Editorial

Future of telerobotic surgery

Agus Rizal Ardy Hariandy Hamid

"Tele-robotics holds the promise to bridge the chasm of inequity in global surgical access, transforming healthcare delivery across borders into remote areas." (Rizal, 2024)

Why do we need telerobotics?

Surgery plays a pivotal role in cancer treatment across various stages: diagnostic, staging, curative, preventive, debulking, palliative, supportive, and reconstructive. Despite its significance, access to skilled surgeons and advanced surgical technologies is often limited, particularly in developing regions.[1] Globally, access to surgical care remains a major issue, especially in low- and middle-income countries. Alkire et al[2] developed a chance tree model to estimate surgical access by evaluating factors such as emergency transport, surgery rates, and basic medical equipment availability. In many countries, especially in Asia, limited access to surgery continues to hinder effective treatment for conditions like cancer.[2]

Surgical practice has progressed from traditional open methods to minimally invasive procedures, particularly in early-stage cancer cases. The idea of telesurgery initially emerged to address the need for performing surgeries in spacecraft, where procedures on astronauts can be controlled remotely from Earth over vast distances.[3] Telerobotic surgery has also rapidly evolved, enabling surgeons to perform complex surgeries remotely by using robotic systems and high-speed communication networks. This technology allows precise and minimally invasive surgery[4] from afar, expanding access to expert care. Telesurgery offers several significant advantages. It provides access to high-quality surgical care in remote locations, reducing the need for travel and associated costs. It also facilitates real-time collaboration among surgeons in different locations, enhancing teamwork and expertise during procedures. Furthermore, by eliminating physiological tremors, it enhances surgical accuracy and minimizes potential damage to healthy tissue.[5]

Indonesia, an archipelago with over 17,000 islands, faces significant challenges in ensuring healthcare accessibility due to the uneven distribution of skilled surgeons and the geographical separation of regions by the ocean. Telerobotic surgery offers a potential solution by enabling remote surgeries, improving access to specialized care for patients in remote areas, and reducing the need for long-distance travel. It also facilitates efficient knowledge transfer, allowing local surgeons to collaborate with experts to perform more complex cases.

Where are we now?

Telerobotic surgery relies on key components: a robotic platform for controlling surgery, a patient cart housing the robotic arms for precise movements, and a communication system to connect these two or more platforms in different locations.[6] The first telerobotic surgery took place in 2001, involving a laparoscopic cholecystectomy conducted remotely between the USA and France, showcasing the potential of telesurgery over high-speed networks.[7] China has been a leader in telerobotic surgery since its first telesurgery performed in 2003. The advent of 5G technology has significantly improved telerobotic surgery by allowing procedures with minimal latency.[8] By 2020, China achieved the world's first 5G remote robot-assisted radical cystectomy. In 2024, a transcontinental surgery was successfully performed between Rome and Beijing, removing a prostate lesion using 5G connectivity.[9] Today, China has performed telerobotic surgery daily, covering distances up to 3,000 km.

Indonesia has also embraced telerobotic surgery in August and September 2024 (Figure 1, a and b). The first telerobotic surgery was performed on August 30, 2024, involving the remote unroofing of kidney cysts over a distance of 1,200 km between Bali and Jakarta. This pioneering procedure was conducted by IGNG Ngoerah Hospital Team at the Surgeon Console, which included

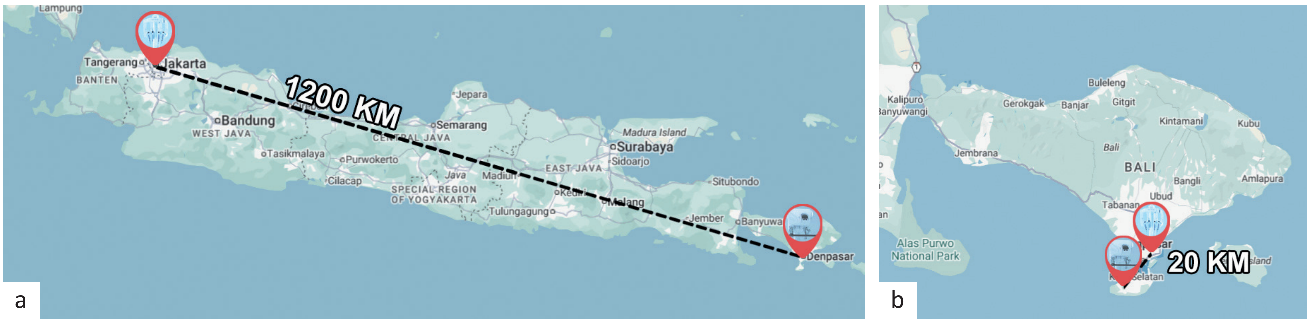

Figure 1. The first two telerobotic surgeries in Indonesia. (a) First telerobotic surgery in Indonesia (unroofing multiple cysts on the right kidney), from Bali (IGNG Ngoerah Hospital) to Jakarta (Cipto Mangunkusumo Hospital); (b) second telerobotic surgery (radical prostatectomy), from Jimbaran, Bali (Udayana Hospital) to Denpasar, Bali (IGNG Ngoerah Hospital)

