Original Article

Comparative Analysis of Splenic Flexure Mobilization (SFM) and Surgical Outcomes in Low Anterior Resection (LAR): da Vinci Si vs. Xi Systems

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Key Words
Robotic surgery;
da Vinci Xi;
da Vinci Si;
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Splenic flexure mobilization

Purpose. Robotic surgery is a cutting-edge platform in the minimally invasive era. However, experience with the previous da Vinci Si robotic system revealed several limitations, especially in splenic flexure mobilization. The increased flexibility and maneuverability of the da Vinci Xi system are expected to improve and facilitate the performance of colorectal surgery. This article seeks to investigate the impact of the da Vinci Xi system in low anterior resection surgery, compared to the da Vinci Si system.
Methods. We retrospectively analyzed the records of patients in our registry database who underwent colorectal surgery from 2012-2022. The selection criteria included all distal sigmoid and rectal cancer patients who received low anterior resection surgery performed with the da Vinci Si or Xi systems. The baseline characteristics and short-term surgical outcomes are presented and the da Vinci Xi vs. Si system outcomes are analyzed.
Results. From 2011-2022, a total of 85 patients underwent da Vinci Si colorectal surgery and 66 patients received da Vinci Xi colorectal surgery. The two groups of patients were comparable regarding baseline clinical characteristics. There was a significant decrease in operation time and estimated blood loss in the Xi group compared to that in the Si group. Compared to the Si system, the Xi system had a lower rate of hybrid or dual docking for splenic flexure mobilization. The length of stay, complication rate, anastomotic leakage rate and readmission rate were similar between the two groups.
Conclusion. The da Vinci Xi system has wider applicability in multi-quadrant surgery, and especially exceled in splenic flexure mobilization. However, further larger scale observational studies are required to reach a more definite conclusion.

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In the realm of colorectal surgery, laparoscopic techniques have gained significant traction in colonic procedures over the past decades.[1] However, there are still some limitations to laparoscopic surgery, including use of a rigid device and restricted vision.[2-4] Addressing the limitations of laparoscopy in confined spaces, robotic systems have emerged as a contemporary alternative. With their ergonomic design, wristed

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instruments, tremor filtering, and three-dimensional views, these systems present promising advancements.[2-5]

While interest in robotic rectal surgery has grown, the global uptake in interest has faced impediments due to technical limitations in earlier models, notably the da Vinci Si system. Issues such as prolonged docking times, arm clashing, and challenges in multi-quadrant surgery hampered the seamless integration of these robotic systems.[2,5-7] Moreover, adoption of a hybrid technique with conventional laparoscopic procedures or dual docking may be required to complete multi-quadrant procedures.[2,5,6,8]

Responding to feedback from surgeons across specialties, Intuitive Surgical® introduced the da Vinci Xi system in 2014. This model aimed to overcome previous limitations with several technological enhancements. The docking procedure is simplified, and thinner arms permit a wider range of motion without increasing the incidence of extracorporeal collision. The instruments are longer, which leads to easily extending to the lesion area, with flexible joints.[2,6,7,9,10] These features increase the flexibility and maneuverability of the Xi system, and aim to improve the performance of multi-quadrant procedures.

Despite the introduction of the da Vinci Xi system and its potential to revolutionize robotic rectal surgery, the question of whether this improved version translates into superior short-term surgical outcomes remains in debate. This article seeks to investigate the impact of the da Vinci Xi system compared to its predecessors. In this study, we analyzed the perioperative outcomes of patients undergoing low anterior resection for colorectal cancer using the two different robotic systems. Our aim was to study whether the da Vinci Xi system is superior to the da Vinci Si system in multi-quadrant operations.

Materials and Methods

We retrospectively evaluated the data of patients who underwent robotic colorectal surgery between January 2012 and December 2022 in our prospectively registered patient database at China Medical University Hospital. We included patients who had distal sigmoid colon cancer or rectal cancer, and who had received robotic low anterior resection surgery. Distal sigmoid cancer was defined as sigmoid tumor > 15 cm and < 20 cm from the anal verge and needed to received low anterior surgery for adequate surgical margin.[11] We excluded patients who had received abdominoperineal resection or subtotal colectomy.

