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Use of laparoscopic surgical resection for pediatric malignant solid tumors: a case series

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Abstract
Background Minimally invasive surgery for malignant pediatric tumors remains controversial, and few cases have been published. The present study reports on our initial experiences of laparoscopic surgical resection for selected pediatric malignant solid tumors.
Methods We retrospectively analyzed data from ten pediatric patients who underwent laparoscopic surgical resection for malignant solid tumors at our institute between April 2005 and January 2010.
Results There were four boys and six girls, including one neonate and four infants. The mean age at surgery was 23.3 months (range, 13 days–69 months). Six patients underwent laparoscopic adrenalectomy for neuroblastoma ($n = 5$) or adrenocortical carcinoma ($n = 1$). Two patients underwent laparoscopic partial hepatectomy for hepatoblastoma, one patient underwent a laparoscopic salpingo-oophorectomy for yolk sac tumor, and one a laparoscopic tumor excision for rhabdomyosarcoma in the pelvis. Complete tumor resection was performed in all cases. Tumors ranged from 2.5 to 5.3 cm maximum diameter. Tumors were placed inside endobags and removed safely without spillage. The mean operation time was 132 (range, 65–250) min. There were no open conversions and no postoperative complications. The mean postoperative hospital stay was 4.9 (range, 2–7) days, and all surgical wounds showed good cosmetic results. There were no local tumor recurrences during the 17.3-month median follow-up period.
Conclusions Laparoscopic surgical resection for selected pediatric malignant solid tumors was found to be feasible and safe. Long-term follow-up data are essential to confirm oncologic safety.

Keywords Laparoscopic surgical resection · Malignant solid tumors · Pediatrics

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Laparoscopic surgery in children has recently made substantial progress due to technical and instrumental advances [1]. Pediatric laparoscopic procedures for various benign diseases have been confirmed as feasible and safe treatment modalities in many studies, and their application is increasing in children, even in infants and neonates [2].

Holcomb et al. first reported on the use of thoracoscopic biopsy for the diagnosis of pediatric mediastinal neuroblastoma [3]. Since then, further studies have shown that minimally invasive surgery can be an effective approach for biopsies of solid tumors, determination of staging and resectability, evaluation of metastatic or recurrent disease, and searching for infectious complications [4].

However, laparoscopic resection for pediatric malignant tumors remains controversial. Saenz et al. reported on the first pediatric series of laparoscopic biopsies for abdominal neuroblastomas [5]; there have been only few reports since, and the oncologic safety remains largely unknown [4–12]. Nevertheless, laparoscopic approaches for pediatric malignancy are being used more frequently not only in diagnosis, but also as an ablative tool in selected patients [5–12]. Although laparoscopic surgery provides many advantages compared with open procedures, its safety and

feasibility in children with tumors remain to be established due to the few studies detailing its use in such circumstances.

The present report describes our experience using laparoscopic surgical resection for various pediatric malignant solid tumors. We also review the current literature.

Methods

This study included all pediatric patients who underwent laparoscopic tumor resection for malignant solid tumors at our institution between April 2005 and January 2010. Demographic data (i.e., age, gender, and bodyweight), clinical information (i.e., diagnosis, location, tumor size, pathologic report, hospital course, and follow-up) and detailed operation data (i.e., operation time, tumor size, number of ports used, and conversions to open procedures) were collected in a retrospective medical record review. The study was approved by our institutional review board (No. 2010-0169).

Results

Ten patients underwent laparoscopic tumor resection for malignant solid tumors during the study period: four boys and six girls (Table 1). The mean age at surgery was 23.3 months (range, 13 days–69 months). Patients included one neonate (13 days old, 3.6 kg) and four infants. Complete tumor resection was performed in all cases. Six patients underwent laparoscopic adrenalectomy for neuroblastoma ($n = 5$) or adrenocortical carcinoma ($n = 1$). Two patients underwent laparoscopic partial hepatectomy for hepatoblastoma. Of the two remaining patients, one underwent a laparoscopic unilateral salpingo-oophorectomy for a yolk sac tumor, and the other a laparoscopic tumor excision for a rhabdomyosarcoma in the pelvis.

Tumors ranged from 2.5 to 5.3 cm in the maximum diameter. Preoperative radiology studies showed clear tumor borders with no evidence of local infiltration. The yolk sac tumor and rhabdomyosarcoma were treated using chemotherapy preoperatively, which resulted in a marked reduction in size such that the operations involved the removal of only a small residual lesion. Hepatoblastomas were located in S5 and S6 and were <5 cm in diameter. All operations were performed using three or four ports (usually 1- × 10-mm umbilical port, which was used for specimen delivery with or without some extension at the conclusion of tumor resection, and 2- or 3- × 5-mm ports). Three-millimeter ports were used in some infant cases and in the neonate case. All tumors were placed inside endobags and removed safely without spillage.

