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Original Article

Comparison of laparoscopic *versus* robot-assisted *versus* transanal total mesorectal excision surgery for rectal cancer: a retrospective propensity score-matched cohort study of short-term outcomes

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Abstract

Background: Laparoscopic total mesorectal excision (TME) surgery for rectal cancer has important technical limitations. Robot-assisted and transanal TME (TaTME) may overcome these limitations, potentially leading to lower conversion rates and reduced morbidity. However, comparative data between the three approaches are lacking. The aim of this study was to compare short-term outcomes for laparoscopic TME, robot-assisted TME and TaTME in expert centres.

Methods: Patients undergoing rectal cancer surgery between 2015 and 2017 in expert centres for laparoscopic, robot-assisted or TaTME were included. Outcomes for TME surgery performed by the specialized technique in the expert centres were compared after propensity score matching. The primary outcome was conversion rate. Secondary outcomes were morbidity and pathological outcomes.

Results: A total of 1078 patients were included. In rectal cancer surgery in general, the overall rate of primary anastomosis was 39.4, 61.9 and 61.9 per cent in laparoscopic, robot-assisted and TaTME centres respectively ($P < 0.001$). For specialized techniques in expert centres excluding abdominoperineal resection (APR), the rate of primary anastomosis was 66.7 per cent in laparoscopic, 89.8 per cent in robot-assisted and 84.3 per cent in TaTME ($P < 0.001$). Conversion rates were 3.7 , 4.6 and 1.9 per cent in laparoscopic, robot-assisted and TaTME respectively ($P = 0.134$). The number of incomplete specimens, circumferential resection margin involvement rate and morbidity rates did not differ.

Conclusion: In the minimally invasive treatment of rectal cancer more primary anastomoses are created in robotic and TaTME expert centres.

Lay summary

The results of this study showed similar and acceptable short-term results for laparoscopic, robot-assisted and transanal total mesorectal excision performed in expert centres. In centres with robot-assisted or transanal technique, more primary anastomoses were made.

Introduction

Total mesorectal excision (TME), combined with neoadjuvant therapy, has reduced locoregional recurrence rates after rectal cancer surgery[1,2]. The introduction of laparoscopic TME was expected to improve oncological results even further. However, to date, oncological superiority compared to an open technique has not been shown[3,4]. A laparoscopic approach has been shown to reduce morbidity, infection rates and duration of postoperative

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hospital stay[5,6]. These benefits have led to the laparoscopic approach being the preferred approach in many countries, including the Netherlands[3,4].

Despite short-term advantages, laparoscopic TME is considered a difficult technique, due to the technical limitations of laparoscopy and the challenge of operating in the confined space of the pelvis. As a consequence, conversion rates of more than 10 per cent are common[5,7]. Conversion is associated with increased morbidity and worse oncological outcome[5,8]. Transanal TME (TaTME) and robot-assisted TME attempt to overcome the technical limitations of laparoscopy.

In TaTME the most difficult part of the rectal dissection is performed from below. Published data to date report that TaTME is safe in expert hands and has reduced conversion rates[9–12], but recent reports have raised concerns about oncological safety during the learning curve[13,14]. Robot-assisted TME also aims to overcome the technical limitations of laparoscopy in the narrow pelvis. Even in the low pelvis, accurate dissection is feasible thanks to the use of three-dimensional vision, lack of tremor, superior ergonomics and instruments with high degrees of freedom that mimic movements made by a surgeon's hands[15,16]. Previous studies report lower conversion rates in robot-assisted TME compared with laparoscopic TME, but no oncological benefit has been found[16–18]. A large randomized controlled trial (ROLARR) found no difference in conversion rates, intraoperative or postoperative complications between robot-assisted and laparoscopic TME[16], although the learning curve may have impacted upon these results[19].

A concern about previous studies of robot-assisted TME and TaTME is that the surgeons performing these techniques were not as experienced as those performing laparoscopic surgery. This may underestimate the benefits of these new techniques[16,19]. In addition, there are no data comparing all three techniques[20]. Therefore, the aim of this retrospective cohort study is to compare intra- and postoperative complications between laparoscopic, robot-assisted and TaTME performed in expert centres.

