Short Communication

The Role of Augmented Reality Telesurgery in Promoting Equity in Global Surgery

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Keywords: Global surgery; Global health; Healthcare inequality; Telesurgery; Augmented reality

Surgery, as described by Dr. Kim, President of the World Bank, is an "indivisible, indispensable part of healthcare", however it is estimated that five billion people do not have access to safe, affordable surgical and anesthesia care [1]. Of an estimated 312.9 million surgical procedures performed in 2012, only 6.3% were undertaken in the poorest nations, which comprise over a third of the global population [2,3]. For too long the myth that surgery is the preserve of the rich has prevailed; however, a new age is dawning. The *Lancet Commission on Global Surgery's* report *Global Surgery 2030*, appositely published in 2015, coinciding with a recommitment to universal health coverage (UHC) and the publication of the post-2015 Sustainable Development Goals (SDGs), has finally brought surgery into the crosshairs of global health focus [1,4,5]. *Global Surgery 2030*, which congregated what was known about global surgery and publicized a number of the Commission's de novo publications (which significantly added to our understanding of surgery in low-income and middle-income countries (LMICs)), is a call to arms for those wishing to reduce healthcare inequality.

Approximately a third of the global burden of disease is attributable to conditions requiring input from a surgical provider [6]. In 2010 an estimated 16·9 million lives (32·9% of all deaths worldwide) were lost from conditions needing surgical care [6]. Furthermore, surgical conditions may stifle LMIC's future economic success, with projected losses in economic productivity forecast cumulatively at $12·3 trillion from 2015 to 2030, with reduced annual GDP growth of almost 2% by 2030 [7]. A conservative appraisal suggests that a minimum annual operative volume of 5000 surgical procedures per 100,000 populations is required as a global average for LMICs [8]. The worldwide unmet surgical need is estimated at 143 million additional procedures per year, with the greatest per capita deficiency found in sub-Saharan Africa [9]. In western sub-Saharan Africa current surgical volume is 13% of the estimated need, with an additional 5625 procedures per year per 100,000 population required; yet spare surgical capacity does not exist given Sierra Leone's surgeon-population ratio is 1:850000 [1,10].

It is forecast that the current global community of about 1.5 million surgeons, of whom only 12% serve the poorest third of nations, must double within 15 years to achieve this proposed minimum annual operative volume [11]. Beyond an increase in their number, the geographic distribution of surgical providers must radically change, with an exponential increase in full-time surgeons stationed in the world's poorest countries, and equally importantly, rurally within these countries. The median distance to a hospital for those living in LMICs is around 30 km, with a quarter of the population in excess of 65 km from a district hospital; this is compared to only a quarter of those in high-income countries further than 10 kilometers from a hospital [1]. Once those with a surgical condition in a LMIC make it to their "local" hospital, by whatever means possible, there is less than a two in three chance that hospital can provide a caesarian section or laparotomy, and less than a 50% chance of open fracture repair [1]. If care is received, the risk of financial ruin ensuing is nearly 20% [12].

Short-term international missions, although providing patients with desperately needed care, can draw away resources from the local providers and introduce uncertainty as to the availability of services [1,13]. A framework of long-term, demand-driven commitments focused on system strengthening is required for the development of surgery in LMICs, with international professional societies, high-income academic medical centers, and NGOs all vital in the coordination of this effort. Central to the pursuit of sustainable growth within global surgery is a mechanism to facilitate meaningful international and regional collaboration.

The global surgical community must urgently decide on how to train a vast workforce of future surgeons, how to motivate them to remain within LMICs and work in the neediest (rural) areas, and how to support these surgeons to provide sustainable, affordable, and high-quality care. It is our belief that augmented reality (AR) telesurgery has a crucial role in facilitating the necessary advances in global surgery. The internet has the ability to revolutionize regional and international surgical partnerships, however the vision for this has previously involved "cold" open-source, online classes, and teleconferencing education [1,14]. AR telesurgery has the potential to transport expert surgeons into any operating room in the world to guide, teach, mentor, and support fellow surgical providers in realtime.

