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Review

Reimagining Rural Surgery: Task-Shifting, Tele-Mentoring, and Decentralized Surgical Networks for Resilient Health Systems in Low-Resource Settings

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Abstract

More than five billion people, predominantly in rural low- and middle-income countries (LMICs), lack timely access to safe surgical care, perpetuating health inequities and limiting universal health coverage. This study employs a systematic integrative review design to synthesize quantitative and qualitative evidence on decentralized surgical networks (DSNs), a systems-level framework integrating task-shifting, tele-mentoring, and digital connectivity to extend surgical capacity from urban tertiary centers to district hospitals. Evidence from sub-Saharan Africa, South Asia, and other LMICs indicates that DSNs enable non-physician clinicians to perform essential procedures under remote specialist supervision, achieving safety outcomes comparable to in-person care while reducing referral delays and strengthening system resilience. By addressing structural, technological, and sociocultural barriers through policy-embedded governance, low-bandwidth innovations, and community learning hubs, DSNs operate as adaptive learning ecosystems, supporting national surgical, obstetric, and anesthesia plans (NSOAPs) implementation and advancing sustainable development goal 3 (SDG 3).

Keywords

Decentralized surgical networks, Task-shifting, Tele-mentoring, Rural surgery, Health systems resilience

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1. Introduction

In many low-resource rural settings, access to comprehensive and timely surgical services remains severely limited. Globally, an estimated five billion people lack safe, timely, and affordable surgical and anesthesia care, with approximately 80% residing in low- and middle-income countries (LMICs) [1]. Limited access contributes to health inequities and undermines universal health coverage (UHC), reinforcing the importance of surgical care as a critical pillar of health system strengthening. Disparities are particularly pronounced in rural and remote regions, where geographic isolation, shortages of specialist surgeons, and under-resourced facilities lead to delayed interventions, preventable complications, and avoidable mortality [2,3]. The concentration of surgical expertise in urban tertiary centers perpetuates centralized delivery models, which may marginalize underserved populations [4].

Traditional centralized surgical and referral-based systems are inefficient, with long delays and poor communication contributing to inadequate access to essential surgical care [5,6]. Two operational approaches have gained prominence. First, task-sharing, defined as the structured redistribution of surgical responsibilities within multidisciplinary teams, can safely expand service capacity when supported by appropriate training, supervision, and regulatory oversight [7]. Second, tele-mentoring leverages digital platforms to provide real-time specialist guidance, reduce professional isolation, and strengthen decision-making among rural providers [8]. When integrated into coordinated referral structures, these strategies form the foundation of decentralized surgical networks (DSNs).

DSNs are systems-level frameworks connecting district-level providers with regional and tertiary specialists through structured mentorship, shared governance, and digital consultation platforms [6,7]. In this context, decentralization refers to operational redistribution of surgical capacity and responsibilities across healthcare levels, distinct from policy-level devolution, which involves administrative authority transfer to subnational entities. Service delivery decentralization focuses on extending procedural capacity and supervision closer to the population.

Beyond improving service access, decentralized surgical models may enhance health system resilience. Expanding district-level capacity can alleviate pressure on tertiary hospitals and improve local responsiveness during crises, including epidemics, climate-related disruptions, and sociopolitical instability [9]. Strengthened district networks support achievement of sustainable development goal 3 (SDG 3) by promoting equitable access to essential surgical care within the broader continuum of health services [10].

Despite these promising developments, implementation barriers remain. Persistent workforce shortages, inadequate digital infrastructure, and regulatory inconsistencies hinder scale-up of decentralized models [11]. Surgery has historically been marginalized within global health policy sometimes described as the “neglected stepchild” of health systems leading to chronic underinvestment in workforce development and infrastructure [12]. Policy inertia perpetuates gaps between evidence from successful pilot programs and national-level adoption [13,14].

Evidence indicates that, under structured supervision and competency-based frameworks, non-physician clinicians can safely perform essential procedures such as cesarean sections and hernia repairs, achieving outcomes comparable to physician-led care [5]. Tele-mentoring programs similarly enhance intraoperative guidance, professional confidence, and decision-making in remote settings [8]. Integrating task-sharing and tele-mentoring within coordinated surgical networks may provide a scalable and cost-effective model for strengthening rural surgical systems [2].

Sustainable decentralization requires more than technology it necessitates systemic reforms, including supportive policy, interprofessional collaboration, adaptive governance, and financial protection mechanisms. Ethical safeguards, standardized competency frameworks, and context-sensitive training curricula are essential to ensure patient safety and maintain surgical quality [14]. Educational reform is equally important. Traditional surgical training remains concentrated in tertiary and subspecialty environments, limiting exposure to community-based practice. Incorporating rural rotations, global surgery principles, and structured mentorship into curricula can better prepare providers for underserved settings [15,16], while emphasizing digital literacy, interprofessional collaboration, and systems thinking to support decentralized models [17].