Methods

A retrospective multicentre cohort study was performed in 11 centres with a large experience in one of the three techniques: three TaTME expert centres, three robot-assisted expert centres and five laparoscopic expert centres. All participating hospitals were considered high volume, with at least 40 TME procedures per year[21,22]. A protocol regarding the study design, methods and statistical analysis was composed prior to initiation of the study. This study was approved by the Medical Research Ethics Committees United medical ethics committee (AW 19.023/W18.100) and was approved by the local ethics boards of all participating centres.

Study design

Patients were divided according to the type of expert technique used in each centre, irrespective of the actual approach used. For further analysis, only low anterior resections (LARs) executed in expert centres with the corresponding technique were included (that is, robot-assisted only from centres where the standard technique was robot-assisted TME, laparoscopic only from centres with laparoscopic TME as standard and TaTME from centres where TaTME was standard). Each centre had to perform at least 30 procedures per year using the expert technique. For two centres that began to use the expert technique as late as 2014 (one robot-assisted and one TaTME centre), procedures from 2015 were excluded because the learning curve was not considered to have been completed. Abdominoperineal resections (APRs) were excluded from this analysis.

Patients

All patients 18 years or older diagnosed with rectal cancer according to the sigmoidal take-off definition[23], operated on between January 2015 and December 2017 in the 11 participating Dutch hospitals were included. All patients were operated upon with curative intent. Excluded from analysis were patients with distant metastasis (cM1 disease), palliative-intent treatment, synchronous colonic tumours, acute procedures and non-TME surgery (including local excision, transanal endoscopic microsurgery (TEM) or transanal minimally invasive surgery (TAMIS)). Each patient was discussed in a local multidisciplinary cancer meeting and neoadjuvant treatment used according to the current Dutch national guidelines for colorectal cancer (last updated in 2014)[24].

Data collection

Data for this multicentre cohort study were derived from the Dutch Colo Rectal Audit (DCRA), an obligatory nationwide registry reporting data related to the quality of colorectal resections[25]. Missing data and additional information not present in the DCRA were added to the database using local electronic medical records. Patients were anonymized before data collection from local records. All data were collected between January and April 2020 and stored in the data management system CASTOR.

Outcomes and definitions

The study primary outcome was the conversion rate, defined as conversion to laparotomy to complete the mesorectal dissection. Secondary outcomes were intraoperative complications, length of hospital stay, 30-day morbidity and mortality, circumferential resection margin (CRM) involvement rate, quality of TME specimen and primary anastomosis rate.

Data collected in the DCRA audit were baseline characteristics such as age, sex, BMI, ASA class, co-morbidities, prior abdominal surgery, tumour location, clinical and pathological TNM stage, neoadjuvant treatment, date of surgery, type of surgery, intraoperative details, 30-day morbidity and mortality, and pathological outcome of all patients.

The type of procedure was categorized as low anterior resection (LAR) with anastomosis, LAR with colostomy or APR. APR included any procedure with perineal dissection with complete proctectomy with definitive end colostomy. LAR included all sphincter-saving procedures, with primary anastomosis. LAR with definitive end colostomy was either a 'Hartmann's procedure' or a procedure with mucosectomy and closing of the rectal stump and anus. A rectal tumour was defined as a tumour with its lower border below the sigmoid take-off on cross-sectional imaging, according to the definition of D'Souza and colleagues, whereby the sigmoid take-off is defined as 'where the mesocolon elongates in ventral and horizontal course on axial and sagittal views on cross-sectional imaging'[23]. In addition, a low rectal tumour was defined according to the LOREC definition, whereby the lower border of the cancer is 'at or below the origin of the levators on the pelvic sidewall'[26]. Investigators involved in reviewing preoperative MRI images had extensive training in defining the definitions used. In cases of doubt, consensus was reached after discussion with radiologists.

