Journal of Pediatric Surgery 49 (2014) 1171–1176

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Review Article

Minimally invasive surgery in the management of abdominal tumors in children

Alpin D. Malkan, Amos H.P. Loh, John A. Sandoval *

Department of Surgery, St. Jude Children's Research Hospital, Memphis, TN

ARTICLE INFO

Article history:
Received 18 January 2014
Received in revised form 3 April 2014
Accepted 16 April 2014

Key words:
Laparoscopy
Children
Solid intraabdominal tumors

ABSTRACT

The application of minimally invasive surgical techniques to pediatric abdominal tumors is a controversial application towards the surgical management of childhood cancer. Although general pediatric surgeons practice minimally invasive surgery techniques in a vast array of abdominal cases, its role in pediatric oncology is still developing, with no consensus in North America about its use for pediatric solid abdominal tumors. The purposes of this article are to review the current literature about the use of minimally invasive surgery in pediatric abdominal oncology and to examine established indications, procedures and technologic advances.

Published by Elsevier Inc.

In 1995, Holcomb et al proposed oncologic indications for the use of laparoscopy, or minimally invasive surgery (MIS), on the basis of data collected by the Children's Cancer Group [1]. These indications included laparoscopy for biopsies; staging and determination of resectability; assessing the potential benefit of second-look procedures; evaluation and resection of metastatic disease; and diagnosis of infectious complications [1]. Although the published evidence about using MIS in pediatric oncologic surgery is limited, pediatric oncology patients potentially could also benefit from the advantages offered by these techniques [2–7]. Conversely, if the oncologic principles are violated there are significant consequences including tumor upstaging which may translate into requiring additional chemotherapy and/or radiation, thereby negatively affecting the long-term outcome of these children. This article will review current literature about the use of MIS in pediatric oncology, including its established indications, procedures, and technologic advances.

1. Uses of laparoscopic surgery in children with abdominal malignancies

1.1. Diagnosis

Evaluating the abdominal cavity via laparoscopy can provide information about the nature of tumors, including their size, location, anatomy, and the presence of metastasis not seen on preoperative imaging. Ultimately, such features influence whether or not a lesion is resectable by using an MIS approach. Although studies have demonstrated the identification of new abdominal masses, metastatic or recurrent disease, or evaluation for resectability to be successful in greater than 93% of diagnostic laparoscopic procedures [8,9], surgeons may use these procedures to decide upon and execute the safest oncologic procedure for the patient. The "conversion" to an open approach should not be mistaken for a "complication" if the maneuver can provide a significant amount of information to the surgical team.

1.2. Biopsy

Many solid tumors of infancy and childhood require an initial biopsy. This is performed via either an image-guided percutaneous approach or a surgical approach. The advantage of laparoscopy is its ability to obtain more tissue than do core needle biopsies while still being minimally invasive and maintaining a high level of diagnostic accuracy [10]. Laparoscopic biopsies for tumors such as abdominal neuroblastoma (NB) and rhabdomyosarcoma and other intraabdominal tumors have resulted in adequate tissue procurement for diagnostic analysis [9,11]. Although initial biopsy for hepatoblastoma, NB, germ cell tumor, rhabdomyosarcoma, desmoplastic tumor, lymphoma, and benign lesions have been shown to have a diagnostic accuracy of 100% [12], conversions to an open surgical approach may be necessary in the case of poor visibility and bleeding [3]. Despite a high rate of success being achieved in these MIS biopsy procedures, caution must be emphasized owing to the potential for upstaging the neoplasm and impacting the overall treatment and prognosis.

1.3. Resection

The use of laparoscopy for retroperitoneal surgery (i.e., retroperitoneoscopy) has been most effective in providing access to retroperitoneal lymph nodes. The use of the method was reviewed for lymph node sampling, diagnostic biopsy, and resection of metastatic

* Corresponding author at: Department of Surgery, MS 133, Room D3045, 262 Danny Thomas Place, St. Jude Children's Research Hospital, Memphis, TN, 38105–3678. Tel.: +1 901 595 5008; fax: +1 901 595 4157.
E-mail address: john.Sandoval@stjude.org (J.A. Sandoval).

http://dx.doi.org/10.1016/j.jpedsurg.2014.04.010
0022-3468/Published by Elsevier Inc.

nodules in 16 children and found to be a safe surgical technique to access the retroperitoneum [13]. Technical challenges include breach of the peritoneum, with carbon dioxide leakage into the peritoneal space caused by port insertion [13].

Transabdominal laparoscopy has been used for retroperitoneal paraaortic lymph node dissection in early stage nonseminomatous germ cell tumors of the testis in young adults [14] and for lymph node sampling in pediatric bladder rhabdomyosarcoma [15,16]. Laparoscopic retroperitoneal lymph node dissection has been performed in pediatric patients with high-risk paratesticular rhabdomyosarcoma after initial radical orchiectomy [17]. Despite long operative times, no postoperative complications occurred. This modality was found to be safe for diagnostic and therapeutic use, with a mean hospital length-of-stay of 2.5 days enabling early commencement of adjuvant chemotherapy [17].

2. Laparoscopy in various abdominal tumor types

2.1. Adrenal tumors

Minimally invasive adrenalectomies (MIAs) have been performed in children with both benign and malignant adrenal tumors [18,19], including pheochromocytomas [19–21], extraadrenal pheochromocytomas (paragangliomas) [20,22], teratomas [19], and NBs [3,19,20,23–28]. Although three different methods for MIA are described including prone retroperitoneal adrenalectomy [23], lateral retroperitoneal adrenalectomy [20,23,29], the most commonly utilized is lateral transperitoneal adrenalectomy [19,20,23–28,30–32]. Theoretically this approach leads to better exposure, larger working space, and facilitates lymph node dissection along the inferior vena cava and aorta [29]. Since most case series have limited numbers, the ability to detail potential differences based on the size or local aggressiveness of tumor in relation to the surgical approach and oncologic outcome is difficult to identify.