As global health priorities increasingly recognize surgery as integral to population health, reimagining surgical systems through structured decentralization offers a pathway to more resilient, equitable, and inclusive health systems. This study examines how decentralization of surgical service delivery can enhance rural surgical capacity, strengthen health system resilience, and inform policies promoting equitable access to essential surgical care in LMICs. Specifically, it synthesizes evidence across three domains: (1) task-sharing and workforce optimization, (2) tele-mentoring and digital surgical support, and (3) integrated DSNs.

2. Methodology

2.1 Research Design and Reporting Framework

This study employed a systematic integrative review design to synthesize quantitative and qualitative evidence on decentralized surgical delivery models in LMICs. The review was conducted and reported following the PRISMA 2020

statement (Preferred reporting items for systematic reviews and meta-analyses) to ensure transparency, reproducibility, and methodological rigor.

An integrative approach was chosen to accommodate diverse study designs, including experimental, quasi-experimental, observational, and qualitative research, reflecting the multidisciplinary nature of global surgery and health systems research. The review focused on publications from 2020 to 2025, capturing contemporary models aligned with post-COVID-19 digital expansion and evolving decentralization strategies.

The primary objective was to evaluate the safety, effectiveness, equity implications, and sustainability of three decentralized surgical strategies: Task-sharing models, tele-mentoring systems, and DSNs. The study selection process is summarized in Figure 1.

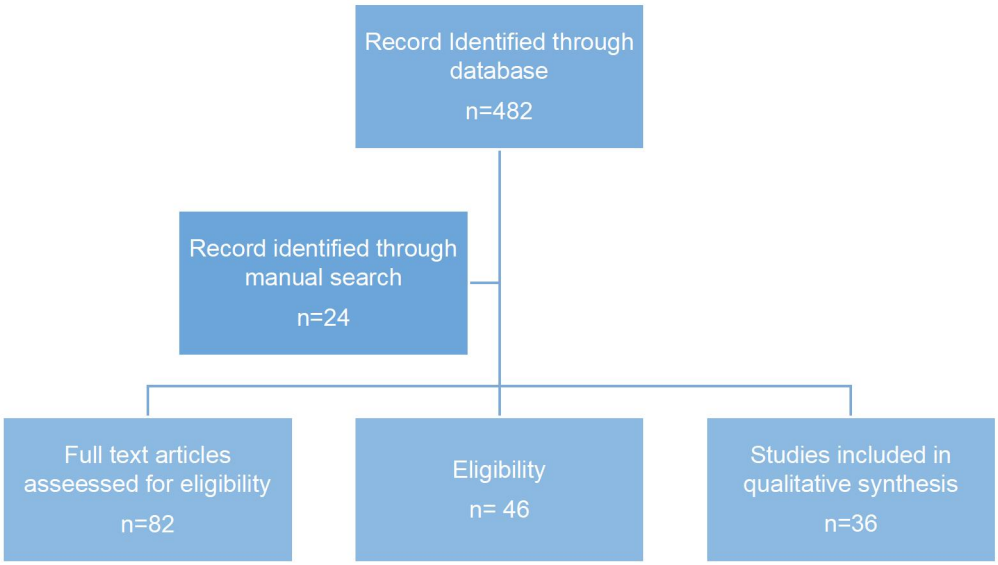

Figure 1. PRISMA diagram.

2.2 Data Sources and Search Strategy

A comprehensive search was conducted across four electronic databases: PubMed/MEDLINE, Scopus, Web of Science Core Collection, and WHO Global Index Medicus, capturing biomedical, surgical, public health, and health systems literature. The search combined controlled vocabulary (MeSH terms) and free-text keywords with Boolean operators. The reproducible core search string was: ("decentralized surgical care" OR "surgical decentralization" OR "district surgery" OR "rural surgery") AND ("task-sharing" OR "task-shifting" OR "non-physician clinician" OR "surgical training") AND ("tele-mentoring" OR "telemedicine" OR "digital health support") AND ("surgical network" OR "referral network") AND ("low-income countr" OR "middle-income countr" OR "LMIC"). Filters applied included human studies, English language, and publication years 2020-2025. The final search was conducted in 2025. Reference lists of included studies and relevant institutional reports were manually screened. Grey literature was included only if it met methodological transparency standards.

2.3 Study Selection Process

Eligibility criteria followed the PICo framework:

Population (P): Rural healthcare providers and patients receiving essential and emergency surgical care in LMICs.

Interest (I): Decentralized surgical strategies, including task-sharing, tele-mentoring, and coordinated surgical networks.

Context (Co): Rural and resource-limited settings in LMICs, constrained by workforce shortages, infrastructure gaps, and geographic isolation.