Thirty-day morbidity was categorized according to the Clavien–Dindo classification[27]. Anastomotic leakage was defined as anastomotic dehiscence or intra-abdominal abscess adjacent to the anastomotic site, requiring radiological or surgical intervention during follow-up, including those beyond 30 days. Leakages were graded according to need for intervention: grade A can be managed without change in management, grade B requires active therapeutic intervention but is manageable without re-laparotomy, and grade C requires re-laparotomy[28]. Early stoma reversal was not defined as readmission or reoperation. A positive CRM was defined as a margin of 1 mm or less. The quality of the mesorectum was graded according to Quirke[29].

Statistical analysis

Three propensity score-matched groups of equal size for each technique were formed. First robot-assisted and TaTME were matched 1 : 1. Then, laparoscopic and TaTME were matched in a similar way. Robot-assisted and TaTME patients that were not included in the second match were excluded.

Propensity score matching was performed using 1 on 1 near-neighbour matching with a calliper of 0.1. The variables used for matching were age (years), BMI (kg/m^2), sex (male/female), ASA class (I–IV), history of abdominal surgery (yes/no), distance to anal verge on colonoscopy in centimetres, MRI-defined low rectal tumour (LOREC), involvement of the mesorectal fascia on preoperative staging MRI of 1 mm or less (yes/no/unknown), clinical TNM stage, and neoadjuvant chemotherapy (yes/no). A standardized mean difference (SMD) less than 0.1 was deemed negligible, indicating appropriate matching. Missing data for the propensity score were imputed using multiple imputations if the type of missing data was missing at random or completely at random.

Data were presented as number and percentages for categorical variables. Continuous variables were presented as mean(s.d.) or median (i.q.r.), depending on the type of distribution. Univariable analysis of unmatched patients was done using the χ^2 test for categorical data. The independent sample t-test or the Wilcoxon rank sum test, depending on the distribution, were used for continuous data. Analyses of matched patients was done using generalized linear modelling. $P < 0.050$ was considered significant. All statistical analysis was performed using R version 3.6.2 (R Foundation for Statistical Computing, Vienna, Austria) using the Matching and Mice packages.

Results

A total of 1834 patients undergoing primary rectal resections were registered in the DCRA registry in the participating centres between January 2015 and December 2017. After excluding patients that were ineligible for inclusion, 1078 patients were included. The study flow chart is shown in *Fig. 1*.

Overall results per centre

Baseline characteristics for the unmatched cohorts for all rectal cancer surgery in each centre are shown in *Table 1*. There were 490 patients in laparoscopic centres, 344 in robot-assisted and 244 in TaTME centres. The rate of primary anastomosis was 39.4 per cent in laparoscopic, 61.9 per cent and robot-assisted and 61.9 per cent in TaTME centres ($P < 0.001$). The APR rate was 41.4 per cent in laparoscopic, 30.8 per cent in robot-assisted and 24.6 per cent in TaTME centres ($P < 0.001$). The rate of open TME approach was 5.5 per cent in laparoscopic, 1.5 per cent in robot-assisted and 3.3 per cent in TaTME centres ($P < 0.001$)

Comparison of specialized techniques in expert centres

Baseline

Baseline characteristics for unmatched and matched LAR by specialized technique in expert centres are presented in *Table 2*. Before matching there were 254 patients in the laparoscopic, 209 in the robot-assisted and 161 in the TaTME group. After matching 108 patients remained per group. There were minor differences in ASA grade (SMD 0.107). No difference was seen in other baseline comparisons after matching with SMD less than 0.1, indicating good-quality matching.

Intraoperative parameters

Conversion rates were 3.7, 4.6 and 1.9 per cent in laparoscopic, robot-assisted and TaTME respectively ($P = 0.518$). The rate of primary anastomosis was highest in robot-assisted (89.8 per cent), followed by TaTME (84.3 per cent) and lowest in laparoscopic centres (66.7 per cent) ($P < 0.001$). Post hoc testing showed no difference between robot-assisted and TaTME ($P = 0.227$). End colostomy rate was highest in the laparoscopic group (33.3 per cent) compared with the robot-assisted (10.2 per cent) and TaTME (14.8 per cent). More diverting ileostomies were constructed in the robot-assisted surgery (60.2 per cent) compared to the laparoscopic (33.3 per cent) and TaTME (39.8 per cent) ($P < 0.001$). Mean operation time was longest in the TaTME group (mean(s.d.)

