Joe Barbieri

Wortman-Wunder

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Applications of Robotics in Surgical Situations

Abstract

The field of robotics is constantly advancing. New technology in robotic surgery is yielding improved medical outcomes for patients, and there is an increasing demand for robotic technology in clinical medicine. This review seeks to highlight the improved medical outcomes robots are creating across multiple fields of surgery by synthesizing available data and research. The shortcomings, limitations, and future improvements needed for surgical robotics will also be discussed.

Robotic assisted surgery makes minimally invasive surgery possible, and this review will focus primarily around minimally invasive surgery. Robots across all fields of surgery share similar positive outcomes and negative costs. Many of the same machines are used in different kinds of surgery, and improvements to one model will carry over to other models. Clinical robots are still changing and improving to keep up with the demand of the medical industry; they are only getting better. Thus, while robots are a costly initial investment, their potential and always changing technological improvements makes them a bright beacon for the future of advanced surgery.

Intro

Across multiple fields of surgery, robots and programs of robotic assisted surgery (RAS) have seen an upturn in data and successful application. With the advent of minimally invasive surgery, robots are finding a new home in the operating room. This review seeks to compile existing data of robotic applications in cardiac procedures, neck surgeries, urology, bariatric surgery, and gynecology and examine the outcomes of RAS in those fields. While these fields are mostly unrelated, the outcomes and data are similar enough to be reviewed together and synthesized.

Robotic surgery is still a new field. RAS holds many advantages over older practices, but there are factors that are deterring many hospitals from adopting the new technology. While older surgical practices are not obsolete, they can often be changed or improved with the application of robotics. When covering the literature in the field, this review also seeks to highlight the advantages of robotic surgery over older practices by synthesizing and assessing available research, answer the question of how robotics needs to change in order to stay in the medical field, and discuss the history and future of applied robotics in medicine.

A Brief History of Robotics

The first robot used in surgery was called the ‘Arthrobot’ and was used in an orthopedic surgery in 1983 (Yates, Vaessen, & Roupret, 2011). From here, it was believed that robots had serious potential applications in clinical medical settings. Robots had already been used in automobile plants for years (Hockstein, Gourin, Faust, & Terris, 2007) with clear advantages over human workers. They were faster and more efficient, and there was a subsequent focus on the medical applications of robots.

In 1992, the computer guided machine known as the ‘Robodoc’ was shown to be more effective in certain areas of hip replacement surgery by a series of clinical trials (Hockstein et al., 2011). This was the first instance of successful RAS trials completed and opened the door for collaborative surgeries between man and machine. It was also the first stage of minimally invasive surgery—the type of surgery performed exclusively by current generation robots.

The American military saw potential for devices controlled remotely by a doctor for operating in a hot zone. The idea was to have the doctor someplace safe while a robot (controlled by the doctor at base) could safely operate on a wounded soldier in the middle of a battle. With funding from the Pentagon, research went into building AESOP, an automated endoscopic machine used in place of a typical surgical assistance team (Hockstein et al., 2011). Though it took up a large amount of space and was expensive to set up, the AESOP machine changed how surgery could be done. Many current generation robotic assisted surgeries still use this same method, and many of the machines used were inspired by this research.

A key note in the case of AESOP was its cost and original flaws. It was believed to be too costly in place of a full surgical team, but slowly improvements were made, and the technology became better for both the hospital and the patient. A repeat of this is happening today with new surgical robots, and to an extent, they are just better versions of the original AESOP machine. The medical industry’s dedication to the robotic technology of AESOP proves that there was a need for better medical technology then, and there still is now. As the technology improved, so did the medical outcomes. This can be seen today with the Da Vinci surgical system and the new Da Vinci XI, which is changing how surgery is done.

