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ORIGINAL ARTICLE

Full robotic multivisceral resections: the Modena experience and literature review

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Abstract

The robotic platform is becoming a multidisciplinary tool, versatile, and suitable for multiple procedures. Combined multivisceral resections may represent an alternative to sequential procedures with a potential favorable impact on postoperative morbidity, and on the timing of administration of adjuvant chemotherapy. We herein present our initial experience with full robotic multivisceral resections, and a review of the literature available. Between January 2018 and April 2020, 11 patients underwent multivisceral full robotic abdominal surgery: 4 patients presented with two synchronous tumors, 4 with primary cancer associated with a benign condition and 3 cases involved deep infiltrating endometriosis. Surgical teams enrolled were: General Surgery, Urology and Gynecology. A systematic bibliographic research up to April 2020 was conducted in PubMed. 4 colorectal resections combined with partial or radical nephrectomy were performed, as well as 2 right colectomies in combination with right adrenalectomy and gastric banding removal, 2 radical prostatectomies with Nissen Fundoplication and abdominal wall hernia repair, and 3 resections of deep pelvic endometriosis with colorectal involvement. Mean total operative time was 367 min. No intraoperative complication or conversion to open was registered. Overall postoperative complication rate was 18.2%. 26 papers were included in the review (10 case series and 16 case reports) with a total of 156 combined multivisceral robotic procedures recorded. Robotic combined multivisceral resections proved to be safe and feasible when performed in high volume centers by expert surgeons. The heterogeneity of reports does not allow for a standardization of the procedure. Further studies and accumulation of experience are needed.

Keywords Robotic multivisceral resections · Synchronous colorectal and renal cancer · Deep infiltrating endometriosis · Combined robotic multiorgan procedures · Robotic multiquadrant surgery

Introduction

In the last two decades, robotic surgery saw a worldwide spreading among different specialties, while Urology started as the main beneficiary of the DaVinci technology, Gynecology, and General Surgery followed shortly, with General Surgery having an exponential growth in number of robotic procedures in the last 2 years and being at this time one of the main fields of expansion of the robotic technology [1]. Nowadays, the robotic system represents a real multidisciplinary platform that, with its continuous technological advancement, is becoming even more versatile and suitable for multiple procedures. This, combined with the advances in diagnostics and imaging technologies that allow to detect synchronous tumors more frequently, has brought to the emergence of several reports of full robotic combined procedures, performed in several cases by different surgical teams [2–4]. Combined minimally invasive surgery may represent an alternative to sequential procedures and allow to treat at the same time coexisting lesions with a potential favorable impact on postoperative morbidity [5], and on the timing of administration of adjuvant chemotherapy for oncological patients. Studies on synchronous robotic procedures remain limited to small series and case reports [6–9], but interest

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towards this new field of application of robotic surgery is growing along with the need of standardization, not only of the procedure, but also of the multidisciplinary approach required. Although robotics has shown the potential to shorten the learning curve for several procedures, the application of such an advanced technology needs high levels of expertise, with dedicated operative room (OR) personnel and a specific training for the surgeons [10]. In the recent times, a direct association between case volume and postoperative and oncological outcomes has been demonstrated [11] not only for conventional surgery, but also for robotics [12]. Besides, surgeon volume can also have an impact on cost effectiveness of robotic surgery; recent studies reported that as the surgeon advanced in the learning curve, costs of robotic-assisted colorectal resection decreased, due to an optimized use of instruments and OR time [13–15]. Optimization of resources is essential in the modern management of healthcare facilities, and a multidisciplinary use of the same platform fully applies to this logic. We herein present our initial experience with full robotic multivisceral resections, in an optic of collaboration between different specialties and operative Units inside the same Hospital for the well-being of the patient that is taken care in his entirety. In addition, a review of literature was carried out to better locate our study in the current scientific panorama.

