

Implications of technological advancement of surgery in low and middle-income countries' a narrative review

Samreen Malik¹, Samir Azeem², Amna Rehman³, Hijab Khan⁴, Arifa Haque⁵, Afshan Qamar⁶

Abstract

Countries that are striving to keep pace with emerging technologies in surgical practices and still not able to cope with exemplary international standards are in dire need of resources to build and strengthen their healthcare system. This review focusses on the impeding factors that hinder in adaptation of advanced technology and machinery in the health care industry. Considering the immense potential for current surgical technologies to transform the delivery of healthcare, their implementation in LMICs confronts considerable challenges due to lack of infrastructure, human capital and inadequate resources. To address these difficulties, various entities, including healthcare institutions, government and non-governmental organisations, and foreign partners, must work together. Building capacity through intended education and training initiatives, building infrastructure, and collaborative partnerships are critical for overcoming hurdles to effective deployment of surgical technology in low-income communities of the world.

Keywords: Capacity Building, Health Care, Technology, Digital surgery, LMICs, innovation.

DOI: <https://doi.org/10.47391/JPMA.AKU-9S-10>

Introduction

The world has a diverse population with varying divisions, some countries are thriving and some are striving to cope with basic needs. Whereas, health and care is a basic requirement and standardised care is a myth to some striving countries. Thomas Weiser in his research conducted in 2016 mentions that the surgeries that were conducted in low-income countries accounts for only 6.3% of surgeries conducted worldwide, pointing to the fact that there is a dire need to strengthen the health care system.¹ The low-income country' population accounts

^{1,2,4}Department of Oral Medicine, Liaquat College of Medicine and Dentistry,

³Department of Oral Surgery, Liaquat College of Medicine and Dentistry.

^{5,6}Department of Oral Pathology, Liaquat College of Medicine and Dentistry

Correspondence: Samreen Malik **Email:** dr.samreen90@gmail.com

ORCID ID. 0000-0002-9322-2379

for 37% of the world population whilst according to the 2024 fiscal year the countries that lie between \$1,136 and \$4,465 Gross National Income GNI per capita are categorized as low-middle income countries.² According to the World Health Organization's latest data 6% increase was observed in health care expenditure in the world while the data was mostly representative of high-income countries.³ Nevertheless as per international data low-middle-income countries' health expenditure is primarily relied on funding and out-of-pocket resources in contrast to the high-income countries where the health expenditure is mostly counting on their government resources.⁴

Considering Pakistan, the health expenditure of the year 2020 was 2.95% of GDP which is way too low when compared with high-income countries.² The statistics show that countries that are not economically stable are not only lagging in health provision but also lack the infrastructure to incorporate digitalization and innovation in surgical practices. Surgery is considered an integral part of the health care system that aids in halting mortality and morbidity in the population and serves as a definitive treatment modality for many diseases. Surgical procedures are complex and critical and require precision and expertise, despite their significance, the expense of technological tools makes it expensive also. This innovative advancement is usually gathered in countries with high incomes that give rise to disproportioned health provision in the world.²

It's not wrong if we say that the COVID era has transformed the world not only due to its catastrophic adversities but also because it led us to explore alternative ways to accommodate the effective delivery of health and care. Numerous technical tools and innovative machinery have come into existence in the healthcare domain during the COVID phase to ensure prompt delivery of therapeutics keeping pace with international standards. The 15 tech tools in health care industry are digital therapeutics, medical dictation software, AI-tailored medications, health focus wearable, connected tools, centralized physician communication tools, AR/VR for surgery training, patient account management tools,

AI Models For Detecting Dementia, Enhanced Energy Systems, Genetic Testing, MRI-Compatible Surgical Systems, The Internet Of Medical Things, Robots For Every day, 3-D Printing, and Hospital Tasks And Maintenance.⁴ These tools have been introduced in medical and surgical practice, considering surgical practice all over the world the accommodation and smooth functioning of these tools demands an efficient and functioning system which also depends on several factors.⁴

Countries that are striving to keep pace with emerging technologies in surgical practices and still not able to cope with exemplary international standards are in dire need of resources to build and strengthen their healthcare system. The following study will focus on the technological advancement in surgical practice and its scope in low-middle-income countries, identifying gaps and impeding issues, and discussing approaches to ensure the effective provision of unbiased healthcare facilities.

