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ORIGINAL ARTICLE

Totally robotic rectal resection: an experience of the first 100 consecutive cases

J. Ahmed[1] · **M. Nasir**[1] · **K. Flashman**[1] · **J. Khan**[1] · **A. Parvaiz**[1,2]

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Abstract
Introduction Robotic surgery provides an alternative option for a minimal access approach. It provides a stable platform with high definition three-dimensional views and improved access, which enhances the capabilities for precise dissection in a narrow surgical field. These distinctive features have made it an attractive option for colorectal surgeons.
Aim The aim of this study was to present a standardised technique for single-docking robotic rectal resection and to analyse clinical outcomes of the first 100 robotic rectal procedures performed in a single centre between May 2013 and April 2015.
Method Prospectively collected data related to 100 consecutive patients who underwent single-docking robotic rectal surgery was analysed for surgical and oncological outcomes.
Results Sixty-six patients were male, the median age was 67 years (range-24–92). Eighteen patients had neo-adjuvant chemoradiotherapy whilst 23 patients had BMI >30. Procedures performed included anterior resection ($n = 74$), abdominoperineal resection ($n = 10$), completion proctectomy ($n = 9$), restorative proctectomy with ileal pouch–anal anastomosis (IPAA) ($n = 5$) and Hartmann's procedure ($n = 2$). The median operating time was 240 min (range-135–456), and median blood loss was 10 ml (range 0–200). There was no conversion or intra-operative complication. Median length of stay was 7 days (range, 3–48) and readmission rate was 12 %. Thirty-day mortality was zero. Postoperatively, two patients had an anastomotic leak whilst two had small bowel obstruction. The median lymph node harvest was 18 (range, 6–43).
Conclusion The single-docking robotic technique should be considered as an alternative option for rectal surgery. This approach is safe and feasible and in our study it has demonstrated favourable clinical outcomes.

Keywords Colorectal · Minimally invasive surgery · Robotic surgery · Pelvic surgery

The data from this article was presented in the annual meeting of Clinical Robotic Surgery Association (2015) held in Chicago, USA

What does this paper add to the literature? There is limited data about the single-docking robotic rectal resection. This series shows that the single-docking approach is a feasible and has been applied successfully in 100 consecutive cases.
This article adds to the evidence to support the potential of robotic rectal surgery as important alternative option for patients with colorectal cancer.

✉ J. Ahmed
drjag@hotmail.co.uk

1 Department of Minimally Invasive Colorectal Unit, Queen Alexandra Hospital NHS Trust, Portsmouth PO6 3LY, UK

2 Head of Laparoscopic & Robotic Programme, Colorectal Cancer Unit, Champalimaud Clinical Foundation, Lisbon, Portugal

Introduction

Rectal cancer surgery has undergone significant evolution over last few decades. Although the original concept was centred on radicality, it came at the cost of both higher morbidity and mortality. With the paradigm shift from radical surgery to precision surgery, organ and functional preservation also become a vital part in clinical outcomes.

Laparoscopy now has become a standard approach for colorectal surgery [1–3]. Various studies have shown that it is safe and has good oncological outcomes. Laparoscopy is also associated with improved short-term outcomes, less morbidity and better cosmetic results [4–6].

Conversely, the laparoscopic approach has various inherent technical challenges particularly associated with rectal resections. These include limited views with restricted range of movement and dexterity of straight surgical instruments as well as, an assistant dependant, unstable and two dimensional view [7, 8]. It is also associated with a steep learning curve [9, 10]. These challenges have prompted the use of innovative new technology such as a robotics system, which has gained popularity in a number of specialities including colorectal surgery.

Robotic colorectal surgery (R-CRS) using the da Vinci® surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) has technical advantages. It provides a stable platform with high definition three-dimensional view. It also improves access and allows sophisticated movements due to Endowrist® instruments [11, 12]. This approach enhances the capability of precise dissection in a narrow surgical field with minimal fatigue for the operating surgeon [13, 14].

Since the first robotic resection by Weber in 2002, a number of case series have shown that the R-CRS is feasible and safe [15–20]. Most of the robotic cases are reported from South Korea, Japan, USA and a few from Europe [18–21]. Though the R-CRS is a promising alternative to overcome the challenges faced by the laparoscopic approach, its widespread adaptation is still in its infancy. We believe that a standardised surgical technique can facilitate the training for the R-CRS, which can bridge this gap [22]. Currently, various robotic approaches such as hybrid, double docking, reversed hybrid and laparoscopic-assisted methods have been described for rectal surgery [23–25].