Materials and methods

Between January 2018 and April 2020, a total of 11 patients underwent multivisceral full robotic abdominal surgery at our Institution. All patients were recorded in a prospectively maintained database. Multiple surgical teams were enrolled, including General Surgeons, Urologists, and Gynecologists. Inclusion criteria were patients aged more than 18 years undergoing full robotic synchronous abdominal procedures, both for malignant tumors and benign diseases. Exclusion criteria were: T4 neoplasms, hybrid procedures (laparoscopic/endoscopic and robotic), and only associated surgery being robotic cholecystectomy. Previous abdominal surgeries and obesity were not criteria of exclusion. All patients were accurately informed, and written consent was obtained. All patients were preoperatively discussed in multidisciplinary board meeting and underwent preoperative imaging and further specific examinations when necessary; in case of colorectal cancer a biopsy was achieved. A preoperative meeting, between the surgical team and the OR personnel involved, was always held to plan the sequence of the surgical steps and dockings, along with the setting of the operating room. Demographic data including age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score and indications to surgery were collected; perioperative and postoperative results, length of hospital stay, morbidity, and mortality, readmission rate, and other short-term outcomes were all reported. Postoperative complications were registered according to Clavien–Dindo classification [16].

Surgical technique

All procedures were performed with the DaVinci Si surgical System (Intuitive Surgical, Sunnyvale, CA) with a full robotic approach.

Pneumoperitoneum was always established with a Verres needle at Palmer's point at a pressure of 12 mmHg. The 12-mm camera port was always inserted first. A standard trocar placement according to the different procedures was adopted, with minor modifications related to the combined planned procedure.

- In case of right colectomy combined with right kidney procedures ($n=2$), the colonic resection was performed first, followed by urologic time. The patient was supine with parted legs in a 15° Trendelenburg position with a 15° left tilt, the robot was docked from the patient's right side. Trocars were placed as standard [17]. For kidney procedures, the robot was undocked, and the patient was placed in a 45° left flank position with his right arm adducted on the head. Pneumoperitoneum was reestablished and urologist adjusted the port placement, adding a 12 mm port for the camera on the pararectal right line, and three 8 mm robotic ports under the right costal margin, in right flank and medially from the right iliac spine, respectively. The Airseal port was inserted through the Alexis system® (Applied Medical, Rancho Santa Margarita, CA). The robot was then docked from the patient's right flank. In the first case, an intracorporeal latero-lateral ileocolic anastomosis was created after the partial nephrectomy by replacing the patient in a supine position with a new docking and ports repositioned as before; in the other case the colorectal procedure including restoration of bowel continuity was completed before urologic phase. Further technical details were described in a previously published paper by our group [17].
- In the case of right colectomy and right adrenalectomy ($n=1$), procedure started with the patient in left lateral decubitus and robotic trocars placed as standard robotic right adrenalectomy. The patient was then moved to a supine position, a new docking was completed, and right colon resection was performed as usual.
- For robotic anterior rectal resection (ARR) procedures combined with partial nephrectomy ($n=2$), rectal resection with partial mesorectal excision (PME) was performed before left kidney approach, while in case of right kidney enucleation the urologic phase was completed as the first step. During the colorectal procedure,

the patient was supine with parted legs, the robotic cart came from the patient's left side and docked from the left lower quadrant over the left hip. Robotic ports were positioned as follow: the 12-mm standard laparoscopic trocar for robotic camera (30°) at 2 cm lateral and 2–3 cm above the umbilicus. Three 8-mm robotic trocars were positioned on the right lower quadrant, in the right upper quadrant, in the left upper quadrant, respectively. The assistant 12-mm standard laparoscopic trocar was placed in right flank. During the TME step, the left upper port was moved to the left lower flank and the right upper one to the left hypochondrium, to achieve optimal access to the mesorectum. In both cases, the specimen was extracted trough a suprapubic incision with wall protector Alexis system® (Applied Medical, Rancho Santa Margarita, CA), and bowel continuity was restored through a trans-anal circularly-stapled end-to-end colorectal anastomosis (Covidien, EEA 28 mm, Mansfield, MA, USA). In these cases, a diverting ileostomy was not performed in consideration of tumor location (upper rectum) and of the fact that patients did not undergo neoadjuvant radiotherapy. Further technical details were described in a previously published paper by our group [17].

