SCIENTIFIC PAPER JSLS

Minimally Invasive Surgery in Gastrointestinal Cancer: Benefits, Challenges, and Solutions for Underutilization

Osama H. Hamed, MD, Niraj J. Gusani, MD, MS, Eric T. Kimchi, MD, Stephen M. Kavic, MD

ABSTRACT

Background and Objectives: After the widespread application of minimally invasive surgery for benign diseases and given its proven safety and efficacy, minimally invasive surgery for gastrointestinal cancer has gained substantial attention in the past several years. Despite the large number of publications on the topic and level I evidence to support its use in colon cancer, minimally invasive surgery for most gastrointestinal malignancies is still underused.

Methods: We explore some of the challenges that face the fusion of minimally invasive surgery technology in the management of gastrointestinal malignancies and propose solutions that may help increase the utilization in the future. These solutions are based on extensive literature review, observation of current trends and practices in this field, and discussion made with experts in the field.

Results: We propose 4 different solutions to increase the use of minimally invasive surgery in the treatment of gastrointestinal malignancies: collaboration between surgical oncologists/hepatopancreatobiliary surgeons and minimally invasive surgeons at the same institution; a single surgeon performing 2 fellowships in surgical oncology/hepatopancreatobiliary surgery and minimally invasive surgery; establishing centers of excellence in minimally invasive gastrointestinal cancer management; and finally, using robotic technology to help with complex laparoscopic skills.

Conclusions: Multiple studies have confirmed the utility of minimally invasive surgery techniques in dealing with patients with gastrointestinal malignancies. However, training continues to be the most important challenge that faces the use of minimally invasive surgery in the management of gastrointestinal malignancy; implementation of our proposed solutions may help increase the rate of adoption in the future.

Key Words: MIS, Minimally Invasive Surgery in GI Cancer, MIS benefits, MIS Underutilization

Department of Surgery, King Hussein Cancer Center, Amman, Jordan (Dr. Hamed).

Department of Surgery, Penn State Cancer Center, Hershey, PA, USA (Dr. Gusani).

Department of Surgery, Medical University of South Carolina, Charleston, SC, USA (Dr. Kimchi).

Department of Surgery, University of Maryland, Baltimore, MD, USA (Dr. Kavic).

Address correspondence to: Osama Hamed, MD, Department of Surgery, King Hussein Cancer Center, 202 Queen Rania Alabdullah Street, PO Box 1269, Amman 11942, Jordan. Telephone: +96265300460, extension 1429; E-mail: ohamed@khcc.jo.

DOI: 10.4293/JSLS.2014.00134

INTRODUCTION

The development of minimally invasive surgery (MIS) over the past 30 years is considered a landmark shift in modern surgery. MIS has revolutionized surgery and brought substantial benefits for patients,[1] health systems, and society as a whole. Patients benefit from reduced perioperative morbidity, enhanced postoperative recovery, and better cosmetic outcomes compared with open surgery.[2] The widespread application and adoption of MIS for benign diseases over the past decade occurred despite the initial absence of level I evidence to support its use.[3] Currently, MIS techniques are considered the standard of care for a wide variety of benign diseases.[3–6]

However, there was little enthusiasm for adopting the MIS techniques in complex resections of gastrointestinal (GI) malignancies in the early 1990s.[7] Proponents were faced with reluctance and concerns regarding the safety and oncologic outcomes of MIS techniques. Several of these key concerns are outlined in **Table 1** and may be loosely grouped into oncologic adequacy, technical demands, and cost. In addition, there have been concerns that the increasing use of laparoscopy was largely driven by the availability and marketing of technology rather than clinical benefits. In his presentation "Uptake of Minimally Invasive Cancer Surgery Often Driven by Nonclinical Forces" at the 14th Annual Conference of the National Comprehensive Cancer Network in 2009, D'Amico stated, "The reasons for the perception [that new surgical technologies are superior] — and the related clinical use of the new products and techniques — often have more to do with nonclinical forces, such as marketing and media

Table 1.

