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Original Article

Outcomes of robotic low anterior resection *versus* transanal total mesorectal excision for rectal cancer

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Abstract

Background: The quality of total mesorectal excision (TME) is regarded as a fundamental key to the oncological outcome of rectal cancer. Robotic low anterior resection (RLAR) and transanal TME (TaTME) were developed to overcome the technical challenges of conventional open TME. This study aimed to compare the short- and long-term outcomes of RLAR *versus* TaTME for rectal cancer.

Methods: Retrospective data from patients undergoing RLAR or TaTME at a colorectal unit in Singapore were analysed. The primary outcomes were the short-term clinical and pathological results including specimen margins and quality of TME. Secondary outcomes were recurrence, disease-free survival (DFS), and overall survival rates.

Results: A total of 80 patients who underwent either RLAR or TaTME were analysed. The TaTME group had a shorter operating time than the RLAR group (354 *versus* 481 min respectively; $P < 0.001$) and fewer stays in the high-dependency and intensive care units (38.1 *versus* 73.7 per cent; $P = 0.010$). There was a higher rate of readmissions at 30 days in the TaTME group (19.0 *versus* 0 per cent; $P = 0.006$). Specimens from TaTME had greater proximal (14.0 *versus* 10.0 cm; $P = 0.045$) and distal (2.50 *versus* 1.65 cm; $P = 0.021$) margins. Patients undergoing TaTME had borderline longer DFS (25.9 *versus* 15.7 months; $P = 0.049$). Subgroup analysis of patients with (y)pT3–4 tumours showed fewer positive circumferential resection margins with TaTME (0 *versus* 18.2 per cent; $P = 0.019$) and improved DFS (25.9 *versus* 15.7 months; $P = 0.017$).

Conclusion: Superior margins were obtained with TaTME, especially in locally advanced tumours, although TaTME was associated with a higher readmission rate compared with RLAR.

Introduction

The optimal surgical approach to rectal cancer remains a topic of debate. Distinct anatomical challenges of middle and lower rectal tumours are characterized by difficult entry into a confined location and poor surgical manoeuvrability, accentuated by various factors such as a narrow pelvis, raised BMI, and bulky tumours. Consequently, poor mesorectal plane visualization and relatively greater association with circumferential resection margin (CRM) involvement have compromised optimal oncological outcomes[1,2]. Transanal total mesorectal excision (TaTME) was developed in the past decade to redefine surgical management of rectal cancer.

Since Heald described the technique in 1979[2,3], the advent of minimally invasive surgery has brought forth the transition of total mesorectal excision (TME) from an open to a laparoscopic approach[4–6].

The laparoscopic approach achieved similar oncological outcomes and comparable surgical safety to the open approach[7,8], as demonstrated in the COLOR II trial[9]. However, both approaches still faced limitations in achieving complete TME and a negative CRM[1,7,10]. This drove the development of newer techniques such as robotic low anterior resection (RLAR)[11] and TaTME[12] as promising alternatives.

In most comparative studies of robotic *versus* laparoscopic rectal cancer surgery, there were no significant differences in oncological outcomes, or short- and long-term postoperative complications[13–15]. This was reinforced by the results of the ROLARR trial[16], whose authors found no significant reduction in risk of conversion to open surgery and no significant differences in the secondary outcome of CRM positivity rate.

TaTME was a natural evolution of natural orifice transluminal endoscopic surgery and the transanal approach, which began with techniques such as transanal endoscopic microsurgery and transanal minimally invasive surgery. Since the first case series[17] demonstrated oncological safety, there has been an increasing interest in the use of TaTME and where it fits into the colorectal surgeon's armamentarium. The TaTME International Registry[2] also provided encouraging data, with an incomplete TME rate of 4.1 per cent and R1 resection rate of 2.7 per cent. Since then, TaTME has been demonstrated in several case series to produce postoperative clinical and pathological outcomes equivalent to those of laparoscopic rectal surgery[18,19].

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Conversely, recent controversy regarding the reliability of TaTME has also been highlighted. An unusually high rate of local recurrence after TaTME in several Norwegian centres (9.5 per cent at a median follow-up of 11 months among 110 patients) led to a moratorium on the technique until auditing is complete[20,21]. This is in contrast to a study[22] in two Dutch centres, which reported relatively lower local recurrence rates of 2.0 per cent at 3 years and 4.0 per cent at 5 years.

