Robot-Assisted Total Mesorectal Excision Versus Laparoscopic Total Mesorectal Excision

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ORIGINAL CONTRIBUTION

Robot-Assisted Total Mesorectal Excision Versus Laparoscopic Total Mesorectal Excision: A Retrospective Propensity Score–Matched Cohort Analysis in Experienced Centers

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BACKGROUND: The superiority of robot-assisted over laparoscopic total mesorectal excision has not been proven. Most studies do not consider the learning curve while comparing the surgical technique.

OBJECTIVE: This study aims to compare laparoscopic with robot-assisted total mesorectal excision performed by surgeons who completed the learning curve of the technique.

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DESIGN: This is a multicenter retrospective propensity score–matched analysis.

SETTINGS: The study was performed in 2 large, dedicated robot-assisted hospitals and 5 large, dedicated laparoscopic hospitals.

PATIENTS: Patients were included if they underwent a robot-assisted or laparoscopic total mesorectal excision for rectal cancer with curative intent at a dedicated center for the minimally invasive technique between January 1, 2015, and December 31, 2017.

INTERVENTIONS: We compared robot-assisted with laparoscopic total mesorectal excision.

MAIN OUTCOME MEASURES: The main outcome was conversion to laparotomy during surgery. Secondary outcomes were postoperative morbidity and positive circumferential resection margin.

RESULTS: A total of 884 patients were included and, after matching, 315 patients per treatment group remained. Conversion was similar between laparoscopic and robot-assisted total mesorectal excision (4.4% vs 2.5% ($p = 0.20$)). Positive circumferential resection margin was equal (3.2% vs 4.4% ($p = 0.41$)). Overall morbidity was comparable as well, although a lower rate of wound infections was observed in the robot-assisted group (5.7% vs 1.9% ($p = 0.01$)). More primary anastomoses were constructed in the robot-assisted group (50.8% vs 68.3% ($p < 0.001$)). Finally, more open procedures were performed in dedicated laparoscopic centers, with an overrepresentation of cT4N+ tumors in this group.

LIMITATIONS: This is a retrospective multicenter cohort; however, propensity score matching was applied to control for confounding by indication.

CONCLUSIONS: Robot-assisted and laparoscopic total mesorectal excision are equally safe in terms of short-term outcomes. However, with the robot-assisted approach, more primary anastomoses were constructed, and a lower wound infection rate was observed. See **Video Abstract** at http://links.lww.com/DCR/B677.

ESCISIÓN MESORRECTAL TOTAL ASISTIDA POR ROBOT VERSUS ESCISIÓN MESORRECTAL TOTAL LAPAROSCÓPICA: UNA PUNTUACIÓN DE PROPENSIÓN RETROSPECTIVA ANÁLISIS DE COHORTES EMPAREJADAS EN CENTROS EXPERIMENTADOS

ANTECEDENTES: No se ha demostrado la superioridad de la escisión mesorrectal total asistida por robot sobre la laparoscópica. La mayoría de los estudios no tienen en cuenta la curva de aprendizaje al comparar la técnica quirúrgica.

OBJETIVO: Este estudio tiene como objetivo comparar la escisión mesorrectal total laparoscópica con la asistida por robot realizada por cirujanos que completaron la curva de aprendizaje de la técnica.

DISEÑO: Este es un análisis multicéntrico retrospectivo emparejado por puntuación de propensión.

AJUSTES: El estudio se realizó en dos grandes hospitales dedicados asistidos por robots y cinco grandes hospitales laparoscópicos dedicados.

PACIENTES: Se incluyeron pacientes que se sometieron a escisión mesorrectal total asistida por robot o laparoscópica para cáncer de recto con intención curativa, en un centro dedicado a la técnica mínimamente invasiva entre el 1 de enero de 2015 y el 31 de diciembre de 2017.

INTERVENCIONES: Comparamos la escisión mesorrectal total asistida por robot con la laparoscópica.

PRINCIPALES MEDIDAS DE RESULTADO: El principal resultado fue la conversión a laparotomía durante la cirugía. Los resultados secundarios fueron la morbilidad posoperatoria y el margen circunferencial positivo.

RESULTADOS: Se incluyó a un total de 884 pacientes y, después de emparejar, quedaron 315 pacientes por grupo de tratamiento. La conversión fue similar entre la escisión mesorrectal total laparoscópica y asistida por robot (4,4% frente a 2,5% [p = 0,20]). El margen de resección circunferencial positivo fue igual (3,2% vs 4,4% [p = 0,41]). La morbilidad general también fue comparable, aunque se observó una menor tasa de infecciones de heridas en el grupo asistido por robot (5,7% frente a 1,9% [p = 0,01]). Se construyeron más anastomosis primarias en el grupo asistido por robot (50,8% frente a 68,3% [p < 0,001]). Finalmente, se realizaron procedimientos más abiertos en centros laparoscópicos dedicados, con una sobrerrepresentación de tumores cT4N + en este grupo.

