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REVIEW ARTICLE

Transanal Minimally Invasive Surgery: State of the Art

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Abstract The treatment for rectal cancer and benign rectal lesions continues to progress in the arena of minimally invasive surgery. While surgical excision of the primary mass remains essential for eradication of disease, there has been a paradigm shift towards less invasive resection methods. Local excision is increasing in popularity for its low morbidity and excellent functional results in select patients. Transanal minimally invasive surgery (TAMIS) is a new technology developed to elevate the practice of local excision to state-of-the-art resection. The goal of this article is to evaluate the history, short-term outcomes, and evolution of the TAMIS technique for excision of benign and malignant rectal neoplasia.

Keywords Rectal cancer · Transanal minimally invasive surgery · TAMIS · Transanal excision · Local excision

Background

For curative resection of all stages of localized rectal cancer, proctectomy with total mesorectal excision (TME) remains the gold standard.[1,2] However, there is significant morbidity, mortality, and impact on quality of life with radical resection.[3–6] Early-stage rectal cancers and benign lesions may not warrant such aggressive treatment, and its associated risks have increased use of sphincter-sparing local excision.[5–7] Studies show successful use of local excision in early-stage rectal cancer and benign lesions.[8,9]

Currently, there are three main approaches to performing full-thickness transanal excision. Traditional transanal excision is limited to tumors less than 4 cm in diameter that lie within 6 to 8 cm of the anal verge.[10–12] While the minimally invasive technique offers lower morbidity and mortality than radical resection, the major disadvantage of traditional transanal excision is the poorer surgical outcomes. There are difficulties with access, precision, proper visualization, higher rates of local recurrence, tumor remnants, and inferior overall and disease-free survival rates.[13–16] Suboptimal visualization has been hypothesized as the cause for the increased risk of positive margins and tumor fragmentation.[15]

To address the technical limitations of conventional transanal excision, Professor Gerhard Buess introduced transanal endoscopic microsurgery (TEM), an advanced videoscopic minimally invasive technique for transanal excision in 1983.[17] TEM utilizes specialized equipment and endoscopic instruments for a magnified three-dimensional view of 220° of the rectum and access up to 24 cm from the anal verge, for precise dissection of select low, middle, and upper rectal tumors.[18] The resectoscope allows access to more proximal rectal lesions than traditional transanal excision; however, as the distal rectum will form the seal with the resectoscope, tumors less than 5 cm from the anal verge are not well visualized. With better visualization, TEM results in improved oncologic outcomes than traditional transanal excision.[15,19,20]

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Several studies have compared TEM to traditional transanal excision, proving a higher rate of negative resection margins, lower incidence of lesion fragmentation, and lower overall recurrence rates than traditional transanal excision.[13,15,20,21] Langer et al. compared the long-term outcomes of 54 traditional transanal excision and 57 TEM patients for rectal adenoma, finding higher local recurrence rates of 31.5 vs. 8.8 %, respectively.[19] Moore et al. had similar results, comparing 171 patients with rectal neoplasms over 15 years.[15] The authors found higher rates of negative margins (90 vs. 71 %, $P=0.001$) and non-fragmented specimen (94 vs. 65 %, $P<0.001$) for TEM compared to traditional transanal excision.[15] Comparing outcomes over a 17-year period between TEM ($n=216$) and traditional transanal excision ($n=43$), de Graaf et al. found lower specimen fragmentation (1.4 vs. 23.8 %, $P<0.001$), recurrence (6.1 vs. 28.7 %; $P<0.001$), and morbidity (5.3 vs. 10 %, $P<0.001$) for TEM, with higher rates of negative resection margins (88 vs. 50 %, $P<0.001$).[21] Despite superior outcomes over traditional transanal excision, TEM has not been widely adopted for several reasons, including the considerable cost of the apparatus, specialized instrumentation, the steep learning curve required to master the TEM technique, risks of defective anorectal function after surgery, and limited indications for the technique.[20,22–24]

