A comparative study on the short-term clinical outcomes of Da Vinci SP versus Da Vinci Xi for rectal cancer surgery

Wed Alshalawi Alshalawi  
King Saud Medical City

Chul Seung Lee  
Hansol Hospital

Byung Chul Kim  
Incheon St. Mary's Hospital

Seung Rim Han  
Ain Hospital

In Kyeong Kim  
Seoul St. Mary’s Hospital

Jung Hoon Bae  
Seoul St. Mary’s Hospital

In Kyu Lee  
Seoul St. Mary’s Hospital

Do sang Lee  
Seoul St. Mary’s Hospital

Yoon Suk Lee (✉ yslee@catholic.ac.kr)  
Seoul St. Mary’s Hospital

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Abstract

Purpose

The Da Vinci SP robot system was recently introduced, but its safety and feasibility for rectal cancer compared to the currently used Da Vinci Xi robot system have not been reported. This study aimed to report the safety and feasibility of the Da Vinci SP robot system for rectal cancer by comparing the short-term outcomes of the Da Vinci Xi robot system.

Methods

This was a single-center, retrospective study. Data from rectal cancer patients who underwent abdominal total mesorectal excision (TME) using the robotic Xi and SP systems from October 2015 to October 2022 were analyzed. After propensity score matching, the short-term clinical perioperative outcomes were compared between the Da Vinci SP and Xi robotic system groups.

Results

A total of 56 patients who underwent robotic TME were analyzed after propensity score matching (SP, n = 28, vs. Xi, n = 28). Intersphincteric resection was more common in the SP group (7 cases (25%) vs. 0 case (0%), p = 0.001). The operation time was significantly shorter in SP (184 vs. 227.5 minutes, p < 0.0001), but the docking time was similar between the two groups. The postoperative complications were similar between the two groups (five cases in the SP group (17.9%) vs. four cases in Xi (14.3%), p = 0.68). There were no differences in the postoperative pain score and length of hospital stay.

Conclusion

The SP robotic system for abdominal TME has acceptable short-term outcomes compared with the Xi robotic system and is safe and technically feasible.

Introduction

Minimally invasive surgery for colorectal cancer has been a significant advancement in the surgical field in recent decades. Several technical limitations of laparoscopic surgery in the early days were resolved through the development of technology, but poor ergonomics is still a major drawback of laparoscopic surgery [1].

The robotic Da Vinci system® (Intuitive Surgical, Inc., Sunnyvale, CA, USA) in the colorectal field is an extension of minimally invasive surgery with advantages, including less fatigue, superior ergonomics, three-dimensional visualization, better wrist-like motion, and tremor correction [2–4]. These are key, especially in technically demanding procedures such as rectal surgery, which require precise dissection in the narrow pelvic space [5,6].
Robotic systems have also been used in single-incision surgery for colorectal cancer. Several surgeons have reported its feasibility, but it is still technically challenging because of the collision between the non-wristed arms system in a single port and poor ergonomics [7,8]. Recently, the Da Vinci SP® system was introduced. It has a double articulating system in each arm, and all four working arms, including the camera, are allocated to a single arm, which can be deployed simultaneously in a specific metallic, four-channel, 25 mm single cannula (Fig. 1).

Early experience and short-term outcomes of transanal total mesorectal excision (TaTME) using the Da Vinci SP® system have been reported previously and have shown its feasibility and safety [9]. However, few studies have reported abdominal total mesorectal excision (TME) using the new SP system, and the safety and feasibility of Da Vinci SP® for rectal cancer are still being investigated [10]. This study aimed to report the safety and technical feasibility of abdominal TME using the Da Vinci SP by comparing the short-term outcomes between the Da Vinci Xi and SP robotic systems.

**Materials And Methods**

The medical records of patients who underwent rectal resection for rectal cancer stages I–III using Da Vinci Xi and the SP robotic system were reviewed. Our center began using the Da Vinci Xi system in 2015 and the SP system in October 2021 for rectal cancer. In the present study, we used propensity score matching to reduce bias between the Xi and SP robotic groups. For more precise comparisons of the two groups, we also matched the sex, age, body mass index (BMI), and American Society of Anesthesiologists (ASA) categories using a non-parsimonious logistic regression model in line with the preset factors. The medical data collected prospectively were retrospectively reviewed. All patients were diagnosed through a colonoscopy with biopsy, computed tomography of the chest and abdomen-pelvis, and magnetic resonance imaging. Neoadjuvant chemoradiotherapy (nCRT) was determined through multidisciplinary team (MDT) discussions. In the case of nCRT, surgery was performed 8–10 weeks after its completion.

