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Review Article

Asia's robotic revolution: Redefining affordable surgery and challenging da Vinci's legacy.

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Abstract

The rapid rise of surgical robotics in Asia is revolutionizing the healthcare landscape, posing a significant challenge to the global dominance of Western systems like the da Vinci robot. Historically, the Da Vinci system has held a near-monopoly in robotic surgery, renowned for its precision, reliability, and widespread adoption. The Asia-Pacific market for surgical robots, valued at $1.4 billion in 2020, is projected to grow at a compound annual growth rate (CAGR) of 18.6%.

However, despite da Vinci's advantages, its high installation and maintenance costs are prohibitive for many low- and middle-income countries in Asia. In response to this challenge, over the past decade, countries like China, Japan, South Korea, and India have made remarkable progress in developing homegrown surgical robots. These innovations are not only cost-effective but also specifically designed to address the unique healthcare needs of the region, including issues of accessibility, affordability, and disease burden. The emergence of these Asian-made surgical robots signals a broader trend of technological self-reliance and innovation, driven by robust government support and a rapidly growing medical device industry.

The present review explores the growth of robotic-assisted surgery in Asia, the impact of these new platforms on healthcare outcomes, and the global implications for competition in robotic surgery. By providing viable alternatives to da Vinci, Asia is poised to reshape the future of minimally invasive surgery, democratizing access to advanced surgical technologies across the region. The challenges facing the region, along with the future trajectory of this healthcare revolution, will also be discussed.

Key words: Asian surgical robots, Asia Pacific robotic surgery, Da Vinci robot, Market growth of medical robotics

Context of Robotic Surgery

Since the early 2000s, robotic-assisted surgeries have experienced substantial growth worldwide, demonstrating numerous evidence-based advantages. These benefits include enhanced precision in surgical dissection, improved magnified three-dimensional visualization of the surgical field, and advanced ergonomics that reduce operator fatigue and discomfort. Additionally, robotic surgeries are

associated with lower transfusion rates, decreased wound complications, faster recovery times, and shorter hospital stays, ultimately leading to quicker returns to work. While minimally invasive procedures, such as laparoscopic and thoracoscopic surgeries, currently dominate the field of robotic assistance, other specialties, including orthopedics and neurosurgery, are increasingly adopting robotic technologies (1). This trend aligns with current market developments (Figure.1).

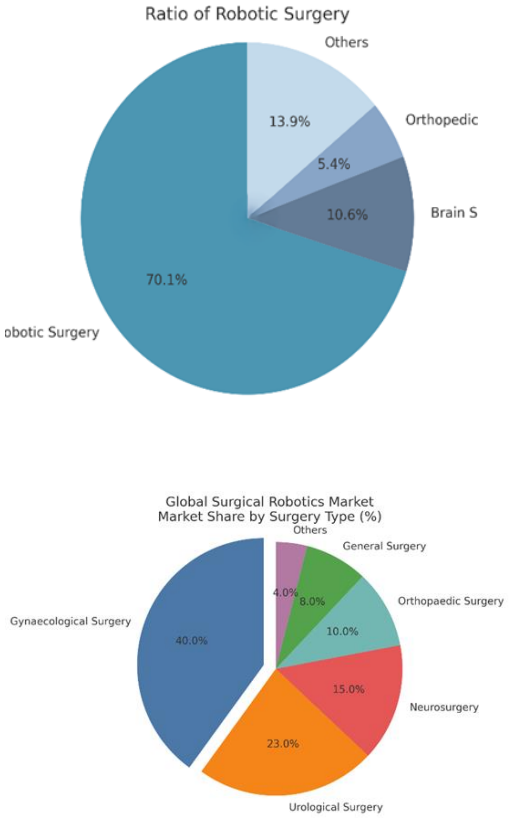

Fig 1. *Distribution of Robotic assistance in surgical specialties and respective market shares.*

As of 2023, more than 8,000 surgical robots have been installed globally, with the Asia Pacific region representing a significant portion of this market. The global surgical robot market was valued at approximately USD 7.1 billion in 2023 and is projected to grow to USD 26.4 billion by 2032,reflecting a compound annual growth rate(CAGR) of 16% from 2022 to 2030(2,3).

Global adoption of da Vinci the benchmark in Surgical Robots.

