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Laparoscopic transanal minimally invasive surgery (L-TAMIS) versus robotic TAMIS (R-TAMIS): short-term outcomes and costs of a comparative study

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Abstract

Background Transanal minimally invasive surgery (TAMIS) has gained worldwide popularity as a method for the local excision of rectal neoplasms. However, it is technically demanding due to limited working space. Robotic TAMIS offers potential enhanced dexterity and ability while allowing for a more aggressive resection with a stable platform. The objective of this study was to review a single institution experience between laparoscopic (L-TAMIS) and robotic TAMIS (R-TAMIS) for treatment of rectal neoplasms and determine if there are significant differences on outcomes.

Methods Forty consecutive patients with rectal neoplasms underwent L-TAMIS or R-TAMIS by two colorectal surgeons from January 2012 to April 2017. We retrospectively reviewed a prospectively maintained database to analyze demographics, peri-operative data, pathology, post-operative complications, and cost.

Results There were no significant differences between L- and R-TAMIS on patient demographics. R-TAMIS showed a statically significant increase in cost of surgery by $880. Median direct cost of L-TAMIS was $3562 compared to $4440.92 for R-TAMIS ($p=0.04$). Wider range of total duration for L-TAMIS is likely due to the variability of body habitus and location of rectal neoplasm, which can significantly limit L-TAMIS compare to R-TAMIS. There was a trend toward decreased blood loss in the R-TAMIS group. Mortality was 0% in both groups.

Conclusions After reviewing our experience, we conclude there is no significant difference between L- and R-TAMIS other than total direct cost. We confirmed that both L- and R-TAMIS are safe and associated with low morbidity. The limitations of this study include its small sample size. In the future, we hope to show promising data on R-TAMIS with increased sample size and experience, which may allow for transanal resection not previously feasible. Studies with long-term follow-up assessing oncological and functional results will be mandatory.

Keywords Transanal minimally invasive surgery (TAMIS) · Robotic TAMIS

Historically, benign or early-stage rectal cancers located short distances from the anal verge were often amenable to local resection utilizing conventional transanal excision (TAE) techniques with anoscopic instrumentation. This approach is often challenging due to difficulties with exposure and visibility within the rectal lumen, often compromising the surgeon's ability to obtain a high-quality oncologic resection. Moreover, lesions in the proximal rectum were often inaccessible with TAE leading to recommendations for major abdominal and perineal resections thus increasing risk of significant morbidity to patients.

The limitations of TAE led to the development of novel and more advanced platforms for local resection of these rectal neoplasms. This included transanal endoscopic microsurgery (TEM), pioneered by Buess in the 1980s. In 2008, Moore et al. described a 15 year retrospective study demonstrating improved outcomes with TEM over TAE. This report demonstrated a higher rate of negative margins (90 vs. 71%, $p=0.001$), increased numbers of non-fragmented specimens (94 vs. 65%, $p<0.001$), and decreased recurrence

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over a mean 37 month follow-up (5 vs. 27%, $p = 0.004$) [1]. Multiple other studies have demonstrated superiority of TEM over TAE [2–5]. Despite seemingly superior outcomes with TEM, this modality has not been widely accepted secondary to the learning curve and the significant upfront cost of TEM instrumentation [6].

With the advancement of Natural Orifice Transluminal Endoscopic Surgery (NOTES), transanal minimally invasive surgery (TAMIS) was introduced in 2009 as alternative to TEM [7]. Since its introduction, TAMIS has gained worldwide popularity as an additional option for the local excision of rectal neoplasms. This procedure utilizes a laparoscopic platform similar to single incision laparoscopic surgery and is more readily available without the requirements and upfront cost of the TEM platform, making it more accessible for surgeons interested in offering local resection for appropriate rectal neoplasms.

The success and inherent limitations of laparoscopic TAMIS led to the utilization of the robotic platform in an effort to improve the feasibility of TAMIS. The robotic platform may allow local resection of lesions previously inaccessible or unresectable by TEM or laparoscopic TAMIS standards. The advantages of robotic surgical systems transcend multiple surgical disciplines and include 3-dimensional imaging, fine motion scaling, articulated instruments providing excellent dexterity, and a stable surgeon controlled camera platform. Few studies have demonstrated the safety, feasibility, and outcomes of robotic TAMIS [8–13].

