Da Vinci Xi: a better platform for robotic-assisted radical prostatectomy?

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Research Article

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Abstract

Background

An upgraded surgical robot platform, da Vinci Xi, had demonstrated multiple advantages over the previous da Vinci Si system. Better surgical outcomes had been reported in various operations except for robotic-assisted radical prostatectomy (RARP). We sought to compare and analyze the outcomes of RARP between using the da Vinci Xi and the da Vinci Si. The learning curve of docking with the new surgical robot and method for RARP was also evaluated.

Methods

An initial series of 77 RARPs have since been performed with the side docking technique since the installation of the da Vinci Xi. Another series of 96 consecutive RARPs were performed immediately before the uptake using the da Vinci Si and central docking technique. We compared the clinicopathological, perioperative, and postoperative outcomes of these two groups. We also analyzed the learning curve of the transition from central docking with the da Vinci Si to side docking with the da Vinci Xi.

Results

The Xi group had a shorter console time (208.2 vs. 285.7 min, $p=0.004$), less estimated blood loss (193.5 vs. 259.9 mL, $p=0.018$), and faster docking time (5.12 vs. 7.95 min, $p=0.002$) than the Si group. There were no significant differences regarding perioperative and postoperative outcomes. The plateau of the learning curve of side docking with the da Vinci Xi system was reached after 27 cases, and led to a significantly shorter docking time than before completing the learning curve (3.72 vs. 7.70 min, $p<0.001$).

Conclusion

Performing RARP with the da Vinci Xi system and side docking improved intraoperative outcomes and the docking time was almost negligible after gaining sufficient experience with the new system and docking technique. However, the complication rate and postoperative outcomes did not significantly benefit from the da Vinci Xi model.

Background

Due to advances in minimally invasive laparoscopic surgery, robotic-assisted radical prostatectomy (RARP) has become an integral part of localized prostate cancer treatment since the first reported case in 2000 (1). A recent randomized controlled trial reported that robotic-assisted surgery could provide better biochemical recurrence-free survival than laparoscopic radical prostatectomy (2). Intuitive Surgical Inc. (Sunnyvale, CA, USA) released the first da Vinci Surgical System in 1999, and it has since become the market leader in surgical robots.

The da Vinci Xi system was launched in 2014, is the fourth-generation system from Intuitive Surgical Inc., and it has demonstrated multiple advantages over the previous da Vinci Si system (2009). A new smaller caliber 8-mm endoscope can be docked onto any arm, and the vision architecture and autofocus function have been upgraded. In addition, longer, articulated instruments equipped with force feedback improve the dexterity and reach of distant targets. The newly designed thinner, boom-mounted arms allow the ports to be placed closer without increasing extracorporeal collision. The process of robotic setup and docking is also simpler because of the user-friendly interface, a targeting laser beam, and boom feature (3).

Central docking with a low lithotomy position is traditionally employed in RARP. However, this inevitably limits access to the perineum, and the use of stirrups with prolonged hip abduction can lead to the rare complication of lower limb neuropraxia. The side docking technique was proposed to solve the drawbacks of central docking. *Cestari et al.* demonstrated that side docking could be a viable method to reduce the setup time of RARP with the da Vinci Si model (4). The upgraded mechanical facilities of the da Vinci Xi system makes side docking more feasible, and thus every RARP since the da Vinci Xi system was installed at our institution has been performed using the side docking method.

In this study, we retrospectively analyzed the outcomes of RARP performed using the da Vinci Xi compared with the da Vinci Si to investigate whether the effectiveness of the new system is reflected in practical use. The learning curve of docking to achieve proficiency in the new surgical robot and method for RARP was also evaluated.

Materials And Methods

The da Vinci Xi system was installed at Mackay Memorial Hospital, a medical center located in Taipei, Taiwan, in September 2019. In this study, we enrolled a cohort of 77 consecutive patients who underwent RARP with the da Vinci Xi system. A cohort of 96 patients who underwent RARP immediately prior to the installation of the da Vinci Xi system with the da Vinci Si system between September 2017 and August 2019 was also enrolled.