Several hypotheses have been proposed to explain the differences in results, including the number of the centres practising the procedures, technical quality, and the learning curves. Stringent patient selection, structured training, and frequent performance of TaTME by high-volume teams have been identified as three areas to improve the outcomes of TaTME[23].

In the literature, comparisons between RLAR and TaTME[24–27] are scant. A meta-analysis[28] of RLAR and TaTME concluded that there was no significant difference in CRM involvement and the quality of TME between the two techniques. The results of the ongoing COLOR III trial[29] are also eagerly awaited. The aim of the present study was to compare the short- and long-term outcomes of RLAR and TaTME for rectal cancer.

Methods

This was a retrospective study of a maintained rectal cancer database. Patients who underwent sphincter-preserving RLAR or TaTME for mid and low rectal tumours at the National University Hospital in Singapore, a tertiary referral centre, between January 2015 and August 2020, were identified. Mid-to-low rectal tumours were defined as those with distal borders that were palpable on digital rectal examination and with the epicentre of the tumour below the peritoneal reflection on rectal MRI.

All patients were discussed at a multidisciplinary tumour board meeting comprising colorectal surgeons, radiologists, and medical and radiation oncologists to decide on the need for neoadjuvant therapy. Short-course radiotherapy (SCRT) was administered as 25 Gy in five fractions, whereas long-course chemoradiotherapy (LCCRT) was given as 50–50.4 Gy in 25–28 fractions with capecitabine as a radiosensitizer. The interval between SCRT and surgery was 1 week, whereas that between LCCRT and surgery was 6–8 weeks.

Surgical approach

RLAR was performed with the da Vinci Si ® (Intuitive Surgical, Sunnyvale, California, USA) system in two phases, with redocking as standard practice at this institution. The first phase consisted of left colon mobilization with ligation of the inferior mesenteric artery (IMA) pedicle. The decision between a high tie at the IMA take-off from the aorta *versus* a low tie after the left colic artery bifurcation was left to the surgeon's discretion. The second phase involved redocking of the robotic arms and subsequent pelvic dissection in the TME plane. Distal transection was performed with endoscopic staplers. Extraction of the specimen was via extension of the camera port into a minilaparotomy wound, and proximal transection undertaken over a purse-string applicator. Anastomoses were performed either with a circular stapler or, in the event of very distal transection for low tumours, a handsewn coloanal anastomosis.

TaTME was carried out by two teams working simultaneously. The transabdominal team undertook mobilization of the left colon, ligation of the IMA pedicle, and dissection of the upper half of the TME plane via a standard laparoscopic approach. For the transanal approach, the rectal tumour was first identified transanally and a purse-string suture applied distal to the tumour. Pneumorectum was established using a GelPoint Path Transanal Access platform. Using standard laparoscopic instruments, a circumferential mucosal incision was made distal to the purse-string suture and dissection performed until the TME plane was entered circumferentially. Dissection then proceeded in a caudal to cranial direction until the transabdominal dissection plane was met. The specimen was extracted transanally when possible, and the anastomosis prepared either with circular staplers or handsewn. For both approaches, the decision regarding a defunctioning ileostomy and drain placement was up to the surgeon. Factors affecting the decision about anastomosis included considerations such as the patient's nutritional and premorbid status, the patient's stability on table, vascularity of the proximal colon, and ability to create a tension-free anastomosis.

Postoperative management was in accordance with the department's enhanced recovery after surgery protocols. Routine follow-up after discharge included a clinic visit at 2 weeks, 3 monthly for the first year, 4 monthly for the second year and every 6 months up to 5 years after surgery.

Data collection

All retrospective data were retrieved from the hospital electronic medical records. Baseline data including age, sex, BMI, ASA fitness grade, and Eastern Cooperative Oncology Group functional scores were retrieved. Postoperative clinical outcome data were also recorded, including duration of hospital stay, time to mobilization, presence of ileus (defined as vomiting, obstipation or abdominal distension on postoperative day 3), and other complications such as anastomotic leak. Anastomotic leak was diagnosed either clinically on digital rectal examination when a defect was felt, or radiologically by CT with rectal contrast that demonstrated extravasation of contrast.