LIMITACIONES: Ésta es una cohorte multicéntrica retrospectiva; sin embargo, se aplicó el emparejamiento por puntuación de propensión para controlar los factores de confusión por indicación.

CONCLUSIONES: La escisión mesorrectal total asistida por robot y laparoscópica son igualmente seguras en términos de resultados a corto plazo. Sin embargo, con el abordaje asistido por robot, se construyeron más anastomosis primarias y se observó una menor tasa de infección de la herida. Consulte **Video Resumen** en http://links.lww.com/DCR/B677. *(Traducción—Dr. Gonzalo Hagerman)*

KEY WORDS: Minimally invasive surgery; Rectal carcinoma; Robot-assisted surgery; Total mesorectal excision.

The primary surgical treatment for rectal cancer is surgical resection, using en bloc sharp dissection of the tumor and the mesorectum, known as total mesorectal excision (TME).[1] TME can be performed using the open, laparoscopic, robot-assisted, and transanal technique. Laparoscopic TME is the current standard of practice in the Netherlands and accounts for 55.4% of the procedures. In addition, 8.8% of the procedures are performed open, 10.4% are performed using transanal TME, and 15.8% are performed using robot-assisted TME.[2] Despite being the standard of practice, the laparoscopic technique is challenging in low rectal cancer because of the combination of anatomic characteristics of the pelvis and technical limitations of laparoscopy.[3] With wristed instruments, stable 3-dimensional vision, and enhanced ergonomics for the surgeon, robot-assisted surgery has been put forward to overcome these limitations.[4,5]

In literature, several studies compare robot-assisted and laparoscopic rectal surgery.[6–9] However, most studies show no benefits of robot-assisted TME over laparoscopic TME. Oncological outcomes,[10] morbidity and mortality rates,[8,10] and quality of life[6,11–13] are comparable. Furthermore, operation times are longer[14] and robot-assisted procedures are more expensive.[15] Nevertheless, some retrospective studies and a meta-analysis[16–18] show lower conversion rates in the robot-assisted group, and some data suggest that urogenital dysfunction is less common.[11] The ROLARR trial is the only randomized controlled trial powered to prove a difference in conversions; it could not show benefits of robot-assisted TME either.[8]

One of the main methodological issues of studies comparing robot-assisted TME with laparoscopic TME is that robot-assisted surgeons are not as experienced as their laparoscopic colleagues participating in the published trials. The ROLARR trial did use criteria for participating surgeons: Of a minimum of 30 minimally invasive procedures, at least 10 laparoscopic procedures and 10 robot-assisted procedures had to be performed by the participating surgeon.[8] However, this is a rather small amount, given the fact that learning curves between 30 and 40 procedures per surgeon have been described.[19–21] Furthermore, it is doubtful whether surgeons can be equally experienced in 2 different minimally invasive techniques.

Therefore, the aim of this retrospective cohort is to compare laparoscopic TME, executed by experienced laparoscopic surgeons, with robot-assisted TME, executed by experienced robot-assisted surgeons.

MATERIALS AND METHODS

A retrospective multicenter cohort study was performed to compare laparoscopic TME with robot-assisted TME in centers with either profound experience in robot-assisted TME or profound experience in laparoscopic-assisted TME. A protocol regarding the design, methods, and statistical analysis was composed before the initiation of the study. The protocol was not registered. This study was reported in accordance with the STROBE guidelines.[22]

Design

Centers were able to participate in this retrospective cohort if they had profound experience either in robot-assisted or in laparoscopic TME. For the robot-assisted centers, 2 large Dutch teaching hospitals were selected. These hospitals started performing robot-assisted TME with the DaVinci Si (Intuitive Surgical, Sunnyvale, CA) in 2011 and 2012, and they performed robot-assisted TME in all patients if this was possible considering logistics and timing. With 2 dedicated colorectal surgeons per dedicated robot-assisted center performing 40 to 60 robot-assisted rectal resections annually with 5 to 10 years of laparoscopic TME experience before the robot-assisted technique, we estimated that they were well beyond the learning curve at the beginning of the cohort in 2015. Furthermore, with more than 10 years of experience with laparoscopic TMEs in the dedicated laparoscopic centers, with 13 surgeons in the laparoscopic centers, these surgeons were estimated to be well beyond their learning curve as well. Therefore, we considered the difference in experience between robot-assisted and laparoscopic TME to be minimal.