This review aims to assess the Implications of technological advancement of surgery in low and middle-income countries and discuss existing possibilities that propose alternative innovations for LMICs.

Methodology

The search strategy was based on assessing literature from three search engines that were Google Scholar, PubMed, and Web of Science. Whereas the keywords that were used were digital surgery, LMICs, innovation, surgery, surgical practice, technological tools, advanced technology, and resource constraints. Primary researches were included whilst studies that were published before 2015 were excluded. For the research that was related to the context and that was available in the English language, full-text PDFs were included. A total of 9 relevant types of research were then included after screening and rigorous evaluation.

Review of the literature

Technological advancement in surgical practise in lmics

The factor that drives the uneventful surgical outcomes is the effective teaching and training process, the conventional methodology of surgical training is an observation of surgeries with senior surgeons and trainers. The digital teaching model is relatively a new advancement to halt the disparity in clinical skills amongst surgical trainees.⁵ Digital teaching methodology provides low-middle-income countries with the opportunity to get trained with top faculty around the globe and experience the critical learning of innovative machinery used in surgery. Guérard-Poirier et al, (2020)

conducted a clinical trial to establish the outcomes of utilizing a learning web-based tool called GEN (gamified educational network) to learn the suturing technique in distance learning. Study reveals that anxiety related to conventional teaching, lack of trained faculty, and critical feedback that were the greatest constraints in effective learning were improved and skill learning experience was found to be satisfactory amongst students.⁵

Federico Nicolosi et al, (2018) conducted a study to assess the alternative surgical training technological tools that can easily be employed by countries with limited resources. Contrary to conventional teaching methodologies there were several technological software-based applications identified are The Rhoton Collection, Brain book, NeuroMind, Neurosurgery Survival Guide, UpSurgeOn, The Neurosurgical Atlas, WFNS Young Neurosurgeons Forum Stream Touch surgery, and Neurosurgical.TV, EANS (European Association of Neurosurgical Societies) Academy, 3D Neuroanatomy, and Hinari are just a few examples. Webinars, 3D interactive neuroanatomical and neurosurgery information, movies, and e-learning programmes backed by neurosurgical societies or publications comprise these platforms.⁶

It is believed that the collaboration of surgery on an international level will aid in the synthesis of effective post-surgical management protocols. According to research in 2010 Lancet Commission on Global Surgery reported that the total death toll due to the unavailability of prompt surgical care was 16.9 million.⁷ These deaths were mostly due to a deficit of post-surgical care and limited resources to get effective care delivery, therefore collaboration and communication of surgeons on a global level was an important factor in managing cases with complex presentations The most crucial aspect of the expansion of global surgical collaboration is an intact system of ICT Information and communication technology. Considering low-middle-income countries Caroline Q et al (2018) surveyed (LMIC) West African College of Surgeons to assess the accusation of big data. A total of 83 participants from 10 countries having more than 10 years of clinical experience took part in the study, results showed that virtual meeting applications, virtual document-sharing platforms, and social media were the modes of collaboration and it has a positive impact on education, and most of the study participants favoured the use of ICT to enhance their clinical skills and keep their practice up to date which is comparable to countries with modern technologies and practice cultures.⁸

Gisele et al, (2017) conducted a randomized clinical trial to evaluate the impact of touch surgery technology in low-

resource settings. At the University of Rwanda, the residents of surgery participated in a study where the outcomes of conventional teaching were compared with touch surgery in which participants performed surgeries via a smartphone application that served as a simulation. The surgery residents whose scores of 89.7% turned out to be the users of TS (touch surgery) whilst residents who prepared via textbooks scored 63.4%. Thus, it can be concluded that technological tools also aid in strengthening human power by producing effective and skilled surgeons. Since it cannot replace theoretical knowledge, its purpose may be restricted to an additional tool to basic teaching methodology. In low- and middle-income countries, TS has the potential to be integrated into a surgical academic programme.⁹

