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DISRUPTIVE INNOVATION IN GLOBAL SURGERY

Toward a Sustainable Innovation Ecosystem for Global Surgery: The Role of Disruptive Innovations

Juan Carlos Puyana, MD, FACS[1], Rifat Latifi, MD, FACS, FICS, FKCS[2]

[1] Institute of Global Surgery, Royal College of Surgeons in Ireland, University of Pittsburgh Global Surgery Office.
Email: jcpuyana@rcsi.ie

[2] Professor of Surgery
University of Arizona, College of Medicine, Tucson, Arizona:
University of Prishtina, Medical Faculty, Kosova
Email: rlatifi@arizona.edu

Corresponding author:

JUAN CARLOS PUYANA, MD, FACS

Email: *jcpuyana@rcsi.ie*

Abstract

This paper presents a comprehensive vision for advancing global surgery through sustainable innovation ecosystems that prioritize local engagement and contextual solutions. Focusing on the pressing challenges in low- and middle-income countries (LMICs), the manuscript emphasizes the importance of identifying and empowering frugal innovators while advocating for a systemic shift away from traditional aid-based models. It outlines a strategic framework that integrates frugal innovation, stakeholder collaboration, financial strategies, and health system reform to enhance surgical access and outcomes. Key case studies, such as the development of cost-effective surgical tools in Malawi and the innovative financing model employed in the Gorongosa National Park, illustrate the feasibility and impact of these approaches. The paper underscores the critical role of telemedicine and telehealth as transformative technologies that enhance access to surgical expertise and improve patient care, particularly in resource-constrained settings. Furthermore, it discusses the Initiate-Build-Operate-Transfer (IBOT) strategy developed by the International Virtual e-Hospital Foundation, which offers a structured approach to establishing and sustaining telemedicine programs in LMICs. By fostering interdisciplinary collaborations and aligning health interventions with local realities, this work aims to pave the way for equitable, durable surgical care for all.

Keywords; Global Surgery; Frugal Innovation; Telemedicine; Health Systems Reform; Low- and Middle-Income Countries (LMICs); Sustainable Healthcare; Stakeholder Engagement; Surgical Access.

Introduction

Providing access to safe and timely surgery remains a critically neglected component of health systems development in Low- and Middle-Income Countries (LMICs), contributing to substantial health disparities and otherwise completely preventable morbidity and mortality (1-5). According to the Lancet Commission on Global Surgery (LCoGS), over 5 billion people lack access to safe, timely, and affordable surgical care, with the burden disproportionately impacting populations in LMICs. Surgical conditions are a leading cause of disability and death yet represent a major gap in global health funding and policy. As a result, many surgical services remain unaddressed in health system frameworks, leaving communities vulnerable and the health systems weak and incomplete. Despite advances in global health, access to safe surgical care continues to be unacceptably limited in many low- and middle-income countries (LMICs). Global surgery remains one of the most underfunded and underprioritized domains in global health policy. Despite increasing awareness since the Lancet Commission on Global Surgery, implementation of sustainable, locally driven innovations remains limted. (2, 6).

Introducing industrial engineering frameworks and cultivating frugal and disrupted innovation must now be emphasized within a true transdisciplinary global surgery community, we must recognize that a pragmatic pathway into the future rests in our ability to see the need for innovation emanating within ecosystems grounded in local realities and built to scale sustainably with the ultimate objective of achieving both, improved health outcomes and local job creation to sustain regional health systems. (4,5).

The link between Global Access to Surgery and the need for a Catalytic Innovation Ecosystems

LCoGS recommendations and metrics including the proposed development of National Surgery Obstetric and Anesthesia Plans (NSOAPS). Following both the Lancet Commission on Global Surgery and the World Health Assembly Resolution 68.15 in 2015 (1), world leaders in surgery, obstetrics and anesthesia came together to produce a comprehensive planning methodology for governments to use to increase capacity in safe surgical, obstetrical and anesthesia care. The (NSOAP) process offers ministries of health a pathway to integrate surgical planning into their overall national health strategies using a systematic and logical approach. Unfortunately, ministries of health in many poor countries have very limited budgets and are constantly faced with health crises. The COVID pandemic and prevalent infectious diseases (polio resurgences, mpox appearances, salmonella outburst etc) continue to impose emergent priorities on very constrained budgets (11-13).