Patient demographics, short-term surgical outcome, and operative and postoperative complications were evaluated. Patient demographics included gender, age, body mass index (BMI), cancer composition, and American Society of Anesthesiologist (ASA) grade.

Operative variables included operative time, estimated blood loss, lymph node harvest and conversion rate. Conversion was defined as from da Vinci surgery to traditional open surgery. We also recorded the splenic flexure mobilization rate during operation. At our medical central, we routinely perform complete splenic flexure mobilization for low anterior resection surgery, aiming to achieve better vascularized and tension-free anastomosis.[12] Complete splenic flexure was defined as medial to lateral dissection of the sigmoid and descending colon, lateral mobilization of the descending colon, and detachment of the greater omentum of the transverse colon.[8] We defined the robotic method as complete splenic flexure mobilization by robotic means only, while the hybrid method was defined as a procedure that was completed by combining the robotic and laparoscopic methods. Dual docking was defined as there being two phases: a pelvic phase and a splenic phase, during operation.[8]

The postoperative clinical data examined included length of stay (LOS), 30-day readmission, 30-day reoperation, 30-day mortality, complications, and clinical anastomotic leaks. Complications were defined using the Clavien-Dindo classification.[13] Anastomosis leakage was defined as an anastomotic leak requiring re-intervention, such as a drain or further surgery. All patients were operated on by the same surgical team at China Medical University Hospital.

Robotic low anterior resection port placement with the da Vinci Xi system

Patients were placed in the Trendelenburg posi-

tion at 30° with the ride side down. An 8 mm robotic port was inserted via the supra umbilicus, as the camera port. Another 12 mm assistance port was inserted via the abdomen right upper quadrant (RUQ), and three 8 mm robotic ports were inserted via the left upper quadrant (LUQ), right lower quadrant (RLQ) and RLQ. The distance between each port was from 6 to 8 mm (Fig. 1). Five ports are used for Xi system surgery (Fig. 2).

Port placement for robotic low anterior resection in the da Vinci Si system

Patients were placed in a lithotomy position. The abdomen and perineum were prepared antiseptically. There are two phases in the Si system: The first one is the pelvic phase (Fig. 3). An 8 mm robotic port is inserted via the supra umbilicus, as the camera port. Another two 12 mm assistance ports are inserted via the abdominal RUQ with distances from the camera port ranging from 6 to 8 mm. Arm 1 was inserted at the RLQ, Arm 2 at the LLQ, and Arm 3 at the LUQ. The distance between each port was at least 6-8 mm (Fig. 3). Line A to Line D indicates the distance between two ports. Then, the splenic phase is used, if the splenic flexure needs to be taken down using the dual docking method (Fig. 4). The camera port and Arm one are located at the same area. Arm 2 is switched to the previous Arm 3 location, and Arm 3 is switched to the assistant port area (Fig. 4).

The surgery procedures were alike between the two systems. After lymph node dissection, the inferior mesenteric artery was divided at its root. The inferior mesenteric vein was divided at the level of the Treitz ligament. The splenic flexure was mobilized to facilitate a tension-free anastomosis, as required. Pelvic dissection was performed according to the principles of total mesorectal excision (TME) for patients with rectal cancer.[14] The tumor-bearing bowel segment was eventually resected through endoscopic stapling or a SureForm stapler, and bowel continuity was restored using intracorporeal end-to-end anastomosis.

In addition, some specific ultra-low rectum cancer patients in our medical center may receive TME + two-stage Turnbull-Cutait Pull-through Coloanal Anastomosis if they refuse or encounter difficulties with stomas formation.[15-17] We also recorded those patients who underwent Turnbull-Cutait Pull-through Coloanal Anastomosis.

