[1] Than Lee Lee
[2] Xia Zhiye

Assessing the Robot-Assisted Surgical Systems between Developed and Developing Economies

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Abstract: - Robot-assisted surgery (RAS) is a revolutionary technology for the surgeons, doctors and physicians. Although RAS deployment is rapid since 2019, despite decades of successful robotic assisted surgeries in the developed economies that have positively impacted millions of patients, RAS was barely explored by the developing countries compared to the developed countries whereby capabilities to enhance and improve the levels of expertise is limited besides acquisition and operating costs. This paper aims to raise awareness and compare what is the future of RAS in selected developing countries given its multitude of needs and challenges? Is RAS still in early days and too expensive to be put to general use in these developing economies today? We applied indicators to test the adoption of RAS using the economic consideration of robotic surgery in health economics. We examine the likelihood of acquiring and using RAS with different market characteristics from 2000 to 2022. We used data on traditional and robot-assisted surgical interventions and transform it into an improved version on Quality-Adjusted Life Year (QALY) and Willingness-to-Pay for Robot-Assisted Surgery (WTPR). Asia growth was spectacular. China's participation resulted in closing the gap much faster in advanced medical technology and treatment such as RAS between developing and developed economies beside knowledge diffusion. South Koreans had catch up with the Europeans i.e., Italy, Germany, France and UK. China's total patents had explosive growth and the robot density was among the highest among the selected economies compared in this study.

Keywords: Emerging technology, healthcare innovation, robotics surgery, robot-assisted surgery, developing countries.

I. INTRODUCTION

With the development of robotics, robots have been applied to more and more fields. In medical science, the robot-assisted surgery (RAS) is a typical product of robotic technology and minimally invasive surgery: surgeons can control one or more robotic arms, which are equipped with surgical tools (console) and high-definition camera (vision system) and manipulate these robotic arms from a console, allowing them to view the surgical area and perform precise movements. Compared to traditional surgeries, RAS are more precise and having advantages of reducing trauma, shorter hospital stays, and faster recovery although each surgery has its risks. Nowadays, it is widely used in various surgical fields of many countries as first line surgical intervention. Such advances have created breakthrough in medical science as the technical knowledge is not constant over time and aims to produce healthcare intervention more efficiently that might benefit the populations. Since it has been promoted among countries for many years, it is important to compare the development of robotic surgeries in different countries and extend the knowledge in health economics. Therefore, we choose 16 typical countries: 9 developed countries and 7 developing countries based on World Bank upper middle income and high-income countries.

To reflect the conditions of RAS technology in each country, we introduce an improved analysis of Quality-Adjusted Life Year (QALY) represent the supply side and Willingness-to-Pay (WTP) represent the demand side in the health economic evaluation that differ between developed and developing countries. QALY is used to compare the value of different healthcare interventions and treatments. It combines both the quantity and quality of life lived after receiving a particular healthcare intervention (see Figure 1). One QALY equates to one year of life lived in perfect health. The QALY score is measured on a scale from 0 to 1, where 0 represents a state equivalent to death and 1 represents full health (Whitehead & Ali, 2010). Negative QALYs are considered that the health state is worse than dead (Schneider, 2021). While WTP has no theoretical limit so long the patient can afford to pay for this RAS. Further prospective studies on health insurance coverage and learning curves of the surgeons related to RAS are needed in our next study.

[1, 2] Xiamen University Malaysia
* Corresponding Author Email: lee2pb@xmu.edu.my,