The docking time was defined as the time from the start of driving the robotic cart to complete port docking for the robot system. Console time was defined as the time from the surgeon's start of the operation at the console until the undocking of the robotic arm. The time for each surgical procedure in each case was re-checked by reviewing the patient's recorded files. The perioperative complications, including estimated blood loss (EBL), intra- or postoperative conversion events, postoperative complications, and postoperative hospital stay, were analyzed.

*Preparation of the Da Vinci SP system*

After general anesthesia, the patient was placed in the trendelenburg and right-tilting positions. A 4 cm skin incision was made in the right lower quadrant, the peritoneal cavity was opened, and uniport (Dalim®, Korea) was applied. A 5–8 mm laparoscopic port was placed in the right upper quadrant for assistance. The Da Vinci SP® robot was brought over to the patient's left side and docked at the uniport. The Da Vinci SP® system was introduced into the peritoneal cavity through a uniport (Dalim®, Korea) containing a 25 mm port, a 12 mm assistant port, and two 5 mm assistant ports (Fig. 1). The camera was
inserted at the bottom, a tooth retractor at the top (arm 2), monopolar curved scissors on the right (arm 3), and fenestrated bipolar forceps on the left (arm 1) in the multichannel SP trocar. All surgical procedures of Da Vinci SP rectal cancer surgery followed the oncologic principle and were similar to those of Da Vinci Xi rectal cancer surgery.

After surgery using the Da Vinci SP system, the specimen was retrieved through a uniport, and an ileostomy was performed at the uniport placement site, depending on the situation [11]. During surgery using the Xi system, the extraction site was determined based on the surgeon's preference.

Statistical analyses and graphical presentation of the results were performed using the R version 3.4.3 software (R Foundation for Statistical Computing, Vienna, Austria). Graphical presentation of the results was performed using GraphPad Prism 6 (GraphPad Software Inc., La Jolla, CA, USA). Fisher's exact test was used for categorical data, while the Mann-Whitney U-test was used for continuous data. In the present study, we used propensity score matching techniques. The scores of the participants were calculated using a non-parsimonious logistic regression model in line with preset factors such as sex, age, BMI, and the ASA category. Using the nearest-neighbor method and 1:1 matching without caliper width or replacement within a match tolerance width of 0.001, patients who underwent colorectal SP robotic surgery were matched to those who underwent multiport robotic surgery. The \( p \)-value cut-off for statistical significance was set at \( p < 0.05 \). This study was approved by the Research Ethics Board of Seoul St. Mary's Hospital (IRB no.: KC22RASI0187).

**Results**

There were no differences in the distribution of sex, age, BMI, and ASA categories between the two groups after matching 224 cases in the Xi group to 28 cases in the SP group (Table 1). The tumor staging was significantly less advanced in the SP group \( (p = 0.001) \). Regarding the operation type, intersphincteric resection was significantly more frequent in the SP group \( (7 \text{ cases vs. } 0 \text{ cases}, p = 0.001) \) (Table 1).

Pathological outcomes are shown in Table 2. The tumor size was significantly smaller in the SP group \( (2.6 \text{ cm vs. } 5.9 \text{ cm}, p = 0.003) \). Regarding harvested lymph nodes, the number of lymph nodes was significantly less in the SP group \( (17 \text{ vs. } 18.5, p = 0.02) \). The distal resection margin was similar between the groups \( (2.3 \text{ cm vs. } 2.8 \text{ cm}, p = 0.9) \), but the proximal resection margin was significantly longer in the Xi group \( (8.6 \text{ cm vs. } 13.5 \text{ cm}, p = 0.001) \). In the present study, there were no cases of distal margin positivity. There was one case of circumferential margin positive cases in the SP group and two cases in the Xi group, which showed no statistical difference.

Regarding the perioperative outcomes (Table 3), the total operation time \( (184.0 \text{ min vs. } 227.5 \text{ min}, p < 0.0001) \) and console time \( (73.0 \text{ min vs. } 116.0 \text{ min}, p = 0.02) \) were significantly shorter in the SP group than the Xi group. However, the docking times were similar between the two groups. The median estimated blood loss was comparable between the two groups. There were no transfusions, conversions to laparotomies, or intraoperative complications in either group. The postoperative complication rates were not different between the two groups \( (five \text{ cases (17.9\%) vs. four cases (14.3\%), } p = 0.68) \). One case
of anastomotic leakage occurred in the Xi group, and reoperation was performed. There was one case of a minor leak in the SP group, which was successfully treated conservatively.