We have adopted a "modified flip arm" technique for single-docking robotic rectal resection in our practice. The aim of this study was to present our standardised technique and to analyse the clinical outcomes of the first 100 robotic rectal procedures.

Patients and methods

The data related to 100 consecutive patients who underwent robotic rectal resection surgery from May 2013 till April 2015 was analysed from a prospectively maintained database for surgical and oncological outcomes.

Preoperative workup

All patients with a known diagnosis of rectal cancer underwent standard preoperative staging with computed tomography (CT) and pelvic magnetic resonance imaging (MRI). Patients with low rectal cancer (5 cm from anal verge) underwent additional staging with the help of endoanal ultrasound. Each colorectal cancer patient was discussed in multidisciplinary team meeting prior to any treatment.

The neo-adjuvant chemoradiotherapy (NCRT) was recommended to patients with T4 rectal cancer or patients with threatened circumferential margins (CRM) of <2 mm. Surgery was planned within 8–12 weeks after completing the NCRT.

Patient selection of robotic approach

All patients with potential curative rectal surgery were offered the robotic approach. Patients who were deemed unsuitable for laparoscopic approach were not considered for robotic surgery. Patients with pelvic reoccurrence or needing multi-visceral resection were excluded from a robotic approach.

Perioperative care and bowel preparation

All patients underwent standard enhanced recovery programme during their perioperative period. The bowel preparation comprising a fibre-free diet for 2 days and two sachets of piclolax ® were given 1 day prior to surgery.

Every patient given a prophylactic dose of antibiotics at induction of general anaesthesia and received a mechanical and chemical thrombo-prophylaxis for venous thromboembolism (VTE) unless contraindicated.

Theatre setup

The da Vinci® Si robotic system is used for colorectal resections. A single-docking method with "modified flip arm" technique was applied for all procedures. The splenic flexure mobilisation and pelvic dissection were performed with only a slight change in port configuration without changing either the patient's position or undocking the robot. The patient's position, placement of ports and surgical approach for rectal surgery is illustrated below.

Patient position

The patient is placed supine in a modified Lloyd Davies position with arms wrapped beside the body. The vacuum bean mattress is used to prevent any migration of patients during the procedure whilst in Trendelenburg position. A protective cross bar is used over the patient's face to prevent any injury by the robotic arm 3 during the abdominal part of the surgery. The patient is placed in steep Trendelenburg position with 15° right tilt to facilitate the exposure. Fig. 1 The room setup along with robotic cart position is shown in Fig. 2.

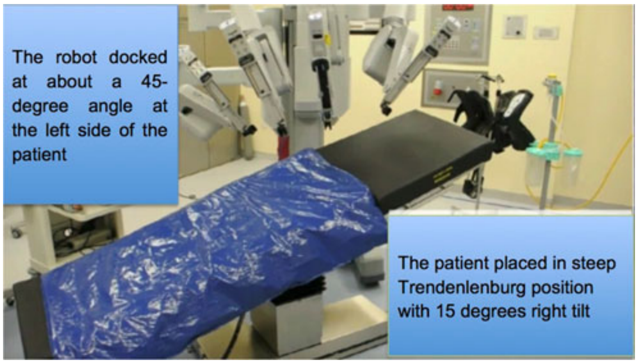


Fig. 1 Robot docked at about a 45° angle at the left side of the patient after ports insertion

Port placement

Placement of ports for both abdominal and pelvic part of the procedure are shown in Figs. 3 and 4.

Abdominal configuration

The 12 mm robotic camera port is placed with open technique at 3–4 cm above and lateral to the right of the umbilicus. The ideal distance between the camera port and symphysis pubis should be 22–24 cm. The 8 mm robotic arm R1 is placed at the right spinoumbilical line (SUL) at the crossing of the mid-clavicle line (MCL). The 8 mm robotic arm R2 is placed about 8 cm below the left costal margin, slightly medial to the left MCL. The 8 mm robotic arm R3 is placed at 2–3 cm sub-xyphoid and about 2 cm medial to the right MCL.

A 10 mm assistant port A, is placed cephalad to R1 port and about 4 cm lateral to the right MCL. This port is used for suction/irrigation, ligation and retraction (Fig. 3).