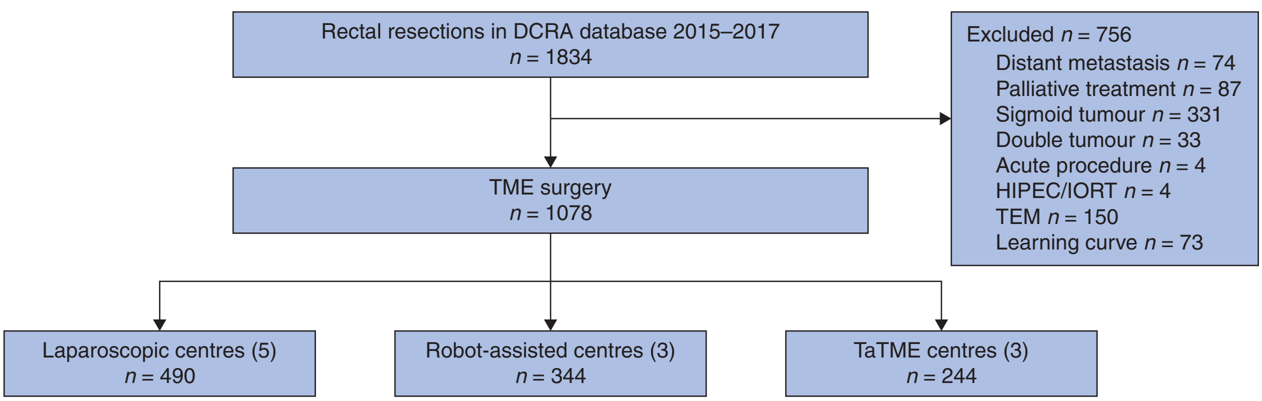

Fig. 1 Flow chart of patients

DCRA, Dutch Colo Rectal Audit; TEM, transanal endoscopic microsurgery; HIPEC, hyperthermic intraperitoneal; IORT, intra-operative radiotherapy; TME, total mesorectal excision

Table 1 Unmatched rectal cancer surgery per type of centre

	Laparoscopy ($n = 490$)	Robot ($n = 344$)	TaTME ($n = 244$)	SMD	P
Age (years)*	68(9.8)	67(10.6)	66(11.0)	0.101	0.144
BMI (kg/m^2)*	26(4.4)	26(4.0)	26(4.2)	0.076	0.255
Gender					
Male	311 (63.5)	218 (63.4)	158 (64.8)	0.019	0.930
Female	179 (36.5)	126 (36.6)	86 (35.2)		
ASA grade					
I	93 (19.0)	75 (21.8)	49 (20.1)	0.156	0.170
II	296 (60.4)	194 (56.4)	151 (61.9)		
III	94 (19.2)	75 (21.8)	43 (17.6)		
IV	7 (1.4)	0 (0.0)	1 (0.4)		
History of abdominal surgery	155 (31.6)	86 (25.0)	71 (29.1)	0.098	0.115
Tumour distance at coloscopy (cm)†	8 (4–10)	7 (3–10)	5 (3–9)	0.185	0.002
LOREC					
Yes	319 (65.1)	178 (51.7)	140 (57.4)	0.223	0.001
Missing	7 (1.4)	8 (2.3)	1 (0.4)		
MRF involvement on MRI					
MRF involved	132 (26.9)	105 (30.5)	87 (35.7)	0.147	0.054
MRF not involved	352 (71.8)	232 (67.4)	155 (63.5)		
Missing	6 (1.2)	7 (2.0)	2 (0.8)		
cT stage					
1 or 2	155 (31.6)	117 (34.0)	75 (30.7)	0.129	0.280
3	297 (60.6)	188 (54.7)	147 (60.2)		
4	37 (7.6)	38 (11.0)	20 (8.2)		
cN stage					
0	219 (44.7)	149 (43.3)	132 (54.1)	0.145	0.023
1 or 2	271 (55.3)	195 (56.7)	112 (45.9)		
Neoadjuvant therapy					
None	196 (40.0)	128 (37.2)	96 (39.3)	0.184	0.035
(Chemo)radiation	280 (57.1)	214 (62.2)	148 (60.7)		
Missing	14 (2.9)	2 (0.6)	0 (0.0)		
Procedure					
APR	203 (41.4)	106 (30.8)	60 (24.6)	0.399	<0.001
LAR + colostomy	94 (19.2)	25 (7.3)	33 (13.5)		
LAR + anastomosis	193 (39.4)	213 (61.9)	151 (61.9)		
Approach					
Open	27 (5.5)	5 (1.5)	8 (3.3)	0.354	<0.001
Laparoscopy	434 (88.6)	28 (8.1)	54 (22.1)		
TaTME	20 (4.1)	2 (0.6)	182 (74.6)		
Robot	9 (1.8)	309 (89.8)	0 (0.0)		