Operations in both groups were performed by a single surgical team consisting of five experienced urologists and a well-trained operating room crew. Leading members of the operating room crew were undergoing a training program provided by Intuitive Surgical Inc. which included observation and on-site practice. A representative of the manufacturer attended the operations on occasions for a 3-month period any time the team needed instruction.

Outcome Measurements

Multiple parameters including clinicopathological characteristics, perioperative, and postoperative outcomes were recorded and analyzed in both groups. Docking time was defined as the period from the first call to position the robot to successful targeting and completion of docking the robotic arms to the surgical ports. Postoperative complications were assessed according to the Clavien-Dindo classification with grades III and IV classified as major complications (5). Undetectable prostate-specific antigen (PSA) after RARP was defined as a level lower than 0.2 ng/dL.

Surgical Techniques

The RARP procedure was identical in both the Si and Xi groups, and was adopted from the method described by *Patel et al* (6). The robot docking of every RARP in the Si group was performed using traditional central docking, while the side docking technique was used in all patients in the Xi group. Unlike the technique reported in a previous study (4), we used a low lithotomy position instead of the supine position to allow for better access to the perineum.

Statistical Analysis

Continuous variables were compared using the independent sample t-test or one-way ANOVA, whereas categorical variables were compared using the $\chi 2$ test. A p value < 0.05 was considered to be statistically significant. All statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA).

Cumulative summation (CUSUM) charts were generated to analyze the learning curves of robot docking time. CUSUM is the running total of differences between individual data points and the mean of all data points. The CUSUM score of the first case was the difference in docking time between the first case and the mean of all cases. The CUSUM score for the second case was the CUSUM of the previous case added to the difference in docking time between the second case and mean of all cases. This procedure was repeated for all of the performed cases. The transition beyond the learning phase was defined as the inflection point of the CUSUM chart, and a stable process was identified by a consistently downward trend or fluctuation around a horizontal axis. Originally devised to quantitatively monitor consecutive performances over time in the industrial sector, the CUSUM method has been applied to evaluate learning curves in newly implemented surgical techniques (7). The Institutional Review Board at Mackay Memorial Hospital approved of this study.

Results

The demographic and clinical characteristics of the patients including age, body mass index, Charlson comorbidity score, serum PSA level, Gleason biopsy grade, and D'Amico risk classification are listed in Table 1. There were no significant differences in these preoperative parameters. Intraoperative and perioperative outcomes are shown in Table 2. The average docking time (5.12 ± 3.19 min vs. 7.59 ± 5.97 min, p = 0.002) and console time (208.2 ± 48.2 min vs. 285.7 ± 65.2 min, p = 0.004) were significantly shorter in the Xi group, while there was no significant difference in the rate of pelvic lymph node dissection between the two groups (45% in the Xi group vs. 43% in the Si group, p = 0.718). Estimated blood loss was 193.5 ± 133.2 mL in the Xi group and 259.9 ± 173.8 mL in the Si group (p = 0.018). The median lengths of stay and catheterization were both shorter in the Xi group than in the Si group, although the difference did not reach statistical significance (7 days vs. 8 days, p = 0.731; and 8 days vs. 9 days, p = 0.517, respectively). As demonstrated in Table 3, tumor aggressiveness was similar between both groups based on the Gleason grade and pathological stage. The ratio of positive surgical margins was significantly higher in the Xi group than in the Si group (61% vs. 45%, p = 0.034). The major complication rate was not significantly different between the two groups (13% vs. 12%, p = 0.871). After excluding all patients with positive pelvic lymph node metastasis who were treated with androgen-deprivation therapy and radiotherapy soon after surgery and a patient who died on postoperative day 1 due to cardiac arrest, the 90-day PSA undetectable rate was also comparable between the Xi and Si groups (88.8% vs. 87.7%, p = 0.830).

