

Robotic surgery for colorectal disease: review of current port placement and future perspectives

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Purpose: As robotic surgery is increasingly performed in patients with colorectal diseases, understanding proper port placement for robotic colorectal surgery is necessary. This review summarizes current port placement during robotic surgery for colorectal diseases and provides future perspective on port placements.

Methods: PubMed were searched from January 2009 to December 2018 using a combination of the search terms “robotic” [MeSH], “colon” [MeSH], “rectum” [MeSH], “colorectal” [MeSH], and “colorectal surgery” [MeSH]. Studies related to port placement were identified and included in the current study if they used the da Vinci S, Si, or Xi robotic system and if they described port placement.

Results: This review included 77 studies including a total of 3,145 operations. Fifty studies described port placement for left-sided and mesorectal excision; 17, 3, and 7 studies assessed port placement for right-sided colectomy, rectopexy, transanal surgery, respectively; and one study assessed surgery with reduced port placement. Recent literatures show that the single-docking technique included mobilization of the second and third robotic arms for the different parts without movement of patient cart and similar to previous dual or triple-docking technique. Besides, use of the da Vinci Xi system allowed a more simplified port configuration.

Conclusion: Robot-assisted colorectal surgery can be efficiently achieved with successful port placement without movement of patient cart dependent on the type of surgery and the robotic system.

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Key Words: Colon, Rectum, Robotics, Robotic surgical procedure, Surgery

INTRODUCTION

Robotic colorectal surgery was first performed in 2002, with studies describing robot-assisted laparoscopic colorectal surgery using the AESOP system (Computer Motion Inc., Goleta, CA, USA) for camera control and 2 patients who underwent da Vinci robot-assisted colonic mobilization [1,2]. Types of colorectal surgery performed robotically have included colectomy, total mesorectal excision (TME), perineal resection, total colectomy and rectopexy, with robotic colorectal surgery performed in patients with various disease, both benign and

malignant [3-5]. Although several types of robotic systems were utilized previously, including the robotic Puma 560, PROBOT, ROBODOC, AESOP, DaVinci Robot, and Zeus systems [6], the da Vinci surgical system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) currently predominate.

Compared with laparoscopic instruments, the da Vinci surgical system provides 3-dimensional imaging, excellent ergonomics, and tremor or motion scaling [7]. Robotic arms have enabled solo laparoscopic surgery, eliminating the need for an assistant, providing greater stability of views and reducing surgeon fatigue [8]. However, it is not presently confirmative

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whether these theoretical benefits of robotic colorectal surgery translate into favorable patient outcomes. Registered randomized clinical trials, including the international robotic versus laparoscopic resection for rectal cancer trial (NCT01196000) and the South Korean trial to assess robot-assisted surgery and laparoscopy-assisted surgery in patients with middle or lower rectal cancer (NCT01423214), are currently comparing laparoscopic and robotic surgery in patients with rectal cancer. Early results of the international robotic versus laparoscopic resection for rectal cancer trial (NCT01196000) have reported a lower conversion rate to open surgery for robotic than for laparoscopic surgery in male and obese patients [9].

Robotic surgery, however, has several drawbacks, including the lack of haptic sense, high cost, a bulky robotic cart, and collision between robotic arms [10]. Although the learning curve appears to be shorter for robotic than for laparoscopic colorectal surgery [10,11], understanding proper port placement for robotic colorectal surgery is necessary. Although the manufacturer of the da Vinci system recommends different pattern of port placements for right abdominal, left abdominal and pelvic surgery, they need to be modified according to diverse surgical approaches.

This systematic review evaluated and analyzed current patterns of port placement for robotic surgery in patients with colorectal diseases, as well as providing future perspectives on port placement.

