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Feasibility of radical sigmoid colectomy performed as natural orifice translumenal endoscopic surgery (NOTES) using transanal endoscopic microsurgery

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Abstract

Background Natural orifice translumenal endoscopic surgery (NOTES), a recent development in the field of minimally invasive surgery, may offer advantages over open and laparoscopic surgery. Most investigations to date have focused on small end-organ resections, and none have described en bloc regional lymphadenectomy. This study aimed to describe a method of anal transcolonic sigmoid colon resection.

Methods A fresh frozen then thawed cadaver model was used. Three male human cadavers were subjected to transanal sigmoid colon mobilization, high vascular ligation, en bloc lymphadenectomy, and stapled end-to-end anastomosis performed by a single operator using transanal endoscopic microsurgery instrumentation.

Results The findings showed that NOTES sigmoid colon resection with en bloc lymphadenectomy and primary anastomosis can be performed successfully. The critical steps of the procedure were (1) luminal suture occlusion of the sigmoid colon, (2) transrectal bowel division, (3) entry through the mesorectum into the presacral space, (4) en bloc mobilization of the sigmoid colon mesentery off of the retroperitoneum, (5) high ligation of the superior hemorrhoidal artery, (6) transanal delivery of the intact sigmoid colon specimen, (7) extracorporeal division of the colon, and (8) creation of a stapled end-to-end colorectal anastomosis. Postprocedure laparotomy confirmed adequate lymphadenectomy and anastomosis with no untoward events.

Conclusions It is possible to complete the critical steps of a NOTES sigmoid resection, en bloc lymphadenectomy, primary anastomosis, and retrieval of an intact specimen without any incisions using transanal endoscopic microsurgery instrumentation.

Keywords Colectomy · NOTES · TEM · Transanal · Transanal endoscopic microsurgery

Natural orifice translumenal endoscopic surgery (NOTES) is a recent development in minimally invasive surgery. Theoretically, NOTES, which avoids any incisions in the abdominal wall, will provide patient benefits by minimizing tissue trauma, postoperative pain, and potential wound complications. This technique uses endoscopic instruments to access the peritoneal cavity then perform diagnostic and therapeutic procedures. Early reports of NOTES focused on small end-organ procedures such as appendectomy, cholecystectomy, and tubal ligation in porcine models [1–4]. To date, a few scattered reports have described NOTES appendectomy and cholecystectomy performed for humans via transgastric or transvaginal approaches [3].

Whereas most investigators have chosen to gain peritoneal access via an oral transgastric route, a few have investigated an anal transcolonic route [5]. The transcolonic approach has several theoretic advantages over the transgastric route. First, it eliminates the need for scope retroflection for visualization of upper abdominal organs, a requirement for the transgastric approach. Second, a transcolonic access route can be created approximately 15 cm from the natural orifice (the anal verge), making access to the peritoneal cavity more direct and closer than a transgastric approach. Third, the anorectum is more compliant and capacious than the pharynx or esophagus and may allow passage of larger-diameter instrumentation and

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retrieval of larger specimens. Naturally, transrectal access raises concerns of infection control and still requires the need for secure closure of the colorectum.

Transanal endoscopic microsurgery (TEM), a minimally invasive alternative to standard transanal excision of rectosigmoid tumors, has been in clinical use since the early 1980s. Initially, TEM was reserved for resection of tumors located below the peritoneal reflection [6] in the extraperitoneal rectum. This restricted use was intended to avoid perforation of the rectum into the free peritioneal cavity. Resection of tumors in the upper rectum with entry into the suture closure of the peritoneum, however, has recently been described, with no apparent increase in short-term complications [7]. Circumferential sleeve resections and extended en bloc mesorectal excisions using the TEM instrumentation also have been described [6].

The TEM technique is facilitated by stable camera and operator orientation and makes use of more precise and controllable rigid instrumentation. This instrumentation may be capable of more proximal and more extensive resections. In addition, TEM provides a proven technology for secure closure of full-thickness rectal wall incisions, which may obviate the need for investigational closure technologies. We hypothesize that a NOTES sigmoid colectomy with radical lymphadenectomy and primary anastomosis performed by a single operator using TEM instrumentation is feasible.

