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# A natural orifice transrectal approach for oncologic resection of the rectosigmoid: an experimental study and comparison with conventional laparoscopy

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**Abstract**
*Background* A transrectal (TR) approach for natural orifice translumenal endoscopic surgery (NOTES) makes sense for colorectal surgery because the colotomy can be incorporated into subsequent anastomosis. Because cancer is a primary indication for left-sided colon resection, oncologic standards will have to be met by a NOTES procedure. This study aimed to assess whether pure TR rectosigmoidectomy can be performed with strict adherence to oncologic principles compared with a conventional laparoscopically assisted approach (LAP).
*Methods* Human male cadavers were allocated to either TR ($n = 4$) or LAP ($n = 2$). A simulated sigmoid lesion was created at 25 cm. Transrectal retrograde mobilization of the rectosigmoid was performed using conventional transanal endoscopic microsurgery (TEM) instrumentation. After ligation of the superior hemorrhoidal artery and further mobilization, the specimen was delivered transanally and divided extracorporeally. Using a circular stapler, NOTES colorectal anastomosis was performed. Lymph node yield, adequate resection margins, and operative time were compared with LAP.
*Results* Transrectal retrograde rectosigmoid dissection was achieved in all attempts (4/4) and showed numbers of lymph nodes (median, 5; range, 3–6) similar to the LAP group (median, 4.5; range, 2–7). One pure TR approach failed to resect the lesion. Three TR procedures required additional mobilization via an abdominal approach to provide adequate margins. The mean length of TR specimens was $16 \pm 4$ cm compared with $31 \pm 9$ cm achieved by LAP ($p < 0.01$). The TR operative time was significantly longer ($247 \pm 15$ vs $110 \pm 14$ min).
*Conclusion* Lymph node yield during TR rectosigmoidectomy was similar to that achieved by the LAP approach. However, conventional TEM instrumentation alone did not permit adequate colon mobilization. This indicates a need for flexible instrumentation or other technical solutions to perform true NOTES colectomies.

**Keywords** Colorectal surgery · Lymph nodes · NOTES · Transanal endoscopic microsurgery

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Natural orifice translumenal endoscopic surgery (NOTES) has been proposed as the next evolutionary step in minimally invasive surgery. From just a conceptual idea in 1998 [1] and a lab-based approach only a few years ago [2], multiple centers have now progressed to clinical implementation of NOTES. Despite early enthusiasm, NOTES has sometimes been criticized for breaching an otherwise intact and uninvolved organ. Indeed, because many routine procedures involve only a few small trocar incisions and already have a rapid patient recovery, the true benefit of NOTES might be questionable for some [3].

A NOTES approach for incisionless colorectal surgery, however, makes sense because a well-planned colotomy used to access the peritoneal cavity can be incorporated into the subsequent anastomosis. Transrectal (TR) NOTES could provide a significant patient benefit because unlike many minimally invasive procedures, conventional laparoscopically assisted colorectal resections still impose an exceptional incisional access burden on the patient [4]. In particular, the need for a handport or a 6- to 10-cm additional incision for specimen retrieval [5, 6] diminishes much of the advantage offered by the laparoscopic approach.

Interestingly, more than 20 years before the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and American Society for Gastrointestinal Endoscopy (ASGE) Working Group White Paper on NOTES [7] was published, a pure natural orifice rectal procedure, known as transanal endoscopic microsurgery (TEM), had already been introduced [8]. The TEM technology allowed full-thickness resection of benign lesions or early-stage rectal cancer, followed by suture closure of the resultant defect [9, 10].

Based on the evolving interest in NOTES, the TEM device has been successfully adopted as a stable NOTES platform enabling TR rectosigmoid resection in the experimental model [11, 12]. More recently, the first clinical cases of natural orifice TR sigmoid resection together with laparoscopic assistance have been described [13, 14].