Important histological data were retrieved, such as surgical margins (including proximal, distal margins, and CRM), grade of TME, histological grading, response to neoadjuvant therapy, and R0 resection rates.

Outcome measures

Short-term outcomes evaluated included duration of operation, duration of stay, and incidence of postoperative complications. Long-term oncological outcomes such as overall survival (OS, defined as interval from surgery to death from any cause) and disease-free survival (DFS, defined as interval from surgery to either local or systemic recurrence) were also analysed.

Statistical analysis

Data are presented as median (range) for continuous variables and frequency with percentage for categorical variables. χ^2 tests (or Fisher's exact tests, where applicable) were used for comparison of categorical variables and Mann–Whitney *U* tests for continuous variables. Survival data are presented as Kaplan–Meier survival curves. Univariable analysis to obtain hazard ratios with 95 per cent confidence intervals was performed using a Cox regression model. Potentially significant variables with $P < 0.100$ were then selected for multivariable analysis. All statistical analyses were done using SPSS® version 26 (IBM, Armonk, New York, USA).

Results

Some 80 consecutive patients treated during the study period were identified and reviewed, of whom 38 had undergone RLAR

and 42 TaTME for histologically proven adenocarcinoma of the rectum. Baseline demographics are presented in *Table 1*. There were no significant differences in patient characteristics, apart from a greater proportion of patients in the RLAR group who had clinically node-positive disease on the initial staging MRI. However, the final pathology (ypN) was similar in the two groups. Notably, there were no differences in tumour distance from the anal verge and the proportion of patients receiving neoadjuvant therapy.

Comparing surgical characteristics, there was a statistically significantly shortened operating time for TaTME (354 *versus* 481 min; $P < 0.001$) and a greater proportion of patients who had a high tie of the IMA (97.6 *versus* 84.2 per cent; $P = 0.049$) (*Table 2*). More patients in the TaTME group had a complete takedown of the splenic flexure (85.7 *versus* 60.5 per cent; $P = 0.01$) and a handsewn anastomosis (50 *versus* 2.6 per cent; $P < 0.001$). There was no significant difference in the conversion rate, blood loss or stoma creation rates. A total of six patients (4 RLAR, 2 TaTME) had end colostomies created instead of primary colorectal anastomoses.

More patients in the RLAR group had initial stays in the high-dependency unit (HDU) or ICU (73.7 *versus* 38.1 per cent; $P = 0.010$), likely because of the longer operating time and anticipated physiological shifts after surgery. The HDU in this institution is an intermediate care unit where patients undergoing major procedures and those with significant co-morbidities are monitored. The HDU and ICU admissions were not differentiated in this series and, for patients who were admitted to HDU/ICU after operation, there was no significant difference in the number of days before transfer to the general ward. There was also no difference in the postoperative duration of hospital stay after the two procedures, although there was a slightly quicker return of bowel movement in the TaTME group (2 *versus* 3 days; $P = 0.013$).

There was no difference in the rate of anastomotic leaks, wound infections or other major morbidities, defined as those with a Clavien–Dindo grade of III and above (*Table 2*).

Four patients in the TaTME group had complications with a Clavien–Dindo grade of at least III, of whom two had anastomotic leaks, one had a pelvic collection not due to leak requiring drainage, and the last had nosocomial pneumonia requiring