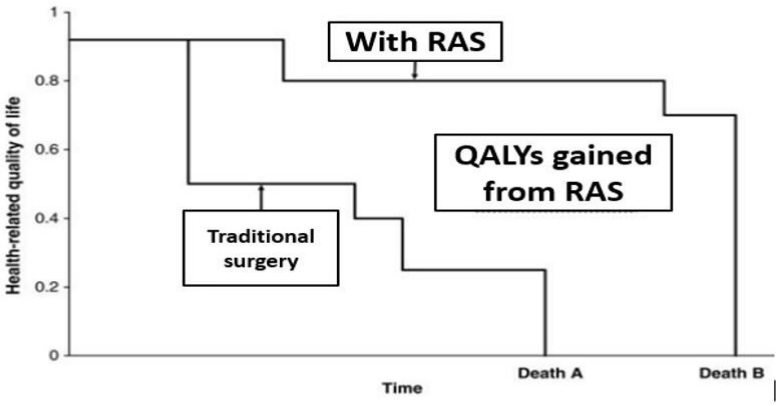

Figure 1. QALY gained from RAS

Source: Modified from Whitehead and Ali (2010)

II. METHODS

Our initial start began with PRISMA guided systematic literature review of RAS, QALY and cost-utility studies indexed in Web of Science, PubMed and ScienceDirect. Subsequently, our goal is to use of these data on traditional and RAS surgical interventions and transform it into a comparison based on the QALY concept from 2 perspectives in this research. First one is the WTP for an additional QALY (WTP/Q), which measures the preference of public to pay for extra one QALY. The multiplier reflects people's attitudes toward their health state, calculated by dividing WTP/Q by the GDP per capita. In Ye et al.'s research, they estimated that the average multiplier is 1.75 in China by using "a pre-designed questionnaire with 18 hypothetical scenarios". And in other research done by Kouakou & Poder, the predicted multiplier was 2.3 times for the province of Quebec, Canada. Therefore, to facilitate the following comparison for 16 countries, we simplified our Willingness-to-Pay for Robot-Assisted Surgery (WTPR) by using the multiplier of 1.75 and 2.3 to represent the developing and developed countries respectively. Second, one is using the incremental cost per QALY gained to compare the expense of traditional and robotic surgery in the same country and across countries. Our calculation depends on the method given by Prieto & Sacristán in 2003, it introduces the process: "in a cost-utility analysis, costs and outcomes are compared by dividing the incremental cost by the incremental outcome of one treatment over the other, which will indicate how much each additional QALY gained with the new treatment will cost". To simplify the calculation, we consider RAS as a new treatment, which will bring better outcomes (measured in QALYs) compared to the traditional methods. And the QALY of robotic surgeries is "3.6 QALYs", while the QALY of conventional surgeries is "1 QALYs".

III. RESULTS AND DISCUSSION

3.1 Article Selection Process

A total of 15041, 31018 and 6574 articles were identified and screened for eligibility through Web of Science, PubMed and ScienceDirect respectively that met our selection criteria in RAS. Of these, 76 articles that uses QALY and cost-utility were included in our quantitative analysis based on the work located in the 16 countries at the specified time frame.

3.2 Method I: WTPR (Willingness to Pay for Robotic Surgery)

WTPR refers to "willingness to pay for the robotic surgery", indicating people's economic capabilities of having robotic surgeries in each country. Figure 1 shows WTPR and changes of 16 countries from 2000 to 2022. During the 23 years, we find that the overall trend of WTPR for all the countries is increasing, which means as a country economy strengthen, the ability of paying the cost of robotic surgery is also stronger at the same time. But in certain periods, some countries facing a dropping WTPR due to some factors. For example, the pandemic in 2020 have a negative impact on WTPR for most of the countries.

To compare the ability of population to pay for the robotic surgery in each country, we depict the progress of RAS over every 5 years: 2000, 2005, 2010, 2015 and 2022 (i.e., the reason why not choose 2020 is the outbreak of COVID-19 at that time) in Figure 2 to Figure 6 accordingly.