The mean operation time was 132 (range, 65–250) min. There were no open conversions and no postoperative complications. Most patients commenced oral feeding on the operation day or the day after the operation. The mean postoperative hospital stay was 4.9 (range, 2–7) days, and all surgical wounds showed good cosmetic results. The median follow-up period was 17.3 (range, 2.4–59.5) months. No local tumor recurrences occurred during that time.

Discussion

Laparoscopic surgery is superior to conventional open surgery in terms of a rapid postoperative recovery (which can be crucial for early initiation of chemotherapy), a lower incidence of postoperative adhesive ileus and intestinal obstruction, and a far better cosmetic result. In addition, in

Table 1 Characteristics of patients who underwent laparoscopic resection for pediatric malignancies

Patient	Sex/age (month)	Weight (kg)	Location	Size (cm)	Operative time (min)	Ports	Hospital stay (days)	Diagnosis	F/U period (month)
1	F/32	16.2	Adrenal, Lt	5.0	65	4	4	ACC	59.5
2	M/8	9.4	Adrenal, Rt	5.3	180	4	7	NBL	54.1
3	F/29	12.4	Ovary, Lt	4.0	70	3	2	YST	30.5
4	M/2.8	6.6	Adrenal, Rt	5.0	90	4	5	NBL	24.8
5	M/0.4	3.6	Adrenal, Rt	4.0	90	3	4	NBL	18.2
6	F/24	10.2	Liver, S6	3.5	250	4	7	HBL	16.4
7	F/58	22.0	Adrenal, Lt	2.8	85	3	4	NBL	9.7
8	F/69	17.2	Retroperitoneal	3.0	150	3	5	RMS	7.3
9	F/9	7.3	Liver, S5	2.5	150	4	7	HBL	5.1
10	M/1	5.5	Adrenal, Rt	4.0	190	4	4	NBL	2.4

ACC adrenocortical carcinoma, *NBL* neuroblastoma, *YST* yolk sac tumor, *HBL* hepatoblastoma, *RMS* rhabdomyosarcoma

some cases laparoscopic surgery can allow for a more meticulous and safe tumor excision by providing a better approach and a magnified view. Studies of adult patients with abdominal malignancies showed that laparoscopic surgery had a similar or better oncologic outcome than open procedures [13–15]. Laparoscopic surgery in children has developed slowly due to the limited number of cases and a lack of outcome documentation [1]. However, the accumulation of laparoscopic experience through treatment of benign tumors and through diagnostic procedures has paved the way for the application of laparoscopic resection for malignant solid tumors in children.

Approximately ten articles have reported on laparoscopic resection for pediatric malignancy. Most studies dealt with benign tumors, malignant tumor biopsies, or staging procedures, whereas a small number involved malignant tumor resection (Table 2). Most reports concluded that laparoscopic resection was acceptable in terms of feasibility and safety. Although one case of port-site metastasis after biopsy of a posttransplant Burkitt lymphoma in a child was recently reported [16], there have been no reports about port-site metastasis after abdominal minimally invasive resection procedures for pediatric malignancies [17]. No reports have provided long-term oncologic results or large-scale comparative studies with conventional operation cases.

Our selection criteria for laparoscopic tumor resection included relatively clear tumor border with no evidence of local infiltration or gross vessel invasion. In addition, the laparoscopic procedures were performed only if tumors were <6 cm in diameter. We performed six adrenalectomies for five neuroblastoma cases and one adrenocortical carcinoma case. In all cases, we performed operations via a transabdominal approach in the supine position. Leclair et al. reported on a multicenter retrospective study of laparoscopic resection in 45 children with abdominal neuroblastomas [18]. Even though four procedures (9%) were converted to open surgery and tumor rupture occurred in three cases, they concluded that laparoscopic resection of the abdominal primary tumor allowed effective local control of the disease in a wide range of neuroblastoma patients, with an acceptable morbidity rate. For adrenocortical carcinoma (ACC), the study by Gonzalez et al. showed that all six adult laparoscopic resection cases had recurrence and that peritoneal carcinomatosis was a component of initial failure in five (83%) of those cases [19]. They concluded that laparoscopic resection for ACC is associated with a high risk of peritoneal carcinomatosis and that open adrenalectomy remains the standard of care for patients presenting with adrenal cortical tumors for which ACC is in the differential diagnosis. Laje and Mattei also commented on the risk of ACC recurrence after rupture and spillage during laparoscopic adrenalectomy in children [20]. According to the International Pediatric Endosurgery Group (IPEG) guidelines for the surgical treatment of adrenal masses in children, an absolute limitation on tumor size cannot be determined, but cases should be evaluated individually, based on the size of the mass relative to the size of the child, and that although there are no absolute contraindications to the laparoscopic approach, care must be taken to maintain the principles of cancer surgery particularly for neuroblastomas and other adrenal neoplasms [6].

