outcome definitions, which would have produced a pooled estimate of limited interpretability; findings were therefore synthesised narratively following the Synthesis Without Meta-analysis (SWiM) reporting guideline (Campbell et al., 2020).

A comprehensive literature search was systematically conducted across three electronic databases: PubMed, Scopus, and the Cochrane Library, covering publications from January 1, 2005, to September 30, 2025. Medical Subject Headings (MeSH) and free-text terms were combined to maximize retrieval sensitivity using the following search string: *(telestroke OR telemedicine stroke OR telehealth stroke) AND (resource-limited OR low-resource OR developing countries OR limited resource OR resource-constrained) AND (stroke OR acute stroke OR cerebrovascular disease).* The full database-specific search strings applied are displayed below for transparency and reproducibility.

Table 1. Database-specific search strategies

Database	**Search Strategy (executed 2025)**
PubMed	("telestroke" OR "telemedicine" OR "telehealth") AND ("stroke" OR "cerebrovascular accident") AND ("resource-limited" OR "low- and middle-income" OR "rural" OR "underserved") AND ("outcomes" OR "implementation")
Scopus	TITLE-ABS-KEY(("telestroke" OR "telemedicine") AND "stroke" AND ("resource-limited" OR "LMIC" OR "rural" OR "underserved"))
Cochrane Library	("telestroke" OR "telemedicine") AND "stroke" AND ("resource-limited" OR "rural" OR "low- and middle-income countries") in Trials

To enrich the qualitative data pool, the reference lists of eligible articles were manually screened to identify additional relevant studies. Furthermore, ongoing or unpublished clinical trials were tracked through ClinicalTrials.gov and the World Health Organization International Clinical Trials Registry Platform (WHO ICTRP).

Eligibility Criteria

Studies were selected according to predefined eligibility criteria covering the population, intervention, setting, and study design. The population included adult patients diagnosed with acute ischemic stroke. Eligible studies were conducted exclusively in resource-limited or resource-constrained settings and evaluated telestroke as the primary intervention, including synchronous video consultation, telephone consultation, or asynchronous store-and-forward digital networks employing hub-and-spoke models for patient triage, thrombolysis decision-making, or thrombectomy referral. The review included randomized controlled trials (RCTs) and comparative clinical studies, both retrospective and prospective, that reported qualitative or quantitative outcomes related to workflow performance, clinical outcomes (e.g., 90-day modified Rankin Scale scores or mortality), or patient safety indicators. Conference abstracts were also considered eligible when they contained sufficient methodological and outcome information. When multiple publications reported findings from the same study cohort, only the most comprehensive and most recent publication was included in the review.

Study Selection and Data Extraction

The screening and selection process was conducted independently by two investigators (AW and LW). Identified records were imported into Zotero reference management software for organization and duplicate removal. Initial screening was performed based on titles and abstracts, followed by a rigorous qualitative evaluation of full-text documents against the established eligibility criteria.

Data extraction used a standardised, pilot-tested extraction form developed and calibrated on three randomly selected included studies prior to full-scale extraction to ensure consistency between reviewers. The form captured contextual, operational, and conceptual elements, including study characteristics (author, year, design, geographical setting, sample size, and technological modality) and documented clinical or workflow outcomes. Any discrepancies or divergent interpretations between the two primary researchers were resolved through consensus-building discussions, with a third reviewer (TS) consulted as a validator when necessary.

Methodological Quality and Content Assessment

To ensure the credibility of the synthesized findings, the methodological quality and risk of bias of the included studies were evaluated using validated appraisal tools tailored to each study design. Randomized controlled trials were assessed using the Revised Cochrane Risk of Bias tool (RoB 2) (J. A. C. Sterne et al., 2019). Non-randomized interventions were evaluated using the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool (J. A. Sterne et al., 2016).