Table 1
Demopraphic and preoperative features

		Da Vinci Si	**Da Vinci Xi**	
Number		96	77	*p*
Median age (years) (IQR)		66 (63–70)	67 (62–70)	0.75
Median BMI (IQR)		24.9 (22.9–27.7)	24.2 (22.9–26.6)	0.52
Median Charlson Comorbidity Index (IQR)		2 (2–3)	2 (2–3)	0.13
Median PSA (ng/mL) (IQR)		10.2 (6.9–19.7)	9.44 (6.55–14.65)	0.58
Gleason Grade (%)	1	32 (33)	27 (35)	0.13
	2	34 (35)	16 (21)	
	3	17 (18)	18 (23)	
	4 and 5	13 (14)	16 (21)	
D'Amico Risk Classification (%)	Low	15 (16)	17 (22)	0.42
	Intermediate	51 (53)	34 (44)	
	High	30 (31)	26 (34)	

Table 2
Intraoperative and perioperative outcomes

	Da Vinci Si	**Da Vinci Xi**	
Number	96	77	*p*
Docking time (min) (SD)	7.95 (5.97)	5.12 (3.19)	**0.002**
Console time (min) (SD)	285.7 (65.2)	208.2 (48.2)	**0.004**
Estimated blood loss (mL) (SD)	259.9 (173.8)	193.5 (133.2)	**0.018**
PLND (n) (%)	41 (43)	35 (45)	0.718
Median hospitalization days (day) (IQR)	8 (6–9)	7 (6–8)	0.731
Median catheterization days (day) (IQR)	9 (8–10)	8 (7–9)	0.517
Bold values are p values < 0.05			

Table 3
Postoperative outcomes

		Da Vinci Si	Da Vinci Xi	
Number		96	77	*p*
Specimen weight (g) (SD)		39.2 (15.5)	39 (19.4)	0.226
Gleason Grade (%)	1	32 (33)	27 (35)	0.572
	2	34 (35)	16 (21)	
	3	17 (18)	18 (23)	
	4 and 5	13 (14)	16 (21)	
Pathological T Stage (%)	T2	69 (72)	45 (58)	**0.064**
	T3	27 (28)	32 (42)	
	T3a	14 (15)	17 (22)	
	T3b	13 (14)	15 (19)	
pN1 (n) (%)		7 (7)	3 (4)	0.569
Positive surgical margin (n) (%)		43 (45)	47 (61)	0.034
Major complications (Clavien-Dindo Grade > 3) (n) (%)		12 (13)	9 (12)	0.871
90-day PSA undetectable for localized disease (n) (%)		79/89 (88.8)	64/73 (87.7)	0.830
Bold values are p values < 0.05				

The docking time of the 76 consecutive RARPs performed with the da Vinci Xi system are plotted in Fig. 1. The CUSUM chart revealed a pyramid-shaped learning curve with an inflection point at case 27 (Fig. 2). The mean docking times before and after completing the learning curve were 7.70 ± 3.55 and 3.72 ± 1.85 min ($p < 0.001$), respectively. The mean docking time of the da Vinci Si system was 7.95 ± 5.97 min, which was not significantly different from the da Vinci Xi system before completing the learning curve ($p = 0.991$) (Table 4).

Table 4
Docking times

Cases	Docking time (min) (SD)	*p*
Si (n = 96)	7.95 (5.97)	< 0.001
Xi (1–27)	7.70 (3.55)*	
Xi (28–76)	3.72 (1.85)*	
*: *p* < 0.001 versus group Xi (28–76)		

Discussion/conclusion

Previous studies have compared the da Vinci Xi and Si models and reported improvements in perioperative outcomes with the newer system in the majority of the cases, including gastric bypass (8), colorectal cancer surgery (9), adrenalectomy (10), partial nephrectomy (11), and nephroureterectomy (12). Interestingly, two studies reported that its application in radical prostatectomy is not ideal due to a longer operative time, which may in turn be due to reduced vision with the smaller 8-mm caliber camera (13, 14).