- For the patient undergoing Nissen Fundoplication combined with radical prostatectomy ($n=1$), the first docking was performed with the robotic cart at the patient's head and standard ports placement for robotic hiatal hernia repair was achieved. Then, the robotic cart was moved between the patient's legs and a new docking was achieved through the same ports.
- For the combined approaches requiring a single docking (right colectomy with removal of laparoscopic adjustable gastric banding (LAGB) and radical prostatectomy with ventral hernia repair, $n=2$), patient and trocars placement reflected the major procedure, and no further ports were added for the associated surgical phase.
- Finally, gynecologic procedures for deep endometriosis ($n=3$) required patients in a supine position with parted legs in a 25° Trendelenburg. The 12-mm camera port was inserted close to the upper umbilicus and other three 8-mm robotic ports were placed in the right and left flank and in left hypochondrium, respectively. The Airseal®(CONMED, Utica, NY) port was inserted in the right hypochondrium. A 0° camera was adopted. The same disposition was maintained in case of rectal resections and no further dockings were required.

Literature review

A systematic bibliographic research for the period between January 2005 and April 2020 was conducted in PubMed independently by two different Authors. The PRISMA method was applied. The search strategy included the following key words: "robotic synchronous surgery" [All Fields] OR "combined robotic surgery" [All Fields] OR "multivisceral surgery" [All Fields] OR "combined robotic liver and colon resection" [All Fields] OR "simultaneous robotic resection of colon and liver" [All Fields] OR "robotic deep endometriosis" [All Fields] OR "robotic colorectal endometriosis" [All Fields]; only English papers were considered. All titles and abstracts of interest were identified; those focusing on full robotic multivisceral surgery were assessed and the full text of the selected papers was evaluated for eligibility. Case reports and retrospective series concerning multivisceral robotic procedures were analyzed, including synchronous malignant tumors and other benign diseases. Studies reporting hybrid procedures or those describing robotic en bloc resections for locally advanced tumors (T4) were excluded. The full texts of relevant articles were further assessed for inclusion in this study. Figure 1 reports the flow chart of the research.

Results

A total of 11 patients underwent multivisceral full robotic abdominal surgery. Patient demographics are summarized in Table 1. 4 patients presented with two synchronous tumors,

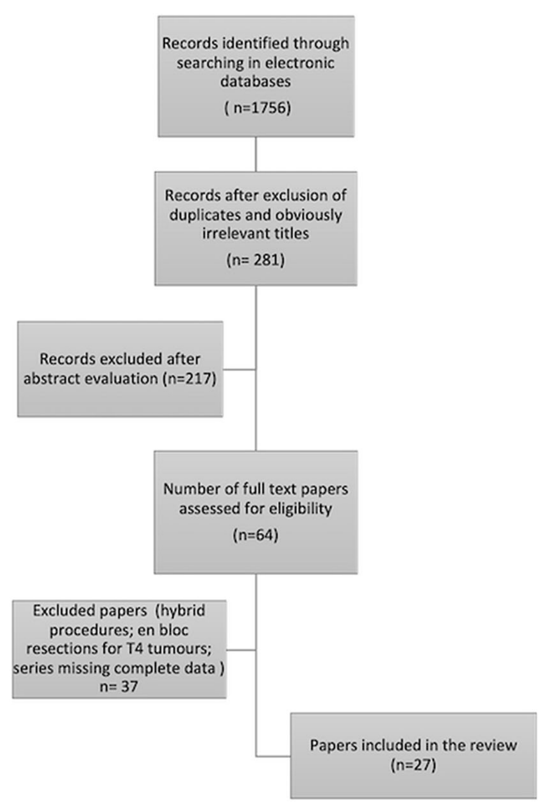

Fig. 1 PRISMA flowchart

Table 1 Patients demographics

Characteristics	$N=11$
Age, mean ± SD, years	59,3 ± 28,3
Sex (n°, %)	
Male	5 (45,5)
Female	6 (54,5)
Body mass index, mean (range), kg/m^2	26.6 (22–31)
ASA score (n)	
1	3
2	7
3	1
4	0
Prior abdominal surgeries (n, %)	4 (36.3)