Short-term data on oncologic outcomes and clinical effectiveness of TAMIS have been promising [7, 14–22]. There are no current comparative studies looking at L-TAMIS vs. R-TAMIS. Much of the data from both techniques come from single center case reports. Therefore, more data are needed to validate the outcomes and generalizability of TAMIS for rectal neoplasms conducted both laparoscopically and robotically. The objective of this study was to review a single institution experience between laparoscopic and robotic TAMIS for treatment of rectal neoplasms in an effort to determine if there are significant differences in short-term outcomes and clinical effectiveness. Our hypothesis was that R-TAMIS would be an efficient and effective technique for curative resection of appropriate rectal neoplasms with outcomes equivalent to L-TAMIS.

Patients and methods

We analyzed 40 patients with rectal neoplasms who were candidates for local resection after pathologic review and standard workup from January 2012 to April 2017. These patients underwent L-TAMIS or R-TAMIS by two colorectal surgeons at a single institution. We retrospectively reviewed a prospectively maintained database to analyze demographics, peri-operative data, pathology, post-operative complications, and cost.

Pre-operatively, patients received mechanical bowel preparation with oral antibiotics and prophylactic antibiotics parentally 30 min prior to incision. Two academic board certified colorectal surgeons at a tertiary-care hospital performed the procedures. All procedures were performed under general anesthesia. Patients were placed in prone jack-knife position, lithotomy, or lateral decubitus position depending on position and location of the rectal lesion. Limited or full colonoscopy was routinely performed prior to resection to confirm the location of rectal lesion(s), feasibility of local resection, and/or to remove additional colon polyp(s). Once the location of the rectal neoplasm was confirmed, the patients were positioned appropriately. For L-TAMIS, patient was positioned such that the lesion is in the dependent portion for ease of laparoscopic suturing. This included lithotomy, prone, left lateral and right lateral positions. R-TAMIS patients were positioned in the lithotomy or prone positions. In our experience, we found less robotic arm collision with the patient in the prone position. However, prone positioning makes posterior based lesions slightly more difficult resection and closure of the full-thickness defect. For patient selection criteria, L-TAMIS was first available and first performed in August 2012 and R-TAMIS was first performed in January of 2016. This was related to the R-TAMIS not being previously reported in the literature. Cost was not an issue in selection of L-TAMIS or R-TAMIS. The location of the neoplasm was not considered as a selection criteria. The size of the lesion was considered as a selection criteria for feasibility of TAMIS in general. The decision to utilize the robotic platform originated from the effort to address inherent difficulties with the laparoscopic platform, to include arm collision, stability, lesion accessibility, and ease of defect closure. There were no additional selection criteria among patients or lesions, which dictated the utilization of either platform. Thus, patients received laparoscopic or robotic TAMIS depending on availability of the robotic platform, or surgeon preference (da Vinci® Si or Xi surgical system, Intuitive Surgery, Sunnyvale, California, USA). We utilized the commercially available transanal GelPOINT Path (Applied Medical, Rancho Santa Margarita, CA) platform. Surgical resection was performed with 5 mm to 1 cm margins circumferentially while ensuring full-thickness excision with either laparoscopic needle point electrocautery or robotic scissors. The defect was closed with running barbed suture to prevent narrowing of the lumen. The closure was inspected endoscopically to ensure closure and to allow for free passage of the colonoscope. We routinely performed bilateral pudendal and perianal nerve block for post-operative pain control. Patients were discharged home the same day and selectively admitted post-operatively, depending on case complexity and the patient's co-morbidities. Most patients were discharged same day unless they had violation of the intraperitoneal cavity or other co-morbidities necessitating 24 h monitoring or disposition to a skilled nursing facility.

Demographic, peri-operative, short-term outcomes and cost data were analyzed. Data fields evaluated included patient age, sex, BMI, American Society of Anesthesiologists (ASA) score, operative time, blood loss, tumor distance from the anal verge, discharge disposition, intra- and post-operative complications, and mortality. Chi square tests were used to compare independent groups on categorical outcomes. The assumption of normality was tested for continuous distributions using skewness and kurtosis statistics. Any distribution with a skewness or kurtosis statistic above an absolute value of 2.0 was assumed to be non-normal. In the event that a statistical assumption was violated, non-parametric Mann–Whitney U tests were employed for between-subjects comparisons (total direct cost, LOS, EBL). Medians and interquartile ranges were reported for non-parametric analyses. When statistical assumptions were met, independent samples *t*-tests were used to compare groups on continuous outcomes. Means and standard deviations were reported for parametric tests. A Bonferroni-adjusted alpha value was used to assume statistical significance in order to account for increased experiment wise error rates when testing multiple hypotheses concurrently. All statistical analyses were conducted using SPSS Version 21 (Armonk, NY: IBM Corp.).