Materials and methods

For our model, we used a fresh frozen then thawed human cadaver. This model has long been recognized as the ideal for training in laparoscopic colectomy [8]. The cadaver was placed in a supine Trendelenberg position, and the rectum was prepped using tap water lavage and aspiration through a rigid proctoscope. Standard video TEM instrumentation (Richard Wolf Medical Instruments Corporation, Vernon Hills, IL, USA) was used. The rectum accommodated the 4-cm-diameter operating TEM proctoscope and allowed insertion high enough for reaching up over the sacral promontory with the rigid operating instruments.

The 12-cm, flat-ended TEM proctoscope was inserted, after which carbon dioxide (CO_2) pneumorectum was established. The rectosigmoid lumen was occluded with a circumferential purse-string suture at the level of the upper rectal fold to avoid ongoing contamination from the proximal colon.

Needle-knife cautery and angled TEM forceps were used to demarcate a circumferential mucosal incision in the upper rectum at a point 1 cm distal to the occluding purse string. The TEM proctoscope was exchanged for the 12-cm beveled scope. A full-thickness, posterior hemicircumferential incision then was deepened through the rectal wall, mesorectum, and fascia propria of the mesorectum, then into the “oncologic” presacral plane [9]. Under endoscopic visualization, the dissection was continued cephalad in this presacral plane between the sacrum and the mesorectum, then out laterally to the pelvic sidewalls. Both ureters were identified and preserved. Anterior dissection then was performed to complete the rectal division and enter the peritoneal cavity. Balanced CO_2 pneumoperitoneum was easily maintained throughout the procedure with the TEM insufflator.

The 12-cm proctoscope then was exchanged for the 20-cm beveled proctoscope. This was maneuvered under the mesosigmoid to open the retroperitoneal plane further and facilitate dissection up off the iliac vessels, aorta, and Gerota’s fascia. The cephalad extent of the dissection was limited by instrumentation length, but was able to reach the proximal superior hemorrhidal artery at the takeoff of the inferior mesenteric artery. The anterolateral congenital sigmoid adhesions then were divided, the sigmoid colon retracted medially, and the white line of Toldt divided up to the descending colon, where instrument length again prevented further dissection.

The left ureter was again identified throughout its course, and the superior hemorrhoidal artery was divided at its origin using a vessel-sealing device (Harmonic Scalpel ACE; Ethicon Endo-Surgery, Cincinnati, OH, USA). The orientation of the proximal bowel was confirmed by inspection of the mesentery. The specimen then was delivered into the lumen of the TEM proctoscope. The proctoscope was removed, and the rectosigmoid colon was delivered out of the anus. The previously placed occluding purse string was inspected to ensure that it was intact and that no fecal spillage had occurred. The superior hemorrhoidal artery, lymphovascular pedicle, and mesorectal planes were identified and checked for hemostasis. The bowel was divided extracorporially at the descending sigmoid colon junction, and the specimen was removed (Fig. 1).

A 29-mm EEA stapler anvil (Endopath ILS; Ethicon Endo-Surgery) was secured in the proximal bowel with a purse-string suture. A 10-in. tail was left on the suture to function as a handle. The proximal bowel then was returned into the abdomen. The 12-cm straight-ended TEM proctoscope was reinserted to the level of the midrectum. Pneumoperitoneum was reestablished, and then a monofilament purse-string suture was sewn around the top of the open rectum. Before tightening of the rectal purse string, forceps were used to orient the proximal bowel properly and then deliver the proximal stapler anvil into the top of the rectum using the suture tail as a handle. The rectal purse string then was tightened around the anvil post and secured into place by tying the purse-string suture intracorporeally.