Values in parentheses are percentages, unless indicated otherwise; *values are mean(s.d.), †values are median (i.q.r.). TaTME, transanal total mesorectal excision; SMD, standard mean difference; LOREC, low rectal cancer definition; MRF, mesorectal fascia; APR, abdominoperineal resection; LAR, low anterior resection.

209(74) mins), compared with robot-assisted (186(59) mins) and laparoscopic (149(53) mins) ($P < 0.001$). The number of intraoperative complications was comparable for each group. In TaTME one patient had a carbon dioxide embolus, one had intraoperative bleeding and two had purse-string failure. In the robot-assisted TME, one patient had a bladder injury. Unintended small bowel injury occurred in two laparoscopic, four robot-assisted and two TaTME patients (*Table 3*).

Postoperative parameters

The overall complication rates were comparable between groups. Postoperative ileus rates were lower in TaTME (9.3 per cent) compared with laparoscopy (18.5 per cent) and robot-assisted TME (25.0 per cent) ($P = 0.003$). The rates of anastomotic leakage were 23.6, 21.6 and 17.6 per cent in laparoscopic, robot-assisted and TaTME respectively ($P = 0.619$). Grade of leakage did not differ. Median length of hospital stay was 6 days in each group (*Table 4*).

Pathology

No difference was seen in pathological outcomes, including histological type, grade of differentiation and pTNM stage (*Table S1*). CRM involvement rates were 2.0, 2.0 and 4.0 per cent in laparoscopic, robot-assisted and TaTME respectively (SMD 0.598). Complete or near complete specimens were achieved in 96.2, 96.3 and 98.1 per cent in laparoscopic, robot-assisted and TaTME respectively (SMD 0.677). CRM involvement or incomplete specimen was found in 7.3, 7.0 and 6.3 per cent respectively (SMD 0.963).

Discussion

This multicentre retrospective cohort evaluating laparoscopic, robot-assisted and TaTME operated on in expert centres found comparable short-term results between all three techniques. However, in robot-assisted and TaTME centres a higher percentage of patients had anastomoses created. This suggests that robot-assisted and TaTME may facilitate the safe creation of an anastomosis.

The overall rates of postoperative morbidity were similar between laparoscopic, robot-assisted and TaTME, with results in keeping with previously reported series that report morbidity rates of up to 40 per cent after laparoscopic TME[5]. Previous randomized trials comparing robot-assisted with laparoscopic TME have shown no difference in morbidity[15,16,30] and some studies of TaTME have shown less short-term morbidity when compared with laparoscopy[31,32].

