Enhancing surgical capacity in the low- to middle-income countries: An initial report of a Global Surgery Partnership Initiative in pediatric and reconstructive urology using a mixed-method approach

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ABSTRACT

Introduction: Pediatric and adult reconstructive urology remain underrepresented in global surgical efforts, despite their critical role in restoring genitourinary function. This global surgery initiative aimed to address the gap in specialized urologic care in low- to middle-income countries (LMICs) through a longitudinal, mentorship-based approach integrating augmented reality (AR) telementoring.

Methods: This report describes an approach used to enhance global surgical expertise in LMICs and summarizes data documenting impact. A Global Surgery Partnership

KEY MESSAGES

- The Global Surgery Partnership Initiative successfully built reconstructive urology capacity in LMICs through a sustained, mentorship-driven model emphasizing collaboration, continuity, and context-specific adaptation.
- A mixed-method approach — integrating preoperative case planning, hands-on surgical mentoring, postoperative coaching, and AR telementoring — resulted in measurable improvements in mentee surgical confidence and technical skill.
- AR telementoring proved feasible in low-resource settings and holds strong promise for scalable, sustainable remote surgical training in future global health initiatives.

Initiative was launched by an academic surgeon from the University of Toronto to address the lack of specialized pediatric and reconstructive urologic training. Through collaboration with local institutions in the Philippines and Vietnam, the program employed a mixed-method approach that delivered longitudinal mentorship, combining virtual case conferences, in-person surgical mentoring, pilot of AR-supported telementoring, and continuous postoperative coaching. Patient outcomes were assessed and mentees self-reported pre- and post-intervention surveys evaluating comfort and technical understanding. Descriptive statistics and paired t-tests were used to analyze outcomes.

Results: Thirty-eight pediatric and adult reconstructive urology cases were performed. Over time, operative times and length of stay decreased, with low complication rates (6/38, 12.7%) and Clavien-Dindo ≥3 complications (3/38, 8%). Mentee comfort and understanding significantly improved (mean comfort score: 3.06 to 6.77; technical understanding: 4.77 to 8.43; $p<0.001$). AR-assisted mentoring, introduced in 2022 and expanded in 2024, showed feasibility, with further enhanced intraoperative feedback and sustainability.

Conclusions: This structured, mixed-method model effectively improved surgical competencies and system-level capacity in LMICs. Unlike short-term missions, this initiative emphasized continuity, adaptability, and sustainability. It presents a scalable framework for integrating reconstructive urology into global health programs while leveraging AR to overcome geographic and resource limitations.

INTRODUCTION

Reconstructive urology, crucial for restoring function and structure to the genitourinary tract, is vital within global surgery initiatives, especially in low- and middle-income countries (LMICs) where specialized care is scarce. (1, 2). This subspecialty, encompassing both pediatric and adult urology, addresses diverse conditions from congenital anomalies in children—such as hypospadias and neurogenic lower urinary tract dysfunction—to adult complications like urethral strictures and urinary diversion reconstruction (2-4). The evolution of this field has led to increased training opportunities, yet many LMICs still face substantial barriers such as insufficient training, lack of surgical infrastructure, and resource limitations (5-7). However, these challenges also present opportunities for innovative teaching methods and collaborative capacity-building initiatives that are crucial for sustainable healthcare development.

As the field of global surgery continues to evolve, there is an increasing recognition of the need to integrate reconstructive urology into comprehensive surgical care programs (8). This integration not only addresses immediate surgical needs but also contributes to the long-term development of surgical expertise in resource-limited settings (1, 6).

The objective of reporting initial experiences in global reconstructive urology partnership initiative is to highlight the significance of these efforts and their transformative potential on healthcare systems in LMICs. Specifically, such reports focus on the impact of mentoring and training local surgeons, which enhances surgical care and builds long-term local expertise. By sharing these experiences, the report aims to shed light on the practical challenges, the learning outcomes of mentees, and the overall effectiveness of mentorship partnership initiative in these settings (1, 2, 6). The study aimed to document measurable improvements in surgical skills and

to establish a train-the-trainer approach. Immediate impacts included enhanced surgical capacity and improved patient outcomes through innovative educational strategies.