Pelvic configuration

The robotic arm R2 is moved to R2A (lateral to the left SUL at the crossing of the MCL) and R3 is moved to R2 port site. A 5 mm port is inserted at the R3 port site, which is also used as second assistant port (Fig. 4).

Standardised surgical technique

Robotic left colonic and splenic flexure mobilisation

The principle of standardised technique developed for laparoscopic colorectal surgery was also applied for the robotic approach [26]. The omentum and small bowel is moved cephalad to achieve optimal view of the vessels. Procedure

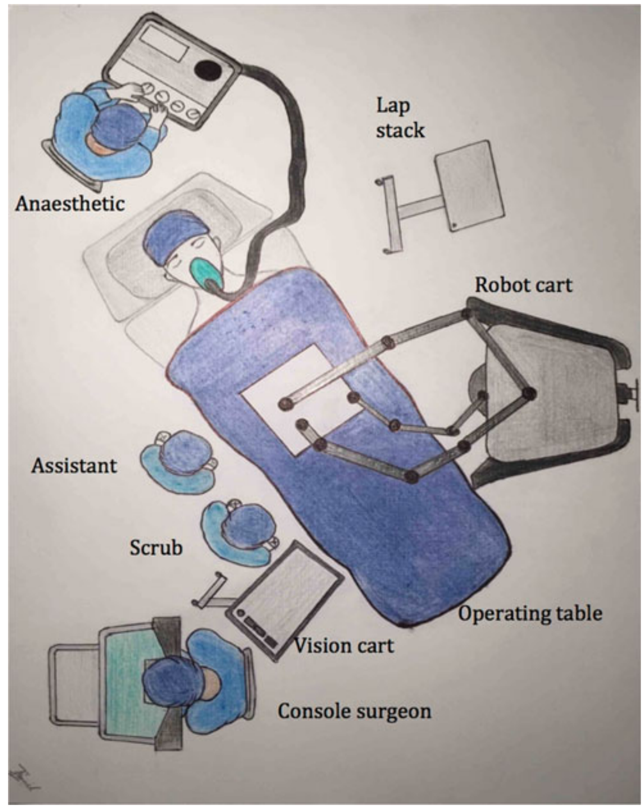
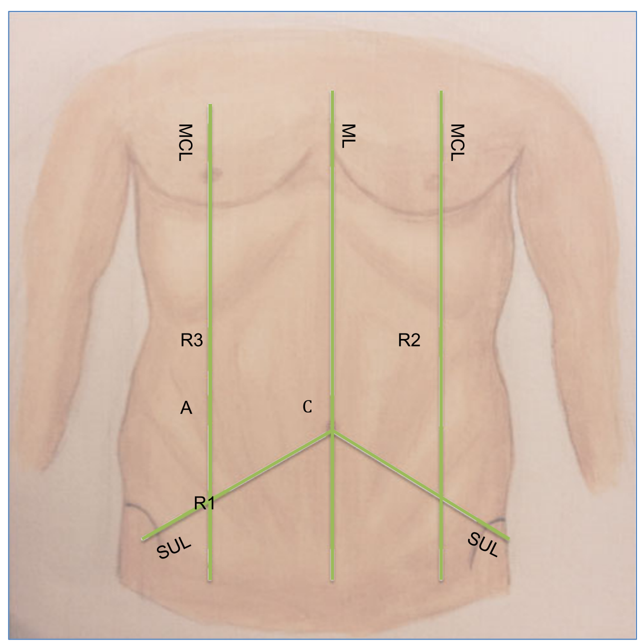