It is imperative than in parallel with the NSOAPs frameworks, local state holders identify and support economically viable solutions aimed at not only improving surgical care provision but simultaneously supporting local economies and new job creation. Many frugal innovators yet to be discovered and supported in LMICs are an untapped resource to alternative and viable economical solutions in addition to health policy interventions. (20).

Innovation in global surgery is badly needed, and it must evolve from the local context and not depend exclusively on donor-driven, or externally designed interventions such as grant promoted time limited funding. A catalytic ecosystem approach should be created to recognize and support local expertise, regional context, and interdisciplinary collaborations. Four core principles are essential for such a system to endure over time: affordability, adaptability, sustainability, and scalability. Within this framework, innovations should not be isolated outputs but instead they need to be interconnected nodes within a dynamic, responsive system of clinical, industrial, and academic actors.

Building a Sustainable Innovation Ecosystem

Sustainability must be the cornerstone of all global health interventions. It is critical that we identify the potential fragmentation between northern-led surgical initiatives and prioritize the realities faced by practitioners in low resource settings (6-10). Addressing this disconnect is essential for creating interventions that endure and evolve within local health systems. Every effort must be made towards seeking dynamic integration of practitioners, engineers, policymakers, and educators to co-create a cohesive and functional innovative ecosystem.

Case Study: Frugal Innovation and Local Manufacturing in Malawi

A notable and very illustrative example is the development of an aluminum orthopedic clamp in Malawi. While

commercially available titanium clamps cost $700, local engineers produced a functionally equivalent device for under $10. This frugal innovation made possible through academic–industry collaboration, demonstrates the potential of contextual manufacturing to reduce costs and improve access to essential surgical tools. This was achieved by leveraging local ingenuity with engineering expertise and partnering with non-profit manufacturing entities. Such examples underscore the potential of localized manufacturing and south-south collaborations in achieving economically viable surgical care solutions. These solutions are not likely to surge within the innovation fields of High-Income Countries as the motivation and business models differ vastly when it comes to defining acceptable and affordable profit margins (1, 12-13).

Integrated Financing: The Gorongosa Model

In Mozambique, a novel approach integrates conservation, education, and health financing through the Gorongosa National Park. Revenue from ecotourism and agro-forestry are now being routed towards obtaining a partial and hopefully later comprehensive economical infrastructure support for the progressive development of a regional health system. In the case of Gorongosa national park, such initiative could eventually provide improved and more robust universal care for at least 300,000 people living within the human development zone around conservations land and the park. This model exemplifies how cross-sector investment in ecosystems can underwrite healthcare infrastructure in a sustainable, locally governed manner and illustrates a novel, circular financing mechanism for sustainable health infrastructure and workforce retention where economic and health goals are co-dependent and mutually reinforcing.

Digital Innovations and Improved Processes supporting community Interventions

A critical enabler of frugal and scalable innovation in global surgery is the integration of digital process innovation tools with community-anchored health system interventions. A compelling example of this is the BloodSafe project in Kenya, led by the University of Pittsburgh in partnership with local academic and public health institutions in Kenya under NHLBI funding (23). Recognizing the logistical and clinical challenges in ensuring timely and safe blood transfusions in peripheral and rural hospitals, the project employed Discrete Event Simulation (DES) models to map the entire blood transfusion supply chain—from donor mobilization and blood collection, through processing, to delivery at the point-of-care. These simulation models allowed stakeholders to visualize delays, test counterfactuals, and co-design optimized solutions that incorporated locally feasible digital tracking systems and community health worker networks. Critically, the DES tools helped identify high-impact leverage points (e.g., mobile blood units, regional cold-chain hubs) and reduce turnaround time while conserving resources. By anchoring technical solutions within local health system workflows, this model illustrated how data-informed digital strategies and systems-thinking frameworks can elevate community-level surgical readiness. It also affirmed the broader principle that systems innovation must be participatory, context-specific, and digitally enabled to be truly catalytic and sustainable in LMICs (24).

