



Retrospective Study

Feasibility and safety of minimally invasive multivisceral resection for T4b rectal cancer: A 9-year review

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Abstract

BACKGROUND

Colorectal cancer is the third most common cancer and the second highest cause of cancer-related mortality worldwide. About 5%-10% of patients are diagnosed with locally advanced rectal cancer (LARC) on presentation. For LARC invading into other structures (*i.e.* T4b), multivisceral resection (MVR) and/or pelvic exenteration (PE) remains the only potential curative surgical treatment. MVR and/or PE is a major and complex surgery with high post-operative morbidity. Minimally invasive surgery (MIS) has been shown to improve short-term post-operative outcomes in other gastrointestinal malignancies, but there is little evidence on its use in MVR, especially so for robotic MVR.

AIM

To assess the feasibility and safety of minimally invasive MVR (miMVR), and compare post-operative outcomes between robotic and laparoscopic MVR.

METHODS

This is a single-center retrospective cohort study from 1st January 2015 to 31st March 2023. Inclusion criteria were patients diagnosed with cT4b rectal cancer and underwent MVR, or stage 4 disease with resectable systemic metastases. Patients who underwent curative MVR for locally recurrent rectal cancer, or metachronous rectal cancer were also included. Exclusion criteria were patients with systemic metastases with non-resectable disease. All patients planned for elective surgery were enrolled into the standard enhanced recovery after surgery pathway with standard peri-operative management for colorectal surgery. Complex surgery was defined based on technical difficulty of surgery (*i.e.* total PE, bladder-sparing prostatectomy, pelvic lymph node dissection or need for flap creation). Our primary outcomes were the margin status, and complication rates. Categorical values were described as percentages and analysed by the chi-square test. Continuous variables were expressed as median (range) and analysed by Mann-

Whitney *U* test. Cumulative overall survival (OS) and recurrence-free survival (RFS) were analysed using Kaplan-Meier estimates with life table analysis. Log-rank test was performed to determine statistical significance between cumulative estimates. Statistical significance was defined as $P < 0.05$.

RESULTS

A total of 46 patients were included in this study [open MVR (oMVR): 12 (26.1%), miMVR: 36 (73.9%)]. Patients' American Society of Anesthesiologists score, body mass index and co-morbidities were comparable between oMVR and miMVR. There is an increasing trend towards robotic MVR from 2015 to 2023. MiMVR was associated with lower estimated blood loss (EBL) (median 450 *vs* 1200 mL, $P = 0.008$), major morbidity (14.7% *vs* 50.0%, $P = 0.014$), post-operative intra-abdominal collections (11.8% *vs* 50.0%, $P = 0.006$), post-operative ileus (32.4% *vs* 66.7%, $P = 0.04$) and surgical site infection (11.8% *vs* 50.0%, $P = 0.006$) compared with oMVR. Length of stay was also shorter for miMVR compared with oMVR (median 10 *vs* 30 d, $P = 0.001$). Oncological outcomes—R0 resection, recurrence, OS and RFS were comparable between miMVR and oMVR. There was no 30-d mortality. More patients underwent robotic compared with laparoscopic MVR for complex cases (robotic 57.1% *vs* laparoscopic 7.7%, $P = 0.004$). The operating time was longer for robotic compared with laparoscopic MVR [robotic: 602 (400-900) min, laparoscopic: Median 455 (275-675) min, $P < 0.001$]. Incidence of R0 resection was similar (laparoscopic: 84.6% *vs* robotic: 76.2%, $P = 0.555$). Overall complication rates, major morbidity rates and 30-d readmission rates were similar between laparoscopic and robotic MVR. Interestingly, 3-year OS (robotic 83.1% *vs* 58.6%, $P = 0.008$) and RFS (robotic 72.9% *vs* 34.3%, $P = 0.002$) was superior for robotic compared with laparoscopic MVR.

CONCLUSION

MiMVR had lower post-operative complications compared to oMVR. Robotic MVR was also safe, with acceptable post-operative complication rates. Prospective studies should be conducted to compare short-term and long-term outcomes between robotic *vs* laparoscopic MVR.

Key Words: Laparoscopy; Minimally invasive surgical procedures; Multivisceral resection; Pelvic Exenteration; Rectal neoplasms; Robotic surgical procedures

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Core Tip: Multivisceral resection (MVR) remains the only potential curative surgical treatment for locally advanced rectal cancer but bears high morbidity. Literature on minimally invasive MVR (miMVR) is scarce. Our results showed that miMVR had lower major morbidity and shorter length of stay compared to open MVR with comparable R0 resection and long-term survival. Robotic MVR was used for more complex cases but had similar post-operative complications compared to laparoscopic MVR. Use of robotic MVR is feasible and safe even in lower volume institutions for locally advanced rectal cancer.

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INTRODUCTION

Colorectal cancer is the third most common cancer and the second highest cause of cancer-related mortality worldwide [1]. About 5%-10% of patients are diagnosed with locally advanced rectal cancer (LARC) on presentation [1-3]. Neo-adjuvant therapy followed by definitive surgery with total mesorectal excision (TME) remains the mainstay curative option for LARC [4-6]. For LARC invading into other structures (*i.e.* T4b), multivisceral resection (MVR) and/or pelvic exenteration (PE) remains the only potential curative surgical treatment [7].