The first breakthrough in robotic surgery was the FDA approval of Intuitive Surgical's da Vinci system made in the USA in 2000. By 2023, the da Vinci system had performed over 12 million procedures (1.8 million done during 2022) using over 7500 robots in the USA, 1,388 in Europe,1,234 in Asia, and 359 in the rest of the world which include more than 70 countries .20% of these surgeries were conducted in Asia. It is estimated that a surgeon initiates a da Vinci procedure every 17 seconds globally. Although Intuitive Surgical retained full patent rights for the da Vinci system until 2019, it now only holds sub-patent rights for specific technical features. This master-slave system has revolutionized minimally invasive surgeries with robotic precision, especially in urology and gynecology and it is calculated that every 17 seconds a surgeon somewhere would start a Davinci surgery!

Over the years, clinical outcomes of four generations of da Vinci robots has been substantiated with over 34,000 publications in peer reviewed clinical journals and clinical efficacy proven by performance of over 300 telerobotic surgery cholecystectomy out of 1,875,000 procedures done during 2022, and over 10 million in total (4,5).Although Intuitive Surgical retained full patent rights only until 2019 it still holds sub-patent rights for specific technical advances in telerobotics and haptic feedback which are featured in the latest model da Vinci- FIVE (3,6,7).

Evolution of robotic surgery in Asia

Asia, home to 60% of the global population, creates vast healthcare demand. The increasing number of chronic diseases, the early detection of curable surgical cancers, a rising aging population, and improvements in healthcare accessibility have made Asia a fertile ground for the expansion of robotic surgery. In this context, the Asia-Pacific market for surgical robots, valued at $1.4 billion in 2020, is projected to grow at a CAGR of 18.6% from 2021 to 2030, representing the highest market growth outside North America (Figure.2) not surprisingly, over 70% of robotic surgeries are being utilized for intra-abdominal procedures in this region (8).

Fig 2. *Surgical robotic systems market - Growth rate by region*

Japan and South Korea were the earliest Asian countries to embrace robotic systems and led the region's development in this field. In 2000, Japan became the first country in Asia to perform a robotic surgery using the da Vinci surgical system, marking the beginning of robotic surgery adoption across Asia. This was followed by South Korea, which, in 2002, became a hub for robotic surgeries in Asia. India witnessed its first robotic surgery in 2005 in New Delhi and rapidly expanded its robotic surgery capabilities, particularly in multi-specialty hospitals.

China's National Medical Products Administration (formerly CFDA) approved the da Vinci surgical system in 2009, leading to rapid adoption in Chinese hospitals. By 2019, there were over 120 Da Vinci systems in use across China. In 2015 India, the Medical Council laid out comprehensive guidelines for robotic surgery, helping standardize its use and training across medical centers. In 2019, Japan's Ministry of Health, Labor, and Welfare approved national insurance coverage for a range of robotic surgeries, including gastrointestinal, urological, and gynecological procedures, significantly increasing patient access.

Collaborations between Asian Companies and Global Firms such as MitrAssist® (China) and Intuitive Surgical® Collaboration (2010) for, specializing in mitral valve repair, and complex cardiac surgeries. CMR Surgical entered a joint venture with China's Fosun Pharma to produce and market its Versius surgical robot in China.in 2022. In 2013 partnership of Apollo Hospitals with Medtronic to bring advanced robotic spine surgery to India expanded robotic surgery's footprint in Asia (4).

Growth promotors behind the rise of surgical robots in Asia

Economic Growth & Healthcare Investments:

The Asia-Pacific region's healthcare expenditure is projected to reach $2.7 trillion by 2025, with China, India, and Japan driving much of this investment. In China, for instance, healthcare spending grew from $357 billion in 2014 to $930 billion in 2022, leading to significant investment in high-tech medical infrastructure, including robotic systems.

Another surging adoption of surgical robots with technological advancements is the

rising demand for minimally invasive surgery in the Increasing aging population, Asia faces a burgeoning elderly population. Japan has the highest proportion of elderly people globally (28% of the population is over 65. Robotic surgery allows minimally invasive techniques that reduce recovery times, crucial for aging populations. China is expected to have over 300 million citizens aged 60 and above by 2030, further driving the demand for advanced surgical technologies. (4,5).Early detection of curable surgical malignancies such as prostatic cancer also has become a major growth promotor in the Asia Pacific region. During the COVID-19 pandemic, robotic surgery saw increased demand across Asia due to the need for minimally invasive procedures that reduce the risk of infection. Tele-operated robotic surgeries also gained popularity in this period (9).