Fig. 2 Theatre setup

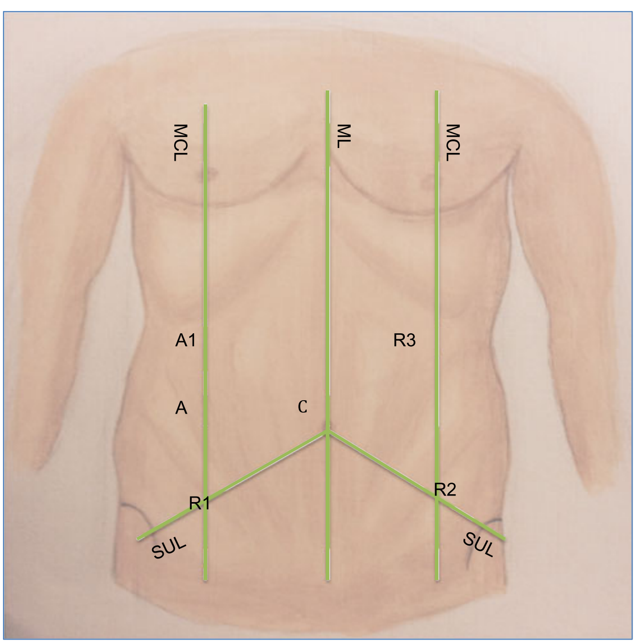


MCL- Mid clavicle line, ML- Midline, SUL- Spinoumbilical line
A- Assistant (10mm port), C- Camera
Abdominal configuration

Fig. 3 Abdominal configuration. *MCL* mid-clavicle line, *ML* midline, *SUL* spinoumbilical line, *A* assistant (10-mm port), *C* camera is commenced from medial to lateral dissection. Primary vascular control is achieved by ligating the inferior mesenteric artery (IMA) at 1 cm from its origin in order to prevent injury to hypogastric nerves and by dividing inferior mesenteric vein (IMV) at the lower boarder of the pancreas. The disposable locking clips (Hem-o-lok®) are used to secure these vessels before division. The medial dissection is carried out towards the left sidewall and superiorly towards the spleen. A plane between the mesocolon and the Gerota's fascia is developed. For splenic flexure mobilisation, a stepwise approach is used. These steps included, firstly, dissection over the lower border of pancreas and access to the lesser sac, secondly, the lateral mobilisation of the left colon up to splenocolic attachments and finally separation of the omentum from the transverse colon and entry in to the lesser sac from the above. During the omental separation from the transverse colon, often the robotic arm R2 is disengaged to minimise the arm clashing.

Robotic total mesorectal excision

For pelvic dissection and total mesorectal excision (TME) arrangement is changed to pelvic configuration as shown in Fig. 4. The TME dissection starts posteriorly and proceeds to laterally and anteriorly in a stepwise manner. For a better view, the uterus or base of the bladder (male patient) is hooked up to the anterior abdominal wall through a stitch using a straight needle. Great care is taken during the whole procedure to avoid injury to the pelvic nerves.



MCL- Mid clavicle line, ML- Midline , SUL- Spinoumbilical line
A- Assistant (10mm port) A1- 2nd assistant port,C- Camera
Pelvic configuration

Fig. 4 Pelvic configuration. *MCL* mid clavicle line, *ML* midline, *SUL* spinoumbilical line, *A* assistant (10-mm port), *A1* secondnd assistant port, *C* Camera

The rectum is divided using Endo GIA 45 mm purple (Covidien's Tri-Staple™) through either assistant port A or R1 port site. Following its division, the specimen is extracted through a 4–5 cm suprapubic incision using a wound protector. The robot is undocked and a standard anastomosis is performed using circular stapling device. A flexible endoscope is routinely used to check the integrity of the anastomosis or bleeding, viability of the colon and the rectum. Patients following low rectal cancer surgery or ileo-anal pouch are de-functioned using loop ileostomy. A liner stapler (GI80) with refills is used for extracorporeal J-pouch formation during pouch surgery.

Statistical analysis

Parametric variables were reported as medians (range). All statistical analyses were performed using IBM SPSS Statistics software for Windows, version 18 (SPSS Inc., Chicago, IL, USA)

Results

Demographics

Sixty-six patients were male and 34 were female. The median age was 67 years (range 24–92). Eighteen (21.7 %) patients had neo-adjuvant chemoradiotherapy whereas 23 patients had BMI > 30. The majority of resections were for cancer (n=83), with 17 for benign conditions. Forty patients had previous laparoscopic or open abdominal surgery. The detail of previous procedures is shown in Table 1.

Operative outcomes

The commonest procedure was anterior resection ($n = 74$), followed by abdominoperineal resection ($n = 10$), completion proctectomy ($n = 9$), restorative proctectomy with IPAA ($n = 5$) and Hartmann's procedures ($n = 2$). The median operating time was 240 min (range, 135–456), with a median blood loss of 10 ml (range 0–200). Median length of stay was 7 days (range, 3–48). There was no mortality within 30 day after procedure whilst readmission rate was 12 %. There were no intra-operative complications with no conversion to laparoscopy or open surgery. (Table 2).