Table 2 Baseline characteristics of TME surgery before and after propensity score matching

	Unmatched cohort				Matched cohort			
	Laparoscopy (*n* = 254)	Robot (*n* = 209)	TaTME (*n* = 161)	SMD	Laparoscopy (*n* = 108)	Robot (*n* = 108)	TaTME (*n* = 108)	SMD
Age (years)*	68(9.7)	66(10.3)	65(10.9)	0.153	66(10.1)	66(10.3)	66(10.4)	0.034
BMI (kg/m^2)*	26(4.3)	26(3.9)	26(4.3)	0.017	26(4.4)	26(3.7)	26(4.3)	0.030
Gender								
Male	155 (61.0)	131 (62.7)	111 (68.9)	0.111	69 (63.9)	65 (60.2)	71 (65.7)	0.077
Female	99 (39.0)	78 (37.3)	50 (31.1)		39 (36.1)	43 (39.8)	37 (34.3)	
ASA grade								
I	58 (22.8)	46 (22.0)	35 (21.7)	0.133	27 (25.0)	21 (19.4)	25 (23.1)	0.107
II	140 (55.1)	125 (59.8)	96 (59.6)		60 (55.6)	68 (63.0)	62 (57.4)	
III	53 (20.9)	38 (18.2)	29 (18.0)		21 (19.4)	19 (17.6)	21 (19.4)	
IV	3 (1.2)	0 (0.0)	1 (0.6)		0 (0.0)	0 (0.0)	0 (0.0)	
History of abdominal surgery	80 (31.5)	48 (23.0)	38 (23.6)	0.128	25 (23.1)	29 (26.9)	26 (24.1)	0.057
Tumour distance at coloscopy (cm)†	10 (7–12)	8 (6–10)	6 (5–10)	0.500	8 (5–10)	8 (6–10)	8 (5–10)	0.025
LOREC								
Yes	118 (46.5)	73 (34.9)	78 (48.4)	0.219	49 (45.8)	44 (42.3)	48 (44.9)	0.047
Missing	3 (1.2)	7 (3.3)	1 (0.6)		0 (0.0)	0 (0.0)	0 (0.0)	
MRF involvement on MRI								
MRF involved	42 (16.5)	54 (25.8)	46 (28.6)	0.267	26 (24.1)	29 (27.1)	23 (21.5)	0.087
MRF not involved	212 (83.5)	150 (71.8)	114 (70.8)		82 (75.9)	78 (72.9)	84 (78.5)	
Missing	0 (0.0)	5 (2.4)	1 (0.6)		0 (0.0)	0 (0.0)	0 (0.0)	
cT stage								
1 or 2	88 (34.6)	72 (34.4)	49 (30.4)	0.188	38 (35.2)	39 (36.1)	35 (32.7)	0.087
3	157 (61.8)	119 (56.9)	104 (64.6)		66 (61.1)	64 (59.3)	69 (64.5)	
4	9 (3.5)	17 (8.1)	7 (4.3)		4 (3.7)	5 (4.6)	3 (2.8)	
Missing	0 (0.0)	1 (0.5)	1 (0.6)		0 (0.0)	0 (0.0)	0 (0.0)	
cN stage								
0	109 (42.9)	89 (42.6)	87 (54.0)	0.154	51 (47.2)	50 (46.3)	49 (45.4)	0.025
1 or 2	145 (57.1)	120 (57.4)	74 (64.0)		57 (52.8)	58 (53.7)	59 (54.6)	
Neoadjuvant therapy								
None	112 (44.1)	84 (40.2)	65 (40.4)	0.147	48 (44.4)	44 (41.1)	46 (42.6)	0.045
(Chemo)radiation	138 (54.3)	123 (58.9)	96 (59.6)		60 (55.6)	63 (58.9)	62 (57.4)	
Missing	4 (1.6)	2 (1.0)	0 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)	

Values in parentheses are percentages, unless indicated otherwise; *values are mean(s.d.), †values are median (i.q.r.). TaTME, transanal total mesorectal excision; SMD, standard mean difference; LOREC, low rectal cancer definition; MRF, mesorectal fascia.

