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Opportunities for Global Health Diplomacy in Transnational Robotic Telesurgery

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Abstract

Globally, barriers to the widespread adoption of robotic surgery have worsened existing inequities in surgical care between low- and middle-income countries (LMICs) and high-income countries (HICs). This article advocates for the creation of sustainable robotic surgery programs in LMICs by drawing from ethical and philosophical theories, including preference utilitarianism, procedural justice, structural violence, and human rights. On this basis, robotic telesurgery is proposed as a form of global health diplomacy (GHD) between LMICs and HICs, and particular emphasis is placed on considerations in robotic surgery GHD program negotiations between LMICs and HICs and on political and ethical questions related to the transnational use of artificial intelligence.

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Global Inequity

Worldwide, 5 billion people lack access to quality, timely, and affordable surgical care. The scarcity of surgery—particularly in low- and middle-income countries (LMICs)—is a major driver of preventable death and disability, given that surgical, anesthesia, and obstetric conditions account for up to one-third of the global burden of disease.[1] Minimally invasive surgery (MIS), including laparoscopy and robotics, is standard of care in high-income countries (HICs) and offers superior patient outcomes for many conditions.[2,3] However, most surgical operations in LMICs—where technological, infrastructural, and financial barriers have curtailed the creation of sustainable MIS centers—are still performed via open approaches.[4,5] This article offers a moral rationale for expanding robotic surgery in LMICs and outlines several complex, unanswered political and ethical questions related to the use of robotic telesurgery as a form of global health diplomacy (GHD).

Robotics, Ethics, and Human Rights

In ethical terms, under-provision of robotic surgical care in LMICs relative to HICs causes health injustice, or the presence of unmerited, avoidable differences in health outcomes that unfairly diminish the quality of life of those most affected.[1] Disparities in access to

robotic surgical treatment contravene Article 25 of the United Nations Declaration of Human Rights, which guarantees the right to all medical care necessary for individuals' health and well-being.[6] Additionally, the worldwide morbidity associated with deficits in robotic surgical care indirectly violates Declaration of Human Rights articles 23, 24, 26, and 27, which describe human beings' right to work, rest and leisure, education, and cultural participation, respectively.[6]

To justify robotic surgery as integral to human rights and health justice, one should consider the following question: Can a *surgically ideal society*—a society in which a surgical system equitably allocates resources to provide timely, affordable care of the highest quality to all—exist today without robotics? For diverse operations, it is well established that the use of MIS techniques like robotics reduces postoperative pain and hospitalization relative to open surgery.[7,8,9,10,11,12] In keeping with the clinical obligation to minimize harm (nonmaleficence), this reduction in patient suffering makes robotic surgery ethically preferable to open surgery. Moreover, MIS reduces the risk of postoperative complications, such as wound infection and incisional hernia; these complications limit patients' labor and social productivity and compel patients to seek additional medical care, including costly re-operation and sepsis treatment.[13,14,15,16] Safer surgical techniques like robotics thus protect individual patients from medical morbidity as well as economic and personal losses, thereby advancing the bioethical principle of beneficence and sustaining human rights. Furthermore, the adverse postoperative events curtailed by robotics cause disproportionate morbidity and mortality in resource-constrained settings, where overall health care capacity is limited. By reducing postoperative morbidity and thus minimizing excess demand for health care in LMIC systems, robotic surgery capability would allow other medically ill patients to receive a greater share of health resources. In this way, the expansion of robotic surgery upholds the bioethical principle of justice (fair resource allocation).

Pragmatically, by requiring advanced technological and human capital, robotic surgery programs in LMICs may also be *enablers* of health systems' capacity to deliver all services.[17,18] The expansion of comprehensive health care permitted by technological growth and advanced training of medical personnel promotes population health at large, as all people require or will require some form of medical care in the future.

