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ORIGINAL ARTICLE

Transanal total mesorectal excision assisted by single-port laparoscopic surgery for low rectal cancer

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Abstract
Introduction We have combined the minimally invasive single-port laparoscopic surgery and the transanal total mesorectal excision (TaTME) for rectal cancer with the goal to standardize the approach and improve the quality of rectal cancer resection.
Methods By using two single-port platforms, selected patients were first operated by TaTME, and then a single-port laparoscopic surgery was introduced to assist and complete the abdominal portion. Short-term outcomes including perioperative outcome and pathologic results of these patients were evaluated.
Results Between July 2014 and March 2015, six patients with low rectal cancer (five males and one female) at a median age of 68 years were successfully operated in a median time of 360 min (range 310–420). The median estimated blood loss was 150 ml (range 50–800). In one patient, the spleen was removed because of a lesion identified preoperatively. Their postoperative recovery was uneventful except one acute myocardial infarction on postoperative day 3. Pathologic specimens showed negative margins and a complete excision of the mesorectum in all cases. The median number of harvested lymph nodes was 11.5 (range 4–12). At a median follow-up of 4 months (range 3–9), after ileostomy closure, none of the patients suffered from fecal incontinence.
Conclusion TaTME assisted by abdominal single-port may be safely achieved in selected rectal cancer patients.

Keywords Transanal total mesorectal excision · Single-port laparoscopic surgery · Rectal cancer · Splenectomy · Short-term outcomes

Introduction

During the last few decades, there has been a tremendous development in minimally invasive surgery, especially in the field of colorectal cancer. While conventional multiports laparoscopic surgery (MPLS) for rectal cancer is still under evaluation in randomized control trails [1, 2], new approaches such as single-port laparoscopic surgery (SPLS), i.e., single-incision laparoscopic surgery (SILS) for rectal cancer, have emerged [3–5]. The recently developed transanal total mesorectal excision (TaTME) surgery embodies the concept of natural orifice translumenal surgery (NOTES) [6], and may be a better approach to resect rectal cancer [5, 7]. This is because TaTME permits a clear and magnified filed to get access to the confined distal rectum (once called "no-man's-land") from below by employing a transanal platform—either the rigid transanal endoscopic platform (i.e., TEM device) [8] or the disposable transanal minimally invasive surgery (TAMIS) platform (more frequently used) [9]. Therefore, it can reduce the difficulty of the operation, avoiding some difficult situations encountered by conventional laparoscopic surgery such as the "multi-stapling" that increased the likelihoods of anastomotic leak and involved distal resection margin [10].

Currently most of TaTME cases have been performed in a hybrid approach—assisted by laparoscopy, among whom

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most are MPLS-assisted. Previous studies have reported a small number of cases using the SPLS–TaTME strategy [5, 11, 12]. Herein, we present our series of consecutive patients, primarily focusing on the technical details, short-term results, and oncologic safety of this technique.

Methods

Patient

Consecutive patients with biopsy-proven adenocarcinoma or high-grade dysplasia who were scheduled to undertake radical surgery were eligible. All lesions were located ≤6 cm from the anal verge. Patients who presented recurrence and unresectable distal metastasis, cT4 tumors, obstruction, synchronous colorectal cancer, fecal incontinence, history of inflammatory bowel disease (IBD), and familial adenomatous polyposis (FAP) were excluded. All patients had undergone full assessment preoperatively, such as thorough colonoscopy, pelvic MRI and/or endorectal ultrasonography, thoracoabdominal CT scan, and sphincter manometry. Patients whose T stage ≥3 or lymph node positive on preoperative evaluation were scheduled to undergo neoadjuvant therapy.

Approval of institutional review board (IRB) had been obtained. All patients had been given full explanations of the benefits and adverse risks of the procedure, and informed consent had been obtained from each patient.