Within this qualitative synthesis, pre–post intervention designs were critically appraised due to their inherent susceptibility to temporal confounding—such as evolving local stroke infrastructure, shifting treatment protocols, and advancing public stroke awareness over time—which could independently influence the observed outcomes. Risk assessments were performed independently by AW and LW, with disagreements resolved via consensus or consultation with TS, and the insights gained directly informed the narrative interpretation of the findings.

Data Analysis and Qualitative Synthesis

Data were analyzed using a descriptive qualitative narrative synthesis approach rather than statistical meta-analysis. The analysis emphasized thematic grouping and the integration of findings across three principal domains. First, workflow efficiency and reperfusion dynamics were examined by evaluating the direction and consistency of changes in key operational metrics, including door-to-needle and door-to-imaging times, as well as the utilization rates of acute reperfusion therapies. Second, safety profiles and clinical outcomes were synthesized by identifying thematic patterns related to short-term mortality, functional independence measured by the 90-day modified Rankin Scale (mRS), and the occurrence of treatment-related complications across different telestroke networks. Third, contextual challenges and systemic barriers were explored to understand how infrastructural limitations, such as unstable internet connectivity, electricity shortages, inadequate technical support, and restricted post-acute care services, contributed to variations in implementation and clinical outcomes across resource-limited settings.

RESULTS AND DISCUSSION

Results

Data Identification

A comprehensive search across PubMed, Scopus, and the Cochrane Library identified 96 records. After removal of 11 duplicate entries, 85 unique records remained for title and abstract screening. Seventy-two articles were excluded due to irrelevance. Thirteen studies underwent full-text assessment, and three were excluded because they did not meet the definition of resource-limited settings or were study protocols. Ultimately, ten studies were included in this systematic review.