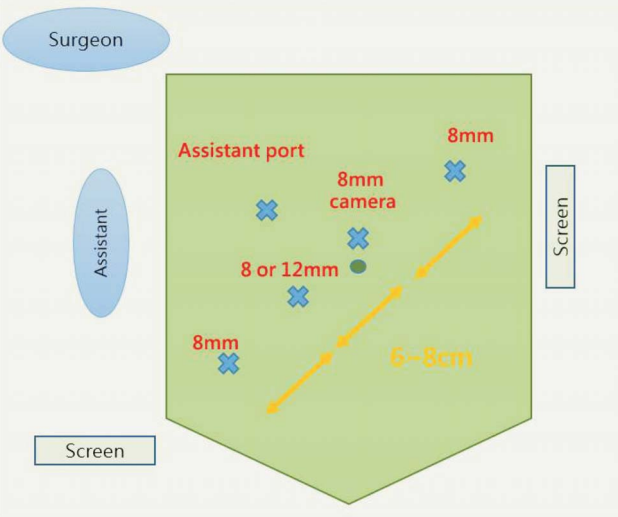

Fig. 1. da Vinci Xi system port placement: An 8 mm robotic port was inserted as the camera port via the supra umbilicus. Another 12 mm assistance port was inserted via the abdomen right upper quadrant (RUQ), and three 8 mm robotic ports were inserted via the upper LUQ, RLQ and RLQ. The distance between each port was 6 to 8 mm.

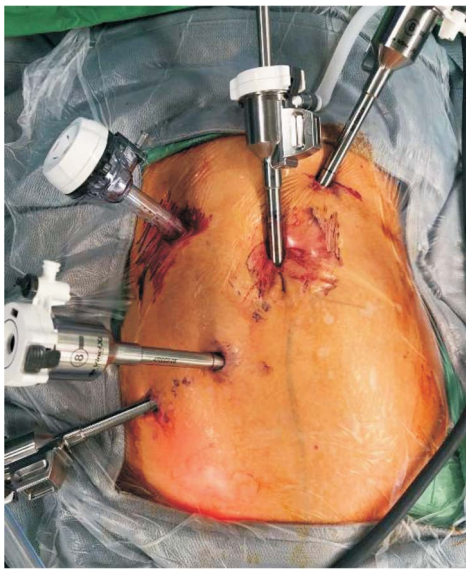

Fig. 2. Five ports were used for da Vinci Xi system surgery.

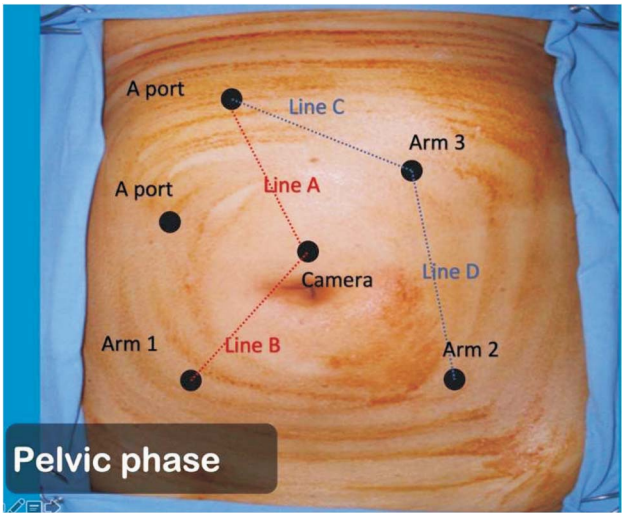

Fig. 3. Pelvic phase for the da Vinci Si system: An 8 mm robotic port was inserted as the camera port via the supra umbilicus. Another two 12 mm assistance ports were inserted via the abdominal RUQ, with distance from the camera port ranging from 6 to 8 mm. Arm 1 was inserted at the RLQ, Arm 2 was at the LLQ, and Arm 3 was located at the LUQ. The distance between each port was at least 6-8 mm.