Nevertheless, MVR and/or PE is a major and complex surgery with post-operative morbidity ranging from 20%-80% [8], and 30-d mortality of 0.5%-2.0% [9-11]. Minimally invasive surgery (MIS) which has been well-established as standard of care both benign and malignant intra-abdominal pathologies [12-15], may prove its utility on short-term post-operative outcomes. A retrospective study by Kazi *et al* [16] on 158 patients who underwent PE for LARC showed reduced intra-operative blood loss (900 *vs* 1600 mL, $P < 0.001$) and incidence of wound infections (8.2% *vs* 17.5%, $P = 0.02$) for minimally invasive PE compared with open PE, with similar 3-year overall survival (OS) [16]. However, existing randomized controlled trials on MIS rectal surgeries exclude T4 rectal tumours requiring extended resections with MVR [17-19]. In addition, while meta-analyses have compared MIS *vs* open PE for pelvic malignancies, only a minority of included patients underwent robotic PE ($n = 53$ of 2009 patients) [20]. Evidence on the use of minimally invasive MVR (miMVR) for LARC is still evolving and not well-established. Hence, the primary aim of this study is to assess the feasibility and safety

of miMVR in terms of the margin status and post-operative complications, and compare the outcomes between robotic and laparoscopic MVR. Our secondary aims are to assess the long-term survival of patients who underwent miVR, as well as compare between miVR and open MVR (oMVR).

MATERIALS AND METHODS

This is a single-center retrospective review of a prospectively maintained database from 1st January 2015 to 31st March 2023. Inclusion criteria were patients diagnosed with cT4b rectal cancer and underwent MVR, or stage 4 disease with resectable systemic metastases; patients with stage 4 disease were included in our study in view of the small sample size in our data set, and also because the presence of systemic metastases will not affect our primary aim (*i.e.* assessing feasibility of miMVR). Patients who underwent curative MVR for locally recurrent or metachronous rectal cancer were also included. Exclusion criteria were patients with systemic metastases with non-resectable disease (these patients were referred for palliative chemotherapy with or without radiotherapy instead); none of these patients had resectable disease and were able to undergo MVR after palliative treatment. Our institution has an average of 60 patients diagnosed with rectal cancer and underwent curative surgery every year. This study was approved by our local institutional review board. This study's conduct is per the Strengthening the Reporting of OBservational studies In Epidemiology statement for retrospective cohort studies[21].

Study variables and outcomes

Patient demographics, presence of neoadjuvant treatment, intra-operative characteristics, histopathological findings and post-operative outcomes, and oncological outcomes were studied. In view of the heterogeneous cohort of patients with varying extents of MVR, we arbitrarily classified patients who underwent laparoscopic or robotic MVR into simple or complex; complex cases were defined as cases which were more technically challenging in view of extent of resection, and/or difficulty with reconstruction (*i.e.* total PE, bladder-sparing prostatectomy and/or pelvic lymph node dissection (PLND), need for flap creation, or sacrectomy)[22]. Other cases were defined as simple (*i.e.* posterior PE, vaginectomy or seminal vesiculectomy).

Post-operative outcomes include the presence of intra-abdominal collection, anastomotic leak, ileus, wound infection, pneumonia, overall complication (defined as presence of any of the above complications), major morbidity, 30-d readmission and 30-d mortality. Major morbidity was defined as Clavien-Dindo \geq Grade 3A complications[23]. Thirty day readmission was defined as re-admission within 30 d from date of discharge, while 30-d mortality was defined as death within 30 d from the date of surgery. Oncological outcomes include presence of local and systemic recurrence, time to local and systemic recurrence, OS and recurrence-free survival (RFS). OS and RFS were defined as proportion of patients alive and proportion of patients alive without local and/or systemic recurrence respectively at the end of last follow-up. Our primary outcomes were margin status (R0 resection), incidence of anastomotic leak and overall complications. Our secondary outcomes were OS and RFS.

Treatment protocol

Enhanced Recovery After Surgery (ERAS) was introduced in our colorectal surgery unit from 2016. Pre-operative workup for newly diagnosed rectal cancer includes basic biochemistry investigations including full blood count and carcinoembryonic antigen, radiological imaging with computed tomography of the thorax, abdomen and pelvis and magnetic resonance imaging of the rectum, and colonoscopy with histological diagnosis. All patients diagnosed with rectal cancer were discussed in a multidisciplinary tumour board consisting of colorectal surgeons, medical oncologists and radiation oncologists both pre-operatively and post-operatively, except for patients who had emergency surgery (only post-operative discussion was made). Our institution adopted the National Comprehensive Cancer Network guidelines for the management of rectal cancer[24]. Briefly, this includes either neoadjuvant long-course chemoradiotherapy[25], neoadjuvant short-course radiotherapy, or totally neoadjuvant therapy[26].

All patients planned for elective surgical resection from 2016 were enrolled into the standard ERAS pathway with standard peri-operative management[27]. Mechanical bowel preparation with polyethylene glycol solution and antibiotics (metronidazole and neomycin) were given in patients planned for diverting stoma. Extended ERAS with dietitian, physiotherapy and/or geriatric medicine review was provided based on existing peri-operative ERAS protocol [28]. ERAS pathway was not applied to patients who underwent emergency surgery due to the nature of presentation (*e.g.* intestinal obstruction). The surgical techniques for robotic MVR and PLND were described previously[22,29]. Post-operatively, multidisciplinary tumour board discussions were also carried out following histological diagnosis after surgical resection, and decided based on the neoadjuvant treatment received, patient co-morbidities and clinical progress post-operatively.

Statistical analysis

Categorical values were described as percentages and analysed by the chi-square test. Continuous variables were expressed as median (range) and analysed by Mann-Whitney *U* test. Cumulative OS and RFS were analysed using Kaplan-Meier estimates with life table analysis. Log-rank test was performed to determine statistical significance between cumulative estimates. Subgroup analysis was performed with the above statistical methods to compare between robotic and laparoscopic MVR. Statistical significance was determined by $P < 0.05$. All statistical analyses were performed with SPSS version 25.0 (SPSS Inc., CHI, ILL., United States) and Stata (version 17.0, StataCorp LLC, College Station, United States).