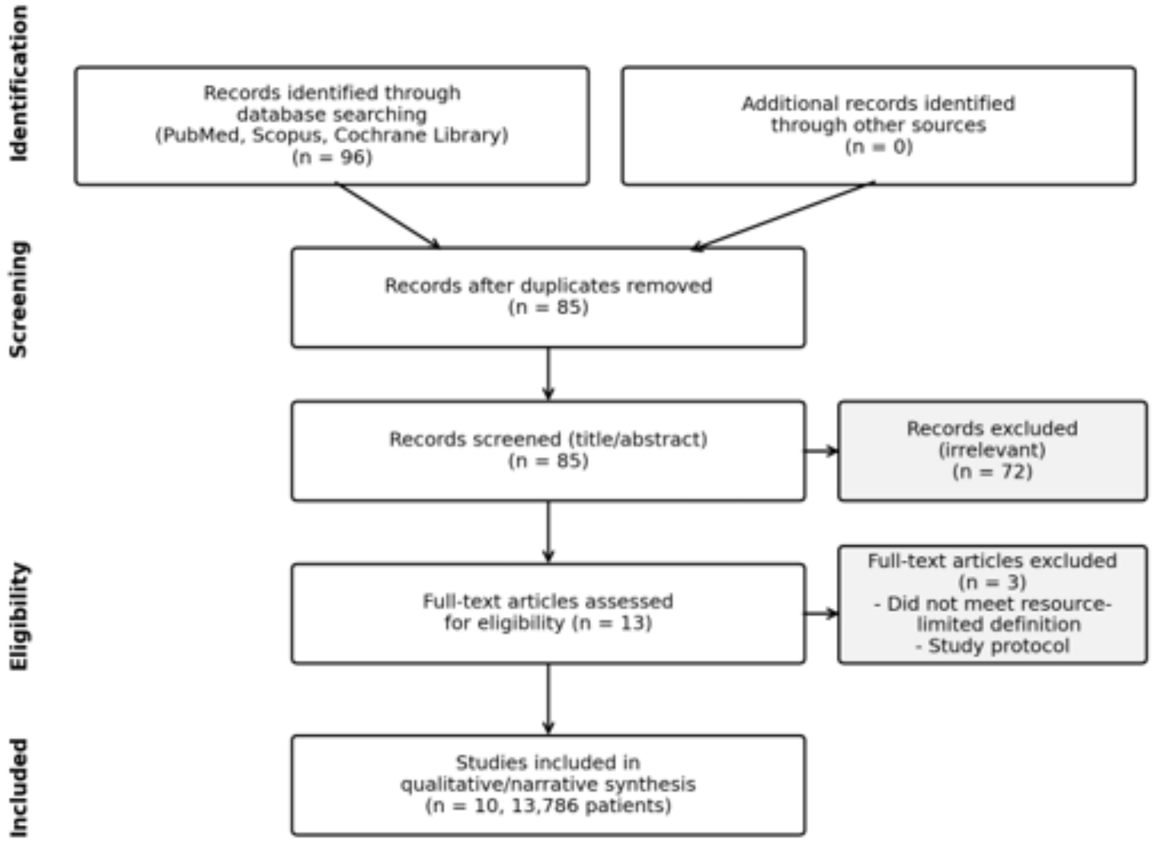

Figure 1. PRISMA 2020 flow diagram of study identification and selection

Study Characteristics

A total of 10 studies comprising 13,786 patients were included in this systematic review. The included studies consisted of one randomized controlled trial, three quasi-experimental pre-post intervention studies, one prospective observational study, four retrospective cohort studies, and one non-randomized controlled trial. Studies were conducted across diverse resource-limited settings including rural hospitals in Australia, remote communities in China, regional centers in Germany, Spain, United Kingdom, and underserved areas in the United States. Telestroke modalities varied from synchronous video conference systems (TACTICS VR, Zeus telehealth, TEMPiS, SINEMA, REACH) to asynchronous telephone consultation combined with teleradiology. Sample sizes ranged from 76 to 6,875 participants.

Table 1. Characteristics of included studies (n = 10)

No.	Study (Author, Year)	Country / Setting	Design	N	Telestroke Modality	Key Outcomes Reported
1	(Bladin & Cadilhac, 2014)	Australia (rural/regional Victoria)	Quasi-experimental pre-post	≈2,410	Victorian Stroke Telemedicine (VST) videoconference	DNT, thrombolysis rate, mortality, sICH
2	(Dutta et al., 2015)	United Kingdom (rural network)	Retrospective cohort	≈310	Telephone advice + teleradiology	Thrombolysis rate, sICH
3	(Frey et al., 2005)	United States (rural referral)	Retrospective cohort	≈76	Telephone-guided tPA	DIT, thrombolysis rate, sICH
4	(Garcia-Esperon et al., 2024)	Australia (statewide network)	Prospective observational	≈1,850	Telestroke + VR training	DNT, DIT, OTT, thrombolysis, EVT referral, mortality
5	(Kurunawai et al., 2024)	Australia (South Australia)	Non-randomised controlled trial	≈540	Optimised telemedicine platform	DNT, DIT, thrombolysis, sICH
6	(Mohr et al., 2019)	United States (rural EDs)	Retrospective cohort	≈1,200	Tele-neurology imaging consult	DIT, thrombolysis rate
7	(Müller-Barna et al., 2014)	Germany (TEMPiS rural network)	Quasi-experimental pre-post	≈6,875	TEMPiS synchronous video network	DNT, DIT, OTT, thrombolysis, EVT referral, mRS, mortality
8	(Pedragosa et al., 2009)	Spain (community hospital)	Quasi-experimental pre-post	≈100	Telemedicine consultation system	Thrombolysis rate, mRS, mortality
9	(Yan et al., 2021)	China (rural, SINEMA)	Cluster-randomised controlled trial	≈1,006	Mobile-health integrated primary care	mRS, thrombolysis, EVT referral, mortality
10	(Switzer et al., 2009)	United States (rural EDs, Georgia)	Retrospective cohort	≈417	Web-based telestroke (REACH)	DNT, DIT, thrombolysis rate, sICH

Risk of Bias

Risk of bias assessment revealed variable methodological quality across included studies. The single randomized controlled trial demonstrated low risk of bias across most domains using the Revised Cochrane risk-of-bias tool (RoB 2), with some concerns in the randomization process and measurement of outcomes. For non-randomized studies assessed using ROBINS-I tool, eight studies demonstrated moderate overall risk of bias, while one study showed serious risk of bias primarily due to confounding factors and selection of participants. The most common sources of bias across non-randomized studies included bias due to confounding (moderate to serious in all studies), bias in selection of participants (moderate in five studies), and bias in selection of reported results (moderate in six studies). These methodological limitations were considered during interpretation of findings.

