Original article

Risk factors for conversion in laparoscopic and robotic rectal cancer surgery

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Background: **The aim of this study was to review risk factors for conversion in a cohort of patients with rectal cancer undergoing minimally invasive abdominal surgery.**

Methods: **A retrospective analysis was performed of consecutive patients operated on from February 2005 to April 2018. Adult patients undergoing low anterior resection or abdominoperineal resection for primary rectal adenocarcinoma by a minimally invasive approach were included. Exclusion criteria were lack of research authorization, stage IV or recurrent rectal cancer, and emergency surgery. Risk factors for conversion were investigated using logistic regression. A subgroup analysis of obese patients (BMI 30 kg/m^2 or more) was performed.**

Results: **A total of 600 patients were included in the analysis. The overall conversion rate was 9·2 per cent. Multivariable analysis showed a 72 per cent lower risk of conversion when patients had robotic surgery (odds ratio (OR) 0·28, 95 per cent c.i. 0·15 to 0·52). Obese patients experienced a threefold higher risk of conversion compared with non-obese patients (47 *versus* 24·4 per cent respectively; *P* < 0·001). Robotic surgery was associated with a reduced risk of conversion in obese patients (OR 0·22, 0·07 to 0·71).**

Conclusion: **Robotic surgery was associated with a lower risk of conversion in patients undergoing minimally invasive rectal cancer surgery, in both obese and non-obese patients.**

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Introduction

Low anterior resection (LAR) and abdominoperineal resection (APR) with total mesorectal excision (TME) remain the mainstays of treatment for locally advanced rectal cancer. Operative techniques have evolved over time to encompass several approaches, including open (hand-assisted), laparoscopic, transanal and robotic procedures[1].

Over the past decade, laparoscopic approaches have demonstrated clear benefits, including faster return of gastrointestinal function, less analgesic use and shorter length of hospital stay[2]. However, laparoscopic surgery for rectal cancer is technically challenging, with a steep learning curve and a high conversion rate of up to 30 per cent[3]. Limitations include working in the bony confines of a narrow pelvic cavity in close proximity to vital structures, restricted instrument motion, poor ergonomic positioning, and dependency on assistants for retraction and camera handling[4].

Studies[3,5] have shown that short-term perioperative, and possibly oncological, outcomes of rectal cancer may be adversely affected in patients who require conversion from a laparoscopic approach.

Robotic surgery was introduced with the potential to overcome some limitations of laparoscopy. The robotic platform provides high-resolution three-dimensional imaging, superior ergonomics, and articulating instruments that mimic the movement of a hand with up to seven degrees of motion. More recently, laparoscopy has given way to robotic approaches in many high-volume centres[6].

The ROLARR trial[7], in which conversion rate was chosen as the primary outcome to reflect the feasibility of completing TME, failed to prove superiority for the robotic approach. This landmark trial has been criticized for the variation of experience with robotic surgery among participating surgeons[8,9]. Moreover, these results have been contradicted by a recent meta-analysis[10], which found lower conversion rates for robotic surgery.

The present study, a large single-centre analysis from a referral centre with long-standing experience in minimally invasive colorectal surgery, aimed to investigate the conversion rate and associated risk factors in patients undergoing minimally invasive surgery for rectal cancer.

Methods

The institutional review board approved a retrospective analysis of a prospectively maintained database of consecutive patients operated on for rectal cancer from February 2005 to April 2018 at the Mayo Clinic in Rochester, Minnesota, and Jacksonville, Florida. Inclusion criteria were curative LAR or APR for rectal adenocarcinoma, minimally invasive approach (either laparoscopic or robotic), and patient age at least 18 years. Exclusion criteria were lack of research authorization, stage IV or recurrent rectal cancer, and emergency surgery.