Innovations: Taxonomy and Scalability

We propose the creation of a taxonomy to classify global surgical innovations according to the basic four criteria described earlier: affordability, adaptability, sustainability, and scalability. Here, global surgery and perioperative stakeholders from both north and south should advocate for a shared language and data-driven strategy to assess, prioritize, and implement innovations.

To operationalize a catalytic innovation ecosystem in global surgery, structured methods such as the Stanford Biodesign framework (5) can offer a validated pathway for developing, validating, and scaling frugal surgical innovations (FSIs). This model emphasizes:

- Context-driven need identification
- Multidisciplinary invention processes
- Commercial planning and regulatory navigation

By embedding these practices into regional training hubs and innovation incubators, LMIC-based innovators can produce and scale high-impact, affordable surgical solutions. The commercialization element, often overlooked in public-sector health innovation, is critical for ensuring diffusion and long-term viability.

Telemedicine and Telehealth as Disruptive Innovations in Global Surgery

Telemedicine and telehealth are transforming the landscape of healthcare delivery, particularly in low- and middle-income countries (LMICs) (26-29). These technologies disrupt traditional models by enhancing access



to surgical expertise and patient care, addressing critical challenges in resource-limited settings. By facilitating remote consultations, pre-operative evaluations, and postoperative follow-up, telemedicine not only enhances the quality of care but also alleviates the burden on local health facilities (26-28).

Improving Access to Surgical Expertise

One of the most significant advantages of telemedicine is its ability to connect local healthcare providers of LMICs with specialists in their own best hospitals without having patients travel abroad in high-resource settings. This connection enables virtual mentorship and real-time assistance during surgeries. For example, surgeons in urban centers can provide guidance to rural practitioners through video consultations, sharing their expertise in real time. This collaboration enhances the skill sets of local practitioners, allowing them to perform complex procedures with support from experienced surgeons. Furthermore, local patients benefit from timely surgical interventions that may otherwise be delayed due to limited access to specialist care. The ability to leverage telemedicine not only accelerates decision-making but also significantly decreases patient morbidity and mortality associated with untreated surgical conditions. By facilitating immediate access to expert advice and support, these technologies ensure that complications are addressed promptly, leading to better patient outcomes.

Enhancing Postoperative Care

Telehealth systems facilitate remote monitoring of patients, ensuring effective postoperative care while addressing the logistical challenges encountered by those in rural areas. Many patients in LMICs struggle to travel long distances for follow-up appointments, often leading to missed check-ups and increased risks of complications. Telehealth mitigates this issue by enabling healthcare providers to monitor patients' recovery through virtual check-ins and remote diagnostic tools. (26, 28). By integrating telehealth solutions with community health initiatives, we promote a more decentralized, patient-centered approach to surgical care. Local health workers trained to utilize telehealth technologies can facilitate follow-ups, monitor recovery, and address any emerging concerns. This approach not only strengthens the healthcare system but also fosters community engagement and resilience.

The International Virtual e-Hospital (IVeH) Initiate-Build-Operate-Transfer Strategy

The International Virtual e-Hospital (IVeH) Foundation employs the Initiate-Build-Operate-Transfer

(IBOT) strategy as a structured approach to ensure the sustainability of telemedicine programs. This model that came out of ware ravaged Kosova (www.iveh.org) (27) provides a framework for developing healthcare projects that can operate effectively after being transferred to local entities, such as governments or community organizations and ensure sustainability.