METHODS

PubMed were searched from January 2009 to December 2018 using a combination of the search terms "robotic" [MeSH], "colon" [MeSH], "rectum" [MeSH], "colorectal" [MeSH], and "colorectal surgery" [MeSH]. Relevant studies were identified, and their reference lists were searched manually for additional relevant publications. Case series, retrospective and prospective studies, and randomized controlled trials with appropriate

data were included if they used the da Vinci S, Si, or Xi robotic system and if they described port placement. Case reports, video vignettes, letters, editorials, review articles, articles describing robotic technologies, animal experiments, studies describing education about or simulation of robotic methods, studies with inappropriate data, non-English literatures, and studies that did not appropriately explain exactly about port placement were excluded (Fig. 1). Publications using the New Senhance Telerobotic and Soloassist systems were also excluded.

Data from the same type of operation performed during the same period at the same institution were considered duplicates, whether or not the corresponding authors were the same. If studies were identified as duplicates, only the study with the largest group of patients, the most parameters reported, or the most recent data was included.

Data collected from all included studies consisted of year of publication, first author, journal, robotic platform, operation type, number of ports, number of docks, docking time, total operation time, and number and rate of conversion. Variables were analyzed separately according to type of operation, including right-sided colectomy, left-sided colectomy, mesorectal excision, rectopexy, transanal approach, and surgery using a single-site platform.

RESULTS

Literature search

The literature search initially yielded 785 titles, with 560 remaining when only those dealing with actual robotic colorectal surgery were included. After excluding the reviews and meta-analyses ($n = 109$), editorials and letters ($n = 77$), video vignettes ($n = 56$), non-English language articles ($n = 38$), training programs ($n = 37$), case reports ($n = 27$), and studies using robotic systems other than the da Vinci system ($n = 8$), 208 studies were included. Of these, 131 studies were excluded, 108 articles that did not describe port placement and 23

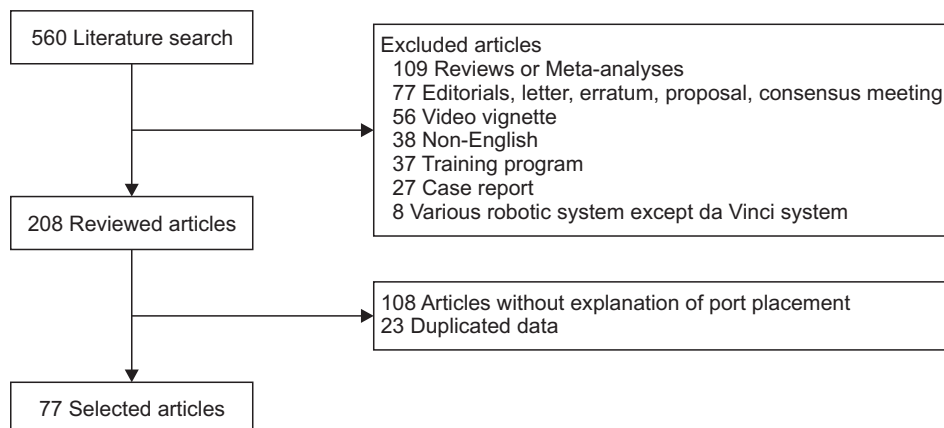


Fig. 1. A diagram of literature search and selection.