In summary, expanding robotic surgery in LMICs prevents unnecessary postoperative death and disability, upholds core principles of bioethics, and strengthens systemic infrastructure to benefit society now and in the future. While difficult to quantify, these benefits generate immense cost savings that would counterbalance and ultimately outweigh the high up-front setup, training, and maintenance costs of robotics programs. For these reasons, we argue that the attainment of the surgically ideal society requires robotics; thus, robotic surgery is a critical component of just, rights-based health systems.

Philosophical Justification

According to bioethicist Peter Singer, a proponent of *preference utilitarianism* (a moral philosophy that urges the maximal cumulative satisfaction of individual interests, or preferences, and which underlies modern global health ethics), we have a moral duty to minimize preventable suffering and death, provided that doing so does not impose an equally significant moral cost upon ourselves.[19,20] From this perspective, all suffering has equal moral weight regardless of national borders.[19] Seeing the world as a global village, Singer would, on the authors' interpretation, assert that a robotic surgeon in New

York City has equal moral duties to patients in Manhattan and Tokyo, since helping either group causes no morally meaningful loss to her. Similar logic is extended to the wealthy private hospital where this surgeon operates; to the extent that the hospital will not suffer significant moral losses by treating Japanese patients, Singer would argue that hospital leadership cannot ethically distinguish between its obligations in Manhattan and Tokyo. Singer's position is often criticized[21,22,23,24] as having unreasonable moral expectations for individuals and local actors when, in reality, national and global institutions play the largest role in perpetuating harm against the less privileged.

Inequitable access to robotic surgery is also contrary to the procedural justice theory of philosopher Thomas Pogge.[19,25] Extrapolating from Pogge's discussion of what HICs owe LMICs,[19,25] HICs with adequate robotic surgery ought to take "compensating action[s]" to reform global institutions if they wish to avoid moral responsibility for inflicting further morbidity and mortality on LMIC populations. By reinforcing surgical outcomes disparities, the ongoing scarcity of robotics in LMICs manifests the structural violence described by sociologist Johan Galtung, whereby those in poorer countries are deprived of fulfilling their fundamental health needs and bear avoidably higher death and disability rates vis-à-vis their HIC counterparts.[26]

What ethical insights should surgeons and surgical centers draw from these theories? While preference utilitarianism is a valuable theoretical construct, we believe it is best applied to the medical profession as a collective actor in the global village. When imposed upon individual physicians and facilities, preference utilitarianism decenters the role of governments and policies in creating global surgical inequities, thereby shifting undue moral burdens onto individual surgeons and hospitals that have neither the resources nor the sociopolitical leverage to adequately rectify them. To some extent, it is natural and ethically permissible for physicians and hospitals to prioritize nearby patients over remote ones. After all, local actors are best positioned to offer timely and accessible care to those in need. Moreover, not all surgeons (or surgical centers) must participate in global surgery in order to uphold the ethics of their profession. Indeed, a plethora of objectives with similar moral implications—from medical education to quality improvement to health policy—also require surgeon involvement. Nevertheless, the surgical community in HICs as a whole—ranging from trainees to department chairs to private practice surgeons—retains a collective obligation to engage international stakeholders and ensure the availability of optimal surgical care across LMICs. In agreement with Pogge's procedural justice theory, HICs' national governments and surgical communities must jointly assume full responsibility for all present and future harm caused by inequities in global surgical care. The compensating actions they must take to fulfill this responsibility will require redistribution of surgical resources in favor of the global poor, including (but not limited to) the diffusion of robotic surgical skills and technologies to LMICs.

Barriers to Capacity Building

Despite compelling moral justifications, global MIS capacity-building efforts have not yet achieved large-scale investments in robotic surgical technology and training in LMICs. Indeed, global surgery initiatives continue to emphasize laparoscopy over robotics due to lower up-front costs and easier implementation.[17,18] For instance, portable laparoscopic simulators and short-term workshops taught by HIC laparoscopists in LMICs are well documented in the literature, while analogous reports of robotics programs are rare.[27] Typically, newly constructed surgical centers in LMICs exclude

robotic technology, citing financial barriers, lack of formal domestic MIS training, and low institutional support.[28,29] In Colombia, where only 5 surgical centers with robotic consoles exist nationwide, a pilot program for robotic cardiac surgery used a "hybrid technique" with manual aortic clamping to lower procedural costs by 6000 USD, yet public insurance providers remained reluctant to participate.[30]