RESULTS

Patient demographics and clinical profile

A total of 46 patients were included in this study [oMVR: 12 (26.1%), miMVR: 34 (73.9%)]. Patients' American Society of Anesthesiologists (ASA) score, body mass index and co-morbidities were comparable between oMVR and miMVR. However, oMVR was more commonly performed in the emergency setting, unlike miMVR (16.7% *vs* 0%, $P = 0.015$). The incidence of neoadjuvant radiotherapy was lower in the oMVR group with near statistical significance (58.3% *vs* 85.3%, $P = 0.052$). The overall patient demographics are summarised in [Table 1](#). The trend of surgical access (open, laparoscopic and robotic) is shown in [Figure 1](#).

Intra-operative characteristics and clinical outcomes

The extent of MVR is summarised in [Table 2](#). Of the patients who underwent oMVR, two cases had bilateral PLND, two cases had sacrectomy and three cases had vertical rectus abdominis myocutaneous (VRAM) flap reconstruction. None of the patients had resectable distant metastases. miMVR is associated with lower EBL (median 450 *vs* 1200 mL, $P = 0.008$), major morbidity (14.7% *vs* 50.0%, $P = 0.014$), post-operative intra-abdominal collections (11.8% *vs* 50.0%, $P = 0.006$), post-operative ileus (32.4% *vs* 66.7%, $P = 0.04$) and surgical site infection (SSI) (11.8% *vs* 50.0%, $P = 0.006$) compared with oMVR. Length of stay (LOS) was also shorter for miMVR compared with oMVR (median 10 *vs* 30 d, $P = 0.001$). Oncological outcomes–R0 resection, recurrence, OS and RFS–were comparable between miMVR and oMVR ([Table 3](#) and [Figure 2](#)). There was no 30-d mortality.

Additional comparison was also made between laparoscopic and robotic MVR. More patients who had complex surgeries underwent robotic compared to laparoscopic MVR (robotic 57.1% *vs* laparoscopic 7.7%, $P = 0.004$). The operating time was longer for robotic compared with laparoscopic MVR [robotic: Median 602 (400-900) min, laparoscopic: Median 455 (275-675) min, $P < 0.001$]. EBL were similar between laparoscopic and robotic MVR (robotic: Median 300 (0-2400) mL, laparoscopic: Median 500 (100-1000) mL, $P = 0.889$). Incidence of R0 resection was similar (laparoscopic: 84.6% *vs* robotic: 76.2%, $P = 0.555$). Overall complication, major morbidity and 30-d readmission were similar between laparoscopic and robotic MVR ([Table 4](#)). Interestingly, 3-year OS (robotic 83.1% *vs* 58.6%, $P = 0.008$) and RFS (robotic 72.9% *vs* 34.3%, $P = 0.002$) was significantly higher for robotic compared to laparoscopic MVR.

DISCUSSION

MVR is a complex surgery with high short-term morbidity and mortality[8-11]. MIS has been shown to improve short-term outcomes in various surgeries for gastrointestinal malignancies[12-14]. Our study demonstrated the safety of mi-MVR in our institution with acceptable long-term oncological outcomes. Additionally, miMVR was associated with a shorter LOS and lower morbidity compared to oMVR.

One of the reasons why MVR is associated with high post-operative morbidity is due to the extent of resection; this results in longer operating time and is more technically challenging for *en-bloc* resection due to the need for more extensive dissection and higher risk of injury to other structures. Despite the low numbers of 46 cases over a period of 9 years, our institution demonstrated acceptable post-operative outcomes with no 30-d mortality and overall complication rate of 65.2%. This is similar to that reported in existing literature, with complication rates of 20%-80%[8], and 30-d mortality of 0.5%-2.0%[9-11].

Since the advent of robotic surgery, there has been an increasing adoption of its use in various institutions over the past decade[30]. Our unit adopted robotic surgery in 2011 and the first use of the robotic platform for MVR was in 2015. As our surgeons gained more experience and proficiency in robotic surgery, we have achieved nearly 100% utilization of robotic surgery in elective MVR rectal surgery over the last three years within our unit. Robotic surgery allows for a 3-dimensional view with depth perception and high-resolution imaging, free manipulation of robotic endowrists with a wider degree of movement, and ergonomic advantages (e.g. elimination of tremors, surgeon's comfort)[31]. This allows for easier manoeuvring within the narrow pelvis, and also makes intracorporeal suturing and reconstruction (e.g. ureterectomy with Boari flap reconstruction for patients with ureteric involvement) much easier[32]. Another benefit of robotic surgery—which may be frequently overlooked—is the provision of an ergonomic environment for the operating surgeon which reduces physical strain and fatigue, especially in the context of complex surgeries requiring long operating hours [33,34]. This is evident in our study, where there were significantly more patients who underwent robotic MVR for complex cases compared to laparoscopic MVR ([Table 4](#)). In complex cases that require fine dissection in a narrow space, such as PLND or bladder-sparing prostatectomy, a stable robotic platform has clear advantages. This may have contributed to the lower incidence of anastomotic leak and intra-abdominal collections (4.8%) in the robotic group, with an absolute reduction of 18.3% compared to the laparoscopic group. This was similarly noted in a recent multi-centre randomised controlled trial (REAL trial) which showed that robotic surgery was associated with fewer intra-operative complications [robotic: $n = 32/586$ (5.5%) *vs* laparoscopic: $n = 51/585$ (8.7%), $P = 0.030$], LOS [robotic: Median 7.0 (interquartile range 7.0-11.0) d *vs* laparoscopic: Median 8.0 (interquartile range 7.0-12.0), $P = 0.0001$], and lower incidence of R1 resection [robotic: $n = 22/547$ (4.0%) *vs* laparoscopic: $n = 39/543$ (7.2%), $P = 0.023$] for middle and low rectal cancers[35].