The longer instruments and increased maneuverability of the arms of the da Vinci Xi can facilitate surgery in a narrow pelvic space. This advantage has been shown in rectal cancer surgery with a shorter operative time and higher full robotic resection rates (15), and this should also be true in RARP, in which vesicourethral anastomosis necessitates meticulous manipulations. In contrast to the previous studies, we demonstrated that performing RARP with the da Vinci Xi had a shorter operative time and less estimated blood loss compared to the da Vinci Si. To the best of our knowledge, the present study contains the largest number of patients to compare the da Vinci Xi and Si models for RARP. The large sample size may better reflect the benefits of the new model, which we believe outweigh the drawbacks of the less clear camera and can lead to better intraoperative outcomes of patients undergoing RARP.

Critiques on robotic surgery generally involve the prolonged operative time, which is influenced by both the docking time and procedural time (7). Robot docking requires extra steps compared to conventional laparoscopy, and upgrades to improve the docking process have been implemented in newer robotic platforms. With the da Vinci Xi system, the docking time has been shown to be significantly shorter than that with the da Vinci Si system in various types of surgery, however no previous study has compared the da Vinci Xi and da Vinci Si systems in patients undergoing RARP (8-10, 15).

The docking technique also contributed to the reduced docking time observed in the present study. Side docking in RARP with the da Vinci S and Si systems has been shown to be quicker and to have additional benefits over central docking (4, 16). We found that the docking time is not lengthened by transition from central docking with the da Vinci Si to side docking with the da Vinci Xi, and it could be shortened further after gaining experience from the initial 27 cases. This result is similar to the 19 cases required to achieve proficiency in da Vinci Xi docking reported by van der Schans *et al.* (7).

Surgical outcomes regarding major complication rate and 90-day PSA undetectable rate were comparable between the Xi and Si groups in this study, however the Xi group had a higher positive margin rate. This could have been due to a combination of a relatively higher T3 rate and rigorous intrafascial dissection strategy for nerve-sparing. The major complications in our study are consistent with those previously reported, including inguinal hernia, incisional hernia, bladder neck contracture, urethral stricture, rectal injury, and medical complications, with one case of mortality due to a cardiac arrest (17-19).

There are several limitations to this study. Its retrospective, single-center nature may have led to selection bias. In addition, the long-term oncological and functional outcomes, which may reflect the impact of the new robotic platform, were not provided due to the short follow-up period. A large, multi-center, prospective randomized controlled trial evaluating the long-term benefits of performing RARP with the da Vinci Xi is required. The “gain-of-proficiency effect” may also be a confounder for operative time. However, we believe that the learning curve for RARP with the da Vinci Si had been completed, as over 100 operations had been performed prior to the series of patients included in the Si group. This effect is also not sufficient to explain an average reduction in console time of 80 minutes. On evaluating the learning curve of robotic docking, an institutional learning curve was obtained instead of an individual one, as the composition of the operating room crew was not completely fixed.

In conclusion, the improved mechanical designs of da Vinci Xi system indeed provide intraoperative advantages over the da Vinci Si system especially in the aspect of surgical time. However, the complication rate and postoperative outcomes did not significantly benefit from the advanced technology. Further studies are needed to validate the effectiveness of the da Vinci Xi system regarding the long-term oncological and functional “trifecta” of RARP.

Declarations

Ethics approval and consent to participate

This study is performed in accordance with the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Review Board of Mackay Memorial Hospital, approval number 22MMHIS054e. The requirement of informed consent was also waived by the same committee of Institutional Review Board of Mackay Memorial Hospital.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors have no conflicts of interest to declare.

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Author Contributions

YCH collected and analyzed the data and wrote the manuscript. MC, WRL, and AWC performed all operations included. LCC supervised the study and revised the manuscript.