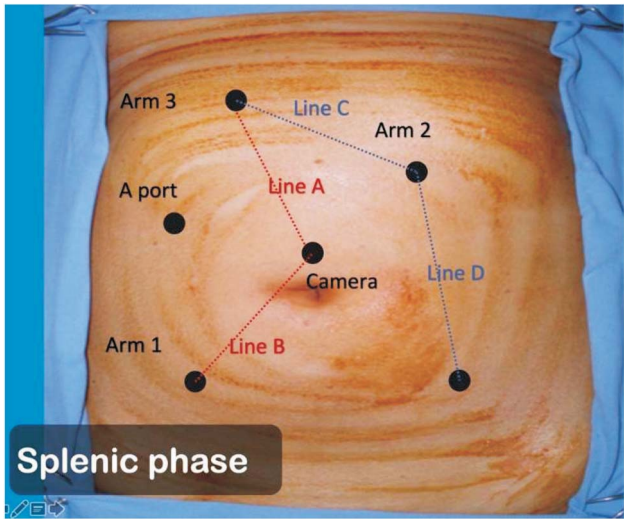

Fig. 4. Splenic phase for the da Vinci Si system. The camera port and Arm one are located at the same area. Arm 2 is switched to the previous Arm 3 location, and Arm 3 is switched to the assistant port area using the trochar in the trochar method.

Statistical analysis

Statistical analysis was performed using IBM SPSS 16.0 software. Categorical variables were compared using the χ^2 test. Continuous variables were compared using the Student *t*-test. $p \leq .05$ was considered statistically significant.

Results

Between January 1, 2011 and December 31, 2022, 151 patients at China Medical University Hospital underwent robotic da Vinci low anterior resection surgery. In all, 85 patients received robotic Si system surgery and 66 patients underwent surgery using the Xi system.

Patient characteristics are listed in Table 1. The Si and Xi groups were comparable with regard to demographics parameters, including sex, age, BMI, sigmoid or rectum cancer proportion, and American Society of Anesthesiologists class. The operative variables are summarized in Table 2. The overall mean operation time was significantly shorter in the Xi group (265.0 ± 125.5 minutes in the Si group vs. 243.7 ± 91.5 minutes in the Xi group, $p = .008$). Mean blood loss was significantly less in the da Vinci Xi group

Table 1. Patient preoperative characteristics by robotic system

Patient characteristics	da Vinci Si (N = 85)	da Vinci Xi (N = 66)	*p* value
Male, %	66.0	63.6	0.947
Age, years, mean (SD)	59.3 (11.1)	60.3 (11.3)	0.843
BMI, kg/m^2, mean (SD)	24.1 (3.8)	23.8 (4.2)	0.441
Distal sigmoid colon cancer, % (n)	21.2 (18)	37.9 (25)	0.134
Rectal cancer, % (n)	78.8 (67)	62.1 (41)	
ASA class, %			0.352
2	76.5	67.8	
3	23.5	32.2	

ASA, American Society of Anesthesiologists; BMI, body mass index.

Table 2. Patient operative characteristics by robot system

Operative variable	da Vinci Si (N = 85)	da Vinci Xi (N = 66)	*p* value
Operative time, min, mean (SD)	295.0 (125.5)	273.7 (91.5)	0.008
Estimated blood loss, mean (SD)	91.2 (201.7)	43.1 (57.6)	< 0.001
Lymph node harvest, mean (SD)	18.6 (7.6)	17.8 (9.3)	0.081
Conversion, %	1.9	0	

(43.1 ± 57.6 mL, compared to 91.2 ± 201.7 mL in the da Vinci Si group, $p < 0.001$). There was no difference in lymph node harvest (18.6 ± 7.6 in the Si group vs. 17.8 ± 9.3 in the Xi group, $p = .0081$). Two cases were converted to traditional surgery in the Si group and none in the Xi group.

Splenic flexure mobilization methods by robotic system are listed in Table 3. There was a significantly higher hybrid and dual docking method use rate in the Si group than in the Xi group (60% vs. 7.6%, $p < 0.001$). In addition, one patient in the Si group and 14 in the Xi group (1.2% vs. 21.2%) underwent the Turnbull Cutait procedure.