The primary outcome was the conversion rate. In a second step, factors associated with conversion were identified. Conversion was defined as the need to perform a laparotomy before completing the TME. Patients were divided into two groups based on conversion status: conversion and no conversion. Operative notes were scrutinized to determine the reasons for conversion. Any conversion that followed an intraoperative complication such as bleeding or iatrogenic organ injury was considered a reactive conversion, whereas pre-emptive conversion was defined as one undertaken to avoid a complication.

Pertinent variables of interest were demographics, surgical approach (robotic or laparoscopic), tumour characteristics, and intraoperative outcomes such as duration of surgery, fashioning a protective ileostomy and type of procedure (LAR *versus* APR). These were assigned as independent variables. The need to convert to an open procedure was chosen as the dependent variable.

A subgroup analysis of obese patients (BMI 30 kg/m^2 or more) was performed, with comparison of conversion rates in obese and non-obese patients.

Postoperative outcomes included length of hospital stay (LOS), readmission rate, need for blood transfusion, postoperative ileus, anastomotic leak, wound infection rate and death at 30 days. Number of lymph nodes retrieved and rate of positive circumferential resection margin were also reported. The Mayo Clinic protocol for blood transfusion was adhered to; this follows international consensus guidelines[11]. Ileus was defined as the inability to tolerate a normal diet within 3 days of surgery or the need for postoperative nasogastric tube insertion. Anastomotic leak was defined according to the definition proposed by the International Study Group of Rectal Cancer[12].

Procedure and perioperative care

The first robotic procedure was performed in the Mayo Clinic in 2007, and a structured colorectal robotic programme was launched in 2010. All operations were performed by a team of ten board-certified colonic and rectal surgeons. All surgeons received dedicated education through simulators, cadaver laboratories and hands-on training before starting the robotic programme. Robotic learning curve cases were included in the analysis. Four of the original surgeons switched entirely to the robotic approach. Three surgeons were hired during the study period to perform robotic surgery exclusively. The remaining three surgeons performing minimally invasive procedures did not switch to the robotic procedure at all and continued to perform laparoscopic resections. Thus, surgeons chose either approach as standard practice according to personal preference and did not alternate with the other technique.

The surgical technique for rectal cancer surgery is standardized across the authors' institution[13]. Of note, since implementation of the robotic platform, robotic surgery has expanded rapidly in the Mayo Clinic and is now the predominant approach to primary rectal cancer. Robotic TME was performed using the da Vinci® Si Surgical System (Intuitive Surgical, Sunnyvale, California, USA) until 2014, when it was replaced by the da Vinci® Xi Surgical System. Further details of the methodology for staging and preoperative evaluation were described in a previous Mayo Clinic publication, as well as detailed description of robotic and laparoscopic techniques[14,15]. An enhanced recovery programme was introduced and adopted in 2010, as described in previous papers[16,17].

Statistical analysis

Continuous variables are described as mean(s.d.) or median (i.q.r.) values as appropriate. Categorical variables are given as frequencies and percentages. Significant differences between the two groups (conversion *versus* no conversion) were tested using the χ^2 test or Fisher's exact test for categorical variables, and Student's *t* test for continuous variables. Univariable analysis for odds to conversion was performed by logistic regression. Relevant univariable variables ($P < 0{\cdot}300$) were included in a multivariable logistic regression model. Results are shown as odds ratio (OR) with 95 per cent confidence intervals. Another model was built that considered only a subgroup of patients with BMI of 30 kg/m^2 or above. All tests were two-sided and $P < 0{\cdot}050$ was considered statically significant. Analysis was performed using JMP® Pro version 13.0 (SAS Institute, Cary, North Carolina, USA).