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Not applicable

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Figures

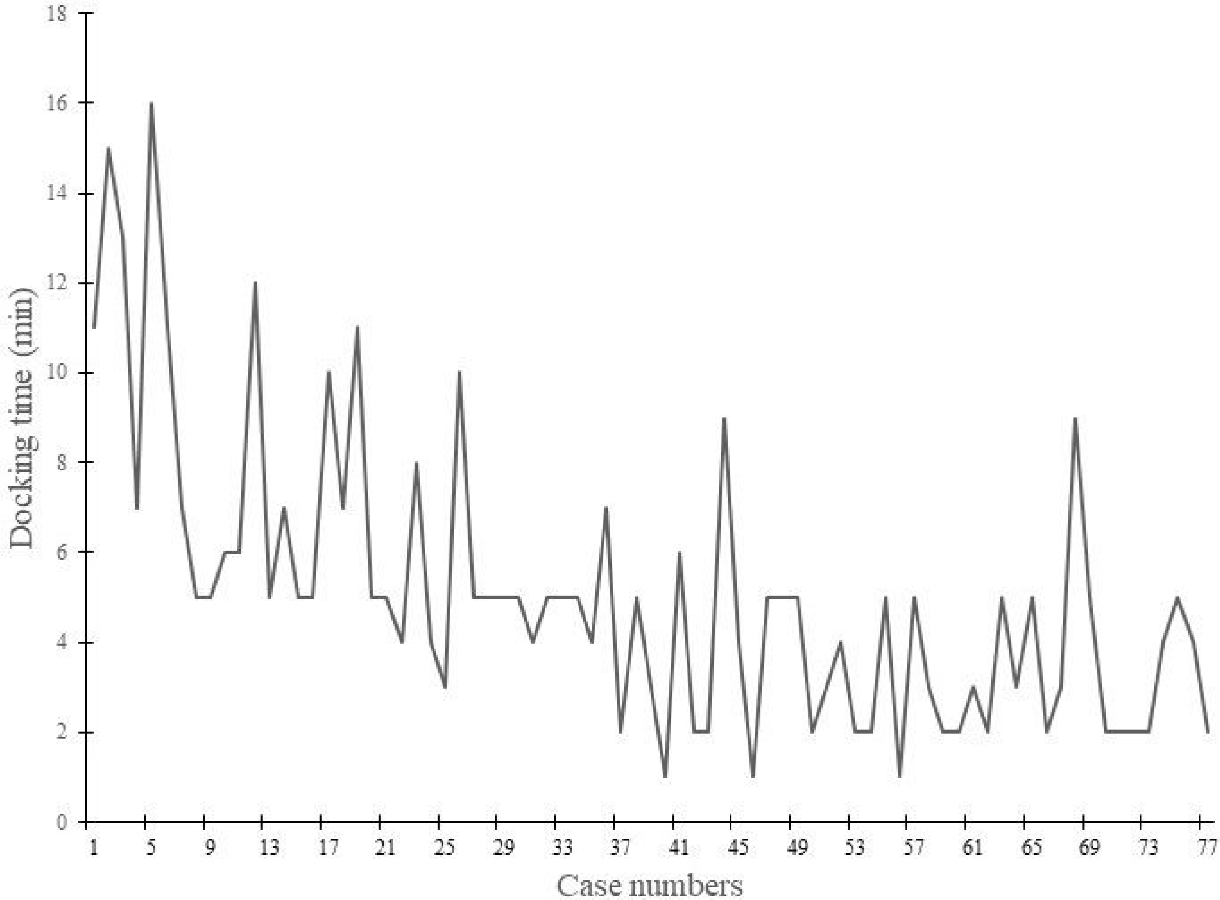

Figure 1

The docking times versus consecutive case number.