Surgical technique

The key technical steps of SPLS–TaTME surgery can be summarized as follows: (1) The patient was placed in lithotomy position. An anal retractor was applied to fully expose the rectum after washout with antiseptic solution; (2) a purse string was placed to tightly occlude the rectal lumen, followed by a full-thickness circumferential dissection into the proper perirectal plane (for low tumor, an intersphincteric dissection was required); (3) proximal dissection progressed after introducing a transanal *SILS* port (Covidien, Mansfield, MA) and establishing a pneumo-pelvis (Fig. 1a), and a rubber tube (16F) was placed through the ischiorectal fossa as a mini-trocar for suction or countertraction by the assistant; (4) after fully mobilizing the extraperitoneal rectum, the peritoneal

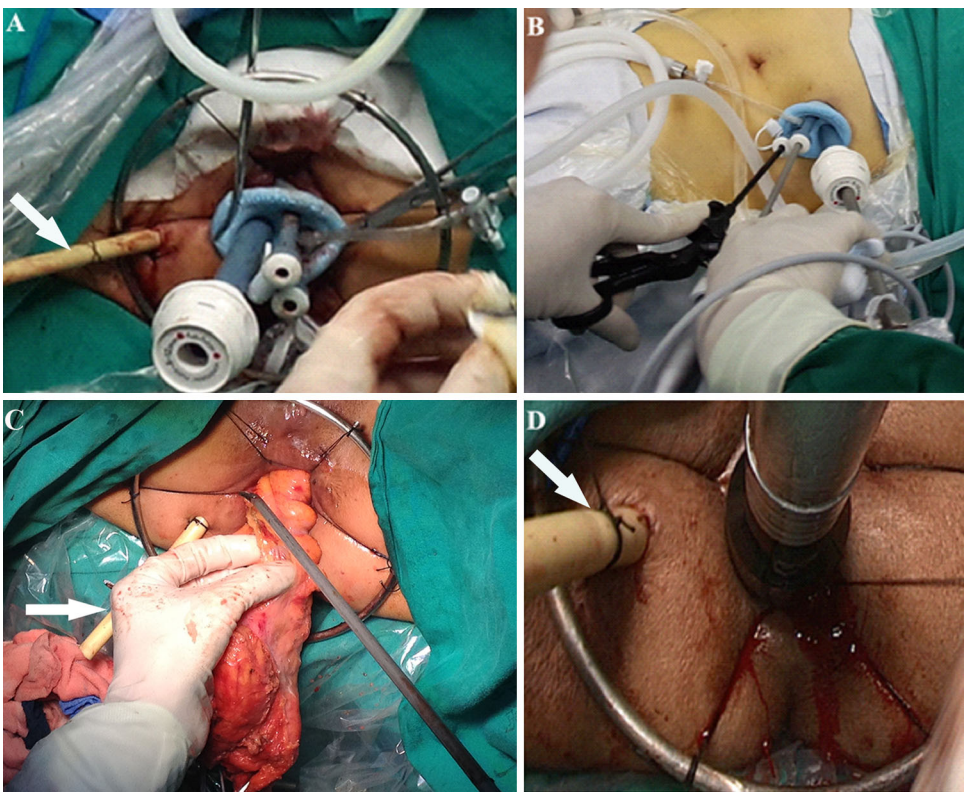

Fig. 1 Demonstrations of surgical procedure. **a** Transanal dissection. The demonstration of the first transanal *SILS* port (Covidien, Mansfield, MA). **b** Single-port assisted laparoscopic dissection. The demonstration of the second *SILS* port in the future ileostomy site. **c** Specimen extracted transanally and **d** an end-to-end stapled anastomosis. *White arrow* indicates the rubber tube that was introduced through the ischiorectal fossa into the anorectum to act as a mini-trocar and a postoperative pelvic drain