Overview of Improved Medical Outcomes of RAS

Robotic applications in surgery have improved since their first showing in the 80s and are now considered integral for some medical procedures and parts of daily human life (Zhang, Wang, Xi, Wang, & Liu, 2018). They have traditionally been used mostly in gynecological procedures, urology, and neck surgery (Li et al., 2016) but have now seen extensive use in bariatric and cardiac surgery. RAS allows doctors to perform minimally invasive surgery. In theory, minimally invasive surgeries will reduce damage to the patient, reduce scarring, and reduce blood loss. The small instruments mounted on most robotic surgical machines can operate with increased accuracy in a minimally invasive way for the patient (Hockstein et al. 2011; Gao, 2014).

Gynecology, neck surgery, urology, cardiac, and bariatric surgeries were selected for this review because they have the most data available. Though these are all different kinds of surgery, they share many benefits from RAS. The unique advantages of each kind of surgery usually can not be compared, so only shared benefits will be compared across the different kinds of surgery. For the purpose of comparison and analysis, surgeries will be organized in descending order of fields with the most data, beginning with cardiac surgery.

Improved Outcomes in Cardiac Surgery

Robots are capable of closed chest surgery, where the heart is operated upon without the need for fully opening the patient’s chest. This is done using current generation robotic technology, similar to the models like AESOP or the Da Vinci XI. A number of different heart procedures can be performed using closed chest surgery (Gao, 2014) and the success rate for them is high, especially with mitral valve repair, which has a 98% success rate with robotic application (Dearani, 2018). As with urology, thyroidectomy, and prostatectomy procedures, robotically assisted cardiac procedures see lowered hospital stay times and less blood transfusions (Dearani, 2018; Ilic et al., 2017).

The real significance and improvement that must be highlighted with cardiac surgery is the closed chest style of surgery, which has only been made possible because of robotics. The robotic arms are more dexterous than a surgeon's hands in close quarters (Gao, 2014) and thus have many improved applications in cardiac surgery. There are procedures where the rib cage must still be split, but RAS has eliminated that need for several kinds of heart surgery. This greatly reduces recovery time and scarring (Gao, 2014; Dearani, 2018) and is an objective advantage over regular open-heart surgery.

Improved Outcomes in Neck Surgery and Urology

Another example of minimally invasive procedures can be seen with the Da Vinci XI's work with neck surgery. The Da Vinci XI, a three-armed robot controlled remotely by a surgeon, can operate with smaller incisions on the patient (Byeon et al., 2017). Neck surgery, particularly thyroidectomy, has seen some of the best results with RAS. Data shows that the use of the Da Vinci XI can reduce total thyroidectomy operation time by 40 or more minutes (when compared to older Da Vinci robots), and total thyroidectomies with modern radical neck dissection is reduced by 30 or more minutes (Byeon et al., 2017). This is achieved by the robotic technology allowing for the skipping of certain steps, and the machines often working faster than a human hand could. Unlike humans, robotic arms don't experience the stress and fatigue associated with long surgeries, and the machining allows for continuous quick movement. This reduces the time spent in surgery.

Along with shorter operations, RAS decreases the time spent in the hospital for the patient, especially when applied in urology (Yates et al., 2011). Most data show that there is no significant difference in time needed to stay, although most fields see a small decrease in days spent in recovery after surgery. This is an advantage for the patient, as they are spending less for hospital charges. RAS have shown improvements in the need for blood transfusions, and number of surgical complications. Across nearly every field we see data highlighting fewer blood transfusions in robotic surgery (Ilic et al., 2017; Yates et al., 2011; Dearani, 2018; Li et al., 2016).

Improved Outcomes in Bariatric Surgery

Bariatric surgery is often used to help treat extreme cases of obesity. RAS can improve outcomes in serious cases of the surgery (Li et al., 2016). RAS have shown improved health outcomes for patents undergoing bariatric procedures. In this field we see many of the shared improvements seen across other surgical fields. Note that robotically assisted bariatric surgery takes longer than regular bariatric surgery. This stands as an anomaly when compared to other fields of surgery. Robotically assisted bariatric surgery still benefits from shorter recovery times and less blood transfusions though (Li et al., 2016).