Fig. 1 Sigmoid colon specimen. The distal margin is adjacent to the marker

Next, the faceplate on the TEM proctoscope was removed, and the EEA stapler was inserted, mated with the anvil, brought into apposition, then fired. The stapler then was removed, and the anastomotic tissue rings were inspected for completeness. The TEM faceplate was reattached, and pneumorectum was reestablished to allow direct inspection of the anastomosis (Fig. 2).

A postprocedure laparotomy was performed (Fig. 3). The proximal bowel was inspected to confirm proper orientation without twisting or tension. The pelvis was filled with saline, and the rectum was insufflated to confirm that the anastamosis was intact (Fig. 4).

Results

The procedure was completed in three male cadavers. The mean procedure time was 4.25 h. In all cases, the bowel had been mobilized up to the mid descending colon. The point of vascular ligation of the mesentery was confirmed to be at the origin of the superior hemorrhoidal artery, and the inferior mesenteric artery was preserved in each case. There were no injuries to the ureters, descending colon, cecum, or small bowel. The segment of colon removed averaged 24 cm and had the complete sigmoid mesentery attached en bloc.

Three untoward events were noted during the procedures including one episode each of an insufficient distal occluding purse string, an incomplete EEA anastomotic tissue ring, and pneumoscrotum. The initial occluding purse-string suture in the first case was noted to be incomplete along the right lateral rectal wall. This was a result, at least in part, of suboptimal rectal visualization

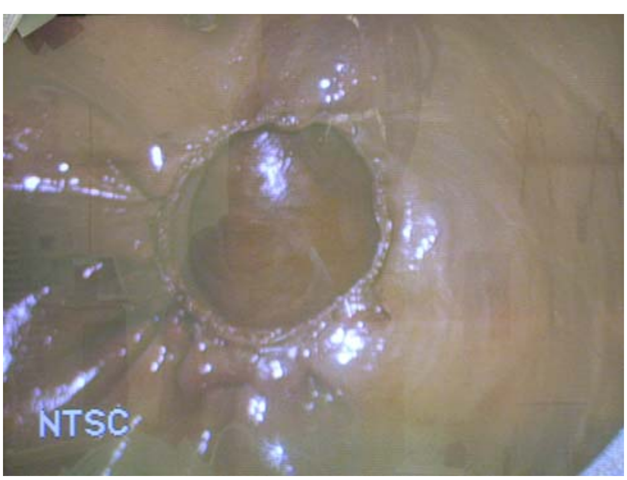

Fig. 2 Proctoscopic view of end-to-end colorectal anastomosis

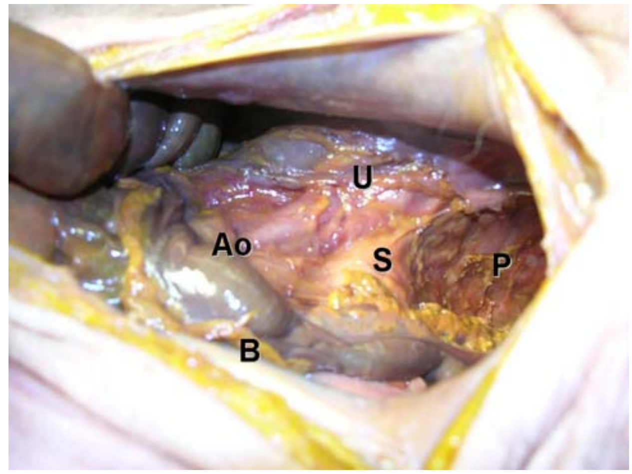

Fig. 3 View via laparotomy of the lower abdomen and pelvis after transanal sigmoid colon resection. Ao, aortic bifurcation; B, retracted bowel; U, left ureter; S, sacral promontory; P, pelvis