Increased Clinical Applications of Robotic Surgery in Asia.

Considering the country-specific Trends Japan with its aging population leads in robotic surgery for prostate and colorectal malignancies South Korea: a well-recognized destination for gastrointestinal surgeries where Over 50% of robotic surgeries on stomach and liver cancer are carried out with robotic assistance. In the same context, China leads in robotic-assisted neurosurgery and orthopedic surgeries, with over 15,000 procedures performed annually. India with its largest population in the world Robotic cardiac surgery is growing rapidly, with over 5,000 robotic surgeries performed in the past decade and with the invention of their local robot catching up rapidly in thoraco-abdominal surgery(10).

Considering the Common Procedures done with Robotic surgery in Asia Urology seems to be at the forefront with Robotic prostatectomy as the leading application. Out of over 1 million procedures performed worldwide, 30% are carried out in Asia. These figures are followed by Gynecology and in South Korea, over 60% of hysterectomies are performed using robotic assistance. India and Japan are emerging as leaders in robotic-assisted heart surgeries, boasting success rates exceeding 95%. Countries like Sri Lanka and Vietnam are slowly adopting robotic surgery through government-backed healthcare initiatives. In Vietnam, for example, da Vinci systems are used in 5 major hospitals, primarily for urological procedures.

Technological Innovations and Key Players in Asian surgical Robotics

With the cessation of exclusive patent rights of intuitive Inc.in 2019 several Asian-made robotic platforms have entered the market through prominent Asian Companies contributing to Indigenous Developments of robotics in Asia.

Key Local players such as China's MicroPort, Japan's Medicaroid and India's SS Innovations, are developing homegrown robotic systems. By 2023, China has a market projected to grow at a 21-25% CAGR through 2030, with a surgical robot market of $1.6 billion (Projected >$ 3.5 billion by 2026.) While already having over 500 da Vinci systems it had deployed more than 200 locally made robotic surgery units, performing over 60,000 surgeries annually (10,11).

Another key regional player is the Republic of Korea with its Revo-I ™ robot from Meerecompany Inc., performing over 10,000 procedures per annum. Supported by a substantial number of Prospective multicentric studies are available with training provided using virtual reality facilities (12, 13).

This regional robotic popularization is further strengthened by Japanese products Medicaroid a joint venture between Kawasaki and Sysmex, presenting Hinotori™ robotic systems which hold the number one position in Asian robots worldwide with over 300 installations in Japan by 2023. Also by Saroa™ robotic platform developed by River Field Inc., Tokyo, They are technically almost similar to Da Vinci system but has additional features like being more compact and modular, with pneumatically driven robotic arms and minimal collision .They also has the advantage of real time haptic feedback (14, 15).

Most recently India has entered the arena as a key player with the launch of the Mantra system, by SS Innovations which costs 60% less than Western models, making it more accessible for smaller hospitals. The surgical robotics market in India was valued at $150 million in 2022 with a CAGR of 20% over the next decade. India has over 70 da Vinci systems performing approximately 20,000 surgeries annually (16, 17, 18).

Collaborations and Joint Ventures

Collaborations and joint ventures between east and the west, in robotic surgery play a pivotal role in accelerating innovation, expanding access to advanced surgical technologies, and fostering global expertise. By leveraging partnerships between medical institutions, technology companies, and healthcare systems, these collaborations drive the development of cutting-edge robotic platforms, improve surgical outcomes, and facilitate the widespread adoption of minimally invasive procedures.

In 2020, Medtronic partnered with China's Titan Medical to develop next-generation robotic surgery systems tailored for emerging markets. These partnerships are accelerating the time to market for innovative solutions while reducing costs. Collaborations between Asian Companies and Global Firms such as MitrAssist® (China) and Intuitive Surgical® Collaboration (2010) for, specializing in mitral valve repair, and complex cardiac surgeries. CMR Surgical entered a joint venture with China's Fosun Pharma to produce and market its Versius surgical robot in China.in 2022. In 2013 partnership of Apollo Hospitals with Medtronic to bring advanced robotic spine surgery to India expanded robotic surgery's footprint in Asia (19, 20).

Challenges and Proposed Solutions for the Surge of Surgical Robotics in Asia

Cost and Accessibility

The financial situation in South Asian countries creates an even direr situation. While South Asia is home to 24% of world's population it contributes only 4-5% of world's GDP. Even in larger South Asian economies like India, Pakistan, and Bangladesh, healthcare budget allocations remain a modest 2-4% making the investment on adequate number of robotic platforms a herculean task and a farfetched goal in this region. (Figure.3) (21).

