The Impact of the da Vinci Surgical System in the Medical and Medical Education Fields and Whether It's Worth the Investment

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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STS Thesis

Introduction

It's not a secret that technology and robots are starting to become more prominent in our society. Not only are they automated, but they are created simply to complete specific tasks as efficiently as possible. That's why a company called Intuitive Surgical has created a surgical robot called the da Vinci Surgical System. This robot allows the surgeon to complete tasks within a surgery that exceed human capabilities, such as being able to rotate the wrist like arms in ways the human wrist cannot. Although this machine sounds revolutionary, the problem lies within the cost and learning how to use the machine itself. This robot is a huge advancement in the medical technology field, but it can also cause changes to medical education because if it takes off, more surgeons are going to need to be able to use the system.

The da Vinci Surgical System first took off in 2000 and has sold more than 1700 systems around the world; they have systems sent out to the US, Switzerland, Germany, UK, France, China, Taiwan, Japan, Korea, and India. Around 775000+ procedures have been completed by the da Vinci Surgical System. The inventor of the system is a company named Intuitive Surgical; Intuitive Surgical is a company that creates advances in the medical field through development in robotic-assisted technology, tools, and services for surgery. They are both the sole creators and developers of the da Vinci Surgical System. Other robotic surgery robots were being developed as well, one named Zeus and the other Aesop, however, Intuitive Surgical bought both out and they dissipated, making Intuitive Surgical the leading company in the medical technology field.

The research I have conducted focuses on articles and experiments that target the effective use of the da Vinci Surgical System and how beneficial it is compared to hands-on

surgeries, its error rate and what impact it makes on a procedure, and lastly, how it will affect the medical education system. These are essential in order to determine the worth of the machine and whether or not it's practical to install this method of surgery within our current medical field.

Literature Review

The following articles relate to the value of Robotic-Assisted Surgeries:

Abrishami, Boer, and Horstman (2020) investigate the qualitative value profile of the da Vinci Surgical System through review of 2 decades of extensive clinical use and research alongside the controversies of such evidence. With controversies around innovation-based, market-based, science-based, or practice-based ideals of technology introduction, it's undecidable whether or not the value profile of the da Vinci Surgical System is positively or negatively impacting the medical field.

Mukherjee and Sinha (2020) explore the possibilities of maximizing clinical outcome benefits while also minimizing the costs of robot assisted surgeries. Data was compiled of all medical expenses, money spent on resources to use the da Vinci Surgical System, and the outcomes of robot assisted surgeries versus manual surgeries. An underlying issue with the da Vinci Surgical System is the great expense that must be paid, however not only from the machine alone. Money must be used to get training for surgeons to effectively use the surgical system to achieve said benefits of robot assisted surgeries. This is something that would be looked into for universities all over the world as training courses for the surgical system would be required for med students if the da Vinci Surgical System were to be commonly utilized.

The following articles relate to occurrences and effects of failures/malfunctions:

Kim, Ham, Jeong, Song, Rha, and Choi (2009) analyze the mechanical failures and malfunctions of the da Vinci Surgical System between July 2005 and December 2008 and evaluates the solutions for them. 1797 robotic surgeries were reviewed with 43 of them having some type of mechanical failure or malfunction. On top of that, only 3 conversion surgeries were needed (1 open and 2 laparoscopic). The low failure rate with an even lower conversion rate exemplifies the safety of the da Vinci Surgical System in its current state and the overall success that it could bring to the technological medical field.

Rajih, Tholomier, Cormier, Samouëlian, Warkus, and Liberman (2017) evaluate the effects of malfunctions that occur with the da Vinci surgical system during a robot assisted surgery. 1228 robotic surgeries between January 2012 and December 2015 in urology, gynecology, and thoracic surgery were reviewed by the author. Of all 1228 surgeries, 61 had malfunctions occur during the surgery; this is a relatively small percentage of surgeries. With only 4.97% of surgeries containing malfunctions, it's hard to fight against the use of robotic assisted surgeries. The author concludes that although malfunctions can be considered not infrequent, rarely they are consequential, meaning that the patient is not negatively affected in the outcome of the surgery.

The following article relates to the comparison of Robotic-Assisted Surgeries with other types of surgeries:

Xie, Li, Wang J., Wang C., and Xiang (2020) compare the differences in safety and effectiveness between open procedures, laparoscopic procedures, and robot-assisted procedures regarding choledochal cyst excisions. The author analyzes choledochal cysts procedures between

January 2015 and December 2018 with the data including demographic information of the patients, their type and size of cyst, operative details, and postoperative outcomes. Out of all three types of operations, laparoscopic took the longest to complete while open procedures created more intraoperative bleeding. This shows the balance of robot-assisted procedures and the benefit of moderate completion time with minimal blood releasing incisions.

The following article relates to the learning tools of the da Vinci Surgical System:

Pandya, Eslamian, Ying, Nokebly, and Reisner (2019) examine the robotic recording and playback accuracy for movements of the da Vinci Surgical System. The author is ideally trying to create training modules for surgeons by using recording and playback features of the surgical system. His research concluded that the recording and playback feature was very accurate with the source only being off by an average error distance of 4mm. When it's fully developed, surgeons will not need to be trained on the spot and would already have pre-existing knowledge on how to operate the robotic surgical systems through a tutorial curriculum.