METHODS

This report describes an approach used to enhance global surgical expertise in LMICs and summarizes data documenting impact. A Global Surgery Partnership Initiative was launched by an academic surgeon from the University of Toronto (REB approval #1000079227). In partnership with IVUMed and Children's Hospital 1 in Ho Chi Minh City, the initiative targeted the lack of pediatric and reconstructive urologic training in LMICs. The initiative employed a sequential mixed-methods design to evaluate the effectiveness of remote longitudinal post-operative coaching using mobile communication platforms. The model employed a sequential mixed-methods design, combining virtual case planning, in-person surgical training, post-operative coaching. In later phase (REB approval # SL-21315), piloted intraoperative telementoring using augmented reality (AR) using Vuzix® M400 smart glasses (Vuzix Corp., Rochester, NY, USA; https://www.vuzix.com/) , with the goal of sustainably training surgeons in underserved regions (9). All patients and mentees provided informed consent, including agreement for AR-assisted and remote mentoring interventions (REB approval #1000079227 and #SL-21315).

Unlike traditional surgical missions focused solely on short-term service delivery, this initiative adopted a longitudinal, mentorship-based model beginning months before each surgical mission. “Trainee hospitals” in the Philippines and Vietnam identified complex reconstructive urology cases and presented them in virtual preoperative case conferences to the mentor team. Pre-mission planning included virtual case conferences. These sessions enabled detailed case-by-case assessments, diagnostic workup reviews, operative planning, and logistical preparations. Discussions routinely addressed context-specific resource limitations and strategies for adaptation; faculty brought essential supplies and suggested alternative techniques to suit the local setting. Multiple preoperative case conferences were held per cycle, creating a platform for iterative learning and preparation. Informed consent was obtained from patients, including consent for AR-assisted telementoring.

The in-person surgical phase included operative workshops where local trainees served as primary surgeons or first assistants under direct mentorship. Rather than merely observing, trainees engaged in hands-on practice with intraoperative guidance tailored to the realities of their health system. Faculty modeled real-time adjustments based on resource availability, enhancing the relevance and applicability of training. This approach fostered the development of technical proficiency and clinical judgment while building confidence among local surgeons. Following the in-person training, ongoing support was sustained through regular communication via WhatsApp and Viber. These communication platforms facilitated real-time consultation, case discussions, and postoperative management guidance. Additionally, the initiative specifically piloted the use of smart glasses, provided in-kind by Ohana One International Surgical Aid, to explore the feasibility of remote surgical mentoring. The integrated AR-assisted telementoring using Vuzix® M400 smart glasses (Vuzix Corp., Rochester, NY, USA; https:// www.vuzix.com) allowed mentors to view live surgeries from the operating surgeon’s perspective and provide step-by-step intraoperative feedback remotely. The AR component was piloted in the Philippines, starting with simpler procedures and gradually incorporating more complex cases. This remote

mentoring model proved essential in enabling local surgeons to refine their skills within their own practice settings, even in the absence of visiting mentors.

Beyond the intraoperative period, the program emphasized longitudinal follow-up, supporting mentees in the management of postoperative complications and in developing care plans for similar future cases. This continuous mentoring ensured high standards of patient safety and reinforced the learning cycle. Estimated resource needs included 4–10 hours per month of virtual mentorship, 1–2 annual visits per site, and costs of approximately $5000–8000 per mission. AR equipment costs averaged $2000–2500 per unit, with additional investment in connectivity infrastructure.

Data were collected on various metrics, including age, sex, type of case (major or mid-minor), operative times, length of stay, complications, and follow-up durations. Surgical cases were classified as major, intermediate, or minor based on procedural complexity, organ reconstruction required, and expected operative time. Pre- and post-intervention assessments were made on the mentees' comfort level and understanding of surgical techniques using Likert-scale survey standardized tools. Statistical analysis was conducted with descriptive statistics to summarize case characteristics and peri-operative outcomes. Furthermore, paired t-tests was used to compare pre- and post-intervention scores for global surgery comfort level and technical understanding across different years and case types. This method was chosen to evaluate the impact of the training interventions on mentee knowledge and skills effectively.

RESULTS

Case characteristics and outcomes

Between 2021 and 2024, a total of 38 major pediatric and adult reconstructive urology cases were completed under this longitudinal mentorship model. Most patients were male (78.9%) with an average age of 16.8 years. The majority of procedures (73.7%) were major cases (Table 1). Over the years, the complexity and number of cases increased, culminating in 19 cases in 2024 alone, indicating the growing scope and impact of the partnership initiative. Appendix A summarizes the cases performed over the year.

The surgical outcomes revealed a decrease in mean operative times from 234.0 minutes in 2021 to 143.33 minutes in 2024, demonstrating improved efficiency as the initiative progressed. The length of hospital stay also decreased over the years, with an average stay of 2.7 days, reflecting enhanced recovery protocols and surgical expertise. The overall complication rate was (6/38) 12.7%, the majority of which was surgical site hematoma, seroma, and site infections, with a low incidence of major complications (Clavien-Dindo >=3), such as repair dehiscence and urine leak needed additional procedures occurring in (3/ 38) 8% of the cases. This indicates a favorable outcome, given the complexity of the surgeries performed.