Regarding postoperative pain, the numerical rating scale (NRS) pain score showed a borderline significant difference (Fig. 2 and Table 3). The hospital stay was significantly shorter in the SP group (5 days vs. 6 days, \( p = 0.01 \)). No mortality was observed in this study.

**Discussion**

Since the introduction of robotic systems in the colorectal field, they have become popular, and many studies have reported their safety and effectiveness, especially in rectal cancer surgery [5], [14,15]. Recently, a new robotic system, composed of three 6-mm wristed and elbowed instruments and a three-dimensional high-definition camera, all allocated to a single robotic arm, has enabled single-incision robotic surgery. Despite being coaxial, these instruments can triangulate their distal tips owing to the elbow joint. The platform boom can rotate 360° within and around the port's remote center, allowing for proper multi-quadrant surgery without the need for de-docking and re-docking. This new SP robotic system was found to be very helpful in retraction and exposure of the correct plane of taTME, as well as endoluminal suturing, providing favorable evidence for its use in transanal surgery [14,15].

However, transabdominal procedures, including TME, have not been explored adequately yet.

The docking step is technically more straightforward in the SP system than in the Xi system because the docking step for SP has only one step in the whole procedure compared to the docking steps for the Xi system, which might need other re-docking for the next operational phase, for example, for the pelvic phase. However, in the present study, the docking times were similar between the Xi and SP groups. Our operation team, including surgical nurses, had a great experience with robotic surgery for a decade, which could explain the equal docking time in both robotic systems. In the early stages of robotic surgery, reducing docking time was one of the issues in robotic surgery, and several studies have reported on the learning curve of docking in robotic surgery [16,17]. However, in the SP system, the author believed that the learning curve was much less steep than in the Xi system. Hence, the docking time was short, even with the initial experience with the SP system.

In the present study, the total operation time and console time were significantly shorter in the SP group than in the Xi group; however, the sample size was too small to demonstrate the superiority of the SP system in terms of operation time. The authors applied the SP system to relatively small and less advanced cases, which could explain the shorter operation time in the SP group. But other than tumor factors, the "relocating" function of SP—moving the SP system from the splenic flexure to the deep pelvis without de-docking and re-docking—could be another potential factor to reduce the operation time.

When single-incision laparoscopic surgery was first introduced, many surgeons expected less postoperative pain and a faster recovery. [18,19]. Recently, the SIMPLE trial, a large prospective randomized trial comparing single-incision and multiport laparoscopic colon cancer surgery, reported that
postoperative pain was similar between the two groups [20]. However, in the SIMPLE trial, rectal cancer was excluded because of the technical difficulties associated with single-incision laparoscopic rectal cancer surgery. Therefore, few studies have evaluated postoperative clinical outcomes, including postoperative pain, in single-incision laparoscopic or robotic rectal cancer surgery. In the present study, the author assessed postoperative pain was assessed using the NRS score, which showed a significant difference between the two groups. Although the mean NRS score appeared similar, the difference in range made a statistically significant difference. However, the sample size of this study was too small to confirm the superiority of SP in terms of postoperative pain. Our center has been applying for a multimodal perioperative pain management program since August 2019 [21]. We believe that postoperative pain could be affected more by perioperative pain management than by the length or number of skin incisions. We believe that more cases should be analyzed in the future to evaluate the clinical impact of single-incision rectal cancer surgery on postoperative pain. Regarding the operation type, intersphincteric resection was significantly more common in the SP group in this study. Unlike the Xi system, the SP system does not have a robotic stapler; therefore, in cases of low anterior resection using the SP system, the SP system should be de-docked after the completion of TME to introduce a laparoscopic stapler. Therefore, the authors believe that intersphincteric resection with hand-sewn coloanal anastomosis for very low rectal cancer could be an optimal indication for SP rectal cancer surgery [11].

One of the advantages of SP over Xi is better cosmesis; a single-port site can be used for diverting an ileostomy. (Fig. 3).