Because cancer is one of the primary indications for most colon resections, established surgical oncology requirements also have to be met by a NOTES procedure. This experimental human cadaver study aimed to assess whether a pure natural orifice TR rectosigmoidectomy with en bloc lymphadenectomy using currently available TEM instrumentation can be performed with strict adherence to oncologic principles similar to a conventional multiport laparoscopically assisted approach (LAP). The results including lymph node (LN) yield, adequacy of specimen length, and operative time were compared.

## Materials and methods

Freshly frozen, then thawed male cadavers were allocated to either TR ($n = 4$) or LAP ($n = 2$) sigmoidectomy. Cadavers were placed in lithotomy position, and a simulated neoplastic lesion was fashioned 20 to 25 cm from the anal verge by creation of a polypoid mass with an endoscopic band ligator unit (Duette Multi-Band Ligator; Cook Medical, Bloomington, IN, USA). For one experiment, no band ligator was available, so the simulated lesion was fashioned by endoscopic submucosal ink injection.

### Pure natural orifice TR rectosigmoidectomy with radical lymphadenctomy

For the pure TR procedure, conventional video TEM instrumentation (Richard Wolf Medical Instruments Corp, Vernon Hills, IL, USA) was used (Fig. 1A, B). The basic surgical technique of radical rectosigmoidectomy performed as NOTES using TEM has been described previously [11]. Briefly, a 12-cm-long operating TEM proctoscope with a diameter of 4 cm was inserted into the rectum, and carbon dioxide ($CO_2$) pneumorectum was established. The rectosigmoid lumen was occluded using a circumferential purse-string suture at the level of the upper rectal fold ($\sim$12 cm above the anal verge; Fig. 2).

About 1 cm distal to the occluding purse-string, a circumferential incision was scored using needleknife cautery and angled TEM forceps. The avascular "oncologic" presacral plane was entered posteriorly, and dissection proceeded cephalad using needletip cautery and $CO_2$ insufflation, staying in the total mesorectal excision planes (Fig. 3).

Next, lateral and anterior retrograde dissection was performed, and the abdominal cavity was carefully entered at the peritoneal reflection (Fig. 4). The 12-cm TEM proctoscope then was exchanged for the 20-cm beveled proctoscope, and mobilization was continued up to the

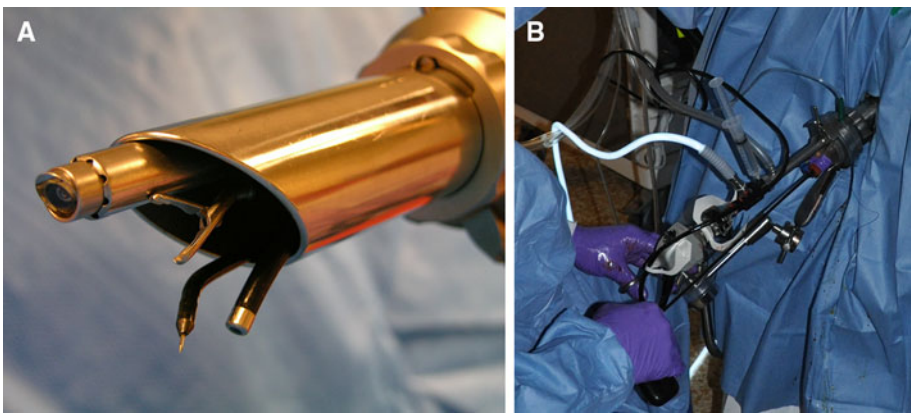


**Fig. 1** **A** Transanal endoscopic microsurgery (TEM) instrumentation used in the transrectal (TR) group. **B** External view of the TEM platform inserted into the rectum for retrograde dissection in the TR group