Postoperative outcomes were similar in both groups (Table 4). The length of stay is almost the same in each group (7.5 ± 4.6 vs. 7.5 ± 4.2, $p = 0.427$). There was no significant difference in complication rate (16.5% vs. 13.1%, $p = 0.732$). Anastomosis leakage was the most surgically-related complication, but with no significant difference (7.5% vs. 6.8%, $p = 0.567$). Only two patients in the Si group and one in the Xi group were readmitted (1.9% vs. 1.3%, $p = 0.459$).

Discussion

The application of robotic technology in performing colorectal surgery could maintain the benefits of minimally invasive techniques while overcoming the constraints associated with traditional laparoscopic methods.[4,18-20] However, experience with the Si system has indicated significant potential for enhancement beyond its initially touted advantage. These issues mainly entailed improvement in the difficult and complex docking process, repeated arm clashing and difficulties in performing multi-quadrant surgery. The issue of multi-quadrant surgery with the da Vinci Si has been addressed by colorectal surgeons with a variety of methods, leading to multiple robotic rectal resection techniques. These methods include a hybrid-approach and a dual docking approach, which have been described in previous reports.[8,10,21]

In this study, we presented the data of a total of 151 robotic distal sigmoid and rectal cancer cases over a period of 11 years. By applying a standardized and modular approach to surgery, robotic surgery was performed with good short-term surgical outcomes. The conversion rate, complication rate, leakage rate, and readmission rate were comparable to those of previous studies.[10,20,22,23] Our data showed there was significantly less operation time and less blood loss with the Xi system, than with the Si system. This may be due to the flexibility of the Xi robotic arm, with less

Table 3. Splenic flexure mobilized by robotic system

Operative variable	da Vinci Si (N = 85)	da Vinci Xi (N = 66)	*p* value
Robotic, % (n)	40.0 (34)	92.4 (61)	< 0.001
Dual docking or hybrid, % (n)	60.0 (51)	7.6 (5)	
Turnbull cutait, % (n)	1.2 (1)	21.2 (14)	

Table 4. Postoperative outcomes by robotic system

Postoperative variable	da Vinci Si (N = 85)	da Vinci Xi (N = 66)	*p* value
Length of stay, days, mean (SD)	7.5 (4.6)	7.5 (4.2)	0.427
Complications, % (n)	15.3 (13)	13.6 (9)	0.732
Clavien-Dindo 1 and 2, % (n)	12.9 (11)	10.6 (7)	
Wound infection (n)	5	3	
Ileus (n)	3	1	
Chylous leak (n)	0	1	
Abscess with drainage (n)	4	2	
Clavien-Dindo 3, % (n)	2.4 (2)	3.0 (2)	
Leakage reoperation (n)	2	2	
Anastomotic leak, % (n)	7.1 (6)	6.1 (4)	0.567
Abscess with drainage (n)	4	2	
Reoperation (n)	2	2	
Readmissions, %	2.3	1.5	0.088

dual docking and use of the hybrid method. Tamhankar et al. reported that rectal surgery using the Xi system enabled single docking and single-phase resection with fewer ports, compared with the Si system.[9] Huang et al. reported similar group compositions of Si and Xi patients, and showed relevant blood loss similar to our study result.[10] It is interesting to note that despite significant blood loss in the Xi group, these results were in agreement with other published reports that revealed an improved blood loss in robotic surgery compared to laparoscopic rectal cancer surgery.[4,18]

Our study clearly demonstrated the benefit to splenic flexure take down with the robotic Xi system. In our study, there were significant differences in splenic flexure take down using the total robotic method in the Xi group. The Xi system's enhanced design allows for more efficient maneuvering and reduced operation time. S. Panteleimonitis et al. reported that the Xi system improved operational efficiency in complex surgeries, reducing docking times significantly, which is critical for minimizing overall surgical duration.[23] In addition, compared to a previous study, most of the robotic surgical centers had a surgical table with Integrated Table Motion (ITM), while we used a regular table for robotic surgery. A previous report mentioned facilitating robust splenic flexure mobilization by moving from the head down to the head-up position without undocking the robot, displacing the transverse colon downwards and therefore assisting in separating the omentum from the transverse colon.[24,25] Nevertheless, we completed splenic flexure using the single docking method with the head down procedure. The highly successful rate of complete splenic flexure take down may be due to there being more flexibility in the Xi system arms and passive joint. By adjusting the arms and joints, splenic flexure can be easily taken down using the IMV approach, lateral approach, and downward from the omentum.