Experience and mentee feedback

Mentee demographics included age ranged from 28 to 45 years, with varying levels of prior surgical experience of mid-career general urologists with 2–10 years of practice. The personal experience of the surgical team and the mentees involved in the partnership initiative was highly positive. The mentorship and training provided substantial improvements in both comfort and technical knowledge among the mentees. Statistically significant improvements were noted in the mentees' comfort levels and technical understanding before and after the initiative across all years. The paired t-tests indicated significant increases from a mean pre-surgery comfort level of

3.06 to 6.77 post-surgery, and a pre-surgery technical understanding of 4.77 to 8.43 post-surgery, both with p-values < 0.001, reflecting highly significant improvements. For major cases, the increase in mentee comfort level was particularly notable in 2021, with the mean scores surging from 3.0 to 8.2 ($p < 0.001$). Similarly, technical understanding improved from a mean of 5.0 pre-surgery to 8.40 post-surgery ($p = 0.001$). These trends continued consistently over the subsequent years, with all p-values remaining significant (<0.05), illustrating robust and sustained gains in skills and confidence among the mentees involved (Table 2).

For medium and minor cases, where detailed feedback was available from 2022 and 2024, significant improvements were also recorded (Table 3). In 2022, the mentee comfort level improved from 5.75 to 8.5 ($p = 0.010$), and technical understanding from 7.25 to 9.0 ($p = 0.006$). In 2024, improvements were evident from a pre-surgery comfort level of 4.70 to 8.10 post-surgery ($p = 0.001$) and a technical understanding increase from 6.9 to 8.70 ($p = 0.001$).

Initial AR-assisted telementoring outcomes

The application of AR-assisted telementoring in the Global Surgery initiative has significantly improved surgical training and outcomes over the years. In 2022, AR assistance was introduced in two major cases with a mean OR time of 390.0 (SD 212.13) minutes and no immediate or long-term complications. In 2024, the expansion of AR-assisted cases to four further demonstrated the scalability and effectiveness of this technology in training environments (Table 4). The data show a consistent improvement across various metrics of mentee feedback, underscoring the efficacy of AR in surgical training (Table 5).

DISCUSSION

The Global Surgery Partnership Initiative, implemented in the Philippines and Vietnam, focusing on pediatric and adult reconstructive urology, has shown notable success in enhancing local surgical capacities through a unique blend of traditional and innovative educational methods. This approach leverages the advantages of real-time in-person and remote guidance and feedback that global surgery for the University of Toronto offers, which is particularly valuable in regions where specialized surgical training and resources are scarce (6). Moreover, the project emphasizes sustainability through its train-the-trainer approach and the development of sustained local capacity (10). The time and cost burden of establishing and maintaining such programs is significant but manageable. Each in-person mission requires logistical coordination, funding for travel, and reliable tech support. Continued partnerships and local champion engagement are essential for long-term sustainability.

The long-term goal was to develop a local reconstructive urology fellowship program that promotes long-term self-sustainable capacity in the Philippines. This strategy ensures the longevity and scalability of training efforts, allowing knowledge and skills to be perpetuated within the community, thereby fostering a self-sufficient educational system (10, 11). Such models are crucial for lasting impact in global surgery initiatives, especially in LMICs where ongoing support and resources are often limited (12, 13). This initiative's structured model—encompassing preoperative planning, hands-on intraoperative mentorship, AR-supported telementoring, and postoperative follow-up—demonstrates a scalable and sustainable alternative to one-off surgical missions. By prioritizing capacity building and long-term skills transfer, it offers a replicable framework for enhancing surgical expertise in resource-limited settings through meaningful global partnerships.

