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Evolving Application of Minimally Invasive Cancer Operations at a Tertiary Cancer Center

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Abstract

Background—Patients and providers are increasingly interested in the utilization, safety, and efficacy of minimally invasive surgery (MIS). We reviewed eleven years of MIS resections (laparoscopic and robotic) for intra-abdominal malignancies.

Methods—Patients who underwent gastrectomy, distal pancreatectomy, hepatic resection, and colorectal resection between 2004 and 2014 were identified. Cases were categorized as open, laparoscopic, and robotic based on the initial operation approach. Diagnostic laparoscopies were excluded.

Results—Of the 10,039 patients who underwent the above procedures, between 2004 and 2014, 2,832 (28%) were MIS. In 2004 12% (100/826) of all resections were performed with MIS approaches, rising to 23% (192/821) of all resections by 2009 and 44% (484/1,092) in 2014. The number of open resections has remained largely stable: 726 (88% of all resections) in 2004 and 608 (56% of all resections) in 2014. Initially, laparoscopy experienced incremental adoption. Robotic surgery was implemented in 2009 and is currently the dominant MIS approach, accounting for 76% (368/484) of all MIS resections in 2014. Overall mortality has remained less than 1%.

Conclusions—While maintaining patient safety, utilization of MIS techniques has increased substantially since 2004, particularly for gastric and colorectal resections. Since 2009 robotic surgery is the predominant MIS approach.

Keywords

minimally invasive surgery; surgical oncology; robotic surgery; laparoscopic surgery

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INTRODUCTION

Following Semm's description of the first laparoscopic appendectomy (called at the time an endoscopic appendectomy) [1], minimally invasive surgery (MIS) has achieved rapid adoption in general surgery procedures ranging in complexity from laparoscopic appendectomy and cholecystectomy [2] to complex hiatal hernia repairs [3-5]. More recently, many surgeons have applied MIS approaches to oncologic operations.

Though the initial reports of laparoscopic colectomy for colon cancer appropriately cautioned slow adoption of this technique [6], subsequent reports have demonstrated that laparoscopic approaches are oncologically equivalent to the corresponding open operation in appropriately selected patients [7-13]. As experience with MIS has increased and surgeons have become comfortable with application for surgical oncology cases, rates of MIS resections have increased [14, 15]. In addition to compelling data on oncologic equivalency [16], MIS approaches have demonstrated lower rates of certain post-operative complications and shorter length of stay [17-20].

The adoption of laparoscopic approaches has been gradual due to technical, time-related, and ergonomic challenges for the operative surgeon [21]. Robotic surgery offers a potential bridge for these downsides, and may shorten the learning curve for both benign and malignant surgical procedures [22]. However, robotic approaches have been challenged because of the perceived expense of the robotic platform [23-26].

We perform a high volume of complex surgical oncology procedures and, over time, have increased the percentage of resections that occur minimally invasively [17, 18]. The aim of this report is to characterize our institutional experience with the adoption of MIS approaches to complex intra-abdominal malignancies.

MATERIALS AND METHODS

Following a waiver of informed consent from our Institutional Review Board, institutional records were queried to identify all gastrectomies, distal pancreatectomies, hepatectomies, and colorectal resections between January 1, 2004 and December 31, 2014. Institutional prospectively maintained disease-specific databases, our institutional MIS database, and operating room records were used to classify the surgical approach as either open or MIS; MIS resections were further classified as either laparoscopic or robotic. Operations that were converted from either a laparoscopic or robotic approach to open were classified by their initial MIS approach. Isolated diagnostic laparoscopies were excluded from this analysis, and operations where a diagnostic laparoscopy preceded a planned laparotomy were analyzed within the open category. Operations were excluded if patients underwent synchronous resection of multiple organs by different surgical teams (for example, synchronous resection of a colorectal lesion and a liver metastasis); staged resections were included and counted multiply. We excluded synchronous resection from this report as combination surgical resection by multiple surgical teams should not be part of initial adoption of any surgical technique and our aim was to describe our adoption of MIS resections.

