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Original Article

Examining the Potential of Advanced Robotic-Assisted Thoracic Surgery in Pediatric Cases

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ABSTRACT

Aim: Robotic-assisted surgery has demonstrated safety and feasibility in numerous pediatric cases. Nevertheless, there is a scarcity of literature regarding advanced pediatric thoracic robotic surgery (APTRS). The objective of this study was to present our experiences with APTRS in 31 patients.

Materials and Methods: From October, 2020 to December, 2023, a total of 31 APTRS procedures were conducted at our institution. A retrospective analysis was carried out, encompassing demographics, indications for surgery, console time, complication rates, length of hospital stay, and postoperative complications.

Results: Twenty-one patients (M/F: 13/17) underwent robotic-assisted surgery, with procedures including thoracic mass excision in 17 cases, esophageal surgery in 8 cases, and various other pathologies in 5 patients. The average age at the time of surgery was 8.4±5.2 years (10 months-17 years), and the average weight was 29.6±18.4 kg (10-65 kg). The mean console time was 165.6±124.8 minutes, with no instances of conversion. The median length of hospital stay was 3.5 days (1-30 days). Postoperative complications occurred in eight patients (25.8%).

Conclusion: Our experience in pediatric robotic thoracic surgery reinforces its suitability even for complex cases. Robotic thoracic surgery appears to offer benefits, particularly in posterior mediastinal mass excision and esophagectomy for corrosive esophageal strictures, when compared to thoracoscopy.

Keywords: Robotic-assisted surgery, thoracoscopy, neuroblastoma, esophageal atresia

Introduction

Robotic surgical procedures in pediatric patients have been becoming more popular, albeit at a slower pace compared to adults, over the years. Robotic-assisted surgery (RAS) brings various advantages such as three-dimensional (3D) vision, enhanced maneuverability, and tremor filtration (1,2). However, there are also notable drawbacks and limitations, with one of the most significant being the inappropriate size of the instruments for small children and neonates.3 Additionally, higher costs and longer operation times can be considered as the other main limitations. Nevertheless, despite these drawbacks, RAS has seen a growing adoption in pediatric surgery in recent years (3). A common concern surrounding pediatric robotic surgeries is the potential limitations posed by the patient's weight and age. However, the literature has reported that this is not an absolute contraindication for RAS (4,5).

RAS has been utilized across various pediatric subspecialties, with pediatric urology being the most commonly reported one (2,3,6). On the other hand, robotic-

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assisted thoracoscopic surgeries (RATS's) have been seldom reported on in the literature (6). Takazawa et al. (7) developed a RATS model specifically for infants and found that robotic suturing was faster than the conventional thoracoscopic approach. Also, there were some reports about esophageal surgeries, thoracic tumoral excision, and lobectomies in the literature (8).

Despite the limited data and the small number of reported cases for RATS, since 2020, we have been conducting robot-assisted thoracoscopic surgery for select cases. This study aimed to share our experience with RATS and delve into the technical aspects of these cases.

Materials and Methods

The present study was conducted in the pediatric surgery department in accordance with international ethical standards and the World Health Organization Helsinki Declaration. Ethics committee approval, confirming that the data collected for this research adhered to ethical guidelines, was obtained from the Ege University Medical Research Ethics Committee (approval no: 24-3.1T/22, date: 21.03.2024). Informed consent was obtained from all participants.

Robotic surgery typically comprises three primary surgical phases. The first step involves thoracoscopic exploration, during which the primary pathology is assessed using thoracoscopy, and port placements are planned. Following this, the second phase is docking, where the robotic arms are positioned and prepared for the surgical procedure. Subsequently, the console phase commences. Finally, the last step is undocking. In some cases, additional steps may be necessary after undocking, such as cervical dissection for procedures such as gastric pull-up.

A retrospective review of the hospital records was conducted for those patients who underwent robot-assisted thoracoscopic surgery between the years 2020 and 2023. The data collected included the patients' demographics, their weight, surgical indications, operational strategies, docking times, and console times, as well as their intraoperative, and postoperative complications.

The patients were categorized into three groups for discussion: thoracic masses, esophageal pathologies, and miscellaneous diseases (Figure 1).