Table 1. Studies describing robotic total mesorectal excision

Year	Study	Platform	No. of patients	No. of 12-mm port	No. of 8-mm (5-mm) port	Port	SF mobil	Extraction site	Intracorporeal	Operation time (min) ^{a)}	Conversion, n (%)
2009	Ng [31]	S	8	3	2	H	Lap/Robot	LLQ	No	192.5 (145–250)	0 (0)
2010	Prasad [32]	S	3	1	4 (hand)	H	Lap	Suprapubic	Yes	339.6	0 (0)
2010	Zimmer [33]	S	58	1	3 (2)	H	Lap	Transanal	Yes	308.8–324.4	2 (3.4)
2011	Patel [34]	Si	48	2	3	H	Lap	Pfannelstiel	Yes	247 ± 91.4	-
2011	Deutsch [35]	S	61	2	3	D	Robot	Umbilical Port	No	219.2 ± 39.2	2 (3.3)
2011	Park [36]	S	52	1	3 (1 or 2)	H	Lap	Periumbilical/NOTES	No	232.6 ± 52.4	0 (0)
2011	Ragupathi [37]	S	24	2	3	H	Lap	Pfannenstiel	No	224.2 ± 47.1	0 (0)
2011	Koh [38]	Si	21	1	4 (1)	D	Robot	LLQ/suprapubic	No	316.1 ± 57.4	0 (0)
2012	Kim [39]	Si	30	2	3 (1)	D	-	-	No	-	-
2012	Shin [40]	Si	17	1	4	D	Robot/Lap	RLQ/suprapubic	No	371.8 ± 87.5	0 (0)
2012	Park [41]	S	8	1	3 (2)	H	Lap	periumbilical/NOTES	No	273 (170–350)	0 (0)
2013	Zawadzki [42]	Si	77	1	3 (2)	H	Lap	Pfannelstiel	No	327 (178–510)	-
2013	Kenawadekar [43]	S	53	3	3	D	Robot	LLQ	No	180 (150–230)	0 (0)
2014	Parisi [44]	Si	40	2	3 (1)	H	Lap	LLQ/ -stomy	No	340 (235–460)	0 (0)
2014	Kim [45]	S	167	1	5	H	Lap	Abdominal wall	Yes or No	197.7–252.0	2 (1.2)
2014	Liang [46]	S	26	2	3	S	Robot	LLQ	No	307.3 ± 74.1	-
2014	Kuo [47]	S	64	2	3	S	Robot	Transanal	No	485.8 (315–720)	0 (0)
2015	Sawada [48]	S	10	3	3	D	Robot	Umbilical port	-	417 (295–629)	0 (0)
2015	Gorgun [49]	S	50	3	3	D	Robot	Suprapubic	-	267 (82–720)	5 (9)
2015	Bae [50]	Si	11	2	4	S	Robot	LLQ	-	327 (226–490)	0 (0)
2015	Huang [51]	Si	38	2	3 (1)	D/S/H	Robot	Camera port	No	492.0 ± 118.69	0 (0)
2015	Pai [52]	S	101	1	3 (1)	D/H	Lap	Pfannenstiel	No	345 ± 78	4 (4)
2016	Eftaiha [53]	S	22	1	3 (1)	S	-	Perineal	No	380 ± 91	2 (9.1)
2016	Kim [54]	S	33	1	5	S	Robot	Ileostomy site	-	441.0 ± 90.2	2 (6.1)
2016	Zaghoul [55]	S	10	2	3	S	-	Pfannelstiel	No	333 (215–480)	1 (10)
2016	Rencuzogullari [56]	Si	21	1	4 (1)	S	-	Ileostomy site	-	304 ± 109	2 (9.5)
2016	Luca [57]	Si	23	2	3	S	Robot	Transanal	-	296.01 (228–420)	0 (0)
2016	Gorgun [58]	S	29	1	4 (1)	D	Lap/Robot	RLQ incision	No	329.0 ± 102.2	1 (3.4)
2016	Ruiz [59]	Si	198	2	4	D/S/H	Lap/Robot	-	No	292 (272–312)	9 (4.5)
2016	Kim [60]	S	60	1	4 (1)	D	Robot	LLQ/suprapubic	No	446.8 ± 115.6	0 (0)
2016	Ahmed [61]	Si	124	2	3 (1)	S	Robot	Midline/suprapubic	No	240 (130–456)	0 (0)
2017	Ngu [13]	Xi	47	1	4	M	Robot	Midline/pfannenstiel	No	265 (130–710)	0 (0)
2017	Huang [62]	Si	40	2	4	S	Robot	Transanal	Yes	274.4 ± 70.9	-
2017	Oldani [63]	Xi	15	0	4 (1)	M	Robot	-	-	-	-
2017	Pesi [64]	Si	31	2	3	S	Robot	RLQ incision	No	338 (180–625)	1 (3)
2017	Huang [65]	Si	95	2	3 or 4	S	Robot	Camera port	No	492.0 ± 118.69	0 (0)
2017	Kuo [66]	Si	108	2	3	H	Lap	Transanal	No	438.2 ± 98.6	-