Extent of resection and indication were classified separately for each resection type. For gastric resections we report their final pathological stage [27] and classified them as either a total or subtotal gastrectomy. Prophylactic total gastrectomies for hereditary diffuse gastric cancer and instances where patients received neoadjuvant chemotherapy with a complete pathological response were grouped within stage 1. It is our practice to perform a D1 lymphadenectomy for prophylactic gastrectomies and gastric resection for benign lesions and a D2 lymphadenectomy for all patients with gastric adenocarcinoma. Hepatic resections were classified as a wedge, segmentectomy, or lobectomy; indication for resection was classified as metastatic colorectal cancer, other metastatic cancer, liver (either hepatocellular carcinoma or a benign hepatic lesion), disease of the biliary tree (including a cholecystectomy as necessary), or gallbladder cancer (that did not include a biliary resection). Cholecystectomies performed for acute cholecystitis or symptomatic cholelithiasis were excluded. Indication for resection for all distal pancreatectomies was classified as pancreatic adenocarcinoma, other malignant disease (including pancreatic endocrine neoplasms, metastases from other solid tumors, and undifferentiated lesions), intermediate lesions (including mucinous cystic neoplasm and intraductal papillary mucinous neoplasm), and benign lesions. For colorectal resections we report the final pathological stage [27] and classify the resection extent as either a right hemicolectomy, left hemicolectomy, low anterior resection, abdominoperineal resection, or a total colectomy. For all rectal resections it is our practice to perform a tumor-specific TME, and for all intra-abdominal colectomies we ligate the appropriate artery and vein at their root. We report R0 resection rates for all gastrectomies, hepatic resections, distal pancreatectomies for pancreatic adenocarcinoma, and all low anterior resections.

All complications are prospectively graded on our modification of the Clavien-Dindo classification [28]. Grades 1 (an event requiring oral medication) and 2 (an event requiring IV medication or a bedside procedure) are categorized as minor complications; grades 3 (an event requiring intubation or operative, endoscopic, or radiologic intervention), 4 (an event resulting in prolonged disability or organ resection), and 5 (death) are categorized as major complication. For the purposes of this analysis, a patient who experienced both minor (grades 1 and 2) and major (grades 3–5) complications was reported as having experienced a major complication.

RESULTS

In total, 10,039 patients underwent gastrectomy, hepatectomy, distal pancreatectomy, colectomy, or proctectomy between 2004 and 2014. Of these, 28% (2,832 / 10,039) were performed laparoscopically (n = 1,955, 19% of all resections and 69% of all MIS resections) or robotically (n = 877, 9% of all resections and 31% of all MIS resections) (Table I); increasing from 12% of all resections (100 / 826) in 2004 to 44% of all resections (484 / 1,092) in 2014 (Fig. 1 and Fig. 2). Throughout this time period, our operative morbidity and mortality have consistently remained low in all approaches (Table I). Though there are no overall differences in body mass index (BMI) between patients based on operative approach (Table I), the BMI of patients undergoing MIS resection early in our experience were significantly different from patients who underwent similar open resection in the same year (Fig. 3). Patients who underwent MIS resection early in our adoption of either laparoscopic

or robotic surgery did not have extremely high or extremely low BMIs, but with each additional year of MIS experience, these differences lessened until there was no discernible difference between the BMIs of patients undergoing MIS resection and those undergoing open resection (Fig. 3). Median American Society of Anesthesiologists classification did not differ between groups (Table I).

Extent of surgical resection

Significant differences in resection extent between MIS and open approaches exist for most organs. Patients undergoing either gastrectomy or hepatectomy were more likely to have an MIS resection if they were undergoing a more limited resection (subtotal gastrectomy represented 69% of all robotic resections and 76% of all laparoscopic resections, but only 62% of open resections; hepatic wedge resections represented 37% of all robotic resections and 41% of laparoscopic resections, but only 19% of all open resections), but surgical approach did not differ substantially for colorectal resections. Though abdominoperineal resections were rarely performed robotically (3.5% of all robotic colorectal resections) or laparoscopically (< 1% of all laparoscopic colorectal resections), low anterior resections, which are equally technically challenging, are the most commonly performed MIS colorectal resection at our institution (55% of all robotic colorectal resections and 20% of all laparoscopic colorectal resections). Due to the need for a myocutaneous flap to repair the perineal defect in many abdominoperineal resection patients, these operations are mostly performed open. The rate of negative surgical margins did not differ by surgical approach (Table I).

Indication for surgical resection

As with extent of resection, organ-specific indications for surgical resection showed significant variation by surgical approach (Table I). Patients with early-stage gastric cancer were more likely to undergo MIS resection (stage 1: 68% of all robotic resections and 63% of all laparoscopic resections, 40% of all open resections), and this pattern held when the more recent years of our experience were examined individually. Resections for metastatic colorectal cancer account for half of all open hepatic resections, 23% of all robotic hepatectomies, and only 6% of all laparoscopic liver resections. A similar pattern occurred for distal pancreatectomies, where malignant lesions (pancreatic ductal adenocarcinoma, pancreatic neuroendocrine tumors, and metastatic lesions) account for 71% of all open distal pancreatectomies, and approximately half of all robotic resections (52%) and laparoscopic resections (55%). Interestingly, final pathologic stage did not differ greatly by approach for colorectal resections.