Table 1 Baseline characteristics

	RLAR ($n = 38$)	TaTME ($n = 42$)	P†
Age (years)*	65.5 (43–86)	65.5 (44–84)	0.537‡
Sex			0.341
M	29 (76.3)	28 (66.7)	
F	9 (23.7)	14 (33.3)	
ASA fitness grade			0.070
I	0 (0)	1 (2.4)	
II	26 (68.4)	36 (85.7)	
III	12 (31.6)	5 (11.9)	
ECOG status			0.222
0–2	36 (94.7)	42 (100)	
3–4	2 (5.3)	0	
BMI (kg/m^2)*	23.8 (16.9–38.9)	24.0 (16.8–38.5)	0.973‡
Co-morbidities			
Hypertension	23 (60.5)	20 (47.6)	0.248
Hyperlipidaemia	18 (47.4)	16 (38.1)	0.402
Diabetes mellitus	8 (21.1)	11 (26.2)	0.590
Acute MI/IHD	7 (18.4)	2 (4.8)	0.054
Stroke/TIA	3 (7.9)	2 (4.8)	0.563
COPD/asthma	2 (5.3)	4 (9.5)	0.470
Liver disease	1 (2.7)	2 (5.1)	0.587
Smoking	4 (10.5)	11 (26.2)	0.073
Alcohol	2 (5.3)	4 (9.5)	0.470
CEA (ng/mL)*	3.8 (1–89)	4.1 (1–146)	0.966‡
Distance from anal verge (cm)*	6.0 (3–10)	6.0 (0–13)	0.512‡
Clincal tumour category			0.502
cT0–2	6 (16.2)	4 (9.5)	
cT3–4	31 (83.8)	38 (90.5)	
Clinical node category			< 0.001
cN0	4 (10.8)	22 (52.4)	
cN+	33 (89.2)	20 (47.6)	
Clinical metastasis category			0.918
cM0	36 (94.7)	40 (95.2)	
cM1	2 (5.3)	2 (4.8)	
Clinical stage			0.149
0–II	8 (21.1)	4 (9.5)	
III–IV	30 (78.9)	38 (90.5)	
Neoadjuvant therapy	30 (78.9)	36 (85.7)	0.426
Type of neoadjuvant therapy			0.150
Short-course RT	6 (20)	13 (36.1)	
Long-course CRT	24 (80)	23 (63.9)	

Values in parentheses are percentages unless indicated otherwise; *values are median (range). RLAR, robotic low anterior resection; TaTME, transanal total mesorectal excision. ECOG, Eastern Cooperative Oncology Group; MI, myocardial infarction; IHD, ischaemic heart disease; TIA, transient ischaemic attack; COPD, chronic obstructive pulmonary disease; CEA, carcinoembryonic antigen; RT, radiotherapy; CRT, chemoradiotherapy. †χ^2 or Fisher's exact test, except ‡Mann–Whitney *U* test.

Table 2 Operative details and short-term outcomes

	RLAR ($n = 38$)	TaTME ($n = 42$)	P§
Conversion	1 (2.6)	4 (9.5)	0.362
Duration of operation (min)*	481 (311–832)	354 (200–976)	< 0.001
Inferior mesenteric artery			0.049
High tie	32 (84.2)	41 (97.6)	
Low tie	6 (15.8)	1 (2.4)	
Splenic flexure takedown			0.011
Complete	23 (60.5)	36 (85.7)	
Incomplete	15 (39.5)	6 (14.3)	
Blood loss (ml)*	200 (10–2500)	125 (30–2700)	0.418¶
Type of anastomosis			< 0.001
Stapled	33 (86.8)	19 (45.2)	
Handsewn	1 (2.6)	21 (50)	
Type of stoma			0.099
No stoma	3 (7.9)	0 (0)	
Defunctioning ileostomy	31 (81.6)	40 (95.2)	
End colostomy	4 (10.5)	2 (4.8)	
Duration of postoperative hospital stay (days)*	6.5 (4–82)	6 (3–33)	0.384¶
High-dependency unit/ICU stay	28 (73.7)	16 (38.1)	0.010
Time to general ward (days)*	2 (1–4)	2 (0–6)	0.822¶
Drain inserted	38 (100)	40 (95.2)	0.495
Time to drain removal (days)*	5.5 (3–23)	5 (2–27)	0.283¶
Time to diet (days)*	2 (1–18)	2 (1–9)	0.713¶
Time to first bowel output (days)*	3 (1–5)	2 (1–7)	0.013¶
Urinary retention after catheter removal	3 (8.3)	7 (17.5)	0.238
Time to mobilization (days)*	1.5 (1–5)	2 (1–10)	0.082¶
Postoperative ileus	8 (21.1)	6 (14.3)	0.426
Wound infection			0.125
Superficial	2 (5.3)	1 (2.4)	
Deep	0 (0)	4 (9.5)	
Anastomotic leak	7 (18.4)	4 (9.5)	0.334
Reoperation within 30 days	1 (2.6)†	1 (2.4)†	0.943
Readmission within 30 days	0 (0)	8 (19.0)	0.006
Clavien–Dindo grade of complication			0.505
0–II	32 (84.2)	38 (90.5)	
III–V	6 (15.8)	4 (9.5)	