Results

Thirty patients underwent RATS. The mean age at operation was 8.4±5.2 years (range: 1-17 years), and the mean weight at operation was 29.6±18.4 kg (range: 10-65

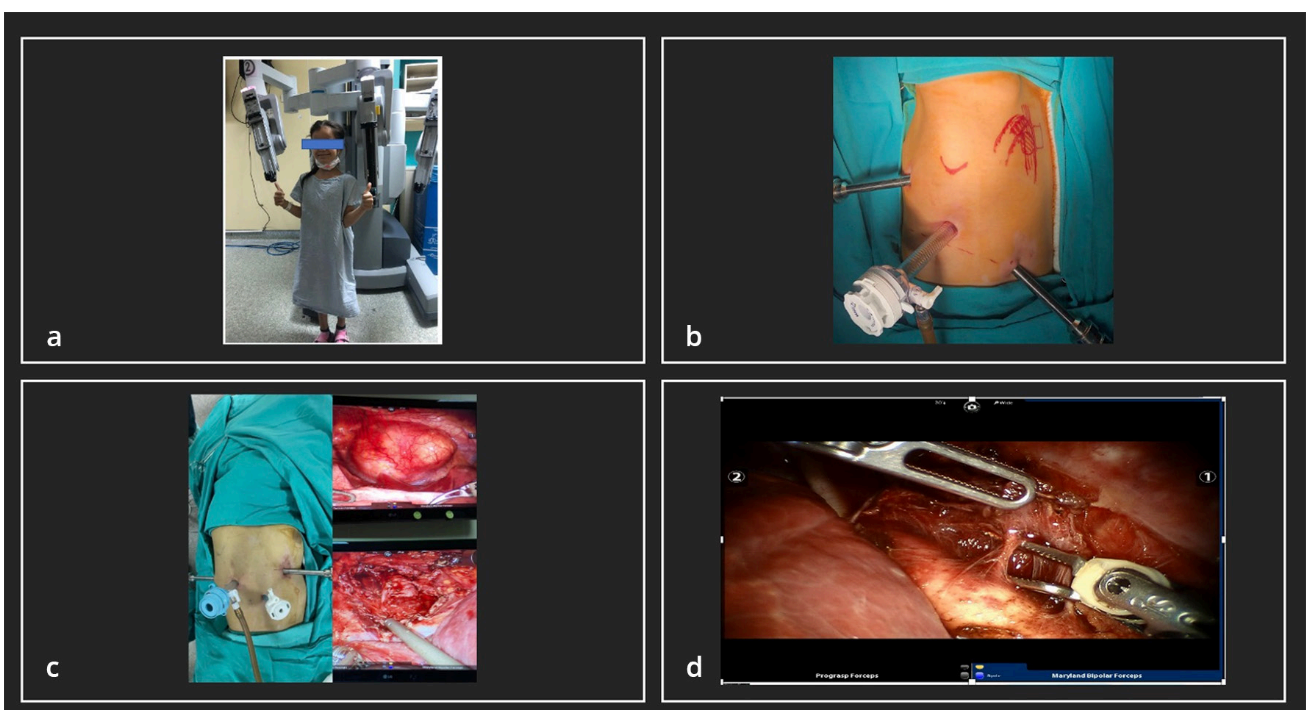

Figure 1. Figures of the robotic system and intraoperative images, a) da Vinci® Si™ Surgical System with patient number 6th. b) port placement of a posterior mediastinal neurogenic tumor; c) port placement and intraoperative views of esophageal duplication, d) the dissection of the neurogenic tumor from the aorta

Table I. Indications for surgery	
Group 1: Thoracic masses (n=17)	
Neurogenic tumors	10
Metastasis	3
Congenital cyst	2
Ewing sarcoma	1
Mature cystic teratoma	1
Group 2: Esophageal pathologies (n=8)	
Corrosive esophageal stricture (CES)	3
Esophageal atresia (EA)	2
Achalasia	2
Hiatal hernia	1
Group 3: Miscellaneous (n=5)	
Morgagni hernia	1
Pulmonary hydatid cyst	1
Abnormal pulmonary venous return	1
CPAM	1
Bronchiectasis	1

CPAM: Congenital pulmonary airway malformation

kg). The primary diseases were categorized into three groups (Table I). The mean console time was 165.6±124.8 minutes. There were no intraoperative complications related to RATS. However, a tracheal injury occurred during the complementary step after undocking in a patient who had undergone a gastric pull-up for a corrosive esophageal stricture. The majority of patients underwent surgery for thoracic masses, primarily neurogenic tumors. Two cases involved metastases, one from osteosarcoma and the other from hepatocellular carcinoma, requiring rib resection and thoracic wall reconstruction in a Ewing sarcoma patient.

Additionally, there were two cases of congenital cysts: one bronchogenic and the other an esophageal duplication cyst. Among replacement techniques, gastric pull-up (GPU) is the only method which can be performed using minimally invasive techniques. Five patients (3 with corrosive esophageal stricture and 2 with esophageal atresia) underwent robot-assisted GPU. Heller myotomy with Dorr fundoplication were performed for achalasia patients, and the myotomy was facilitated by robotic vision, offering greater reliability compared to laparoscopy. Re-do Nissen fundoplication for recurrent hiatal hernia was deemed more feasible with robotic assistance due to its superior maneuvering capabilities. Lobectomy was performed on two patients with congenital pulmonary airway malformation and bronchiectasis.