4 with primary cancer associated with a benign condition and, lastly, 3 cases involved deep infiltrating endometriosis (DIE). 4 colorectal resections combined with partial ($n=3$) or radical ($n=1$) nephrectomy were performed, as well as 2 right colectomies in combination with right adrenalectomy ($n=1$) and LAGB removal ($n=1$), 2 radical prostatectomies with Nissen Fundoplication ($n=1$) and abdominal wall hernia repair ($n=1$), and 3 pelvic endometriosis resections. Table 2 summarizes the procedures and the operative technical details, along with the indication to surgery. Operative and postoperative outcomes are summarized in Table 3. Mean total operative time was 367 min (range 170–580). Estimated blood loss was inferior to 200 ml in all cases. No intraoperative complication was registered, all operations were completed with a full robotic approach and no conversion to hand assisted laparoscopy or laparotomy or hybrid approach was required. We registered an overall postoperative complication rate of 18,2%. In detail, two cases of anastomotic leak (Clavien–Dindo IIIb) were recorded, one after ARR combined with right partial nephrectomy, and the other after ARR performed during endometriosis-related surgical procedures. Both cases needed a laparoscopic reintervention with the fashioning of a loop ileostomy combined with endoscopic local treatment of the leak. The mean length of hospital stay was 12.5 days (range 3–37). The mortality rate was 0% and no cases of readmission was recorded. At a median follow-up of 11 months (range 2–28), no recurrence was registered for oncological cases.

A total of 26 papers were included in the review (Tables 4,5, and 6), with a total of 156 combined

Table 2 Procedures and operative data

Patient #	Diagnosis		Procedures		Total OT	Dockings n°	Trocars n° rob/lap
	1st	2nd	1st	2nd			
1	Prostate cancer	GERD	Radical prostatectomy	Nissen Fundoplication	360	2	5/3
2	Prostate cancer	Right iliac incisional hernia (L2)	Radical prostatectomy	IPOM	420	1	4/1
3	Deep infiltrating endometriosis		Hysterectomy + right salpingo-oophorectomy + debulking	Appendectomy	265	1	4/1
4	Right colon cancer	Dysphagia	Right colectomy	LAGBT removal	170	1	4/1
5	Right colon cancer	Renal cell carcinoma	Right colectomy	Right partial nephrectomy	405	3	8/2
6	Rectal cancer	Renal cell carcinoma	Anterior rectal resection	Left Partial Nephrectomy	580	2	7/4
7	Deep infiltrating endometriosis		Hysterectomy + ureteral shaving + left salpingo-oophorectomy + debulking	Rectal shaving + sigmoid discal resection	480	1	4/1
8	Adrenal adenoma	Right colon cancer	Right adrenalectomy	Right colectomy	270	2	7/1
9	Deep Infiltrating Endometriosis		Hysterectomy + left salpingectomy, right oophorectomy + debulking	Anterior rectal resection	575	1	4/1
10	Right colon cancer	Renal cell carcinoma	Right colectomy	Right radical nephrectomy	290	2	8/2
11	Renal cell carcinoma	Rectal cancer	Right partial nephrectomy	Anterior rectal resection	570	2	8/2

OT Operative time, *lap* laparoscopic, *rob* robotic, *GERD* gastroesophageal reflux disease, *LAGB* laparoscopic adjustable gastric banding, *IPOM* intraperitoneal onlay mesh repair

Table 3 Operative and postoperative outcomes

Mean total operative time (min)	367 (170–580)
Conversion to open	0
Intraoperative complications	0
Length of hospital stay (mean, days)	12,5 (3–37)
Postoperative complications n° (%)	2 (18.2%)
Clavien–Dindo I–II	0
Clavien–Dindo III–IV	2
Anastomotic leak (*n*)	2
30 days Readmission	0
Mortality	0

multivisceral robotic procedures recorded. For all the reported cases, demographic and surgical technical details were considered.

Discussion

Since the robotic platform was purchased at our Institution in 2005, our General Surgery Unit performed a total of 1136 robotic procedures including endocrine surgery procedures (thyroid, parathyroid, adrenal and pancreatic), colorectal resections, and upper GI functional and oncological procedures. The surgical team and OR staff are both proficient in robotic surgery, and the same applies for Urology and Gynecology Units. This technical experience, along with the spirit of collaboration between different specialties and the regular multidisciplinary use of the robotic platform, were the premise for this study.