Values in parentheses are percentages unless indicated otherwise; *values are median (range). †Anastomotic leak requiring examination under anaesthesia and endosponge placement. RLAR, robotic low anterior resection; TaTME, transanal total mesorectal excision. §χ^2 or Fisher's exact test, except ¶Mann–Whitney *U* test.

intubation and ICU admission. In the RLAR group six patients had complications of grade III and above, of whom four had anastomotic leaks, one had a postoperative biloma from a synchronous liver resection, and one had narrowing of the afferent limb of the defunctioning ileostomy that required surgical revision.

There was a significantly greater proportion of readmissions within 30 days in the TaTME group (19.0 *versus* 0 per cent, $P = 0.006$). Among a total of eight readmissions after TaTME, three patients were readmitted because of anastomotic leak, three returned owing to presacral collections without leaks, one had rectal stump dehiscence associated with a collection, and the final patient had a high stoma output.

The TaTME group achieved greater proximal (14.0 *versus* 10.0 cm; $P = 0.045$) and distal (2.50 *versus*1.65 cm; $P = 0.021$) margins. None of the patients had positive distal margins. There was also a greater proportion of patients with locally advanced lesions (defined as (y)pT3 or 4 tumours) in the TaTME group (83.3 *versus* 57.9 per cent; $P = 0.012$). There was otherwise no difference in the CRM distance and positivity rates, completeness of TME, lymph node harvest or pN category. However, on subgroup analysis of locally advanced lesions, TaTME had a significantly lower rate of CRM positivity (0 *versus* 18.2 per cent; $P = 0.019$) (*Table 3*).

Median follow-up was 23.3 months in the RLAR group and 29.1 months in the TaTME group. There was no difference in local and systemic recurrence rates between RLAR and TaTME. The local recurrence rate was 10.5 per cent after RLAR and 7.1 per cent for TaTME ($P = 0.703$). However, patients in the TaTME group had longer DFS (25.9 *versus* 15.7 months; $P = 0.049$), with similar OS (29.1 *versus* 23.3 months; $P = 0.138$). Kaplan–Meier survival curves for recurrence and mortality are shown in *Figs. 1 and 2*. On subgroup analysis of T3 and T4 tumours, the DFS advantage was amplified in the TaTME group (*Fig. 3*).

In the multivariable analysis of risk factors for overall recurrence, only CRM positivity remained statistically significant (*Table 4*). The surgical approach was not associated with a higher recurrence rate.

Discussion

RLAR and TaTME have not been extensively compared in terms of both short-term postoperative and long-term oncological outcomes. This is especially true in the Asian context, attributed to the steep learning curve for TaTME.

According to the results documented here, TaTME achieved relatively better proximal and distal resection margins, although it should be highlighted that a positive CRM is still the prime determinant of local recurrence. Indeed, in the subgroup analysis of patients with bulky tumours (ypT3–4), TaTME resulted in a better rate of CRM negativity than RLAR.

The shortened operating time for TaTME in this series is attributed to the simultaneous two-team approach, whereas the increased duration of surgery in RLAR is accounted for by the need