Table 1. Continued

Year	Study	Platform	No. of patients	No. of 12-mm port	No. of 8-mm (5-mm) port	Port	SF mobil	Extraction site	Intracorporeal	Operation time (min) ^{a)}	Conversion, n (%)
2018	Panteleimonitis [67]	Xi	33	2	3	M	Robot	RLQ	No	331 (249–372)	0 (0)
2018	Nolan [68]	Si/Xi	16	2	3	S	-	Pfannestiel/midline	No	231.5 (180–301)	-
2018	Aselmann [69]	Si	44	2	4	S	Robot	-	Yes or No	280 ± 76	3 (6.8)
2018	Debakey [70]	Si	21	1	4	S	Robot	Pfannestiel/small incision/transanal	Yes or No	201 (140–280)	1 (4.8)
2018	Cassini [71]	S	61	2	2	H	Lap	Suprapubic	No	172.5 ± 55.64	0 (0)
2018	Ishihara [72]	Si	130	2	4	D	Robot	-	-	388 (294–520)	0 (0)

SF mobil, splenic flexure mobilization; Intracorporeal, intracorporeal anastomosis; H, hybrid; D, double; S, single; M, manufacturer; Lap, laparoscopic; Robot, robotic; Umbilical, periumbilical incision including umbilical port extension; LLQ, left lower quadrant; NOTES, natural orifice transluminal endoscopic surgery; RLQ, right lower quadrant.

^{a)}Mean ± standard deviation or median (range).

duplicate data. Thus, 77 studies were systematically reviewed (Fig. 1).

Characteristics

The number of publications that include robotic colorectal surgery has been constantly increasing over time, from 16 titles in 2009 to 183 titles in 2018 among the total of 785 titles. The 77 included studies described a total of 3,145 operations. Forty-three studies included 2,425 patients who underwent mesorectal excision, including anterior, low anterior, intersphincteric, and abdominoperineal resection, and Hartmann's procedure. Sixteen studies included 468 patients who underwent right-sided colectomy, 6 studies described 155 patients who underwent left-sided colectomy, 4 studies included 90 patients who underwent mesh ventral rectopexy, 7 studies described 113 patients who underwent transanal surgery, 2 studies included 19 patients who underwent total colectomy or total proctocolectomy, 1 study included patients who underwent transverse colectomy, and 1 study described patients who underwent surgery using a single-site platform. The robotic platforms included the da Vinci S or Si system for 2,920 operations and the da Vinci Xi system for 225 operations.

Port placement for TME and left-sided colectomy

Although the da Vinci system has been used for colorectal surgery, more than 70% of these operations were robotic TME. Although no technique has become standardized for left colon dissection and low anterior resection, several procedures have been described for the da Vinci S and Si systems (Table 1). The hybrid approach, in which various types of ports are placed using laparoscopic approach, consisted of laparoscopic mobilization of the splenic flexure and left colon, followed by robotic docking for dissection of the pelvis and completion of the procedure (Fig. 2A). The double- or triple-docking technique included docking from the left upper or left hemi-abdomen for dissection of the splenic flexure, followed by docking to the left lower abdomen and placing an extra-port on the right side (Fig. 2B). The single-docking technique included mobilization of the second and third robotic arms for the different parts without movement of patient cart (Fig. 2C) [12].

Use of the da Vinci Xi system allowed a more simplified port configuration, with most studies using the configuration recommended by the manufacturer with minor variations (Fig. 2D). Basically, the left-sided colectomy incorporated mobilization of the splenic flexure. Four studies using the da Vinci S or Si system described the double docking or hybrid technique as port placement, and 2 studies involving the da Vinci Xi system used the procedure described by the manufacturer, along with instruction and universal port placement (Table 2).