Patients

Patients were eligible for inclusion if they 1) underwent a robot-assisted TME in 1 of the 2 dedicated robot-assisted centers, or underwent a laparoscopic TME in 1 of the 5 dedicated laparoscopic centers by a dedicated surgeon; 2) were operated between January 1st, 2015, and December 31st, 2017; 3) were older than 18 years; 4) were diagnosed with rectal cancer; 5) were registered in the obligatory national Dutch ColoRectal Audit (DCRA) database; 6) were operated with curative intent; and 7) in an elective setting. Patients were excluded if they 1) had a double tumor, or 2) underwent another procedure that was performed simultaneously with the TME.

Data Capturing

All hospitals provided their local DCRA data, including the unique patient number. After pseudonymization with a unique study number for every patient, all data was imported into the electronic data management system Castor, and patients could only be identified through a converting table containing both the unique patient ID and the unique study ID. The converting table was only accessible in the local hospital and was encrypted. Missing and incomplete data was added in Castor by accessing the local hospitals' electronical medical record (EMR). Furthermore, conversion, circumferential resection margin (CRM), 90-day morbidity, 90-day readmission, and 90-day mortality were double checked in the EMR. Finally, additional variables that were not part of the DCRA database were added for each patient.

Informed consent was deemed unnecessary according to the Dutch Medical Treatment Agreement Act. Ethical approval was obtained through the regional medical ethical committee (MEC-U, W18.100) and the local medical ethical committee for all hospitals.

Outcomes

The primary outcome was conversion of endoscopic surgery (ie, robot-assisted TME or laparoscopic TME) to open surgery. Conversion was defined as discontinuation of robot-assisted or laparoscopic surgery and completion of the TME dissection through a midline or Pfannenstiel laparotomy.

Baseline characteristics were age, BMI, sex, ASA classification, history of abdominal surgery, distance of the tumor from the anal verge, mesorectal fascia involvement on preoperative MRI, clinical TNM classification based on the preoperative MRI, intent of the treatment, and use of neoadjuvant therapy.

Perioperative outcomes were skin-to-skin time, defined as time from incision to closure. Furthermore, reason for conversion, construction of primary anastomosis, construction and type of stoma, and perioperative complications were registered.

Postoperative outcomes were 90-day mortality and morbidity. The latter was classified according to the Clavien-Dindo grading system.[23] Major morbidity was defined as Clavien-Dindo grade 3 or higher. Anastomotic leakage was defined according to the definition of the International Study Group of Rectal Cancer.[24] Wound infection was defined as any superficial incisional surgical site infection according to the Centers for Disease Control and Prevention definition.[25] Finally, reintervention, readmission, and length of stay was registered.

Pathological outcomes were histological type of the tumor, quality of TME specimen, pathological TNM classification, and positive CRM rate, defined as a margin ≤1 mm. Pathological parameters were defined according to TNM classification as described in the Dutch guideline for colorectal cancer.[26]

Power Calculation

For detecting a difference in conversion rate between robot-assisted and laparoscopic TME, 244 patients were needed per arm based on a significance level (α) of 0.05, a power (β) of 0.80, a conversion rate in the laparoscopic group of 10%, and a conversion rate in the robot-assisted group of 4%. The laparoscopic conversion rate was based on the average conversion rate of the Dutch DCRA database, ALaCaRT trial, ACOSOG trial, and ROLARR trial.[2,8,27–29] The conversion rate in the robot-assisted group was based on the rate of conversions in the ROLARR trial (8%) and a recent meta-analysis of randomized trials of robot-assisted TMEs[9] (7%), with the expectation that more experienced surgeons would result in an even lower rate.

Statistical Analysis

Analyses were conducted in R using the packages "matching" and "mice." Missing data, if missing at random or missing completely at random, were imputed using multiple imputation. Patients were propensity score–matched according to age, sex, ASA classification, BMI, history of abdominal surgery, distance of the tumor to the anal verge, preoperative tumor stage, and neoadjuvant chemotherapy. Patients were matched in a 1:1 ratio using a caliper of 0.20. Univariate analyses were done using independent sample *t* test for normally distributed numeric data, and the Wilcoxon rank-sum test was used for nonnormally distributed numeric data. The χ^1 test was used for binary and categorical data. Categorical and binary variables of matched patients were compared using the McNemar test. Continuous variables of matched patients were compared using the paired *t* test or the Wilcoxon signed-rank test for nonnormally distributed numeric data. Baseline characteristics were compared using the standardized mean difference. A standardized mean difference lower than 0.10 was deemed negligible.

RESULTS

Between January 1, 2015, and December 31, 2017, 1254 patients were identified in the 2 dedicated robot-assisted and 5 dedicated laparoscopic centers. A total of 54 patients were excluded because the intent of the operation was palliative, 48 patients were excluded because the tumor was more than 15 cm above the anal verge, 125 patients were excluded because they underwent another procedure for the rectum carcinoma (ie, transanal endoscopic microsurgery), 17 patients were excluded because they had a double tumor, 4 patients because they underwent an acute procedure, and 6 because another procedure was performed at the same time. This resulted in 1000 patients who received a TME for rectal cancer. Another 116 patients were excluded because they either underwent a procedure other than the robot-assisted technique in a dedicated robot-assisted center, or they underwent a procedure other than the laparoscopic technique in a dedicated laparoscopic center. This resulted in 884 patients, of which 325 patients underwent a robot-assisted TME and 559 patients underwent a laparoscopic TME. After matching, 315 patients per group remained (Fig. 1).