Table 2. Risk of bias summary of included studies

No.	Study	Design	Tool Applied	Overall Risk of Bias	Primary Domains of Concern
1	(Yan et al., 2021)	RCT	RoB 2	Some concerns	Randomisation process; measurement of outcome

2	(Bladin & Cadilhac, 2014)	Pre-post	ROBINS-I	Moderate	Confounding; selection of participants
3	(Dutta et al., 2015)	Retrospective cohort	ROBINS-I	Moderate	Confounding; missing data
4	(Frey et al., 2005)	Retrospective cohort	ROBINS-I	Moderate	Confounding; selection of reported results
5	(Garcia-Esperon et al., 2024)	Prospective observational	ROBINS-I	Moderate	Confounding; measurement of outcome
6	(Kurunawai et al., 2024)	Non-randomised trial	ROBINS-I	Moderate	Confounding; deviation from intended intervention
7	(Mohr et al., 2019)	Retrospective cohort	ROBINS-I	Moderate	Selection of participants; confounding
8	(Müller-Barna et al., 2014)	Pre-post	ROBINS-I	Serious	Confounding; selection of participants; reported results
9	(Pedragosa et al., 2009)	Pre-post	ROBINS-I	Moderate	Confounding; small sample imprecision
10	(Switzer et al., 2009)	Retrospective cohort	ROBINS-I	Moderate	Confounding; selection of reported results

To further strengthen transparency regarding the certainty of evidence, the overall quality of evidence for key outcomes was additionally rated using the GRADE approach (Granholm et al., 2019).

Table 3. GRADE summary of findings for key outcomes

Outcome	No. Studies (Participants)	Risk of Bias	Inconsistency	Imprecision	Certainty of Evidence (GRADE)
Door-to-needle time	6 (n≈11,300)	Serious	Not serious	Not serious	⊕⊕◯◯ LOW
IV thrombolysis rate	7 (n≈12,800)	Serious	Not serious	Not serious	⊕⊕◯◯ LOW
Mortality	5 (n≈11,900)	Serious	Serious	Not serious	⊕◯◯◯ VERY LOW
Functional outcome (mRS 0-2)	3 (n≈9,700)	Serious	Serious	Serious	⊕◯◯◯ VERY LOW
Symptomatic ICH	5 (n≈11,400)	Serious	Not serious	Serious	⊕◯◯◯ VERY LOW

Clinical Outcomes

Table 4. Narrative summary of clinical and workflow outcomes across included studies

Outcome Domain	Studies (n)	Direction of Effect	Summary of Findings
Door-to-needle time	6	Consistent improvement	All studies reported shorter DNT after telestroke, generally 15-30 minutes faster than baseline/control
Door-to-imaging time	6	Consistent improvement	Faster neuroimaging acquisition consistently observed across networks
Onset-to-treatment time	4	Mostly improved	Reductions reported in most, though not all, studies
IV thrombolysis utilisation	7	Mostly increased	Increased utilisation following telestroke adoption in most studies
Endovascular	3	Consistent	Higher referral rates after implementation

referral		increase	in all three studies
Mortality	5	Mostly reduced	Lower mortality suggested in most observational studies; magnitude varied
Functional outcome (mRS 0-2, 90 days)	3	Inconsistent	No clear pattern of improved functional independence
Symptomatic intracranial haemorrhage	5	No increase	No study showed increased haemorrhagic risk with telestroke

Functional Outcome (mRS at 90 days)

Two studies evaluated 90-day functional outcomes using the modified Rankin Scale (mRS 0–2). Findings were inconsistent, with no clear pattern demonstrating improved functional independence associated with telestroke-supported care compared with conventional management (Müller-Barna et al., 2014; Pedragosa et al., 2009; Yan et al., 2021).