Moreover, our colorectal surgery team used the Turnbull Cutait procedure for ultra-low rectal cancer patients who refused or encountered difficulties with stomas formation, and needed complete splenic flexure take down for the procedure.[15] We had included 14 cases in the Xi group by the end of the study. Therefore, the Xi system really offers greater application in multi-quadrant surgery.

There was no significant difference in postoperative length of stay, complications, or readmission rate. The complication rates in both groups were comparable to those reported for robotic colorectal surgery in previous studies.[3,10,20,22,26] Moreover, there was no mortality in the two groups of patients, indicating that robotic surgery using both generations of systems was a safe procedure to treat colorectal cancer patients. In our study, there was a total of 6 cases of leakage in the Si group and 4 in the Xi group. There was no difference between the two groups in terms of leakage. In the Si group, two of the patients needed reoperation and four had drainages of the abscess; two in the Xi group needed reoperation. The readmission rate was 2.3 in the Si group and 1.5 in the Xi group, respectively. The patient in the Xi system group was a case of delayed anastomosis leakage that was resolved using transanal approach suturing.[27]

However, there are limitations to this study that must be noted, including the small number of patients, the lack of data on long-term outcomes, no randomization of the patients, and no comparative studies. In addition, usage of the da Vinci Si system at China Medical University Hospital began in 2012, and Xi system usage commenced in 2021. Therefore, the bias of surgical technique improvement should be considered. Nevertheless, further studies with long-term outcomes and follow-up are required to establish whether the robotic Xi system is truly superior to the Si system.

Conclusion

In conclusion, from our preliminary results, the robotic da Vinci Xi system is more flexible in splenic flexure mobilization. The da Vinci Xi system also allows wider applicability in multi-quadrant surgery, less blood loss, and decreased operation time. However, further studies are needed to assess the long-term outcomes of this operative device.

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原　著

達文西 Si 系統與 Xi 系統：低位前切除術脾曲鬆動術與手術結果的比較分析

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前言　機器人手術是微創時代的最新技術。然而，先前的達文西 Si 系統也顯示了一些局限，尤其在脾曲鬆動術。達文西 Xi 系統憑藉增強的靈活性和機動性，預期將改善並促進結直腸手術的應用。這篇文章旨在探討達文西 Xi 系統在低位前切除手術中相比達文西 Si 系統的影響。

方法　我們回顧性地分析了 2012 年至 2022 年間在我們的登記數據庫中接受結直腸手術的患者記錄。選擇標準包括所有接受達文西 Si 和 Xi 系統低位前切除手術的遠端乙狀結腸和直腸癌患者。本文介紹了患者的基本臨床特性和短期手術結果，並對達文西 Xi 系統和 Si 系統的結果進行了分析與比較。

結果　在 2011 至 2022 年期間，有 85 位患者接受達文西 Si 手術，66 位接受 Xi 手術。兩組在基本臨床特性上沒有顯著差異，達文西 Xi 組在手術時間有顯著降低，估計出血量也有顯著減少。相較於 Si 系統，Xi 系統在脾曲鬆動術上需要混合手術或者二次組裝的機會較低。兩組的住院時間、吻合口滲漏率和再住院率相似。

結論　達文西 Xi 系統在多象限手術中提供了更廣的應用可能，但未來還需更多大型觀察研究來確認這些結論。

關鍵詞　機械手臂手術、達文西 Si 系統、達文西 X 系統、低前位切除、脾曲鬆動術。