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Anesthesia experience of pediatric robotic surgery in a University Hospital

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Abstract

Robotic technology has a promising future in surgical field. Robotic-assisted laparoscopy is a newly advance technology which is highly accepted by most of surgeons in various surgical procedures. As the pediatric surgeons adopt and master robotic technique, anesthesiologists familiarized themselves with this technique as well. Robotic surgery required a high-quality of perioperative anesthesia care that is essential for optimizing surgical outcome and patient safety. A retrospective analysis of robotic-assisted surgery for all children under age of 18 years from June 2004 to November 2013 at King Khalid University Hospital was conducted. Data of demographic (age, sex, and weight), type of procedures, operative time, intra-operative and postoperative complications were noted. Seventy robot assisted laparoscopy procedures were performed using the da Vinci surgical system. All procedures except three cases were successfully completed using robot with mean opera-tive time of 110 min. Nissen fundoplication (34 cases) was the commonest robotic surgical procedure performed followed by cholecystectomy, anal-pull through and gastric banding. There were no intraoperative and postoperative complications related to anesthesia. Robotic-assisted laparoscopy is a safe and feasible technique for a variety of pediatric procedures. Our findings suggest that, perioperative anesthesia care should be considered in advance with high anesthetic precautions to maximize patient safety and improve surgical outcome. It is worth to have more studies measuring clinical anesthesia outcome of pediatric robotic surgery.

Keywords Robotic-assisted surgery system · Pediatric surgery · Perioperative anesthesia care

Introduction

Technology revolution has extended worldwide in various areas including teaching, learning, engineering and medicine. Technology in medical field has also exhibited rapid growth and a huge expansion in the clinical practice that improves patient's safety and health care outcome. Minimally invasive laparoscopic technology was used for the first time for cholecystectomy in 1985 [1]. Since then, it has continued to increase in the surgical field and has become a highly popular technique among surgeons in different specialties. In a comparison with a standard open procedure, laparoscopic intervention improved wound healing and shape, minimized postoperative pain and recovery period

and reduced hospital stay as well as it is more cost effective [2]. With the technology advancement and growing market pressure for minimal invasive surgery, computer-assisted robotic surgery has been developed to overcome the difficulties that are associated with the standard laparoscopic surgery. Robotic surgery improved visibility of surgical field with three-dimensional imaging systems, better control of fine movements and prevented hand tremors through computer scaling system. Finally, robotic surgery improved instrument's movement with 7 degree of motion that mimics the movement of the human wrist [2–4].

Himpens and Cardiere performed the first robotic assisted surgery in 1997 using the da Vinci Surgical System [2]. Today computer-assisted robotic surgery has several applications in a variety of general surgeries as well as subspecialties including urology, gynecology, cardiology, thoracic and pediatric surgery as well as otorhinolaryngology [5–8].

During the last two decades the application of computer-assisted robotic surgery has increased rapidly in pediatric surgery. It has been performed safely for simple and complex

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procedures such as pyeloplasty, PDA closure and nephrectomy, Bochdalek hernia repair, Kasai portoenterostomy and choledochal cyst excision [9, 10]. Gutt et al. [11] and Heller et al. [12] published their first report on the use of robotic assisted surgery for abdomen in children [5]. Since then, several studies have described robotic surgery experience in infants and children [13–16]. Al Bassam [5] from Saudi Arabia reported his experience with pediatric robotic surgery at King Khalid University Hospital (KKUH). He had performed 46 robotic procedures that included fundoplication, cholecystectomy, splenectomy, appendectomy, anorectal pull-through, adrenalectomy, Heller myotomy and excision of choledochal cyst. Al Bassam et al. also reported that robotic-assisted Nissen fundoplication is more safe, feasible and effective technique as compared to the conventional laparoscopic approach in children [17].

As robotic-assisted laparoscopy procedure continues to increase in pediatric surgery, anesthesia care has also progressed dramatically. Several important issues are taken into consideration for robotic surgery that include positioning of the patient, airway access, avoiding hypothermia, duration of the procedure, physiological changes of the pneumoperitoneum and blood loss [2]. The anesthesiologists are also required to understand the setting of robotic surgery to provide safe and sufficient perioperative anesthesia care for infants and children.