The incidence of multiple primary tumors is reported to be in the range of 2–17% [18] and the treatment of these patients is challenging and often a therapeutic dilemma. A multidisciplinary team discussion is mandatory and consensus on the therapeutic strategy is not always easily reached. In localized disease, combined surgery seems to be a valid option. The principle behind a simultaneous approach is to carry out two procedures at the same time, gaining advantages in terms of length of hospital stay and postoperative morbidity [5]. Furthermore, in oncological cases a postponed second surgery could result in a delay in the administration of adjuvant chemotherapy, with possible oncological drawbacks.

A minimally invasive approach for simultaneous surgical procedures has been described before, as pure laparoscopic [19–21] or hybrid (laparoscopic and robotic) [22–24]; the latter is especially the case of robotic radical prostatectomy in which the consolidated robotic experience has been associated with laparoscopy to treat concurrent colorectal cancer [22–24].

We performed a literature review on full robotic combined multivisceral procedures, in which the benefits of a minimally invasive approach are associated with the technical advantages of the robotic system over standard laparoscopy. Out of the 26 studies selected, 10 are case series (more than 3 cases), the rest case reports. 5 case series are exclusively related to the treatment of deep infiltrating endometriosis, with the largest series being that published by Siesto et al.[25]. Our study consists of 11 cases is among the largest case series currently reported in literature.

The majority of cases described involved simultaneous full robotic liver and colorectal resections for liver metastasis from colorectal cancer. In the largest series being that by Navarro et al.[3] the authors described 12 cases of full robotic colorectal resections (including 9 anterior resections) combined with liver resections (including 2 major hepatectomies and an ALPPS procedure). 7 patients presented with multiple liver metastases. No conversion to open was reported, while major complications (Clavien–Dindo III) were one anastomotic leak and one liver abscess. While Navarro et al. always performed colorectal procedures before the hepatic resections [3], on the other hand, Dwyer et al. [26], in their series of 6 patients, reported to perform the liver procedure as the first step, to better assess the degree of liver involvement with intraoperative ultrasound. Both groups concluded that robotic simultaneous liver and colorectal resections are technically safe and feasible, even in cases requiring major liver resections, but should be reserved to specialized centers, performed by experienced surgeons, and preceded by accurate patient selection. Konstantinidis et al. [27] found combined liver resections particularly beneficial for elderly patients, due to the avoidance of two surgeries. However, according to Navarro et al., the advancement in technology do not change the biological burden of the disease and the risks of combining two major surgeries, thus the importance of an experienced team capable to evaluate each case and to manage possible complications [3]. At last, but not least, cost effectiveness should always be considered. Navarro et al. reserved the robotic approach to complex resections that would gain the most from the robotic approach, since at their institution this would come with an additional cost for the patient, thus patient's economical status had a major impact on their case selection [3].

Among the studies selected in our review, a total of 9 patients who underwent colorectal resection combined with a urological procedure was registered. Cases of combined full robotic radical prostatectomy (RP) and low anterior resection (LAR) for synchronous cancers were reported by Park et al. [28] and DeAngelis et al. [29]. Both groups performed rectal resection with TME before radical prostatectomy, however, the second group preferred to delay the fashioning of the colorectal anastomosis after radical prostatectomy. To date robotic prostatectomy is

