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Review Article

Are You Ready to Take Off as a Robo-surgeon?

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Abstract
Robotic-assisted surgery is the latest iteration toward less invasive techniques. Surgeons have slowly adapted minimally invasive and robotics techniques into their armamentarium. We have developed a robotic cardiac surgery program in Japan that utilizes the da Vinci Surgical System, allowing the surgeon to perform complex procedures through 5-mm port sites rather than a traditional median sternotomy. In this rapidly evolving field, we review the evolution and clinical results of robotic-assisted surgery and take a look at the other general surgical procedures for which da Vinci currently being used.

Key words TECAB · Robotic surgery · da Vinci Surgical System

Introduction

Accompanying the Westernization of dietary habits and our aging population in Japan, the heart diseases treated by surgery have changed over the past few decades. We have witnessed a transition from heart diseases centered on rheumatic valvular disease 30 years ago, to coronary artery diseases and the inception of bypass surgery 20 years ago, and then on to the present-day diseases such as coronary artery disease, arteriosclerotic aortic valve disease, and valvular disease caused by degenerative changes of the mitral valve. Furthermore, with the remarkable advances in adult and pediatric cardiac catheter interventions and various devices, many diseases that were conventionally treated by surgery can now be treated in departments of cardiovascular medicine or pediatrics. This trend is a welcome development in the sense that operative techniques traditionally developed in surgical departments have now diffused to various disciplines of medicine. On the other hand, the decrease in surgical cases has halted an increase in young doctors aspiring to become cardiac surgeons. In addition, the trend toward minimally invasive surgery represented by endoscopic procedures in general surgery continues to accelerate, and we are faced with a situation in that we can no longer avoid deploying minimally invasive techniques, even in heart and neuron surgery. Naturally, surgeons who are not equipped or proficient to perform such techniques will be left out of the trend. To those aspiring to become surgeons in the future and newly qualified surgeons who are envisaging the surgical treatments in the next 10 or 20 years, it is our duty as leaders in surgery to show them new ingenious operations and procedures that can only be performed in the department of surgery. In this context, the superiority of surgery as the final safety net, and the creation and publication of new surgical procedures as a way to show the world the dignity of surgery are extremely important. In this review I discuss the global trend and our approaches to heart surgery. The hottest topic related to heart surgery in the last decade has been the advent of robotic surgery.

The da Vinci Surgical System

Development of the da Vinci Surgical System began in 1994 and the breakthrough system was unveiled in 1998. Originally designed for building a remote-controlled robotic surgical system that could be applied in the Gulf War, Intuitive Surgical Inc., which is a venture enterprise in Sunnyvale, California, USA, raised the initial venture capital and invested over 10 billion yen initially, followed by some 300 million yen every month thereafter. After 3 years and a huge investment, the system was almost completed. Many technological scientists from

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the Massachusetts Institute of Technology and the National Aeronautics and Space Administration reputedly participated in the development of this machine, and the fact that the founding president is a surgeon himself may have accounted for the impressive success of this equipment. Around the same time, Computer Motion Inc. (Goleta, CA, USA) also launched the Zeus robotic surgical system, providing a great driving force for the unfolding of the era of robotic surgery. Using the Zeus system, a trans-Atlantic operation called the "Lindenberg operation" was conducted, in which a patient in France was operated on by a surgeon in New York.

What kinds of diseases can be treated by the da Vinci Surgical System? To date, over 280000 operations using the da Vinci Surgical System have been reported worldwide. Urological procedures dominate, accounting for over 200000 (70%), but many gynecological, obstetric, gastroenterological, and other operations have been performed using the robotic system as well, including over 20000 heart operations. Because the system was originally developed to excel in intricate manipulations in the deep surgical field, such as coronary artery anastomosis, the da Vinci Surgical System allows us to perform very fine surgical maneuvers. Structurally, the surgical arm, with its seven degrees of freedom combined with a three-dimensional endoscope, enables fine and intricate surgical procedures to be performed. There follows a description of the application of this system to heart surgery, with a brief reference to gastroenterological surgery.

The application of the da Vinci Surgical System to the treatment of heart disease was first reported in 1998 by Dr. Mohr at the University of Leipzig in Germany, and then in 2000 by Carpentier's group at the University of Paris. The operations performed were internal thoracic artery harvest and coronary artery anastomosis in an arrested heart. To arrest the heart, an endoaortic balloon was inserted via the femoral artery into the aorta, which was occluded, and a cardioplegic solution was infused to protect the myocardium. The coronary artery was then dissected, and the internal thoracic artery was anastomosed with the anterior descending coronary artery conventionally with sutures.