Postoperatively, eight patients experienced various complications, including Horner syndrome after neurogenic tumor excision, swallowing dysfunction following gastric transposition, atelectasis, pleural effusion, prolonged air leakage in a lung cyst hydatid case, and one recurrence following Heller myotomy.

The operations were concluded with tube thoracostomy in 20 patients, with a median time of 3 (1-25) days for tube insertion and a median hospital stay of 3.5 (1-30) days.

Discussion

Robotic systems were originally developed for adults. In 2001, robotic surgery was adapted for children for the first time (9). Since then, RAS's have been performed across various subspecialties in pediatric surgery (8). However, there is limited information available specifically regarding thoracic robotic surgery in the pediatric population. A literature review by Saxena et al. (8) identified only seven relevant studies (four on thoracic surgery and three on esophageal surgery) on thoracic robotic surgery published between 2017 and 2022. This highlights the scarcity of data and series focused on thoracic robotic surgery in pediatric patients during that period (8).

Robot-assisted surgery (RAS) brings numerous advantages, including 3D visualization, tremor filtration, and the use of articulating instruments, all of which enhance surgical procedures (3,10). However, in pediatric cases, there are certain challenges (1). The primary limitation is the size difference between the large instruments used in robotic surgery and the small body size of pediatric patients (11). This challenge can be addressed by adjusting the placement of ports or the patient's position during surgery (12,13).

The literature has discussed whether patient-weight poses a limitation for robotic surgery. Molinaro et al. (5) categorized patients into two groups based on their weight and found that operations took significantly longer in those patients weighing less than 15 kg. However, there was no difference in conversion or complication rates between the groups. This led to the conclusion that patient-weight is not an absolute contraindication for robotic surgery (5). In our series, the smallest patient weighed 10 kg and successfully underwent gastric transposition using RAS. This experience supports the feasibility of robotic surgery even in small pediatric patients.

RAS in pediatric surgical oncology has recently gained popularity. However, thoracic tumor cases are rarely reported on in the literature. A systematic review covering the years 2012-2021 identified 10 patients with thoracic tumors out of 134 patients (14). Blanc et al. (15) reported their experience with 100 oncologic patients and formulated a guideline for patient selection. They suggested that RAS can be considered for paravertebral tumors, tumors limited to the thymic bed, and single lung metastasis. However, they noted that patients younger than 2 years of age are a relative contraindication, while encasement of vessels and extension to the median mediastinum are considered formal contraindications (15). The majority of patients in our series had a posterior mediastinal mass.

Surgeons also perform robotic-assisted esophageal surgery. There are several articles in the literature about gastroesophageal reflux (GER) with or without hiatal hernia and achalasia. Laparoscopic Nissen fundoplication remains the gold standard for the treatment of GER. However, robotic-assisted Nissen fundoplication can be considered in certain cases (16). In our opinion, RAS can be considered for redo procedures. Additionally, robotic-assisted Heller myotomy in achalasia is safer than the laparoscopic technique with regards to mucosal perforation (17).

In our series, we performed five gastric pull-ups. Three patients had corrosive esophageal strictures, and two had esophageal atresia. We performed thoracic esophageal resection and gastric pull-up using robotic assistance. This technique had not been reported on in the literature before. We plan to discuss this technique in subsequent studies.

Li et al. (18) compared the surgical outcomes of thoracoscopic and robotic-assisted pulmonary resection in the pediatric population. They found no difference in perioperative complications, hospital stays, or drainage lengths between the two techniques. However, they noted that while the total operative time was longer, the pure operative time was shorter in RAS (18).

Study Limitations

This study was conducted in order to summarize our experiences with RATS. The operation indications and patients' demographics were varied. Therefore, it was not possible to describe the techniques or port placements for all of the procedures in this study. These will be described separately for each procedure in future publications.

Conclusion

RATS has emerged as a valuable and increasingly utilized approach in pediatric surgery. Our experience and the existing literature suggest that RATS offers several advantages, including improved visualization and greater precision in complex procedures. However, further research is needed to fully understand the optimal applications and outcomes of RATS in pediatric patients. As technology advances and surgical techniques evolve, RATS is likely to play an even more significant role in the management of thoracic conditions in the pediatric population.

Ethics

Ethics Committee Approval: Ethics committee approval, confirming that the data collected for this research adhered to ethical guidelines, was obtained from the Ege University Medical Research Ethics Committee (approval no: 24-3.1T/22, date: 21.03.2024).

Informed Consent: Informed consent was obtained from all participants.

Authorship Contributions

Surgical and Medical Practices: C.Ş., Z.D., C.Ö., Concept: C.Ş., Z.D., Design: Z.D., Data Collection and/or Processing: Ü.Ç., Z.D., Analysis and/or Interpretation: Ü.Ç., Z.D., C.Ö., A.E., Literature Search: Ü.Ç., Z.D., Writing: Ü.Ç., Z.D.

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