Table 1 Baseline patient demographics

	Conversion (n = 55)	No conversion (n = 545)	Total (n = 600)	P†
Age (years)*	59·9(13·2)	58·4(15·8)	58·5(13·4)	0·480‡
Sex ratio (M : F)	43 : 12	360 : 185	403 : 197	0·059
BMI (≥ 30 kg/m²)	26 (47)	133 (24·4)	159 (26·5)	< 0·001
ASA grade				0·344
I	3 (5)	18 (3·3)	21 (3·5)	
II	32 (58)	371 (68·1)	403 (67·2)	
III	19 (35)	154 (28·3)	173 (28·8)	
IV	1 (2)	2 (0·4)	3 (0·5)	
Treated stage				0·296
I	9 (16)	137 (25·1)	146 (24·3)	
II	13 (24)	100 (18·3)	113 (18·8)	
III	33 (60)	308 (56·5)	341 (56·8)	
Neoadjuvant therapy	31 (56)	314 (57·6)	345 (57·5)	0·858
Previous abdominal surgery	19 (35)	147 (27·0)	166 (27·7)	0·241

Values in parentheses are percentages unless indicated otherwise; *values are mean(s.d.). †χ^2 or Fisher's exact test, except ‡Student's t test.

Table 2 Surgical details

	Conversion (n = 55)	No conversion (n = 545)	Total (n = 600)	P†
Procedure (LAR)	36 (65)	398 (73·0)	434 (72·3)	0·241
Surgical approach				< 0·001
Robotic	16 (29)	301 (55·2)	317 (52·8)	
Laparoscopic	39 (71)	244 (44·8)	283 (47·2)	
Diversion	26 (47)	314 (57·6)	340 (56·7)	0·142
Anastomosis				0·380
None	19 (35)	147 (27·0)	166 (27·7)	
Stapled	27 (49)	275 (50·5)	302 (50·3)	
Handsewn	9 (16)	123 (22·6)	132 (22·0)	
Duration of surgery (min)*	259·8(80·2)	273·7(109·9)	272·0(107·5)	0·243‡

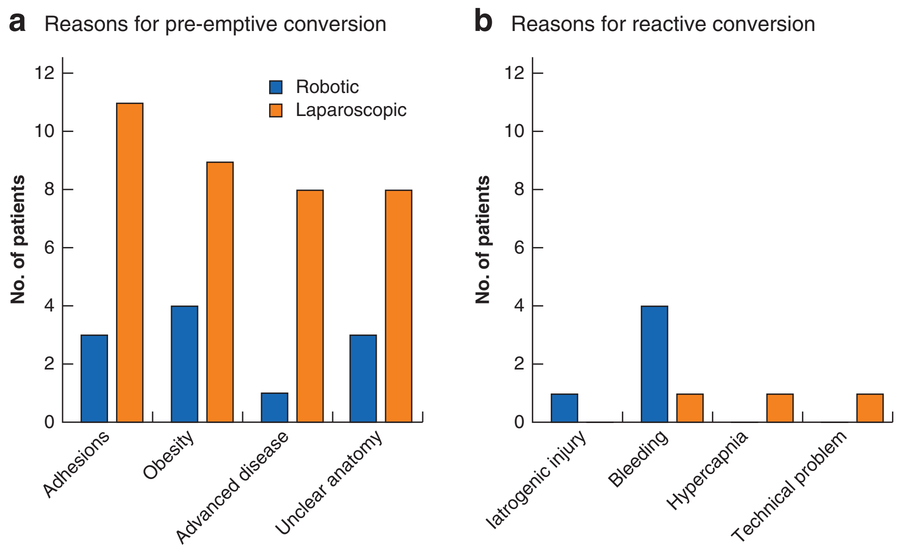
Values in parentheses are percentages unless indicated otherwise; *values are mean(s.d.). LAR, low anterior resection. †χ^2 or Fisher's exact test, except ‡Student's t test.