Prof. Agus Rizal Ardy Hariandy Hamid, MD, PhD, Prof. Ponco Birowo, MD, PhD, and I Wayan Yudiana, MD. Meanwhile, Cipto Mangunkusumo Hospital Team operated the Patient-side Cart, consisting of Prof. Chaidir Arif Mochtar, MD, PhD, Fakhri Rahman Taher, MD, Prof. Gede Wirya Kusuma Duarsa, MD, PhD, and Fekhaza Alfarissi, MD.

This was followed by a more complex procedure on September 5, 2024, a radical prostatectomy over a shorter distance of 20 km between Jimbaran and Denpasar. For this surgery, Universitas Udayana Hospital Team at the Surgeon Console included Prof. Agus Rizal Ardy Hariandy Hamid, MD, PhD, Pande Made Wisnu Tirtayasa, MD, PhD, Ida Bagus Putra Pramana, MD, PhD, Kurnia Penta Seputra, MD, PhD, and Ahmad Zulfan Hendri, MD, PhD. The Patient-side Cart was managed by IGNG Ngoerah Hospital Team, which included I Wayan Yudiana, MD, Fakhri Rahman Taher, MD, Edi Wibowo, MD, Kadek Budi Santosa, MD, PhD, Nyoman Gede Prayudi, MD, Rheza Maulana, MD, and Ario Baskoro, MD.

What is the future?

Healthcare is evolving rapidly with the rise of Healthcare 5.0, which builds upon the technological advances of Industry 4.0. This new phase focuses on personalized, patient-centered care, leveraging cutting-edge technologies to enhance efficiency, precision, and global accessibility in medical practice. Indonesia's Golden Vision 2045 exemplifies this drive for healthcare improvement through technology.[10]

Telementoring and telesurgery are revolutionizing access to skilled surgical care, especially in underserved areas. Telepresence enables surgeons to mentor peers in real time, overcoming geographical barriers. Despite challenges like time delays and high costs, innovations such as augmented reality (AR)-based simulators with artificial intelligence (AI) and haptic feedback improve surgical education and training.[5,11] Haptic feedback technology enhances robotic surgery by allowing surgeons to feel tissue and suture tension, improving precision. Devices like the Telelap Alf-x prototype have shown reduced surgery times with integrated feedback. Additionally, microrobotics are making surgeries less invasive and more efficient, with future innovations focusing on autonomous microrobots for drug delivery and complex procedures. AI and machine learning are expected to transform decision-making in surgery, improving real-time assessments, and reducing reliance on traditional pathology. As AI becomes more integrated into surgery, it will enhance safety and efficiency.[5] Moreover, AR enhances surgical visualization by overlaying real-time data, improving coordination, and reducing cognitive load. It also minimizes radiation exposure and facilitates remote collaboration, addressing latency issues in telesurgery.[11]

The development of 5G networks is crucial for enabling telerobotic surgery, as it provides low latency and high bandwidth needed for real-time communication during procedures. The ideal communication delays for telesurgery are under 200 milliseconds, with a maximum of 300 milliseconds still being acceptable.[5,12,13] However, some areas still face challenges in developing 5G connectivity, highlighting the need for improved robotic systems operating with lower connections.

In conclusion, the widespread use of telerobotics as a daily procedure is approaching. The main reason for developing telerobotic surgery is to address global disparities in access to surgery, enhance the spread of knowledge and skill across borders with reduced travel, and improve patient outcomes and life expectancy, especially in early-stage cancer cases. However, challenges remain in developing the supporting preparation for telerobotic procedures, including robotic platforms and connectivity systems. Indonesia's success in performing telerobotic surgery demonstrates that many developing countries can leverage this technology to maximize surgical access to remote areas.

"In the era of Healthcare 5.0, the fusion of tele-robotics, AI, and seamless connectivity paves the way for a revolution in precision and accessibility in surgery."
(Rizal, 2024)

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Corresponding author:
Agus Rizal Ardy Hariandy Hamid
E-mail: rizalhamid.urology@gmail.com

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