Table 3 Oncological outcomes

	All patients			(y)pT3–4 disease		
	RLAR ($n = 38$)	TaTME ($n = 42$)	P†	RLAR ($n = 22$)	TaTME ($n = 35$)	P†
(y)pT category			0.012			
(y)pT0–2	16 (42.1)	7 (16.7)				
(y)pT3–4	22 (57.9)	35 (83.3)				
(y)pN category			0.107			
0	23 (60.5)	23 (54.8)				
1	14 (36.8)	12 (28.6)				
2	1 (2.6)	7 (16.7)				
(y)pTNM stage			0.888			
0–II	25 (65.8)	27 (64.3)				
III–IV	13 (34.2)	15 (35.7)				
Tumour length (cm)*	2.85 (1.0–13.0)	3.0 (1.0–6.5)	0.731‡	3.0 (1.0–5.0)	3.0 (1.0–6.5)	0.779‡
Proximal margin (cm)*	10.0 (2.0–47.0)	14.0 (1.4–36.7)	0.045‡	9.75 (2.0–35.0)	13.0 (1.4–30.8)	0.154‡
Distal margin (cm)*	1.65 (0.2–7.2)	2.50 (0.3–10.0)	0.021‡	2.0 (0.2–5.0)	2.50 (1.1–10.0)	0.078‡
CRM (cm)*	1.20 (0.1–4.5)	1.0 (0.1–5.0)	0.460‡	1.10 (0.1–4.5)	1.0 (0.2–5.0)	0.961‡
CRM-positive (≤ 1 mm)	4 (10.8)	1 (2.4)	0.185	4 (18.2)	0 (0)	0.019
Complete TME	36 (94.7)	37 (90.2)	0.676	21 (95.5)	32 (94.1)	1.000
Lymph node harvest*	13.0 (0–28)	14.5 (2–28)	0.308‡	12.5 (1–28)	14 (2–28)	0.079‡
Histological grade			0.434			0.603
Well differentiated	0 (0)	1 (2.4)		0 (0)	1 (2.9)	
Moderately differentiated	33 (94.3)	38 (90.5)		21 (95.5)	31 (88.6)	
Poorly differentiated	1 (2.9)	3 (7.1)		1 (4.5)	3 (8.6)	
Lymphovascular invasion	2 (5.3)	3 (7.1)	1.000	2 (9.1)	3 (8.6)	1.000
R0 resection	37 (97.4)	40 (95.2)	1.000	21 (95.5)	35 (100)	0.386
Any recurrence	10 (26.3)	8 (19.0)	0.437	8 (36.4)	8 (22.9)	0.269
Local recurrence	4 (10.5)	3 (7.1)	0.703	4 (18.2)	3 (8.6)	0.411
Systemic recurrence	10 (26.3)	7 (16.7)	0.292	8 (36.4)	7 (20.0)	0.172
Disease-free survival (months)*	15.7 (1.0–69.6)	25.9 (0.8–57.1)	0.049§	11.1 (1.0–69.6)	25.9 (0.8–57.1)	0.017§
Overall survival (months)*	23.3 (1.27–69.6)	29.1 (3.50–57.1)	0.138§	21.4 (1.27–69.6)	37.5 (3.50–57.1)	0.046§
Duration of follow-up (months)*	23.3 (1.27–69.6)	29.1 (3.50–57.1)	0.134‡	21.4 (1.27–69.6)	37.5 (3.50–57.1)	0.043‡

Values in parentheses are percentages unless indicated otherwise; *values are median (range). RLAR, robotic low anterior resection; TaTME, transanal total mesorectal excision; CRM, circumferential resection margin; †χ^2 or Fisher's exact test, except ‡Mann–Whitney *U* test and §log rank test.

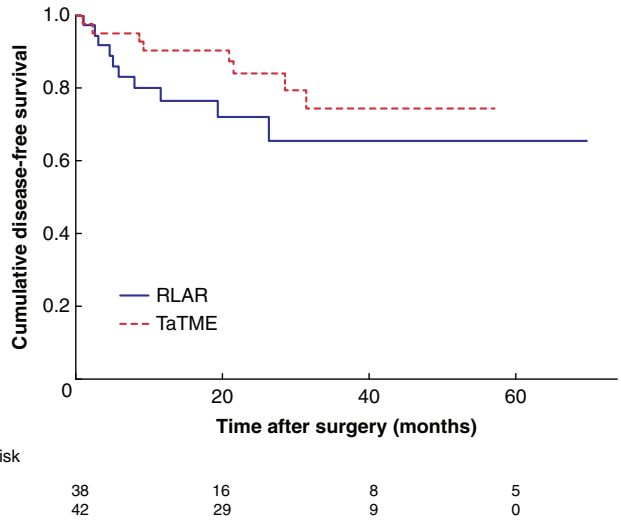

Fig. 1 Kaplan–Meier curves for disease-free survival

RLAR, robotic low anterior resection; TaTME, transanal total mesorectal excision. $P = 0.049$ (log rank test).

