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Research Article

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Enhancing Surgical Capacity in Low to Middle-Income Counties: An Initiative Study of Global Surgery Experience in Pediatric and Reconstructive Urology

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ABSTRACT

Background: Global Surgery in pediatric and adult reconstructive urology plays a critical role in improving healthcare outcomes in low- and middle-income countries (LMICs).

Integrating this specialty into global health efforts, mainly through capacity building with innovative educational methods such as mixed-method in-person and piloting the augmented reality (AR)-assisted telementoring, could enhance local surgical capacities. We aim to evaluate the impact of a Global Surgery Collaborative Project that utilizes both traditional and pilot use of AR-assisted telementoring to train local surgeons in pediatric and reconstructive urology in the Philippines.

Methods: This sequential mixed-methods study assessed the efficacy and sustainability of in-person and AR-assisted remote training programs from 2021 to 2024. Data were collected and summarized for performed case characteristics, surgical information and peri-operative outcomes, mentee comfort levels, and technical understanding, which were analyzed pre- to post-mentoring differences using paired t-tests.

Results: A total of 38 major surgical cases were undertaken, with appropriate operative times and acceptable postoperative outcomes noted over the study period. Mentees demonstrated substantial gains in comfort and technical knowledge, with statistically significant improvements in both domains ($p < 0.001$). The pilot use of AR-assisted telementoring showed feasibility and safety in global surgery initiative training effectiveness and surgical precision.

Conclusion: The Global Surgery Collaborative Project improved the surgical capabilities within the LMICs but also set a precedent for the potential of technology-enhanced medical education in global health. The pilot use of AR in telementoring presents a possible scalable, effective training model that could be pursued in LMIC settings to improve local surgeons capacity and provide acceptable healthcare outcomes.

Keywords: Global Surgery, Reconstructive Urology, Telementoring, Augmented Reality, Medical Education, Low-Resource Settings

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. This subspecialty, encompassing both pediatric and adult urology, addresses diverse conditions from congenital anomalies in children—such as hypospadias and neurogenic lower urinary tract

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dysfunction—to adult complications like urethral strictures and urinary diversion reconstruction. 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. 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. This integration not only addresses immediate surgical needs but also contributes to the long-term development of surgical expertise in resource-limited settings.

The objective of reporting initial experiences in global reconstructive urology 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 not only enhances surgical care but also 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 programs in these settings.

The study aimed to document measurable improvements in surgical skills and to establish a train-the-trainer program. The long-term goal was to develop a local pediatric urology fellowship program that promotes long-term self-sustainability in the Philippines. Immediate impacts included enhanced surgical capacity and improved patient outcomes through innovative educational strategies.

Methodology

This Global Surgery Collaborative Project in LMICs, employed a sequential mixed-methods design to evaluate the efficacy and feasibility of surgical mentoring with pilot remote telementoring for training surgeons in underserved areas on pediatric and reconstructive urology techniques. The study incorporated both in-person and initiated augmented reality (AR) assisted telementoring, utilizing Vuzix® Smart Glasses technology.

Surgeons in the Philippines participated as mentees in this study. They were selected based on their interest in pediatric urology and their location within resource-limited settings. A total of 38 major cases were performed across the years 2021 to 2024. The training program was structured into two distinct phases to maximize learning and skill application among local surgeons. The in-person training involved intensive workshops and hands-on surgical sessions. These sessions were led by a visiting surgeon from the Global Surgery section, Department of Surgery, University of Toronto, focusing on essential pediatric and adult reconstructive urological procedures and safety protocols. Following this, the program also piloted the use of the AR- technology (Vuzix 400) Assisted Remote telementoring. The AR sessions were initiated for simple case appropriate and later included more complex cases surgical telementoring and case consultations. These AR sessions allowed local surgeons to apply their surgical skills under the guidance of remote supervision and provided them with real-time feedback, enhancing their practical and decision-making abilities in clinical settings.

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. Pre- and post-intervention assessments were made on the mentees' comfort level and understanding of surgical techniques using 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.