Ability to obtain adequate margin
Extent of lymphadenectomy
Effect of pneumoperitoneum on intra-abdominal spread of tumor cells
Large specimen and need for extraction
Long-term oncologic outcomes
Port-site metastasis (as high as 20%)[9]
Poor instrumentation and technology
Cost and availability
Inadequate training/technically demanding

coverage, than with evidence-based medicine."[8] Given the oncologic concerns and the technical demands, MIS remains underused in most patients with GI malignancies.[10]

SPECIFIC BENEFITS OF MIS IN CANCER PATIENTS

Time of Initiation and Tolerance of Adjuvant Therapy

Much of the morbidity in open surgery is related to the laparotomy incision; this can result in a delay in the administration of adjuvant therapy.[11] Delays in the initiation of adjuvant chemotherapy have been shown in multiple studies to negatively affect disease-free survival and overall survival.[12]

MIS techniques, when applied to cancer resection, can result in quicker recovery and earlier administration and better tolerance of adjuvant therapy, and they may result in improved survival. Unfortunately, the timing of initiation and overall tolerance to adjuvant chemotherapy were not recorded in the laparoscopic colon cancer resection randomized trials.[13–17] Up until recently, there was little evidence to support these presumed benefits for MIS in treating GI malignancies. Day et al[18] in their recent publication showed that laparoscopic resection of colorectal cancer resulted in earlier administration of adjuvant chemotherapy and better overall survival. Strouch et al[19] found that patients who underwent laparoscopic rectal cancer surgery received adjuvant chemotherapy 25 days earlier and stated, "Time to initiation of postoperative chemotherapy should serve as an outcome measure for improved recovery in laparoscopic rectal cancer surgery." In lung cancer, Petersen et al[20] found that patients who underwent thoracoscopic lobectomy for non–small cell lung cancer had significantly fewer delayed or reduced adjuvant chemotherapy doses than the thoracotomy group. In this study, although there was no difference in the time of chemotherapy initiation, Petersen et al found that the thoracoscopy group had better overall tolerance to the adjuvant chemotherapy regimen.

MIS for GI Cancer and Quality of Life

In most patients with cancer diagnoses, a wide variety of psychosocial symptoms will develop that can result in a substantial decrease in their quality of life.[21] In one randomized controlled trial, short-term quality-of-life benefits were found to be statistically significant for laparoscopic colectomy compared with open colectomy at 2 weeks postoperatively.[22] This particular advantage of MIS in cancer patients should not be underestimated and needs to be emphasized more in the future. In a small randomized trial of palliative laparoscopic gastrojejunostomy for malignant gastric outlet obstruction, patients treated laparoscopically had a shorter hospital stay and faster resumption of oral intake compared with palliative open gastrojejunostomy patients.[23]

MIS for Colon Cancer and Other GI Malignancies

The most studied GI malignancy in laparoscopic surgery is colon cancer. Early attempts at resection showed feasibility, but questions remained concerning oncologic adequacy.[7] In addition to the long-term survival and disease recurrence, there were significant concerns about peritoneal seeding and port-site metastasis.[9] Johnstone et al,[24] in their review article on the subject in 1996, clearly advised against the use of MIS techniques in resection of malignancy until better prospective evidence was made available. These concerns resulted in many MIS pioneers abandoning the use of the technology for GI malignancy at that time.

Since then, a plethora of basic science and clinical research has confirmed the safety of MIS in cancer resection. Laparoscopy is associated with better preservation of immune function,[25,26] less inflammatory response reaction,[27,28] and no increased risk of tumor spread in relation to the pneumoperitoneum compared with open surgery.[29] Several randomized clinical trials were also published and showed that MIS for colon cancer provided at least equivalent oncologic results and better short-term outcomes.[13–17] Despite all the evidence, the rate of adoption of MIS in colon cancer was persistently low in the first half of the past decade. Kemp and Finlayson[30] found that MIS techniques applied to only 4.3% of colon cancer resections between 2000 and 2004. Robinson et al[9] found that the rate of MIS adoption for colon cancer resection was only 6.7% in 2007. Although this represents an increase from 4.7% in 2005, it still reflects slow implementation of this procedure in the treatment of colon cancer.[10] One major limitation for these studies was the lack of specific codes to identify laparoscopic colon procedures before 2008, making reported rates inaccurate and inconsistent.[31] More recent reports have found that almost one third of colon cancer resections are performed laparoscopically.[32,33] Although this represents an increase compared with the first half of the previous decade, the adoption rate is still much lower compared with laparoscopic cholecystectomies and gastroesophageal reflux procedures.[34,35] This low rate of adoption was discussed extensively at the SAGES 2011 meeting.[36] The largest barrier to increasing use of MIS techniques in cancer patients seems to be training. Most of these cases are technically demanding, with a significant learning curve, and are not covered adequately in the course of surgical residency.[33]

For other GI malignancies, the evidence for MIS application has not been as extensive because of lower disease incidence and limited expertise. Laparoscopic resections for gastric adenocarcinoma have been shown in multiple small randomized trials from Japan to result in better short-term results and equivalent long-term oncologic outcomes.[37–39] Although there are no randomized trials available for MIS application in liver, pancreas, and esophageal malignancies, MIS has been shown to be feasible and safe with good short-term outcomes in multiple retrospective trials in the hands of experts and in high-volume centers.[40–42]

MINIMALLY INVASIVE GI CANCER MANAGEMENT: WHICH SPECIALTY?