Introduction of Transanal Minimally Invasive Surgery

To meet these needs, a novel hybrid between TEM and single-port laparoscopy for transanal excision was introduced.[23] Transanal minimally invasive surgery (TAMIS)—also referred to as transanal single-port microsurgery[25] and transanal endoscopic video-assisted excision[26]—is defined as the use of any single-access multichannel port inserted transanally, combined with ordinary laparoscopic instruments, a laparoscopic camera, and a standard laparoscopic CO_2 insufflator.[27] Atallah and the Florida Hospital Center Colorectal Surgery group developed TAMIS in 2009.[23] Since its introduction, the TAMIS platform has reignited global interest in transanal endoluminal surgery and furthered the possibilities of minimally invasive surgery. TAMIS uses conventionally available single-incision laparoscopic surgery ports and standard laparoscopic instruments, leading to a lower cost for the disposable equipment, compared with the reusable TEM device.[28]

Patient Selection

The lesions appropriate for transanal resection using any platform are defined by the NCCN guidelines: mobile rectal tumors, less than 3 cm in size, occupying less than one third of the circumference of the bowel, not extending beyond the submucosa, with well to moderate differentiation, and low-risk histopathological features. Transanal local excision is not appropriate for rectal tumors with high-risk characteristics, including lymphovascular invasion, perineural invasion, and mucinous components.[29,30] Transanal excision is also not standard for rectal adenocarcinoma T2N0M0 and greater, as these lesions have a lymph node involvement rate between 12 and 29 %.[31] While not the gold standard, indications have expanded past curative treatment of benign and early-stage rectal cancer to palliation in patients with advanced rectal cancer who are unfit for surgery or have refused radical resection.[32]

The use of TAMIS in distal lesions is limited by the length of the port (37–44 mm) and the need to seat the platform above the anorectal ring. For lesions below this level, traditional transanal excision or a hybrid approach can be used. TAMIS is better suited for distal lesions than TEM because the shorter shaft of the single-incision port compared to the TEM resectoscope allows the dissection to begin in the very distal rectum and a wider working angle can be achieved.[33]

Technical Aspects

TAMIS is performed under general endotracheal anesthesia. A complete oral bowel preparation is recommended in case you need to convert and adjust your approach during the procedure. Patient positioning for TAMIS depends on the tumor location. The best preoperative evaluation of the mass is digital rectal exam with rigid proctoscopy. Lithotomy may be used for all lesions, as the camera allows visualization of lesions 360° and cases can be readily converted to an abdominal procedure, if needed. For lesions in the lower and mid-term (distal to the second valve of Houston), lithotomy positioning is recommended. For lesions in the upper rectum and rectosigmoid, prone positioning is recommended for anterior lesions and lithotomy for posterior lesions. Technically, these positions promote visualization and access. Above the peritoneal reflection, having the patient prone is important, as in cases of inadvertent intraperitoneal entry, the positioning of the antimesenteric bowel wall against the abdomen wall will tamponade the intra-abdominal pressure and pneumorectum is able to be maintained to facilitate closure. The hybrid technique utilizes a single-incision multi-port device to leverage the similarity in working angles between TEM and single-access devices.[23] Currently, there are two ports approved for TAMIS in the USA by the Food and Drug Administration: the SILS Port (Covidien, Mansfield, MA, USA) and the GelPOINT Path or GelPOINT Path Long Channel Transanal Access Platform (Applied Medical, Rancho Santa Margarita, CA, USA). The SILS Port (diameter 35 mm, length 37 mm) is composed of a soft, flexible thermoplastic elastomer that facilitates easy placement into the anal canal and a conforming