The da Vinci system has subsequently been used to perform totally endoscopic procedures off-pump.[1] In 1999, my group was the first in the world to perform totally endoscopic coronary artery bypass without using the da Vinci system, and we reported our experience in *The Lancet*.[2] Many totally endoscopic coronary artery bypass operations have been reported since, and some institutions have even started to use this bypass procedure for multivessel lesions. Needless to say, the advantage of completely endoscopic coronary bypass, which requires only mini-incisions, is that sternotomy can be avoided and the patient is able to resume the same activities of daily living (ADL) as before surgery, without having to wait for the sternum to heal. Consequently, the overall quality of life is extremely good. We estimate that a person who undergoes conventional median sternotomy will take approximately 2–3 months to return to their preoperative working capacity, whereas a patient who undergoes totally endoscopic surgery using the da Vinci system is discharged on hospital day 3 and rehabilitates completely, even up to performing manual labor, within 1 week. This quality of life is the characteristic of endoscopic surgery, a merit that is invaluable. There is a need for better understanding of "quality of life": an important term that cannot be estimated simply by comparing the number of days in hospital stay and the length of incision, because even surgeons may have misconceptions of this. The cosmetic merit of endoscopic surgery is also crucial, especially for women, as they are spared the large incisions including longitudinal sternotomy, left thoracotomy, and right thoracotomy, whereas the resulting wound from a da Vinci procedure is hardly noticeable. A third advantage is the short hospital stay, which obviously translates to a reduction in medical costs.

Surgical robots also have great potential for treating mitral valve disease, the surgery for which is carried out conventionally via a median incision. Nowadays, with the increasing popularity of mitral annuloplasty, it is difficult to observe the physiological closure insufficiency of the mitral valve in an arrested heart. This is because when the mitral valve is approached through a median incision, it is positioned vertically, making detailed observation difficult. Anatomically, the mitral valve can be observed in the most physiological manner from the right thoracic cavity. We perform mitral annuloplasty via a right thoracotomy, and visibility of the valve is best from the right thorax. Mitral valve repair is one heart operation for which the da Vinci Surgical System excels. The da Vinci system exhibits its power in repairing the valve in a deep and narrow surgical field, and also in observing and repairing the subvalvular lesion inside the ventricle (Fig. 1). The first mitral valve repair using the da Vinci system was performed by Carpentier's group in 1998.[3] The proportion of mitral valve repairs for mitral value insufficiency has been increasing with a rate of approximately 20–25% year over year to reach over 2,000 cases in March 2009. Undoubtedly, almost all mitral valve repairs in the United States in the future will be performed using the da Vinci system. Because the da Vinci system is used so effectively for mitral valve repair, many devices and techniques have been developed, including the loop technique, which enables reconstruction using artificial chordae. In this technique, a pledget with artificial chordae attached is prepared beforehand and sutured to the papillary muscle. Another device called a "U clip" is used for

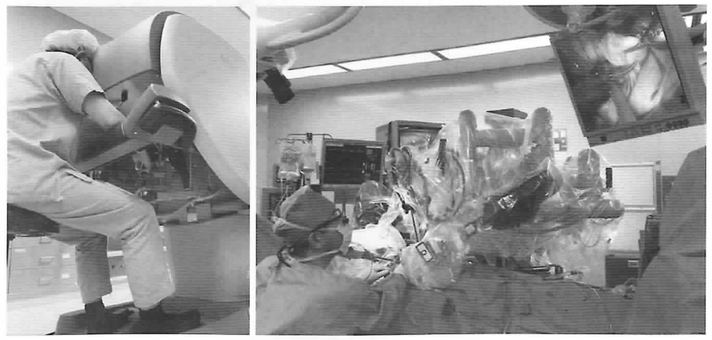

Fig. 1. da Vinci Surgical System. Console surgeon (*left*) and surgical cart (*right*) in da Vinci mitral valve plasty

suturing the annuloplasty ring with special clips, instead of conventional sutures. These devices were developed when robotic surgery was first introduced and they are now being used even in general surgery. These facts illustrate that when new machines or new surgical methods are developed, the ripple effect in the periphery is often great. The da Vinci Surgical System is also used in other simpler surgery such as atrial myxoma resection and atrial septal closure, and its effectiveness has been reported by many surgeons. My group has reported the usefulness of the da Vinci system for mitral valve repair and bypass surgery, as well as for Atrial Septal Defect (ASD) closure and left atrial myxoma resection.[4] Further development of this technology is anticipated.

General Surgery

Intuitive Surgical Inc. did not have high expectations about the active use of the da Vinci system in the field of gastroenterological surgery; however, in our neighboring country, Korea, there are institutions leading the world in using the da Vinci system for gastroenterological surgery. Yonsei University is one such institution, where every year over 200 laparoscopy-assisted distal gastrectomies and total gastrectomies are being performed using the da Vinci system. My group has also watched their line surgery, which is extremely precise, rapid, and performed with small incisions. With the growth of medical tourism, some experts foresee that Japanese patients in search of minimally invasive treatment may travel to Korea to undergo gastric cancer surgery.

Conclusion

I have given a brief overview of the current status of heart surgery and general surgery. Through the development of new surgical techniques and the entry of robots into the field of surgery, we may accomplish much with an entirely different concept to the conventional surgical discipline. It is hoped that young doctors will take every opportunity to use these new devices and machines actively, and face the challenges as the flagbearers of Japan, aiming to establish a nation built on medical care.

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