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Evolution and future of laparoscopic colorectal surgery

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Core tip: Laparoscopic surgery has been a major revolution in surgery and clearly has become a core technique in colorectal surgery. The paper reviews the evolution of the technology, analyzes its results with regards to patient outcomes, and provides a basis for future research and fine tuning of its applications.

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Abstract

The advances of laparoscopic surgery since the early 1990s have caused one of the largest technical revolutions in medicine since the detection of antibiotics (1922, Flemming), the discovery of DNA structure (1953, Watson and Crick), and solid organ transplantation (1954, Murray). Perseverance through a rocky start and increased familiarity with the chop-stick surgery in conjunction with technical refinements has resulted in a rapid expansion of the indications for minimally invasive surgery. Procedure-related factors initially contributed to this success and included the improved postoperative recovery and cosmesis, fewer wound complications, lower risk for incisional hernias and for subsequent adhesion-related small bowel obstructions; the major breakthrough however came with favorable long-term outcomes data on oncological parameters. The future will have to determine the specific role of various technical approaches, define prognostic factors of success and true progress, and consider directing further innovation while potentially limiting approaches that do not add to patient outcomes.

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EVOLUTION OF A CONCEPT

The general history of laparoscopy has previously been described^[1-3]. Earliest steps were found in notes of Hippocrates (460-375 B.C.) describing insertion of instruments through various orifices in order to visualize internal anatomy and pathology. The methodology improved when illumination was introduced by Arabian physician, Albukasim (936-1013). The “modern” endoscopic/laparoscopic era dates to the early 19th century, when Philipp Bozzini (1773-1809) described a “Lichtleiter” cystoscope (1805)^[4]. After the invention of the electric light bulb by Edison in 1879, Maximilian Nitze (1848-1906) developed the first rigid endoscopic instrument with built-in light source. By the end of the nineteenth century, endoscopies had become well established for evaluation of natural orifices (cystoscopy, proctoscopy, gastroscopy, laryngoscopy).

George Kelling, a surgeon from Dresden (1901), and Dimitri Ott, a gynecologist from St. Petersburg, were the first to perform a true laparoscopic procedure^[1,2]. Ott inserted a “ventroscope” through a postero-vaginal incision in order to inspect the pelvic and abdominal viscera. Kelling’s “celioscopy” employed a small abdominal wall incision to insert a cystoscope and examine the peritoneal cavity in a dog while creating a pneumoperitoneum by

injection of filtered air^[5]. The first clinical series in 17 patients was reported in 1910 by Hans Christian Jacobaeus (1879-1937), a Swedish surgeon, who adapted and developed the technique and coined it “laparoscopy”^[6]. Within one year’s time, he reported 115 laparoscopies and thoracoscopies, while Kelling followed with his publication of 45 celioscopies. At the same time, Bertram Bernheim at Johns Hopkins University performed the first laparoscopic procedure (“organoscopy”) in the United States (1911)^[1]. Subsequently, diagnostic laparoscopy (without any therapeutic component) became an accepted tool of internists and gynecologists for assessing liver diseases, tumors, and inflammatory conditions. Carbon dioxide (CO₂) to create the pneumoperitoneum was introduced in 1924 to minimize the risk of intra-abdominal explosion^[7]. The first textbook on laparoscopy and thoracoscopy was published in 1927 by Korbsch^[8].

The following five decades after that up to the 1980s showed only very limited progress, and the concept did not get any traction, until in Germany Kurt Semm performed the first laparoscopic appendectomy in 1982 and Erich Muehe with his “Galloscope” the first laparoscopic cholecystectomy in 1985^[9,10].

The major breakthrough in laparoscopic surgery was the result of technological progress with invention of a computer chip television camera that allowed all members of an operating team to watch and to actively participate in a procedure. Numerous publications from around the world mirrored the sudden interest of surgeons in this new video-laparoscopic technique, exploring applications in almost every organ system. Close collaborations between industry and surgeons were at the forefront of developing sophisticated instrumentation and technology according to the true needs in the operative field. Multiple aspects of various surgical procedure steps were optimized by introduction of new devices and equipment such as energy and sealing devices, staplers, and clip appliers.