DISCUSSION

Since 2004, we have seen significant adoption of MIS approaches to a variety of intra-abdominal malignancies (Fig. 1), an adoption which occurred in two discrete phases: incremental increases in laparoscopic volume between 2004 and 2009, and then a rapid increase in robotic volume (with a decrease in laparoscopic volume) after 2009 (Fig. 1). These increases have occurred without an increase in morbidity, mortality, or positive resection margin, though differences between patients undergoing an MIS resection and an

open resection remain. Procedure-specific trends (Fig. 2) are similar, but differences within the resection types highlight the most important aspect of MIS approaches to any surgical procedure: laparoscopic and robotic approaches are a tool in the surgeon's armamentarium, to be used for appropriately selected cases in which oncologic equivalency is the first and foremost goal.

Ability to achieve complete tumor resection with negative margins, complete lymphadenectomy, restoration of intestinal continuity, and, most importantly, patient selection, remain, regardless of which approach a surgeon chooses for their patient's resection. Despite the high volume of procedures performed at our institution, differences remain between patients who undergo open resection and patients who have an MIS resection. Patients undergoing total gastrectomy and those with more advanced disease are more likely to undergo an open gastrectomy, the vast majority of our hepatic lobectomies are performed open, and benign pancreatic lesions account for a higher percentage of MIS pancreatectomies than open pancreatectomies (Table I). The evolution of our use of MIS techniques and the associated patient selection is demonstrated by BMIs in patients early on in our MIS experience (Fig. 3). As familiarity with the MIS techniques increased, this selection factor was mitigated, and the BMI differences narrowed and then disappeared (Fig. 1 and Fig. 2). We have also narrowed, but not eliminated, the differences between procedure-specific resection extent of patients undergoing open and MIS resections. More extensive gastric and hepatic resections (total gastrectomy, hepatic lobectomy) are more commonly performed open than MIS, while there are no differences in resection extent for our colorectal procedures. Differences in MIS utilization between resection types likewise reflect technical considerations of these different operations, with gastric and colorectal resections far more likely to be performed with an MIS approach than either a distal pancreatectomy or a hepatectomy.

While numerous institutions have published series describing their adoption of either laparoscopic or robotic approaches for a given surgical procedure, we are not aware of many other institution-level reports describing the evolution from open to MIS resections across a variety of surgical procedures. Recently, Yuh et al presented City of Hope's experience with robotic surgery [29]. They found, as we did, that their institution was able to transition from open approaches to robotic approaches with no change in morbidity and mortality. Nationally, however, the role for robotic surgery is still being actively debated [15]. Nevertheless, our institutional experience demonstrates a rapidly growing and evolving interest in robotic approaches for well-selected oncologic resections.

We have previously reviewed our institutional experience with MIS resections for gastrectomies [11, 17], hepatectomies [13], and distal pancreatectomies [9, 18] as well as a review of our early adoption of laparoscopy [10]. Each of these reports separately describes the organ-specific factors important in selecting a patient for a specific MIS resection. Broadly, both laparoscopic and robotic surgical approaches have been shown as oncologically equivalent to their open counterparts. However, the technical challenges inherent to these approaches highlight the need for individual surgeons to carefully evaluate their surgical outcomes and ensure that, especially early on in one's MIS experience, the priorities of patient outcomes, safety, and oncologic equivalency remain, regardless of

surgical approach. In this institutional report, we did not focus on rates of conversion from MIS to open approaches. While these rates are important, they reflect procedure-specific patient selection and technical considerations that are best discussed in disease and procedure-specific reports [9, 13, 17, 18].

CONCLUSIONS

This manuscript describes our institutional experience with the adoption of MIS approaches for a variety of intra-abdominal malignancies and highlights the importance of patient selection in deciding whether a patient is a suitable candidate for an MIS resection. Since 2004 we have shown a rapid adoption of MIS and, particularly, robotic approaches to patients with intra-abdominal malignancies, demonstrating safety, patient selection, oncologic equivalency, and feasibility. These techniques have a clear and ever-growing place in the armamentarium of approaches that can be effectively applied to the cancer patient.

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Fig. 1.
Overall surgical volume by surgical approach between 2004 and 2014.

Fig. 2.
Procedure-specific resection volume between 2004 and 2014.

Fig. 3.
BMI, by year and resection approach, for all resections between 2004 and 2014.