Table 1 Detailed information of the six patients

	#1	#2	#3	#4	#5	#6
Gender	Male	Male	Male	Male	Female	Male
Age (years)	80	64	77	55	72	64
BMI (kg/m^2)	22.68	22.72	22.84	26.56	27.76	19.37
ASA	2	2	3	1	2	1
Comorbidity	HTN, CAD, lithiasis, prostatectomy	No	Type 2 DM	No	SSS	No
Previous abdominal surgery	Yes	No	No	No	No	No
Location of tumor	6 cm from AV, right lateral	4 cm from AV, anterior	3 cm from AV, posterior	5 cm from AV, anterior	4 cm from AV, 2/3 circumferential	3.5 cm from AV, 1/2 circumferential
Diameter of tumor (cm)	3	1.5	2	2.5	4	3
Initial TNM stage[a]	cT2N0M0	cT3N2M0	cT3-4aN0Mx[b]	cT2N0M0	cT1N0M0	cT3N1aM0
Neoadjuvant therapy	No	Yes	Yes	No	No	Yes
(y)cTNM stage[a]	cT2N0M0	ycT2N1aM0	ycT3N0Mx[b]	cT2N0M0	cT1N0M0	ycT3N0M0
OT (min)	370	310	420	350	375	320
EBL (ml)	50	50	800	100	300	200
Mobilization of splenic flexure	Yes	Yes	Yes	No	No	No
Ileostomy	Yes	Yes	Yes	No	Yes	Yes
Transfusion	No	No	RBC 3 IU	No	No	No
Length of specimen (cm)	9.5	10	11.5	12	7.5	13
Lymph node no.	12	4	12	12	11	8
(y)pTNM stage	pT2N0M0	ypT0N0M0	ypT2N0M0	pT2N1M0	pT3N0M0	ypT0N0M0
CRM	Negative	Negative	Negative	Negative	Negative	Negative
Completeness of mesorectum	Intact	Intact	Intact	Intact	Nearly Intact	Intact
Recover to flatus (days)	4	3	3	4	4	3
LOS(days)	20	11	13	9	10	10
Remarks	Experienced an acute myocardial infarction in the postoperative day 3, but was treated conservatively	Complete recession to neoadjuvant therapy	The suspected splenic tumor was confirmed to be an inflammatory myofibroblastic tumor after splenectomy	Without constructing an ileostomy; discharged with bowel movement of 4–5 times a day; pTNM: III	Converted to SPLS assistance when performing a planned pure TaTME because of unsatisfactory expose	Complete recession to neoadjuvant therapy

BMI body mass index, *ASA* American Society of Anesthesiologists, *HBP* high blood pressure, *CAD* coronary artery disease, *DM* diabetes mellitus, *SSS* sick sinus syndrome, *AV* anal verge, *OT* operative time, *EBL* estimated blood loss, *CAA* coloanal anastomosis, *RBC* red blood cell, *IU* international unit, *No.* number, *CRM* circumferential margin, *LOS* length of hospital stay

[a] Based on MRI

[b] Suspected splenic metastasis

reflection was cut open in the anterior aspect, and the peritoneal cavity was thereby entered; (5) the second *SILS* port placed at the future ileostomy site was introduced by one team or simultaneously two teams if step 4 was done or the above steps could not be smoothly progressed (Fig. 1b); (6) after abdominal exploration, a medial-to-lateral approach was adopted: The inferior mesenteric vessels (IMV) were skeletonized, ligated and divided. Attachments of descending colon, splenic flexure (if necessary) and the upper rectum were dissected until the specimen was in free continuity with the previous transanal dissection. (7) The specimen was extracted through the anus (Fig. 1c). After extracting the specimen, a stapled end-to-end coloanal anastomosis (Fig. 1d) was fashioned, while a protective ileostomy was created. The rubber tube was left in place as a pelvic drain and would usually be removed in the postoperative days 3–5 (Fig. 1 *white arrow*), while abdominal drain was not regularly placed.

Result

Totally six patients operated in the dual-mode SPLS–TaTME surgery between July 2014 and March 2015 were included in this study. The detailed demographic characteristics, operative outcomes and pathologic results of the patients are summarized in Table 1. Apart from one female patient, the other five patients were males. Their median age was 68 years (range 55–80). None of them were obese patients (BMI < 30 kg/m^2). The biopsied proven adenocarcinomas were all located in low rectum with a median distance from anal verge of 4.0 cm (range 3–6). One patient with a history of prostatectomy for prostate cancer presented splenic mass (Fig. 2). Metastasis could not be excluded, and an extra splenectomy was planned. Due to the locally advanced stage of tumors, case 2, 3 and 6 underwent neoadjuvant therapy. In the case requiring splenectomy, the spleen was not morcellated and extracted transanally (Fig. 2b). Median operative time of these six patients was 360 min (range 310–420). The case requiring splenectomy was the most time-consuming with an estimated blood loss of 800 ml due to a massive hemorrhage when mobilizing the gastrosplenic ligament, which necessitated a transfusion postoperatively. The splenic tumor was not a metastasis but an inflammatory myofibroblastic tumor that was characterized by proliferation of spindle cells with variable inflammatory cells, according to the pathologic (Fig. 2c) and immunostaining results (Actin++, CD 21+, CD 23+, ALK+, Desmin−, not shown in figure). The mesorectal fascia was intact, and the distal and circumferential margins were uninvolved in all patients. The median number of the harvested lymph nodes was 11.5 (range 4–12). The pathologic TNM stage is listed in Table 1. In the fourth case, we did not fashion a protective ileostomy because the patient asked for no stoma and during operation his risk of leak was not estimated high. As for postoperative recovery, the median time of recovering to flatus was 3.5 days (range 3–4). All patients recovered uneventfully except the first case who experienced an acute myocardial infarction in the postoperative day 3 which was treated conservatively. Up till now, after a short-term follow-up (median 4 months, range 3–9 months), all ileostomies had been closed without complications, and all the six patients have been free of recurrence and are fully continent.