Table 3 Postoperative and oncological outcomes

	Conversion (n = 55)	No conversion (n = 545)	Total (n = 600)	P†
Length of stay (days)*	6 (5–9)	4 (3–6)	4 (3–6)	< 0·001‡
Readmission	8 (15)	65 (11·9)	73 (12·2)	0·580
Postoperative transfusion	5 (9)	23 (4·2)	28 (4·7)	0·141
Ileus	14 (25)	87 (16·0)	101 (16·8)	0·088
Leak	4 (7)	33 (6·1)	37 (6·2)	0·726
Wound infection	4 (7)	21 (3·8)	25 (4·2)	0·267
No. of lymph nodes resected*	21 (15–30)	22 (15–31)	22 (15–31)	0·922‡
Positive CRM	1 (2)	4 (0·7)	5 (0·8)	0·383
Died within 30 days	1 (2)	1 (0·2)	2 (0·3)	0·175

Values in parentheses are percentages unless indicated otherwise; *values are median (i.q.r.). CRM, circumferential resection margin. †χ^2 or Fisher's exact test, except ‡Student's t test.

Fig. 1 Reasons for conversion according to surgical approach



a Pre-emptive conversion; **b** reactive conversion.

Table 4 Logistic regression analysis of conversion risk in all patients

	Univariable analysis		Multivariable analysis	
	Odds ratio	*P*	Odds ratio	*P*
Sex (M *versus* F)	1·84 (0·95, 3·58)	0·059	2·08 (1·03, 4·23)	0·004
BMI (≥ 30 *versus* < 30 kg/m²)	2·76 (1·57, 4·84)	< 0·001	2·90 (1·60, 5·27)	< 0·001
Procedure (LAR *versus* APR)	0·7 (0·39, 1·26)	0·241		
Type of surgery (robotic *versus* laparoscopic)	0·33 (0·18, 0·61)	0·001	0·28 (0·15, 0·52)	< 0·001
Treated stage				
I	1·00 (reference)		1·00 (reference)	
II	1·98 (0·81, 4·81)	0·132	2·80 (1·10, 7·10)	0·031
III	1·63 (0·76, 3·50)	0·209	2·24 (1·01, 4·98)	0·048
Previous abdominal surgery	1·43 (0·79, 2·57)	0·233	1·95 (1·03, 3·70)	0·041
ASA grade (III–IV *versus* I–II)	1·42 (0·80, 2·55)	0·231	1·13 (0·61, 2·11)	0·689
Age	0·99 (0·97, 1·12)	0·407		
Duration of surgery	1·00 (0·99, 1·00)	0·362		
Neoadjuvant therapy	0·95 (0·60, 1·84)	0·858		

Values in parentheses are 95 per cent confidence intervals. LAR, low anterior resection; APR, abdominoperineal resection.

Results

A total of 600 patients were included in the analysis; the demographics and tumour characteristics for converted and non-converted groups are shown in *Table 1*. *Table 2* provides surgical details of the two cohorts. Overall, 317 patients (52·8 per cent) had a robotic and 283 (47·2 per cent) had a laparoscopic approach. Patients who had robotic surgery had a higher rate of stage III tumour (63·5 per cent *versus* 50·2 per cent in those having laparoscopic surgery; $P = 0·001$), a higher rate of APR (33·4 *versus* 21·2 per cent respectively; $P < 0·001$) and longer duration of surgery (324·1 *versus* 214·6 min; $P < 0·001$). *Table 3* reports postoperative outcomes.

The overall conversion rate was 9·2 per cent (55 of 600). The proportion of obese patients was higher in the conversion than in the no conversion group (47 *versus* 24·4 per cent respectively) (*Table 1*). Conversion rates were 13·8 per cent (39 of 283) for laparoscopic surgery and 5·0 per cent (16 of 317) for robotic surgery (*Table 2*). Of the 55 conversions, eight (15 per cent) were reactive (3 of 39 for

Table 5 Logistic regression analysis of conversion risk in patients with BMI of 30 kg/m² or above