Patient Characteristics

In the unmatched study cohort, clinical tumor stage T4 was significantly more prevalent in the robot-assisted group. In the laparoscopic centers, an open TME was performed more commonly (5.2% vs 2.2%) with a higher proportion of T_4 and N_+ tumors (Table 1). After matching, no significant differences were seen (Table 2).

Perioperative Outcomes

Conversion was equal between both groups for the total cohort: Fourteen (4.4%) procedures were converted in the laparoscopic group versus 8 (2.5%) procedures in the robot-assisted group ($p = 0.20$). In the laparoscopic group, low anterior resections (LARs) with a primary anastomosis were constructed less often (50.8% versus 68.3% ($p < 0.001$)), end colostomies were constructed more often (43.8% versus 27.3% ($p < 0.001$)), and fewer patients received a diverting ileostoma (20.0% versus 33.7% ($p < 0.001$); Table 3). In addition, mean skin-to-skin time was significantly shorter in the laparoscopic group (146 (121–182) versus 191 (147–238) minutes; $p < 0.001$; Table 3). Multivariable regression analysis showed that robot-assisted technique was not associated with an increased skin-to-skin time. However, total splenic flexure mobilization, LAR with the construction of an anastomosis and a diverting stoma, abdominoperineal resection, and the center performing the procedure were independently associated with skin-to-skin time (Supplemental Table 1 at http://links.lww.com/DCR/B676).

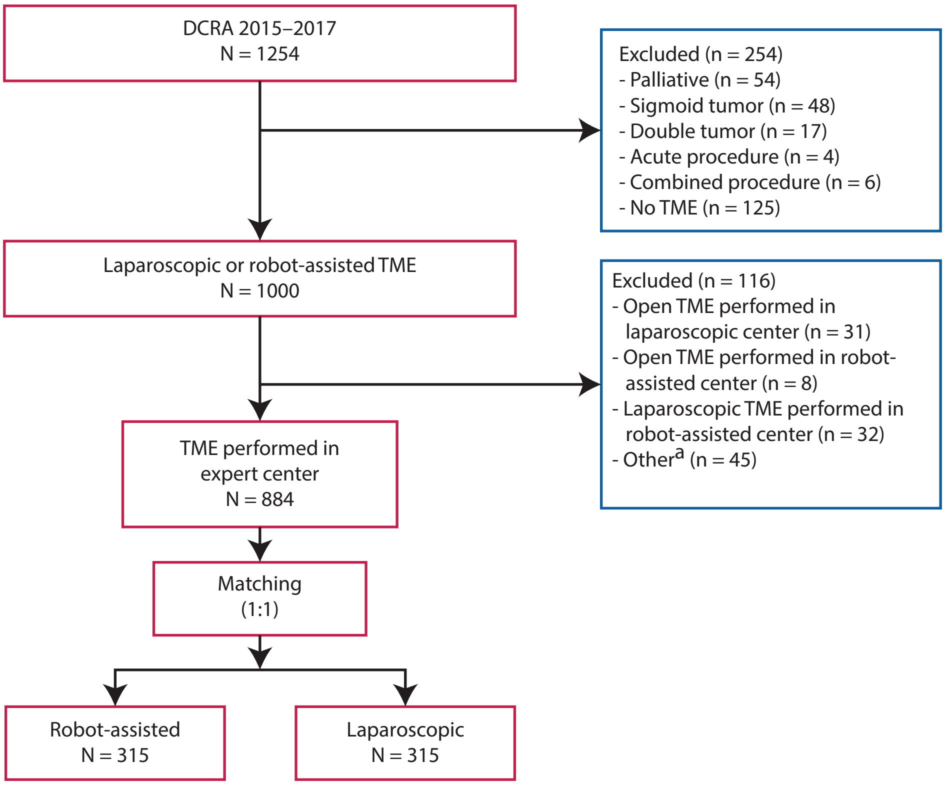

FIGURE 1. Patient flow. [a]Robot-assisted TME performed in a laparoscopic center, or transanal TME performed in a robot-assisted or laparoscopic center. DCRA = Dutch Colorectal Audit; TME = total mesorectal excision.

Postoperative Outcomes

Ninety-day mortality and morbidity were similar. Major morbidity (17.5% vs 18.4% (p = 0.34)) and surgical complications (32.1% vs 31.7% (p = 0.93)) were also comparable. Wound infection was significantly more prevalent in the laparoscopic group (5.7% vs 1.9% (p = 0.01)). Reintervention rate, readmission rate, and length of stay were equal between groups (Table 4).

