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ORIGINAL ARTICLE

Robotic-assisted surgery in children: advantages and limitations

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Abstract The use of surgical robots in minimally invasive surgery was developed to overcome difficulties seen with conventional laparoscopic surgery. I report my experience with pediatric robotic-assisted surgery and highlight its feasibility, safety, advantages, and limitations. Children and infants included in this study underwent robotic-assisted laparoscopic procedures performed by the author, using the original da Vinci surgical system, between July 2005 and July 2008. Their medical records were reviewed with respect to demographic data, robot setup times, techniques and operative procedures, complications, outcomes, and follow-up duration. Forty-three patients (20 female, 23 male), ranging in age from 2.5 months to 16 years, underwent 46 robotic-assisted procedures. Mean setup time was 17.6 min. One primary and two to four working ports were used, allowing insertion of 5- and 8-mm robotic instruments. Five- and 11-mm telescopes were used based on patient size. All procedures were successfully completed except for two. The most common procedure was Nissen fundoplication ($N = 26$). There were no intraoperative complications or deaths, but three patients developed postoperative complications. Mean follow-up time was 12 months. Robotic-assisted surgery in children is safe, feasible, and applicable to a wide range of procedures. Advantages include improved visibility, dexterity, and ergonomics, although it does have certain limitations. Technological refinements will allow its use in more complex procedures, with probable greater use of robots in pediatric surgery.

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Introduction

Surgical robotics in minimally invasive surgery is a relatively new technology. It was developed to overcome some of the difficulties seen with conventional laparoscopic surgery, mainly limited mobility, decreased ergonomics, and other problems, with the aim of improving the surgeon's dexterity. Since the introduction of the da Vinci surgical system in 1995, several centers around the world have used this system in a variety of general, cardiac, gynecological, and urological procedures [1, 2]. The first reports on the use of surgical robots for abdominal surgery in children were published by Gutt et al. and Heller et al. in 2002 [3, 4]. Since then, a number of reports have been published describing case experiences with a variety of or certain procedures [5–15]. Here, I present my experience with robot-assisted surgery in infants and children and examine its feasibility, safety, advantages, and limitations.

Materials and methods

This is a retrospective study of all infants and children who underwent robot-assisted laparoscopic procedures using the original da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA) performed by the author at King Khalid University Hospital, Riyadh, Saudi Arabia between July 2005 and July 2008. Informed consent was obtained prior to the procedures. Medical records were reviewed with respect to demographic data, setup times for the robot, technique and operative procedures, complications, outcomes, and duration of follow-up. Initially, I used the three-arm system with 8-mm instruments and an 11-mm three-dimensional (3-D) telescope; later we purchased the fourth arm and added 5-mm instruments and a 5-mm two-dimensional (2-D) telescope. The patient's position at surgery, the number and size of the ports, and the type of robotic telescope and instruments used are usually individualized according to the age and size of the patient as well as the kind of procedure performed. Generally I used 5-mm instruments and the 5-mm 2-D telescope in patients weighing less than 10 kg.

Our departmental policy for using surgical robots requires all surgeons to attend a training course on the use of the da Vinci surgical system before using the robot. Then, each surgeon is allowed to use the system in straightforward cases involving his or her first four patients as introductory teaching cases. Because of the high cost, the use of surgical robots should be reserved for major and complex cases only.

Results

A total of 43 selected patients underwent 46 robotic-assisted procedures. There were 20 females and 23 males, aged between 2.5 months and 16 years (mean 7.9 years). Body weight ranged from 3.5 to 45 kg (mean 12.5 kg). Setup time (interconnection and draping) ranged from 7 to 25 min (mean 17.6 min). Docking time ranged from 3 to 18 min (mean 8.9 min). Console time (actual operative time) ranged from 39 to 180 min (mean 106 min).

One primary and two to four working ports were used, allowing insertion of 5- and 8-mm robotic instruments. The 5-mm 2-D and 11-mm 3-D telescopes were used as dictated by patient size. For patients weighing less than 10 kg, we usually used the combination of the 5-mm telescope and 5-mm robotic instruments. The fourth arm was introduced into service lately; it was used in the last 12 patients and was found to be useful in retracting the liver in cases of Nissen fundoplication.

Pneumoperitoneum was created by Veress needle at the infraumbilical site, and an insufflation pressure between 8 and 14 mmHg (mean 12 mmHg) was maintained. Various procedures were performed (Table 1). Nissen fundoplication was the commonest procedure performed in our series, with console time ranging from 39 to 129 min (mean 84.6 min). The smallest patient was a 3.5-kg, 2.5-month-old infant who underwent Nissen fundoplication. All procedures were completed successfully except for two procedures that required conversion to open technique. In one case, conversion to open technique was needed for a redo Nissen fundoplication; in another, it was needed for biliary-enteric anastomosis after robotic-assisted excision of a choledochal cyst (Fig. 1). There were no unwanted intraoperative incidents, and there was no mortality. Three patients (7.5%) developed postoperative complications. Two patients who were severely neurologically impaired developed pyloric spasm after Nissen fundoplication, which resolved spontaneously after 2–3 weeks. One patient developed recurrent left epididymoorchitis after an anorectal pull-through for a high anorectal malformation. A cystourethrogram showed a diverticulum at the site of the divided recto-urethral fistula. The patient remained under close follow-up. All of the patients were followed up for 3–24 months (mean 12 months).