Another benefit of the robotic platform includes the inbuilt integrated fluorescence capability with indocyanine green (ICG) (Firefly on the Da Vinci® robotic system), which can be activated at the surgeon's console without the need to change to an ICG-enabled imaging system unlike laparoscopic surgery. In low rectal surgery, use of ICG allows for easy identification of ureters to avoid ureteric injury, as well as guide lymph node dissection[36]. While our series had 2 cases of intra-operative ureteric injury (1 laparoscopic, 1 robotic), both cases occurred prior to the routine pre-operative ureteric

Table 1 Clinical demographics of patients who underwent multivisceral resection, *n* (%)

| | Total (<i>n</i> = 46) | Minimally invasive (<i>n</i> = 34) | Open (<i>n</i> = 12) | <i>P</i> value ^a |
|----------------------------|------------------------|-------------------------------------|-----------------------|-----------------------------|
| Age, yr | 68.0 (44.0-85.0) | 68.0 (44.0-85.0) | 67.5 (45.0-85.0) | 0.573 |
| Sex, male (%) | 21 (45.7) | 15 (44.1) | 6 (50) | 0.725 |
| BMI, kg/m ² | 22.5 (12.6-37.9) | 22.0 (12.6-32.1) | 23.3 (16.4-37.9) | 0.708 |
| ASA score, median | 2.0 (1.0-3.0) | 2.0 (1.0-3.0) | 2.0 (1.0-3.0) | 0.966 |
| 1 | 13 (28.3) | 10 (29.4) | 3 (25.0) | |
| 2 | 27 (58.7) | 19 (55.9) | 8 (66.7) | |
| 3 | 6 (13.0) | 5 (14.7) | 1 (8.3) | |
| Co-morbidities | | | | |
| Hypertension | 23 (50.0) | 17 (50.0) | 6 (50.0) | 1.000 |
| Hyperlipidemia | 18 (39.1) | 14 (41.2) | 4 (33.3) | 0.632 |
| Diabetes mellitus | 11 (23.9) | 9 (26.5) | 2 (16.7) | 0.494 |
| Ischemic heart disease | 3 (6.5) | 3 (8.8) | 0 (0) | 0.287 |
| Previous abdominal surgery | 7 (15.2) | 5 (14.7) | 2 (16.7) | 0.871 |
| Neoadjuvant chemotherapy | 31 (67.4) | 25 (73.5) | 6 (50.0) | 0.135 |
| Neoadjuvant radiotherapy | 36 (78.3) | 29 (85.3) | 7 (58.3) | 0.052 |
| Previous local recurrence | 3 (6.5) | 2 (5.9) | 1 (8.3) | 0.768 |

^aStatistical significance is expressed as $P < 0.05$.

All continuous variables were expressed as median (range) unless specified. All categorical variables were expressed as *n* (%) unless otherwise specified. ASA: American Society of Anesthesiologists; BMI: Body mass index.

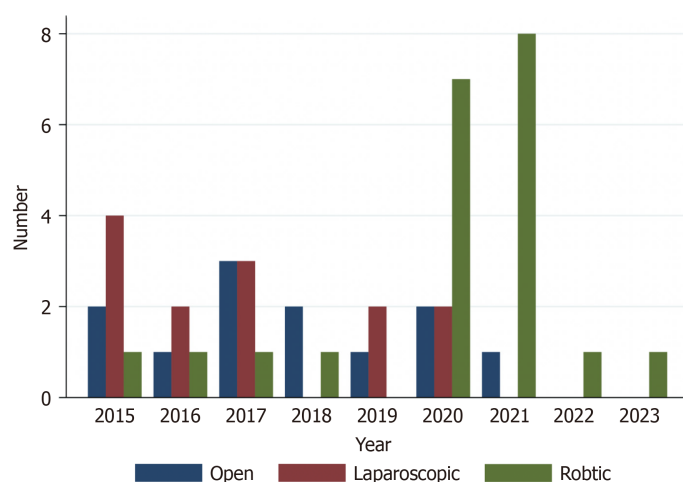


Figure 1 Graph representing the trend in open, laparoscopic and robotic multivisceral resection in rectal surgery from 2015 to 2023 in our unit.

stenting and intra-operative ICG. No further cases of intra-operative ureteric injury were noted thereafter.

Nevertheless, despite the advantages of the robotic system described above, our study did not show a statistically significant difference in post-operative complications between laparoscopic and robotic MVR, which may be due to the initial learning curve of robotic MVR[37]. The surgeons' experience in our robotic group had varying experience levels, with some having completed 10 to 20 robotic cases before undertaking MVR rectal surgery. However, for complex MVR procedures, an experienced robotic surgeon was always present. This underscores the notion that acquiring competence in robotic surgery can be achieved more swiftly compared to laparoscopic surgery. Nevertheless, an absolute reduction of 18.3% in anastomotic leak is clinically significant. Lack of statistical significance may be because our study was underpowered to detect a true effect. To add on, despite cases being more complex in the robotic group, overall complications were similar between robotic and laparoscopic MVR (rather than higher), which may be off-set the abovementioned advantages of robotic surgery. We postulate that robotic surgery will result in lower post-operative complications due to