Initiate: In this phase, IVeH collaborates with various stakeholders, including academic institutions, governmental agencies, and local communities, to identify project opportunities. This involves conducting feasibility studies, securing necessary regulatory approvals, and engaging local stakeholders to ensure alignment with community needs.

Build: Once a project is initiated, IVeH focuses on the design, engineering, and construction of telemedicine infrastructure. This phase includes developing detailed plans, procuring necessary technology, and building local capacity through training programs. By enhancing the skills of healthcare workers, the foundation ensures that local expertise is developed to support ongoing telehealth initiatives.

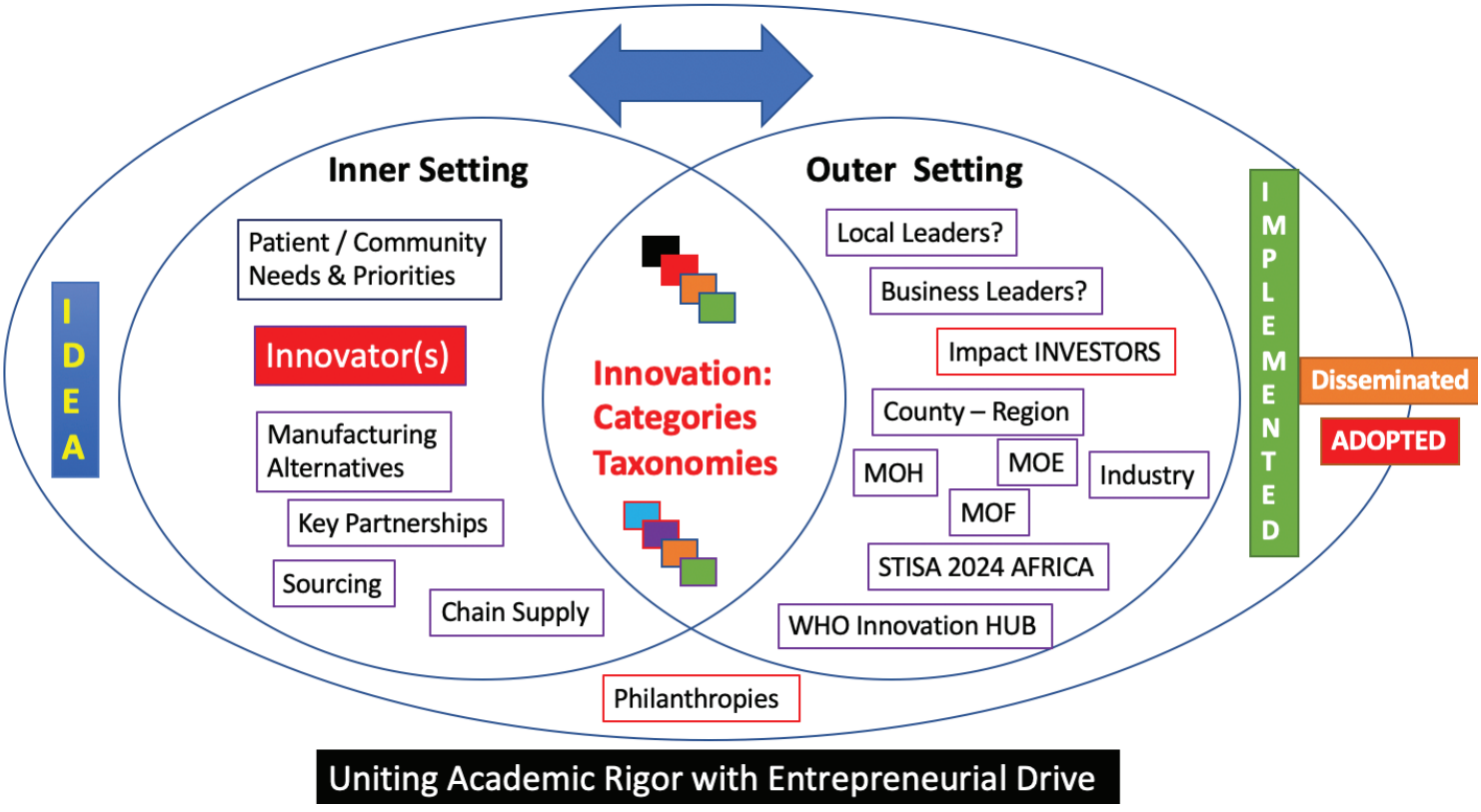
Operate: Upon completion, the project enters the operational phase where a designated institution manages the telemedicine services. This includes overseeing daily operations, ensuring service quality, and maintaining equipment. The IVeH Foundation emphasizes the importance of transparency and effective management practices, which are crucial for building trust with stakeholders and ensuring the program's success.