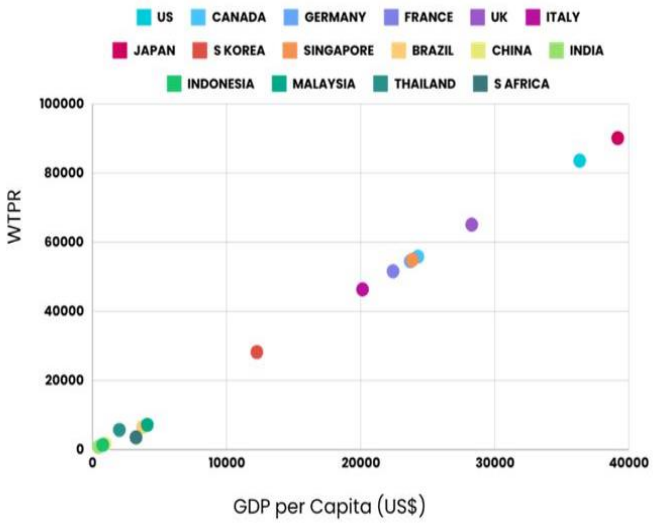

Figure 2. WTPR in 2000, Japan, US and UK were leaders in RAS

Source: Authors' calculation (2024)

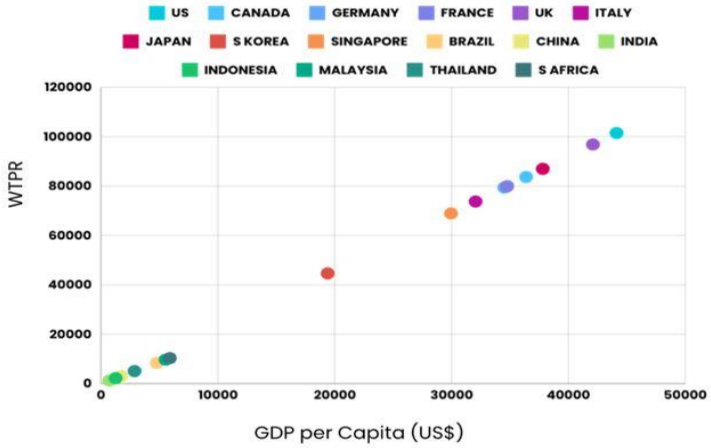

Figure 3. WTPR in 2005, US leap over Japan with the rise of Intuitive Surgical, European was catching up rapidly against the Americans, while China was slow in catching up against Thailand.

Source: Authors' calculation (2024)

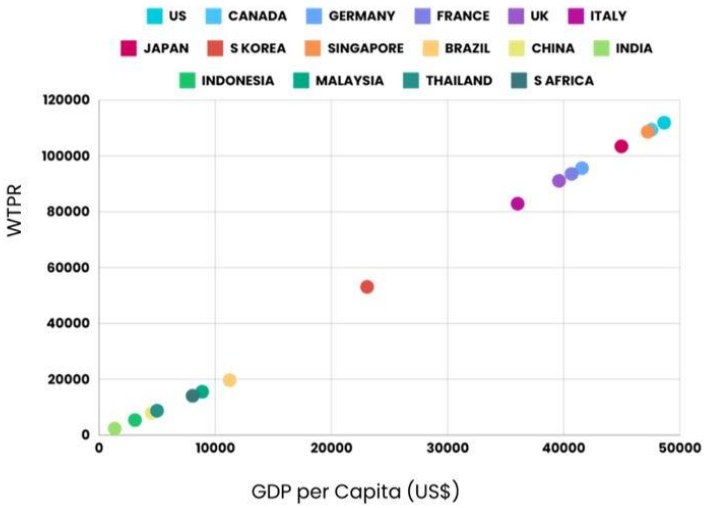

Figure 4. WTPR in 2010, Americans lead while China has started to compete very closely with Thailand.