Table 2 Intra-operative characteristics of patients who underwent multivisceral resection, *n* (%)

| | Total (<i>n</i> = 46) | Minimally invasive (<i>n</i> = 34) | Open (<i>n</i> = 12) | <i>P</i> value |
|---------------------------------|------------------------|-------------------------------------|-----------------------|--------------------|
| Surgical access | | | | N/A |
| Laparoscopic | 13 (28.3) | 13 (38.2) | - | |
| Robotic | 21 (45.7) | 21 (61.8) | - | |
| Urgency of surgery | | | | 0.015 ^a |
| Elective | 44 (95.7) | 34 (100) | 10 (83.3) | |
| Emergency | 2 (4.3) | 0 (0) | 2 (16.7) | |
| Type of surgery | | | | 0.147 |
| ULAR with DI | 30 (65.2) | 25 (73.5) | 5 (41.7) | |
| APR | 11 (23.9) | 6 (17.6) | 5 (41.7) | |
| Hartmann's procedure | 3 (6.5) | 2 (5.9) | 1 (8.3) | |
| LAR | 1 (2.2) | 0 (0) | 1 (8.3) | |
| taTME | 1 (2.2) | 1 (2.9) | 0 (0) | |
| Extent of resection | | | | - |
| <i>En-bloc</i> seminal vesicles | 5 (10.9) | 5 (14.7) | 0 (0) | |
| Posterior vaginectomy | 4 (8.7) | 4 (11.8) | 0 (0) | |
| Salpingo-oophorectomy | 1 (2.2) | 1 (2.9) | 0 (0) | |
| Bladder sparing prostatectomy | 5 (10.9) | 4 (11.8) | 1 (8.3) | |
| Posterior exenteration | 22 (47.8) | 16 (47.1) | 6 (50.0) | |
| Total pelvic exenteration | 9 (19.6) | 4 (11.8) | 5 (41.7) | |
| Small bowel resection | 1 (2.2) | 1 (2.9) | 0 (0) | |
| Sacrectomy | 3 (6.5) | 0 (0) | 3 (25.0) | |
| Initial stoma creation | 35 (76.1) | 27 (79.4) | 7 (58.3) | 0.153 |
| Eventual reversal | 18 (51.4) | 15 (55.6) | 3 (42.9) | |
| Intra-operative ureteric injury | 2 (4.3) | 2 (5.9) | 0 (0) | 0.390 |
| Operating time, min | 562 (225-900) | 566.5 (275-900) | 502.5 (225-751) | 0.150 |
| Estimated blood loss, mL | 500 (0-4000) | 450 (0-2400) | 1200 (200-4000) | 0.008 ^a |
| Pathological TNM stage | | | | 0.836 |
| Complete pathological response | 1 (2.2) | 1 (2.9) | 0 (0) | |
| 1 | 1 (2.2) | 1 (2.9) | 0 (0) | |
| 2 | 20 (43.5) | 15 (44.1) | 5 (41.7) | |
| 3 | 17 (37.0) | 11 (32.4) | 6 (50.0) | |
| 4 | 7 (15.2) | 6 (17.6) | 1 (8.3) | |
| R0 resection | 37 (80.4) | 27 (79.4) | 10 (83.3) | 0.768 |

^a*P* < 0.05. Values indicate statistical significance, where *P* < 0.05.

All continuous variables were expressed as median (range) unless specified. All categorical variables were expressed as *n* (%) unless otherwise specified. APR: Abdominoperineal resection; DI: Defunctioning ileostomy; N/A: Not applicable; LAR: Low anterior resection; taTME: Transanal total mesorectal excision; TNM: Tumour, Node, Metastasis; ULAR: Ultra-low anterior resection.

the abovementioned advantages of robotic surgery, but statistical insignificance is possibly because our study was underpowered to detect a true effect, or due to the initial learning curve of robotic MVR[38]. However, this will need to be verified prospectively by future studies.

One criticism regarding the use of robotic MVR would be the longer operating time without any additional benefits compared to laparoscopic MVR. Robotic surgery has traditionally been shown to be associated with longer operating time, possibly because of initial learning curves and familiarity with the use of a robotic system[39], but this has been

Table 3 Post-operative outcomes of patients who underwent multivisceral resection, *n* (%)

| | Total (<i>n</i> = 46) | Minimally invasive (<i>n</i> = 34) | Open (<i>n</i> = 12) | <i>P</i> value |
|----------------------------|------------------------|-------------------------------------|-----------------------|----------------------|
| Short-term complications | | | | |
| Anastomotic leak | 7 (15.2) | 4 (11.8) | 3 (25.0) | 0.272 |
| Intra-abdominal collection | 10 (21.7) | 4 (11.8) | 6 (50.0) | 0.006 ^a |
| Ileus | 19 (41.3) | 11 (32.4) | 8 (66.7) | 0.038 ^a |
| SSI | 10 (21.7) | 4 (11.8) | 6 (50.0) | 0.006 ^a |
| Pneumonia | 2 (5.9) | 2 (5.9) | 0 (0) | 0.390 |
| Overall complications | 30 (65.2) | 20 (58.8) | 10 (83.3) | 0.125 |
| Major morbidity | 11 (23.9) | 5 (14.7) | 6 (50.0) | 0.014 ^a |
| Length of stay, d | 12.0 (3.0-62.0) | 10.0 (3.0-42.0) | 30.0 (6.0-62.0) | < 0.001 ^a |
| 30-d readmission | 11 (23.9) | 8 (23.5) | 3 (25.0) | 0.918 |
| 30-d mortality | 0 (0) | 0 (0) | 0 (0) | N/A |
| Adjuvant chemotherapy | 31 (67.4) | 24 (70.6) | 7 (58.3) | 0.436 |
| Follow-up, months | 32.2 (1.1-100.8) | 29.2 (1.1-100.8) | 36.2 (2.2-73.9) | 0.582 |
| Overall survival | | | | |
| Median, months | 43.2 (41.5-N/A) | 43.1 (40.4-N/A) | 47.1 (14.5-N/A) | 0.257 |
| 1-year | 93.2 (80.3-97.8) | 93.9 (77.6-98.4) | 91.3 (52.4-98.7) | 0.774 |
| 3-year | 71.5 (54.1-83.3) | 71.1 (49.8-84.6) | 72.1 (35.9-90.1) | 0.473 |
| 5-year | 36.5 (18.2-55.0) | 32.1 (11.9-54.6) | 45.9 (13.6-73.8) | 0.446 |
| Recurrence-free survival | | | | |
| Median, months | 43.2 (19.5-N/A) | 43.2 (15.4-N/A) | 47.1 (3.6-N/A) | 0.501 |
| 1-year | 77.3 (61.9-87.1) | 75.4 (56.8-86.9) | 82.6 (46.5-95.3) | 0.800 |
| 3-year | 60.8 (43.8-74.1) | 56.1 (36.0-72.2) | 72.9 (37.1-90.4) | 0.879 |
| 5-year | 37.1 (19.0-55.3) | 33.7 (13.1-55.8) | 17.2 (13.8-74.2) | 0.371 |