In terms of the pathological outcomes of this study, the tumor size was significantly smaller in the SP group. The author believes this was a selection bias because rectal cancer surgery using the SP system is in its early stages; the author applied the SP system for relatively small and early-stage rectal cancer. The number of lymph nodes harvested was less in the SP group, but 17 lymph nodes were appropriate for the oncologic principle. The distal resection margin was similar between the two groups, but the proximal margin was shorter in the SP group. We think it is a matter of a small sample size and less advanced cases in the SP group, so we will evaluate in the future with much more extensive cases.

Although the new SP system has several advantages, there are still several technological limitations of the SP system. In the previous robotic system, stable and powerful traction was available; however, the SP system had a relatively weaker grasping power and a short distance for traction. The SP endo-elbow system has a relatively limited articulating angle compared with the Xi endo-wrist system. For this reason, we believe that bulky tumors and obese patients may be challenging for the SP system. Currently, the SP system does not include energy devices or staplers. The development of these instruments and technological advancements are necessary for colorectal surgeons to apply the SP system to more colorectal surgeries.

The present study has several limitations. First, this was a retrospective study; therefore, a selection bias was inevitable. Second, the SP system has recently been applied in the colorectal cancer field. Therefore,
this study had a small sample size. A larger-scale study is needed in the future to evaluate the potential advantages of SP colorectal surgery.

**Conclusion**

The Da Vinci SP Robotic System for abdominal TME is safe and technically feasible, and it showed acceptable short-term outcomes compared to the Xi Robotic System. Future large-scale evaluations are required to define the ultimate utility of SP robots in the colorectal field.

**Declarations**

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**Competing Interests**

The authors report no conflicts of interest.

**Author contributions**

Conception and design: All Authors

Acquisition of data: In Kyeong Kim, Jung Hoon Bae

Analysis and interpretation of data: Wed Alshalawi, Chul Seung Lee

Software: Wed Alshalawi, Byung Chul Kim

Drafting the article: Wed Alshalawi, Yoon Suk Lee

Critical revision: Dosang Lee, Yoon Suk Lee

Final approval: all authors

**Ethics approval**

This study was approved by the Research Ethics Board of Seoul St. Mary's Hospital (IRB no.: KC22RASI0187)

**Consent to participate**
Informed consent was obtained from all individual participants

Consent to publish

Informed consent was obtained from all individual participants

Data Availability

The datasets generated during and/or analyzed during the current study are not available.

References


Tables

Table 1: Basic characteristics of the SP group and Xi group after propensity score matching analysis
Table 2. Pathologic outcomes between the SP and Xi group

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>SP (n=28)</th>
<th>Xi (n=28)</th>
<th>p -value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M:F)</td>
<td>15:13</td>
<td>15:13</td>
<td>NS</td>
</tr>
<tr>
<td>Age, median (ranges), years</td>
<td>66.5 (53.7-72.5)</td>
<td>64.0 (56.0-70.3)</td>
<td>0.90</td>
</tr>
<tr>
<td>Body Mass Index (BMI, kg/m²), median (ranges)</td>
<td>22.5 (20.6-25.1)</td>
<td>22.5 (21.2-24.8)</td>
<td>0.87</td>
</tr>
<tr>
<td>ASA classification</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASA I</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>ASA II</td>
<td>18</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Operation type, n(%)</td>
<td></td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Intersphincteric resection with ileostomy</td>
<td>7 (25%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Low Anterior resection (with/without ileostomy)</td>
<td>17 (60.7%)</td>
<td>25 (89.3%)</td>
<td></td>
</tr>
<tr>
<td>Ultra-Low Anterior resection with ileostomy</td>
<td>4 (14.3%)</td>
<td>3 (10.7%)</td>
<td></td>
</tr>
<tr>
<td>Tumor staging, n (%)</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage I</td>
<td>11 (39.3%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Stage II</td>
<td>11 (39.3%)</td>
<td>17 (60.7%)</td>
<td></td>
</tr>
<tr>
<td>Stage III</td>
<td>6 (21.4%)</td>
<td>11 (39.3%)</td>
<td></td>
</tr>
<tr>
<td>Variables</td>
<td>SP (n=28)</td>
<td>Xi (n=28)</td>
<td>p-value</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-----------</td>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td>Tumor size, cm, median (ranges)</td>
<td>2.6 (0.97-4.45)</td>
<td>5.9 (1.63-11.63)</td>
<td>0.003</td>
</tr>
<tr>
<td>Tumor Differentiation, n (%)</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>Well Diff.</td>
<td>19 (67.9%)</td>
<td>22 (78.6%)</td>
<td></td>
</tr>
<tr>
<td>Moderated Diff.</td>
<td>5 (17.9%)</td>
<td>4 (14.3%)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>4 (14.3%)</td>
<td>2 (7.1%)</td>
<td></td>
</tr>
<tr>
<td>pT category, n(%)</td>
<td></td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>T1/T2</td>
<td>14 (50%)</td>
<td>14 (50%)</td>
<td></td>
</tr>
<tr>
<td>T3/T4a</td>
<td>14 (50%)</td>
<td>14 (50%)</td>
<td></td>
</tr>
<tr>
<td>pN category, n(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N0</td>
<td>21 (75%)</td>
<td>10 (35.7%)</td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>5 (8.92%)</td>
<td>15 (53.6%)</td>
<td></td>
</tr>
<tr>
<td>N2</td>
<td>2 (3.57%)</td>
<td>3 (10.7%)</td>
<td></td>
</tr>
<tr>
<td>Harvested lymph nodes, median (range)</td>
<td>17.00 (13.25-19.0)</td>
<td>18.5 (15.50-26.75)</td>
<td>0.02</td>
</tr>
<tr>
<td>Distal resection margin, median (range)</td>
<td>2.3 (0.5-5.2)</td>
<td>2.8 (1.6-3.7)</td>
<td>0.90</td>
</tr>
<tr>
<td>Proximal resection margin, median (range)</td>
<td>8.6 (5.6-10.9)</td>
<td>13.5 (10.0-18.0)</td>
<td>0.001</td>
</tr>
<tr>
<td>Circumferential resection margin, n (%)</td>
<td></td>
<td></td>
<td>0.52</td>
</tr>
<tr>
<td>Positive</td>
<td>1 (3.57%)</td>
<td>2 (7.14%)</td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>27 (96.42%)</td>
<td>26 (92.86%)</td>
<td></td>
</tr>
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</table>
Table 3. Perioperative outcomes