Inclusion criteria: (1) Peer-reviewed studies on decentralized surgical or obstetric care in LMICs. (2) Studies on task-sharing, tele-mentoring, or integrated DSNs. (3) Outcomes on safety, effectiveness, cost-efficiency, or patient satisfaction. (4) English-language publications from 2020-2025.

Exclusion criteria: (1) Articles lacking original research data. (2) Conference abstracts, theses, or unverified policy briefs. (3) Studies unrelated to surgical or obstetric contexts.

2.4 Data Extraction and Quality Appraisal

A standardized, pilot-tested extraction template captured country and region, rural versus urban context, level of care (district, regional, tertiary), type of decentralization strategy, provider cadre and training model, digital platforms used

(synchronous *vs.* asynchronous), governance or referral structures, and clinical, economic, workforce, and system-level outcomes. Risk of bias and study quality were independently assessed by two reviewers using AMSTAR 2 for systematic reviews and ROBINS-I for observational and quasi-experimental studies. Studies were classified as high, moderate, low, or critically low quality, with disagreements resolved by consensus.

2.5 Data Synthesis

A structured thematic synthesis integrated quantitative and qualitative findings, coded inductively and deductively across three domains: task-sharing and workforce optimization; tele-mentoring and digital surgical support; and DSNs. Quantitative results were standardized where feasible, comparing surgical volume, complication rates, mortality, costs, and workforce retention. Statistical meta-analysis was not possible due to heterogeneity; narrative synthesis and comparative tables were used instead. Findings were triangulated with health systems and implementation science frameworks to assess effects on access, equity, quality, governance, and resilience.

2.6 Ethical Considerations

This review analyzed previously published studies, so institutional ethical approval was not required. All included studies were assessed for documented ethical clearance.

Unique ethical challenges of tele-mentoring and digital surgical support were considered, including patient privacy in remote supervision, data security, cybersecurity, and governance of surgical recordings. Ensuring informed consent, equitable access, and culturally sensitive communication is essential to protect patients, uphold professional accountability, and enable safe and responsible implementation of DSNs in LMICs.

2.7 Methodological Limitations

Several methodological limitations should be acknowledged. First, the review may be subject to publication bias, as studies reporting positive outcomes are more likely to be published, potentially overestimating the effectiveness of decentralized surgical strategies. Second, included interventions were highly heterogeneous in design, context, and outcomes, limiting direct comparability and precluding statistical meta-analysis. Third, the review relied exclusively on English-language publications, which may have excluded relevant studies from non-English-speaking LMICs. Finally, while structured thematic synthesis allowed integration of quantitative and qualitative findings, parts of the analysis were inherently narrative, which may introduce subjectivity in interpretation despite rigorous coding and triangulation with health systems frameworks. Acknowledging these limitations provides context for interpreting the findings and underscores areas for further primary research.

3. Integrated DSNs

Evidence and conceptual frameworks converge across three interrelated domains: task-sharing in rural surgery, tele-mentoring and digital surgical support, and DSNs. Together, these strategies support equitable access to surgical care and health system resilience in low-resource settings [17].

Surgery contributes to nearly 30% of the global burden of treatable disease but remains under-prioritized in international health policy, often described as the “neglected stepchild” of global health [12]. Consequently, over five billion people lack timely, safe, and affordable surgical and anesthesia care, with the largest gaps in sub-Saharan Africa and other low-resource regions.

Addressing this inequity requires more than additional surgeons or infrastructure. Evidence shows that optimizing human resources, implementing tele-mentoring, and establishing coordinated DSNs improves access and outcomes while shifting care from tertiary centers to district and community-level facilities [11,18].

3.1 Task-Sharing in Rural Surgery

Evidence: Task-sharing redistributes defined surgical responsibilities from specialists to non-specialist clinicians within structured teams [5]. Studies from Ethiopia, Malawi, and Nigeria demonstrate that trained non-physician clinicians can safely perform essential surgical procedures, including cesarean sections, hernia repairs, and basic orthopedic interventions, achieving outcomes comparable to fully trained surgeons under supervision [2,3,6].

Implementation considerations: Successful task-sharing requires standardized curricula, competency assessment, mentorship, and supervision. Institutionalization through national health policy, career pathways, and workforce planning ensures sustainability, mitigates professional burnout, and enhances local surgical capacity [2,6].

3.2 Tele-Mentoring and Digital Surgical Support

Evidence: Tele-mentoring connects rural providers with specialists via synchronous or asynchronous platforms, enhancing clinical confidence, reducing errors, and improving procedural efficiency [2,8]. Programs like Project ECHO

and telementoring for cesarean safety provide real-time guidance, case-based learning, and peer support, reducing professional isolation [6].