fit to maintain pneumorectum. It contains three 5-mm channels that can accommodate instruments up to 15 mm and a separate access point for insufflation. The upper rim anchors just above the anorectal ring, allowing the use of regular laparoscopic instruments.[23] The SILS port is preferred in patients with narrow or fibrotic anal canals where the GelPOINT Path transanal access device cannot be placed or properly seated.[24] The GelPOINT (diameter 34 mm, length 44 mm) is the only multichannel port specifically designed for TAMIS. The GelPOINT has a soft, disposable anal retractor and a gel matrix cap where cannulas can be placed per the operator's preference. The wound protector portion of the GelPOINT platform is an advantage over the SILS port. The GelPOINT is used for lesions up to 8 to 10 cm from the anal verge; for more proximal lesions, the GelPOINT Path Long Channel can be employed, reaching lesions up to 15 cm from the anal verge.[24] The AirSeal® access port (SurgiQuest, Milford, CT, USA), an adjunct to the GelPOINT Path, can assist visualization by providing stable pneumoperitoneum and continuous smoke evacuation even when energy devices and electrocautery are used.[34,35] The single-incision port is lubricated and then inserted into the anal canal with steady manual pressure. Once the port is seated, pneumorectum is established. Standard laparoscopic instruments and energy devices are used for the transanal excision. After the lesion is identified, a 1-cm circumferential margin is marked using standard electrocautery. A full-thickness or a submucosal excision is performed with the use of an energy device.[24] Upon completion of resection, intraluminal suturing can be performed to reapproximate the excision defect.[23] However, a study has shown the defect can be left open with no effect on complications or continence.[36]

TAMIS Benefits

TAMIS has several technical benefits over other transanal excision methods. The magnified endoscopic image allows precise dissection, favoring TAMIS over the traditional open transanal excision technique.[37] TEM uses a specialized rigid proctoscope (12 or 20 cm in length) with an adapted insufflator, a 30° TEM scope, and bended instruments.[38] TAMIS provides the benefits of advanced videoscopic transanal excision at a fraction of the cost of TEM.[23] The technique can be used on lesions not amenable to colonoscopic or standard transanal removal.[26] Compared to TEM, TAMIS requires no investment. The SILS ports are relatively inexpensive, and normal laparoscopic instruments, including graspers, thermal energy devices, and needle drivers, are used for resection.[23,37] The TAMIS port also has a shorter shaft length, allowing an increased working angle and more distal dissection possible compared to the TEM port.[22] In addition, TAMIS may be less traumatic to the anal sphincter than traditional TEM.[37]

TAMIS Outcomes

Though still in its infancy, TAMIS has been explored worldwide in over 30 retrospective studies covering almost 400 procedures.[22] TAMIS has been shown to be safe and feasible for benign lesions and selected, early-stage malignancies of the mid- and distal rectum with favorable pathology and a promising alternative to TEM.[23,27,39] In the initial trial evaluating the feasibility of TAMIS resection of rectal lesions in six patients, Atallah et al. had an average operating time of 86 min, no conversions to open transanal excision, no morbidity, and no mortality observed.[23] The group further validated the feasibility of TAMIS in their first 50 consecutive patients, confirming TAMIS provides a safe and effective method for resecting benign and select early-stage malignancies of the mid- and distal rectum.[27] The authors used TAMIS for 25 benign neoplasms, 23 malignant lesions, and 2 neuroendocrine tumors, with an average distance of 8.1 cm from the anal verge (range, 3–14 cm). All lesions were excised completely with grossly negative margins and only 6 % microscopically positive margins. Early complications occurred in 6 %. After a 20-month follow-up, there were two recurrences and no long-term complications.[27]