In a 2020 report on this intervention, Andrade et al emphasize the importance of fee-for-performance and bundled payment models that promote value-driven patient care, thus incentivizing the sustainable and large-scale use of robotic techniques, which are known to reduce surgeon error and improve patient outcomes.[30] Specifically, they reaffirm an ethical mandate to universalize robotic surgery in Colombia: "Limiting the most minimally invasive and technologically advanced techniques to high-income patients only and providing a low-income population with cheaper more traumatic incisions is a socioeconomic problem that needs to change. Pursuing the most optimal approaches for all patients, regardless of their health coverage … guarantees a more universal approach to the highest standards and quality of care."[30] To build a robust domestic robotic surgery program, Andrade et al argue that robotic surgeons and surgical centers in HICs must increase their on-the-ground robotics teaching, clinical care, and technological investment in Colombia:

> Throughout the years, cardiothoracic surgery in Colombia has grown following American footsteps and techniques. From the country's first heart transplantation using techniques from Stanford, to lung transplant surgery in Bogotá following Duke surgical approaches, and now robotic cardiac surgery learned from the University of Chicago Medicine … Colombia owes a great part of its cardiothoracic evolution to North American pioneers and centers. To ensure the continued growth of RACS [robotic-assisted cardiac surgery] in the country, attention needs to be kept first and foremost on the needs of "the patient" and recognize the importance of international/visiting RACS teams.[30]

To our knowledge, the Colombia pilot program is the only published account of dedicated robotic surgery capacity building in a middle-income country. In analyzing its impact, Andrade et al reinforce the indispensable role of HIC-LMIC collaboration in advancing surgical equity as well as health equity more broadly.

A core public health challenge in resource-limited health care settings is making just trade-offs between the often-competing priorities of societal and individual well-being.[1] One unique aspect of robotic surgery is its potential for longer operating times relative to laparoscopic or open approaches (particularly during the learning curve immediately following adoption of robotics), which can translate to lower case volumes.[31,32,33] Since robotic cases occupy surgical and anesthesia personnel for longer time spans, they may delay care for patients presenting with acute conditions in the interim. At the societal level, annual caseload is 1 of 6 *Lancet* Commission on Global Surgery indicators of equitable global surgery, and timely surgery is 1 of 3 intervenable targets in the Three Delays Framework.[34] Centralizing robotic surgery in large hospital centers with capacity for simultaneous emergency and elective cases is a natural response to this dilemma in HICs. However, in LMICs with poor transportation infrastructure, centralization may effectively exclude poor and rural groups from receiving robotic surgery.

Indeed, the logistical complexities and capital-intensive nature of expanding robotic surgery in LMICs are among the greatest practical obstacles to attaining a surgically ideal world, one in which reliable, sustainable robotics programs are ubiquitous and readily available to the entire global village. Currently, LMICs house over half the world population but only 19% of surgeons.[35] Based on global data, robotic surgical volume

grew by 17% annually between 2015 and 2019, with 1.24 million cases performed across all specialties in 2020.[36,37] However, these gains are highly concentrated in HICs, with 71% of all robotic cases in 2020 occurring in the United States alone.[36,37] Considering the estimated 1.3 million USD cost of installing a single robotic surgical system[38] and the additional 3000 to 5000 USD cost per procedure,[39,40] a sobering prospect emerges for LMICs. It then comes as little surprise that robotics programs in LMICs remain rare and understudied in the published literature.[37]

Robotic Telesurgery

Telesurgery, in which a surgeon operates in a location far from the patient via a robotic console and digital image technologies, may offer a unique opportunity to mitigate some practical limitations of expanding robotic surgery in LMICs. A particular advantage of robotic surgery is that the surgeon need not be in physical contact with the patient. In telesurgery, moreover, only a portion of the surgical team and robotic technology must be present in the patient's home country, potentially enabling the global pool of surgeons and robotic consoles to be available to all LMIC patients. Such international resource sharing upholds the principle of *cosmopolitanism* inherent to Singer's ideology, whereby human beings are, in a moral sense, global citizens bound to help all others in need regardless of the geopolitical borders separating them.[1,20]