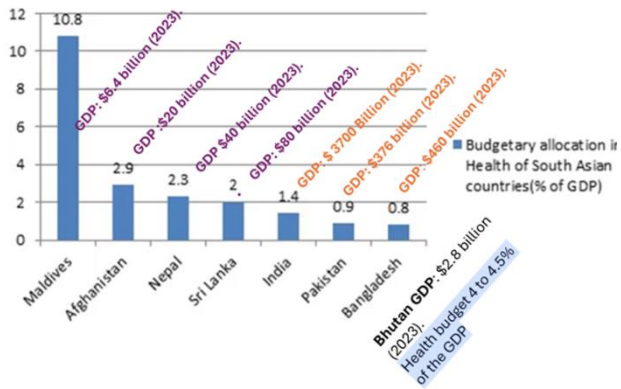

Fig 3. *Budgetary allocations in Health of South Asia*

Western robotic systems like da Vinci can cost $2 million upfront, with annual maintenance costs around $150,000. In contrast, Asian systems like Mantra and MicroHand S are available for $500,000–$1 million, lowering the barrier for hospitals in developing countries (Figure 2).

While leading hospitals in metropolitan areas in Asia can afford robotic systems, rural hospitals struggle with the high costs. In China, for instance, only 1,000 out of 34,000 hospitals have access to robotic surgery, highlighting the disparity.

In middle income countries, Robotic assistance is used for Laparoscopic surgery in 70% of instances followed by neurosurgery (10.6%), Orthopaedic surgery (5.4%) and miscellaneous procedures (13.9%).It is rather disheartening to see at present only 1-3 % of all surgical procedures in this geographical region are performed with robotic assistance compared to that of 15-20% in the USA (Figure 4)(20).

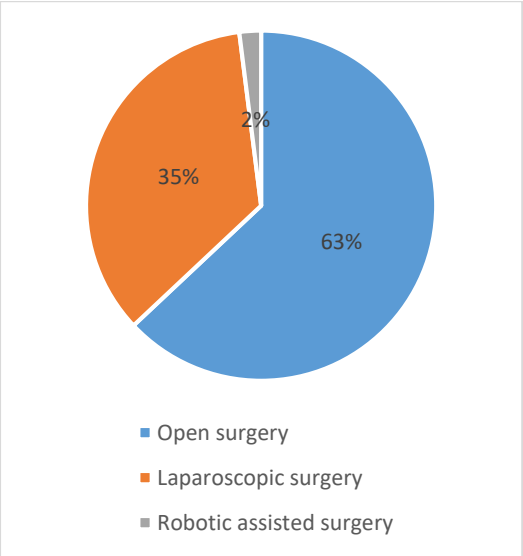

Fig 4. *Ratio of surgical access in Asian countries*

The emergence of affordable and customized Robotics seems to be an important solution for the affordability in developing nations. It is noteworthy that all Chinese, Korean and Japanese robots are in the range $1- 1.5 million and Indian robots are even more economical with an initial cost of less than $ 1 million leading the charge in creating cost-effective robots tailored to the needs of a larger number of smaller hospitals. The Mantra surgical robot from India has been designed to be affordable, costing around $500-600,000 USD (INR 4-5 crore) compared to $2-2.5 million for the da Vinci system. Although currently there is a slow adoption rate of homegrown robotics, by 2025, it is estimated that 50% of all robotic systems sold in Asia will be Asian made robots and priced under $1 million (20, 21).

Limited Acceptance of Domestic Products and Cultural Resistance

In some areas, patients and surgeons alike are wary of robotic systems. A 2021 survey in India revealed that 30% of patients were reluctant to opt for robotic surgery due to concerns over reliability and cost (38).Currently, the adoption of Asian-made robots in their home countries has been relatively slow. Although da Vinci systems are already in place, Asian-made robots should become a strong contender for consideration in future installations.

Competing Against Non-da Vinci Brands of Surgical Robotics

Apart from the Da Vinci system, Asian robots must face a strong competition from established and emerging players from the UK, Germany, Canada, and Israel, who are making their presence felt with competitive pricing and technological innovations. These innovations include advancements in natural orifice transluminal endoscopic surgery (NOTES) and single-incision

laparoscopic surgery (SILS), with the incorporation of newer technologies such as haptic feedback and eye-tracking camera systems.