Table 4 Synchronous multivisceral robotic resections

Reference	Diagnosis		Sex, Age	Simultaneous procedures		Da Vinci system	N° dockings	OT (min)	Complications
	Lesion 1	Lesion 2		First	Second				
Baik et al. [48] $n=1$	Rectal cancer	Uterus myoma	F,46	Hysterectomy	ARR	S	2	320	none
Yoo et al. [49] $n=1$	Distal Gastric Cancer	Prostate cancer	M,65	Distal Gastrectomy	RP	S	2	417	none
Kim et al. [50] $n=1$	Early Gastric Cancer	Right RCC	F,55	Distal Gastrectomy	Right PN	Si	2	670	Renal site fluid collection
Perrin et al. [7] $n=1$	Right colon cancer	Right RCC	M,82	Right Colectomy	Left RN	Si	2	300	none
Ong et al. [51] n = 1	Segment 7 HCC	Right RCC	M,66	Retroperitoneal right PN	Retroperitoneal partial hepatectomy	-	1	n.a	none
Park et al. [28] $n=1$	Rectal cancer	Prostate cancer	M,64	ARR	RP	-	1	360	none
Suh et al. [8] $n=1$	Early Gastric Cancer	Right colon cancer	F,71	Distal Gastrectomy	Right Colectomy	Si	2	640	none
Morelli et al. [2]*									
$n=2$	Right colon cancer	Right RCC	n.a	Right Colectomy	Right RN	Xi	1	300 370	none
$n=1$	Right colon severe dysplasia	Cervix high-grade SIL	n.a	Hysterectomy	Right Colectomy	Xi	2	280	none
$n=2$	Right colon cancer	Rectosigmoid junction cancer	n.a	Right Colectomy/ileocolic resection	Sigmoidectomy / ARR	Xi	2	305 450	none
$n=1$	Rectal cancer	Pancreatic tail NET	n.a	Pancreatic enucleation	ARR	Xi	1	490	none
$n=1$	Right colon cancer	Pancreatic tail NET	n.a	Right Colectomy	Pancreatic enucleation	Xi	1	200	none
Jiang et al. [42] $n=1$	Vater ampulla carcinoma	Rectal cancer	M,37	Pancreaticoduodenectomy	ARR	Xi	2	480	none
Boni et al. [52] $n=1$	Left RCC	Pancreatic body metastasis	F,68	Pancreatic metastasectomy	Left RN	Si	1	213	none
Soh JS et al. [9]*									
$n=3$	Rectal cancer	Uterus myoma	n.a	Hysterectomy	ARR	Xi	1	n.a	n.a
$n=3$	Rectal cancer	Left RCC	n.a	ARR	Left RN	Xi	1	n.a	n.a
De'Angelis et al. [29] $n=1$	Rectal cancer	Prostate Cancer	M,66	ARR	RP	Xi	1	n.a	n.a
Cochetti et al. [6] $n=1$	Rectal cancer	Left kidney angiomyolipoma	F,53	Left PN	ARR	Xi	1	260	none
Piccoli et al. [17]									
$n=1$	Right colon cancer	Right RCC	M,81	Right colectomy	Right PN	Si	3	400	none
$n=1$	Rectal cancer	Left RCC	F, 59	ARR	Left PN	Si	2	600	none

(*) Case series

OT operative time, *min* minutes, *LOS* length of hospital stay, *F* female, *M* male, *ARR* anterior rectal resection, *RP* radical prostatectomy, *RCC* renal cell carcinoma, *PN* partial nephrectomy, *HCC* hepatocellular carcinoma, *RN* radical nephrectomy, *Sil* squamous intraepithelial lesion, *NET* neuroendocrine tumor, *n.a.* not available, authors reported median value for all cases in the cohort

rapidly becoming the gold standard treatment of prostate cancer [30] and among colorectal procedures, robotic TME is the one that proved to have more advantages over its laparoscopic counterpart [31, 32] hence, the combination of RP and LAR appears to be the one that can benefit the most from the robotic platform, also considering the shared surgical field.

Furthermore, the incidence of synchronous colorectal and renal cancer has been variously reported with percentages ranging from 0.4 to 4.85% [33–35]. Several reports of

Table 5 Synchronous robotic procedures for gastrointestinal primary tumors and liver metastasis