TABLE I

Clinical Demographics for Patients who Underwent Gastrectomy, Hepatectomy, Distal Pancreatectomy, or Colorectal Resection Between 2004 And 2014 at Memorial Sloan Kettering Cancer Center by Their Initial Surgical Approach

	Open (N=7207; 72%)	Laparoscopic (N=1955; 19%)	Robotic (N=877; 8.7%)
Age, years (range)	62.0 (52.0, 72.0)	62.0 (51.0, 71.0)	58.0 (49.0, 68.0)
Female	3395 (47%)	1022 (52%)	413 (47%)
BMI (range)	27.0 (23.7, 30.9)	27.7 (24.2, 31.5)	27.3 (23.9, 31.0)
ASA (N=5572)			
1	8 (0.2%)	12 (1.0%)	12 (1.4%)
2	1565 (44%)	571 (50%)	320 (37%)
3	1870 (53%)	539 (47%)	511 (59%)
4	111 (3.1%)	30 (2.6%)	22 (2.5%)
5	1 (<0.1%)	0 (0%)	0 (0%)
Procedure			
Gastrectomy	719 (10%)	83 (4.2%)	71 (8.1%)
Hepatectomy	2424 (34%)	174 (8.9%)	70 (8.0%)
Distal pancreatectomy	565 (7.8%)	153 (7.8%)	48 (5.5%)
Colorectal resection	3499 (49%)	1545 (79%)	688 (78%)
Major 30-day complication	739 (10%)	84 (4.3%)	42 (4.8%)
30-day mortality	53 (0.7%)	2 (0.1%)	2 (0.2%)
Gastrectomy (N=873)			
Extent of resection			
Subtotal gastrectomy	443 (62%)	63 (76%)	49 (69%)
Total gastrectomy	276 (38%)	20 (24%)	22 (31%)
AJCC 7th edition stage			
1	287 (40%)	52 (63%)	48 (68%)
2	209 (29%)	20 (24%)	14 (20%)
3	223 (31%)	11 (13%)	9 (13%)
Negative surgical margin	716 (100%)	81 (98%)	70 (99%)
Hepatectomy (N=2668)			
Extent of resection			
Wedge	462 (19%)	71 (41%)	26 (37%)
Segmentectomy	1341 (55%)	83 (48%)	36 (51%)
Lobectomy	621 (26%)	20 (11%)	8 (11%)
Indication for resection			
Metastatic colorectal cancer	1208 (50%)	11 (6.3%)	16 (23%)
Other metastatic cancer	431 (18%)	76 (44%)	20 (29%)
Liver	336 (14%)	75 (43%)	17 (24%)

	Open (N=7207; 72%)	Laparoscopic (N=1955; 19%)	Robotic (N=877; 8.7%)
Biliary	275 (11%)	4 (2.3%)	8 (11%)
Gallbladder	174 (7.2%)	8 (4.6%)	9 (13%)
Negative surgical margin (N=2178)	1770 (89%)	125 (92%)	53 (87%)
Distal pancreatectomy (N=766)			
Indication for resection			
Adenocarcinoma	203 (36%)	19 (12%)	4 (8.3%)
Other malignant tumor	196 (35%)	65 (42%)	21 (44%)
Intermediate *	119 (21%)	52 (34%)	19 (40%)
Benign / Other	47 (8.3%)	17 (11%)	4 (8.3%)
Negative surgical margin (N=224) ‡	187 (87%)	5 (100%)	4 (100%)
Colorectal resection (N=5732)			
Extent of resection			
Right hemicolectomy	789 (23%)	716 (46%)	155 (23%)
Left hemicolectomy	389 (11%)	413 (27%)	109 (16%)
Low anterior resection	1522 (43%)	303 (20%)	378 (55%)
Abdominoperineal resection	579 (17%)	2 (0.1%)	24 (3.5%)
Total colectomy	220 (6.3%)	111 (7.2%)	22 (3.2%)
AJCC 7th edition stage (N=3311)			
1	473 (24%)	237 (26%)	134 (30%)
2	721 (37%)	346 (37%)	136 (31%)
3	745 (38%)	344 (37%)	175 (39%)
Negative surgical margin (N=576) ‡	158 (94%)	91 (97%)	303 (96%)

BMI, body mass index; ASA, American Society of Anesthesiologists Physical Classification System; AJCC, American Joint Committee on Cancer

* Intermediate grade lesions including mucinous cystic neoplasm, intraductal papillary mucinous neoplasm

‡ In patients with pancreatic adenocarcinoma

‡ In patients undergoing a low anterior resection

Continuous variables are expressed as median (IQR) and categorical variables as N (%).