Our series included two laparoscopic liver resection cases. There are only a few reports on large-volume laparoscopic liver resection cases in adults, and pediatric laparoscopic liver resections for pediatric benign tumors have been recently reported [21, 22]. To the best of our knowledge, only one report has described laparoscopic

Table 2 Publications detailing laparoscopic resection and conversions for pediatric malignancies

Study	Year	Total	No. of laparoscopic tumor resections	Conversion rate (%)	Tumors composition
Saenz	1997	46	4	Not identified	Not identified
Waldhausen	2000	15	5	Not identified	3 HBL, 1 NBL, 1 Germ cell tumor
Sailhamer	2003	9	5	0	2 NBL, 3 ovarian cancer
Warmann	2003	5	5	60	Not identified
Kadamba	2004	5	5	40	1 ACC, 1 GN, 3 NBL
Spurbeck	2004	64	7	0	1 HD, 2 Leuk, 1 Lym, 1 GN, 1 Pheo, 1 Meso
Iwanaka	2004	16	6	33	5 NBL, 1 ovarian cancer
Metzelder	2007	24	24	42	Not identified
Chan	2007	6	6	Not identified	2 ovarian cancer, 3 NBL, 1 Wilms' tumor
Leclair (7 centers)	2008	45	45	9	All NBL cases

ACC adrenocortical carcinoma, *NBL* neuroblastoma, *HBL* hepatoblastoma, *RMS* rhabdomyosarcoma, *GN* ganglioneuroma, *HD* Hodgkin's disease, *Leuk* leukemia, *Lym* lymphoma, *Pheo* pheochromocytoma, *Meso* mesothelioma

Table 3 Preoperative and postoperative chemotherapy regimens

Patient	Sex/age (month)	Diagnosis	Preoperative chemotherapy (no. of courses)	Postoperative chemotherapy (no. of courses)
1	F/32	ACC	No	No
2	M/8	NBL	No	No
3	F/29	YST	PEB (7)	VAC (3) ICE (5) HSCT + ASCR
4	M/2.8	NBL	CARBO/VP(1) CARBO/DOXO/CPM (1)	CARBO/VP (1) CARBO/VP/DOXO (1)
5	M/0.4	NBL	No	No
6	F/24	HBL	CDDP/VCR/5-FU (4)	CDDP/VCR/5-FU (4)
7	F/58	NBL	CDDP/DOXO/CPM/VP (7) ICE (4) CPM/TPC (8)	Tandem HDCT + ASCR
8	F/69	RMS	VAC (2) VIE (2)	VIE (6) VC (2)
9	F/9	HBL	CDDP/VCR/5-FU (4)	CDDP/VCR/5-FU (6)
10	M/1	NBL	No	No

PEB cisplatin, etoposide, bleomycin, *VAC* vincristine, actinomycin-D, cyclophosphamide, *ICE* ifosfamide, carboplatin, etoposide, *HDCT* high-dose chemotherapy, *ASCR* autologous stem cell rescue, *CARBO* carboplatin, *VP* etoposide, *DOXO* doxorubicin, *CPM* cyclophosphamide, *CDDP* cisplatin, *VCR* vincristine, *5-FU* 5-fluorouracil, *TPC* topotecan, *VIE* vincristine, ifosfamide, etoposide, *VC* vincristine, cyclophosphamide

hepatectomy for hepatoblastoma [23], and no detailed information about hepatectomy cases was included in that paper. Because the present hepatoblastomas were relatively small (3.5 and 2.5 cm maximum diameter) and were located in S5 and S6, which belong to the so-called anterolateral segments (segments 2, 3, 4b, 5, and 6), laparoscopic nonanatomical liver resection was not particularly difficult. Laparoscopic resection of a liver tumor requires a team that has extensive expertise in both laparoscopic and hepatobiliary surgery. Liver masses are not common in children, and therefore, it may be difficult for surgeons to accumulate experience in pediatric laparoscopic hepatic resection unless their institution has a large pediatric patient population. Ovarian yolk sac tumors and retroperitoneal rhabdomyosarcomas are uncommon. The few pediatric laparoscopic resection cases that have been published are listed in Table 2.

Neoadjuvant chemotherapy was tailored according to the pathology diagnosis. The duration and intensity of chemotherapy was based on the extent of the primary disease and metastasis (Table 3). Patient 3 was treated with high-dose chemotherapy (HDCT) and autologous stem cell rescue (ASCR) due to pulmonary relapse after the completion of adjuvant chemotherapy. Patient 7 was treated with tandem HDCT and ASCR due to a stage IV neuroblastoma.

Conclusions

Laparoscopic surgical resection for various pediatric malignant solid tumors was found to be technically feasible and safe in selected cases, and provided the advantages of minimally invasive surgery. Long-term follow-up data and prospective, randomized studies are necessary to validate the oncologic safety.

Disclosures Drs. Taehoon Kim, Dae-Yeon Kim, Min Jeong Cho, Seong-Chul Kim, Jong Jin Seo, and In-Koo Kim have no conflicts of interest or financial ties to disclose.

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