Transfer: The final phase involves transferring ownership and operational control to the public sector or local entities. This transition is critical for the program's sustainability, as it empowers local stakeholders to take charge of health services. The transfer process includes the handover of physical assets, operational responsibilities, and any contractual agreements necessary for seamless continuity.

Strengthening Health Systems Through Telemedicine

The integration of telemedicine within local health systems promotes a holistic improvement in healthcare delivery. This strategy not only leverages existing technologies but also builds local capacity, enhances efficiency, and improves healthcare access. With telemedicine, the potential for collaboration between local health workers and external experts creates a dynamic and responsive healthcare ecosystem.

Additionally, the IBOT strategy employed by IVeH exemplifies how a structured approach can enhance the



effectiveness of telemedicine programs in LMICs. By following the systematic phases of initiation, building, operating, and transferring, the foundation ensures that telemedicine initiatives are sustainable and tailored to the needs of the communities they serve (26-28).

Toward an Innovation Framework

We propose a framework to encourage systematic thinking and catalyse collaborative refinement. This framework illustrates a catalytic innovation ecosystem designed to foster sustainable, scalable, and context-sensitive surgical innovation within low- and middle-income countries (LMICs). The framework integrates both inner and outer settings—emphasizing the co-evolution of local clinical insight, manufacturing potential, community needs, and policy and investment structures—across the continuum from idea generation to implementation and adoption.

Stages of Innovation Maturity: The horizontal axis shows the life cycle of innovation: from IDEA generation to Implementation, then Dissemination and full Adoption. Each stage requires a distinct set of stakeholders.

Inner Setting: Includes local actors and systems such as innovators, patients, manufacturing alternatives, key partnerships, sourcing options, and philanthropic funders. These are the core of academic rigor and clinical insight where frugal innovation is born.

Outer Setting: Encompasses policy makers, local leaders, business stakeholders, and global entities [e.g., WHO Innovation Hub, African Union (STISA 2024 Africa)]. Their involvement is critical for political sustainability, resource mobilization, and national integration.

Central Taxonomy Core: The intersection zone reflects the necessity of categorizing innovations by function, specialty, or readiness, enabling prioritization, comparability, and scaling based on defined criteria such as affordability, scalability, adaptability, and sustainability.

Strategic Message: The diagram's base line—'Uniting Academic Rigor with Entrepreneurial Drive'—summarizes the critical balance required for sustainable innovation in global surgery. Innovations must be supported by both rigorous evaluation and agile implementation strategies to survive beyond pilot phases.

Furthermore, the success of this model in LMICs hinges on access to catalytic capital, technical mentorship, and regulatory support—necessitating philanthropic, governmental, and non-dilutive financial mechanisms. Adoption of such frameworks at institutional levels (e.g., COSECSA, RCSI, Fraunhofer) could empower South-based innovation pipelines while aligning with the broader goal of global surgical equity

Policy Alignment and Global Governance

We need a paradigm shift in global health policy—one that integrates surgery into national and regional innovation strategies. Despite the African Union's 2024 Innovation Strategy, surgery and anaesthesia remain largely absent. Similarly, WHO innovation hubs have not integrated surgical access within their primary goals. To maintain surgical innovation, stronger engagement with global policy actors is required. National surgical, obstetric, and anaesthesia plans (NSOAPs) must clearly delineate options for financing strategies and innovation pipelines aligned with industrial policies encouraging deeper engagement with global bodies like WHO to ensure surgical innovation is embedded in global health discourse and resourcing priorities.