Notable products include the Versius Surgical System™ by CMR Surgical (UK) and the Hugo™ RAS (Robotic-Assisted Surgery) System by Medtronic™ (Ireland), both of which are primarily used in general surgery, gynecology, urology, and thoracic surgery. These systems feature modular and portable robotic arms that mimic human arm movements, along with advanced data and analytics capabilities, aiming for cost-effectiveness to enhance their appeal.

Country	Da Vinci units	Asian Robots
China	>500	100-150
Japan	>300	40
Korea	>250	20-30
Singapore	>30	<5
Malaysia	<10	<5
Thailand	<10	<5
Indonesia	<10	<5
India	>70	>20
Middle east /Turkey	80-100	<5
Other South Asian countries	15	<5
Russia	80-100	Not known

Fig 5. *Adoption of homemade robotics in Asian countries*

Additionally, Titan Medical's SPORT Surgical System™ (Canada) and the Hominis® Surgical System by Memic Innovative Surgery specialize in NOTES and SILS, utilizing small, flexible robotic arms. The Ascensus Surgical Robot™, a USA/Germany joint venture, offers haptic feedback, eye-tracking camera control, and advanced digital laparoscopy capabilities. Most recently, endoscopic giant Karl Storz™ partnered with Trans Enterix™ to enter the market (22).

Training and Expertise

Many hospitals, especially in developing regions, struggle to invest in both the robots and the necessary training programs, limiting access to this cutting-edge technology. Second, there is a shortage of skilled trainers. Robotic surgery requires specialized expertise that many surgeons and educators in Asia may not yet possess, slowing the spread of comprehensive training programs. Additionally, due to the steep learning curve of robotic surgery, existing surgeons need significant time and resources to upskill, further limiting their ability to mentor other Thirdly the lack of standardized training protocols across countries in Asia creates inconsistencies in the level of expertise, making it difficult to achieve uniformity in patient care and surgical outcomes. Variations in healthcare infrastructure and government policies further compound this issue.

Lastly, cultural resistance to adopting new technologies in traditional medical institutions can slow training efforts. In response, greater investment in training centers, incentives for surgeon upskilling, and collaboration between nations can help overcome these barriers and drive the advancement of robotic surgery in Asia.

There is a shortage of qualified robotic surgeons in Asia. In South Asian countries only 20% of surgeons are trained in Robotics. Training programs can take up to two years, costing $20,000–$50,000 per surgeon. South Korea is addressing this by setting up specialized robotic training centers, while India has launched the Robotic Surgery Training Program (23, 24).

Regulatory Issues

Each Asian country has its regulatory framework, creating hurdles for companies trying to market their systems regionally.

Japan has stringent approval processes, while China has more streamlined pathways but imposes heavy oversight on foreign companies.

China promotes its own surgical Robots by reducing reliance on imported foreign robots, increasing the affordability and accessibility by 30% of the market share in the Asia Pacific (APAC) region, Governmental Regulatory Incentives include National Medical Products Administration (NMPA) expediting approval times by 25% developing Partnerships with global leaders like Intuitive Surgical. These initiatives are supported by national policies like the "Made in China 2025" strategy with the 14th Five-Year Plan.

When it comes to India, Incentives provided by the central health authorities include a fast-track approval process by the Indian Central Drugs Standard Control (CDSCO) which is approved in 56 countries. While over 40 Mantra robots are installed in major hospitals of the country it is awaiting FDA (US) and CE (European) with the incorporation of new technology to compete with established brands. The local investors are expecting a better market penetration supported by national health regulatory policy and Government initiatives like 'Make in India' and affordable insurance coverage like, 'Ayushman Bharat' (India) (25,26).

Medico-legal issues

Medico-legal issues surrounding robotic surgery stem from the complexity of integrating advanced technology with human skill in high-stakes medical environments. One of the primary concerns is accountability for surgical errors. When complications arise, determining whether the fault lies with the surgeon, the robot, or a combination of both can be challenging. Surgeons are responsible for mastering robotic systems, and inadequate training or misuse could result in claims of negligence. If a surgeon's skill falls short or if the technology is not used properly, legal consequences can follow.

