Robotic colorectal surgery

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Abstract

Master–slave manipulators (otherwise known as telemanipulators) were introduced into minimally invasive surgery in the 1990s to overcome the limitations of laparoscopic surgery. This led to the development of the first robotic surgical systems which, over the last 10 years, have rapidly gained acceptance among colorectal surgeons. Advantages of robotic surgical systems such as superior instrumentation and field of vision enable precise dissection in confined spaces such as the pelvis which make it a particularly attractive tool for rectal surgery. The feasibility and safety of robotic rectal surgery is now well established and there is increasing evidence that it might offer superior peri- and postoperative outcomes when compared to laparoscopic rectal surgery. Robotic rectal surgery is easier to learn than laparoscopic surgery and the creation of a structured training programme for robotic rectal surgery in Europe has facilitated the learning of this technique in an environment that promotes patient safety and improved patient outcomes through equipment fidelity and operator skill. It is foreseeable that in the near future robotic systems will become part of routine surgical practice in colorectal surgery.

Keywords colorectal surgery; rectal surgery; robotic surgery

Introduction

Minimally invasive surgery has transformed general surgery over the last two decades. In fact, the benefits of minimally invasive surgery such as shorter hospital stay, earlier return to normal function, reduced postoperative pain and improved cosmesis are now evident across almost all surgical subspecialities, including colorectal surgery.

Despite initial scepticism, laparoscopic colorectal surgery has progressively expanded since it was first described in 1991 and has now become the standard of care for benign and malignant colorectal diseases in most of the Western world.[1] However, laparoscopic colorectal surgery is limited by the inherit difficulties of conventional laparoscopy. These include two-dimensional (2-D) imaging (although 3-D platforms are becoming increasingly available), an unstable assistant-dependent camera, poor ergonomics, straight fixed tip instruments and an enhanced tremor effect.[2] These challenges are especially relevant when operating in narrow spaces such as the pelvis, making laparoscopic rectal surgery particularly difficult. This is evident from the poor number of overall procedures, high conversion rates and steep learning curve of laparoscopic rectal surgery. For example, in 2009 in the USA less than 20% of rectal resections were performed laparoscopically and the conversion rate was 46.2%.[3]

Robotic surgical systems were designed to overcome the limitations of laparoscopic surgery by providing stable 3-D views from a surgeon-controlled camera, angulated instruments with seven degrees of freedom, markedly improved ergonomics and tremor filtering. This has led to the increasing adoption of robotic surgery across many surgical specialities over the last 10 years and its increasing application in colorectal and in particular rectal surgery.[4] The effectiveness of robotic colorectal surgery is evident form the increasing number of research published on the subject every year since the first robotic colectomy was performed by Weber in 2002.[1]

The robotic surgical system

Telepresence or telemanipulation systems otherwise known as master–slave manipulators are devices where a human operator (master) controls mechanical arms (slave). The first of these systems were developed in the 1950s and over the years were used to handle hazardous materials or enter hazardous environments such as the bottom of the ocean or outer space. During the 1980s this technology made impressive leaps forward due to advances in microelectronics and computing. At the same time laparoscopic surgery was introduced. Laparoscopic techniques rapidly gained popularity for simple surgical procedures but were slow to gain acceptance with more complicated surgical tasks due to the reduced dexterity of the laparoscopic instruments. This brought the marriage of minimally invasive surgery with master–salve manipulators and during the 1990s the first robotic surgical systems were developed.

At present the da Vinci surgical system designed by Intuitive Surgical is the only clinically applied platform for robotic surgery. However, this is likely to change in the near future, with a number of new robotic surgical platforms being introduced from 2017. The da Vinci surgical system consists of a surgeon console (master), a patient side cart (slave) with four interactive arms and a vision cart (Figures 1 and 2). The surgeon sits on the console, unscrubbed, from which he has access to a stable 3-D view of the anatomy and controls the side cart arms through the master controls. The patient side cart is 'docked' to the patient and three of the side cart arms attach to surgical instruments and one to the camera. The instruments have flexible wrists with seven degrees of freedom. The surgeon's assistant sits on the side of the patient and through a laparoscopic port can perform tasks such as suction/irrigation, vessel ligation and retraction. In Figures 3–5 we present examples of a theatre set during robotic rectal surgery and pictures of the da Vinci Xi system in action.

Similar to all new technology, Intuitive Surgical has been evolving da Vinci and introducing new and improved versions of the system every few years. Currently, the da Vinci Xi is the fourth-generation model of the da Vinci surgical systems and

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Figure 1 Patient side cart (robot cart).

Figure 2 On the right; dual surgeon console. On the left; vision cart. The second surgeon console is for training purposes.

includes several improvements over its predecessor, the da Vinci Si, including longer thinner arms that are more flexible, overhead instrument arm architecture that permits flexible positioning around the patient and makes it easy to dock and the ability to integrate the system with other technologies such as intra-operative table motion and fluorescence-imaging.

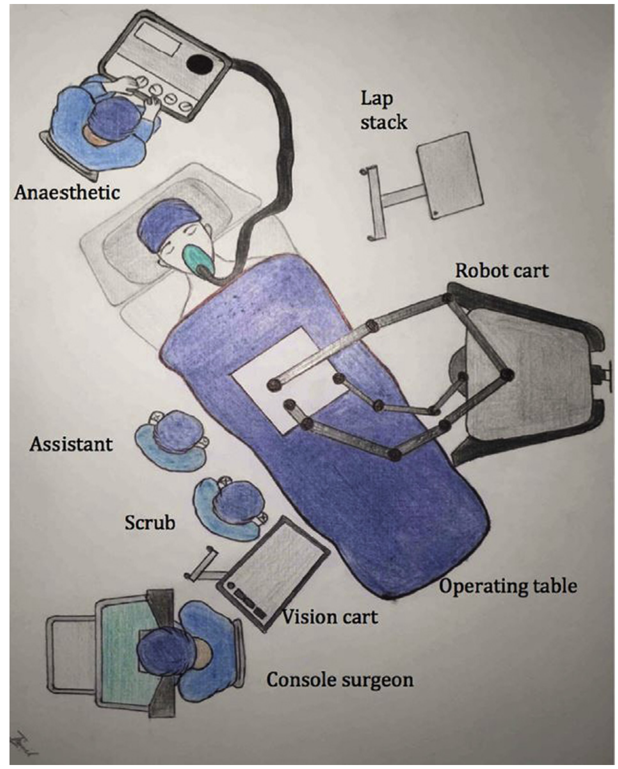

Figure 3 Example of theatre set up during robotic rectal surgery.

Figure 4 da Vinci Xi system in action during a robotic anterior resection training case. There is a surgeon sitting in each console, the surgeon on the right is teaching the second surgeon.

Advantages and disadvantages of robotic surgical systems

The da Vinci robotic system addresses most of the limitations of conventional laparoscopic surgery while at the same time preserving the advantages of minimally invasive surgery. The surgeon has access to stable 3-D views of the anatomy and the camera is controlled by the primary surgeon. The instruments have flexible tips with a jointed wrist design that exceeds the natural range of motion of the surgeons hand with 180° articulation and 540° rotation. Moreover, the robotic system is able to filter the physiological tremor of the surgeon's hand. These are

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