Editorial

ROLE OF INNOVATION IN SURGERY: HISTORICAL PERSPECTIVE AND A WAY FORWARD IN LOW-RESOURCE SETTINGS

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Innovation in operative techniques and instruments is the lifeline of surgical advancement, as surgery has always stood at the intersection of skill, science, and technology. Historically, innovation has played a pivotal role in the evolution of surgical instruments and techniques, refining them from crude tools and basic open procedures to complex and highly advanced minimally invasive and robotic techniques. Thus, innovation has shaped every aspect of surgical care. This editorial highlights key historical milestones, recent advancements, and future prospects of innovation in surgery, emphasizing its critical role in improving patient outcomes, surgical safety, and expanding the scope of procedures—especially in low-resource settings. Although the history of surgery dates back to ancient times, early surgical practices were extremely limited due to poor understanding of anatomy, lack of infection control, and absence of anesthesia. Past surgeons like Hippocrates, Al-Zahrawi and many others innovated many surgical instruments and techniques.[1,2] Later, landmark innovations—such as antisepsis by Joseph Lister, ether anesthesia by William Morton, and the discovery of antibiotics by Alexander Fleming—revolutionized surgical safety and feasibility [3]. John Hunter is recognized as the father of modern surgery due to his introduction of evidence-based and systematic surgical innovations.[4] The development of sutures, sterilization techniques, and blood transfusion further expanded the possibilities of surgery. Throughout the early 20th century, open surgery dominated, gradually becoming more refined with improved anatomical knowledge and surgical physiology. By the late 20th century, new innovations like minimally invasive surgical techniques i.e. laparoscopic and thoracoscopic surgeries, brought a paradigm shift by improving the patient outcomes in terms of reduced trauma, faster recovery, safety, cost-effectiveness, and cosmetic results .[5] Today's surgical landscape is increasingly shaped by ongoing widespread adoption of robotic systems, computer-assisted navigation, and image-guided interventions that enhance precision and control[6.] Technologies such as Artificial Intelligence (AI), Augmented Reality (AR), and 3D printing are now progressively integrated to preoperative planning, intraoperative guidance, and postoperative care—particularly in complex surgeries.[7,8] Telemedicine and virtual surgical training have opened new doors, especially for surgeons in low-resource settings, by providing real-time mentorship and continuous professional development.[8] Looking ahead, surgical innovation is set to deliver personalized, data-driven, and patient-centered care. AI-powered platforms will likely assist in clinical decision-making, risk prediction, and real-time intraoperative navigation with minimal human input. [7,8] Emerging fields such as regenerative medicine, tissue bioprinting, and nanotechnology may soon enable repair or replacement of complex structures like the esophagus in long gap esophageal atresia or corrosive injuries, colon

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in extensive Hirschsprung's disease or short gut syndrome, and diaphragm in congenital diaphragmatic hernias, the challenges previously considered nearly insurmountable. [9,10] Fully autonomous robotic systems, capable of executing complex tasks independently, represent a future possibility. A key challenge is preserving the human element in surgical care as we adopt AI-driven and autonomous technologies. Ensuring equitable access to innovation is also crucial; advanced tools such as robotic surgery are often costly and infrastructure-dependent, posing significant barriers to their usage in low-resource settings. Another challenge is preparing future surgeons to balance technology with clinical judgment and empathy. The long learning curves and risk of over-reliance on technology must be addressed. These issues can be mitigated through cost-effective innovations, telesurgery, and mentorship-based training. [7,8] Surgeons must not only master new tools but also apply them with compassion and clinical wisdom. The real challenge is how to make these innovations more useful and practical in third world countries like Pakistan, which have large populations and limited infrastructure. In low-resource settings, innovation assumes a different but equally important role. Minimally invasive surgeries (laparoscopic/endoscopic) can reduce hospital stays, speed up recovery, and decrease complications, thus resulting in early discharge of patients, so helping in reducing the burden on healthcare systems in such settings. Development of low-cost surgical kits, utilizing solar-powered sterilizers, and using portable anesthesia devices can enable safe surgeries in remote areas. Telementoring platforms can train local surgeons, reducing dependency on visiting specialists[7,8.] Low-cost simulators and box trainers can help build technical capacity. low cost systems are now introduced by countries like China, India and Pakistan and more widely utilized. AI-powered portable imaging and diagnostic devices can improve early detection of surgical diseases and help in preoperative planning, reducing unnecessary referrals and delays from periphery to tertiary care hospitals. AI-driven logistics and inventory systems can help manage limited surgical resources more efficiently. In the future, simplified and affordable robotic systems may perform essential procedures even in peripheral health facilities. In this digital age, data privacy, device regulation, and informed patient consent are major ethical concerns that must be addressed in implementation strategies especially in resource constrained settings where ethical practices are poorly observed. Strong ethical, legal, and regulatory frameworks are essential to ensure safe and equitable implementation of surgical innovations.[11] So surgical innovations, if adapted to simplicity, affordability, and local relevance, can significantly improve surgical capacity, safety, and outcomes in underdeveloped countries. It is suggested that future efforts should prioritize cost-effective, durable, and scalable solutions, combined with local training programs, to bridge the surgical equity gap globally, regionally and locally. The true success of Innovation lies in mindful adoption. The IDEAL framework (Idea, Development, Exploration, Assessment, Long-term follow-up) provides a structured method for safe introduction and evaluation of surgical innovations .[12] Surgeons, especially those from resource-constrained countries like Pakistan, should always be prepared and develop the habit of introducing new ideas, innovative techniques, and cost-effective solutions to make advanced surgical technologies feasible in local settings. However, they must receive hands-on training through simulation and mentorship before integrating these new tools into their clinical practice .[13] Surgical innovation has transformed the field from basic manual procedures to advanced, technology-driven care. As we enter an era of personalized and data-guided surgery, it is important that progress should remain focused on patient needs, ethical considerations, and global perspective. For low-resource settings like third

world countries and rural areas, cost-effective and accessible innovations are pivotal. The journey of surgical innovation is ongoing so every surgeon should make habit of innovating new techniques and instruments feasible to their local setting. By working together and introducing new innovations, surgeons, researchers, and technologists can improve patient's safety, expand treatment options, and enhance quality of life even in resource constrained settings.

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