Liability can also extend to hospitals, medical device manufacturers, and software developers. Equipment malfunctions, poor system maintenance, or design flaws may implicate the parties responsible for providing and maintaining the robotic systems. This expands the scope of legal responsibility beyond just the operating surgeon.

Informed consent is another critical aspect. Patients must be thoroughly informed about the risks, benefits, and possible alternatives to robotic surgery. Miscommunication or failure to provide adequate information could lead to legal action based on insufficient consent.

Lastly, data privacy in robotic systems raises ethical concerns, as patient data stored or transmitted during procedures must be securely handled. As robotic surgery continues to evolve, legal frameworks need to adapt to ensure clear liability and patient safety (27).

Future Trends and Outlook

Technological Specialization

Asian manufacturers are focusing on customizing robotic systems for specific surgeries. For instance, China's MicroHand S ™is a leading choice in neurosurgery, and Ti Robot™ (Tinavi medical technologies) and Sky walker™ robots (China) and Cuvis, Curexo Inc. (Korea) are meant for orthopedics. United Kingdom-based Versius system™ which has been adopted by several new hospitals in India optimized for minimal access surgeries, such as hernia repairs and hysterectomies.

Expansion of AI and Machine Learning

AI will play a crucial role in the future of robotic surgery, particularly in decision support and real-time analytics. By 2030, it is estimated that 40% of robotic surgeries will involve some form of AI assistance, reducing human error (28, 29, 30).

Telemedicine and Remote Surgery

Telesurgery or remote surgery is a promising surgical advancement, with many challenges. Such as the requirement of Zero-latency time with Technologies like 5G networks, IoT and improvement in haptic feedback technology, with some legal and ethical issues remaining to be addressed.

Following the pioneering work by Professor Jacques Marescaux on September 7, 2001, performing the first telerobotic Cholecystectomy performed in New York on a patient in Strasbourg, France, (‘Lindbergh Operation') Asia followed in 2019, performing telerobotic spinal surgeries using robotics and 5G network on 12 patients in six hospitals from six different cities in China.

Indonesia became the first Southeast Asian country to successfully performed live remote telerobotic surgery to excise a renal cyst between Jakarta and Bali.South Korea performed its first 5G-enabled remote robotic surgery in 2021, and China with the advent of 5G technology, remote surgery with less than 300 milliseconds delay is becoming a reality in Asia developing rural tele-surgery programs for underserved populations (31, 32).

Influence of Robotic Surgery on Medical Tourism in Asia

With Asia projected to capture 50% of the global medical tourism market by 2025, countries like India and Thailand are poised to benefit from the growing demand for robotic surgeries among international patients. Robotic surgery to pave the way for medical value tourism contributes 40-50% of total health tourism in Asia.

Asia’s medical tourism market, worth $4.8 billion in 2020, has been fueled by countries like Thailand, India, and Singapore offering state-of-the-art robotic surgeries at a fraction of the cost in Western nations. A prostatectomy in Singapore, for example, costs around $10,000, compared to $25,000 in the United States (33).

Type of Robotic Surgery	USA	UK	India	Thailand	Singapore
Robotic Abdominal	$35,000	$28,000	$6,000	$12,000	$13,500
Robotic Cardiac	$40,000	$32,000	$9,500	$18,000	$20,500
Robotic Spine	$30,000	$26,000	$10,000	$18,000	$20,000
Robotic Urology	$35,000	$28,000	$8,000	$18,500	$18,000

Figure 6.*Comparison of common surgical procedures done in Asia Pacific region and the west*

It is evident that the percentage of surgical health tourism Income contributes significantly to the total health tourism and the developing of surgical robotics in the region is certainly will be a clear attraction.

Country (2023)	Total Income Health Tourism ($ Million)/yr	Surgical Health Tourism Income ($ Million)/yr	% of Surgical to Total
Income			
Thailand	1180	700	59.32%
India	1480	800	54.05%
Malaysia	370	200	54.05%
South Korea	740	500	67.57%
Japan	296	150	50.68%
Philippines	222	120	54.05%
Vietnam	148	70	47.30%

Figure 7. *Percentage of surgical health Tourism Income relative to total health tourism*

Impact of Robotic Surgery on Healthcare Employment and Skills

The rise of surgical robots is reshaping the healthcare workforce in Asia. With robots handling complex surgeries, the demand for highly skilled surgeons and technicians proficient in robotic systems is increasing. However, this shift may also widen the skills gap, especially in rural or underfunded hospitals, where access to advanced training is limited.