Pathological Outcomes

Circumferential resection margin positivity was equal between the laparoscopic and robot-assisted groups (3.2% vs 4.4% (p = 0.41)). Histological type, pathological TNM classification, and quality of TME specimen did not differ between groups in the total cohort (Table 5).

DISCUSSION

Robot-assisted TME has not yet been shown to be superior to laparoscopic TME, possibly because most comparative studies include patients operated by surgeons with a variety of experience in robot-assisted TME surgery.[6,8,9,15,30] Therefore, this study aimed to provide a comparison between both techniques in patients operated by surgeons well beyond their learning curve in dedicated centers.

In this propensity score–matched retrospective cohort, no difference in conversion rate or reason for conversion was seen. First, the conversion rates found in this study are clearly below the rates published in earlier studies[6,8,27–29] and compared to the national conversion rates in the DCRA database.[2] This indicates that for both laparoscopic and robot-assisted TME conversion, rates are low in these dedicated centers. The reason, however, remains uncertain. This could be a result of the enhanced overall experience of colorectal surgeons, an increased resistance of surgeons toward conversion because of its associated morbidity, or the fact that all participating hospitals have profound experience with either robot-assisted or laparoscopic TME. Second, the reason for conversion was equal between the 2 groups, underlining our statement that surgical approach does not influence conversion rate.

Circumferential resection margin positivity for laparoscopic and robot-assisted TME in this study was 3.2% versus 4.4%. Especially compared with earlier randomized controlled trials, these numbers are low, because most studies report CRM positivity rates between 4% and 10%.[6,8,27–29] Although these studies are not as recent as our study, the national CRM positivity rates reported by the DCRA are between 4.0% and 5.1% for 2015 until 2017. This indicates the good quality of the oncological resection in our study, both for laparoscopic and robot-assisted

TABLE 1. Baseline characteristics of unmatched patients, including excluded patients who underwent open TME

	Study cohort				Excluded group			
Characteristics	*Laparoscopy*	*Robot-assisted*	*p value*	*SMD*	*Open in lap center*	*Open in robot center*	*Lap in robot center*	*Other*
Patients	559	325			31	8	32	45
Age, mean (SD)	67.63 (9.80)	67.13 (10.64)	0.48	0.049	64.71 (10.50)	74.12 (14.66)	71.56 (8.98)*	67.67 (9.91)
BMI, mean (SD)	26.19 (4.20)	25.88 (4.16)	0.30	0.073	26.92 (4.60)	25.27 (4.62)	24.42 (3.00)*	35.50 (48.16)*
Sex, n (%)								
Male	356 (63.7)	200 (61.5)	0.57	0.044	17 (54.8)	3 (37.5)	19 (59.4)	28 (62.2)
Female	203 (36.3)	125 (38.5)			14 (45.2)	5 (62.5)	13 (40.6)	17 (37.8)
Missing	0 (0.0)	0 (0.0)			0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
ASA classification, n (%)								
I	110 (19.7)	60 (18.5)	0.05	0.213	3 (9.7)	1 (12.5)	3 (9.4)	7 (15.6)
II	338 (60.5)	190 (58.5)			24 (77.4)	5 (62.5)	24 (75.0)	28 (62.2)
III	102 (18.2)	75 (23.1)			3 (9.7)	2 (25.0)	5 (15.6)	10 (22.2)
IV	9 (1.6)	0 (0.0)			1 (3.2)	0 (0.0)	0 (0.0)	0 (0.0)
Missing	0 (0.0)	0 (0.0)			0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Abdominal history, n (%)								
Yes	163 (29.2)	80 (24.6)	0.17	0.103	13 (41.9)	5 (62.5)	13 (40.6)	17 (37.8)
Missing	0 (0.0)	0 (0.0)			0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Tumor location, n (%)								
<5 cm	186 (33.3)	101 (31.1)	0.24	0.117	7 (22.6)	2 (25.0)	6 (18.8)	15 (33.3)
5–10 cm	189 (33.8)	128 (39.4)			16 (51.6)	3 (37.5)	13 (40.6)	17 (37.8)
>10 cm	184 (32.9)	96 (29.5)			8 (25.8)	3 (37.5)	13 (40.6)	13 (28.9)
Missing	0 (0.0)	0 (0.0)			0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
MRF +, n (%)								
Yes	135 (24.2)	104 (32.0)	0.05	0.150	10 (32.3)	4 (50.0)	12 (37.5)	4 (8.9)*
Missing	93 (16.6)	36 (11.1)			6 (19.4)	1 (12.5)	4 (12.5)	14 (31.1)
cT, n (%)								
1	19 (3.4)	5 (1.5)	0.004	0.257	1 (3.2)	0 (0.0)	3 (9.4)	3 (6.7)
2	170 (30.4)	110 (33.8)			5 (16.1)	1 (12.5)	11 (34.4)	12 (26.7)
3	322 (57.6)	164 (50.5)			13 (41.9)	6 (75.0)	13 (40.6)	28 (62.2)
4	36 (6.4)	40 (12.3)			12 (38.7)*	1 (12.5)	3 (9.4)	1 (2.2)
Missing	12 (2.1)	6 (1.8)			0 (0.0)	0 (0.0)	2 (6.2)	1 (2.2)
cN, n (%)								
0	253 (45.3)	148 (45.5)	0.90	0.033	8 (25.8)	4 (50.0)	18 (56.2)	25 (55.6)
1	181 (32.4)	102 (31.4)			9 (29.0)	2 (25.0)	8 (25.0)	13 (28.9)
2	115 (20.6)	71 (21.8)			14 (45.2)*	2 (25.0)	6 (18.8)	7 (15.6)
Missing	10 (1.8)	4 (1.2)			0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
cM, n (%)								
0	509 (91.1)	277 (85.2)	1.000	0.003	26 (83.9)	5 (62.5)	24 (75.0)	41 (91.1)
1	29 (5.2)	16 (4.9)			4 (12.9)	1 (12.5)	5 (15.6)*	3 (6.7)
Missing	21 (3.8)	32 (9.8)			1 (3.2)	2 (25.0)	3 (9.4)	1 (2.2)
Neoadjuvant therapy, n (%)								
None	263 (47.0)	134 (41.2)	0.12	0.316	10 (32.3)	3 (37.5)	15 (46.9)	24 (53.3)
Radiotherapy	162 (29.0)	111 (34.2)			6 (19.4)	3 (37.5)	11 (34.4)	13 (28.9)
Chemoradiation	134 (24.0)	80 (24.6)			15 (48.4)*	2 (25.0)	6 (18.8)	8 (17.8)
Missing	0 (0.0)	0 (0.0)			0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