The current urban surgical practice is characterized by services provided by specialists. “Minimally invasive cancer management” does not lend itself easily to categorization within a department of surgery. The “minimally invasive” component is typically under the purview of the MIS division, which deals primarily with benign disease, and the “cancer management” component is most commonly treated by surgical oncologists.[43]

For MIS, <10 programs existed for advanced MIS training beyond residency in 1993. Currently, there are >120 postgraduate fellowships in MIS/bariatrics available through the fellowship council.[44] Most of these fellowships consist of a full year during which the surgeon acquires a unique set of laparoscopic skills that are not acquired during general surgery residency.[45] Although the MIS fellowship curricula require the fellow to establish clinical knowledge and experience in the management of GI malignancies, most of these fellowships concentrate on minimally invasive management for benign diseases.[46] In a survey by Tichansky et al,[47] MIS fellows reported on their actual case volumes, as well as the case volumes they would desire in an ideal fellowship. There was a clear and striking discrepancy between actual and ideal case volumes for laparoscopic complex resection of GI malignancies (esophagus, stomach, liver, and pancreas). In the same survey, the fellows' ideal case volume for benign diseases exactly matched their actual case volume.[47] This resulted in most graduates of the MIS fellowships having practices concentrating on MIS management of benign diseases.

Most institutions with an interest in oncology establish cancer centers according to National Cancer Institute (NCI) guidelines.[48] One of the six essential components for NCI-designated cancer centers is transdisciplinary cooperation between different specialists and disciplines in the care of cancer patients for better outcomes. This aspect of cancer care is heavily instituted and established in the training of surgical oncologists and hepatopancreatobiliary (HPB) surgeons during their fellowships. However, most surgical oncologists and HPB surgeons in practice today have not received formal training in advanced MIS techniques.[49] Program directors of some HPB/surgical oncology surgery fellowships have incorporated a 1- to 2-month MIS rotation with the MIS service in their fellowship curriculum[44,50]; this short period is inadequate to master the skills of complex laparoscopic GI reconstruction required for minimally invasive GI cancer management. In a recent survey of program directors of HPB surgery fellowships, Subhas and Mittal[49] found that <10% of hepatic, pancreatic, and complex biliary cases were performed laparoscopically. For that reason, although surgical oncology/HPB fellows will gain significant experience in the care and management of GI cancer patients in multidisciplinary fashion, they will lack the skills of the minimally invasive surgeon required for complex GI reconstructions.

So, on the basis of a divide in the current training systems, neither the graduates of MIS fellowships nor the graduates of surgical oncology/HPB fellowships are able to provide the services of minimally invasive management of GI malignancies individually. They either will lack the skills and techniques of the MIS surgeon or will lack the knowledge and multidisciplinary approach of the surgical oncologist and HPB surgeon.

PROPOSED SOLUTIONS FOR UNDERUTILIZATION OF MIS IN GI CANCER MANAGEMENT

Because the most important challenges that face the use of MIS in GI cancer patients are the lack of well-established training programs and the fact that most of these cases are technically demanding, we suggest 4 possible solutions to increase the use of MIS in the management of GI malignancies. These solutions are based on extensive literature review, observation of current trends and practices in this field, and discussion made with experts in the field.

Collaboration Between Minimally Invasive Surgeons and Surgical Oncologists at Same Institution

The simplest and the currently available solution is to develop collaboration between two specialists, one from a surgical oncology/HPB background and the other from an MIS background, each bringing his or her own expertise and skills to an individual patient's care. We have implemented this approach numerous times at the University of Maryland Medical Center with excellent results,[51] and colleagues from other institutions have described similar anecdotal experiences. Typically, the surgical oncologist/HPB surgeon would initiate the process because of the nature of the referral practice and would ask the minimally invasive surgeon for help mainly in the reconstructive part of the surgical procedure. Although this solution is tempting based on the available resources and expertise, it has significant drawbacks from a system-based practice standpoint. First, the minimally invasive surgeon has to be involved as a member of the multidisciplinary team in the perioperative care and planning, and this will place a significant burden on the minimally invasive surgeon. This is as logistically complicated in the setting of private practice as it is at an academic institution. Second, in an era in which individual surgeon productivity means a great deal for institutions and departments, the application of this process would cut the overall surgical capacity in half and decrease individual case productivity. This may be partially solved if the department and institution leaders believe that minimally invasive cancer management is considered a significant factor for patient recruitment and physician referral, which may ultimately compensate for the reduction in surgical capacity.