Table 1 Operative procedures

Procedure	No. of patients	No. of procedures
Nissen fundoplication ± gastrostomy	26	26
Cholecystectomy	5	5
Interval appendectomy	2	2
Anorectal pull-through for anorectal anomalies	3	3
Right adrenalectomy (pheochromocytoma)	1	1
Splenectomy	1	1
Cholecystectomy + splenectomy	1	2
Cholecystectomy + Nissen's fundoplication	1	2
Heller cardiomyotomy + Dor fundoplication (achalasia)	1	2
Excision of choledochal cyst	1	1
Excision of left ovarian teratoma	1	1
Total	43	46

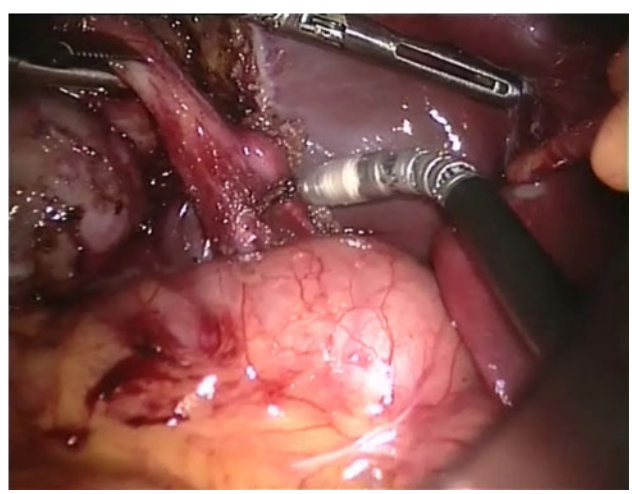

Fig. 1 Operative photograph, showing robotic dissection of the lower end of a choledochal cyst

Discussion

The surgical robot is considered the second revolution in general surgery after the introduction of laparoscopy during the last two decades [16]. Numerous reports have addressed the feasibility of using surgical robots. However, experience with use of robotics in pediatric surgery is limited. A systematic database search up to October 2007 identified a total of 31 published studies that described use of robotic-assisted procedures in 566 pediatric patients [17]. In this systemic review, robotic pyeloplasties and fundoplications were the commonest procedures performed. At our institution, a robot is chosen for use only in major and complex procedures except for the initial educational cases. As reported by others, fundoplication is the most common procedure performed. Although this procedure is straightforward, having a low-volume setup, it provides a good educational case for residents. The procedure also maintains the experience of the surgeon and other team members until the time comes when they need to use the robot for complex procedures.

Surgical robots have been used in a variety of procedures; these include fundoplication, splenectomy, Kasai portoenterostomy, excision of choledochal cyst, Heller myotomy, Ladd's procedure, adrenalectomy, repair of diaphragmatic hernia, excision of posterior mediastinal cysts, ligation of patent ductus arteriosus, division of vascular ring, repair of high anorectal malformation, surgery for morbid obesity, and others [5, 14, 17, 18]. Previous studies have demonstrated the safety and efficacy of robotic surgery in children of all sizes [5, 17, 19]. In my current series of 43 patients who underwent 46 procedures, a surgical robot was used in a variety of procedures, and the youngest patient to undergo robotic-assisted surgery was 2.5 months of age (weight 3.5 kg). There were no untoward intraoperative or postoperative incidents related to the use of the surgical robot in clinical practice. However, many pediatric surgeons remain unclear about the benefits of using robots. At present, there are no published randomized controlled studies regarding the use of surgical robots in children. Few studies have compared the use of robots with the standard laparoscopic approach to Nissen fundoplication [7, 19, 20]. These studies have documented longer operative times and higher costs in patients who underwent robotic surgery compared with those who underwent conventional laparoscopy.

Since the introduction of the da Vinci surgical system in our institution, I have witnessed refinement of the system, and this has allowed us to evaluate change. Our experience has shown that, in regard to the visualization system, the 11-mm 3-D telescope is superior to the 5-mm 2-D telescope. However, both have the disadvantage of displaying a narrow operative field compared with that visualized with the laparoscopic endoscope. With respect to the robotic instruments, the 8-mm (endowrist) instruments allow more precise and delicate movements compared with the 5-mm (snakewrist) instruments. This is due to the short distance between the tip of the instrument and the articulation, which is important during surgery in a narrow operative field. The introduction of the fourth arm permits the surgeon to utilize it as a retractor and to use the other two arms as active working instrument arms.

Although the main objective of using robotic-assisted surgery is to improve surgical outcomes in patients, nothing has been proven yet. I, like others [5, 6, 9, 13], feel that the 3-D vision offered by surgical robots improves the surgeon's dexterity, allowing greater ease in dissecting tissue, placing sutures, and tying knots.

The use of the surgical robot has several limitations; these include higher cost, longer operative time due to complex and time-consuming setup, loss of tactile feedback, limited selection of instruments compared with laparoscopic surgery, limited bedside access due to the huge size of the robotic arms, and limited use in small infants due to the large size of the device and the length of the instruments. In my opinion, most of these disadvantages have already been solved as the experience of surgeons with this new technology is improving and refinement of the system continues. One of the remaining major limitations is the high cost, which is hampering the promotion of this new technology among surgeons.

In conclusion, robotic-assisted surgery in children is safe, feasible, and applicable to a wide range of procedures. It offers the advantages of high-quality vision, improved dexterity, and better ergonomic position for the surgeon. Nevertheless, it has certain limitations. Technological refinements and reduced costs will allow its use in more complex and demanding procedures and will probably lead to greater use of robots in pediatric surgery.

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