In countries like India and China, where large populations strain healthcare systems, robots offer an opportunity to improve surgical precision and efficiency. The rise of robotics will reshape healthcare teams, leading to the creation of new roles, such as robotic surgery coordinators and AI specialists, while reducing the physical demands on surgeons. Yet, as automation grows, concerns arise about job displacement, requiring hospitals to focus on retraining staff and integrating human expertise with robotic technology (34).

Key Trends in Future Growth

Increased affordability and the availability of cost-effective robotic platforms, reducing expenses by 30-40%, are driving the expansion of robotic surgery clientele. By 2030, over 50% of major surgeries are projected to be performed using robotic systems. Training is improving with the establishment of dedicated national and international robotic centers in countries like Sri Lanka, India, and China. Additionally, new marketing strategies are being developed to promote locally made robots, alongside partnerships with reputable Western robotic companies. These efforts are supported by favorable national health regulatory policies, government initiatives, and the integration of advanced technologies like AI, 5G, and telerobotics, boosting health tourism.

In summary, Asia is leading the charge in the surgical robotics revolution. Key factors such as economic growth, aging populations, advancements in healthcare technology, and a surge in health tourism have created an ideal environment for the widespread adoption of robotic systems. Local manufacturers are developing cost-effective solutions that are increasingly competitive with Western alternatives. However, challenges like high costs, regulatory barriers, and a shortage of trained professionals persist. The future looks promising, with AI, telemedicine, and affordable robotics transforming surgery across the region (35).

As Asian-made surgical robots gain traction in their home countries, both governments and the private sector are expected to increase investments. Market dynamics will continue to evolve, and Asian companies must enhance their offerings by introducing innovative technological advances into locally produced robots. Expanding training opportunities and publishing research to demonstrate non-inferiority are crucial steps to encourage more hospitals in the region to adopt Asian robotic surgical platforms (36, 37).

References

1. Rivero-Moreno, Y., Echevarria, S., &Vidal-Valderrama,C.,et al.(2023). Robotic surgery: A comprehensive review of literature and currenttrends.Cureus,15(7),e42370. https://doi.org/10.7759/cureus.42370
2. Zaman, M. F., Buchholz, N., &Bach, C. (2021). Robotic surgery and its application in urology:72-82

3. Pugin, F., et al. (2011). History of robotic surgery: From AESOP® and ZEUS® to da Vinci. Journal of Visceral Surgery, 148(5,Supplement)S3S8.https://doi.org/10.1016/j.jviscsurg.2011.04.0074.
4. Sundram,M.(2010).Urologiconcology:Asian robotic experience. Seminars and Original Investigations, 28, 677-681.11
5. Jakovljevic, M., Wang, L., &Adhikari,C.(2023).Editorial:Asian health sector growth in the next decade Optimism despite challenges ahead. Frontiers in PublicHealth,11,1150917.https://doi.org/10.3389/fpubh.2023.1150917
6. Freschi, C., et al. (2012). Technical review of the da Vinci surgical tele manipulator. International Journal of Medical Robotics and Computer Assisted Surgery. Https://doi.org/10.1002/rcs.1468
7. Grand View Research. (2021).Surgical robots market size, share & trends analysis report. (2021). The healthcare market in Asia: Growth, opportunities, and challenges.
8. Mc Kinsey & Company. (2020).Asia's healthcare: A shift in priorities amid COVID-19 and beyond. Surgical robot market by product and service, application, and enduser: Global forecast 2030 (ReportID: MRHC19479). (2024).
9. Gu, L., Yin, C., Jia, T., He, K., Ma,X., & Zhang, X. (2023). Robotic surgery in China. Innovation,4(5),100499.https://doi.org/10.1016/j.xinn.2023.100499
10. Kim, S., et al. (2021). Robotic-assisted surgeries in South Korea:Current landscape. Korean Journal of Surgical Research, 47(3), 245-252.
11. Lee, T., & Lee, H. (2021).Development of robotic surgery in South Korea: Achievements and future trends. Korean Journal of Robotic Surgery.
12. Ogawa, T., et al. (2021).Introduction of robotic surgery in Japan: The past, present, and future. Asian Journal of Endoscopic Surgery, 14(2), 150-157.
13. Japan Ministry of Health, Labour,and Welfare. (2021). Aging population and health care systems in Japan.
14. Dhanvijay, G., et al. (2021).Robotic surgery in India: A review of advancements and challenges. Indian Journal of Surgery, 83(2),104-110.
15. Adhikari, K., Penmetsa, G. K.,Taori, R., Kumar, A., & Raghunath,S. K. (2023). Robotic platforms in urology: Indian scenario. Robotics in Oncology, 1(1).
16. Bora, G. S., Narain, T. A., Sharma,A. P., Mavuduru, R. S., Devana, S.K., Sgh, S. K., & Mandal, A. K.(2020). Robot-assisted surgery in India: A SWOT analysis.
17. Indian Journal of Urology, 36(1), 1-3.https://doi.org/10.4103/iju.IJU_220_19 Allied Market Research. (2022).Asia-Pacific surgical robots' market 2021-2030.
18. Medtronic. (2020). Medtronic partners with Titan Medical to develop robotic surgery systems. Asian Development Bank. (2020). Healthcare infrastructure and technology investments in Asia.
19. Asian Development Bank. (2020). Healthcare infrastructure and technology investments in Asia.