TRANSLATION TO COLORECTAL SURGERY

Jacobs *et al*^[11] reported in 1991 the first laparoscopically assisted colectomy. Compared with cholecystectomy, appendectomy, or Nissen fundoplication, laparoscopic colon surgery was a significantly more challenging operation as it involved often more than one abdominal quadrant, required determination of the correct target segment to be removed, safe identification and transection of named vascular structures, mobilization and resection of the bowel, specimen retrieval and creation of an anastomosis. Most of the procedures initially were directed to the management of benign disease. An early report raised concerns about horrendously high rates of 21% of port site recurrences and nearly led to a shut-down of laparoscopy for malignant disease^[12]. Fortunately enough, the issue was investigated further in a number of reports whereby a port site recurrence rate closer to 1% was

noted which appeared to be in a similar range as wound implants after open surgery for colorectal cancer^[13-16]. In addition, a number of prospective randomized trials were undertaken to investigate the impact of laparoscopic surgery on oncological outcomes^[17-22]. In the United States, a well-designed prospective randomized multicenter trial was conducted under the umbrella of the National Cancer Institutes to document non-inferiority of the laparoscopic approach when compared with open surgery^[20,21]. Other trials were initiated in other parts of the world, most notably in Spain, the United Kingdom, and Hong Kong^[18,19,22]. While the larger picture remained in evolution, all studies including several meta-analysis came to similar conclusions that laparoscopic colectomy in skilled hands was associated with shorter postoperative recovery at the price of longer operative times; but most notably it was safe and oncologically at least equivalent to the standard of open surgery^[23-25]. However, a steep learning curve was acknowledged throughout the literature, and at least 20-50 laparoscopic cases were considered the minimum to achieve basic proficiency in the technique. Along those lines, the professional societies ASCRS, ACS, and SAGES supported the use of laparoscopy for cancer by appropriately trained surgeons and engaged in respective training protocols.

It should be noted though that the initial study designs were highly selective and excluded transverse colon and rectum^[17,18,20,22]. Extrapolation of the results to related but not identical scenarios involving the transverse colon or the rectum would therefore not have been permissible. Nonetheless, opinions about the interpretations of these randomized and numerous additional non-randomized studies varied considerably insofar as some surgeons read them as laparoscopic being superior rather than not-inferior to open surgery and considered the study outcomes a free pass for performing any colorectal resection laparoscopically. Others remained cautious and attempted, to a large degree in vain, to maintain the order of a scientific approach. The concerns were relevant in light of the evidence gained during the mid-1990s to 2000s that optimization of surgical technique alone (total mesorectal excision) represented a key factor in reducing the local recurrence rates in rectal cancer^[26-29]. Those efforts resulted in the initiation of trials specifically evaluating the role of laparoscopy for transverse colon and for rectal cancer^[30-32].

Rebutting even the most vocal critics of laparoscopy, at the end of the first decade, laparoscopy was undoubtedly there to stay - also for colorectal surgery. Even though plenty of opportunities for further prospective trials would have existed, the reality of risking to be perceived as old-fashioned, paired with increasing patient demands, stopped many approaches and left the field to the flow of Darwinist self-definition.

MISSED OR OPEN RESEARCH OPPORTUNITIES

The complexity of the field with details of abdominal

and pelvic anatomy, multimodality treatment, functional and quality of life aspects, as well as multiple confounding patient factors and expectations would provide an infinite number of research questions that have not been addressed in systematic fashion. Examples could include: (1) definition of what entails a laparoscopic colorectal resection - objective distinction between pure laparoscopic procedures (which commonly also need some incision for specimen retrieval), hand-assisted laparoscopic surgery (HALS), as opposed to converted or primarily open surgery should be made on the basis of defined criteria other than just length of the incision. It should be determined what fraction of a several hour procedure would have to be done with a pneumoperitoneum in order to still maintain the benefits of laparoscopic surgery; (2) true impact of conversion - reported conversion rates have varied from 0%-45%. Even though the need for conversion may frequently be related to variations in patient populations, unfavorable habitus, or advanced disease, they have unfortunately become a quality measure. Apart from complacency, one should determine true predictors of the inability to pursue the minimally invasive route and study the unbiased impact of conversion; (3) shorter length of stay - a trend to shorter hospital stays was observed in most laparoscopic trials. However, in parallel, a paradigm shift occurred in open surgery where enhanced fast-track recovery protocols contributed to impressive reduction in hospital stays^[33-37]. If open surgery has substantially reduced its LOS, how much shorter than that can laparoscopic procedures be? If laparoscopic procedures were combined with fast track recovery protocols^[38] could and should they be done as outpatient procedures? (4) financial impact and/or benefit of laparoscopy - higher technical cost and longer operative times have to be weighed against shorter length of stay and potentially lesser long-term morbidity (*e.g.*, hernia formation, adhesion-induced bowel obstructions, *etc.*); (5) rectal cancer - even though a number of studies have been initiated, there appears to still be a significant gap in our definition of the optimal management for rectal cancer. Unfortunately, surgeons contributed to the self-inflicted chaos insofar as they introduced in parallel several surgical modalities (open, laparoscopically, robot, transanal endoscopic microsurgery or minimally invasive surgery, TME *vs* partial TME, length of distal margin, radial margin, various degrees of sphincter preservation *vs* abdominoperineal resection, local excision, non-operative management after complete response to neoadjuvant chemoradiation. Studies should focus on the impact of laparoscopy on outcome with specific attention to the level of dissection, proximity to sphincter muscles, gender, tumor size on the ability to have an intact fascia propria and on the rate of preserving sphincter and autonomic nerve function; (6) obesity - a limited number of studies have evaluated the role and suitability of laparoscopic surgery in obese *vs* non-obese patients^[39-41]. However, most US surgeons have gotten used to substantially higher average body mass indexes