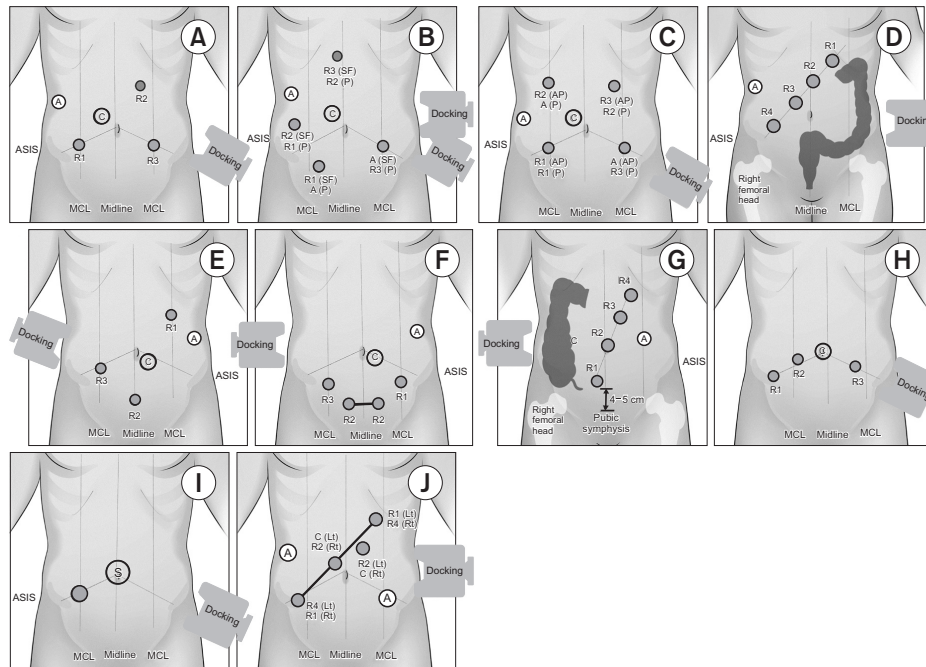


Fig. 2. Port placement for robotic total mesorectal excision (A–D) or left-sided colectomy (A, B) using the da Vinci S, Si, or Xi system. (A) Port placement for hybrid technique including laparoscopic splenic flexure or left colon mobilization. (B) Double docking port placement with movement of the patient cart according to the dissection area. (C) Single-docking port placement including the rotation of robotic arms without movement of patient cart. (D) Port placement recommended by the manufacturer using the da Vinci Xi system. Port placement for robotic right-sided colectomy (E–G) and ventral mesh rectopexy (H). (E) Reversed-L-shaped port placement with minor variation using the da Vinci S or Si system. (F) Suprapubic port placement with wound extension between the 2 suprapubic ports for the extraction of the specimen. (G) Port placement that was recommended by the manufacturer using the da Vinci Xi system. (H) Port placement with minor variations for robotic ventral mesh rectopexy that was focused on the pelvic dissection. Extraordinary port placement. (I) Reduced port placement for anterior resection using single-site platform with an additional port. (J) Universal port placement for all 4-quadrant colorectal surgery. R1, arm 1 for monopolar scissors or cautery hook; R2, arm 2 for Maryland or Fenestrated bipolar forceps; R3, arm 3 for tip-up fenestrated grasper or Cadierre forceps; A, assistant port; C, camera port; ASIS, anterior superior iliac supine; MCL, mid-clavicular line; SF, dissection for splenic flexure; P, dissection for pelvis; Docking, placement of the patient cart; S, single-site platform.

Port placement for right-sided colectomy

Port placement of the da Vinci S or Si system for right-sided colectomy usually consisted of the reversed-“L”-shaped procedure, except 4 studies that used left lateral or vertically-straight port placement (Table 3, Fig. 2E). The da Vinci Xi system used the procedure described by the suprapubic port placement and manufacturer’s recommendation (Fig. 2F, G). All right-sided colectomies were performed using the single-docking technique.

Port placement for mesh ventral rectopexy

Complete rectal prolapse was treated by mesh ventral rectopexy using the da Vinci S or Si system. All 4 studies reported transverse port placement with the single-docking technique (Table 4, Fig. 2H).