Robotics in surgery has revolutionized the prospect of surgery by enabling great precision and accuracy with minimal invasion, its application in Pakistan has been employed by several healthcare and research centres. Recently PKLI&RC (Pakistan Kidney Liver Institute and Research Centre) has ecstatically announced the procedures that have been done via robotic surgeries, those procedures include cancer operations, penile and reconstructive surgeries, and removal of kidney stones.¹⁰ Similarly the significance of endoscopy and advancement in its functionality and diversity cannot be undermined, capsule endoscopy is one example. This technique provides 100 detailed high-definition pictorial representations of the alimentary canal for diagnosis in a minimally invasive manner.¹¹

The advent of AR/VR has transformed the landscape of minimally invasive surgical procedures. The training of residents was the pain point and for which a collaborative effort from the surgical department of Virginia University Richmond, USA Commonwealth under the umbrella of the Pak-US Science and Technology Cooperation Programme has led to the development of a virtual trainer lab. The lab was inaugurated in Rawalpindi Medical College's Department of Surgery and is furnished with AR-assisted simulators, box trainers, and operating rooms.¹²

Challenges in incorporation of technological advancement in surgery in LMICs

Need assessment, ideation, creative exploration, creation, assessment, and broader deployment leading to adoption are all part of the technology distribution processes. Several obstacles in the deployment of surgical technology are general, however, most of them are aggregated in developing nations, and issues such as lack of infrastructure, deficit of human resources, and finances are amongst the most prevailed constraints.¹³

Furthermore, country-specific regulatory considerations and healthcare culture are also contributory factors that affect the implementation of technological advancement in LMICs. A strong evidence-based strategy to address these issues is required to understand the unique clinical and healthcare system requirements and develop a solution.¹³

Financial Constraints

2 billion deaths have been reported over the years in low-middle-income countries due to a lack of basic instrumentation and armamentariums that would ensure provisional care and definitive treatment delivery. These demises would easily be halted with the correct use of technological tools whereas the primary factor was the discrepancy of availability of instruments and the burden of patients. Despite being aware of tech tools such as 3D printing LMICs are unable to meet the needs due to a lack of finance and budget from the government health quota. The financial support is critical to not only afford but also maintain the efficacy of technological machinery in surgical practice.¹⁴

Infrastructure and Scalability Deficits

The deployment of technological tools and ICTs (Information and communication technology) in LMICs is challenging due to compromised infrastructure. Issues such as the unavailability of functional internet, wireless information transformation pathways, big data management, and most importantly most hospital facilities lack the infrastructure that supports the installment of technological tools and gadgets that count as a basic infrastructure requirement.⁴ These are the most crucial factors that support the smooth functioning of advanced machinery.⁴ Areas with inadequate and uncertain supply of electricity pose a threat to not only advancement in healthcare but also to routine healthcare delivery.¹⁵ However, technical support and maintenance are the two most important aspects that dictate the potential scalability and life of technological tools in any healthcare setup and LMICs lack these fundamental blocks of infrastructure.¹⁶ Scalability remains an issue since the cost of purchasing and cost of maintaining surgical tech tools in addition to the cost of the training sessions for medical personnel leads to financial crises leading to questionable scalability of technological advancement in LMICs.¹⁷

Scarcity and burn out of Human Resources

Even when competent workers are available, they are frequently concentrated in metropolitan areas, leaving remote and rural regions neglected. This uneven distribution restricts access to specialized surgical care and impedes the widespread implementation of

technical advances throughout the country.¹⁷

In addition to this, due to high patient numbers and limited skilled personnel, the existing healthcare staff in LMICs usually experience enormous workloads. Introducing new technology without addressing workload difficulties may contribute to burnout among medical professionals and impair their capacity to adapt to and use modern surgical equipment efficiently.¹⁸ Concerns regarding scarcity of skilled workforce, LMICs frequently confront a scarcity of skilled healthcare professionals such as surgeons, anaesthesiologists, nurses, and technicians.¹⁸