^a*P* < 0.05. Values indicate statistical significance, where *P* < 0.05.

All continuous variables were expressed as median (range) unless specified. All categorical variables were expressed as *n* (%) unless otherwise specified. N/A: Not applicable; SSI: Surgical site infection.

largely mitigated by the ease of use of the latest Da Vinci Xi® system. Although our study showed that robotic MVR had a longer median operating time of 602 min, compared to 455 min in laparoscopic MVR, it was not surprising given that most of these cases were more complex surgeries. These surgeries would also have been technically more challenging if performed laparoscopically.

With the theoretical benefits of robotic surgery over laparoscopic surgery, it is postulated that long-term survival will be higher, and recurrence will be lower in the robotic group. This was supported by our study which showed superior 3-year OS and 3-year RFS in robotic MVR compared with laparoscopic MVR. However, the Robotic *vs* Laparoscopic Resection for Rectal Cancer (ROLARR) trial in 2017 failed to show any statistical significance between robotic *vs* laparoscopic rectal resection in rectal adenocarcinoma [local recurrence hazards ratio (HR) 1.137, 95%CI: 0.554, 2.335, *P* = 0.756] [18]. However, the primary aim of the ROLARR trial was to compare the risk of conversion to open laparotomy, rather than assessing long-term survival outcomes. Sample size calculation was performed based on the primary aim, and may have been underpowered to detect statistical significance in long-term survival between robotic and laparoscopic surgery. Use of learning effects model also showed that increasing level of robotic experience was associated with better treatment effects when comparing robotic *vs* laparoscopic surgery; benefits of robotic surgery may not be reaped when surgeons are still in the initial learning curve[40].

Conflicting results on long-term survival were shown by Kim *et al*[41], who performed a 1:1 propensity score matching (PSM) (*n* = 224 patients per arm) for patients who underwent robotic *vs* laparoscopic TME for rectal cancer[41]. While 5-year OS (robotic 90.5% *vs* laparoscopic 78.0%) and 5-year cancer-specific survival (CSS) (robotic 90.5% *vs* laparoscopic 79.5%) were statistically insignificant between robotic *vs* laparoscopic TME, this may be due to the reduced sample size following PSM (prior to PSM, 5-year OS and 5-year CSS was superior in the robotic group). Multivariate analysis also showed that robotic TME was a significant prognostic factor for OS (HR 0.333, *P* = 0.004) and CSS (HR 0.367, *P* = 0.0161). We postulate that robotic surgery may improve long-term survival with more precise dissection and adequacy of re-

Table 4 Subgroup analysis comparing outcomes of patients who had minimally invasive multivisceral resection, *n* (%)

| | Robotic (<i>n</i> = 21) | Laparoscopic (<i>n</i> = 13) | <i>P</i> value |
|---------------------------------|--------------------------|-------------------------------|--------------------|
| Intra-operative ureteric injury | 1 (4.8) | 1 (7.7) | 0.724 |
| Open conversion | 1 (4.8) | 3 (23.1) | 0.107 |
| Surgical complexity | | | 0.004 ^a |
| Simple | 9 (42.9) | 12 (92.3) | |
| Complex | 12 (57.1) | 1 (7.7) | |
| Short-term complications | | | |
| Anastomotic leak | 1 (4.8) | 3 (23.1) | 0.107 |
| Intra-abdominal collection | 1 (4.8) | 3 (23.1) | 0.107 |
| Ileus | 6 (28.6) | 5 (38.5) | 0.549 |
| SSI | 1 (4.8) | 3 (23.1) | 0.107 |
| Pneumonia | 1 (4.8) | 1 (7.7) | 0.724 |
| Overall complications | 12 (57.1) | 8 (61.5) | 0.800 |
| Major morbidity | 3 (14.3) | 2 (15.4) | 0.930 |
| Length of stay, d | | 11.0 (4.0-28.0) | 0.807 |
| 30-d readmission | 5 (23.8) | 3 (23.1) | 0.961 |
| 30-d mortality | 0 (0) | 0 (0) | N/A |
| Adjuvant chemotherapy | 15 (71.4) | 9 (69.2) | 0.891 |
| Follow-up, months | 24.2 (4.8-100.8) | 41.5 (1.1-76.5) | 0.158 |
| Overall survival | | | |
| Median, months | 43.2 (43.1-N/A) | 40.4 (12.9-53.0) | 0.149 |
| 1-year | 95.0 (69.5-99.3) | 92.0 (55.3-98.8) | 0.083 |
| 3-year | 83.1 (56.1-94.3) | 58.6 (27.2-80.2) | 0.008 ^a |
| 5-year | 49.9 (13.1-78.8) | 21.0 (3.7-47.9) | 0.175 |
| Recurrence-free survival | | | |
| Median, months | 43.2 (19.5-N/A) | 12.9 (2.6-53.0) | 0.096 |
| 1-year | 85.0 (60.4-94.9) | 60.0 (29.0-81.0) | 0.607 |
| 3-year | 72.9 (46.2-87.8) | 34.3 (10.8-59.8) | 0.002 ^a |
| 5-year | 40.5 (9.3-70.9) | 22.9 (4.3-50.1) | 0.070 |

^a*P* < 0.05. Values in bold indicate statistical significance, where *P* < 0.05.