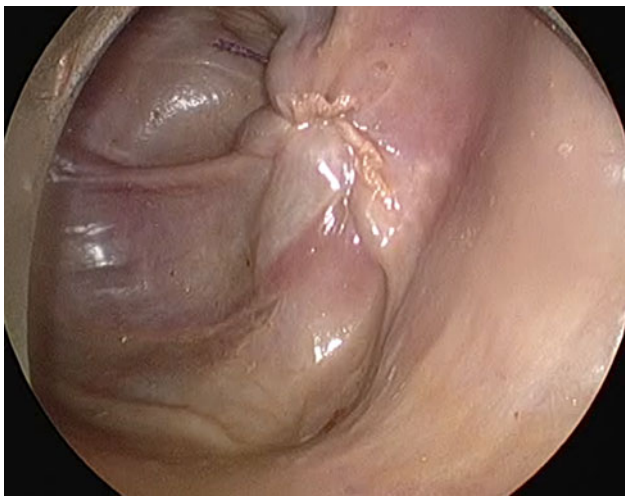

**Fig. 2** In the transrectal (TR) group, the rectosigmoid lumen was occluded using a circumferential purse-string suture (transanal endoscopic microsurgery [TEM] view)

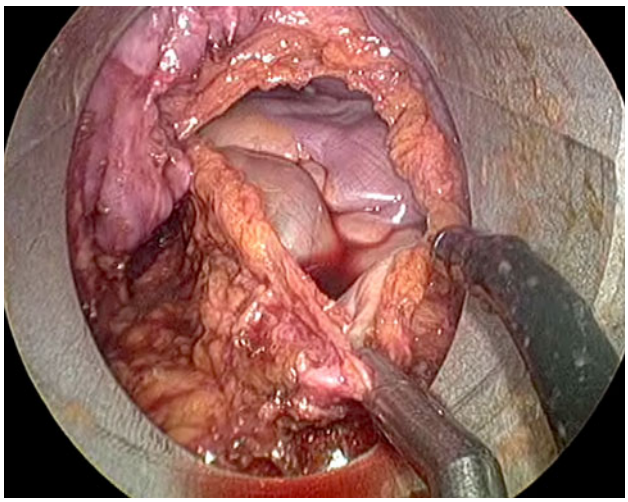

**Fig. 4** After complete circumferential retrograde dissection, the peritoneal cavity was entered

**Fig. 3** The presacral plane was entered posteriorly

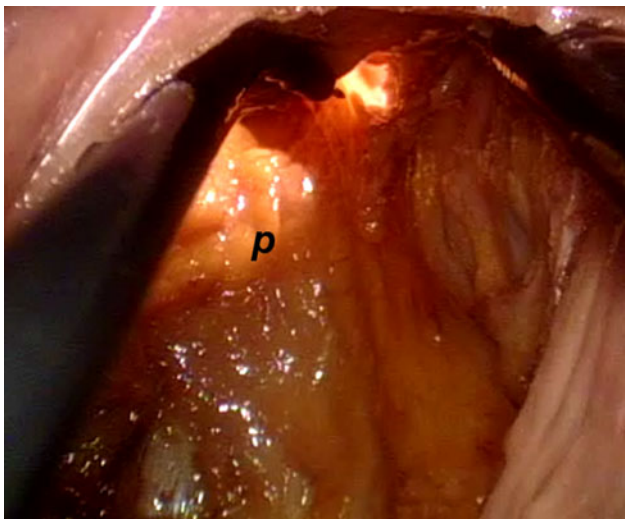


**Fig. 5** Transrectal dissection at the sacral promontory (*p*)

sacral promontory (Fig. 5) to reach the superior hemorrhoidal artery, which was divided with ultrasonic shears (Ultracision Harmonic Scalpel; Ethicon Endosurgery, Cincinnati, OH, USA) The rectal stump then was reflected into the abdominal cavity, and retrograde division of congenital sigmoid adhesions was performed until the procedure was limited by instrument length. The specimen was delivered transanally and divided extracorporeally. The length of the specimen was measured, inspected for the simulated lesion, and subsequently stored in formaldehyde.