and would draw the line of obesity-related complexity at a BMI of 45-50. While even superobese patient might benefit from minimally invasive approaches, their body habitus may set limit to the mechanics of operative tables, physical and physiological ability to tolerate extreme positioning, length of instruments, surgeon's durability; and (7) locally advanced cases and multi-organ resections - what role does laparoscopy play in such cases?

FUTURE

A number of new approaches have already evolved, some even aggressively marketed, even though they have not yet been sufficiently established or their impact adequately studied. It should be in the interest of our specialty to develop objective guidance to such efforts and determine the goals and possible benefit/risk analysis in the context of health economics before pushing too hard into a respective direction.

Robotic vs laparoscopic surgery

The topic is hot, the financial cost significant, the benefit on patient outcome questionable^[42-44]. Before indulging too much in the results of retrospective studies, it would be necessary to analyze the elements of potential benefits from using the robot. Undoubtedly, the 3-dimensional view combined with the higher degrees of instrument versatility are the core of attractiveness. However, the bulkiness of the machine as such, the fact that the surgeon's assistants at the table only see a 2-dimensional image, the cost and some recent data from other specialties about increased rates of nerve injury appear as distinct disadvantages and warrant a more objective evaluation in the near future^[45,46]. Furthermore, technological advances in the "conventional" laparoscopic optics and imaging technology have resulted in 3D laparoscopes that likely eliminate the robot's advantage and allow all participants to have the same three-dimensional view.

Number of incisions

Single port laparoscopic surgery and/or natural orifice transluminal endoscopic surgery (NOTES) was once perceived to be the ultimate goal of minimally invasive surgery. The latter - as a result of a concerning incidence of complications in experimental settings - has not gotten beyond pilot settings. Single port or single incision laparoscopic surgery however has been reported in increasing frequency. However, despite enthusiasm, it appears that single port surgeries offer no advantage compared to conventional laparoscopic surgery^[47-49].

Transanal endoscopic microsurgery or transanal minimally invasive surgery

This method has achieved convincing results for benign rectal lesions that are not amenable to colonoscopic removal or too high for conventional transanal excisions. When it comes to the role in malignant disease, however, concerns exceed the ones for laparoscopic surgery

for cancer insofar as local excision of rectal cancers has always been associated with unjustifiably high local recurrence rates. The reasons are speculative, but a combination of overlooked nodal disease and seeding of tumor cells into the surgical bed are the considered to be responsible. While some reports have suggested that Transanal endoscopic microsurgery/transanal minimally invasive surgery can remove parts of the mesorectal fat or even complete total mesorectal excisions^[50,51] that approach is oncologically even more concerning as seeding would lead to recurrences that might extend to the presacral fascia and become a very poor prognostic indicator.

Laparoscopically-assisted colonoscopic polypectomies (endoscopic-laparoscopic resections)

This combination of two procedures has been suggested for larger colon lesions^[52,53] similar to TEMS/TAMIS for rectal lesions. However, the difference is that typically a laparoscopic segmental colon resection is much less of a problem than a rectal resection might be. Hence, it remains doubtful what if any parameter would define superiority of outcome compared to a laparoscopic resection in the first place. Furthermore, one should caution that the probability of harboring a malignancy within a polyp parallels the size of the lesion. Manipulating such a malignancy to the point of transmural dissection would not only be a primarily insufficient oncological resection but furthermore carry the risk of turning a curable tumor into a non-curable one if cancer cells are spilled into the peritoneal cavity.

Last but not least the science fiction

At the present time, appropriate surgical tumor management is defined by the tissue specimen being retrieved. Gross and microscopic pathology are core elements of tumor staging and relevant prognostic and predictive factors for treatment planning of a multimodality management. In the future, however, the rapid evolution of molecular technology and genetic mapping might provide more specific and individualized tumor and patient characteristics, comparable to a fingerprint, such that classical morphological evaluation of the primary or recurrent tumor would not add any additional information to guide treatment decisions. In that case, it might not be necessary to retrieve an intact specimen; instead a tumor-bearing segment might be resected intracorporeally, placed in a bag, homogenized *in situ*, and removed with the suction device.

CONCLUSION

Laparoscopic surgery has been a major revolution in surgery and clearly has become a core technique in colorectal surgery. The fine tuning of its applications remains in evolution. At times of economic constraints, institutions should resist to jump on every single trend but employ the wisdom of controlled research to define true prog-

ress that results in measurable value for the patient.

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