<table>
<thead>
<tr>
<th>Variables</th>
<th>SP (n= 28)</th>
<th>XI (n= 28)</th>
<th>p -value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total operative time, minutes, median, (range)</td>
<td>184.0 (150.8-195.0)</td>
<td>227.5 (186.3-305.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Docking time, minutes, median, (range)</td>
<td>4.0 (3.0-4.75)</td>
<td>4.0 (3.0-6.75)</td>
<td>0.15</td>
</tr>
<tr>
<td>Console time, minutes, median, (range)</td>
<td>73.0 (60.25-90.00)</td>
<td>116.0 (57.50-206.0)</td>
<td>0.02</td>
</tr>
<tr>
<td>Operative Blood loss (mL), median, (range)</td>
<td>20.0 (20.0-50.0)</td>
<td>30.0 (20.0-70.0)</td>
<td>0.16</td>
</tr>
<tr>
<td>Post-operative complication, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total complication</td>
<td>5 (17.9%)</td>
<td>4 (14.3%)</td>
<td></td>
</tr>
<tr>
<td>1. Clavien-dindo class I</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2. Clavien-dindo class II</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3. Clavien-dindo class IIIa</td>
<td>0</td>
<td>0</td>
<td>0.68</td>
</tr>
<tr>
<td>4. Clavien-dindo class IIIb</td>
<td>0</td>
<td>1 (leak)</td>
<td></td>
</tr>
<tr>
<td>Pain score (NRS), median</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative day 1</td>
<td>3.0 (3.0-3.0)</td>
<td>3.0 (3.0-4.0)</td>
<td></td>
</tr>
<tr>
<td>Postoperative day 2</td>
<td>3.0 (0.25-3.0)</td>
<td>3.0 (2.0-3.0)</td>
<td>0.05</td>
</tr>
<tr>
<td>Postoperative day 3</td>
<td>2.0 (0-3.0)</td>
<td>2.0 (0-2.7)</td>
<td></td>
</tr>
<tr>
<td>Length of stay (days), median, (range)</td>
<td>5.0 (4.0-6.0)</td>
<td>6.0 (5.0-8.0)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Note: Mann-Whitney tests were used to assess the significance of differences in continuous variables between groups; Chi-square tests were used to assess the significance of differences in discrete variables between group.

Figures
Figure 1

uniport with metallic 4 channels trocar

Figure 2

Numerical rating scale (NRS) pain score difference between SP group and Xi group
Figure 3

Post-Operative SP robotic patient