20. Wang, X., et al. (2020). Clinical applications of robotic surgery in Asia: Trends and outcomes. Asian Journal of Surgery, 43(6), 550-558.
21. Mehta, A., et al. (2022). Embracing robotic surgery in low- and middle-income countries: Potential benefits, challenges, and scope in the future. Annals of Medicine and Surgery(London).https://doi.org/10.1016/j.amsu.2022.104803
22. Cepolina, F., & Razzoli, R. (2024). Review of robotic surgery platforms and end effectors. Journal of Robotic Surgery, 18, 74. https://doi.org/10.1007/s11701-023-01781-x
23. Bang, S. L., Png, K. S., & Yeow, Y. Y.,etal.(2014).Developing technical expertise in robot-assisted laparoscopic prostatectomy in a moderate-volume center through a proctor-based team approach. Journal of Robotic Surgery, 8, 245-250.https://doi.org/10.1007/s11701-014-0460-5
24. Sharma, S., & Park, K. (2022). Training programs and the future of robotic surgery in Asia. Journal of Robotic Surgery, 16(3), 445-458.
25. O'Sullivan, S., Nevejans, N., Allen, C., Blyth, A., Leonard, S., Pagallo, Ashrafian, H. (2019). Legal, regulatory, and ethical frameworks for development of standards in artificial intelligence (AI) and autonomous robotic surgery. International Journal of Medical Robotics and Computer Assisted Surgery, 15(1), e1968.
26. Shaikh, S. (2022). Robotics in healthcare: A detailed analysis of Asian companies. Robotics & Automation News.
27. Muacevic, A., & Adler, J. R. (2023). In the hands of a robot: From the operating room to the courtroom:The medicolegal considerations of robotic surgery. Cureus,15(8).https://doi.org/10.7759/cureus.50415
28. Siemens Healthineers. (2021). AI-powered robotics in surgery: The next frontier in Asia-Pacific.
29. Ahmed, G., et al. (2024). Artificial intelligence in surgery: The future is now. European Surgical Research, 65(1),22.https://doi.org/10.1159/000536393
30. Weihang,Y.(2024).Revolutionizing surgery: The impact of machine learning and artificial intelligence on surgical robotics. Transactions on Computer Science and Intelligent Systems Research.
31. Lee,B.R.,etal. (1999). Telemedicine and surgical robotics: Urologic applications. Reviews in Urology, 1(2), 104-120.
32. Ahuja,V., et al. (2021). The promise of 5G in remote robotic surgeries: The Asian experience. Journal of Telemedicine and Telecare, 27(5), 345-350.
33. Frost & Sullivan. (2021). Asia-Pacific medical tourism market: Future growth opportunities and trends.
34. Ravichandran, A., et al. (2024). Managerial perspectives of scaling up robotic-assisted surgery in healthcare systems: A systematic literature review. Laparoscopic, Endoscopic, and Robotic Surgery, 7(3),113122.https://doi.org/10.1016/j.lers.2024.05.002
35. Global Data. (2021). Asia-Pacific medical robotics company's profile: MicroPort, SS Innovations, and more.

36. Deloitte. (2021). The cost of robotic surgery in emerging markets: A barrier or a challenge to overcome?

37. Musbahi,A.,Rao,C.B.,& Immanuel, A. (2022). A bibliometric analysis of robotic surgery from 2001 to 2021. World Journal of Surgery, 46(6), 1314-1324.