The following article relates to gender gap:

Chiu, Kang, Wang, Tong, Chang, Fong, and Wei (2020) examine the difference in performance of robotic suturing between male and female medical students. The author uses virtual reality robotic simulations and robotic dry-laboratory simulation training as a means to compare the aptitude of the two test groups. 39 males and 19 females were used in this experiment, which is not ideal as there is a difference in the sample size between the two groups; this will cause skewed data as there are fewer female testers which can mean less failures or less successes compared to the male group. The experiment resulted in females outperforming the

males in both the VR and dry-lab portions. However, the experiment should be conducted more times with a more balanced set of test groups to achieve a better analysis of the results.

The following articles relate to the difficulties of using robotic surgeons:

Eslamian, Reisner, and Pandya (2020) examine different camera controlling algorithms of the da Vinci Surgical System. Through his experiment, he used 20-participant test subjects to try an autonomous camera algorithm, a standard clutched control, and an experienced camera operator using a joystick. He was able to conclude that the autonomous camera algorithm was the best option. Manual control of the camera creates an increase of workload for the surgeon controlling the robot as they have to worry about moving the camera into place for their tool arms which disrupts the surgery altogether. This adds on to the difficult learning curve of using robot surgeons compared to hands-on surgeries.

Dal Moro, Secco, Valotto, Artibani, and Zattoni (2012) research the effective learning curve of using robotic-assisted laparoscopic radical prostatectomy and reached a conclusion that efficiency improvements plateaued after 60 consecutive robotic procedures, thus showing how improvements in using the da Vinci Surgical System are capped due to effective port placement.

Sumi, Dhumane, Komeda, Dallemagne, Kuroda, and Marescaux (2013) also research the effective learning curve of the da Vinci Surgical System by comparing the effective use of the machine between a new and experienced user. She concludes that the learning curve is steep and the effective use is plateaued which is shown when the new user is able to reach the same capabilities as the experienced user after only 1 training program for creating 5 internal stitches on non-surviving animals.

STS Framework (Hughes' Prospective)/Research Method

The system builders for the da Vinci Surgical System is Intuitive Surgical. They developed the da Vinci Surgical System to help enhance rehabilitation by allowing surgical methods that are incapable for the human body to perform. Such methods include a rotating wrist-like arm that is able to twist and maneuver around in ways that surpass the way a human arm is limited to. This allows surgeons who control the robot to cause less internal bleeding by creating less incisions within the body, which also leads to less stitches that need to be made so that the patient can have less parts of their body that need tissue healing. Even though there is criticism behind the da Vinci Surgical System, such as the pricing of the overall robot, the innovation capabilities push big advances in the medical industry and opens the path of robotic and medical hybrid collaboration.

The reasoning behind the high price is due to the technical features that are implemented; it vastly improves both the quality of surgical procedures and the visual aspect for the surgeon. The da Vinci Surgical System is equipped with a high quality 3-D visual camera that is 10 controlled by the surgeon and gives them greater control over the surgery at hand. Due to the high needed knowledge of the system itself, the system's expansion is solely in the hands of its creator, Intuitive Surgical.

The main reverse salient of the da Vinci Surgical System is the tough learning curve. The system itself is hard for users to learn and uses a proprietary system which doesn't allow any modifications to the surgical system. This creates a limitation to the operation system and stunts the growth of the system overall. This best way for this reverse salient to be removed would be

allowing the system to be modified, allowing others to supply inputs on how to further improve the system and help the development of the da Vinci Surgical System overall.

The leading argument of why the da Vinci Surgical System is a needed improvement in the medical field is that it helps reduce the recovery time for patients. This is a tempting reason for many to use this new technology, but the cost of these surgeries is the main reason it's not fully accepted into society.

My choice of research method is solely document analysis. I believe this is the best method for my topic as I do not have access to any participant observations due to COVID and with the lack of networking in the medical field, I would be too complicated for me to try to get an interview with someone experienced with the da Vinci Surgical System. Lastly, there is not much to survey on regarding my topic, so that was not considered as well.

Data Analysis

The da Vinci Surgical System hypothetically will create a great impact on the advancement in the medical field, however, it has underlying issues that aren't appealing to society. There are many controversies revolving around the innovation-based, market-based, science-based, and practice-based ideals surrounding the system, such as creating a job deficiency for surgeons as well as a huge financial cost of the machine (Abrishami, Boer, Horstman 2020). After compiling all medical expenses, money spent on resources to use the da Vinci Surgical System, and the outcomes of robot assisted surgeries versus manual surgeries, it's concluded that currently, the cost of the machine and its maintenance is a big factor on why it's hard to fully incorporate it into our daily lives (Mukherjee, Sinha 2020). However, there are multiple medical benefits of using the da Vinci Surgical System over hands-on surgeries, such as

less intraoperative bleeding during operations (Xie, Li, Wang J., Wang C., Xiang 2020). This is due to the fact that using the robotic arms of the machine allows movement that humans aren't able to make, thus needing less incisions to reach the target area. Another benefit resides within the decrease in recovery time. With less incisions comes less stitches, meaning less work the body needs to do to heal the opened wounds as well as creating less internal and external scars. This becomes revolutionary towards the older generation and may increase the average life span as some patients become too old to withstand an increase of blood loss from open surgeries and have weaker bodies that may be unable to recover from a multitude of open wounds.