The pilot integration of AR-assisted telementoring in the Global Surgery Partnership Initiative has proven to be a transformative approach for enhancing surgical education and patient outcomes in low- and middle-income countries. AR technology allows for real-time, hands-on training without the physical presence of expert surgeons, overcoming geographical and resource-related barriers (14, 15). This method not only enhances the learning experience but also provides a scalable model for surgical training, particularly in remote and underserved regions (16). The success observed in the pilot implementation suggests that AR can significantly enhance the precision, efficiency, and outcome of surgical procedures (17). By providing immediate visual feedback and guidance, AR assists mentees in refining their techniques and understanding complex surgical procedures in real-time. The use of AR in medical education aligns with emerging trends that suggest this technology can significantly boost the precision and efficiency of the Global Surgery partnership initiative, enhancing learning outcomes across various medical disciplines (18, 19).
However, the project faced several challenges, such as logistical difficulties in deploying high-tech solutions like AR in remote areas and securing continuous funding to support the necessary infrastructure. The foremost is the technological requirement that might not be readily available in all settings, particularly in resource-constrained environments (20). Issues such as compatibility with existing medical equipment, the need for stable and high-speed internet connections, and the initial cost of setting up AR systems pose significant barriers (21). Furthermore, while AR offers considerable advantages in training and procedural guidance, it cannot fully replicate the tactile feedback and hands-on experience of traditional surgical training. There is also a learning curve associated with the use of AR technology, requiring additional training and adaptation by the surgical teams. These challenges highlight the complex landscape of implementing advanced technologies in resource-limited settings but also underscore the potential for innovative solutions to overcome these barriers.

The outcomes of this pilot study are valuable for informing future global health initiatives. Beyond surgical outcomes, the project demonstrates the practicality of integrating continuous mentorship with AR-supported telementoring. Likewise, the use of AR technology with traditional mentoring underscores the importance of building local capacities to improve healthcare delivery in underserved areas (8, 10). As global surgery continues to evolve, the insights gained from this project can help guide similar Global Surgery initiatives aiming to enhance surgical care and education worldwide (10). To address these challenges and optimize the benefits of technology and remote communications for intraop AR-assisted telementoring as well as remote post-operative continuous coaching and communications using WhatsApp or Viber. Future initiatives should focus on developing more adaptable and cost-effective technology solutions that are suitable for low-resource settings. Partnerships with technology providers and continued funding support can facilitate the broader deployment of such communication technologies (21).

Moreover, ongoing research and feedback mechanisms should be implemented to continuously refine AR applications in medical training (19). Establishing a standardized protocol for a longitudinal sustainable Global Surgery Partnership Initiative program with the incorporation of continuous post-operative coaching and possibly the initiation of AR-assisted telementoring could further enhance its effectiveness and ensure consistent training outcomes across different regions.

This study has some limitations, such as the lack of a formal control group limits comparative analysis and the ability to draw definitive conclusions about the program's impact. Furthermore, the combined use of traditional in-person mentoring and AR-based telementoring makes it difficult to isolate the specific effect of augmented reality technology. Logistical challenges such as internet connectivity issues and equipment compatibility affected the consistency of remote interactions for intraoperative telementoring. The implementation of AR also required additional training for mentees, introducing a learning curve that may have influenced initial performance. Thus, it is recommended to give brief orientation sessions and hands-on trials with hardware before live use to minimize the learning curve. Future efforts may explore standardized AR training modules and mentorship toolkits to support broader deployment in similar LMIC contexts. Finally, the findings from this initiative may not be generalizable to all LMICs due to variations in infrastructure, institutional readiness, and available local partnerships.

CONCLUSIONS

In conclusion, the Global Surgery Partnership Initiative improved surgical capabilities within the Philippines and Vietnam and set a precedent for the potential of technology-enhanced medical education in global health. The project's focus on sustainable education and empowerment of local healthcare professionals offers a replicable model for other LMICs facing similar healthcare challenges. The continued expansion of such partnership initiatives is essential for integrating reconstructive urology into global health strategies, ultimately leading to improved patient care and healthcare systems in resource-constrained environments. Furthermore, the pilot use of AR-assisted telementoring holds significant promise for revolutionizing surgical training and care, particularly in regions that lack specialized training facilities. While early results are promising, future comparative studies isolating AR's specific contribution are necessary to optimize and tailor global surgical training frameworks.

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FIGURES AND TABLES

Table 1. Summary of all cases performed in Global Surgery Partnership Initiatives from 2021–2024