2.1.1. Neuroblastic tumors

Neuroblastoma is the most common extracranial solid malignant tumor in children [23,24,30] and accounts for 40% of pediatric patients undergoing adrenal surgery [23]. Potential indications for MIA in NB include tumors that are small, localized, and well encapsulated [23,29]. Evidence of enlarged renal veins on preoperative imaging or at the time of laparoscopic resection should prompt close evaluation for a possible thrombus [25]. According to the International Neuroblastoma Risk Group, image-defined risk factors are features detected on imaging that make safe, complete tumor excision impractical at the time of diagnosis, such as masses that encase major blood vessels or nerves or invasion of structures such as organs or the spinal canal [29,33], which may preclude an MIS approach. However, patients who have undergone biopsy with a finding of favorable biologic features and who do not have any surgical risk factor involvement (i.e., inferior vena cava, aorta, renal vessel) on reassessment after neoadjuvant chemotherapy may also be candidates for MIA [29].

Effective local disease control of pediatric NB by MIA is greater than 86.7% [3,19,23,26,28,30,31]. Immediate laparoscopic resection has been performed for stage 1 and 2 tumors [24,26,30,34], and delayed resection after preoperative chemotherapy, in stage 4 disease [24,34]. Laparoscopy has been performed primarily for smaller, well-encapsulated lesions smaller than 4 cm [19,27], although lesions up to 7 cm have also been successfully removed [19,24,30,34]. Complete resection of the primary NB was achieved in 88%–100% of patients with stage 1 or 4 disease[24,30] and in all patients with stage 1, 2, or 4 disease [34], without evidence of disease in follow-up periods of 15–48 months [24,30,34]. Most patients experienced full enteral feeds and were discharged from the hospital by postoperative day 1 [24].

Open surgery continues to be the gold standard for the resection of NB, however, MIA may be useful in controlling localized, resectable NB. Conversely, performing MIS tumor biopsy in advanced disease decreases postoperative recovery time and time to resumption or commencement of postoperative therapy [23]. Patients who underwent early NB resection had a similar length of operation and amount of intraoperative blood loss as compared to the open excision group. However, the average time to start postoperative feeding and length of hospital stay were significantly less in those who underwent laparoscopic resection as compared to open excision ($p < 0.05$) [26]. Among patients who underwent biopsies for advanced NB, the time to start postoperative feeding (33 vs 129 h) and time to chemotherapy (3.7 vs 11.2 d) were significantly shorter in the laparoscopic group ($p < 0.05$) [26].

In a subsequent study, the same group demonstrated that intraoperative blood loss, time to start of postoperative feeding, and hospital length of stay were also significantly lower in patients undergoing early laparoscopic excision of NB than in those undergoing open excision procedures ($p < 0.05$) [35]. The advanced NB group that underwent laparoscopic biopsy also had a significantly lower average time to the start of postoperative feeding and chemotherapy ($p < 0.05$) [35]. They found that preoperative appreciation of the relationship between the tumor and large vessels was critical for preventing conversion to open surgery [35]. Technical factors such as tumor size and proximity to vital structures may also influence the success of MIA for pediatric NB. Technical reasons for conversion are often owing to bleeding [2] and, less commonly, to adhesions to renal vessels [30].

MIA has also been successfully used to treat ganglioneuromas arising from the adrenal gland [20,25,36]. Resections via the lateral transperitoneal approach have been performed with minimal blood loss and short postoperative stay [25]. Since these benign peripheral neuroblastic tumors are typically large, difficult to surgically expose, and encase vital structures [20,29,37], potentially only the small, less invasive ganglioneuromas may be amenable to an MIS approach.

2.1.2. Pheochromocytoma

Pheochromocytomas are catecholamine-secreting tumors of the adrenal medulla that are mostly benign. They can be unilateral, bilateral, or extraadrenal. These lesions can occur sporadically or in association with hereditary syndromes such as von Hippel-Landau syndrome, familial paraganglionoma syndromes, multiple endocrine neoplasia type 2, and neurofibromatosis type 1 [29,38]. Diagnostic laparoscopy is recommended to determine resectability by identifying the tumor's origin and its relationship to surrounding structures and vascular structures [22]. Minimally invasive adrenalectomy is described by some authors as the approach of choice for these lesions [29], with reports of resection of both pheochromocytomas [25] and paragangliomas [20]. Although low intraoperative blood loss, controllable intraoperative hypertension, and lack of postoperative complications were reported in one study [25], other authors have reported conversions owing to massive venous bleeding from an anomalous secondary adrenal vein draining to the liver [19,32] and poor visibility [20].

2.1.3. Adrenocortical tumors

Caution should be exercised when deciding to use MIA for adrenocortical tumors [39,40]. These tumors are usually large and well encapsulated, have a 60% rate of malignancy, and are often very friable at presentation, which predisposes them to frequent capsule rupture and spillage [29]. Patient undergoing minimally invasive adrenalectomy for adrenocortical carcinoma (ACC) have higher rates of margin-positive resections and earlier local recurrence than do patients who undergo open adrenalectomy [40]. Nonetheless, MIA has been performed safely for selected cases of ACC [28,39,41]. The European Society for Medical Oncology asserts that MIA is safe and effective in patients having small ACCs without preoperative evidence of invasiveness [42]. Although MIA is feasible, conversion to open