Aside from the financial situation, the da Vinci Surgical System performs at a high level and should not give patients worry whether a malfunction occurs or not. Errors occur at an extremely low rate and cause harm to the patient at an even lower rate. After a review of 1797 robotic surgeries between July 2005 and December 2008, only 43 of them had some type of mechanical failure or malfunction and only 3 conversion surgeries were needed, 1 being open surgery and 2 being laparoscopic (Kim, Ham, Jeong, Song, Rha, Choi 2009). Another review of 1228 robotic surgeries was conducted between January 2012 and December 2015, which ended with similar results; only 61 had malfunctions occur during the surgery (Rajih, Tholomier, Cormier, Samouëlian, Warkus, Liberman 2017). On average, between the two sample sizes, only 3.428% had malfunctions occur while only 0.099% required a switch to hands-on surgery. With the low percentage of malfunctions and surgery switches, this helps ease the case of patients who are worried about the difference between a human and a machine conducting their operation.

Lastly, teaching a new generation of medical students how to use the da Vinci Surgical System, if it were to be fully implemented, may be tough in the beginning, but the tools are there for students to get a full grasp of its functionality. In its current state, the effective learning curve

of the machine plateaus early due to the difficulty of finding more efficient ways of using the system. After only 60 consecutive robotic procedures, efficiency improvements plateaued because the user was capped due to a steep learning curve and effective port placement (Dal Moro, Secco, Valotto, Artibani, Zattoni 2012). With the steep learning curve in mind, we must also be aware of any impending increase in gender gap. A test group consisting of 39 women and 19 men were tasked with a virtual reality robotic simulation and a robotic dry-laboratory simulation to compare the aptitudes of the two test groups (Chiu, Kang, Wang, Tong, Chang, Fong, Wei 2020); the results ended with the women out performing the men in both simulations. Albeit a small sample size, there may be an underlying issue on why this result occurred and is something that would have to be looked into. However, teaching students the current knowledge of how to use the machine will invoke faster progress on its capabilities. With robotic recording and playback accuracy, this allows experienced users to create training modules that help students learn what is currently known about the use of the da Vinci Surgical System (Pandya, Eslamian, Ying, Nokleby, Reisner 2019). Thus, the impact of the da Vinci Surgical System in the medical education field will eventually become easier to handle as each generation will be supplied with more information than the previous. This will help steadily lower the cost of implementing robotic surgeries as less money/resources would be needed to fund the teaching of using the da Vinci Surgical System.

Discussion/Conclusion

Using the data collected, it's shown that the da Vinci Surgical System provides strong health benefits that may increase the average persons' life span with minimal risk, but it comes with cons that create bigger concerns to the public. Unfortunately, many aspects of a healthy lifestyle are stuck behind a pay-wall, with the use of robotic surgeries not being an exception.

In comparison to open surgeries, the da Vinci Surgical System excels at decreasing blood loss, internal and external scarring, and recovery time, but is much more costly. Taking into account the cost of the machine itself, its maintenance, and the cost of educating new, up-and-coming, and existing surgeons, the overall price of conducting robotic surgeries increases exponentially. However, robotic surgeries remove human error, perform tasks that the human body is incapable of such as reaching areas within the body that hands are either too big for and/or cannot reach, and can overall be safer than open surgeries.

The data collected also helps prove the overall safety of the machine itself, boasting a small 3.428% malfunction rate and an even smaller 0.099% surgery switch rate within the cases reviewed. Although the word “malfunction” may worry patients, this does not always indicate that the patient is in danger; it purely means that the system is not working as intended.

Lastly, although the surgical machine has been out for 21 years, there is still much to learn on how to effectively use it. The main reverse salient is one of the most troubling aspects of robotic surgeries with the data showing that the steep learning curve is causing an early plateau of efficient use of the da Vinci Surgical System, but that there’s also hope of being able to fully implement it into the medical field. With a set of medical students coming in each year, the use of robotic recording and playback accuracy will help stimulate the exponential growth in knowledge of this machine as each generation will be able to provide more and more information to the next. This begins the transition of system builders from Intuitive Surgical to the new generation of medical students and where the true development of the da Vinci Surgical System occurs.

In conclusion, the da Vinci Surgical System has the potential to become revolutionary in the medical field and can become life changing for a lot of patients. However, the current state,

and especially the price, is not something that can be overlooked and will have to be accounted for before its full implementation into our society. The use of the Hughes' Prospective framework helps map out the key issues of learning curve and price while also establishing the groups that will play the biggest role in improving the use of the da Vinci Surgical System (Intuitive Surgical and the new generation of medical students). For future works, I hope to be able to observe the procedures in person and interview the surgeons manning the system in order to create my own set of data points and qualitative notes.

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