cT = clinical T classification; cN = clinical N classification; cM= clinical M classification; MRF = mesorectal fascia involvement; SMD = standardized mean difference; TME, total mesorectal excision.

*p value <0.05 compared to study cohort (robot-assisted + laparoscopic).

TME. This underlines the assumption that the participating hospitals are experienced centers.

Robot-assisted surgery resulted in significantly more patients having a LAR with an anastomosis and a higher rate of patients with a diverting ileostomy. Conversely, it resulted in fewer APRs or LARs with an end colostomy. These results suggest that the robot-assisted procedure is better at constructing an anastomosis. This could have resulted in more "high-risk anastomoses," which might be an explanation for the higher rate of diverting ileostomies. Although the overall number of stomas is equal, most diverting stomas will probably be reversed. This is important for the patient, because having a permanent stoma is associated with a decline in quality of life compared with no stoma or a temporary stoma.[31,32] Clearly, there is a difference in treatment policy between hospitals in which

TABLE 2. Baseline characteristics of matched patients

Characteristics	*Laparoscopy*	*Robot-assisted*	*p value*	*SMD*
Patients	315	315		
Age, mean (SD)	67.48 (9.47)	67.14 (10.65)	0.67	0.034
BMI, mean (SD)	25.93 (4.06)	25.89 (0.908)	0.91	0.009
Sex, n (%)				
Male	196 (62.2)	194 (61.6)	0.94	0.013
Female	1219 (37.8)	121 (38.4)		
Missing	0 (0.0)	0 (0.0)		
ASA, n (%)				
I	59 (18.7)	59 (18.7)	0.98	0.016
II	188 (59.7)	186 (59.0)		
III	68 (21.6)	70 (22.2)		
IV	0 (0.0)	0 (0.0)		
Missing	0 (0.0)	0 (0.0)		
Abdominal history, n (%)				
Yes	74 (23.5)	79 (25.1)	0.71	0.037
Missing	0 (0.0)	0 (0.0)		
Tumor location, n (%)				
<5 cm	92 (29.2)	98 (31.1)	0.85	0.046
5–10 cm	128 (40.6)	122 (38.7)		
>10 cm	96 (30.2)	95 (30.2)		
Missing	0 (0.0)	0 (0.0)		
MRF, n (%)				
Positive	89 (28.3)	97 (30.8)	0.96	0.012
Negative	174 (55.2)	185 (58.7)		
Missing	52 (16.5)	33 (10.5)		
cT, n (%)				
1	5 (1.6)	5 (1.6)	1.00	0.020
2	110 (34.9)	110 (34.9)		
3	164 (52.1)	163 (51.7)		
4	30 (9.5)	32 (10.2)		
Missing	6 (1.9)	5 (1.6)		
cN, n (%)				
0	142 (45.1)	144 (45.7)	0.94	0.028
1	104 (33.0)	100 (31.7)		
2	66 (21.0)	68 (21.6)		
Missing	3 (1.0)	3 (1.0)		
cM, n (%)				
0	282 (89.5)	270 (85.7)	0.60	0.058
1	20 (6.3)	15 (4.8)		
Missing	13 (4.1)	30 (9.5)		
Neoadjuvant therapy, n (%)				
None	125 (39.7)	130 (41.3)	0.92	0.032
Radiotherapy	108 (34.3)	105 (33.3)		
Chemoradiation	74 (23.5)	77 (24.4)		
Missing	8 (2.5)	3 (1.0)		