Challenges and innovations: Infrastructure gaps such as unreliable internet, limited devices, and intermittent power supply can limit effectiveness. Solutions include low-bandwidth platforms, offline-compatible tele-consultation tools, and solar-powered systems. Data security, ethical safeguards, and digital literacy are critical for safe and effective deployment [2,18].

Workforce impact: Tele-mentoring supports continuous professional development, retention, and interprofessional learning, fostering a collaborative community of practice in rural settings [17]. A schematic representation of this model is shown in Figure 2.

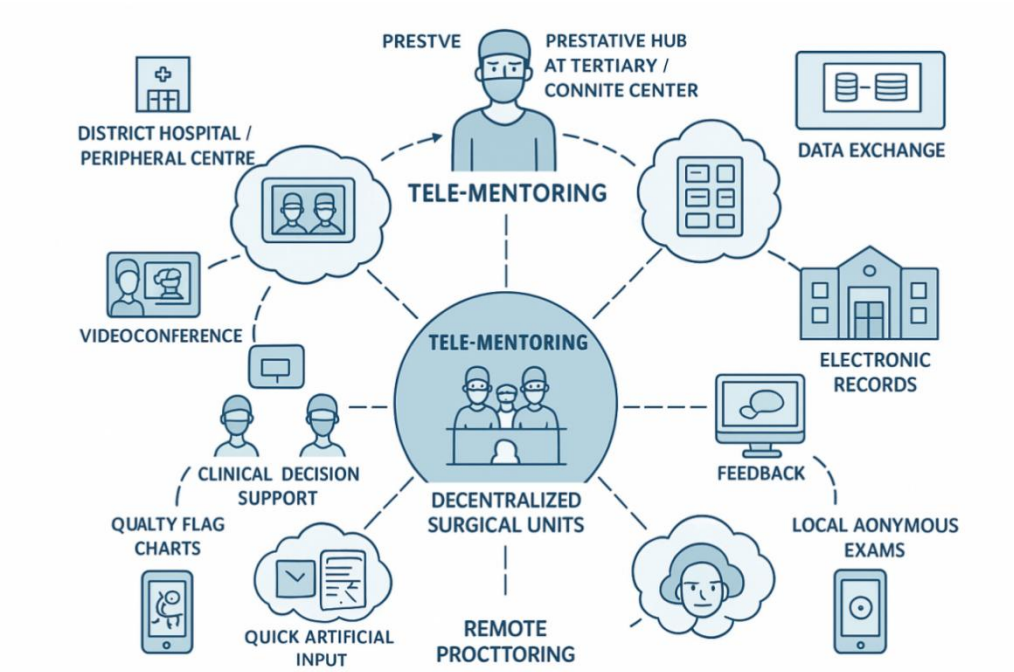

Figure 2. Tele-mentoring networks for decentralized surgical care in low-resource setting. This figure illustrates a DSN tele-mentoring hub linking tertiary hospitals to district-level surgical units through videoconferencing, electronic health records, remote proctoring, and clinical decision support tools.

3.3 DSNs

Evidence: DSNs integrate task-sharing and tele-mentoring into a coordinated, multi-tiered surgical system. Frontline providers perform essential procedures under supervision, while tertiary centers serve as knowledge hubs, ensuring quality assurance and timely referral [5,6,10].

Systemic benefits: DSNs support resilient health systems through feedback loops, digital monitoring, and data-driven performance improvement. Multi-sectoral partnerships with government, academia, Non-Governmental Organization (NGO), and private sectors promote local ownership and sustainability [19].

3.4 Comparative Outcome Synthesis

Clinical outcomes: Evidence indicates that decentralized models maintain or improve safety for high-volume, low-complexity procedures, reduce infection rates, shorten waiting times, and enhance perioperative outcomes in district hospitals [2,5].

System-level outcomes: Local delivery reduces patient travel, improves continuity of care, and decreases the logistical burden on tertiary centers [11]. Integration with digital health registries strengthens interoperability and supports evidence-based policy reforms.

Workforce outcomes: Decentralized models enhance provider retention, reduce burnout, and support career development. Tele-mentoring and peer networks build professional communities, reinforcing local capacity and innovation [17]. A synthesis of these outcomes is presented in Table 1.

While Integrated DSNs offer promising models for expanding surgical access, their implementation is not without obstacles. The operationalization of task-shifting, tele-mentoring, and coordinated networks faces structural, technological, and socio-cultural constraints that must be addressed to achieve sustainable impact. The next section explores these challenges in detail and highlights mitigation strategies that align with national surgical plans, digital equity, and workforce resilience.

Table 1. Comparative outcomes of decentralized *vs*. centralized surgical care models in LMICs.