Table 3 Intraoperative parameters after propensity score matching

	Matched cohort				Post hoc testing		
	Laparoscopy (*n* = 108)	Robot (*n* = 108)	TaTME (*n* = 108)	P	P Laparoscopy *versus* robot	P Laparoscopy *versus* TaTME	P Robot *versus* TaTME
Procedure							
LAR + colostomy	36 (33.3)	11 (10.2)	17 (15.7)	<0.001	<0.001	0.003	0.227
LAR + anastomosis	72 (66.7)	97 (89.8)	91 (84.3)				
Operating time (min)*	149(53)	186(59)	209(74)	<0.001	<0.001	<0.001	0.015
Conversion	4 (3.7)	5 (4.6)	2 (1.9)	0.518			
Reason for conversion							
Extensiveness of tumour	0 (0.0)	0 (0.0)	1 (50.0)				
Accessibility	3 (75.0)	5 (100.0)	1 (50.0)				
Preoperative complication	1 (25.0)	0 (0.0)	0 (0.0)				
Primary anastomosis	72 (66.7)	97 (89.8)	91 (84.3)	<0.001	<0.001	0.003	0.227
Stoma							
No stoma	29 (26.9)	32 (29.6)	48 (44.4)	<0.001	0.653	0.005	0.018
Diverting ileostomy	36 (33.3)	65 (60.2)	43 (39.8)	<0.001	<0.001	0.323	0.003
Diverting colostomy	7 (6.5)	0 (0.0)	1 (0.9)				
End colostomy	36 (33.3)	11 (10.2)	16 (14.8)		<0.001	0.003	0.291
Additional resection	2 (1.9)	6 (5.6)	6 (5.6)	0.303			
Intraoperative complication	3 (2.8)	5 (4.6)	4 (3.7)	0.771			

Values in parentheses are percentages, unless indicated otherwise; *values are mean(s.d.). TaTME, transanal total mesorectal excision; LAR, low anterior resection.

Table 4 Postoperative parameters after propensity score matching

	Matched cohort				Post hoc testing		
	Laparoscopy (*n* = 108)	Robot (*n* = 108)	TaTME (*n* = 108)	P	P Laparoscopy *versus* robot	P Laparoscopy *versus* TaTME	P Robot *versus* TaTME
Complications	55 (50.9)	59 (54.6)	47 (43.5)	0.251			
Cardiac complications	6 (5.6)	4 (3.7)	1 (0.9)	0.167			
Pulmonary complications	6 (5.6)	9 (8.3)	9 (8.3)	0.667			
Surgical complications	42 (38.9)	46 (42.6)	30 (27.8)	0.063	0.580	0.084	0.023
Abscess	8 (7.4)	4 (3.7)	4 (3.7)	0.349			
Ileus	20 (18.5)	27 (25.0)	10 (9.3)	0.009	0.250	0.053	0.003
Wound infection	3 (2.8)	4 (3.8)	1 (0.9)	0.141			
Anastomotic leakage	17 (23.6)	21 (21.6)	16 (17.6)	0.619			
Anastomotic leakage grade							
A	3 (17.6)	1 (4.8)	4 (25.0)	0.290			
B	6 (35.3)	10 (47.6)	3 (18.8)				
C	8 (47.1)	10 (47.6)	9 (56.2)				
Clavien–Dindo classification							
Major morbidity	23 (21.3)	19 (17.6)	22 (20.4)	0.776			
Minor morbidity	32 (29.6)	40 (37.0)	24 (22.2)				
No complication	53 (49.1)	49 (45.4)	62 (57.4)				
Reintervention	23 (21.3)	19 (17.6)	21 (19.4)	0.789			
Readmission	19 (17.6)	25 (23.1)	17 (15.7)	0.350			
LOS (days)*	6 (4–10)	6 (5–12)	6 (4–9)	0.742			
Mortality within 30 days	1 (0.9)	0 (0.0)	0 (0.0)	0.363			

Abbreviations: TaTME, transanal total mesorectal excision; LOS, length of hospital stay.