Importantly, the technology for long-range telesurgery already exists. The first fully transnational robotic operation was an uncomplicated cholecystectomy on a patient located in Strasbourg, France, in 2001, performed in 54 minutes by remote surgeons in New York City with a safe average time lag of 155 milliseconds.[41] To enable a safe speed of image transmission between the robotic arms in Strasbourg and the robotic console in New York City, the surgical team used an asynchronous transfer mode [ATM] system whose nodes were "interconnected through a high-speed terrestrial fiberoptic network" at a bandwidth of 10 megabits per second.[41] To ensure the technological safety of the operation, network quality control tests were completed in advance and an identical, separate back-up transmission system was created in case of technical difficulty. The robotic system was further bolstered by specific rate parameters for transmitting data on robotic arm motion within the 10 megabits-per-second bandwidth, as well as by intraperitoneal phone and video conferencing systems linked to the network.[41]

Although conducted over 2 decades ago, this historic operation sheds light on the technical requirements for safe transatlantic robotic surgery. In the present day, continued unavailability of technical resources in LMICs results from broader logistical and infrastructure development problems. In a 2022 review of robotic surgery uptake in LMICs, Mehta et al state that it "is estimated that a delay of 300 ms [milliseconds] was the maximum delay that is compatible with safe robotic surgery and can become compromised in areas with poor network connectivity. Though 5G internet technology and ATM fibers can reduce the delay, their implementation may take another 3-5 years in low-income countries."[37]

A formal transnational robotic telesurgery program could be employed as a form of GHD between HICs and LMICs. GHD is a foreign policy strategy, broadly defined as "a multidisciplinary approach that combines public health, foreign affairs, management, law and economics by focusing on negotiations to manage global health policies."[42] Traditionally, GHD efforts have focused on responding to infectious diseases, armed conflict, and sociopolitical instability. One notable example is Cuba's physician export

program, established in 1960. This initiative has sent Cuban medical personnel to support humanitarian causes, from the Misión Barrio Adentro program in Venezuela to the COVID-19 crisis in Italy.[43,44] Similar diplomatic efforts to minimize surgical disease in LMICs remain rare, and, to date, none have incorporated the unique characteristics of robotic surgery in their diplomatic and humanitarian strategies.

Broader Adoption

This section introduces 3 complex political and ethical questions about the use of robotic telesurgery as a form of GHD between HICs and LMICs: combatting medical imperialism in patient consent as well as in patient and surgeon autonomy, distributing clinical ownership across a transnational team, and combatting unforeseen inequities created by technological dependency.

Dangers of medical imperialism. First and foremost, large-scale initiatives with HIC surgeons operating on LMIC patients must safeguard against medical imperialism. As stated in a case report of GHD negotiations between a foreign surgical service provider and the government of Botswana, LMIC stakeholders must be inclusively defined and actively prioritized in order to sustainably build capacity and prevent further dominance by HICs.[42] For instance, GHD efforts may inadvertently stunt development of domestic MIS training programs in LMICs, thereby increasing the dependence of LMICs on HICs for surgical human capital in the long-term. As the autonomy of surgical trainees declines in the United States, global telesurgery may also be seen as an opportunity for trainees to expand their robotic case volume with relatively minimal supervision.[45] Trainees practicing beyond their scope threaten the joint efforts of HICs and LMICs to establish a just culture of safety and accountability. A relevant historical parallel is Germany's colonial experimentation on East Africans in attempts to cure African sleeping sickness, which created lasting intergenerational trauma and undermined trust in Western medicine.[46]