Outcome Domain	Decentralized Model (DSN/Task-Shifting + Tele-Mentoring)	Centralized Model (Referral-Based)	References
Access to Essential Surgery	60%-75% of procedures performed at district level; < 48 h wait time	< 30% at district level; 3-14 day referral delay	[5,6]
Perioperative Mortality	1.2%-2.8% (non-physician clinicians under supervision)	3.1-5.6% (delayed referrals)	[2,3]
Surgical Site Infection Rate	4.1% (with tele-mentored protocols)	7.3% (urban tertiary overload)	[18]
Cost per Case (USD)	$85-$220 (local delivery + digital support)	$350-$1,200 (travel + tertiary care)	[1,11]
Provider Confidence (Scale 1-10)	8.4 post-tele-mentoring (6-month follow-up)	6.1 (no remote support)	[17,20]
System Resilience (Crisis Response)	Maintained 80% service volume during COVID-19/conflict	Dropped to < 40% (central facility closure)	[21,22]

Note: DSN: Decentralized surgical network. Data synthesized from peer-reviewed studies in sub-Saharan Africa and South Asia. Costs adjusted to 2024 USD.

4. Challenges and Mitigation Strategies

The decentralization of surgical care through task-shifting and tele-mentoring offers a unique chance to enhance access to vital and emergency surgical care in resource-poor settings. Nonetheless, implementing these systems from pilot to sustainable and scalable programs faces structural, technological, and socio-cultural obstacles. This part of the paper categorizes the challenges and provides integrated solutions aligned with current policies such as the national surgical, obstetric, and anesthesia plans (NSOAPs). Further, it promotes digital equity and professional resilience across the health system [2].

4.1 Structural and Logistical Barriers

Structural and logistical restrictions in LMICs are among the most common barriers to organizing decentralized surgical systems. The lack of surgical support services, such as operating rooms, supply chains for consumable products, and sterilization services, limits the potential for tele-mentoring and the expansion of local surgery [2]. Various training standards and credentialing pathways for mentors and mentees result in heterogeneity in skills and variable quality of surgical care. In many countries, surgery laws have not changed to allow task-shifting. Thus, non-physician clinicians may be technically able but not legally allowed to perform safe and essential surgeries [23].

Due to regulatory uncertainty, institutional de-support of decentralized surgery, and reliance on tertiary centers, patients are often referred to hospitals that are suboptimal. Weak linkages between public and private hospitals and lack of standardized curricula for surgical tele-mentoring further increase variability in care quality. To resolve these structural problems, capacity expansion must be accompanied by systems-level redesign, embedding tele-mentoring and task-sharing into the national surgical policy architecture. This provides institutional legitimacy, scalability, and accountability [2].

4.2 Technological Limitations

Technological obstacles are among the most pressing limitations for scaling tele-mentoring and decentralized surgery. Poor internet connectivity, unstable power supply, and lack of digital infrastructure disrupt real-time video mentoring, delay case-based learning sessions, and degrade continuity of digital supervision [24]. Differences in digital literacy of healthcare providers and patients further inhibit technology-enabled surgical training.

Compounding these issues are ethical and data protection concerns. Using surgical videos, medical records, and live data poses risks to privacy, informed consent, and jurisdiction over data [24]. Tele-mentoring platforms must therefore be designed for efficiency and ethical compliance with local and international standards.

Innovations are emerging to close these technology gaps. Low-bandwidth adaptive platforms, mobile-based tele-mentoring applications, and offline-enabled decision-support systems allow learning to continue in low-connectivity environments. Solar-powered routers and backup power systems stabilize tele-mentoring units in resource-poor districts. The incorporation of AI-driven analytics creates opportunities for real-time skill assessment and personalized feedback, enhancing mentorship efficiency and process precision.

4.3 Sociocultural and Institutional Challenges

Resistance from social communities and professional hierarchies to decentralized surgical reform is a formidable barrier. Medical systems in many countries value specialization and centralization and may perceive task-shifting and tele-

mentoring as lowering surgical standards or encroaching on professional roles [25]. Legacy training systems and hierarchical cultures further hinder adoption.

In rural areas, challenges also arise from patient trust and acceptance. Skepticism toward digitally mentored procedures, professional isolation, limited promotion opportunities, and rigid bureaucratic processes contribute to turnover and fatigue [2]. Financial sustainability is another concern. Tele-mentoring programs often rely on short-term donor funding or research grants, creating vulnerability once funding ends. Lack of remuneration for mentors and absence of incentives for specialists also threaten program continuity [2].

Mitigation strategies include change management interventions, awareness campaigns to build community trust, and formal recognition of mentorship roles within surgical career pathways. Establishing a mentoring culture supported by leadership, adequate feedback processes, and recognition of rural practitioners as equal partners in care enhances participation and retention [20,25].