For a NOTES colorectal anastomosis, a 29-mm EEA stapler anvil was extracorporeally sutured into the proximal colon using a standard purse-string suture with the suture tail left long for later manipulation and connection to the EEA stapler handle. The bowel was returned into the abdomen, and the TEM proctoscope was changed again to the smaller length.

After reestablishment of the pneumorectum, a purse-string suture was placed at the proximal end of the open rectum. Appropriate orientation of the colon was visualized, and the previously placed proximal anvil was delivered into the rectal stump using the suture tail as a handle. The rectal purse-string suture then was tightened intracorporeally with the anvil kept in place. The TEM faceplate was removed. The stapler was inserted and mated with the anvil shaft under direct vision of a transanal laparoscope. The stapler was brought into apposition, fired, and removed. Pneumorectum was reestablished, and the anastomosis was endolumenally inspected.

### Conventional laparoscopically assisted rectosigmoid resection in control specimens

A conventional laparoscopically assisted medial-to-lateral sigmoid colectomy [15] was performed in the two control cadavers. After they were positioned in lithotomy position, standard laparoscopic instrumentation and a video tower were used for this purpose.

When pneumoperitoneum had been achieved using open abdominal access technique, a 10-mm 30° laparoscope was placed together with additional 5- and 12-mm working/retraction ports. The small bowel was swept out of the pelvis, and the right peritoneal reflection of the root of sigmoid mesocolon was incised for entrance to the presacral plane.

Dissection was performed, starting medially, and the superior hemorrhoidal vessel was divided at its origin. After complete mobilization of the sigmoid and descending colon, the upper rectum was mobilized by division of the mesorectum. The upper rectum then was divided using a standard 45-mm laparoscopic articulating GIA stapler. The proximal colon loop was exteriorized through a Pfannenstiel incision and divided.

After a standard 29-mm EEA stapler anvil had been secured into the descending colon, the bowel was inserted back into the abdomen. The abdominal incision then was closed and after reestablishment of pneumoperitoneum, passing of the EEA stapler per-rectally enabled a standard end-to-end colorectal anastomosis. Flexible sigmoidoscopy was performed for direct inspection of the anastomosis.

A formal midline laparotomy was performed in all six human cadavers after en bloc rectosigmoid resection, and the abdomen was inspected thoroughly to identify potential major injuries. All resected colorectal specimens were placed in formaldehyde and stored until routine macroscopic pathologic analysis. The pathologist was blinded to the surgical procedure.

Standard parametric or nonparametric tests were used to evaluate differences between groups. The SPSS 17.0 statistical software (SPSS, Inc, Chicago, IL, USA) was used for analysis, and $p$ values less than 0.05 were considered significant.

## Results

### Operative results

Full-thickness en bloc TR rectosigmoid retrograde mobilization and dissection using TEM equipment were achieved in all (4/4) attempts. Both laparoscopically assisted procedures (2/2) also were performed successfully. However, for three of the cadavers (3/4) in the TR group, shortened sigmoid mesentery or intraabdominal adhesions prevented the proximal resection site from being completely brought out through the TEM scope. Therefore, conversion to a hybrid abdominal/transanal approach was performed to mobilize the mid and proximal sigmoid colon sufficiently to allow for transanal specimen delivery and anastomosis. The most proximal limit of retrograde dissection achieved using pure TR rigid instruments was observed to be the sacral promontory in three cadavers and the aortic bifurcation in one cadaver.

The simulated lesion was noted to be within the resection specimen in the LAP group and in three of four specimens in the TR group. One pure NOTES attempt (1/4) using standard TEM instrumentation failed to resect the simulated lesion due to limited mobilization and specimen length (12 cm) after transanal delivery and resection. An anastomotic staple line defect (1/4) also was observed in this specimen. The mesorectal plane was intact in all the specimens.