The unique improvement with robotically assisted bariatric surgery is the lessened occurrence of anastomotic leaks. Anastomotic leaks happen when fluid escapes a surgical join or sutured area in the gastrointestinal region. Left untreated, they can be fatal. Robotically assisted bariatric surgeries yielded 17 leaks compared to 118 in conventional laparoscopic bariatric surgery (Li et. al 2016). The tools of the robots can secure sutures more securely in the compressed areas of the surgical site, thus reducing the risk for anastomotic leak to occur.

RAS in Gynecology and Patient Response

Robots have found positive reviews in the field of gynecology and oncology. One study covered patient responses on minimally invasive RAS at the Sheffield Teaching Hospitals. Patients were asked about their experiences with RAS, and the results were very positive. 99% of patients were satisfied with the procedure and care they received, and 91% would recommend RAS (Long & Kew, 2017). 62% of the 99% of satisfied patients said that the procedure done with the help of robots was excellent (Long & Kew, 2017). These results are not taking in medical data per se, rather patient response to working with new minimally invasive surgical robots.

Limitations of Medical Robotics and Necessary Future Changes

Surgical robotics and RAS are hindered by several problems. In several studies, it was found that RAS is much more expensive for both the hospital and the patient. One study focused on five different procedures and compared costs between traditional open surgery and RAS. The procedures were colectomy, cholecystectomy, inguinal and ventral hernia repairs, and bariatric procedures, and studies found a 4% cost increase with RAS (Armijo, Pagkratis, Boilesen, Tanner, & Oleynikov, 2017). The lowered hospital stay times are generally seen as statistically irrelevant as they tend to only take a day or less from the overall recovery time. Patients were paying more for procedures that had similar if not slightly improved medical outcomes (Armijo et al., 2017) and this is a concern for an already expensive medical system.

Another concern stands for the hospital administrative staff. Though robots have seen a general trend of improvement in surgery, the initial cost is still high. In 2011, the cost of installing a robotic system capable of surgical application ranged from 1.4 million dollars to 2.2 million dollars (Yates et al., 2011). Maintenance fees were expensive, ranging from $100,000-$200,000 each year (Yates et. al 2011). Though improvements have been made in an attempt to make the machines more cost effective, their price still sits in the millions and the maintenance is still a costly problem (Gao, 2014; Li et al. 2016). For future applications to continue, medical robotics will have to find a way to become more affordable for the patient and the hospital (Armijo et. al 2017).

Because the technology is still so new, robots are not accepted in every hospital. Many hospitals are hesitant to pay the high price of purchase for a machine that has limited data to back it up. As of now they are limited in the surgeries they can complete. One big reason for this is the lack of automation and ability to adapt to a new situation. Many of the robots in surgical rooms today are still controlled in some way or another by a surgical team. Most automated machines working today are either doing the same movement repeatedly, or are slow moving machines driving in a familiar environment (Nebot, 2018).

Challenges still exist in making robots that are aware of their own environments. It’s only recently that robots have been programmed to adapt to situational changes, and we see this mostly in agriculture technology (Nebot 2018). Because of this challenge, robots are limited in the types of surgeries they can perform, as many still need a team of surgeons directing the procedure to compensate for a robot’s lack of adaptability. Adaptation technologies will have to advance further before robotic applications in the operating room can improve. Until then, they will act as assistants to a surgical team.

Discussion and Conclusion

Robotics has opened a new door in medicine. Though their applications are limited now, they are already improving outcomes in their fields. Doctors can work in new ways that improve the outcome for the patient and make their own job easier. Operation times can be reduced, and surgical complications are almost always lessened. Patients lose less blood, recover quickly, and go home with less scarring. The patients of robotically assisted cardiac, neck, and bariatric surgeries have unique positive outcomes specific to the field of surgery. Through this synthesis of data, there is clear evidence that robots provide positive outcomes across the selected fields of surgery. While their work has improved medical outcomes across these surgeries, their cost is making some hospitals wary of the new technology, and the limitations that come with being a machine show in some operations.

Constant improvements are required to ensure the health and longevity of robots in the medical field. With positive data and a constant demand for improved medical outcomes, the technology will continue to improve. Robots are making a difference in the medical field and may be the future of surgery.

Resources

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