Mariano et al. discussed the anesthetic concerns of robotic surgery in a 2-months-old patient [9]. Another Korean study reviewed anesthetic considerations for robotic-assisted surgery including pediatric patients [18].

This paper describes the author's experience in perioperative anesthesia care for pediatric robotic surgery at KKUH.

Materials and methods

A retrospective analysis was carried out after the institutional review board's approval. All the cases of infants and children for robotic surgery that were performed at KKUH from June 2004 till November 2013 were included in this study. Medical records were reviewed for patient´s demographic data, preoperative diagnosis, surgical procedures, induction medication, intraoperative monitors, duration of procedures, postoperative emergence, and perioperative complications.

According to the standard protocol all the pediatric cases that were booked for robotic surgery were seen 1 day earlier by a senior anesthesiologist. During preoperative assessment, type and risks of anesthesia in such procedures were explained to the parents. Moreover, parents were informed about blood transfusion and postoperative intensive care that might be needed. Few cases were postponed to optimize their clinical status and were rescheduled again.

The da Vinci Surgical System was performed for all cases. It has three essential components: a console, a surgical cart and an optical three-dimensional vision tower. The age and size of the patients as well as type of procedures performed, determined the position of patients during surgery; the number and size of ports, type of robotic telescope and instruments used.

Usually, two surgeons performed the operations. The skilled surgeon sat at the console to view the operational field and manipulated the robotic arms for performing the surgery. The assistant surgeon stayed at the tableside to connect the robotic arms, changing and manipulating the robotic and endoscopic instruments. For most of the procedures, surgeons initially used three-arm system with 8 mm instruments and an 11 mm three-dimensional telescope. Later, they used fourth-arm and added 5 mm instruments and a 5 mm two-dimensional telescope. As the da Vinci surgical system is heavy and bulky, all the robotic surgeries were performed in a specific operating room, at the theater suite. Because robotic surgery is a lengthy procedure, most of the procedures were scheduled early as the first or second on the operating list.

Results

A total of 70 robotic-assisted laparoscopic procedures were performed for 67 patients including 38 females and 29 males using the da Vinci Surgical System. Table 1 shows demographic data of this study. All the patients were in the age group of 2.5 months to 18 years, with a mean of 8.4 years.

This institution defined the age of patients from birth till 12 years. However, some patients of 13–18 years of age had gastric banding which was performed by pediatric surgeons, were also included in this study. Twenty-eight of the patients were under the age of 10 years. Body weight of the patients ranged between 3.5 and 102 kg with a mean of 13.2 kg.

Table 2 shows variety of robotic-assisted laparoscopic procedures that were performed for abdominal surgery under general anesthesia including Nissen fundoplication (34), cholecystectomy (9), anorectal pull-through (6), gastric banding (5), Heller myotomy (4), splenectomy (3), interval appendectomy (2), excision of liver cyst (2), excision of choledochal cyst (1), excision of left ovarian teratoma (1),

Table 1 Demographic data

Number of female patients	38
Number of male patients	29
Mean of age	8.4 years
Mean of body weight	13.2 kg

Table 2 Types of robotic assisted laparoscopic procedure

Name	Number
Nissen fundoplication	34
Cholecystectomy	9
Anorectal pull-through	6
Gastric banding	5
Heller myotomy	4
Splenectomy	3
Interval appendectomy	2
Excision of liver cyst	2
Others	5
Total	70

right adrenalectomy (1), sympathectomy (1) and Morgagni hernia repair (1).