4.4 Mitigation and Policy Innovations

A complex set of solutions combining policies for infrastructure investment, digitalization, and workforce development is required to tackle these issues nationally. Integrating tele-mentoring and decentralized surgical care into NSOAPs ensures initiatives are adopted, costed, and monitored at institutional levels [2]. Embedding these within national e-health frameworks promotes regulatory coherence and facilitates cross-sector collaboration between health, education, and technology ministries.

Rural Surgery Learning Hubs, which provide technology-enabled simulations and coordinate tele-mentorship for rural practitioners, can serve as the backbone of DSNs, preserving local autonomy while maintaining technical oversight [2].

Financial sustainability must be prioritized. Hybrid funding models combining state support and private sector involvement can expand internet connectivity, subsidize devices, and support low-cost open-source digital platforms [26]. Legal reform to formalize task-shifting and regulate digitally guided surgical practice is essential [3]. Integrating tele-mentoring and low-cost simulation into national surgical curricula ensures digital learning becomes a core competency rather than an optional supplement.

AI and machine learning can further enhance these systems, enabling predictive and adaptive learning, real-time performance evaluation, procedural marking, and error identification [27]. By applying these technologies ethically and equitably, high-tech and low-cost solutions can enhance mentorship quality and democratize surgical training globally.

Decentralizing surgery in low-resource settings faces infrastructure deficits, digital inequities, institutional inertia, and cultural resistance. However, these barriers are not insurmountable. Strong policy alignment, context-specific technological solutions, and sociocultural transformation can allow tele-mentoring and task-shifting to become sustainable pillars of resilient surgical systems. Emphasizing equity, professional empowerment, and digital inclusion ensures DSNs provide not only access but lasting improvements in quality, safety, and system resilience [22,26].

Addressing structural, technological, and sociocultural barriers provides practical insights for the implementation of DSNs. However, to ensure long-term success, decentralized surgical systems must be embedded within broader health system structures. This requires integration of clinical practice, digital innovation, and governance mechanisms into a coherent framework. The following section introduces a conceptual and theoretical model for DSNs, situating them within health systems resilience thinking to enhance sustainability and adaptive capacity.

5. Systems Integration and Theoretical Framework

DSNs can cal practice, digital innovation, and policy mechanisms. Moving beyond conventionsucceed only through systems-level integration of clinial surgical delivery models, these networks leverage human task-shifting, digital tele-mentoring, and health system governance to establish an ecosystem that generates ongoing learning, quality assurance, and adaptive resilience. This section proposes a conceptual model for DSNs and situates them within health systems resilience thinking for sustainability. Local ownership, coordinated multi-sector collaboration, and adaptive capacity are critical in low-resource settings.

5.1 Conceptual Model of DSNs

The DSN framework is based on the triangular interaction of three essential pillars: human task-shifting, digital tele-mentoring, and policy integration. Together, these pillars support a cycle of knowledge transfer, skills strengthening, and systems governance, aimed at enhancing surgical capacity in decentralized settings.

The vision is for district hospitals and rural surgical units to be operationally connected through a digital network. Regional surgical hubs provide real-time tele-mentoring, case-based consultations, and continuous competency assessments for these nodes. Effective two-way feedback between satellite and central facilities ensures quality assurance and experiential learning. Surgical teams in remote locations receive timely support, while specialists access data to refine training content and identify recurring system-level gaps [14].

This framework emphasizes systems learning and adaptive governance. Technological support in both academic and surgical settings enables regular monitoring of surgical outcomes. DSNs are dynamic, learning-oriented networks that rely on cross-sector collaboration and data-driven insights rather than purely reactive service-delivery models [2].

DSNs also require coordination among multiple stakeholders, including ministries of health, university faculties, professional associations, and NGOs [28]. This collaboration standardizes curricula, credentialing, financing, and technical systems, and institutionalizes tele-mentorship within national surgical programs. Multi-sectoral governance facilitates resource sharing, including digital infrastructure and simulation facilities.

Explicit feedback and accountability mechanisms are essential for DSN sustainability. Surgical log data can be continuously analyzed to provide targeted mentorship when performance thresholds are not met. This allows individual capacity building while reinforcing system-level quality control, transforming DSNs into learning networks rather than purely reactive support systems. Over time, these networks are capable of long-term evolutionary development, ensuring resilience, efficiency, and continuous improvement in decentralized surgical care. The key components and enabling factors of DSNs are summarized in Table 2.

Table 2. Core components and enabling factors of DSNs.