Conversions in general and conversions due to intraoperative complications were rare in the present study. This is indicative of high-quality surgery and reflects that surgery was performed in expert centres. Previously reported conversion rates for laparoscopic TME vary from 0–16 per cent[2,7]. In the ROLARR trial the conversion rate was 8.1 per cent in the robot-assisted group, compared with 12.2 per cent in the laparoscopic group[16]. However, the ROLARR trial was probably underpowered due to a higher anticipated difference based on a conversion rate of up to 25 per cent in the MRC CLASSICC trial[33]. Another explanation for the higher conversion rate in the ROLARR trial might be that data were captured in the learning curve. The learning curve for robot-assisted and TaTME is at least 30–40 procedures[16,22,34,35]. Since centres in the current study performed at least 30 procedures in the year before inclusion, the learning curve effect was believed to be diminished. The results in this study are comparable to other studies on robot-assisted TME and TaTME in which only experienced surgeons participated[15,17,32,36].

Significantly more primary anastomoses were made in robot-assisted and TaTME expert centres. Restorative rates were higher in all groups compared with a previous national snapshot study in which the anastomosis rate was only 50 per cent[37]. The technological advantages of the new techniques could have contributed to these higher restorative rates. Both robot-assisted and TaTME provide better access to the distal rectum, enabling surgeons to complete the TME dissection safely and create an anastomosis. Robot-assisted TME can overcome the technical limitations of laparoscopy in the narrow pelvis by improved vision and superior instrument handling, while the transanal approach allows for direct access to the distal part of the rectum and eliminates cross stapling[9,10,15,16]. Olthof and colleagues also reported higher restorative rates in a robot-assisted implementation cohort[38]. Other explanations for the higher restorative rate should be considered including patient-, surgeon- or centre-specific preferences. Furthermore, the construction of an anastomosis in patients who otherwise would undergo APR does not necessarily contribute to better functional outcome or quality of life[39].

The rate of anastomotic leakage in this study was in accordance with a large Dutch national audit in which anastomotic leakage was 20.0 per cent beyond 30 days[37]. Another Dutch audit based on DCRA data reported similar results[10]. It should be noted that all types of leakages, including occult leakages or leakages beyond 30 days, are included in this study. Furthermore, previous studies did not use a clear definition of the rectum, and might have included more proximal tumours, resulting in an underestimation of anastomotic leakage rate[40]. In this study, rectal carcinoma was defined according to the MRI-based sigmoid take-off definition, thereby eliminating the inclusion of distal sigmoid tumours[23]. Although the rate of primary anastomosis was higher in robot-assisted and TaTME centres, this did not lead to a higher rate of anastomotic leakage.

The most important predictor for local recurrence is the involvement of the CRM. In this study, CRM involvement rates for all three techniques were comparable: 2.0 to 4.0 per cent. In the ROLARR trial, a 5.1 per cent CRM involvement rate was seen with relatively proximal tumours. The exclusion of distal sigmoid tumours in the present study did not result in higher CRM involvement, indicating good-quality surgery for all three techniques. Specifically for TaTME, the observed positive CRM rates were lower than the 12.7 per cent encountered in Norway which led to a local recurrence rate of 11.6 per cent and a halt on TaTME in that country[41]. The observed CRM rates in the present study are comparable with the results from early adopters in Australia and the Netherlands, which showed local recurrence rates to be 2–4 per cent[11,42].One of the most important parameters in assessing the quality of each technique is whether a radical resection can be achieved, with complete resection of the mesorectum. The overall number of incomplete specimen in this study was lessthan 4%, and rates were comparable between groups. This is in line with previous research[43].

The most important limitation of this study is its retrospective nature; confounding by indication might therefore be apparent. In order to correct for confounding by indication, three balanced cohorts were created using propensity score matching. Studies comparing robot-assisted with TaTME are scarce[20]. Some contain only small series of patients, while others lack important outcome measures such as conversion rate. Additionally, one of the most important drawbacks in previous research is the inability to take the learning curve into account[44]. The effect of the learning curve was diminished in this study, by selection of experienced centres[45,46]. Further work is required to establish the potential benefits of each technique in the hands of experienced and less experienced surgeons.

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