Preoperative assessment revealed that 78% of patients had moderate to severe diseases with American Society of Anesthesia (ASA) classification of II and III. Neurological insults and respiratory complications were the most important preoperative anesthetic considerations. The anesthesiologists examined blood laboratory results and gave preoperative sedition as per requirement. Intraoperative standard monitors for cardiovascular and respiratory system were connected to all patients before starting induction. Arterial line was optional for some cases based on their clinical status. Intravenous induction was performed with a suitable dosage of propofol, fentanyl and rocuronium. Airway was secured with proper size of endotracheal tube and was checked by auscultation. An orogastric tube was inserted to decompress the stomach. Temperature probe and folly catheter was inserted to avoid hypothermia and to maintain adequate urine output during the surgical procedure. Patient´s eyes were closed with proper cover and pressure points were padded adequately to prevent tissue and nerve injuries. Patient's airway, intravenous line and monitors were appropriately placed and secured before final positioning to avoid kinking and displacement. Patient's positioning varied with each robotic procedure to facilitate surgical exposure. The operating table was rotated away from anesthesiologist, and anesthesia machine moved around 90° that allowed robotic cart to be adjusted over the table head. Finally, patient's position was optimized prior to draping and docking the robot.

Anesthesia was maintained with sevoflurane at 1–2 minimum alveolar anesthetic concentration in oxygen /air, fentanyl and rocuronium with volume control ventilation and positive end-expiratory pressure (PEEP) of 5 cm H_2O. Intraoperative monitors of patients showed stable hemodynamics and adequate oxygen saturation above 95% throughout the robotic procedures.

All robotic procedures were performed at KKUH by two skilled pediatric surgeons. The laparoscopic procedure started with gas insufflation of 8–14 mmHg over a variable surgical time. Surgical time was defined as the time from skin incision to its closure. It ranged between 134 and 259 min with a mean of 110 min. The setup time of robot (draping and interconnection) was not included in surgical time. However, surgical time varied with each robotic procedure and depended on surgeon's skills. All procedures were completed successfully using the robot except for two cases which were converted to open technique and the other was switched to conventional laparoscopy due to surgical technical issues.

All patients gained smooth and pleasant consciousness from anesthesia at the end of the procedure; trachea was extubated and transferred stably to postoperative care unit. Six patients with major preoperative neurological and respiratory complications were transferred to pediatric intensive care unit for observation and two of them had extubation the next day. Three patients developed postoperative surgical complications, two of them had pyloric spasm after Nissen fundoplication and the third had epididymo-orchitis. There were no major complications related to anesthesia during perioperative period and there was no mortality. Patients stayed in hospital for 3–9 days and were discharged in a stable condition with close monitoring and follow-up in surgical clinic.

Discussion

The general concept of robotic device is technically powered, computer controlled manipulator is present with artificial sensing that can be reprogrammed to move and position tools that carry out a wide range of tasks [19]. Robotic systems used today in the surgical field are known basically as computer-assisted device. Therefore, it is not truly robot and it cannot replace a surgeon and complete surgical procedures independently. In fact, it enhances the performance and precision of the surgeon's hand [2]. Thus, surgeons view the operative site and manipulate robotic arms as they are in the surgical field. There are two robotic surgical systems; the da Vinci Robotic Surgical System and the Zeus Robotic Surgical System. The da Vinci Robotic Surgical System is the only commercially available and predominant robot in Kingdom of Saudi Arabia. It is composed of three essential parts: a control console, an optical three-dimensional vision tower and a surgical cart (Fig. 1) [2, 18].

A control console is the place where surgeon physically sits and is away from surgical site and control the robot that is performing the procedure. Surgeons move their hands through manipulators inside the console that manipulates robotic arms in the surgical field. The console contains a three-dimensional viewer and three foot-pedals for disengaging robotic instruments, changing the robotic arms, focusing

Fig. 1 Da Vinci surgical system

video camera and controlling electrocautery or ultrasonic instruments. The console has a computer system that runs the entire robotic device and it has the capacity to adjust video system, robotic arms and comfortable ergonomics. It provides 7 degrees of motion that allows robotic instrument's movement in different directions similar to human wrist. In addition, motion scale up to ratio of 5:1 and filter system of more than 6 Hz can regulate instrument motion and prevent hand tremors. The second part of robot is an optical tower, which contains computerized equipment to record and display the surgical site images and it contains other instruments such as insufflator. Finally, the robotic cart consists of four arms by which a surgeon is able to manipulate and complete the procedure from the console. Two arms represent surgeon's arms, third arm holds endoscope, and fourth-arm is optional and its use depends if the surgeon needs additional tasks such as tractions and running suture. The benefits of robotic laparoscopy over the standard techniques allow most of the surgeons to learn and implement it for both adult and pediatric surgical procedures.