Table 1 Demographics of patient

Demographic	L-TAMIS $n=21$	R-TAMIS $n=19$	*p*-value
Age at surgery	65.09	67.20	0.79
ASA	2.59	2.75	0.38
BMI	28.52	29.52	0.69
Male:female (%)	55.20	66.70	0.73

Results

Forty consecutive patients underwent either L-TAMIS or R-TAMIS resection of benign and malignant rectal neoplasms between January 2012 and April 2017. Of note, the learning curve was established for L-TAMIS when adoption of R-TAMIS began in January 2016 shortly after R-TAMIS proved feasible in the literature. There was no significant difference between L- and R-TAMIS on patient demographics. Mean age of L-TAMIS was 65 years old and R-TAMIS 67 years old. Also, ASA and BMI of patients were similar between L-TAMIS and R-TAMIS. The summary of demographics of patient is on Table 1.

The peri-operative variables are shown in Table 2. The median time for both L- and R-TAMIS was similar at approximately 100 min with *p*-value of 0.7. Distance from anal verge was similar 7.8 cm for L-TAMIS and 8.2 cm for R-TAMIS. However, this was not statically significant with *p*-value of 0.56. For L-TAMIS, we positioned the patient with the neoplasm was oriented in the dependent position. For R-TAMIS, most patients were placed in prone position to minimize robotic arm collision except patients with posterior

Table 2 Peri-operative data of L-TAMIS vs. R-TAMIS

Peri-operative data	L-TAMIS $n=21$		R-TAMIS $n=19$		*p*-value
	Median	Interquartile range	Median	Interquartile range	
Total duration (min)	100	55	102	22	0.70
EBL (mL)	15	45	5	5	0.07
Distance from anal verge (cm)	7.8	2.3	8.2	2.1	0.56
Location of lesion (%)					
Anterior	20.7		41.7		
Right lateral	31.0		16.7		
Left lateral	13.8		25.0		
Posterior	34.5		16.7		
Patient positioning (%)					
Prone	13.8		83.3		
Left lateral	27.6		0		
Right lateral	10.3		0		
Lithotomy	48.3		16.7		
Admit to discharge (h)	10	20	10.5	12	0.77
End of case to discharge (h)	5	18	4	12	0.36
Total direct cost ($)	3562.00	1565.00	4440.92	740.13	0.04

lesion was placed in lithotomy position. The only statistical difference between L- and R-TAMIS was direct cost of the procedure. Median direct cost of L-TAMIS was $3562 compared to $4440.92 for R-TAMIS with p-value of 0.04. Thus, R-TAMIS costs approximately $880 more in direct cost compared to L-TAMIS. Wider range of total duration for L-TAMIS is likely due to the variability of body habitus and location of rectal neoplasm, which can significantly limit L-TAMIS compared to R-TAMIS. Admit to discharge and end of case to discharge was similar for both L- and R-TAMIS.

Histopathologic results of L- and R-TAMIS are shown in Table 3. The majority of patients had a benign adenoma and/or high-grade dysplasia (71.4% in L-TAMIS and 73.7% in R-TAMIS). Four out of 21 patients in L-TAMIS had invasive adenocarcinoma with one patient from each T0 and T1 and 2 patients with T2 stage. R-TAMIS had 5 patients out of 19 patients with invasive adenocarcinoma with 3 patients with T1 stage and 2 patients with T2 stage. Of note, one patient had grade 2 neuroendocrine tumor invading into the submucosa and another patient with a T2 gastrointestinal stromal tumor were resected utilizing L-TAMIS. R0 resection was achieved at a higher rate on R-TAMIS with 94.74% compare to 90.48% with L-TAMIS, although this was not statistically significant. Specimen size (cm^2) was compared between L- and R-TAMIS, and both had a mean size of 17 cm^2 with varying range. Smaller specimen sizes were related to few patients have re-excision of polypectomy sites.

Table 4 summarizes the complications of both L- and R-TAMIS. One L-TAMIS required abdominal laparoscopy to complete a 2-layer closure of the intraperitoneal proctotomy made during full-thickness excision and to provide an air insufflation leak test. The patient was discharged post-operative day 2. The rectal lesion was 12.5 cm from anal verge. This increased the direct cost of the L-TAMIS to $8510 which was about a $5000 increase in direct cost compared to the median cost of other L-TAMIS. One patient from each L- and R-TAMIS required temporary urinary catheterization for urinary retention. Three patients underwent subsequent radical resection due to advanced malignancy. Mortality was 0% in both groups. There was no readmission identified related to our surgery on both L- and R-TAMIS.