Four patients required re-operation within 30 day after the index procedure, two for anastomotic leak and two for small bowel obstruction. All complications were managed laparoscopically. Other morbidities included prolonged ileus

Table 1 Patient characteristics $n = 100$

	Total ($n = 100$)	Percentage (%)
Adenocarcinoma	83	83 %
Benign	17	17
Sex:male:female	66:34 (2:1)	
Age (years)—median	67 (range 24–92)	
Body mass index (kg/m^2)	27 (range 19–41)	
ASA grade		
I	9	
II	77	
III	14	
IV	0	
Previous abdominal surgery	40	%
Appendectomy	11	27.5
Total abdominal hysterectomy	7	17.5
Caesarean section	3	7.3
Subtotal colectomy	9	22.5
Bowel resection	1	2.5
Cholecystectomy	5	12.5
Laparotomy	3	7.5
Other	1	2.5

NB values are given as number or median (range)

$n = 11$, urinary tract infection $n = 9$, chest and wound infection $n = 17$ (Table 3)

Oncological outcomes

Preoperative staging showed the majority of patients had T2 or T3 disease. Five patients had nodular involvement (N2) whilst four had distant metastases (M1) disease during preoperative staging. 18 out of 83 (21.7 %) patients had neoadjuvant chemoradiotherapy (Table 4).

The postoperative histology showed that 42 patients had tumour stage T3 or T4 and the median lymph node harvest was 18 (range, 6–43). The median distal resection margin was 2.7 cm (range, 0.4–8.0 cm). In three cases (3.6 %), circumferential resection margin (CRM) was reported as positive (<2 mm) (Table 5).

Discussion

Although minimal access surgery has become the goal standard for colorectal cancer, penetration of laparoscopy for rectal surgery remains limited. Furthermore, with inherent difficulties associated with laparoscopy, robotic approach to rectal resection is certainly very appealing [27, 28]. The da Vinci robotic® system provides a three-dimensional view, using a stable platform for precise dissection. The endowrist provides an unprecedented range of movement allowing 7 degrees of freedom, 180° articulation and 540° rotation [11, 12]. The robotic wristed instruments allow a much more sophisticated range of movements compared to straight laparoscopic instruments, especially during dissection on the right pelvic sidewall.

A systemic review quotes several studies that show the robotic approach in colorectal surgery is safe and feasible (21). In our series, the largest single centre series to our knowledge, we also confirm the feasibility and safety of single-docking robotic surgery for rectal resection. The robotic approach is associated with low conversion rate as reported by many authors [17, 29, 30]. In our series of 100 consecutive cases, there was no conversion to open or laparoscopic surgery. Similarly there was no intra-operative complication in our series of patients. The median length of stay in hospital was 7 days whereas readmission rate was 12 % without any mortality in 30 days after operation. These findings are also comparable to the published data [25].

We used "modified flip arm technique" for single-docking approach for our entire procedure using the da Vinci *Si* ® system as discussed above. A similar approach of single-docking technique such as "flip arm technique" and "one step

Table 2 Operative details $n = 100$

Procedures	Malignant	Benign	Total
Anterior resection	70	4	74
Abdominoperineal resection	10	0	10
Completion proctectomy	0	9	9
Hartmann procedures	2	0	2
Restorative proctectomy with IPAA	1	4	5
Operation time	240 (135–456)	230 (105–360)	240 (105–456)
Blood loss (ml)	10 (0–200)	20 (0–200)	10 (0–200)
Conversion rate	0	0	0
Total cases	83	17	100

NB Values are given as number or median (range)

Table 3 Postoperative and morbidity outcome

	Number	%
Total surgery	100	
30 Days postoperative mortality	0	0
30 Days back to theatre for surgery	4	4
30 Days readmission	12	12
Median postoperative hospital stay (day)	7 (3–48)	
Anastomotic leakage	2	2
Bowel obstruction needed operation	2	2
Anastomotic bleeding	0	0
Prolonged ileus	11	11
Urinary tract infection	9	9
Wound infection	17	17
Chest infection	4	4
Total major complications	4	4

Values are given as median (range)

setup" has been reported in the past [31, 32]. For the flip arm technique, authors reported only four resections (two left colectomies and two anterior resections) whilst the "one step" approach was used only in three cases (one human cadaver and two involving patients). Our technique includes further modification in the single-docking approach and helps to overcome the shortcomings of previously reported approaches. In our series of patients, no technical difficulties relating to dissection in the various compartments of abdominal cavity were recorded. We believe that the single docking is safe and practice. It is also probably easy to learn, if the standardised approach is adopted, especially during the initial phase of learning. It also reduces operating time as compared to hybrid or double docking approaches [24, 25].