No other untoward events or injuries to the ureters, descending colon, cecum, or small bowel were detected in either group. The TR operative time ($247 \pm 15$ min) was significantly longer than for LAP ($110 \pm 14$ min) ($p < 0.01$).

### Pathologic results

Macroscopically evaluated by a pathologist blinded to the surgical procedure, en bloc rectosigmoid resection showed similar numbers of LNs between the TR group (median, 5 LNs; range, 3–6 LNs) and the LAP group (median, 4.5 LNs; range, 2–7 LNs). The median LN yield per 10 cm of specimen length was found to be 2.5 LNs (range, 1.5–5 LNs) in the TR group and 1.3 LNs (range, 0.8–1.9 LNs) in the LAP group ($p = 0.165$, nonsignificant difference). The mean length of the specimen in the TR group was $16 \pm 4$ cm compared with $31 \pm 9$ cm achieved by LAP ($p < 0.01$).

## Discussion

Initially, NOTES was described as using an oral transgastric approach [2]. More recently, the transvaginal approach, long used by gynecologists and having an established closure method, has become popular. Currently, both routes have been implemented in clinical practice with a substantial number of transvaginal cases [16, 17].

The TR approach, however, has had more resistance due to a perception of contamination risk. This is unfortunate because the ability to remove a large specimen through this natural orifice, the gender universality, and the ability to close the viscotomy under direct visualization make this

the ideal NOTES access in many ways. For colorectal surgery, a TR NOTES approach is even more appropriate because it overcomes the need to violate an otherwise uninvolved organ and provoke potentially avoidable complications.

However, some difficulties are associated with standard flexible endoscopic NOTES procedures. These include insufficient insufflation due to difficulty maintaining a seal around the endoscope at the anus, difficulty keeping the long endoscope from sliding out of the anus while rectal work is performed, potential damage to the nondilated rectum or anus during extraction of large specimens, and lack of a secure suturing device to close rectotomies in the proximal and mid rectum.

As a "proto-NOTES" platform, the TEM device has many desirable features. It maintains a continuous pressure-regulated pneumorectum/peritoneum, has four working ports including one for a stabilized laparoscope or flexible endoscope, has specially modified rigid laparoscopic instruments, and is reusable. Perhaps most important, suture closure of full-thickness rectotomies has been validated over the past 20 years [9, 18].

In 2007, our group originally described the feasibility of using the TEM device to perform a NOTES radical sigmoidectomy in a cadaver model [11]. The intention of this study was to compare the oncologic effectiveness of a pure TR retrograde approach with that of a formal laparoscopically assisted sigmoid colectomy for cancer, specifically observing the numbers of LNs harvested, the maintenance of the mesorectal capsule, and the adequate length of the resected specimen.

The oncologic principle in colorectal cancer surgery is to perform a radical en bloc lymphadenectomy of the tumor-laden segment of bowel. In the rectum, this includes a tumor-specific mesorectal excision performed in the embryonic tissue planes of the pelvis. Consequently, any NOTES procedures for colorectal cancer must adhere to these principles.

In this study, we found that the retrograde transanal dissection gave good access and visibility to the mesorectal plane and that the $CO_2$ insufflation actually helped with the dissection. The LN yield during pure TR rectosigmoidectomy was found to approximate that obtained by the conventional laparoscopically assisted approach. The generally recommended number of at least 12 nodes in a human resection specimen [19], however, was not achieved in our resected cadaver specimens.

Other investigators also have found a similarly low number of LNs retrieved in human cadaver mesorectal specimens [20]. This might be related to our frozen and thawed cadaver model or to the fact that the specimens were stored in formalin without any specific clearance solution until routine macroscopic pathologic evaluation. The fact that our resection lengths were relatively short also may play a role. In a survey of multiple international hospitals, the LN counts in colon specimens ranged only from 0.9 to 3.8 LNs per 10-cm length [21]. A specimen shorter than 20 cm achieved with the NOTES approach or a median length of 31 cm attained with the LAP approach made a median number of five detected LNs seem reasonable for this experimental model. Historical data on LN harvest rates in cadaveric colorectal surgery and funding limitations also seemed to justify the lower number of specimens evaluated in the conventional laparoscopic control group.