cT = clinical T classification; cN = clinical N classification; cM = clinical M classification; MRF = mesorectal fascia involvement; SMD = standardized mean difference.

surgeons perform robot-assisted TME compared with laparoscopic TME, but these results were not seen in earlier studies[6,8,33]; therefore, we are cautious interpreting these results. Whether this is a result of the difference in operative technique, difference in patient counseling, or simply a result of preference of the local surgical team is not clear. Nor do we know how constructing more primary anastomoses in the robot-assisted group affects quality of life. Constructing more and lower anastomoses might result in more patients with low anterior resection syndrome symptoms.[34,35]

Operating times were longer in the robot-assisted group. This is in concordance with earlier research.[6,8,9,14,33] However, the type of the procedure, total splenic flexure

TABLE 3. Perioperative results of matched patients

Perioperative results	*Laparoscopy*	*Robot-assisted*	*p value*
Patients	315	315	
Skin-to-skin time, median [IQR]	146 [121–182]	191 [147–238]	<0.001
Procedure, n (%)			
APR	102 (32.4)	85 (27.0)	0.15
LAR + ending colostomy	53 (16.8)	15 (4.8)	<0.001
LAR + anastomosis	160 (50.8)	215 (68.3)	<0.001
Conversion, n (%)			
Conversion	14 (4.4)	8 (2.5)	0.20
No conversion	301 (95.6)	307 (97.5)	
Reason for conversion, n (%)			
Extensiveness tumor	2 (0.6)	1 (0.3)	0.40
Accessibility	10 (3.2)	7 (2.2)	
Intraoperative complication	2 (0.6)	0 (0.0)	
Missing	0 (0.0)	0 (0.0)	
Stoma constructed, n (%)			
No stoma	97 (30.8)	120 (38.1)	0.06
Diverting ileostomy	63 (20.0)	106 (33.7)	<0.001
End ileostomy	2 (0.6)	1 (0.3)	0.56
Diverting colostomy	15 (4.8)	2 (0.6)	0.002
End colostomy	138 (43.8)	86 (27.3)	<0.001
Missing	0 (0.0)	0 (0.0)	
Total splenic flexure mobilization, n (%)	69 (21.9)	67 (21.3)	0.85
Additional resection performed, n (%)	15 (4.8)	14 (4.4)	0.85
Intraoperative complication, n (%)	22 (7.0)	24 (7.6)	0.76

APR = abdominoperineal resection; IQR = interquartile range; LAR = low anterior resection.

TABLE 4. Postoperative outcomes of matched patients

Postoperative outcomes	*Laparoscopy*	*Robot-assisted*	*p value*
Patients	315	315	
90-day mortality, n (%)	5 (1.6)	6 (1.9)	0.76
90-day morbidity, n (%)	147 (46.7)	140 (44.4)	0.58
Major morbidity (CD ≥3)	55 (17.5)	58 (18.4)	0.34
Surgical complications, n (%)	101 (32.1)	100 (31.7)	0.93
Abscess	21 (6.7)	12 (3.8)	0.12
Ileus	44 (14.0)	53 (16.8)	0.30
Anastomotic leakage	18/160 (11.2)	28/216 (13.0)	0.61
Wound infection	18 (5.7)	6 (1.9)	0.01
Reintervention required, n (%)	48 (15.2)	52 (16.5)	0.66
Length of stay, days, median [IQR]	6.00 [5.00, 9.00]	5.00 [4.00, 9.00]	0.24
Readmission required, n (%)	44 (14.0)	55 (17.5)	0.24

CD = Clavien-Dindo classification; IQR = interquartile range.