All continuous variables were expressed as median (range) unless specified. All categorical variables were expressed as *n* (%) unless otherwise specified. N/A: Not applicable; SSI: Surgical site infection.

section, and also by reducing short-term complications with downstream long-term complications (*e.g.* inadvertent ureteric injury requiring need for repeat surgeries). Nevertheless, the overall evidence regarding the superiority of robotic surgery over laparoscopic in rectal cancer remains equivocal and this needs to be validated.

Comparing miMVR as a whole *vs* oMVR, our study demonstrated better short-term outcomes. This is not surprising; benefits of MIS have been shown to be superior compared with open surgery in both benign and malignant conditions, such as omental patch repair for perforated peptic ulcer, oesophagectomy, colorectal resection and liver resection[12-15]. The concept behind the benefits of MIS remains the same regardless of the type of surgery. The incision from MIS is smaller and less traumatic. As a result, this leads to lesser pain, LOS, incidence of SSI and intra-abdominal collection, as shown by our results. It is noteworthy that the incidence of post-operative ileus and SSI were high in the oMVR group, at 66.7% and 50.0% respectively. One plausible reason for this finding may be due to the extent of MVR, with 2 cases of bilateral PLND, 2 cases of sacrectomy, and 3 cases with VRAM flap. Ileus is expected following sacrectomy due to the denervation of the distal gastrointestinal tract during neural transection[42]. Use of VRAM flap also increases operating time, which consequently increases risk of post-operative ileus[43].

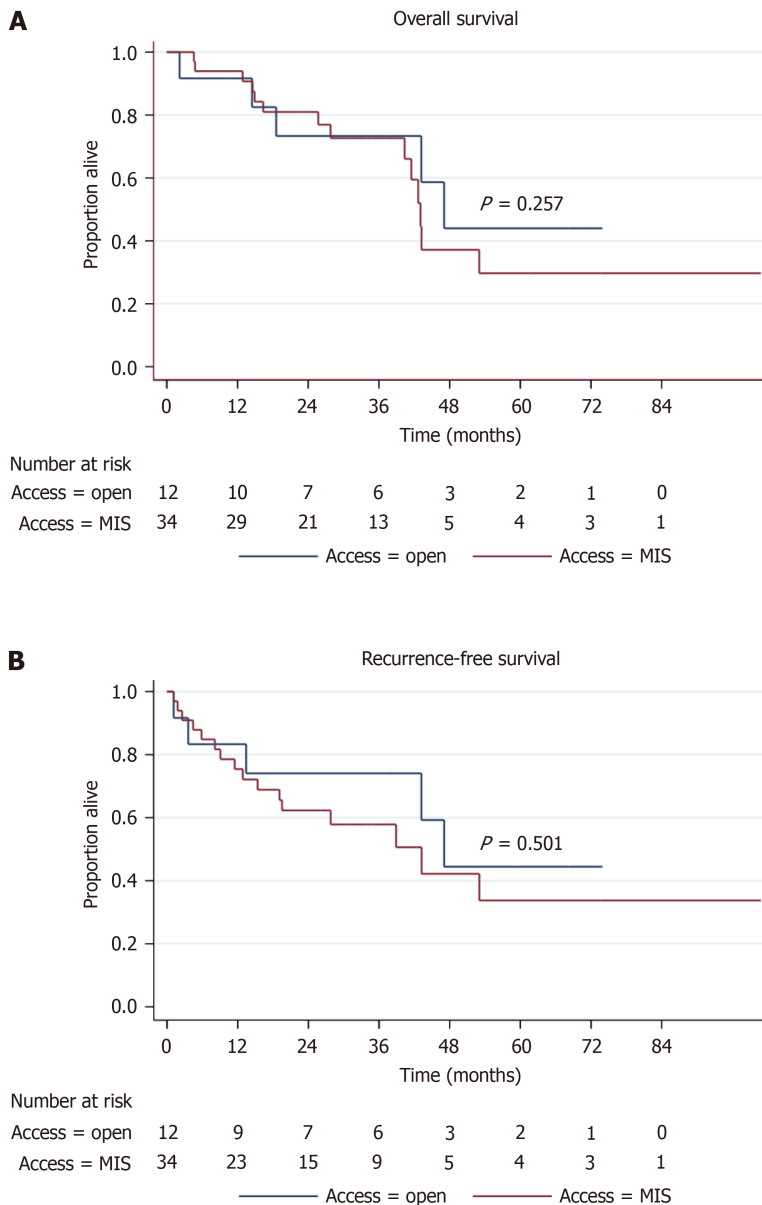


Figure 2 Kaplan-Meier curve comparing the survival of patients who underwent minimally invasive multivisceral resection vs open multivisceral resection. A: Overall survival; B: Recurrence-free survival. MIS: Minimally invasive surgery.

There are a few limitations to this study. Firstly, this is a retrospective cohort study with inherent selection bias. This is primarily a single-arm study with an aim of looking at the feasibility and safety profile of minimally miMVR; while we compared minimally invasive *vs* oMVR, sample size for the open group is small and the study is possibly underpowered to detect significant differences between the group[44]. Long-term oncological outcomes such as OS and DFS may also not be conclusive or representative of other cohorts, especially for the oMVR group, with a small sample size of 12 only. However, the main aim of this study was to assess safety profile of miMVR and also robotic MVR in our institution—a low volume centre—for cT4b rectal cancer; hence the results presented here are promising. Lastly, quality of life outcome measures and total costs were not collected; robotic surgery has been shown to result in superior quality of life and sexual function at 12 months post-operatively[45].