One Surgeon Performing 2 Fellowships in Both MIS and Surgical Oncology/HPB Surgery or Establishing Combined MIS and Surgical Oncology/HPB Surgery Fellowships

Because the currently available postgraduate training system will not result in a single specialist who can provide minimally invasive GI cancer management services individually, one way to master both disciplines is to have one individual surgeon performing 2 fellowships, one in MIS and the other in surgical oncology/HPB surgery. Pioneers of minimally invasive GI cancer management have used this approach and performed 2 fellowships in MIS and surgical oncology/HPB surgery[52]; on the basis of our discussion with them, this solution may represent the best approach for the future to increase the use of MIS in GI cancer management. They have encouraged their mentees who are interested in the subject to do the same, and this can be noted in the applications for the MIS and surgical oncology/HPB fellowships over the last several matches. The HPB fellowship at Penn State College of Medicine adopted this model; 5 of the last 6 HPB fellows at Penn State College of Medicine have performed an MIS fellowship, and they found it to be very helpful and would recommend the same for surgeons with similar interests.[53] This particular strategy was described in detail by Brar et al[54] in a recent publication on the topic; they suggested a model to incorporate evidence-based strategies in MIS training while maintaining essential elements of rigorous surgical oncology training. In their model fellows will complete 1 full year of dedicated MIS training, followed by 15 months of surgical oncology training. They realize that combining the 2 fellowships is very challenging and would require significant cultural changes and strategic planning within the different divisions in the same department.

Although the aforementioned model will require a longer training period for the individual surgeon, as the number of surgeons performing this approach increases, minimally invasive GI cancer management will develop itself and mentors will be available in various training programs. In addition, the timing of the rotation may matter, and an unanswered question will concern the preferred sequence of performing the 2 fellowships.

Centers of Excellence of Minimally Invasive GI Cancer Management

Volume–outcome relationships have been extensively scrutinized over the past decade, and a large number of studies have linked better outcomes to high-volume status of hospitals for a variety of surgical procedures.[55,56] This relationship was most evident and consistent in complex surgical resection of malignant GI diseases.[35,57–59] For this and other reasons, the current designation of NCI cancer centers was established to improve outcomes in cancer patients. A good example to look at for benign diseases is the center of excellence (COE) designation of bariatric surgery by the American College of Surgeons; this designation follows the same principle of volume–outcome relationships described earlier.

Based on the above, it is prudent to establish COEs for cancer management and make the minimally invasive cancer management service an essential component for such a designation. These centers will include both the expertise and the technology for the service and would encourage collaboration. This strong collaboration should result in maintaining a longitudinal prospective database and will help provide prospective evidence to support the use of MIS in GI cancer management in the future. For instance, Luketich et al[60] in a phase II study have shown that minimally invasive esophagectomy is safe and feasible at a multi-institution level in high-volume centers, with oncologic outcomes similar to open esophagectomy.

Though tempting and feasible, this solution has its own drawbacks. First, credentialing of such centers may be complex and would require extensive collaboration among a wide variety of societies invested and interested in the subject. This includes, but is not limited to, NCI, Society of Surgical Oncology (SSO), SAGES, National Comprehensive Cancer Network (NCCN), Americas Hepatopancreatobiliary Association (AHPBA), Society for Surgery of the Alimentary Tract (SSAT), American College of Surgeons (ACS), and American Society of Clinical Oncology (ASCO). Second, collaboration committees on the subject need to be established, and serious decisions have to be made by leaders of these societies to help increase the use of MIS in surgical oncology patients.