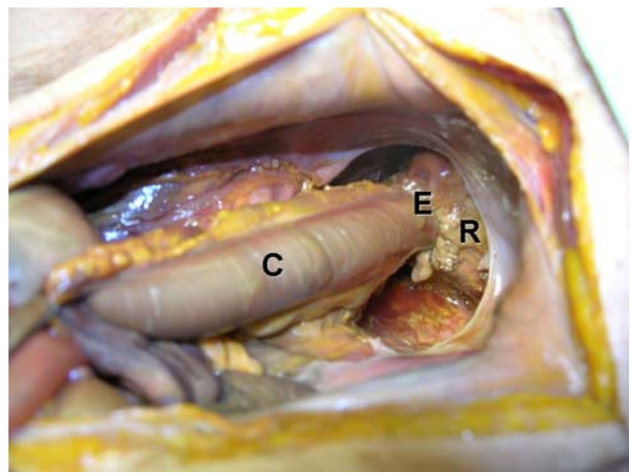

Fig. 4 View via laparotomy of the lower abdomen and pelvis showing insufflated colorectal anastomosis. C, colon; E, end-to-end anastomosis; R, rectum

from an inadequate bowel prep and residual stool impairing accurate suture placement. The defect was immediately recognized and reinforced with a second suture. The distal EEA anastomotic donut was noted to be incomplete in this same cadaver, but did not appear to compromise the anastomosis on the leak test. Significant pneumoscrotum was noted during the procedure in another cadaver. However, this did not interfere with successful completion of the procedure.

Discussion

The NOTES technique currently is an area of intense interest in minimally invasive surgery. Most investigators to date have focused on small end-organ resections using a variety of access points (stomach, colon, vagina) without the need for abdominal incision [2, 4, 5, 10] Cosmesis aside, skeptics see little advantage of NOTES cholecystectomy or appendectomy over current laparoscopic procedures. On the contrary, they foresee higher morbidity related to the clumsiness and imprecision of current NOTES instrumentation and to the creation and closure of the viscotomy.

With this in mind, our study set out to investigate the feasibility of a more substantial operation that requires removal of a large specimen and creation of an anastomosis. We also sought to reduce the added morbidity of the viscotomy site by incorporating it with anastomosis. Compared with the use of flexible endoscopes, TEM offers markedly improved optics, lighting, camera stability, and special orientation. By using rigid instruments, the operator has more precision, tactile feedback, degrees of freedom, and true bimanual operating abilities.

This study demonstrates the feasibility of performing a major NOTES gastrointestinal resection with restoration of intestinal continuity. We were able to accomplish this in our cadaver model using currently available instrumentation and by respecting the embryonic fusion planes with standard surgical dissection principles. Cadavers were used instead of animal models due to the uniqueness of the human pelvic anatomy and because of our desire to assess the benefits and deficiencies of current TEM instrumentation for this advanced application.

This study illustrates two important perspectives. First is the potential use of anal NOTES techniques for large organ resection, en bloc specimen retrieval, and anastomosis. Second is the use of TEM instrumentation as a portal to the peritoneal cavity for NOTES procedures, providing as it does, a secure access platform and a proven method for a safe endoluminal closure of rectal incisions.

The described NOTES technique evolved from our clinical experience using TEM for resection of rectal tumors in humans [7, 11] Specifically, we have seen no increase in short-term complications resulting from peritoneal entry and suture closure of rectal wall defects during TEM procedures [7].

For the current study, we attempted to perform a clinically relevant oncologic sigmoid resection with en bloc lymphadenectomy, high vascular ligation, and primary anastomosis. Our final pathology specimen confirmed this goal. In all three cases, we achieved this goal, removing an adequate length of colon en bloc with its mesentery equivalent to what would be removed by an open or laparoscopic resection.

Several modifications of standard abdominal sigmoid colectomy were obviously necessary. First, to avoid potential soiling from the proximal bowel, we performed an endolumenal purse-string occlusion and additional rectal lavage before embarking on full-thickness bowel division.

Second, we anticipated and utilized our viscotomy site in the rectosigmoid colon as the distal site for our colorectal anastomosis, thereby obviating the need for an additional viscotomy closure site.