Port placement for transanal approach and reduced port placement

The transanal approach using a robotic system included

robotic transanal minimally invasive surgery (TAMIS) and transanal total mesorectal excision (TATME). Four studies reported robotic TAMIS, and 3 reported robotic TATME. Robotic TAMIS was usually performed using 3 robotic arms due to limitations of the transanal space, whereas, robotic TATME used all 4 robotic arms due to abdominal phase (Table 5). One study described port placement for reduced port anterior resection using the robotic single-site platform with an additional 12-mm port (Fig. 2I).

DISCUSSION

Robotic surgery is a major advance in colorectal surgery and is increasingly utilized for colorectal resection, irrespective of tumor locations [3]. However, beginning colorectal surgeons hesitate to perform robotic surgery because of its various drawbacks including the need for proper port placement, the absence of tactile sensations, and high cost. This review summarizes current pattern of port placement for colorectal surgery and

Table 2. Studies describing robotic left-sided colectomy

Year	Author	Platform	No. of patients	No. of 12-mm port	No. of 8-mm (5-mm) port	Docking time (min) ^{a)}	Port	SF mobil	Extraction	Intracorporeal	Operation time (min) ^{a)}	Conversion, n (%)
2009	Luca [73]	S	27	1	3 (1)	-	D	Robot	LLQ	No	290 ± 69	0 (0)
2012	Shin [40]	Si	7	1	4	8.3 ± 2.1	D	Robot	RLQ/pubic	No	337.1 ± 137.5	0 (0)
2014	Bae [74]	S	61	2	4	4 (3-8), 3 (3-9)	D	Robot	LLQ	No	227 (137-653)	0 (0)
2014	Maciel [75]	Si	20	1	3 (1)	-	H	Robot or Lap	Pubic	Yes	207.67	0 (0)
2017	Oldani [63]	Xi	20	0	4 (1)	-	M	Robot	-	-	-	0 (0)
2017	Kim [76]	Xi	20	2	4	-	U	Robot	Umbilicus	No	170 ± 29	0 (0)

SF mobil, splenic flexure mobilization; Intracorporeal, intracorporeal anastomosis; H, hybrid; D, double; M, manufacturer; U, universal; Lap, laparoscopic; Robot, robotic; LLQ, left lower quadrant; RLQ, right lower quadrant; Pubic, suprapubic area.

^{a)}Mean ± standard deviation or median (range).

provides information to easily overcome problems related to port placement during various types of robotic colorectal surgery.

Earlier published studies described the collision-related difficulties encountered during docking and port placement, especially when surgeons attempted to operate across other abdominal quadrants [13]. Reflecting the learning curve inherent to the adoption of robotic colorectal surgery, the use of standardized techniques and increased experience have resulted a shortening of port placement and docking time [11,14-16]. The present review described the simplified port placement associated with the da Vinci system and type of operative, findings that may be helpful for those learning robotic colorectal surgery. Improvements in the da Vinci system require robotic surgeons to review previous as well as recent studies.

Port placement for earlier da Vinci models, including the 3 arm-based S to Si system, generally involved scattered sites across the abdomen [17]. The Xi model, however, allows a more simplified port configuration and a reduced learning curve, resulting in shorter docking times [13]. Studies about TME or left-sided colectomy that were published during the early 2010s, reported more frequent use of hybrid techniques and increases in the number of ports. The hybrid approach and double docking technique allowed to overcome the limited range of motion of the robotic arm during splenic mobilization and pelvic dissection, however, those techniques had longer operation time, compared with the single-docking technique [18,19]. The single-docking technique provides advantages in omitting the movement of the patient cart, resulting in shorter operative time, whereas, that technique might need to overcome the learning curve and to understand the port configuration and the proper distance between the ports [18]. Although the da Vinci S and Si systems are being replaced by the da Vinci Xi system, studies describing port placement have decreased over time, making port placement slightly problematic when using the Xi platform. Although the console experience and operative technique of the Xi system similar to those of the S and Si systems, the extra features of the Xi system, including collision avoidance mechanisms, automatic targeting, motion-censored table, and boom features, appear to reduce the stress associated with port placement [13,20].