Robotics

Over the past decade, robotic technology had gained a large amount of attention in the world of MIS. As a technology for demanding laparoscopic skills, robotic surgery allowed surgeons to perform complex surgical procedures in a minimally invasive fashion, especially in small confined anatomic spaces like the pelvis.[61] After the widespread use of robotics by urologists[62,63] and gynecologists,[64] surgical oncologists and HPB surgeons looked at this technology as a potential solution for the underutilization of MIS in GI surgical oncology patients. Over the past several years, a variety of case series have shown the feasibility of robotic surgery in minimally invasive resection of rectal, pancreatic, hepatic, and gastric malignancies.[65–68] Although robotics provides some advantages over classic laparoscopy (ie, 3-dimensional images, 360° hand rotation, elimination of surgeon's tremor, and better ergonomics for surgeons),[69,70] it has some inherent limitations especially for use in abdominal surgery. First, the robotic systems are designed to work on small areas of the body; however, many abdominal procedures require a surgeon to operate on 2 or more subdivisions of the abdomen.[71] Because of this, the robotic systems must be readjusted and recalibrated over the course of a single surgical procedure. This will result in prolongation of the operating room time. Second, the lack of tactile feedback has been shown to limit surgeon dexterity and maneuverability; this represents another major problem that may inhibit the surgeon's ability to operate successfully and safely.[72] Third, the use of the currently available robotic technology comes with significant cost to the health system; this include the purchase cost of around $1.2 million, as well as maintenance costs of up to $100,000 per year.[73] Fourth and most important is the lack of standardized training programs for the use of robotic surgery in complex abdominal procedures. Most surgical oncologists who adopted the technology did so after completing short "mini-fellowship" courses over several days and 1 or 2 days of proctoring by a specialist in the field. Although this training model is typical for any new technology, we should learn from other specialties that were ahead of us in adopting this technology and currently have established training programs and credentialing processes like the case of urologic oncology.[74]

CONCLUSION

Multiple studies have confirmed the utility of MIS techniques in dealing with patients with GI malignancies. However, training continues to be the most important challenge that faces the use of MIS in the management of GI malignancies. Potential solutions for the current problem include collaboration between surgical oncologists/HPB surgeons and minimally invasive surgeons; a single surgeon performing 2 fellowships in surgical oncology/HPB surgery and MIS; establishing COEs in minimally invasive GI cancer management; and finally, using robotics technology to help with complex laparoscopic skills. Ultimately, it is undeniable that the use of MIS will continue to increase in the treatment of complex surgical conditions, and although many obstacles remain, we must continue to push forward to provide optimal care to our patients.

References:

1. Cuschieri A. Whither minimal access surgery: tribulations and expectations. *Am J Surg*. 1995;169(1):9–19.

2. Cuschieri A. The spectrum of laparoscopic surgery. *World J Surg*. 1992;16(6):1089–1097.

3. Gaskin TA, Isobe JH, Mathews JL, Winchester SB, Smith RJ. Laparoscopy and the general surgeon. *Surg Clin North Am*. 1991;71(5):1085–1097.

4. Suc B, Fontes Dislaire I, Fourtanier G, Escat J. 3606 cholecystectomies under celioscopy. The Register of the French Society of Digestive Surgery [in French]. *Ann Chir*. 1992;46(3):219–226.

5. Paterson HM, Qadan M, de Luca SM, Nixon SJ, Paterson-Brown S. Changing trends in surgery for acute appendicitis. *Br J Surg*. 2008;95(3):363–368.

6. Chrysos E, Tsiaoussis J, Athanasakis E, Zoras O, Vassilakis JS, Xynos E. Laparoscopic vs open approach for Nissen fundoplication. A comparative study. *Surg Endosc*. 2002;16(12):1679–1684.

7. Milsom JW, Fazio VW. Concerns about laparoscopic colon cancer surgery. *Dis Colon Rectum*. 1994;37(6):625–626.

8. Uptake of Minimally Invasive Cancer Surgery. Available at: http://www.medscape.com/viewarticle/589667. Nick Mulcahy March 16, 2009. Accessed January 16, 2009.

9. Berends FJ, Kazemier G, Bonjer HJ, Lange JF. Subcutaneous metastases after laparoscopic colectomy. *Lancet*. 1994;344(8914):58.

10. Robinson CN, Chen GJ, Balentine CJ, et al. Minimally invasive surgery is underutilized for colon cancer. *Ann Surg Oncol*. 2011;18(5):1412–1418.

11. Shamberger RC, Devereux DF, Brennan MF. The effect of chemotherapeutic agents on wound healing. *Int Adv Surg Oncol*. 1981;4:15–58.

12. Chau I, Norman AR, Cunningham D, et al. A randomised comparison between 6 months of bolus fluorouracil/leucovorin and 12 weeks of protracted venous infusion fluorouracil as adjuvant treatment in colorectal cancer. *Ann Oncol*. 2005;16(4):549–557.