The pediatric robotic surgery started at KKUH in 2004 using the da Vinci surgical system. The KKUH is a non-specialized academic institution. It provides a high standard of health care for both adults and children by highly qualified and specialized physicians. Pediatric patients do receive a proper medical and surgical management in specialized units separated from adults. Total pediatric surgeries performed at KKUH were approximately one-fifth of total surgical procedures [20].

Several pediatric surgical procedures are available at KKUH, including general as well as some subspecialties such as orthopedic, urologic, dental, plastic, and neurological surgery. According to surgical department policy, pediatric surgeons are allowed to use the da Vinci surgical system after attending the required training courses. Later, they start using robot with the first four straight forward patients as preliminary learning cases [5, 18]. A successful perioperative anesthesia management for robotic surgery in children requires a good understanding of set up that interferes with child access, physiological changes of CO_2 insufflation with prolonged operative time and the need of teamwork with continuous communication between anesthesiologists, surgeons and nurses during crisis management.

Robotic-assisted surgery has certain limitations mainly related to high cost, prolonged operative time comparing with other conventional techniques and time-required for operating room setup. Additionally, it is heavy and bulky device for small sized children. These limitations can be overcome and managed through effective teamwork, increased surgical volume and experience. Pediatric anesthesiologists gain experience of using robot as well and do

preoperative assessment, anesthetic plan, operating preparation of each robotic procedures accordingly [2, 5].

The study also showed that surgical time improved gradually as experience of operating team increased. Although, it was difficult to accurately measure the time required for the operating room setup before surgery.

Earlier studies demonstrated that the safety and feasibility of robotic-assisted laparoscopy significantly vary in different pediatric surgical procedures [5, 10, 21, 22]. A meta- analysis of 31 published studies about pediatric robotic surgery showed that this procedure is frequently used for pyeloplasty and fundoplication [15].

Moreover, comparison of robotic fundoplication compared with laparoscopy showed similar time and cost for both the approaches in short term outcome [17, 23–26], this clearly suggests that robotic fundoplication is as effective as laparoscopic approach. On the other hand, few studies demonstrated higher cost with robotic fundoplication compared to the cost of standard laparoscopy [27]. Furthermore, surgeons reported a great experience of using robot in dissecting tissue, running sutures and tying knots [5, 13, 14, 22, 28]. These benefits are based on the presence of three-dimensional vision, delicate instrument movement and improved ergonomics. However, these beneficial experience have not been fully supported by clinical studies especially when compared robotic laparoscopy to conventional approach [5, 17].

There were only limited published reports that discussed anesthetic considerations for robotic-assisted surgery in both adult and pediatric patients [2, 8, 9, 18, 29]. In addition, there were no published studies that discussed the outcome of robotic surgery from anesthesia point of view. Moreover, no randomized controlled trails have been under taken using robotic system in children. The result of this study revealed that pediatric anesthesiologist played critical role in providing high quality perioperative care that contribute effectively in the surgical outcomes and patient's safety.

Conclusion

Robotic surgical system is a new invention of minimal invasive laparoscopic procedures. It is a safe, reasonable as well as effective technique in a wide range of pediatric surgery. It provides the benefit of visibility, dexterity and ergonomics to the surgeons with controllable limitations. However, anesthesia implications of using robotic laparoscopy in children emphasized that major precautions must be taken especially with smaller and younger children. Pediatric anesthesiologists should be familiarized with all the anesthetic precautions to maximize patient safety and minimize technical and physiological risks. Therefore, it is worth to keep robotic laparoscopy technique for major and complex procedures

as indicated. More studies using robot in pediatric surgery are essential to measure the anesthetic experience outcomes.

Compliance with ethical standards

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