CONCLUSION

Our study showed the feasibility and safety of miMVR even in a low-volume institution for cT4b rectal cancer, with acceptable short-term morbidity, 30-d mortality and long-term survival. Additionally, miMVR was associated with shorter LOS and lower incidence of ileus and SSI. More prospective studies are required to evaluate the long-term oncological outcomes of miMVR; further studies should also compare robotic *vs* laparoscopic approach in MVR.

ARTICLE HIGHLIGHTS

Research background

About 5%-10% of patients are diagnosed with locally advanced rectal cancer (LARC) on presentation. Multivisceral resection (MVR) and/or pelvic exenteration (PE) remains the only potential curative surgical treatment for LARC invading into other structures (*i.e.* cT4b tumours). However, MVR and/or PE is a major surgery with significant post-operative morbidity. There is currently no randomized controlled trial assessing T4 rectal tumours requiring extended resections with MVR.

Research motivation

Minimally invasive surgery (MIS) for other intra-abdominal pathologies has been shown to improve post-operative outcomes. However, evidence on the use of MIS for MVR and PE is not well established. Evidence on the use of robotic MVR and/or PE is even more scarce and needs to be reported.

Research objectives

Our primary aim is to assess the feasibility and safety of minimally invasive MVR (miMVR) in terms of the margin status and post-operative complications, and compare the outcomes between robotic and laparoscopic MVR. Our secondary aims are to assess the long-term survival of patients who underwent miVR, as well as compare between miVR compared to open MVR (oMVR).

Research methods

This is a single-center retrospective review of a prospectively maintained database from 1st January 2015 to 31st March 2023. Inclusion criteria were patients diagnosed with cT4b rectal cancer and underwent MVR, or stage 4 disease with resectable systemic metastases. Comparison in outcomes were made between miMVR and oMVR. Categorical values were described as percentages and analysed by the chi-square test. Continuous variables were expressed as median (range) and analysed by Mann-Whitney *U* test. Cumulative overall survival and RFS were analysed using Kaplan-Meier estimates with life table analysis. Subgroup analysis was performed with the above statistical methods to compare between robotic and laparoscopic MVR.

Research results

Forty-six patients were included in this study [oMVR: 12 (26.1%), miMVR: 34 (73.9%)]. Patients' American Society of Anesthesiologists score, body mass index and co-morbidities were comparable between oMVR and miMVR. The incidence of neoadjuvant radiotherapy was lower in the oMVR group with near statistical significance (58.3% *vs* 85.3%, $P = 0.052$). There was a trend towards an increase in robotic MVR, with decrease in oMVR over the years. miMVR is associated with lower estimated blood loss (median 450 *vs* 1200 mL, $P = 0.008$), major morbidity (14.7% *vs* 50.0%, $P = 0.014$), post-operative intra-abdominal collections (11.8% *vs* 50.0%, $P = 0.006$), post-operative ileus (32.4% *vs* 66.7%, $P = 0.04$) and surgical site infection (11.8% *vs* 50.0%, $P = 0.006$) compared with oMVR. Length of stay was also shorter for miMVR compared with oMVR (median 10 *vs* 30 d, $P = 0.001$). More patients who had complex surgeries underwent robotic compared to laparoscopic MVR (robotic 57.1% *vs* laparoscopic 7.7%, $P = 0.004$). Incidence of R0 resection, overall complication, major morbidity, 30-d readmission were similar between laparoscopic and robotic MVR.

Research conclusions

miMVR is safe and feasible even in a low-volume institution for cT4b rectal cancer with acceptable R0 resection, short-term morbidity, 30-d mortality and long-term survival.

Research perspectives

Robotic MVR should be considered even in low volume institutions in view of the advantages conferred by robotic surgery in the presence of a proctor.

FOOTNOTES

Co-corresponding authors: Kai Siang Chan and Kar Yong Wong.

Author contributions: Wong KY conceptualized and designed the research; Chan KS, Liu B, and Wong KY acquired and analysed the data; Chan KS, Liu B, Tan MNA, How KY and Wong KY interpreted the data; Chan KS drafted the paper; Chan KS, Tan MNA, How KY and Wong KY revised the article; Chan KS, Liu B, Tan MNA, How KY and Wong KY approved the final article. Both Chan KS and Wong KY have made crucial and indispensable contributions towards the administration and completion of the project and are thus qualified as the co-corresponding authors of the paper; Wong KY was instrumental in the conceptualization and design of the study. In addition, Wong KY was also responsible for the analysis, interpretation of data and review of the article prior to its final publication. Chan KS was responsible for data collection, played a major role in the data analysis and draft of the initial manuscript. Hence both authors are qualified as co-corresponding authors of the paper.

Institutional review board statement: This study was approved by our local institutional review board. Prior to April 2019, institutional board review approval was not required by our institution; data was prospectively collected and extracted from a database managed by

our colorectal department coordinator using FileMaker® (Clarisc International Inc., United States of America) from January 2015. Data was de-identified when extracted for analysis with no traceable data or reference codes for re-identification of included patients. For data after April 2019, institutional review board approval was obtained for our prospectively maintained database. Data was stored on REDCap and de-identified by our colorectal department coordinator prior to analysis by the study team. The study team made no attempts to access patients' medical records.

Informed consent statement: Informed consent was obtained from patients included (No. SDB-2023-0069-TTSH-01).

Conflict-of-interest statement: All the authors report no relevant conflicts of interest for this article.

Data sharing statement: The data used in this study is not publicly available due to institutional policies. However, requests may be made to the corresponding author for access to de-identified data at kchan023@e.ntu.edu.sg.

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