13. Lacy AM, García-Valdecasas JC, Delgado S, et al. Laparoscopy-assisted colectomy versus open colectomy for treatment of non-metastatic colon cancer: a randomised trial. *Lancet*. 2002;359(9325):2224–2229.

14. Clinical Outcomes of Surgical Therapy Study Group. A comparison of laparoscopically assisted and open colectomy for colon cancer. *N Engl J Med*. 2004;350(20):2050–2059.

15. COLOR Study Group. COLOR: a randomized clinical trial comparing laparoscopic and open resection for colon cancer. *Dig Surg*. 2000;17(6):617–622.

16. Guillou PJ, Quirke P, Thorpe H, et al. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. *Lancet*. 2005;365(9472):1718–1726.

17. Milsom JW, Böhm B, Hammerhofer KA, Fazio V, Steiger E, Elson P. A prospective, randomized trial comparing laparoscopic versus conventional techniques in colorectal cancer surgery: a preliminary report. *J Am Coll Surg*. 1998;187(1):46–54; discussion 54–55.

18. Day AR, Middleton G, Smith RV, Jourdan IC, Rockall TA. Time to adjuvant chemotherapy following colorectal cancer resection is associated with an improved survival. *Colorectal Dis*. 2014;16(5):368–372.

19. Strouch MJ, Zhou G, Fleshman JW, Birnbaum EH, Hunt SR, Mutch MG. Time to initiation of postoperative chemotherapy: an outcome measure for patients undergoing laparoscopic resection for rectal cancer. *Dis Colon Rectum*. 2013;56(8):945–951.

20. Petersen RP, Pham D, Burfeind WR, et al. Thoracoscopic lobectomy facilitates the delivery of chemotherapy after resection for lung cancer. *Ann Thorac Surg*. 2007;83(4):1245–1249; discussion 1250.

21. Badger TA, Braden CJ, Mishel MH, Longman A. Depression burden, psychological adjustment, and quality of life in women with breast cancer: patterns over time. *Res Nurs Health*. 2004;27(1):19–28.

22. Weeks JC, Nelson H, Gelber S, Sargent D, Schroeder G. Short-term quality-of-life outcomes following laparoscopic-assisted colectomy vs open colectomy for colon cancer: a randomized trial. *JAMA*. 2002;287(3):321–328.

23. Navarra G, Musolino C, Venneri A, De Marco ML, Bartolotta M. Palliative antecolic isoperistaltic gastrojejunostomy: a randomized controlled trial comparing open and laparoscopic approaches. *Surg Endosc*. 2006;20(12):1831–1834.

24. Johnstone PA, Rohde DC, Swartz SE, Fetter JE, Wexner SD. Port site recurrences after laparoscopic and thoracoscopic procedures in malignancy. *J Clin Oncol*. 1996;14(6):1950–1956.

25. Allendorf JD, Bessler M, Whelan RL, et al. Better preservation of immune function after laparoscopic-assisted vs. open bowel resection in a murine model. *Dis Colon Rectum*. 1996;39(10 Suppl):S67–S72.

26. Whelan RL, Franklin M, Holubar SD, et al. Postoperative cell mediated immune response is better preserved after laparo-

scopic vs open colorectal resection in humans. *Surg Endosc.* 2003;17(6):972–978.

27. Belizon A, Balik E, Feingold DL, et al. Major abdominal surgery increases plasma levels of vascular endothelial growth factor: open more so than minimally invasive methods. *Ann Surg.* 2006;244(5):792–798.

28. Braga M, Vignali A, Zuliani W, et al. Metabolic and functional results after laparoscopic colorectal surgery: a randomized, controlled trial. *Dis Colon Rectum.* 2002;45(8):1070–1077.

29. Tomita H, Marcello PW, Milsom JW, Gramlich WL, Fazio VW. CO2 pneumoperitoneum does not enhance tumor growth and metastasis: study of a rat cecal wall inoculation model. *Dis Colon Rectum.* 2001;44(9):1297–1301.

30. Kemp JA, Finlayson SRG. Nationwide trends in laparoscopic colectomy from 2000 to 2004. *Surg Endosc.* 2008;22(5):1181–1187.

31. Wexner SD. Underutilization of minimally invasive surgery for colorectal cancer. *Ann Surg Oncol.* 2011;18(6):1518–1519.

32. Kiran RP, El-Gazzaz GH, Vogel JD, Remzi FH. Laparoscopic approach significantly reduces surgical site infections after colorectal surgery: data from national surgical quality improvement program. *J Am Coll Surg.* 2010;211(2):232–238.