Augmented reality, defined as "a technology that superimposes a computer-generated image on a user's view

of the real world, thus providing a composite view", enables multilateral audiovisual communication where each party can demonstrate their thoughts and ideas with the aid of their hands, annotations, and diagrams overlying a live video stream [15]. For successful interactive telesurgery, required equipment includes a video camera for the surgical field; microphone, speakers and visual display screen within the operating room; a reliable internet connection to stream the two-way communication of quality to meet the bandwidth required by the stream; an internet-based platform to host the communication; and remote parties with technology to access the platform (internet and laptop, tablet, etc.) with audiovisual input and output. The addition of speakers and visual display within an operating room, combined with an intelligent AR platform, vastly improves the scope of global telesurgery, enabling surgeon trainers to 'show' colleagues how to carry out a procedure as opposed to 'telling' them.

Training plentiful surgeons in LMICs in advanced surgical techniques will require international support for the foreseeable future. Innovation is essential to provide the requisite number of surgeons in LMICs with high-quality, regular education with adequate oversight throughout their development. This necessitates the conversion of short-term missions into long-term, long-distance training collaborations. AR telesurgery is a scalable innovation for providing global surgery a sustainable means for this educational model. An AR platform (PROXIMIE™) has already been successfully utilized to provide a viable educational program for cleft lip and palate repair between a Californian surgeon (RMV) and Peruvian surgeons, where the number of annual missions required for effective training has fallen from six to two. This creates the potential for each globally-oriented expert surgeon to train a greater number of those in LMICs, while simultaneously providing those trainees with year-round support and, importantly, their patients with expert input when needed. PROXIMIE™ enabled complex hand reconstruction for a young man in Gaza whose hand had previously been grievously injured in a bomb blast [16]. In this case, an expert Lebanese hand surgeon (GAS) guided a general plastic surgeon in Gaza through the repair, thus demonstrating the ability of AR telesurgery to be successfully employed in a resource-scarce environment.

Developing on international collaboration, AR telesurgery can ameliorate the disparity in surgical care between urban and rural areas within LMICs. A shared AR platform, such as PROXIMIE™, for international and regional collaboration would enable the exchange of ideas between, for example, a high-income academic medical centre, a LMIC academic medical centre, and the district hospitals within the LMIC academic medical center's catchment. Within this model, surgical residents (the surgeons of 2030), would cement these relationships through training rotations in rural centers (and the high-income academic medical center if feasible), with the LMIC academic medical center as their hub, as it is in the AR model. Exposing trainees to rural surgery, while ensuring adequate clinical support, mentorship, and continued professional development (CPD) is more likely to encourage their interest in a rural practice than financial incentives, bonding, or scholarships [1,17,18]. AR telesurgery has an important role in reducing the professional isolation of these (future) rural surgeons. A study of rural American urologists found a majority (79%) felt telesurgical mentoring would improve their practice and two-thirds of these surgeons felt its greatest benefit would be intraoperative consultation for unexpected findings; it is reasonable to expect the same desire for telesurgical mentoring among rural surgeons in LMICs. Beyond increased training opportunities and improved supervision, a holistic AR platform would enable rural surgeons to access CPD material, further boosting their moral and retention [19].

Surgery, "the neglected stepchild of global health", desperately requires investment and innovation to reduce global inequality [19]. The global burden of treatable surgical disease is greater than that of tuberculosis, HIV/AIDs, and malaria combined [20]. To manage this humanitarian crisis, over one million surgeons need to be trained and supported to provide high-quality surgical care. The rapid expansion of the internet presents an opportunity to rethink regional and international global surgical education and collaboration. AR telesurgery allows expert surgeons or trainees to remotely "scrub in" on any procedure worldwide, and allows one surgeon to "show" another how to manage a complex case. This technology can promote equity in global surgery by training a workforce of surgeons in LMICs and providing them with the potential career as a rural surgeon with guidance and support from sub or super-specialists to provide their community with comprehensive surgical care.

Ethical Approval

This article was deemed IRB exempt.

Conflict of Interest

Nadine Hachach-Haram is co-founder of PROXIMIE™.

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Submitted: April 17, 2017; Accepted: April 24, 2017; Published: May 01, 2017

Special issue title: Community-based Research
Handled by Editor(s): Dr. Okafor Innocent Igwebueze, Esut College Of Medicine, Nigeria