Year	Total cases	Age, yrs, mean (SD)	Pediatric, n (%)	Sex (nale), n (%)	Major cases, n (%)	Medium and minor cases, n (%)	Overall complications (%)	Complication Clavien-Dindo ≥3	Operative time, minutes, mean (SD)	Length of stay, days, mean (SD)	Followup duration, months, mean (SD)
2021	5	21.2 (19.8)	3 (60%)	5 (100%)	5 (100%)	–	–	–	234.0 (53.7)	2.8 (1.9)	75.2 (9.3)
2022	6	29.5 (17.4)	2 (33.3%)	5 (83.3%)	4 (66.7%)	2 (33.3%)	–	–	168.8 (177.6)	3.7 (3.0)	28 (0.5)
2023	8	17.5 (18.1)	6 (75%)	7 (87.5%)	8 (100%)	–	1 (12.5%)	1 (12.5%)	140.0 (110.2)	2.8 (1.7)	16 (1.0)
2024	19	11.4 (10.7)	16 (84.2%)	13 (68.4%)	11 (57.9%)	8 (42.1%)	5 (25%)	2 (10%)	143.33 (124.48)	2.2 (2.5)	6.0 (2.7)
Total	38	16.8 (15.6)	30 (78.9%)	30 (78.9%)	28 (73.7%)	10 (26.3%)	6 (12.7%)	3 (8%)	158.5 (126.7)	2.7 (2.3)	20.1 (22.5)

Table 2. Summary of mentee feedback for major cases									
Year	**Total major cases**	**Number of nentee**	**Prior number done on similar case**	**Pre-global surgery comfort level**	**Post global surgery comfort level**	**p**	**Pre-global surgery technique understanding**	**Post-global surgery understanding**	**p**
2021	5	5	0.4 (0.89)	3.0 (0.71)	8.2 (0.45)	<0.001	5.0 (0.71)	8.40 (0.55)	0.001
2022	4	5	1.8 (0.84)	4.6 (1.52)	7.0 (1.58)	0.024	5.2 (0.84)	7.60 (1.14)	0.001
2023	8	9	1.22 (1.92)	2.44 (1.67)	5.56 (1.81)	<0.001	4.56 (1.94)	8.22 (1.39)	<0.001
2024	11	16	0.94 (1.57)	2.94 (1.88)	6.94 (1.29)	<0.001	4.69 (1.92)	8.81 (0.75)	<0.001
Total	28	31	1.06 (1.51)	3.06 (1.73)	6.77 (1.59)	<0.001	4.77 (1.65)	8.43 (1.04)	<0.001

Table 3. Summary of mentee feedback for medium to minor cases									
Year	**Total mid-minor cases**	**Number of mentees**	**Prior number done on similar case**	**Pre-global surgery comfort level**	**Post global surgery comfort level**	**p**	**Pre-global surgery technique understanding**	**Post-global surgery understanding**	**p**
2021	0								
2022	2	4	4.75 (6.95)	5.75 (1.71)	8.5 (1.29)	0.010	7.25 (0.96)	9.0 (0.82)	0.006
2023	0								
2024	8	10	6.30 (10.52)	4.70 (2.71)	8.10 (0.99)	0.001	6.9 (1.29)	8.70 (0.67)	0.001
Total	10	14	5.19 (8.93)	4.6 (2.60)	7.87 (1.45)	<0.001	6.69 (1.66)	8.94 (0.77)	<0.001

Table 4. Summary of cases piloted using AR assisted tele-mentoring

Year	Total cases	Age, yrs, mean (SD)	Pediatric, n (%)	Sex (male), n (%)	Major cases, n (%)	Medium and minor cases, n (%)	Overall complications (%)	Complication Clavien-Dindo ≥3	Operative time, minutes, mean (SD)	Length of stay, days, mean (SD)	Followup duration, months, mean (SD)
2022	2	27 (14.14)	1 (50%)	2 (100%)	2 (100%)	0 (0%)	0 (0%)	0 (0%)	390.0(212.13)	4.0 (1.41)	28. (2.2)
2024	4	24.25 (11.03)	2 (50%)	3 (75%)	2 (50%)	2 (50%)	1 (25%)	0 (0%)	155 (174.45)	7 (2.0)	10 (3.37)
Total	6	25.17 (10.72)	3 (50%)	5 (83.3%)	4 (66.67%)	2 (33.3%)	1 (16.7%)	0 (0%)	233.33 (204.91)	5 (2.0)	16.0 (9.65)

Table 5. Mentee feedback for cases piloted using AR-assisted telementoring

Year	Total cases	Number of mentees	Prior number done on similar case	Pre-global surgery comfort level	Post global surgery comfort level	p	Pre-global surgery technique understanding	Post-global surgery understanding	p
2022	2	2	1.5 (0.71)	4 (1.41)	6.50 (0.71)	0.344	6.0 (1.0)	8.50 (0.71)	0.126
2024	4	4	11.25 (16.52)	5.25 (1.71)	7.75 (1.89)	0.003	6.0 (1.15)	8.75 (0.50)	0.01
Total	6	6	8.0 (13.75)	4.83 (1.60)	7.33 (1.63)	0.002	6.0 (0.89)	8.67 (0.52)	<0.001