33. Kwon S, Billingham R, Farrokhi E, et al. Adoption of laparoscopy for elective colorectal resection: a report from the Surgical Care and Outcomes Assessment Program. *J Am Coll Surg.* 2012;214(6):909–918.e1.

34. Kemp JA, Zuckerman RS, Finlayson SRG. Trends in adoption of laparoscopic cholecystectomy in rural versus urban hospitals. *J Am Coll Surg.* 2008;206(1):28–32.

35. Finlayson SRG, Laycock WS, Birkmeyer JD. National trends in utilization and outcomes of antireflux surgery. *Surg Endosc.* 2003;17(6):864–867.

36. 2011 SAGES Scientific Meeting and Postgraduate Course Advance Program. Available at: http://www.sages.org/meetings/annual_meeting/2011/advprog2011/scisession.php. Accessed January 26, 2013.

37. Memon MA, Khan S, Yunus RM, Barr R, Memon B. Meta-analysis of laparoscopic and open distal gastrectomy for gastric carcinoma. *Surg Endosc.* 2008;22(8):1781–1789.

38. Cai J, Wei D, Gao CF, Zhang CS, Zhang H, Zhao T. A prospective randomized study comparing open versus laparoscopy-assisted D2 radical gastrectomy in advanced gastric cancer. *Dig Surg.* 2011;28(5–6):331–337.

39. Huscher CGS, Mingoli A, Sgarzini G, et al. Laparoscopic versus open subtotal gastrectomy for distal gastric cancer: five-year results of a randomized prospective trial. *Ann Surg.* 2005; 241(2):232–237.

40. Nguyen KT, Gamblin TC, Geller DA. World review of laparoscopic liver resection-2,804 patients. *Ann Surg.* 2009;250(5):831–841.

41. Luketich JD, Pennathur A, Awais O, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. *Ann Surg.* 2012;256(1):95–103.

42. Kendrick ML, Cusati D. Total laparoscopic pancreaticoduodenectomy: feasibility and outcome in an early experience. *Arch Surg.* 2010;145(1):19–23.

43. Stitzenberg KB, Sheldon GF. Progressive specialization within general surgery: adding to the complexity of workforce planning. *J Am Coll Surg.* 2005;201(6):925–932.

44. The Fellowship Council. Directory of Fellowships. Available at: https://fellowshipcouncil.org/directory-of-fellowships/. Accessed January 28, 2013.

45. Swanstrom LL, Park A, Arregui M, Franklin M, Smith CD, Blaney C. Bringing order to the chaos: developing a matching process for minimally invasive and gastrointestinal postgraduate fellowships. *Ann Surg.* 2006;243(4):431–435.

46. The Fellowship Council. Curricula. Available at: https://fellowshipcouncil.org/current-fellows/curriculum/. Accessed January 28, 2013.

47. Tichansky DS, Taddeucci RJ, Harper J, Madan AK. Minimally invasive surgery fellows would perform a wider variety of cases in their 'ideal' fellowship. *Surg Endosc.* 2008;22(3):650–654.

48. Office of Cancer Centers. Grants & Funding. Available at: http://cancercenters.cancer.gov/grants_funding/index.html. Accessed January 28, 2013.

49. Subhas G, Mittal VK. Training minimal invasive approaches in hepatopancreatobilliary fellowship: the current status. *HPB (Oxford).* 2011;13(3):149–152.

50. Society of Surgical Oncology. Program List. Available at: http://www.surgonc.org/training-education/surgical-oncology/program-list. Accessed January 28, 2013.

51. Hamed O, Jain A, Kligman M. Laparoscopic sleeve gastrectomy for gastric lieomyosacroma in morbidly obese patient: a case for collaboration. Available at: http://www.sages.org/meetings/annual-meeting/abstracts-archive/laparoscopic-sleeve-gastrectomy-for-gastric-lieomyosacroma-in-morbidly-obese-patient-a-case-for-collaboration/. Presented at Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) 2012, March 7–10, 2012, San Diego Convention Center. Accessed January 28, 2013.

52. Mayo Clinic. Michael L. Kendrick, M.D. Available at: http://www.mayoclinic.org/bio/12574457.html. Accessed January 28, 2013.

53. HPB Special Issue: Abstracts of the Twelfth Annual Americas Hepato-Pancreato-Biliary Congress, Annual Scientific Session and Postgraduate Program, 7–11 March 2012, Miami Beach, FL, USA HYPERLINK "/doi/10.1111/hpb.2012.14.issue-s1/issuetoc" Volume 14, Issue Supplement s1, pages 1–91, March 2012 Page 31.