DSN Component	Description	Enabling Factors	References
Human Task-Shifting	Delegation of essential procedures (e.g., C-section, hernia repair) to trained non-physician clinicians	Standardized curricula, competency accreditation, career pathways	[5,6]
Digital Tele-Mentoring	Real-time or asynchronous specialist guidance via low-bandwidth platforms	Solar-powered devices, offline apps, AI-assisted feedback	[12,23]
Network Governance	Multi-tiered coordination (district → regional → tertiary) with feedback loops	District health management teams, digital dashboards, PPPs	[13,29]
Resilience Mechanisms	Redundancy, modularity, and adaptive learning during crises	Simulation hubs, blockchain supply chains, community ownership	[9,19]
Educational Integration	Curriculum reform embedding global surgery, VR/AR training, and rural immersion	NEP 2020 alignment, interprofessional learning modules	[17,30]

Note: NSOAP: National surgical, obstetric, and anaesthesia plan; PPP: Public-private partnership; NEP: National education policy; UHC: Universal health coverage.

5.2 Health Systems Resilience Perspective

Using DSNs in the context of health system resilience enables surgical services to continue functioning during crises such as pandemics, conflicts, or supply disruptions. According to Beerannavar et al.[16], DSNs decentralize surgical capabilities into primary healthcare and referral systems, ensuring essential surgical services remain operational even if central facilities are incapacitated.

Integrating DSNs into UHC aligns surgical capacity development with broader population health goals [13]. Through redundancy, adaptability, and modularity, DSNs achieve resilience. Redundancy is created by equipping multiple district-level centers with essential surgical capacity, alleviating pressure on urban tertiary hospitals. Adaptability arises from digital mentorship, allowing rapid skill acquisition and procedural updates during emergencies. Modularity enables DSNs to expand or contract according to resource availability without service interruptions.

The sustainability of DSNs depends on local ownership and community participation [22,31]. Empowering district-level leadership ensures programs are relevant, trusted, and accountable, shifting surgical decentralization from a top-down model to a community-driven approach.

Funding DSNs offers dual benefits: Increased surgical access and improved system capacity to absorb shocks [21]. During the COVID-19 pandemic, decentralized surgical hubs supported by tele-mentoring delivered emergency procedures and trauma care under movement restrictions. In conflict zones or during supply disruptions, remote guidance allows procedures to continue safely.

From a governance perspective, DSNs must coordinate closely with district health management teams and regional authorities [1,10]. This ensures timely procurement of surgical and anesthetic supplies, consistent reporting of clinical outcomes, and equitable staff support. Embedding DSNs within existing frameworks strengthens the continuum of care and enhances interoperability among emergency obstetric, anesthesia, and trauma services.

Interprofessional collaboration is another pillar of resilient DSNs. By integrating surgery, obstetrics, anesthesia, nursing, diagnostics, and critical care, DSNs exemplify systems thinking in service delivery [32]. This holistic approach improves patient outcomes, reduces surgical risks, and enhances procedural efficiency.

Effective financing and governance are critical for long-term DSN sustainability [33]. Transparent funding flows and performance-based incentives maintain accountability and mentor engagement. Equitable global partnerships facilitate resource mobilization and technical exchange, reducing dependence on short-term external assistance [10].

By embedding DSNs into primary care platforms and national surgical plans, they evolve from standalone innovations into essential components of resilient health systems. Through continuous learning, digital connectivity, and participatory governance, DSNs enhance both accessibility and quality of surgical services and strengthen adaptive capacity across entire health systems [21,22].

Ultimately, DSNs provide a blueprint for adaptive, equitable, and sustainable surgical care, connecting human capacity, digital technology, and systemic governance. These networks are resilient, inclusive, and innovative, ensuring no population regardless of geography or resource scarcity is left without access to essential surgical care.

With a conceptual framework in place that links task-shifting, tele-mentoring, and policy integration, attention must now turn to the future. Scaling DSNs and ensuring their long-term impact depends on evidence generation, technology adaptation, and policy translation. The next section outlines future research priorities, including longitudinal outcomes, AI integration, economic modeling, cross-country comparisons, and capacity-building strategies to strengthen decentralized surgical systems globally.

6. Future Directions and Research Opportunities

DSNs represent a turning point toward sustainable and equitable surgical systems globally. To ensure the long-term success of these cross-sectoral solutions, a coordinated research agenda linking empirical evidence, technology, and policy translation is essential. Future research should move beyond descriptive data to include longitudinal, comparative, and predictive analyses that assess outcomes and optimize DSN design for scalable, sustainable implementation across low-resource settings.

6.1 DSN Outcomes Evaluated Over Time

A key priority is evaluating the long-term outcomes of DSNs, including patient safety, surgical mortality, workforce retention, and system efficiency. Most contemporary studies focus on short-term feasibility rather than long-term impact. Implementing continuous monitoring systems that collect real-time data on patient and provider outcomes will enable evidence-based refinement of decentralized surgical models.

Quality-of-care indicators, such as perioperative morbidity and infection rates, must be assessed alongside workforce indicators, including competency, retention, and satisfaction. Incorporating this evaluation framework into national surgical plans and digital health registries produces high-resolution data that guides adaptive policy, establishes benchmarks, enhances surgical governance, and improves transparency in global health systems [34].