	Univariable analysis		Multivariable analysis	
	Odds ratio	*P*	Odds ratio	*P*
Sex (M *versus* F)	1·34 (0·52, 3·43)	0·533		
Procedure (LAR *versus* APR)	0·83 (0·33, 2·09)	0·702		
Type of surgery (robotic *versus* laparoscopic)	0·28 (0·11, 0·7)	0·004	0·22 (0·07, 0·71)	0·011
Treated stage				
I	1·00 (reference)		1·00 (reference)	
II	2·52 (0·68, 9·33)	0·164	3·24 (0·83, 12·63)	0·090
III	1·60 (0·55, 4·79)	0·382		
Previous abdominal surgery	1·15 (0·47, 2·78)	0·761		
ASA grade (III–IV *versus* I–II)	1·01 (0·43, 2·36)	0·985		
Age	1·00 (0·96, 1·00)	0·992		
Duration of surgery	1·00 (1·00, 1·00)	0·192	1·00 (0·99, 1·01)	0·869
Neoadjuvant therapy	0·90 (0·37, 2·17)	0·808		

Values in parentheses are 95 per cent confidence intervals. LAR, low anterior resection; APR, abdominoperineal resection.

laparoscopic and 5 of 16 for robotic surgery) and 47 (85 per cent) were pre-emptive (36 of 39 for laparoscopic and 11 of 16 for robotic surgery). Reasons for reactive conversion were intraoperative bleeding, hypercapnia, iatrogenic injury and technical problems. Reasons for poor progression and consecutive pre-emptive conversion included unclear anatomy, obesity, presence of adhesions and locally advanced disease. *Fig. 1* describes the reasons for conversion according to surgical approach.

Univariable logistic regression demonstrated BMI to be a risk factor for conversion (OR 2·76, 95 per cent c.i. 1·57 to 4·84; $P < 0·001$), whereas robotic surgery was associated with a lower risk of conversion (OR 0·33, 0·18 to 0·61; $P = 0·001$). This was confirmed in the multivariable model for both BMI (OR 2·90, 1·60 to 5·27; $P < 0·001$) and robotic surgery (OR 0·28, 0·15 to 0·52; $P < 0·001$). In other words, patients undergoing laparoscopic surgery had a 3·6-fold greater chance of having conversion to open surgery than those operated on with a robotic approach. Male sex, advanced tumour stage and previous abdominal surgery were other risk factors for conversion in multivariable analysis (*Table 4*).

Table 5 shows the subgroup analysis of the 159 obese patients with a BMI of 30 kg/m² or above. Robotic surgery was associated with a decreased risk of conversion, even in the obese group (OR 0·22, 95 per cent c.i. 0·07 to 0·71; $P = 0·011$).

Discussion

This investigation suggests that robotic surgery is associated with a decreased risk of conversion in patients undergoing minimally invasive surgery for rectal cancer. Male sex, BMI, advanced tumour stage and previous abdominal surgery were identified as additional risk factors for conversion in multivariable analysis. Patients with a BMI of 30 kg/m² or above had a nearly threefold increased risk of conversion, whereas robotic surgery was found to decrease the conversion rate, even in the obese cohort.

Conversion has been used as a marker of proficiency since the advent of minimally invasive techniques[18]. Conversion to open surgery may have a negative impact on both short- and long-term outcomes[19–21]. Decreasing conversion rate is therefore important to improve surgical and oncological quality.

The ROLARR trial[7] was powered to investigate a potential beneficial effect for robotic surgery with respect to conversion. Conversion rates were 8·1 per cent for robotic and 12·2 per cent for laparoscopic surgery (overall rate 10·1 per cent). This difference was not statistically significant. Male sex, higher BMI and LAR (*versus* APR) were risk factors for conversion, whereas there was no difference in intraoperative complications between the two procedures. A similar overall conversion rate of 9·2 per cent was found in the present study, but a statistically significant difference was found between the two techniques, favouring the robotic approach.

Although the ROLARR trial[7] represents the largest RCT on robotic surgery and therefore the strongest available evidence, a *post hoc* sensitivity analysis[8] adjusting for participating surgeons suggested that the wide variety of robotic experience may have had a confounding effect on the results. Thus, the results of the present analysis, deriving from a single organization with a long-standing experience in minimally invasive surgery using a highly standardized technique, may account for more homogeneity and address this potential shortcoming of the ROLARR trial, despite limitations related to the retrospective study design. In line with the present results, several retrospective series[22–24] have revealed lower conversion rates for robotic compared with laparoscopic surgery.

