Early experiences of robotic surgery in children

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Abstract
Background: Laparoscopic surgery using a robotic system (Da Vinci) was recently introduced into surgical practice for adult patients. To investigate the feasibility of this system in pediatric surgery, laparoscopic fundoplication (Thal and Nissen), cholecystectomy, and bilateral salpingo-oophorectomy were performed.

Methods: Eleven children with a mean age of 12 years (range, 7–16 years) underwent either laparoscopic anterior partial fundoplication (Thal, n = 8) or Nissen fundoplication (n = 3) for correction of gastroesophageal reflux disease in the presence of uncontrolled symptoms of regurgitation and pulmonary infection. Two children underwent laparoscopic cholecystectomy due to symptomatic cholecystolithiasis. One child underwent bilateral salpingo-oophorectomy due to a gonadoblastoma.

Results: Mean operating time for fundoplication was 146 min (range, 105–180 min), the operating times for cholecystectomy were 150 and 105 min, and that for salpingo-oophorectomy was 95 min. No complications were registered during either the robotic procedures or the postoperative courses.

Conclusions: Compared to conventional laparoscopy, the three-dimensional high-quality vision, advanced instrument movement, and improved ergonomic position of the surgeon appear to enhance surgical precision. Robotic surgery in children using the Da Vinci system seems to be feasible and safe. However, the technique is limited due to the fact that instruments adapted to the size of small children are not available. Furthermore, the high costs and prolonged system setup are disadvantages.

Key words: Laparoscopy — Robotic — Fundoplication — Cholecystectomy

In laparoscopic surgery, the mobility of the instrument is decreased significantly due to the invariant point of insertion through the abdominal wall. Compared to open surgery, only four of seven degrees of freedom remain [12]. Limited instrument mobility causes significant handling restrictions in procedures that require complex surgical techniques. The restoration of the functional freedom available in open surgery is an important step for the advancement of laparoscopic surgery. Robotics for increasing instrument function was first used in the field of robotic camera guidance [1, 11].

Complex laparoscopic procedures involving suturing, ligation, and intracorporal knotting techniques require advanced instruments with increased degrees of freedom of motion. For applications in laparoscopic surgery, robotic manipulation technologies seem to be inevitable to improve steerability and dexterity of advanced surgical instruments. Recently, the Da Vinci robotic system entered the clinical testing phase and the technology is now used in practical surgery mainly for adult patients [2, 3, 8]. The system translates surgeon hand movements made outside the body to movements inside the body using the laparoscopic approach and electronically enhanced, mechanical instruments with wrists. The stereoscopic camera of the system provides real three-dimensional imaging. The optimal ergonomic working position is selected by reindexing the master arms at the console.

To investigate the feasibility of robotic surgery in children using the Da Vinci system, laparoscopic cholecystectomy, fundoplication, and salpingo-oophorectomy, including tissue dissection and intracorporal suturing, were performed.

Materials and methods

Robotic system

The surgical procedure was performed using the Da Vinci computer enhanced telemanipulator system (Intuitive Surgical, Mountain View, CA, USA). The system consists of three major components: a surgeon...
interface device equipped with a three-dimensional optic system and two manipulator handles, a computer controller, and a double-armed surgical robot. The surgeon sits, at a distance away from the patient, at an ergonomically designed console, resting his or her elbows on a bench. The screen of the console allows three-dimensional visualization and 10-fold magnification of the operative field. The surgeon's fingertips manipulate handles, and their movements are transferred to robotic arms containing surgical tools with intracorporeally articulated instruments. A selection of instruments is available: different types of forceps, needle holders and scissors, an electrocautery hook, and a clip applicer. A built-in pivot point on each instrumental arm eliminates the use of the patient’s body for leverage, minimizing tissue damage. Pedals in the console enable the surgeon to change the position of the handles and the camera to perform coagulation. It is possible to downscale the surgeon’s motions, resulting in very precise instrument motions.

System setup

Surgery was always performed under general anesthesia with the patient in reverse Trendelenburg position. All patients had a thin nasogastric tube placed in their stomach and underwent invasive blood pressure monitoring and arterial blood gas sampling, in addition to standard monitoring. After skin disinfection and draping, a 12-mm optic trocar was placed above the umbilicus via mini laparotomy and a CO₂ pneumoperitoneum with an intraabdominal pressure of 12 mmHg was established.

Under endoscopic vision, two additional 8-mm special robotic instrument trocars were introduced into the middle abdomen. For additional retraction, a regular 5-mm instrument port was inserted at the right side laterally along the subcostal margin so that it did not interfere with the robotic arms. The robot was approximated to the patient from the left side in the case of fundoplication and from the right side in the case of cholecystectomy (Fig. 1). The sterile wrapped robotic instruments were connected with the trocars. A scrub nurse and assistant surgeon stood at the patient’s side to change instruments and introduce suture materials.

Patients and procedures

Eleven children with a mean age of 12 years (range, 7–16 years) underwent either laparoscopic anterior partial fundoplication (Thal) (n = 9) or Nissen fundoplication (n = 3). The indication was pulmonary-related gastroesophageal reflux disease in the presence of uncontrolled symptoms of regurgitation and pulmonary infection in 10 cases and recurrent retrosternal pain and heartburn in 1 case.

Prior to surgery, in-depth diagnostic measures and a minimum of 3 months' conservative therapy were necessary. In particular, in children with bronchopulmonary-related reflux diseases, the following diagnostic measures were taken: 24-h pH-metry, barium swallow, allergologic and immunologic tests, bronchoscopy, pulmonary lavage and estimation of fat-containing macrophages (ALLM), and esophagoscopy with biopsies. Additional diagnostic measures (ciliary function and gastric scintigraphy) were taken only when necessary.

Two children, aged 12 and 15 years, underwent laparoscopic cholecystectomy due to symptomatic cholecystolithiasis. One child, aged 16 years (genotype: 46 XY), with female phenotype and a gonadoblastoma with parts of dysgerminoma in the right ovary and a break ovary on the left side, underwent bilateral salpingo-oophorectomy.

Preparation for fundoplication was performed with a coagulation hook, beginning at the peritoneal cover at the side of the hiatus of the esophagus, liberating the esophagus, fundus, and the crura (Fig. 2). After fully mobilizing the esophagus, retroesophageal crural repair was conducted with two sutures of 2.0 Ethibond with an SH needle. A 28- to 36-F gastric tube was inserted to demonstrate patency of the esophageal passage. The paraesophageal space was closed with Vicryl sutures to prevent paraesophageal hernias. Then, a left and dorsal row of sutures was inserted between the gastric fundus and the esophagus. The sutures on the right side completed hemifundoplication (Fig. 3). Mobilization of the spleen was necessary only when there was tension of the gastric fundus. For the complete fundoplication (Nissen), two anterior sutures and two additional antisilpping sutures were inserted.

Preparation for cholecystectomy was performed with a coagulation hook. The cystic duct and cystic artery were ligated (Vicryl 3.0). Preparation for bilateral salpingo-oophorectomy was performed with a