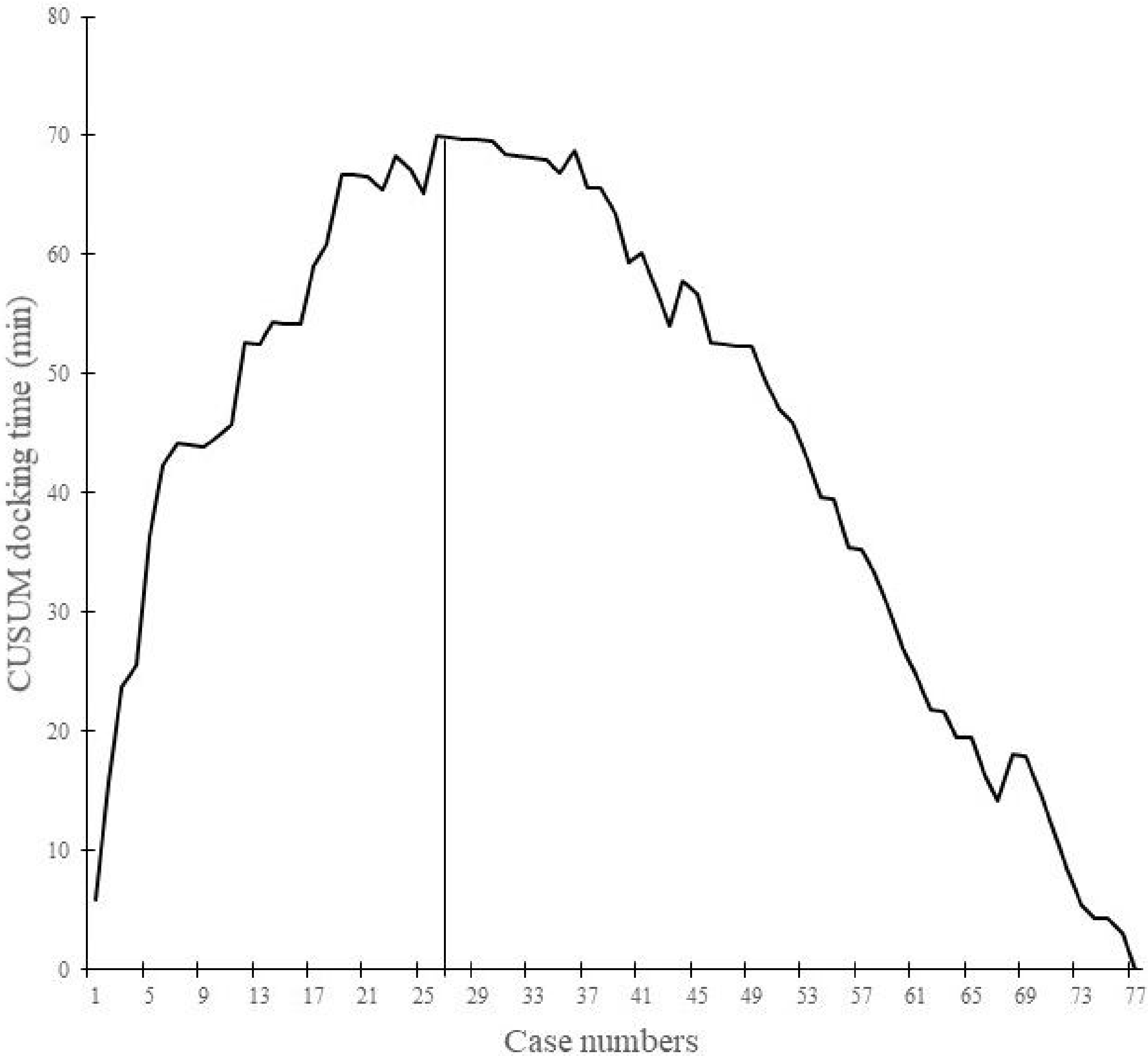

Figure 2

The CUSUM chart versus consecutive case number. The vertical dashed lines indicate the inflection point of the CUSUM curves.