Crolla and colleagues[22] published a series of 352 patients (168 robotic and 184 laparoscopic) operated on for rectal cancer by two experienced laparoscopic surgeons. Although there was no difference in positive circumferential margins, anastomotic leak rate or mortality, the conversion rate was lower in the robotic group (1·8 per cent *versus* 12·5 per cent in the laparoscopic group). This evidence is further strengthened by the slightly different setting of the present investigation, with multiple operators from a single institution.

A recent French retrospective study[25] of 400 consecutive patients confirmed the benefit of a robotic approach on conversion rate (2 per cent *versus* 9·5 per cent for the laparoscopic approach). However, although the robotic approach was superior in men and patients having LAR (*versus* APR), a statistically significant benefit for robotic surgery in obese patients was not found. This result may reflect lack of power, given the small sample size (55 obese patients). In contrast, the present study involving 159 obese patients confirmed a significantly lower robotic conversion rate in these patients.

Whereas risk factors for conversion to open surgery have been investigated extensively, specific reasons for conversion are reported less often[26]. In the present series, poor vision or adhesions and intra-abdominal obesity were main reasons for conversion from laparoscopic surgery, and bleeding accounted for one-quarter (4 of 16) of robotic conversions. Adhesions can limit the ability to move inside the abdominal cavity, and increase the risk of injury to contiguous structures or organs during traction. Robotic technology may help surgeons by means of tremor-free, sharp dissection, and thereby facilitate the time- and effort-demanding lysis. Bleeding complications can be hard to visualize and control during a minimally invasive procedure. Further challenges related to the robotic approach when encountering bleeding (working on a distant console, time-consuming undocking process) may have affected surgeons' decision to convert the procedure. Obesity is a risk factor for conversion in both surgical approaches. Fatter tissues tend to be more fragile and vessels harder to visualize. Obese patients undergoing robotic surgery had a 78 per cent lower risk of conversion compared with laparoscopic surgery in the present series. This could also be due to anatomical characteristics. A thicker abdominal wall requires additional strength by the operator for the disadvantageous angle and relative immobility of the trocars, whereas this appears not to be a particular issue in robotic surgery.

Ongoing technological innovation in rectal cancer surgery has an important role in improving surgical care and patient outcomes. In 2005, the authors of the landmark CLASICC trial[3] questioned the safety of a laparoscopic approach to rectal cancer in terms of short-term outcomes, compared with open surgery. At 34 per cent, the conversion rate was much higher than in both the ROLARR trial[7] (12·2 per cent for the laparoscopic group) and the present study (13·8 per cent). This trend of lower conversion rates over time in both RCTs and large retrospective cohorts may be an indicator of acquired skills and experience. Robotic surgery has shown a lower conversion rate than laparoscopic surgery in many trials since its introduction[26], and this gap is likely to widen in large-volume centres where the burden of higher cost is easier to overcome.

This study has limitations beyond its retrospective design. Despite the inclusion of consecutive patients, it is prone to selection bias, favouring the robotic approach in the more recent study period. However, surgeons switched either entirely to the robotic approach or not at all, thus eliminating bias related to patient selection for either approach. Advances in perioperative care occurred over the long study period and may have affected outcomes. However, perioperative care was highly standardized regardless of the surgical approach in the authors' institution during the study period. Even though the analysis was performed from prospectively collected data, observer bias may confound the results considering the long study interval.

In this large retrospective analysis of patients with rectal cancer undergoing minimally invasive procedures, robotic surgery was associated with a lower risk of conversion compared with the laparoscopic approach. This effect was retained in a subgroup analysis of obese patients. Future prospective trials are needed and should include experienced minimally invasive surgeons for both approaches.

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Because of the sensitive nature of the data collected for this study, requests to access the data set from qualified researchers trained in human subject confidentiality protocols may be sent to the corresponding author (D.W.L.).

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