Discussion

The quest of less surgical trauma has been an important direction of current abdominal surgery. So the progress of multiple-port laparoscopic surgery (MPLS) to single-port

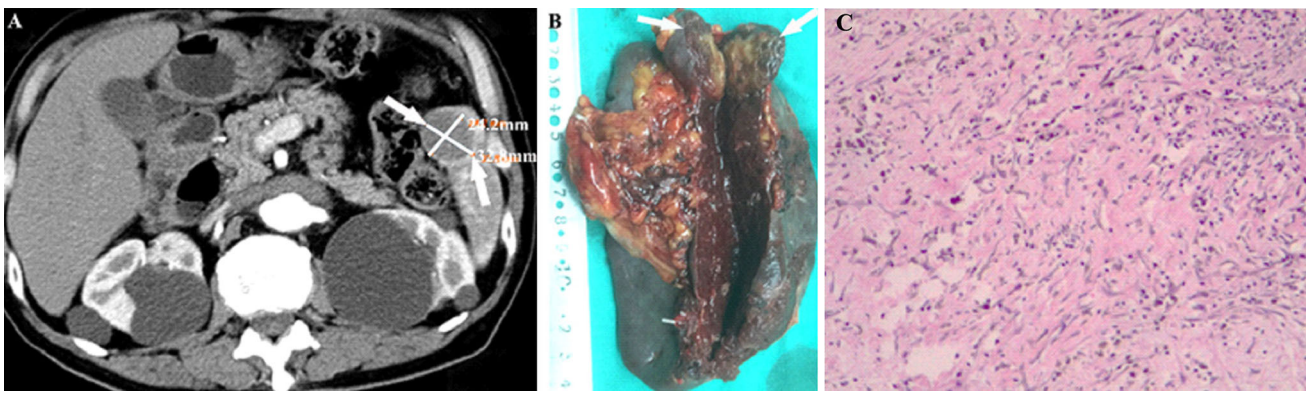

Fig. 2 **a** Well-demarcated and non-enhanced mass (32 × 24 mm) located in the upper pole of spleen (*white arrow*) was shown in abdominal CT scan. **b** Gross specimen showing the tumor in the cut-opened spleen and **c** optical microscopy at low power showing the hematoxylin–eosin-stained lesion of the spleen. Spindle cell proliferated in a collagenous stroma, predominantly infiltrated by an admixture of inflammatory cells

Table 2 Comparison of the three previous studies using SPLS–TaTME technique with the present study

Author	Tuech et al. [12]	Dumont et al. [5]	Velthuis et al. [11]	Our study
Published year	2010	2012	2013	
Case no.	1	4	5	6
Age (years)	45	65.5 (60–76)[b]	69 (36–79)[b]	68 (55–80)[b]
Gender	F	4M	3M/2F	5M/1F
BMI (kg/m^2)	20	23.2 (22.4–24.5)[b]	NR	22.78 (19.37–27.76)[b]
Distance from anal verge (cm)	3[a]	5 (4–7)[b]	6 (5–8)[b]	4 (3–6)[b]
Neoadjuvant therapy	No	All patients	All patients	3/6
Transanal platform	Endorec	GelPoint	SILS	SILS
Operative time (min)	300	360 (270–460)[b]	175 (160–194)[b]	360 (310–420)[b]
EBL (ml)	NR	175 (50–300)[b]	NR	150 (50–800)[b]
Location of single port	Ileostomy site	Ileostomy site	Ileostomy site	Ileostomy site
Mobilization of splenic flexure	Yes	Yes	No	3/6
Conversion	No	No	One case needed two extra 5-mm trocars	No
Complications	No	Anastomotic fistula (1)	Pneumatosis, small bowel ileus, pneumonia (1); presacral abscess (1)	Acute myocardial infarction (1)
Anastomosis	Handsewn CAA	Handsewn CAA	Handsewn CAA (2); stapled CAA(3)	Stapled CAA
Tumor stage	pT1sm3N0M0	cT3N0-1M0	ypT0-3N0-1M0	ypT0-3N0-1M0
Length (cm)	20	NR	NR	10.75 (7.5–13)[b]
Lymph node no.	15	16 (8–22)[b]	12 (11–17)[b]	11.5 (4–12)[b]
Quality of mesorectum	NR	Good (100 %)	Intact (100 %)	Intact (100 %)
LOS (days)	NR	13 (10–21)[b]	NR	10.5 (9–20)[b]
Remark	The first case reported	Specifically enrolled male patients with narrow pelvis	Using a combination of SILS achieved intact mesorectal fascia and clear resection margins in all specimens	A combined splenectomy was performed in one case