Results from other centers have supported these outcomes. Hahnloser et al. assessed perioperative complications and long-term functional outcomes in 75 patients who underwent TAMIS for 37 benign lesions and 38 low-risk cancers.[36] In this large series, the authors had an 8 % intraoperative complication rate, 19 % postoperative morbidity, one patient requiring re-operation for local infection, and no impact on continence after a median follow-up of 12.8 months.[36] Other smaller series confirmed the low morbidity and mortality, safety, and feasibility for early rectal cancers, adenomas, and benign lesions[24–26,37,40–47] (Table 1). A systematic review evaluating 4 years of published reports for a combined 390 TAMIS procedures worldwide described the average lesion size resected as 3.0 cm; the mean distance from the anal verge as 7.6 cm; a conversion rate for both benign and malignant lesions of 2.3 %; and rates of positive margins, tumor fragmentation, and overall complications of 4.36, 4.1, and 7.4 %, respectively.[22] These pooled results further support the benefits of TAMIS for benign and malignant disease and broad future direction.

Future Direction of TAMIS

The utilization of TAMIS has continued to spread internationally, with both creative applications and intuitive progress of the platform. Robotic TAMIS is an evolution of the TAMIS platform, with advantages of greater precision for dissection and ease of intraluminal suturing of the surgical defect compared to standard TAMIS.[48,49] Studies have shown the safety

Table 1 Short-term outcomes of selective TAMIS studies

Author	Year	Port	Sample size	Lesion size (cm)	Distance from anal verge (cm)	Operative time (min)	Length of stay (days)	CX	RX	F/U (months)
Atallah	2010	SILS	6	2.93	9.3	86	0.83	0	NA	1.5
Cid	2011	SILS	5	3	8	55	2	0	NA	3
Lorenz	2011	SILS/ TriPort	13	NA	6.5	NA	NA	0	NA	0.5
van den Boezem	2011	SILS	12	3.5	7	55	1	2	NA	NA
Lim	2012	SILS	16	0.8	7.5	86	3	0	NA	3
Hompes	2012	Glove	14	1.7	5	93	1.5	2	1	5.7
Ragupathi	2012	SILS	20	3	10.6	80	1	1	1	NA
Barendse	2012	SSL	15	3.6	6	57	2	2	NA	NA
Albert	2013	SILS/GP	50	2.8	8.2	74.9	0.6	4	2	20
Lee	2013	SILS	25	2.4	9	45	3	1	0	9.8
Gorgun	2013	GP	12	2.9	8.4	79	1	3	NA	NA
McLemore	2014	GP	32	3	4	123	2.5	5	0	8
Maglio	2015	SILS	15	3.5	7	86	2	0	0	6

SILS Covidien SILS™ Port, *GP* Applied Medical GelPoint Port, *SSL* Ethicon Single Site SSL™ Port, *TriPort* Olympus TriPort+Surgical System, *CX* complications, *RX* recurrence, *F/U* follow-up, *NA* not available

and feasibility,[48·50] but benefits will need to be weighed against the costs when considering the use of this platform. Transanal TME using TAMIS is an important next step in the evolution of the platform. Multiple reports demonstrate that transanal TME is safe and feasible for mid- or low rectal tumors.[51–59] This approach is particularly advantageous for obese male patients with a narrow pelvis where exposure to the distal rectum from the abdominal approach is challenging.[22·33] Short-term outcomes for transanal TME show shorter operative times, lower readmission rates, and acceptable morbidity and mortality with no apparent compromise in the oncological quality of the resection.[51·53–55] Using the robotic TAMIS platform for TME is further expanding possibilities for resection. Performed through a hybrid laparoscopic abdominal and robotic transanal approach, the technique has been shown safe and feasible in a limited number of case reports.[49·50·60–63] Long-term oncologic outcomes and controlled trials are pending for this emerging application. For all emerging application of TAMIS, further study is needed before the technique is accepted as standard of care. However, with careful patient selection, in-depth procedural training, and surgical expertise, TAMIS approaches are feasible and provide inspiration for the future of local excision.[54]