The greatest disappointment was the inability to achieve a significant length of resection with a pure transanal approach. Failure to resect a 25-cm lesion occurred with one cadaver, and three of four cadavers required supplemental mobilization using hybrid abdominal techniques. The limiting factors observed were the length of the standard rigid TEM instrumentation used and the inability of an even-angled rigid endoscope to provide visualization over the sacral promontory. This prevented visualization and manipulation of retroperitoneal structures cephalad to the common iliac vessels and aortic bifurcation. Inability to access the origin of the inferior mesenteric artery, inferior mesenteric vein, proximal sigmoid, descending colon, and splenic flexure precluded reliable mobilization for resection and a tension-free anastomosis.

Interestingly, with our previous cadaver resection using similar techniques, we were able to resect an average colorectal specimen length of 24 cm. However, much less attention was paid to meticulous oncologic principles.

One method for overcoming the limits of TR dissection is to use a hybrid laparoscopic approach. Based on substantial laboratory research in this field [22], the clinical implementation of rectal cancer resection using TEM together with laparoscopic assistance has been presented recently [14]. By performing the previously described retrograde TR dissection together with laparoscopic mobilization of the descending colon, oncologic resection was carried out, and a hand-sewn coloanal anastomosis was accomplished successfully. The authors report that the mesorectal excision was facilitated using this access and retrograde $CO_2$ insufflation. They concluded that lower rectal cancer might be an excellent indication for this NOTES access. Others also have already reported on their initial experience with laparoscopically assisted human TR NOTES cases [13, 23].

In an effort to overcome the problems of adequate TR colon mobilization and to maintain a true incisionless approach, other investigators have used transgastric flexible endoscopy to perform sufficient colon mobilization in a porcine model [24, 25]. The mean porcine colon specimen

length achieved reportedly was up to 15 cm with transgastric endoscopy or 10 cm without it, similar to other reports [25, 26]. This approach has the obvious drawback of requiring a gastrotomy for accessory scope access and of all the related concerns about a secure closure that this approach engenders. We have favored an approach that uses the multiport TEM platform, potentially allowing both modified rigid and flexible scopes as well as the use of instruments in tandem.

The use of novel sophisticated flexible NOTES platforms [27] or longer instruments [28, 29] together with flexible endoscopy might overcome at least some of these drawbacks regarding sufficient mobilization in the near future. Complete transanal splenic flexure mobilization and high ligation of the inferior mesenteric artery have already been demonstrated by one such advanced flexible endoscopic surgical platform [30].

Transanal/TR specimen delivery after standard laparoscopic colon dissection has long been described but not widely practiced [31–33]. This component of our study probably has more potential to decrease patient morbidity than the achievement of a completely incisionless colectomy. Transrectal specimen removal during laparoscopic colorectal procedures could therefore serve as an appealing less invasive bridge to NOTES. However, for more widespread use of pure incisionless colorectal surgery in the near future, more sophisticated platforms and flexible instruments seem necessary.

In conclusion, we found that a pure NOTES oncologic appropriate rectosigmoid resection could be feasible because LN yield appeared to approximate that of a conventional laparoscopically assisted approach, and a mesorectal resection was possible. However, due to the limited length of the currently available instrumentation, as used in this study, a stand-alone approach for transanal retrograde resection seems applicable only for rectal lesions. A TR hybrid approach using laparoscopic assistance currently appears to be a necessary compromise. New developments in flexible endoscopic platforms and instruments such as flexible staplers together with a TEM-like platform could enable pure NOTES colorectal surgery via this appealing access route in the not too distant future.

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