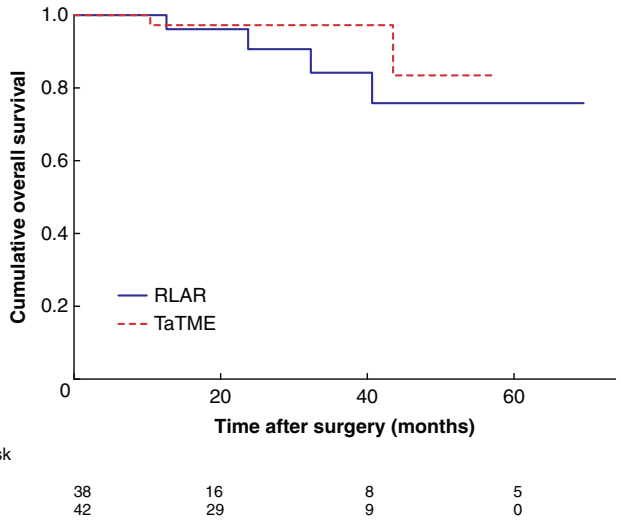

Fig. 2 Kaplan–Meier curves for overall survival

RLAR, robotic low anterior resection; TaTME, transanal total mesorectal excision. $P = 0.138$ (log rank test).

to dock the system twice, first for the colonic mobilization then for the pelvic dissection. The two-team approach in TaTME does have its limitations, as it has greater manpower requirements from two surgical and nursing teams. It also requires two senior surgeons to lead each approach. A sequential approach to TaTME would not have resulted in a reduced operating time, as noted in another experience[24], which found no difference in duration of surgery between TaTME and RLAR.

The higher rate of splenic flexure mobilization in TaTME was due to the need for increased colonic mobility for transanal

extraction of the specimen. Furthermore, the more distal anastomosis and open distal rectum after transanal extraction of the specimen contributed to a higher rate of handsewn anastomoses in the TaTME group. This higher rate did not result in a significant difference in anastomotic leak rates. Additionally, despite the higher rate of stapled anastomoses in the RLAR group, in a subgroup analysis of stapled anastomoses, there was also no difference in the leak rate (9.1 per cent with RLAR *versus* 0 per cent with TaTME; $P = 0.176$). These leak rates appear comparable to those reported in a recent meta-analysis[28], which reported a leak rate of up to 12.5–12.7 per cent for the procedures. The TaTME International Registry[2] also documented an anastomotic failure rate of 15.7 per cent in TaTME, of which 9.8 per cent were early or delayed anastomotic leaks. In this series, only one patient in each group required reoperation for anastomotic leaks, but neither required a laparotomy. Both patients had pelvic abscesses drained transanally and the leak managed with the Endo-SPONGE® (B-Braun Medical®, Germany) system.

Although there was no difference in the incidence of complications of Clavien–Dindo III grade and above, there was a significantly higher readmission rate (8 patients) at 30 days in the TaTME group. Of these eight readmissions, three were for presacral collections without clinical or radiological evidence of anastomotic leak. The higher rate of pelvic collections was likely due to the exposure of rectal flora to the pelvic cavity during the transanal dissection. Additionally, inadequate irrigation during dissection or contamination from transanal specimen retrieval in the authors' early experience could have contributed to this finding. Since the last report[30], surgery has been implemented by performing irrigation routinely before and after purse-string suturing as well as before and after transanal specimen extraction.

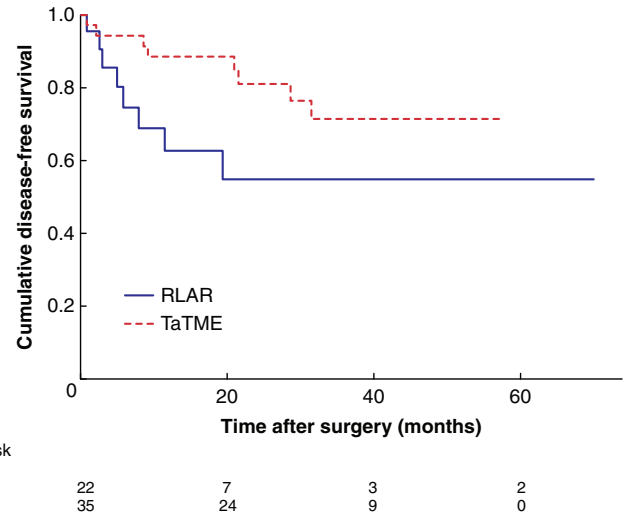

Fig. 3 Kaplan–Meier curves for disease-free survival in patients with (y)pT3–4 tumours

RLAR, robotic low anterior resection; TaTME, transanal total mesorectal excision. $P = 0.017$ (log rank test).