No. number, *F* female, *M* male, *BMI* body mass index, *Endorec* endorec trocar (Aspide France), *GelPoint* GelPoint device (Applied Medical, Rancho Santa Margarita, CA, USA), *SILS* SILS Port (Covidien, Mansfield, MA), *EBL* estimated blood loss, *CAA* coloanal anastomosis, *Length* length of fixed specimen, *LOS* length of hospital stay, *NR* not reported

[a] Distance from the dentate line

[b] Data are expressed as median (range)

laparoscopic surgery (SPLS), to natural orifice transluminal endoscopic surgery (NOTES)—so called "no-scar" surgery, represents a logical and important developing route. Although the feasibility of SPLS for colon cancer has been well demonstrated [13], SPLS for rectal cancer, particularly for cancer lying in the distal rectum, is definitely more difficult and challenging [3, 14, 15]. NOTES in the field of rectal surgery was more of an ideal concept rather than a general practice before the advent of TaTME. The emerging of TaTME makes it possible to resect the diseased rectum through the anus without difficulty of opening the vagina or enlarging the stoma site [8]. The preferred TaTME platform is the disposable multi-channels single-port (TAMIS) [16]. However, TaTME performed totally in a transanal with the division of the inferior mesenteric vessels and mobilization of the proximal colon and splenic flexure can be challenging [17]. That is why in subsequent cadaveric studies, laparoscopic assistance through the abdomen was introduced (TAMIS-assisted) [18]. Many surgical teams still prefer to use the standard

MPLS as assistance on human patients, that s probably because it is considered easier and more straightforward than SPLS assistance. In fact, some authors have employed a SPLS-assisted technique in which they used a single-port plus one or more extra trocars, which, strictly speaking, represents MPLS assistance [18, 19].

However, as shown in Table 2, some surgical teams have already shown the feasibility of the pure SPLS–TaTME technique. In 2011, Tuech et al. [12] reported the first case of a 45-year-old female using two endorec trocars (Aspide France). Recently, they reported a large case series of TaTME in a study ($n = 56$) with eight cases operated by SPLS–TaTME technique (no detailed information provided) [4]. In 2012, Dumont et al. [5] specifically enrolled four consecutive male patients with narrow pelvis in a small study and concluded that SPLS–TaTME approach might be easier and safer to operate than traditional approach. Similar to us, in 2013, Velthuis et al. [11] reported five cases using two *SILS* ports, which all achieved clear surgical margins and intact mesorectal fascia.

Given the fact that totally more than 10 cases of pure TaTME without laparoscopic assistance have been reported so far [20–22], pure TaTME is no longer regarded as a mission impossible. Therefore, it is rational to hypothesize that if the majority of operation including the most difficult part encountered by conventional laparoscopic surgery—the mobilization of the extraperitoneal rectum could be completed by the transanal approach, the abdominal assistance would become much easier and less important, even be neglected in selected patients. Thus, SPLS assistance might be adequate. A direct comparison between SPLS–TaTME and MPLS–TaTME is needed. In fact, previous studies have utilized both approaches, e.g., Tuech et al. [4], Velthuis et al. [23], Sourrouille et al. [7] and Chouillard et al. [20]. Unfortunately, none of them made such a subgroup comparison, which might be due to the limited sample size. Herein, we made a list of several theoretical advantages and disadvantages among SPLS–TaTME, MPLS–TaTME and conventional SPLS (Table 3).