Reference	Diagnosis		Sex, Age	Simultaneous procedures		Da Vinci system	N° dockings	OT (min)	Complications
	Lesion 1	Lesion 2		First	Second				
Xu et al. [53] $n=1$	Rectal cancer	Liver + lung metastases	M,59	Right lung resection	Segmental hepatectomy (SVII), ARR	Si	3	480	none
Calin et al. [54] $n=1$	Pancreatic NET	Liver metastasis	F, 52	Left hepatectomy	Distal Pancreatectomy	n.a	2	369	none
Morelli et al. [2]*									
$n=3$	Rectal cancer	Liver metastases	n.a	ARR	Hepatic resection	Xi	2	403	none
Sunil et al. [55] $n=1$	Rectal cancer	Liver metastasis	M,59	ARR	S IV–VIII wedge resection	S	2	390	none
Dwyer et al. [26]*									
$n=6$	Right colon cancer (n = 1)/ rectal cancer (n = 5)	Liver metastases	2 M/4F 59.3*	Hepatic resection ($n=4$)/ Ablation ($n=1$)/ No identifiable lesion ($n=1$)	Right Colectomy ($n=1$)/ ARR ($n=3$)/ APR ($n=2$)	Si	2	401 (mean)	1 Anastomotic leak 2 Pelvic abscesses
Soh JS et al. [9]*									
$n=3$	Rectal cancer	Liver metastases	n.a	ARR	SIII segmentectomy	Xi	1	n.a	n.a
Konstantinidis et al. [27]									
$n=1$	Right colon cancer	Liver metastases	F,84	S V–VI resection	Right Colectomy	Xi	1	n.a	none
$n=1$	Abdominal RCC recurrence	Liver metastases	F,75	S VII resection	Debulking + retroperitoneal lymphadenectomy	Xi	1	n.a	none
$n=1$	Pancreatic tail cancer	Liver metastasis (S III)	F,71	Distal pancreatectomy + splenectomy	Wedge resection	Xi	1	n.a	none
Navarro et al. [3]*									
$n=12$	Right colon cancer ($n=3$) Sigma-rectum cancer ($n=9$)	Liver metastases	7 M/5F 59*	Right colectomy ($n=2$) ARR ($n=11$)	Hepatic resections (multiple procedures)	Si ($n=5$) Xi ($n=7$)	2 ($n=5$) 1 ($n=7$)	449 (mean)	1 Anastomotic leak 2 Liver abscesses

(*) case series

ARR anterior rectal resection, *APR* abdominal perineal resection, *RCC* renal cell cancer, *n.a.* not available, authors reported median values for all cases in the cohort

colon resections combined with kidney procedures located in the same hemiabdomen were recorded [2, 6, 7, 36]. In particular, Morelli et al. [2] reported two cases of right radical nephrectomy (RN) combined with right colectomy. They managed to perform both procedure with a single docking technique, making the most out of the oblique trocar positioning and the improved dexterity of the arms of the Da Vinci Xi system. Perrin et al.[7], for their combined right

Table 6 Robotic treatment of deep infiltrating endometriosis with colorectal involvement

Reference	Mean Age	Simultaneous procedures		Da Vinci system	N° dockings	Mean total OT (min)	30 days Complications
Lim et al [36] *n* = 8	47	LAR	Ureterolysis, Hysterectomy, bilateral salpingo-oophorectomy	Si	1	238,5	2 (non specified)
Ercoli et al. [38] *n* = 12	38	Rectosigmoid resection	Debulking of DIE	Si	1	370	1 SBO
Neme et al. [41] *n* = 10	37	Rectosigmoidectomy	Debulking of DIE	Si	1	157 (console time)	none
Siesto et al. [25] *N* = 43	34	19 rectosigmoidectomies 23 rectal shavings	Debulking of DIE with various associated procedures	S	1	200	2 (1 hemoperitoneum, 1 anastomotic leak)
Morelli et al. [40] *n* = 10	36.5	6 segmental rectal resections 4 rectosigmoidectomies	Debulking of DIE	Si		280	1 wound infection
Grahm et al. [39] *n* = 15	38	3 LAR 12 rectal shavings/discoid resections	Debulking of DIE	Si	1	342	4 pelvic abscesses 1 of which associated with rectovaginal fistula

DIE deep infiltrating endometriosis, *SBO* small bowel obstruction, *LAR* low anterior rectal resection

colectomy and right RN, had to perform two dockings, since the system adopted was the Da Vinci Si. Both groups started with colonic resection, followed with radical nephrectomy and proceeded to create the ileocolic anastomosis as the final step of the procedure. Perrin et al.[7] performed an extracorporeal anastomosis, thus avoiding a third docking. In our series we reported two cases of synchronous right colon cancer and right kidney cancer [17]. In the case of right colectomy and right partial nephrectomy we followed the same sequence reported by Morelli et al.[2] and Perrin et al. [7], performing 3 dockings to fashion an intracorporeal anastomosis, while later on, in the case of RN we preferred to complete the reconstructive time before the urological step to avoid one docking. For left kidney tumors (treated with both partial or radical nephrectomy) combined with rectal resection 4 cases were recorded, including 3 LAR combined with radical nephrectomy in the series by Soh et al. [9] and one rectal resection combined with left partial nephrectomy by Cochetti et al. [6]. Both groups used the Da Vinci Xi system and two dockings were necessary to change patient's position. In our series we report one case of anterior resection combined with left partial nephrectomy performed with the DaVinci Si system, 2 dockings were needed as well, but with a rather longer operative time (580 versus 260 min by Cocchetti et al. [6]).