6.2 Integrating Artificial Intelligence and Decision Support

Emerging AI-driven technologies hold promise for supporting DSNs through tele-mentoring, surgical training, clinical decision-making, and resource allocation. AI systems can detect procedural errors faster than human operators, reduce workload and cognitive stress, and provide real-time feedback [23,34].

Beyond clinical support, AI algorithms can optimize scheduling, triage, supply logistics, and coordination across distributed facilities. In tele-mentoring, AI can track instrument paths, identify mistakes, and provide personalized guidance to each mentee, enhancing both mentor efficiency and trainee skill acquisition [35].

Ethical and regulatory safeguards covering algorithmic bias, data privacy, and accountability are critical. Collaborative governance among ministries of health, academic institutions, and regulatory authorities will be necessary to ensure responsible AI deployment in decentralized surgery.

6.3 Economic and Cost-Benefit Modeling

A major gap in global surgery research is the rigorous evaluation of the economic impact of DSNs in LMICs. While DSNs demonstrate operational effectiveness, their cost-effectiveness, return on investment, and broader macroeconomic implications remain underexplored [10].

Future research should employ system dynamics modeling and cost simulations to quantify how strategies such as task-sharing, tele-mentoring, and digital mentorship affect national budgets, hospital efficiency, and health workforce productivity. Such analyses can highlight potential savings from reduced referral costs, shorter hospital stays, and more efficient resource utilization [21,22].

Linking these economic outcomes to population-level indicators, including employment, gender equity, and broader health system strengthening, will clarify the societal benefits of decentralizing surgical services. Furthermore, multi-sectoral cost modeling involving private and non-profit stakeholders can inform sustainable financing mechanisms and public-private partnerships that subsidize digital infrastructure and broadband expansion, ensuring tele-mentoring networks remain financially viable in remote settings [28].

6.4 Comparative and Policy Context Across Countries

Global progress in decentralized surgical care requires harmonized policy frameworks and comparative studies that evaluate the influence of context governance structures, workforce regulations, and technology adoption on DSN implementation outcomes.

Such analyses can identify success drivers and barriers, inform best-practice models, and facilitate South-South learning and regional cooperation. Cross-border collaboration can standardize data collection, enable interoperable registries, and support regulatory alignment for digital health technologies and workforce credentialing [11].

6.5 Blockchain for Supply Chain and Data Management

Blockchain technology offers opportunities for data integrity and supply chain management within DSNs. Its immutable, transparent record-keeping ensures traceability of surgical procedures and medications, protects patient privacy, and prevents procurement delays [36].

Effective implementation requires common procedural standards, interoperable infrastructure, and integration across hospitals, suppliers, and policymakers to create a seamless digital ecosystem [36].

6.6 Immersive and Simulation-Based Capacity Development

Virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies provide immersive surgical training in decentralized settings. Simulation-based learning allows non-specialist providers to practice procedures without risk to patients [30].

Integrating VR-based curricula into tele-mentoring platforms democratizes access to high-quality surgical training in areas lacking traditional training centers. Future research should assess the long-term impact of these technologies on surgical competency, confidence, and patient outcomes in LMICs.

6.7 Enhancing Research Equity and Capacity

Funding for surgical research must include under-resourced regions and promote equitable collaboration [11]. Academic journals, funders, and research consortia should support LMIC investigators through mentorship, open-access publishing, and equal partnerships.

Standardized monitoring and evaluation frameworks will improve transparency and comparability across DSN studies. Implementation science and participatory research methods ensure innovations are contextually relevant and responsive to the needs of frontline providers and communities.

The next stage of DSN research should be evidence-based, technology-adaptable, and equity-centered. Longitudinal evaluations, AI integration, economic modeling, and cross-national collaboration will be essential. By combining ethical technology use, sustainable financing, and inclusive governance, future research can establish decentralized surgery as a core pillar of resilient and equitable health systems.

7. Conclusion

Integrating task-shifting, tele-mentoring, and DSNs provides a scalable approach to improve surgical access and equity in low-resource settings. DSNs can safely upskill local providers, enhance patient outcomes, and strengthen health system resilience by reducing referral delays and maintaining service continuity during crises. When embedded within existing care and referral systems, they promote local ownership while ensuring quality oversight and accountability. Strategic investment in digital infrastructure, workforce development, and multi-sector collaboration is essential for sustaining these networks. Overall, implementing DSNs can expand essential surgical coverage, reinforce resilient health systems, and advance progress toward UHC and equitable access to essential surgery for underserved populations.

Conflict of Interest

The author declares no competing interests.

Generative AI Statement

The author declares that no Gen AI was used in the creation of this manuscript.

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