Our results are comparable to the studies using SPLS–TaTME technique (Table 2). Furthermore, we presented

Table 3 Comparisons among SPLS–TaTME, MPLS–TaTME and conventional SPLS for low rectal cancer surgery

	MPLS–TaTME	SPLS–TaTME	Conventional SPLS
Platforms	Transanal and transabdominal portions	Transanal and transabdominal portions	Only transabdominal portion
Transanal platform	Yes[a]	Yes	No
Transabdominal port	2–4 rigid single-channel ports (10, 5 mm)	One flexible multichannel port	One flexible multichannel port
Cost of platforms	++	+++[b]	++
Placed site of port	Umbilicus, other quadrants	Site of planned ileostomy	Usually umbilicus
Gas tightness	++−	+−[c]	+
Specimen extraction	Mostly transanally[d]	Mostly transanally	Transabdominally
Number of staplers used	0–1[d]	0–1	Usually 2
Operative direction	↓, ↑, ↕[e]	↓, ↑, ↕	↓
Operative difficulty	+−	++−	++[f]
Invasiveness	++	+	+++[g]
Cosmetic effect	++	+[h]	+
Hernia formation	++	+[i]	+++

Many variables (e.g., operative time, complications, postoperative pain, recovery process, learning curve, total cost) could not be acquired, yet further studies are needed in the future

[a] Currently only two ports are approved by Food and Drug Administration for transanal minimally invasive surgery (TAMIS), i.e., *SILS*, GelPoint Path [16]

[b] Single-port device is more expensive than standard trocars

[c] Stability of single-port device and transanal platform may be unsatisfactory with intermittent loss of pneumoperitoneum

[d] Mostly TaTME surgery extracts specimen through the anus without transecting the rectum intracorporeally by a stapler, and some cases utilize handsewn coloanal anastomosis, while standard SPLS usually uses double-stapler technique (DST)

[e] ↓ refers to up to down; ↑ refers to down to up; ↕ refers to both directions simultaneously

[f] Theoretically, SPLS is the most difficult, due to the "chopsticks effect"—confined working space and crowding of instruments; Regardless of SPLS or MPLS assistance, TaTME provides a solution to reduce operative difficulty

[g] Although MPLS–TaTME employs more trocars, SPLS requires a small abdominal incision (*Pfannenstiel* incision) to extract specimen

[h] Cosmetic effect is actually hard to evaluate and relies on subjective body image and scar scale and there are very limited literatures showing that single-port laparoscopic surgery has better cosmetic effect

[i] Laparoscopic single-port surgery may increase chance for hernia formation if single-port is not placed in the planned ileostomy

the first case combined a splenectomy with SPLS–TaTME. The specimen was extracted through the anus, which represented a better embodiment of NOTES. This case was more time-consuming, but bleeding was managed without adding extra trocars or converting to open laparotomy. Given that the single-port placement is similar, liver resection may also be attempted with this method.

Despite SPLS–TaTME being more costly as shown in Table 3, it might be superior to the pure SPLS or pure TaTME technique with respect to the operative complexity and difficulty in low rectal cancer. As for considerations of economics and asepsis, we wonder whether it is feasible to complete the abdominal portion first, and then perform TaTME by transferring down to reuse the same port.

The present study has several limitations. First of all, the small sample size. Second, none of the patients in the present series were obese, which increases operative difficulty. Third, despite the fact that we suggested SPLS–TaTME is more minimally invasive, we could not make a direct comparison with MPLS–TaTME or conventional rectal surgery regarding postoperative pain, trauma-induced inflammatory response [24], or body image and scar scale [5]. Last but not least, due to the limited follow-up, we could not draw any conclusion about the oncologic and functional outcomes of this technique, particularly given the fact that the benefits of TaTME itself have not been adequately proven.

Conclusion

In conclusion, this study demonstrated that SPLS–TaTME technique is safe and feasible in low rectal cancer in selected patients. Further studies with larger sample size and long-term results including oncologic and functional outcomes are warranted in future.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and with the ethical standards of Helsinki declaration.

Informed consent Informed consent was obtained from all individual participants included in the study. Patients also gave permission for publication of technique and results.

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