54. Brar SS, Wright F, Okrainec A, Smith AJ. A structured strategy to combine education for advanced MIS training in surgical oncology training programs. *Surg Oncol.* 2011;20(3):129–133.

55. Birkmeyer JD, Stukel TA, Siewers AE, et al. Surgeon volume and operative mortality in the United States. *N Engl J Med.* 2003;349(22):2117–2127.

56. Birkmeyer JD, Siewers AE, Finlayson EVA, et al. Hospital volume and surgical mortality in the United States. *N Engl J Med.* 2002;346(15):1128–1137.

57. Friese CR, Earle CC, Silber JH, Aiken LH. Hospital characteristics, clinical severity, and outcomes for surgical oncology patients. *Surgery.* 2010;147(5):602–609.

58. Simunovic M, Rempel E, Thériault M-E, et al. Influence of hospital characteristics on operative death and survival of patients after major cancer surgery in Ontario. *Can J Surg.* 2006;49(4):251–258.

59. Birkmeyer JD, Sun Y, Goldfaden A, Birkmeyer NJO, Stukel TA. Volume and process of care in high-risk cancer surgery. *Cancer.* 2006;106(11):2476–2481.

60. American Society of Clinical Oncology meeting abstracts. Luketich JD, Pennathur A, Catalano J, et al. Results of a phase II multicenter study of minimally invasive esophagectomy (Eastern Cooperative Oncology Group Study E2202). Available at: http://meeting.ascopubs.org/cgi/content/abstract/27/15S/4516. Accessed January 29, 2013.

61. Wexner SD, Bergamaschi R, Lacy A, et al. The current status of robotic pelvic surgery: results of a multinational interdisciplinary consensus conference. *Surg Endosc.* 2009;23(2):438–443.

62. Babbar P, Hemal AK. Robot-assisted urologic surgery in 2010—advancements and future outlook. *Urol Ann.* 2011;3(1):1–7.

63. Coelho RF, Rocco B, Patel MB, et al. Retropubic, laparoscopic, and robot-assisted radical prostatectomy: a critical review of outcomes reported by high-volume centers. *J Endourol.* 2010;24(12):2003–2015.

64. Reza M, Maeso S, Blasco JA, Andradas E. Meta-analysis of observational studies on the safety and effectiveness of robotic gynaecological surgery. *Br J Surg.* 2010;97(12):1772–1783.

65. D'Annibale A, Pende V, Pernazza G, et al. Full robotic gastrectomy with extended (D2) lymphadenectomy for gastric cancer: surgical technique and preliminary results. *J Surg Res.* 2011;166(2):e113–e120.

66. Zureikat AH, Nguyen KT, Bartlett DL, Zeh HJ, Moser AJ. Robotic-assisted major pancreatic resection and reconstruction. *Arch Surg.* 2011;146(3):256–261.

67. Berber E, Akyildiz HY, Aucejo F, Gunasekaran G, Chalikonda S, Fung J. Robotic versus laparoscopic resection of liver tumours. *HPB (Oxford).* 2010;12(8):583–586.

68. deSouza AL, Prasad LM, Marecik SJ, et al. Total mesorectal excision for rectal cancer: the potential advantage of robotic assistance. *Dis Colon Rectum.* 2010;53(12):1611–1617.

69. Berguer R, Smith W. An ergonomic comparison of robotic and laparoscopic technique: the influence of surgeon experience and task complexity. *J Surg Res.* 2006;134(1):87–92.

70. Nikiteas N, Roukos D, Kouraklis G. Robotic versus laparoscopic surgery: perspectives for tailoring an optimal surgical option. *Expert Rev Med Devices.* 2011;8(3):295–298.

71. Taylor GW, Jayne DG. Robotic applications in abdominal surgery: their limitations and future developments. *Int J Med Robot.* 2007;3:3–9.

72. Hubens G, Ruppert M, Balliu L, Vaneerdeweg W. What have we learnt after two years working with the da Vinci robot system in digestive surgery? *Acta Chir Belg.* 2004;104(6):609–614.

73. Morris B. Robotic surgery: applications, limitations, and impact on surgical education. *MedGenMed.* 2005;7(3):72.

74. Zorn KC, Gautam G, Shalhav AL, et al. Training, credentialing, proctoring and medicolegal risks of robotic urological surgery: recommendations of the society of urologic robotic surgeons. *J Urol.* 2009;182(3):1126–1132.