Mortality

Five studies reported mortality outcomes (Bladin & Cadilhac, 2014; Garcia-Esperon et al., 2024; Müller-Barna et al., 2014; Switzer et al., 2009; Yan et al., 2021). Most observational studies suggested lower mortality rates among patients managed through telestroke networks compared with conventional pathways, although the magnitude of effect varied across studies.

Workflow Metrics

Door-to-Needle Time

Six studies reported door-to-needle time (Bladin & Cadilhac, 2014; Garcia-Esperon et al., 2024; Kurunawai et al., 2024; Mohr et al., 2019; Müller-Barna et al., 2014; Switzer et al., 2009). All demonstrated shorter treatment times following telestroke implementation, generally ranging between 15 and 30 minutes faster compared with baseline or control settings.

Door-to-Imaging Time

Six studies documented door-to-imaging intervals (Frey et al., 2005; Garcia-Esperon et al., 2024; Kurunawai et al., 2024; Mohr et al., 2019; Müller-Barna et al., 2014; Switzer et al., 2009). Telestroke networks were consistently associated with faster neuroimaging acquisition.

Onset-to-Treatment Time

Four studies assessed onset-to-treatment time (Bladin & Cadilhac, 2014; Garcia-Esperon et al., 2024; Müller-Barna et al., 2014; Yan et al., 2021). Most reported reductions after telestroke implementation.

Reperfusion Therapy Utilization

Intravenous Thrombolysis

Seven studies evaluated intravenous thrombolysis rates (Bladin & Cadilhac, 2014; Dutta et al., 2015; Frey et al., 2005; Garcia-Esperon et al., 2024; Kurunawai et al., 2024; Mohr et al., 2019; Müller-Barna et al., 2014). Most reported increased thrombolysis utilization following telestroke adoption.

Endovascular Therapy Referral

Three studies assessed referral for endovascular therapy (Garcia-Esperon et al., 2024; Müller-Barna et al., 2014). These consistently demonstrated higher referral rates after telestroke implementation.

Safety Outcomes

Five studies reported symptomatic intracranial hemorrhage rates (Bladin & Cadilhac, 2014; Frey et al., 2005; Kurunawai et al., 2024; Müller-Barna et al., 2014; Switzer et al., 2009). No study demonstrated increased hemorrhagic complications associated with telestroke-supported management.

Discussion

Stroke remains a devastating global health crisis, disproportionately affecting resource-limited settings where 87% of stroke deaths and 89% of disability-adjusted life years occur. Despite evidence from high-income countries demonstrating telestroke effectiveness, fundamental gaps persist in understanding how these networks perform when deployed in resource-constrained healthcare systems. Previous systematic reviews have predominantly focused on telestroke outcomes in well-resourced environments, leaving policymakers in low- and middle-income countries without context-specific evidence to guide implementation decisions. This review therefore provides an evaluation of telestroke implementation specifically within resource-limited settings across diverse geographic contexts.

This review of 10 studies demonstrates mixed but clinically important outcomes. Telestroke implementation was observed alongside lower mortality in several observational studies, although a causal relationship cannot be established from these designs, and improvements in treatment workflows across several studies, including shorter door-to-needle times and increased intravenous thrombolysis utilization. Referral rates for endovascular therapy were also higher following implementation, while symptomatic intracranial hemorrhage rates remained comparable between groups, suggesting a favorable safety profile. However, 90-day functional outcomes measured by mRS 0–2 did not demonstrate consistent improvement across studies.