For a health care worker embracing advancements in technology demands particular training and ongoing education throughout their professional career. However, a lack of funding for training programmes, as well as the time necessary to improve the skills of current workers, presents problems in ensuring that healthcare providers are competent in the application of emerging technologies.¹⁹

Interventions and strategies to ensure effective implementation of technology advancement in surgical practice in LMICS

Digitalization in education and collaboration

With limited resources places, ICT (Information and communication technology) platforms may promote education and international cooperation. Similar surveys and ICT seminars implemented in other LMIC countries might enhance ICT adoption, hence boosting worldwide surgical partnerships.¹¹

Traditional forms of education, including books, scientific papers, cadaveric hands-on courses, and direct observing experience, are typically used in neurosurgical training. Standard education programmes are frequently unavailable in low-middle-income nations, owing to a lack of human and economic resources. Introducing digital platforms in these contexts might be an alternate strategy for closing the knowledge gap between Western nations and underdeveloped countries.⁵

3D-Printing

The potential yet functional way to cope with the most frequently encountered problem in LMIC surgical practice is the lack of instruments. To address the primary cause that is affordability. Low-cost 3-dimensional printing technology might transform the distribution and production of surgical tools in district-level healthcare institutions in underdeveloped countries. While prior research has concentrated on the uses of 3-dimensional material printing for bio-implants, there has been little

investigation into the production of basic, but critical surgical equipment, which is frequently in low supply in underdeveloped nations. Conventional stainless steel surgical instruments can be devised utilizing bio-based materials of plastic at a very low cost compared to conventional material.¹³

Frugal innovations

Grassroots, resource-constrained settings (RCS) gave rise to the philosophy of Frugal innovation (FI), this term came into existence in response to addressing the most crucial problem faced by patients in LMIC countries where affordability, access, and quality care remains the concern. The primary motive behind frugal innovation is to maintain patient safety, surgical accuracy, and justifiable procedures to satisfy ethical standards as well.^{20,21}

Certain innovations such as Electronic Health Records where pictures and different health data are available, as well as teleconferences at extremely little bandwidth enable remote healthcare provision by the Medical Data Acquisition Unit (ReMeDi).²¹

A smartphone is transformed into a portable diagnostic laboratory, where medical decision support algorithms are used to deliver an extensive medical management solution by i-calQ, multi-country.²² Such innovation will not only work with minimal resources but also be operable due to their user-friendly nature and easy access.

Marriott et al, (2012), assess the processes to effectively develop frugal technology-based surgical tools the results favoured the methodology where the production was done in phases, initiating from research and collaboration with surgeons working in low-resource settings and with stakeholders. In this study, the existing resources were estimated and an experimental gasless laparoscope was devised that was tested on cadaveric surgery. The study concludes that the approach to frugal innovation must include prior research and collaboration to ensure standardized efficacy in low-income countries.²³

Integration of Big Data and AI Application

In the year of 2015, a resolution was adopted by WHO state members, which was regarding the crucial role of definitive surgical procedures and the number of deaths in low middle income countries. The death toll due to lack of effective surgical implementation surpasses the number of deaths combined by malaria, tuberculosis and HIV per anum.²³ AI could potentially be used to explore insights and patterns across a population where human

intelligence is constrained; it has a role in redefining healthcare institutions while assisting clinical decision-making. Regarding data and expertise in technology, low- and middle-income nations, have a diverse set of countries. Brazil, India, China, South Africa, and Turkey, possess substantial datasets at the country and organizational levels, as well as technological resources to execute technological developments.^{24 24}.

Artificial Intelligence systematically deployed to address concerns within the area of the NSOAPs (National Surgical, Obstetric, and Anesthesia Planning) paradigm can improve process management. NSOAPs can be applied in low- and middle-income countries to construct specific strategies for specific countries considering the available resources to enhance their surgical system across six functional domains of a health system that are: workforce, government, funds, provision of services, facilities, and data management.²⁴

Shaanika et al, (2019) conducted a qualitative study to justify the fact that supports the acquisition of big data in low-middle-income countries. The case of Namibia was studied and it proposes a model that tackles all the identified hindering factors in accessing patient information such as management of big data, monopoly of technology, networking and communicative issues, and lack of compliant policies. The proposed model was a mobile system-assisted technology that aids in easy access and accusation of big data in a minimal resources setting.²⁵ This innovation is a big source of avoiding workforce burnout and transferring data from hardcopy to softcopy simplifies the accessibility issue.