To avoid further trust erosion and to begin rebuilding solidarity in LMIC-HIC relations, many precedent-setting questions should be negotiated among all participating countries of a global robotic telesurgery program. To best safeguard against medical imperialism, who will obtain patients' informed consent and which country's informed consent practices will be followed? Surgery without adequate informed consent is tantamount to torture; superimposed onto complex LMIC-HIC political relations, it is not difficult to imagine that poorly consented telesurgeries could be considered an act of aggression and quickly lead to diplomatic escalation. From Nazi experimentation on concentration camp prisoners to the deliberate extermination of Indigenous peoples in North America by European colonizers, historical examples of genocide—sometimes under medical guise—abound. Cybersecurity and physical security precautions, patient confidentiality, proper waste disposal, and adequate machine maintenance must be coordinated to ensure that the robotic telesurgery infrastructure in LMICs is not weaponized by other nation-states, gangs, or individual actors who desire to harm patients for personal or political motives.

In the course of providing transnational robotic surgery, surgeons and other stakeholders will inevitably develop new knowledge and best practices. Historically, Western medicine has claimed credit for various Indigenous and Eastern knowledge forms, appropriating cultural expertise to create profitable therapies whose financial gains were never shared with their communities of origin.[47] How will LMICs be protected from biopiracy on the part of HICs conducting robotic telesurgery on their patients?

Creating equitable intellectual property agreements, drafted and revised collectively with broad stakeholder involvement and enforced fairly, is an initial step. In academic research and patent applications, clear authorship protocols should center the contributions of LMIC surgeons and scientists, and transnational research outputs should be continually analyzed for equitable representation. Robotics partnerships also have potential to stimulate the brain drain of talented, highly educated individuals from LMICs to HICs, so deliberate investment in domestic robotic capacity—from surgeon credentialing to technology manufacturing—ought to be a precondition for transnational telesurgery.

Ownership of transnational clinical teams. By definition, even when robotic surgery is performed remotely, an in-person surgical team is necessary to employ hybrid techniques (as in the case of Colombia, described above), manage intraoperative complications, or convert to open surgery when indicated.[30] With 2 surgical teams involved in patient care (one in a remote HIC and another in the patient's home country), the ethical obligations that traditionally belonged to a single surgical entity are now distributed across 2 cross-cultural teams in different countries, and additional responsibilities are introduced. For instance, if a power outage or machine malfunction occurs intraoperatively, who will be held accountable for its effects on patient outcomes? How will medicolegal and malpractice liability be distributed in the event of avoidable and damaging surgical complications?

Clear mechanisms of transnational accountability are difficult to build and enforce, yet they are essential to the delivery of safe and high-quality care. They provide a pathway for patient grievances to be heard, robotic surgery protocols and techniques to be modified in response to adverse events, and appropriate reparations to be implemented when injustices and preventable errors cause harm to patients. Standardized, transparent review processes are equally necessary to allow HIC and LMIC surgical teams to exchange honest feedback about prior errors by minimizing the cultural, linguistic, and power divides between them. Potential solutions include utilizing the international court system, engaging the legal system of a "neutral" third-party country, or conducting focus groups comprising local patients and surgeons to identify the quality-control avenues best suited to the sociocultural and political particularities of each partnership. Since levels of generalized trust in health systems are highly variable across both LMICs and HICs,[48] transnational surgical initiatives must develop strategies not only to assure LMIC patients of their rights, but also to protect those rights.

Combating unforeseen technological inequities. Lastly, advances in digital imaging and artificial intelligence technologies used in robotic surgery raise many ethical questions relevant to GHD. As robots become increasingly autonomous and develop the ability to "think" independently, they may assume a greater role in nontechnical aspects of surgical care, such as patient selection and counseling, particularly where human surgeons are scarce.[49,50] As a result, there is potential for unintended harm via biased algorithms and artificial intelligence systems, especially when these tools are developed in HICs without HICs' genuine collaboration with LMICs.[49,50,51] To date, robotic surgical technology has been almost universally developed in HICs and calibrated on majority-White patient populations, although these populations and their LMIC counterparts have notable sociodemographic, lifestyle, and possibly genetic differences. If HIC technologies that use algorithms trained on White populations inadvertently mischaracterize the anatomy, symptoms, or clinical status of LMIC patients, then the use of these

technologies in LMICs may ultimately exacerbate—rather than eradicate—global surgical disparities.