Table 4 Preoperative staging (cancer only) $n = 83$

	Number	Percentage
Preoperative T staging		
T no data	2	2.4
T1	3	3.6
T2	38	45.8
T3	36	43.4
T4	4	4.8
Preoperative N staging		
N no data	2	2.4
N0	53	63.9
N1	24	28.9
N2	5	4.8
Preoperative M Staging		
Mo	79	95.2
M1	3	3.6
Neo-adjuvant Chemoradiotherapy	18	21.7

Table 5 Pathological results $n = 83$

	Number	%
Total cases	83	
TME cases	83	–
pTNM stage		
T0	2	2.2
T1	15	18.9
T2	24	31.1
T3	38	44.4
T4	4	3.3
Number of harvested nodes	18 (6–43)	
Tumour size (cm)	3.5 (0.3–7.0)	
Quality of mesorectum		
Distal resection margin (cm)	2.7 (0.4–8.0)	%
R0	76	91.1
R1	3	3.6
R2	0	0

NB Values are given as number or median (range)

The principle of a standardised approach developed for the laparoscopic colorectal surgery, previously published, was applied for robotic resections [22, 33]. Therefore, advanced laparoscopic skills can be considered as a key factor for smooth adaptation of the R-CRS [34, 35].

The median operating time was 240 minutes (range, 128–456), with blood loss of 10 ml (range, 0–200). These findings are comparable to various reports published related to the R-CRS [36]. It is important to highlight that our last 50 procedures were performed as part of teaching workshops, where national and international delegates had demonstration of live robotic surgery. This resulted in slightly prolonged operative duration as more time was set aside for the discussion and delegates' interaction during the live surgery.

The short-term results from various studies have reported comparable oncological outcomes amongst the robotic and laparoscopic groups. In a sub-group analysis of patients with higher BMI, male pelvis and mid to low rectal cancer, a robotic approach was more advantageous [37]. We concur with this statement. In our series, 66 patients were male and more than 23 % had BMI > 30 whilst over 21.7 % patients had neo-adjuvant chemoradiotherapy. Our oncological outcomes such as lymph node count and R0 resection rates were also comparable to the robotic and the laparoscopic rectal cancer resections reported in the literature [38].

A number of factors are accountable for the limited uptake of the R-CRS. The higher capital cost and the use of consumable instruments are amongst those key factors [39]. However, it is likely that competition for the robotic system would drive this down in the near future. Another factor is the lack of structured training and mentorship, which may result in poor clinical outcomes during the initial phase of the robotic surgery. The professional bodies such as the European Academy of Robotic Colorectal Surgery (EARCS) are aiming to provide a structured and supervised training for the robotic colorectal surgery. This will help to monitor both clinical outcomes and trainees' pathways to minimise the consequences of the learning curve [40]. These incentives may also improve the uptake for the R-CRS in future. Similarly, we believe that the development of a standardised approach is also important in mastering the skills and shortening the learning curve.

Our study was limited as it did not compare the outcomes of the R-CRS to other approaches. Though during this period of the R-CRS, the laparoscopic colorectal resections were also performed, and there was no selection bias. Patients were allocated to an operating list based on cancer breach dates or if patients wanted to have the R-CRS. To our knowledge, this is the first large series from the UK to report this approach and the short-term clinical and oncological outcomes.

We believe that the R-CRS will find its place in pelvic and rectal cancer surgery. The future applications of this technology and the development of new generations of robotic system like da Vinci Xi robotic system may overcome some of the challenges faced by the current robotic approach. Similarly, the clear view of surgical planes and the conservation of pelvic nerves due to the precise dissection may have a significant impact on clinical outcomes and the quality of life after rectal surgery due to better bladder and sexual function [41]. Though further data are required to establish this notion.

Conclusion

A minimal access surgery has provided the perfect mix for both precision and organ preservation. The robotic platform has pushed that boundary even further due to better views and articulated instruments.

The single-docking robotic rectal resection can be considered as an alternative approach. This approach is safe, feasible and can be adopted in surgical practice without compromising the clinical and the oncological outcomes.

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