Source: Authors' calculation (2024)

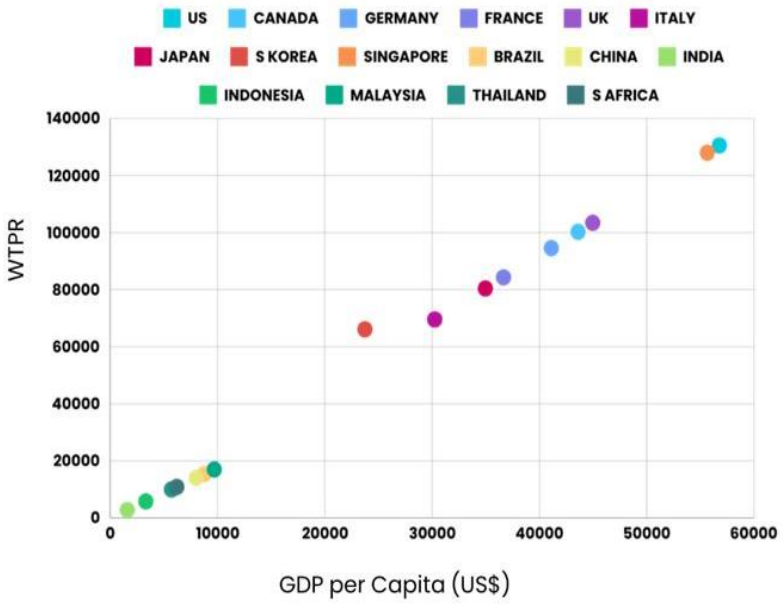

Figure 5. WTPR in 2015, Singapore had a huge improvement rapidly towards competing with US, while China has tremendous progress leap over Thailand.

Source: Authors' calculation (2024)

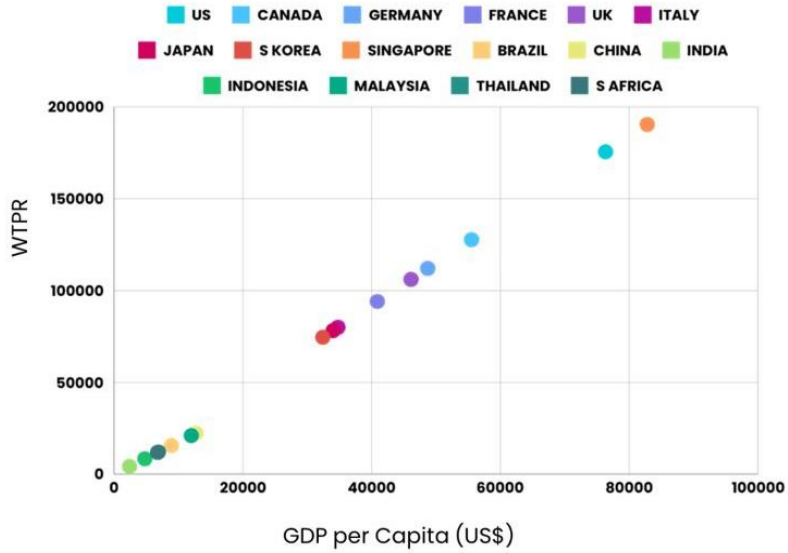

Figure 6. WTPR in 2022, 22 years later as the technology adoption matures and creation agglomerate and scale up, Singapore leads, Japan declined, while South Koreans progress. China has overtaken Malaysia and Thailand.

Source: Authors' calculation (2024)

From Figures 2 to 6 above, we can see the points of developing countries move fast along the curve and have smaller gap with developed countries, which can be verified with the average WTPR: in 2000, the WTPR of developed countries is more than 15 times larger than developing countries, while in 2022, the gap shrinks to only around 8 times.

3.3 Method II: Incremental QALY

For those developing countries that we have selected, they are typical representatives in their regions and have strong economic performance. Therefore, we categorize them as upper middle-income countries. DALY (disability and/or death) per 100,000 population in Table 7 and 8 provided by World Health Organization in 2020 shows that there is a high degree of similarity in diseases faced by these people even though in different income groups i.e., heart disease, stroke, diabetes, pulmonary, trachea, bronchus, lung cancer and respiratory. To simplify the situation,

the focus of robotic surgery technology companies or hospitals can be recognized as almost the same. Therefore, the comparison between 2 groups are meaningful. So, we choose 9 common diseases to calculate the cost by collecting the data of expenses of traditional and robotic surgeries from various journals from 2015 to 2024.