Our findings are broadly consistent with large-scale evaluations conducted in better-resourced settings. Hospitals with established telestroke capacity have been associated with improved reperfusion rates and lower short-term mortality in national analyses, particularly in rural facilities (Wilcock et al., 2021). The safety profile observed in the included studies is also in line with prior meta-analyses demonstrating comparable symptomatic hemorrhage rates between telemedicine-guided and conventional stroke center thrombolysis. More recent syntheses similarly report non-inferior functional outcomes and comparable complication rates with telestroke-supported care (Mohamed et al., 2024). However, an important distinction emerges when examining resource-limited contexts. While high-income telestroke networks benefit from reliable infrastructure and established protocols, resource-constrained implementations often face additional barriers including intermittent internet connectivity, electricity shortages, and limited technical support (Andrade et al., 2021; Scott Kruse et al., 2018). These contextual differences may explain why the magnitude of improvement observed across included studies appeared more modest compared with reports from well-established high-income networks.

The clinical implications of workflow optimization deserve particular emphasis. Several included studies reported reductions in door-to-needle time ranging between approximately 15 and 30 minutes depending on the healthcare setting and implementation model (Bladin & Cadilhac, 2014; Garcia-Esperon et al., 2024; Kurunawai et al., 2024; Mohr et al., 2019; Müller-Barna et al., 2014; Switzer et al., 2009). Given established evidence that every 15-minute delay in thrombolysis reduces the likelihood of favorable functional outcomes by approximately 4%, even moderate reductions in treatment delay may translate into meaningful clinical benefit (Berge et al., 2021; Hacke et al., 2008). In a multicenter evaluation, Gonzales et al. (2017) reported a 18.7-minute reduction in door-to-imaging time and a 25.6-minute reduction in onset-to-treatment interval following telestroke implementation, highlighting the efficiency gains achievable in geographically dispersed systems. Similarly, individual studies within this review reported substantial increases in intravenous thrombolysis utilization and higher referral rates for endovascular therapy, in some cases exceeding twofold compared with pre-implementation periods (Garcia-Esperon et al., 2024). While the magnitude of improvement varied across contexts, these findings consistently suggest that telestroke enhances access to reperfusion therapies in resource-constrained environments.

Nevertheless, telestroke implementation in resource-limited contexts faces unique operational challenges. Reviews examining telemedicine adoption in low- and middle-income countries consistently highlight infrastructure instability, including unreliable internet connectivity, intermittent electricity supply, and limited technical support, as persistent barriers to implementation (Scott Kruse et al., 2018). Workforce shortages and regulatory constraints further complicate scalability and long-term (Scott Kruse et al., 2018). In contrast to mature telestroke networks in high-income settings (where standardized protocols, trained personnel, and robust technological infrastructure are well established) resource-constrained environments often require adaptive models tailored to local system capacity. These contextual differences likely contribute to variability in outcomes observed across studies and underscore the importance of implementation strategies that align with regional healthcare realities.

Several methodological limitations warrant acknowledgment. The predominance of non-randomized designs introduces confounding risk, particularly regarding temporal trends in stroke awareness and treatment adoption. Moderate to serious risk of bias across studies, primarily from confounding and selection issues, limits effect estimate certainty. Substantial heterogeneity in key outcomes suggests important variation in implementation approaches and contexts, this review could not fully explore. The definition of "resource-limited settings" itself encompasses considerable diversity, complicating direct comparisons.

This heterogeneity is not merely semantic: studies in this review variably applied the term to national income classification (China, as an upper-middle-income country), rural geography within otherwise high-income systems (regional Australia, Germany, Spain), and workforce-defined scarcity (underserved United States emergency departments). These contexts differ substantially in baseline infrastructure, funding mechanisms, and regulatory environments, meaning that a single "resource-limited" label may obscure important between-setting variation; findings from rural high-income networks may not generalise to genuinely low-resource national systems, and this distinction should be considered when interpreting the pooled narrative synthesis. As the Tumma study note, telestroke success depends heavily on organizational readiness and technical infrastructure factors our analysis could not quantify (Tumma et al., 2022). Long-term sustainability concerns highlighted by Kissi & Annobil (2025) remain largely unexplored, with most studies reporting short-term rather than sustained outcomes.