TABLE 5. Pathological outcomes of matched patients

Pathological outcomes	Laparoscopy	Robot-assisted	p value
Patients	315	315	
Histological type, n (%)			
Adenocarcinoma	292 (92.7)	299 (94.9)	0.50
Mucinous	20 (6.3)	16 (5.1)	
Other	3 (1.0)	0 (0.0)	
Missing	0 (0.0)	0 (0.0)	
Differentiation grade, n (%)			
Well/moderate	285 (90.5)	281 (89.2)	0.66
Poor	13 (4.1)	10 (3.2)	
Unknown	17 (5.4)	24 (7.6)	
Missing	0 (0.0)	0 (0.0)	
pT, n (%)			
0	13 (4.1)	22 (7.0)	0.23
1	34 (10.8)	28 (8.9)	
2	116 (36.8)	103 (32.8)	
3	142 (45.1)	151 (48.1)	
4	10 (3.2)	10 (3.2)	
Missing	0 (0.0)	1 (0.3)	
pN, n (%)			
0	214 (67.9)	204 (64.8)	0.80
1	76 (24.1)	87 (27.6)	
2	25 (7.9)	24 (7.6)	
Missing	0 (0.0)	0 (0.0)	
pM, n (%)			
0	294 (95.5)	298 (94.6)	0.72
1	14 (4.5)	17 (5.4)	
Missing	7 (2.2)	0 (0.0)	
Quality of TME, n (%)			
Incomplete	17 (5.6)	20 (6.3)	0.47
Nearly complete	74 (24.6)	69 (21.9)	
Complete	210 (69.8)	226 (71.7)	
Missing	14 (4.4)	0 (0.0)	
CRM, n (%)			
>1 mm	305 (96.8)	301 (95.6)	0.41
≤1 mm	10 (3.2)	14 (4.4)	

CRM = circumferential resection margin; pT = pathological T classification; pN = pathological N classification; pM = pathological M classification; TME = total mesorectal excision.

mobilization, and the center in which the procedure was performed significantly impacted operating time. More specifically, operating times of robot-assisted TME performed in 1 center were significantly longer than laparoscopic TME, whereas operating time was significantly shorter in the other robot-assisted center. This could be due to institutional factors, because operating times remained different between the dedicated centers when controlling for the type of procedure and total mobilization of the splenic flexure.

Considering postoperative outcomes, we saw a similar incidence of 90-day morbidity and surgical morbidity and mortality rate between the 2 techniques. Overall complication rates of 44% to 46% and anastomotic leakage rates of 11.2% to 13.0% are high compared with national audit data.[2] However, we registered 90-day morbidity, whereas the national audit registers 30-day morbidity. In addition, it is known that anastomotic leakage rate during long-term follow-up is close to 20%.[36] The rate of wound infection was more than twice as high in the laparoscopic group (5.7%) versus the robot-assisted group (1.9%). Perhaps this was because end colostomies were performed more frequently in the laparoscopic group, because stomas are a known risk factor for wound infections,[37] and the left colon is suggested to contain a higher bacterial load which may increase the risk of wound infections.[38,39] However, because we did not specify the location of the wound infection, we cannot verify this.

Finally, we saw that more patients underwent an open TME in laparoscopic centers, and more clinical T_4 and N_+ tumors were seen in the open TME group performed in laparoscopic centers. Although this might suggest that T_4N_+ tumors are more often resected using the open technique in laparoscopic centers, whereas the robot-assisted technique is used in robot-assisted centers, this cannot automatically be contributed to the technique. Patient counseling, institutional policy, or surgical preference for surgical approach in the case of T_4N_+ tumors could be explanatory. In addition, because of the small number of T_4N_+ tumors, we are not able to compare both approaches for this specific group, nor can we compare open TME with robot-assisted TME.

Despite the outcomes of this study, certain limitations should be considered. First, because this is a retrospective study, bias is introduced due to the method of data collection. However, because most of the presented data are registered for the Dutch national audit DCRA, most data are collected prospectively. Furthermore, to enhance the quality of data, we controlled primary outcomes in the patient's EMR. In addition, we used a propensity score–matched analysis, thereby aiming to reduce confounding and create comparable groups. Nevertheless, we could not completely control for the fact that patients with larger tumors and more nodal involvement were more often offered an open TME in the laparoscopic centers, despite using cT and cN in our propensity score matching. Second, this study involves a comparison between 2 robot-assisted and 5 laparoscopic rectal cancer centers. Therefore, practice variation and differences in treatment policy between centers and surgeons could influence outcomes, especially for the robot-assisted group, because we only included 2 dedicated robot centers. Third, although we aimed to reduce the difference in surgical experience, robot-assisted surgeons with 3 to 5 years of experience are compared with laparoscopic surgeons with about 10 years of experience. Nevertheless, the introduced bias would be minimal, because learning curves are between 30 and 40 procedures for robot-assisted surgery.[19–21] In addition, all robot-assisted surgeons were well-experienced laparoscopic rectal cancer surgeons before learning the robot-assisted technique.

CONCLUSIONS

This study shows that conversion rate, CRM positivity, and postoperative complications are equal between robot-assisted TME and laparoscopic TME performed by experienced surgeons. However, because robot-assisted TME shows fewer wound infections and more primary anastomoses, this technique might therefore be favorable. Nevertheless, because the implications on quality of life remain unknown, larger prospective, population-based cohorts of patients operated on by surgeons well beyond their learning curve are needed.

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