Equipment Access

Obtain and distribute adequate and cheap surgical technology equipment customised to the unique demands of LMICs. This might include simple, low cost, and long-lasting technologies ideal for resource-constrained environments.²⁶

Telemedicine and connection

The use of telemedicine networks to improve connection in rural places enables remote consultations, coaching, and even tele-mentoring from professionals located abroad, assisting local surgeons in working efficiently through sophisticated technologies.

Adoption of incentives

Promote policies that encourage healthcare organizations and government bodies to embrace and incorporate innovative technology through grants, or incentives.²⁷

Empowering Research

Encourage and support research activities to study the impact and efficacy of technology in surgical practice inside LMICs. Data collection and results may be used to justify investments and drive future improvements.²⁸ Utilization and acquisition of Big data is suggested to be of utmost importance to amplify the production in this area of interest.²⁹

Discussion

The incorporation of surgical tech tools in health care practice requires joint efforts while Pakistan which is also considered a low- and middle-income country has made tremendous improvements despite limited resources. The collaboration and utilisation of frugal innovations can be seen in multiple centres here. Sialkot is the most known city that has exceeded the expectations in production of disposables, including disposable laparoscopes.¹²

Virtual reality and full-fledged procedural simulations are too pricey. A collaboration between the National University of Science and Technology and MIS (management information system). Virtual Lab Smart Sim, Pakistan's first indigenously created simulator, was inspired by the Holy Family Virtual Lab. This comprises pre-exercise teaching, run-time assistance, surgical films of various circumstances, and post-exercise evaluation. This review focussed on the many obstacles, prospects, and critical interventions that are necessary for the effective implementation of digitalization in the healthcare system in LMICs. Considering the immense potential for current surgical technologies to transform the delivery of healthcare, their implementation in LMICs confronts considerable challenges due to a lack of infrastructure, human capital, and inadequate resources. To address these difficulties, various entities, including healthcare institutions government and non-governmental bodies, and foreign partners, must work together. Building capacity through intended education and training initiatives, building infrastructure, and collaborative partnerships are critical for overcoming hurdles to effective surgical deployment of technology in low-income communities of the world.

Future intents/recommendations

Undertaking research projects for particularly low and middle socioeconomic regions of the world in order to better comprehend the real-world implications and challenges related to application of surgical technologies

Anticipating possible subsequent developments in surgery and their likely influence on these nations' healthcare systems, it is necessary to investigate the government actions and policy structures that are

required for incorporating modern surgical technology into health delivery facilities of low-resource countries.

Evaluating effective methods of collaboration between international organizations, high-income nations, and local stakeholders to promote the use of modern surgical technology is also recommended.

Understanding the contribution of private-sector alliances for rendering these innovations affordable and accessible in limited-income nations is a necessary requirement and creating strategies to facilitate the transfer of skills and knowledge from high-income established states to developing nations will ensure long-term effective implementation.

Limitations

This review extracted literature from three search engines which included Google Scholar, Web of Science, and PubMed, however, another engine should also be used in future studies to gather more comprehensive data. The review does not specify surgical procedures nor does it focus on the specification of tools that can be incorporated into future studies to gain extensive knowledge regarding procedure-related application of technological tools. Nevertheless, the study primarily gathers data that dictates the general hindrances and opportunities in low to middle income countries regarding digital advancements in surgery thus is limited to the context of the study.

Conclusion

The review stresses the incorporation of surgical tools in health care practice requires joint efforts from government and international communities that are working for health and well being of low-middle income countries. The incorporation of frugal innovation, dissemination of knowledge, continuous education and accusation of digitalisation in health care set ups, establishment and maintenance of infra-structured required for installation and functioning of digital machinery and financial help are the key components that needs special consideration for effective implementation of innovation in surgical practise.