Limitations of TAMIS

There are limitations with this emerging technology. TAMIS is a fairly new technique with short-term follow-up only.[22] Currently, case reports and small series are the only publications evaluating outcomes, and long-term oncologic outcomes on local recurrence and survival are pending. Further, controlled studies and long-term outcomes are needed to assess the full benefits of TAMIS for local excision. The learning curve for TAMIS is also yet to be described. The TAMIS platform allows surgeons to translate familiar laparoscopic skills to transanal surgery, which is expected to result in rapid acquisition of the skills necessary for competency.[64] Comparative studies between the available transanal excision platforms are also needed. To date, many clinical series on TAMIS have been published, but there are no comparative in vivo trials to assess the resection quality of TEM and TAMIS. Rimonda et al. did compare the feasibility and efficacy of the advanced videoscopic platforms—TAMIS and transanal endoscopic microsurgery (TEM)—in a trainer box pilot study with 10 novice transanal surgeons. The authors reported both approaches achieved a good

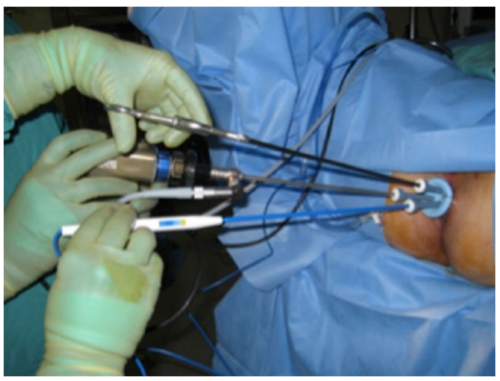

Fig. 1 TAMIS external port view

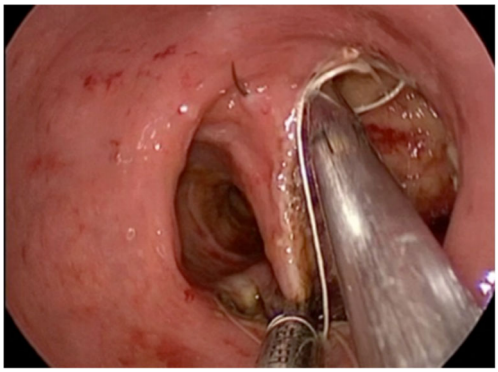

Fig. 2 TAMIS internal view

dissection, with comparable quality of vision, and instrument conflicts, but TEM had a better subjective appreciation for dissection and suturing difficulty.[65] However, this ex vivo comparison portrays a limited view on the comparative effectiveness, as it does not account for the accessory devices commonly used by TAMIS surgeons, such as automated suturing and knot-forming devices, that facilitate the technically challenging closure of the surgical defect after local excision has been completed, the rapid learning curve from use of familiar laparoscopic skills and instruments, or the ease of setup compared to the complexity of the TEM system.[64] Based on current clinical data, TEM and TAMIS appear to be effectively equivalent advanced transanal platforms, but we await controlled comparative studies for a definitive position. In the meantime, surgeons are encouraged to report their preliminary results with TAMIS including margin status, specimen fragmentation, and complications for comparative effectiveness to TEM.[24] Finally, with all transanal excision, patient selection is a limitation. Though local excision has gained popularity, its utility should be reserved for removal of low-risk, early lesions in patients who comprehend and favor the associated increased risk of tumor recurrence and aggressive surveillance over radical surgery (Figs. 1 and 2).[1,31,66,67]

Conclusions

TAMIS is a new technology developed to elevate the practice of local excision to state-of-the-art resection. While still in its infancy, short-term outcomes and new applications of TAMIS have been promising. As with all procedures, there is a learning curve with TAMIS, and additional training should be sought prior to using this technique. Courses are widely available through Applied Medical. When ascending any learning curve, it would be prudent to start with benign cases, if feasible. Long-term oncologic outcomes and controlled trials of the technique are needed to further use in clinical practice. In the meantime, a registry would be an ideal way to compile data and collaborate on studying the outcomes, limitations, and future direction of this platform.

Compliance with Ethical Standards

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Conflict of Interest The authors declare that they have no competing interests.

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