Table 1: This table provides a summary of the patient characteristics and outcomes of pediatric and reconstructive surgical cases from before 2021 to 2024

Year	Total Cases	Age in year 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)	Follow-up duration in 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: This table presents the surgical outcomes of major procedures based on survey responses, evaluating both surgeon comfort levels and their understanding of surgical techniques before and after the program

Year	Total Major Cases	Number of Mentees	Prior number done on similar case	Pre-global surgery comfort level	Post global surgery comfort level	p-value	Pre-global surgery technique understanding	Post-global surgery understanding	p-value
<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

Results

Case Characteristics and Outcomes

The Global Surgery program, spanning from 2021 to 2024, involved a total of 38 major surgical cases with a focus on pediatric and reconstructive surgery across several years. The average patient age was 16.8 years, with a notable pediatric predominance (78.9%). The majority of patients were male (78.9%), and most cases were categorized as major surgeries (73.7%). 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 program.

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 program 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 12.7%, with major complications (Clavien-Dindo >=3) occurring in 8% of the cases. This indicates a favorable outcome given the complexity of the surgeries performed.

Table 3: This table shows the surgical outcomes of mid-minor procedures based on survey responses, evaluating both surgeon comfort levels and their understanding of surgical techniques before and after the program

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-value	Pre-global surgery technique understanding	Post-global surgery understanding	p-value
<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

Experience and Mentee Feedback

The personal experience of the surgical team and the mentees involved in the program 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 program 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.

For medium and minor cases, where detailed feedback was available from 2022 and 2024, significant improvements were also recorded. 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 program has demonstrated significant improvements in 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. The data show a consistent improvement across various metrics of mentee feedback, underscoring the efficacy of AR in surgical training (TABLE XX).

Table 4: This table provides a summary of patient characteristics and outcomes for pediatric and reconstructive surgical cases in 2022 and 2024 following the application of augmented reality-assisted telementoring

Year	Total Cases	Age in year 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)	Follow-up duration in 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: This table shows the surgical outcomes of procedures performed in 2022 and 2024, based on survey responses, assessing both surgeon comfort levels and their understanding of surgical techniques following the application of augmented reality assisted telementoring

Year	Total Cases	Number of Mentee	Prior number done on similar case	Pre-global surgery comfort level	Post global surgery comfort level	p-value	Pre-global surgery technique understanding	Post-global surgery understanding	p-value
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

Discussion

The Global Surgery Collaborative Project, implemented in the Philippines and 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 guidance and feedback that global surgery for University of Toronto offers, which is particularly valuable in regions where specialized surgical training and resources are scarce. Moreover, the project emphasizes sustainability through its train-the-trainer program and the development of a local pediatric urology fellowship. 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 ecosystem. Such models are crucial for lasting impact in global surgery initiatives, especially in low- and middle-income countries (LMICs) where ongoing support and resources are often limited.

The integration of AR-assisted telementoring in the Global Surgery Collaborative Project 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. This method not only enhances the learning experience but also provides a scalable model for surgical training, particularly in remote and underserved regions. The

success observed in the pilot implementation suggests that AR can significantly enhance the precision, efficiency, and outcome of surgical procedures. 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 training programs, enhancing learning outcomes across various medical disciplines (Chua et al., 2024).

However, the project also 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. 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. Despite its benefits, the implementation of AR-assisted telementoring faces several challenges.

The foremost is the technological requirement that might not be readily available in all settings, particularly in resource-constrained environments. 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.

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.

The outcomes of this pilot study are vital for informing future global health initiatives. They demonstrate the effective integration of technology with traditional mentoring and underscore the importance of building local capacities to improve healthcare delivery in underserved areas. As global surgery continues to evolve, the insights gained from this project can help guide similar programs aiming to enhance surgical care and education worldwide. To address these challenges and optimize the benefits of AR-assisted telementoring, future initiatives should focus on developing more adaptable and cost-effective AR solutions that are suitable for low-resource settings. Partnerships with technology providers and continued funding support can facilitate the broader deployment of such technologies.

Moreover, ongoing research and feedback mechanisms should be implemented to continuously refine AR applications in medical training. Establishing a standardized protocol for AR-assisted telementoring could further enhance its effectiveness and ensure consistent training outcomes across different regions.

In conclusion, the Global Surgery Collaborative Project not only improved the surgical capabilities within the Philippines but also 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 programs is essential for integrating reconstructive urology into global health strategies, ultimately leading to improved patient care and healthcare systems in resource-constrained environments. In conclusion, AR-assisted telementoring holds significant promise for revolutionizing surgical training and care, particularly in regions that lack specialized training facilities. The Global Surgery Collaborative Project serves as a valuable model for integrating cutting-edge technology with traditional medical education, aiming to enhance surgical capabilities and ultimately improve patient care in LMICs.