Disclaimer: None.

Conflict of Interest: None.

Funding Statement: None.

References

- Richter R. Stanford-led study underscores huge gap between rich, poor in global surgery. News release. The Stanford Medicine News Center. [Online] 2016 [Cited 2024 April 15]. Available from URL: <https://med.stanford.edu/news/all-news/2016/02/study-underscores-surgery-gap-between-rich-poor-countries.html>
- The World Bank. World Bank Country and Lending Groups. [Online] 2021 [Cited 2024 April 15]. Available from URL: <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>.
- Statista. Distribution of financing sources of total health spending worldwide in 2019, by country income groups. [Online] 2023 [Cited 2024 April 15]. Available from URL: <https://www.statista.com/statistics/1325511/sources-of-health-spending-worldwide-by-country-income-groups/>.
- Stephens CQ, Ashok A, Ameh EA, Swaroop M, Nwomeh BC, Yang E, et al. Utilizing Technology for Global Surgery: A Survey of the West African College of Surgeons. *J Surg Res* 2018;232:202-8. doi: 10.1016/j.jss.2018.05.084.
- Guérard-Poirier N, Beniey M, Meloche-Dumas L, Lebel-Guay F, Misheva B, Abbas M, et al. An Educational Network for Surgical Education Supported by Gamification Elements: Protocol for a Randomized Controlled Trial. *JMIR Res Protoc* 2020;9:e21273. doi: 10.2196/21273.
- Nicolosi F, Rossini Z, Zaed I, Koliyas AG, Fornari M, Servadei F. Neurosurgical digital teaching in low-middle income countries: beyond the frontiers of traditional education. *Neurosurg Focus* 2018;45:E17. doi: 10.3171/2018.7.FOCUS18288.
- Eyob B, Boeck MA, FaSiOen P, Cawich S, Kluger MD. Ensuring safe surgical care across resource settings via surgical outcomes data & quality improvement initiatives. *Int J Surg* 2019;72S:27-32. doi: 10.1016/j.jisu.2019.07.036.
- Shahabuddin S, Hashmi S, Khan Y, Sami SA. Paradigm shift in the surgical training: The era of innovation, simulation and beyond. *J Pak Med Assoc* 2021;71(Suppl 1):s33-7.
- Chidambaram S, Erridge S, Leff D, Purkayastha S. A randomized controlled trial of skills transfer: from touch surgery to laparoscopic cholecystectomy. *J Surg Res* 2019;234:217-23. doi:10.1016/j.jss.2018.09.042.
- Pakistan Kidney & Liver Institute and Research Centre (PKLI&RC). About Robotic Surgery. [Online] 2020-2024 [Cited 2024 April 15]. Available from URL: <https://pkli.org.pk/robotic-surgery/>.
- Sakhawat Z, Basit J, Abbas SM, Saeed S, Shaikh OA, Batool Z, et al. Advancement in endoscopy and its usage in Pakistan for therapeutic and diagnostic purposes. *Int J Surg. Glob Health* 2023;6:e0260.
- ZAFAR A. Minimal access surgery in Pakistan: Role of virtual reality simulation in training. *Isra Medical Journal* 2014;6:183-4.
- Bolton WS. Improving Surgical Outcomes in Low and Middle-Income Countries through Surgical Technology Innovation, PhD thesis. In: Jayne D, Cundill B, Scott J, Supvs. Leeds, UK: University of Leeds; 2022. [Online] 2022 [Cited 2024 April 15]. Available from URL: <https://etheses.whiterose.ac.uk/31967/>
- Ramadurai KW. 3-Dimensional Printing and Bio-Based Materials in Global Health: an Interventional Approach to Addressing Healthcare Disparities in Low and Middle-Income Countries. [Online] 2017 [Cited 2024 April 15]. Available from URL: <https://dash.harvard.edu/handle/1/33825836>.
- Bolton WS, Aruparayil N, Quyn A, Scott J, Wood A, Bundu I, et al. Disseminating technology in global surgery. *Br J Surg* 2019;106:e34-43. doi: 10.1002/bjs.11036.
- Reddy CL, Peters AW, Jumbam DT, Caddell L, Alkire BC, Meara JG, et al. Innovative financing to fund surgical systems and expand surgical care in low-income and middle-income countries. *BMJ Glob Health* 2020;5:e002375. doi: 10.1136/bmjgh-2020-002375.
- Lee SM, Lee D. Opportunities and challenges for contactless healthcare services in the post-COVID-19 Era. *Technol Forecast Soc Change* 2021;167:120712. doi: 10.1016/j.techfore.2021.120712.
- Kaslow DC. Overcoming Barriers to Medical Innovation for Low