Table 3 Histopathologic results of L- and R-TAMIS

Histopathologic results	L-TAMIS $n=21$	R-TAMIS $n=19$
Benign adenoma, *n* (%)	15 (71.4)	14 (73.7)
Adenocarcinoma, *n* (%)	4 (19.0)	5 (26.3)
T0, *n*	1	0
T1, *n*	1	3
T2, *n*	2	2
Neuroendocrine, *n* (%)	1 (4.8)	0
Gastrointestinal stromal tumor, *n* (%)	1 (4.8)	0
Mean specimen surface in cm^2 (range)	17 (2.1–55.04)	17 (3.23–28.4)
R0 resection	90.48%	94.74%

Table 4 Complications of L-TAMIS and R-TAMIS

Complications	L-TAMIS	R-TAMIS	Total (%)
Urinary retention, *n* (%)	1 (4.76)	1 (5.26)	5
Abdominal laparoscopic closure of defect, *n* (%)	1 (4.76)	0 (0)	2.5
Mortality	0%	0%	0
Readmission	0%	0%	0

Discussion

The local excision for rectal neoplasms has evolved significantly since the Parks technique described in 1968. TEM was first described by Buess et al. [23]. Several studies have demonstrated TEM as oncologically superior to transanal excision of rectal neoplasms [1, 3] Since the first experimental report of transanal rectosigmoid resection in 2007, the potential impact of transanal NOTES in colorectal surgery has been extensively investigated in experimental models and recently transitioned to clinical application.

Several additional studies have documented the feasibility and safety of TAMIS [7, 14–22]. One of the first large series published by Albert and Atallah [21], included 50 patients (25 benign neoplasms, 23 malignant lesions, and 2 neuroendocrine tumors). In this study with a 20-month follow-up, the overall loco-regional recurrence rate was 4.3%. Positive margins were demonstrated in 6% of the specimens [21]. A more recent larger series by Keller and Haas outlines 75 patients (59 benign, 17 malignant lesions) with a median follow-up of 39.5 months. Positive margins were evident in 6.6% of patients and only one patient developed recurrence at the conclusion of the review period. Three patients had intraperitoneal entry and all were able to be closed transanally [18].

There have been multiple studies comparing TEM to TAMIS which have recently been reported. Lee et al. reported the largest multi-institutional matched cohort consisting of 428 patients (247 with TEM and 181 with TAMIS). TAMIS was associated with shorter operative time and length of stay. Poor quality excision was similar (8% vs. 11%; $p=0.233$). There were also no differences in peritoneal violation (3% vs. 3%; $p=0.965$) and post-operative complications (11% vs. 9%; $p=0.477$). Cumulative 5-year disease-free survival for patients undergoing transanal endoscopic microsurgery was 80% compared with 78% for patients undergoing transanal minimally invasive surgery (log rank $p = 0.824$). The incidence of local recurrence for patients with malignancy who did not undergo immediate salvage surgery was 7% (8/117) for TEM and 7% (7/94) for TAMIS ($p = 0.864$). Their overall conclusion was that the choice of operating platform for local excisions of rectal neoplasms should be based on surgeon preference, availability, and cost [24].

In 2018, Lee et al. demonstrated the learning curve of TAMIS for local excision of rectal neoplasms. They analyzed 254 TAMIS procedures, with an overall R1 resection rate of 7%. Among those resected, 57% of the cases were conducted for malignancy. TAMIS reached an acceptable R1 rate between 14 and 24 cases. Moving average plots also showed that the mean operative times stabilized by proficiency gain [14]. We had a positive margin on final pathology in two of our L-TAMIS cases and 1 of our R-TAMIS cases. The duration of our operative interventions in both groups was similar with median operative times of approximately 100 min. Based on the above study, we believe that R0 resection percentage will improve and operative times will shorten as our experience increases.

The safety, feasibility, and short-term outcomes have been previously described in a limited number of R-TAMIS publications [8–13]. Atallah et al. described R-TAMIS in a cadaveric model [8]. Hompes et al. had the one of the first the series of 16 consecutive R-TAMIS procedures conducted at three centers. The median distance from the anal verge was 8 cm with a median size of the resected specimen being 5.3 cm^2. Median operative time was 108 min with an average length of stay of hospitalization of 1.4 days. The additional cost of the robot was approximately 1000 euros (excluding the capital expenditure on the robotic system and its maintenance) [9].