The reversed-"L"-shaped port placement for robotic right colectomy was used in almost all studies using the S or Si system, except that 22 studies published in 2010 involved diamond-shaped or vertically-straight port placement using the 3 arm-based S system and 2 studies with left lateral port placement. The reversed-"L"-shaped port placement for the S or Si system results in wider coverage of the right upper quadrant than diamond-shaped or left lateral port placement. A recent study described use of a suprapubic approach, with extension of the incision between the ports and the extra features of the

Table 3. Studies describing robotic right colectomy

Year	Author	Platform	No. of patients	No. of 12-mm port	No. of 8-mm (5-mm) port	Docking time (min) ^{a)}	Port placement	Extraction	Intra-corporeal	Operation time (min) ^{a)}	Conversion, n (%)
2010	Zimmern [33]	S	42	1	2 (1)	-	Reversed "L" Vertically-straight	Umbilicus Port	No	158.9	1 (2.4)
2010	deSouza [77]	S	40	1	2 (1)	-			No	158.93 ± 36.69	1
2010	D'Annibale [78]	S	50	1	3 (1)	8 (7-8)	Reversed "L"	Pfannen	No	223.5 (180-270)	0 (0)
2011	Huettnner [79]	Si	59	2	3	32.4 ± 10.5	Reversed "L"	RLQ	Yes	212.3 ± 46.4	-
2011	Deutsch [35]	S	18	1	3	-	Reversed "L"	Umbilicus	No	289.7 ± 61.8	2 (11.1)
2011	Luca [80]	S	33	2	2	-	Reversed "L"	RUQ	No	191.7 (134-250)	-
2012	Shin [40]	Si	6	1	4	11.9 ± 4.4	Reversed "L"	Pubic	No	342.5 ± 106.5	0 (0)
2012	Park [81]	S	35	1	4	6.7 ± 1.1	Reversed "L"		30	191 ± 41	0 (0)
2013	Lujan [82]	Si	22	2	2	-	Reversed "L"	RLQ	Yes	258.3 ± 40.9	0 (0)
2013	Trastulli [23]	Si	20	2	3	-	Reversed "L"	RLQ	Yes	327.5 (255-485)	0 (0)
2014	Zawadzki [83]	S	14	2	2	-	Left lateral	Midline	No	168 ± 49	0 (0)
2017	Oldani [63]	Xi	15	0	4 (1)	-	Vertically-straight				1
2018	Nolan [68]	Si/Xi	10	2	2	-	Left lateral			130.5 (98-194)	-
2018	Reitz [22]	Si	49	2	2	-	Left lateral	Port	29 Cases	143.5 ± 24.5 (139.8 ± 28.0)	4
2018	Lee [21]	Xi	5	0	4 (1)	-	Suprapubic	Pfannen	Yes	183 ± 29.37	0 (0)
2018	Mégevand [84]	Si	50	2	3	-	Reversed "L"	Pubic	49 Cases	204 (180-230)	0 (0)

Intra-corporeal, intra-corporeal anastomosis; Pfannen, Pfannenstiell incision; RLQ, right lower quadrant; RUQ, right upper quadrant; Pubic, suprapubic incision.

^{a)}Mean ± standard deviation or median (range).

Table 4. Studies of robotic mesh ventral rectopexy

Year	Author	Platform	No. of patients	No. of 12-mm port	No. of 8-mm (5-mm) port	No. of docking	Docking time (min) ^{a)}	Port	Operation time (min) ^{a)}	Conversion, n (%)
2013	Buchs [85]	Si	5	1	2 (1)	1	-	Transverse	170 (120–270)	0 (0)
2013	Mantoo [86]	S	44	2	3	1	17 (9–28)	Transverse	191 ± 26	1 (2)
2014	Mehmood [87]	Si	17	2	3	1	-	Transverse	137.5 (110–242.4)	-
2017	Inaba [88]	Si	24	2	3 (1)	1	-	Transverse	191 (164.3–242.5)	0 (0)

^{a)}Mean ± standard deviation or median (range).