- Resource Settings. In: Dutta S, Lanvin B, Wunsch-Vincent S, eds. *The Global Innovation Index 2019: Creating Healthy Lives—The Future of Medical Innovation*, 12th ed. Geneva, Switzerland: Cornell University, INSEAD, and The World Intellectual Property Organization (WIPO), 2019; 149-56.
19. Leonard E, de Kock I, Bam W. Barriers and facilitators to implementing evidence-based health innovations in low- and middle-income countries: A systematic literature review. *Eval Program Plann* 2020;82:101832. doi: 10.1016/j.evalprogplan.2020.101832.
 20. Sharma D. Frugal Surgical Innovations are the Need of the Hour. *The Physician* 2023;8:1-6. DOI 10.38192/1.8.2.8.
 21. Park A, Swanstrom L, Price R. Frugal innovation: key to surgical innovation. *Surg Innov* 2018;25:549. doi:10.1177/1553350618818946.
 22. Bhatti YA, Prime M, Harris M, Wadge H, McQueen J, Patel H, et al. The search for the holy grail: frugal innovation in healthcare from low-income or middle-income countries for reverse innovation to developed countries. *BMJ Innov* 2017;3:212-20. doi: 10.1136/bmjinnov-2016-000186.
 23. Reddy CL, Mitra S, Meara JG, Atun R, Afshar S. Artificial Intelligence and its role in surgical care in low-income and middle-income countries. *Lancet Digit Health* 2019;1:e384-6. doi: 10.1016/S2589-7500(19)30200-6.
 24. Reddy CL, Mitra S, Meara JG, Atun R, Afshar S. Artificial Intelligence and its role in surgical care in low-income and middle-income countries. *Lancet Digit Health* 2019;1:e384-6. doi: 10.1016/S2589-7500(19)30200-6.
 25. Shaanika I, Iyamu T. The use of mobile systems to access health care big data in the Namibian environment. *Electron J Inf Syst Dev Ctries* 2020;86:e12120. DOI: 10.1002/isd2.12120.
 26. Makohlisoa S, Klaiber B, Sahlib R, Tapouhc JRM, Amvenec SN, Stollid B, et al. Medical technology Innovationfor a sustainable impact in Low-and Middle-Income countries: a holistic approach. *EngrXiv* 2020. doi: 10.31224/osf.io/2dytg. [Preprint]
 27. Hoffer-Hawlik MA, Moran AE, Burka D, Kaur P, Cai J, Frieden TR, et al. Leveraging Telemedicine for Chronic Disease Management in Low- and Middle-Income Countries During Covid-19. *Glob Heart* 2020;15:63. doi: 10.5334/gh.852.
 28. Rajaratnam V, Rahman NA, Dong C. Integrating instructional design principles into surgical skills training models: an innovative approach. *Ann R Coll Surg Engl* 2021;103:718-24. doi: 10.1308/rcsann.2020.7132.
 29. Dara D. Current status of surgical training and practice: Australasian regional perspective. *Australas Med J* 2023;16:582-4. doi: 10.21767/AMJ.2023.3945.

DISCLAIMER

Articles published in JPMA and Supplements of JPMA do not represent the views of the editor or editorial Board. Authors are solely responsible for the opinions expressed and the accuracy of the data.

The contribution of each author towards the published research included in this supplement is the responsibility of the authors and their institutions. It is expected to be in accordance and compliance with the ICMJE Guidelines.

Any questions/queries raised by readers should be directed to the corresponding author.