Importantly, the potential use of biased algorithms in robotic surgery is not limited to the operating room. The logic underlying self-modifying machine learning algorithms is often unknown even by its developers; in other words, the algorithms are a "black box."[52] At the same time, these algorithms are capable of risk-stratifying surgical candidates by medical and demographic characteristics to assess the probability of a suboptimal outcome, interpreting imaging studies to inform preoperative planning, or gauging the likelihood that a given set of postoperative symptoms represents a true complication.[53,54,55] From an ethical perspective, how must we ensure that black-box algorithms do not subordinate patient interests to the interests of other actors in the health system? For instance, an algorithm that overweighs young age and high income as predictors of surgical success might unintentionally exclude elderly patients of lower income levels who would, in a traditional medical practice, be offered surgery. By preferentially selecting the youngest and wealthiest patients, however, this same algorithm may simultaneously allow surgeons to enjoy lower complication rates and higher compensation; here the surgeons would benefit, unknowingly, from data-driven discrimination.

Particularly in resource-constrained areas with few surgeons, machine learning algorithms offer an attractive strategy for streamlining surgical decision making, thereby increasing the efficiency and availability of clinical care. However, on a population level, even small imperfections in assistive technologies—which are often masked by the relatively small sample sizes of beta-testing efforts—can harm thousands of patients, with no clear mechanisms of accountability, quality measurement, or medicolegal liability.[54,55] How much risk of harm should LMICs be willing to undertake in employing foreign, black-box algorithms to guide robotic surgery operations and decision making? How should this risk be weighed against the potential expansion of surgical access and reduction in health disparities enabled by such algorithms? This conundrum demonstrates the tensions between nonmaleficence (eg, avoiding unintended harm from biased algorithms or the subordination of patient interests to external interests) and justice (eg, broadening care access in under-resourced areas) in technologically advanced global surgery endeavors.

Paths to Equity

Robotic telesurgery is an attractive albeit complex option for combatting disparities in surgical access and outcomes between HICs and LMICs, yet it is far from a singular solution. To close the LMIC-HIC gap in robotic surgical care, a portfolio of diverse strategies must be pursued simultaneously, with telesurgery representing only one point along a broad continuum of interventions. As previously stated, we should continue conventional global surgery initiatives in collaboration with local stakeholders by building robotics facilities in LMICs, offering MIS fellowships and simulation-based training to LMIC surgeons and residents, and growing health care capacity more broadly (from ensuring reliable, environmentally sustainable power supplies in hospitals to training and hiring ancillary staff).

An international robotic surgical corps of skilled surgeons that assists LMICs in stewarding robotic technology, disseminating robotic surgical expertise, and managing clinical operations constitutes an alternative form of GHD with the potential to incite long-term, sustainable change. Exchange programs in which surgical trainees from

LMICs obtain hands-on clinical training at robotics-intensive HIC hospitals facilitate ethical knowledge sharing in robotics and have a sustained positive impact. Meanwhile, humanitarian organizations and governments should arrange for ill patients in resource-constrained LMICs to travel to HICs for surgery, a model refined by NGO-government partnerships, including Haiti Cardiac Alliance.[56] On a broader level, a stronger incorporation of technological targets in the diplomatic agreements and health equity objectives set by the United Nations and the World Health Organization will be necessary. Only in concert with these and similar initiatives might transnational robotic telesurgery meaningfully reduce surgical health inequities in LMICs and uphold the ethical principles of the medical profession.

Conclusion

There are strong ethical justifications for reducing inequities in robotic surgical care between LMICs and HICs, which currently contribute to an unjust distribution of global morbidity and mortality. Robotic telesurgery is a novel and uniquely promising medium for GHD efforts aimed at surgical disease reduction in LMICs. However, its use compels the global surgical community to address uncharted legal, ethical, and political issues. This article has raised several such considerations within a global health framework and argued for the expansion of robotic surgical capacity in LMICs.

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