Strategic Recommendations

To effectively enhance global surgical care—especially in underserved regions—it is essential to adopt a coherent framework that incorporates innovative strategies tailored to local realities and needs including:

1. Develop a Taxonomy of Global Surgical Innovation Needs: Establish a comprehensive classification system to identify specific surgical needs within different contexts, allowing for targeted innovations and resource allocation.
2. Invest in Regional Innovation Clusters Tied to Universities and Surgical Colleges (e.g., COSECSA): Foster collaboration between academic institutions and surgical training programs to promote research and development of localized surgical solutions.
3. Establish Financing Strategies Leveraging Conservation, Agriculture, and Education Revenues: Create innovative funding models that integrate revenues from these sectors to support sustainable healthcare initiatives, particularly in resource-constrained environments.
4. Forge South–South and North–South Academic-Industry Partnerships: Encourage collaborations across geographical boundaries to facilitate knowledge exchange, technology transfer, and capacity building in surgical care.

5. Incorporate Frugal Innovation Metrics in Global Health Funding Assessments: Develop criteria for evaluating health funding that prioritize cost-effective and contextually appropriate innovations, ensuring that resources are directed toward interventions that deliver the greatest impact.
6. Integrate Telemedicine and Telehealth as Strategic Components: Leverage telemedicine and telehealth technologies to enhance access to surgical expertise, enable remote consultations, and improve patient follow-up care. By incorporating these digital health solutions, we can overcome geographical barriers, strengthen local healthcare capacity, and ensure timely surgical interventions, ultimately leading to improved health outcomes in low- and middle-income countries.

Summary:

We envision a transformative approach to innovation in global surgery, shifting from isolated interventions to integrated ecosystems that are contextually relevant and led by local stakeholders. The pathway ahead demands collaboration, systems thinking, and a steadfast commitment to sustainable and scalable innovations. Achieving advancements in global surgery requires more than merely providing tools; it necessitates a comprehensive rethinking of how innovations are designed, funded, and implemented.

A catalytic ecosystem, firmly grounded in local realities and focused on cross-sector integration, presents a compelling alternative for pursuing sustainable surgical care for everyone. Telemedicine and telehealth stand as transformative solutions rather than just technological fixes; they signify a fundamental shift in the delivery of surgical care in resource-limited environments. By eliminating geographical barriers and enhancing the capabilities of local healthcare providers, telehealth has the potential to significantly elevate surgical outcomes across low- and middle-income countries (LMICs).

The structured methodology employed by the IVeH Foundation, particularly through the IBOT strategy, illustrates a practical framework for developing sustainable telemedicine programs. These programs can be tailored to meet local needs, ultimately improving healthcare delivery in underserved regions.

These initiatives can propel the advancement of global surgery, broaden access to essential surgical services, and empower communities to take ownership of their health initiatives. This empowerment leads to greater resilience and enhanced health outcomes in LMICs.

By fostering collaboration between local healthcare practitioners and specialists via telemedicine, alongside systematic strategies like the IBOT framework, stakeholders can cultivate a more equitable and sustainable healthcare system. This system will effectively tackle the unique challenges faced in LMICs. Thus, the incorporation of telemedicine into global surgery marks a significant milestone in the effort to diminish healthcare disparities and enhance surgical care for all, establishing it as an essential element of future health policy and practice. Through cohesive efforts in this direction, we can lay the groundwork for a healthier and more sustainable future, ensuring that even the most remote populations receive the care they need when they need it.

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