Gomez et al. described a series of 9 patients, median of 6.22 cm from anal verge, 15.8 cm^2, operative time 71.9 min, and with all procedures in the lithotomy position. Median hospital stay was 2.5 days [11]. Liu et al. recently reported the largest series to date of 34 patients. Lesions measured up to 4.5 cm. The average operative time was 100 ± 70 min with robotic console time of 76 ± 67 min. Patients were placed in lithotomy in 32 (94%) cases and were prone in only 2 (6%) cases [12]. Warren et al. recently described technical details regarding R-TAMIS with the Davinci Xi [13].

Our series offers similar R-TAMIS outcomes to the above mentioned studies. We found that prone positioning instead of lithotomy helped with less robotic arm collision externally. However, prone positioning makes the resection and closure of posterior based neoplasms slightly more difficult. As our series progressed, we transitioned to utilizing prone positioning for anterior and laterally located rectal lesions and lithotomy for posterior located rectal neoplasms. For L-TAMIS, the patient was positioned such that the rectal lesion was in the dependent portion for ease of laparoscopic closure of the defect.

R-TAMIS may overcome the limitations of L-TAMIS as well as expanding the indication for local transanal resection, precluding the need for proctectomy. Based on our experience, L-TAMIS is technically and ergonomically demanding secondary to working in a limited space. Subjectively, R-TAMIS allows seated surgeons with optimized ergonomic position. Moreover, it does allow for increased ease of suturing compared to L-TAMIS and a more aggressive approach with respect to resection of rectal neoplasms.

There is a paucity of literature comparing robotic and laparoscopic TAMIS. After reviewing our experience, we conclude there is no significant difference between L- and R-TAMIS in terms of peri-operative parameters and 30 day post-operative complications other than total direct cost. Nevertheless, this only counts for direct cost of the procedure with no data for indirect cost, which includes anesthesia, facility cost, administrative cost and others. As we improved our technique with R-TAMIS, we saw the trend of total time duration of the case decreasing. Moreover, in certain cases we were able to be more aggressive with our resection of certain lesions with the aid of a robotic platform which allowed for better visualization and maneuverability. We believe that in a well-selected patient population, R-TAMIS may save patients from radical resection such as low anterior resection or abdominoperineal resection. We confirmed that both L- and R-TAMIS are safe and associated with low morbidity.

Our data demonstrate that L-TAMIS is $880 less costly in comparison to R-TAMIS. This is due to the cost of the robotic instruments. Juxtaposing this savings with quicker recovery, accurate diagnosis/treatment of benign polyps, and avoided risks of formal colectomy, R-TAMIS improves the Value of the care delivered, with Value defined as (outcomes + quality)/cost [25].

The findings related to higher hospital costs associated with robotic surgery are consistent with similar studies in the literature evaluating other laparoscopic surgical procedures. Although there is a difference in hospital charges versus costs, charges are directly correlated to costs, and the trend is still the same, with robotic surgery consistently demonstrating increased costs. For example, Davis et al. demonstrated inpatient procedures with robotic assistance were significantly more costly than those without robotic assistance ($17,445 vs. $15,448, $p = 0.001$) [26]. Although these are inpatient surgeries, these results do provide directional understanding of cost comparisons for other robotic-assisted minimally invasive procedures.

We recognize the limitations with TAMIS and with our study. First, TAMIS has long-term clinical and oncologic outcomes still pending. To date, TAMIS has been found safe and feasible for benign lesions and selected, early-stage malignancies of the mid and distal rectum. In this study specifically, the study design was a retrospective review and was subject to the inherent biases of the study design. Last our sample size was small in each arm.

Despite a paucity of comparative data including long-term oncologic and functional data, TAMIS is a safe and effective means of local resection for benign and favorable early-stage (T1) cancers following adequate workup for rectal neoplasms. It can be used to define T-stage pathology for indeterminate T-staged lesions. T1 lesions exhibiting adverse pathologic features and greater than T2 lesions should be offered radical resection. It may also be used as palliative resection for T3 cancers in patients medically unfit or unwilling to undergo an oncologic resection. Furthermore, TAMIS resection can confirm complete pathologic response after neoadjuvant chemotherapy and radiation. The TAMIS platform is most advantageous for mid- and distal rectal lesions that are unable to be removed with the colonoscope. The R-TAMIS platform makes access for endoluminal surgery of the rectum straightforward, and expansion of its applications is expected to continue. Our study represents one of the first to compare outcomes of traditional laparoscopic TAMIS to robotic TAMIS, adding diversity and further supporting previous outcome reports. In the future, we hope to show promising data on R-TAMIS with increased sample size and experience, which may allow for transanal resection not previously feasible due to location and limitation of the L-TAMIS platform. Studies with long-term follow-up assessing oncological and functional results will be mandatory.

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Compliance with ethical standards

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