TaTME yielded significantly longer proximal and distal resection margins than RLAR. The superior visualization of the distal rectum through the transanal approach and pneumodissection allows greater precision in determining the distal margin. TaTME also overcomes the limitation of needing to manoeuvre an endoscopic stapler into the narrow pelvis. The improved proximal margin is likely due to increased rates of splenic flexure mobilization in the TaTME group. However, the multivariable analysis showed that a positive CRM rate was the sole independent risk factor for disease recurrence, and recurrence was not dependent on the proximal nor distal margin. Interestingly, in the subgroup analysis, TaTME had a superior CRM than RLAR mainly for bulky tumours. Anatomically, the deep sacral curve can be mitigated by the endowrist of robotic instruments. However, with a bulky tumour within a fixed bony pelvis, the funnelling effect continues to pose a challenge for 'top–bottom' TME approaches owing to the lack of space. Conversely, TaTME dissection starts from the narrow end of the funnel, circumventing the need to work around the bend of the deep sacral curve and exposure becomes progressively easier as the dissection continues. Furthermore, a two-team approach facilitates TME dissections from both ends. Others[26] reported a greater median CRM and distal margin with RLAR, whereas results from larger series seem to support the finding that TaTME has a greater distal resection margin[27]; however, none have analysed this subgroup between two-team TaTME and RLAR. As a *post hoc* analysis, more studies are needed to validate this finding.

There are two main limitations to the present study. The first is that selection bias may be present. The need for neoadjuvant therapy is usually discussed at the multidisciplinary team meeting, whereas the surgical approach is decided primarily based on the individual surgeon's experience. This is due to the lack of guidelines to influence the choice of either. An exhaustive list of confounders was included in the analysis to minimize this risk. Second, although both RLAR and TaTME have steep learning curves, RLAR is a more mature technique in the authors' department. The outcomes of TaTME, being a newer technique, may

Table 4 Univariable and multivariable Cox regression analyses for all recurrence

	Univariable analysis		Multivariable analysis	
	Hazard ratio	P	Hazard ratio	P
Surgical approach		0.218	–	
TaTME	1.00 (reference)			
RLAR	1.80 (0.71, 4.58)			
CRM-positive	8.47 (2.73, 26.22)	< 0.001	5.17 (1.06, 25.22)	0.042
(y)pN+	6.04 (1.99, 18.37)	0.002	3.70 (0.69, 19.79)	0.126
(y)pT4	3.12 (1.02, 9.56)	0.046	4.10 (0.75, 22.35)	0.103
MRI cN+	3.28 (0.95, 11.35)	0.061	2.64 (0.51, 13.51)	0.245
Poor response to neoadjuvant therapy	3.33 (1.28, 8.65)	0.014	2.19 (0.70, 6.86)	0.179
TNM stage ≥III	5.99 (2.13, 16.84)	0.001	1.38 (0.28, 6.79)	0.689
Anastomotic leak	2.81 (0.92, 8.65)	0.071	2.04 (0.34, 12.21)	0.434

Values in parentheses are 95 per cent confidence intervals. TaTME, transanal total mesorectal excision; RLAR, robotic low anterior resection; CRM, circumferential resection margin.

reflect the surgeons' learning curve, whereas the learning curve for RLAR may have already been passed.

TaTME and RLAR are meant to be alternative surgical techniques that optimize patient outcomes. Both techniques require vigorous training and a surgeon's specific experience to decide on the right approach for each patient. Therefore, TaTME should not be employed for all patients with rectal cancer. Experience in individual centres may also vary, depending on the availability of technology and trained personnel. Studies of a single-centre experience may provide a better comparison owing to high-volume practice and homogeneity of treatment protocols. With only one ongoing RCT (ROTA)[31], more prospective studies are needed to shed light on this subject in the future.

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