Table 7: Leading Causes of DALY in High Income Countries

High income				
2000				
Rank	Cause	DALYs (000s)	% DALYs	DALYs per 100,000 population
0	**All Causes**	**311,085**	**100.0**	**28,541**
1	Ischaemic heart disease	33,598	10.8	3,083
2	Stroke	17,983	5.8	1,650
3	Trachea, bronchus, lung cancers	11,461	3.7	1,052
4	Back and neck pain	10,520	3.4	965
5	Chronic obstructive pulmonary disease	9,740	3.1	894
6	Road injury	8,966	2.9	823
7	Diabetes mellitus	8,060	2.6	739
8	Depressive disorders	7,600	2.4	697
9	Falls	6,706	2.2	615
10	Self-harm	6,261	2.0	574

Source: WHO database (2024)

Table 8: Leading Causes of DALY in Upper Middle-Income Countries

Upper middle income				
2000				
Rank	Cause	DALYs (000s)	% DALYs	DALYs per 100,000 population
0	**All Causes**	**803,749**	**100.0**	**32,274**
1	Stroke	66,931	8.3	2,688
2	Ischaemic heart disease	54,801	6.8	2,201
3	Neonatal conditions	54,221	6.7	2,177
4	Chronic obstructive pulmonary disease	33,303	4.1	1,337
5	Lower respiratory infections	31,657	3.9	1,271
6	Road injury	31,207	3.9	1,253
7	Congenital anomalies	21,160	2.6	850
8	HIV/AIDS	17,814	2.2	715
9	Interpersonal violence	16,451	2.0	661
10	Tuberculosis	16,219	2.0	651

Source: WHO database (2024)

Table 9 below demonstrates the result of the incremental QALY in 9 fields for developed and developing countries. In many cases, developing countries have a higher incremental QALY, while developed countries have lower and even negative incremental QALY, which means the developed countries have mature robotic surgery technology and operation system in that particular area. In other words, they have already started enjoying the benefit of the economic scale, bringing the lower cost. Some other cases developed countries have higher incremental QALY. It may due to the high cost of labor or the immaturity of the technology at this moment. This phenomenon may also indicate that some developing countries have their own technology and have potential to compete with developed countries.

Table 9: Incremental QALY for Different Types of Robot-Assisted Surgery Operations

Economy	RAS Surgical Operation Type								
	Colorectal	Urology	Gastric	Uterine	Laparoscopy	Pancreatic	Prostate	Spine	Thoracic
Developing Economies	China: 736.65	India: 152.34	China: 1252.97	China: 611.15	Brazil: 1093.25 Thailand: 1818.24	China: 64.37	China: 1637.51	Thailand: 666.15	China: 1344.74
Developed Economies	Canada: 558.85 Italy: 2317.33 United States: -17645.59 South Korea:1795.77	United States: 630.77	United States: -360.38	United States: -506.54	Germany: 1511.92 Canada: -381.16	Germany: -97.34 Italy: 1070.84	Canada: 1081.57 France: -915.46 South Korea: 4133.08 UK: -2518.08 United States: -1970.42	United States: 420.21	Japan: 1415

Note: "- sign" shows a cost reduction in robot-assisted type of operation cost.

Source: Authors' calculation (2024)

IV. Conclusion

By analyzing with two methods, we found that the capabilities of people in developed countries is stronger than people in developing countries, which means that the demand of robotic surgeries from the developed countries is higher than in developing countries. As for the supply side, developed countries generally have more mature technology and therefore, the overall cost of robotic surgeries is lower than the developing countries. In conclusion, the robotic surgery market in developed countries is more popular and mature compared to developing countries. However, the development in some developing countries is incredibly fast, especially China, while South Korea and Thailand progresses positively too. From 2000, China's average WTPR is only 1,678.881 to 22,260.37856 in 2022, which has increase more than 13 times within 3 decades.

V. Acknowledgement

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