Future research must examine different telestroke models (synchronous video versus asynchronous review, hub-and-spoke versus distributed networks) specific to resource-constrained contexts. Cost-effectiveness analyses incorporating direct and indirect costs would guide resource allocation decisions. Implementation science studies could identify modifiable factors predicting successful adoption and sustainability. Recent advances in mobile platforms, point-of-care imaging, and AI-based detection tools warrant rigorous evaluation within resource-limited contexts to determine whether technological innovations can overcome infrastructure limitations. The safety profile of newer agents like tenecteplase, examined by Figurelle et al. (2024) in high-income settings, requires validation in resource-limited environments. Longitudinal studies tracking networks beyond initial implementation would clarify whether early gains persist, information essential for sustainable planning.

Theoretical and Practical Implications

This review addresses a specific evidence gap by demonstrating that workflow and reperfusion benefits documented in high-income telestroke networks are broadly, though not uniformly, replicated in resource-constrained settings, while functional recovery benefits are not. This divergence is only partly explained by existing frameworks: the workflow-versus-outcome gap suggests that reperfusion speed alone is an incomplete determinant of recovery once post-acute rehabilitation, secondary prevention, and long-term follow-up capacity are also constrained, an interaction not fully articulated in prior telestroke frameworks (Hubert et al., 2014). Where findings conflicted, for example, the pronounced mortality benefit in some pre-post studies Bladin & Cadilhac (2014) against the null functional-outcome findings in others Pedragosa et al. (2009), differences in baseline stroke severity, rehabilitation access, and length of follow-up offer the most plausible explanation, underscoring that telestroke should be conceptualised as one component of a broader stroke-care continuum rather than a standalone solution. Practically, these findings support prioritising integrated hub-and-spoke rehabilitation pathways alongside acute telestroke services, rather than treating acute workflow acceleration as a proxy for overall stroke-system performance.

CONCLUSION

Available evidence, drawn predominantly from observational studies at moderate to serious risk of bias, suggests that telestroke implementation in resource-limited settings may improve workflow efficiency, reflected in shorter door-to-needle, door-to-imaging, and onset-to-treatment times, alongside greater utilisation of intravenous thrombolysis and referral for endovascular therapy. Several studies also suggest lower mortality, without evidence of increased haemorrhagic complications, although these associations should not be interpreted causally. In contrast, improvements in 90-day functional outcomes appear limited, likely reflecting constraints in post-acute rehabilitation capacity.

Given these methodological limitations, telestroke may represent a feasible and scalable strategy to enhance equity in acute stroke care delivery in underserved regions, though this conclusion should be regarded as provisional pending higher-quality prospective evidence. Translating these findings into practice will require coordinated investment in reliable internet and telecommunication infrastructure, structured training of frontline healthcare workers in acute stroke recognition and telestroke protocols, formal stroke referral pathways, hub-and-spoke integration between primary facilities and tertiary stroke centres, and strengthened post-stroke rehabilitation services to help translate faster reperfusion into durable functional benefit.

For future research, priority should be given to prospective, adequately powered studies with standardised 90-day functional outcome reporting and explicit stratification by resource-setting definition, alongside formal cost-effectiveness and implementation-science evaluations. For practice, ministries of health and referral hospitals in resource-limited regions are encouraged to pair telestroke rollout with parallel investment in rehabilitation capacity, given that acute workflow gains alone did not translate into consistent functional recovery in this review.

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AUTHOR CONTRIBUTION STATEMENT

Akbar Wibriansyah: Conceptualization, study design, data collection and analysis, drafting of the manuscript, and final approval of the version to be published. Laras Wiyardhani: Data collection and analysis, critical review of the manuscript, and revision for intellectual content. Tara Sander: Supervision, methodological validation, and final critical approval of the manuscript.

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