Third, because surgical dissection is most easily performed along embryonic fusion planes, we chose to begin our dissection by gaining access to the presacral plane located between the fascia propria of the mesorectum and the presacral fascia. This procedure is an extension of the technique we have used to encompass an en bloc resection of mesorectum during transanal removal of rectal tumors [12]. Entry and subsequent dissection in this avascular plane during abdominal surgery is technically easier and generally recommended as a means to reduce the risk of injury to the ureters, pelvic nerves, and major vascular structures.

Fourth, we needed to maintain adequate exposure to the operative field as well as traction and counter traction. We were able to accomplish this using a combination of techniques including use of the anterior lip of the beveled proctoscope; temporary preservation of congenital sigmoid attachments, which would be divided later in the case; and use of up to three rigid instruments, which are permitted by the three working ports of the TEM faceplate. The CO_2 pneumoperitoneum maintained by the TEM insufflator also provided good intraabdominal visualization.

Fifth, we were able to simulate intracorporial vascular control of the root vessel using a vessel-sealing device routinely applied in laparoscopic colon resections.

Sixth, we were able to mobilize sufficient colon to permit transanal specimen delivery with extracorporeal bowel division and secure placement of an EEA stapler anvil. There was no resistance to delivery of this large specimen via the rectum.

Finally, we needed to close the top of the rectum around the EEA stapler anvil. This was accomplished by placing a purse-string suture around the top of the open rectum, bringing the anvil post into the top of the rectum, and securing the purse string around it. The anvil post was now accessible to an anally placed EEA stapler for anastomotic creation.

Postprocedure laparotomy confirmed that we achieved the goals of our study. We were able to achieve total removal of the entire sigmoid colon along with a formal lymphadenectomy and high ligation of the superior hemorrhoidal artery. Our dissection planes were maintained along accepted embryonic fusion planes, with avoidance of the ureters as well as major vascular and retroperitoneal structures. A properly oriented, tension-free, airtight colorectal anastomosis was observed in all cases. No inadvertent injuries were noted.

Several technical challenges also were identified. First, the major anatomic obstacle for this technique is overcoming the acute angle created by the sacral promontory. Because our cadavers to date have been of average to thin build, the 20-cm-long TEM proctoscope could be inserted easily into the top of the sacrum. This point of placement may not be possible in larger patients, thereby limiting instrument access.

Second, the current generation of TEM instruments, which are essentially laparoscopic tools, have a limited reach. We were able to introduce our rigid camera system and instruments in far enough to see the retroperitoneum adequately up as far as the inferior mesenteric artery and the descending colon, but for more extensive resections, longer instruments and a flexible endoscope would be required.

Third, the gap noted in the first cadaver's initial purse string and the incomplete distal anastomotic tissue ring indicate the need for careful placement of the sutures, which with TEM is known to be technically demanding. It should be noted that the investigators were very experienced in both TEM and laparoscopic colorectal surgery, and that these skills probably are a prerequisite for NOTES sigmoid colectomy.

We noted several advantages of TEM instrumentation over standard flexible endoscopy as a platform for NOTES. The TEM platform is mounted to the operating table, thereby relieving the operator from bearing the weight and supporting the scope during the procedure. The TEM instrumentation includes an integrated combination CO_2 insufflation and suction unit. This unit permits synchronous balanced suction and insufflation to maintain constant pneumodistention and smoke evacuation in a closed sterile system. The rigid TEM camera system also maintains constant visual orientation and horizon, and because it is simply an angled laparoscope, its use is familiar to the surgeon and assistant. The TEM faceplate has a camera port, two 6-mm working ports, and one 9-mm working port. This allows for synchronous use of three independent and relatively hefty rigid instruments. It also permits passage of most 5-mm laparoscopic instruments and flexible endoscopes up to 9 mm.

In conclusion, our experiment demonstrates the feasibility of a standard sigmoid resection, en bloc lymphadenectomy, and primary anastomosis performed without any incisions. It also highlights the potential for TEM instrumentation as a portal to the peritoneal cavity for NOTES procedures.

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