Table 5. Studies of robotic transanal surgery

Year	Author	Platform	No. of patients	Operation type	No. of 12-mm port	No. of 8-mm (5-mm) port	No. of docking	Docking time (min) ^{a)}	Operation time (min) ^{a)}	Conversion, n (%)
2014	Hompes [89]	Si	16	TAMIS	1	2 (1)	-	36 (18–75)	108 (40–180)	0 (0)
2014	Atallah [26]	Si	3	TATME	-	1 (1)	1	-	376	0 (0)
2015	Gómez Ruiz [28]	Si	5	TATME	2	3	2	-	398 ± 88	0 (0)
2017	Ngu [90]	Xi	6	TAMIS	0	3	-	-	106.5 (69–217)	0 (0)
2017	Kuo [29]	Si	15	TATME	SS	1 (1)	2	-	473 (335–569)	2 (13.3)
2018	Arnott [91]	Xi	10	TAMIS	0	3 (1)	1	-	167 ± 26	4
2018	Tomassi [92]	Si/Xi	58	TAMIS	0	3 (1)	1	-	66.2 (17.0–180.0)	0 (0)

TAMIS, transanal minimally invasive surgery; TATME, transanal total mesorectal excision.

^{a)}Mean ± standard deviation or median (range).

Xi system providing a more cosmetic effect, and the longer arm and boom system resulting in wider and more flexible coverage than previous platforms [21]. Many of the reviewed studies described intracorporeal anastomosis during robotic right colectomy, with a rate of adoption higher than that of robotic TME. Although this intracorporeal technique required a longer operation time, it maximized the outcomes of robotic right colectomy, including better cosmetic results and easier suturing, compared with a laparoscopic approach, resulting in a completely minimally invasive procedure [22-24].

Although the innovative transanal and transrectal techniques have been developed in recent years, the present review included only 7 studies describing port placement using these robotic methods. A pure TATME procedure for rectal cancer remains technically challenging, with almost 40% of patients requiring abdominal assistance [25]. Abdominal assistances also remained essential when robotic systems were utilized to overcome the limitations of the TATME [26-29]. The robotic abdominal approach requires appropriate port placement, whereas the optimal docking angle is required for the robotic transanal approach. One study suggested that the optimal docking angle for the robotic cart to avoid external collisions was an oblique approach from the left of the patient, at a 45° angle to the operating table [29]. The port configuration of the transanal area usually included 2 operative trocars at the base and a trocar for the 30° upward-looking endoscope at the apex [29], and the port placement sometimes changed 2 operative trocars in the apex according to the tumor location during TAMIS. The da Vinci SP model, which recently became available, may be more efficient in the transanal approach. Further experiences are needed to assess the outcomes of TATME using the SP model.

Apart from the ordinary robotic procedures, the reduced port placement with the intracorporeal anastomosis would allow it

to maximize the cosmetic effect even this study included only 1 study. This reduced port placement with a sing-site platform or the SP model may have the possibility of an advance. Port placement using the Xi system may be optimal for single-stage totally robotic dissection of the entire abdomen [30]. Universal port placement maximally utilized the advantages of the da Vinci Xi model, including the universal 8-mm da Vinci port that allowed insertion of the endoscope into any port, a rotatable boom that could cover all 4 quadrants of the abdomen, without any instrumental collisions (Fig. 2) [30]. Universal port placement may be required for proper placement of the assistant port and for determining the axis of the linear port line.

In conclusion, recent studies show that the operation time and conversion rate of single-docking technique in the da Vinci Si system are similar to previous dual or triple-docking technique and use of da Vinci Xi system allows a more simplified linear port configuration. Although port placement using the robotic system varies by operation type and surgeon preference, development of port placement would allow to reduce the number of port and movement of cart and to realize more minimally invasive surgery.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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