Moreover, our series featured a case of robotic ARR combined with right partial nephrectomy, where the urology performed their part before rectal resection. For this procedure the robotic cart had to be moved from one side of the operative room to the opposite one, impacting negatively on total operative time. Morelli et al. [2] described several multiquadrant surgeries involving resections in opposite sides of the abdomen (i.e., combination of ileocecal resection and ARR, or right colectomy and sigmoid resection) performed with the Da Vinci Xi system; in their experience moving the cart wasn't necessary since the new robotic cart has a boom with the ability to rotate of 180°. In addition, the Integrated Table Motion (ITM) system was available, allowing to change patient's position without undocking the robot and with instruments connected to the robotic arms. They concluded underlining the massive advantages brought by these two devices in minimally invasive multiquadrant combined surgery, minimizing issues such as instruments clashing, reduced visual field, and longer docking and operative room set up times.

In the last decade, robotic surgery has also spread in the field of Gynecology, where the number of robotic procedures for benign and malignant gynecological conditions has rapidly grown worldwide. One of the main areas of interest is the treatment of deep infiltrating endometriosis (DIE) with colorectal involvement [37]. Rectum and rectosigmoid junction account for 70–93% of all intestinal lesions [38] and in these cases two suitable surgical approaches are available: segmental resection or nodule excision (by shaving or disc excision) [37]. A recent review seems to favor rectosigmoid resection in terms of postoperative symptoms, fertility, and quality of life with laparoscopy being the technique of choice [37]. The robotic technology could be particularly beneficial for this kind of surgery that involves a challenging operative field like the pelvis and requires precise dissection, especially when shaving is performed [39]. Several studies reported that full robotic treatment of DIE with colorectal involvement is safe and feasible [25, 40, 41] with advantages over laparoscopy in terms of conversion to open [37], median blood loss and blood transfusion rates [38]. In their series of 43 cases, Siesto et al. [25] supported the use of the robotic technology to treat DIE especially when bowel or bladder were involved. More recently, Graham et al. [39], confirmed this statement, adding that segmental resection and anastomosis may be more beneficial than extensive shaving. As reported in Table 2, our series includes 3 cases of DIE, 2 of which presented rectosigmoid involvement. In one case, a rectal shaving was performed, while in the other ARR was deemed necessary. As agreed by the majority of the authors, DIE is a complex disease that necessitates a multidisciplinary approach and should be treated in high volume centers with the availability of both Urologists and General Surgeons [25, 38–41]. Finally, the combination of colorectal and Gynecological procedures has also been reported for synchronous malignant diseases, this is the case of severe dysplasia polyp of the right colon combined with high-grade intraepithelial squamous lesion of the cervix treated by Morelli et al. [2], with a single robotic procedure.

Multivisceral simultaneous robotic resections can involve basically any abdominal organ, several reports include pancreatic resections combined with colorectal or kidney resections, with authors even combining major surgeries, such as pancreaticoduodenectomy and TME [42] reporting no postoperative complications. Nonetheless, in our opinion, even if technically feasible, indication and sustainability of surgery should always be considered also in terms of risk–benefit balance. A thorough evaluation of both tumor's and patient's characteristics remains essential to choose the appropriate surgical strategy. Preoperative planning should take into consideration laterality of involved organs, changes in patient's position, trocar layout, and sequencing of the steps of the procedure. Soh et al. [9] compared robotic rectal resections for rectal cancer combined with other major surgeries with those of single rectal surgery; interestingly, they found similar total operative time and estimated blood loss, with a greater number of harvested nodes and larger distal resection margin in the combined group. This result, although not statistically significant, could support the use of combined robotic operations in surgical oncology, since it does not compromise the adequacy of the resection.

Our series has comparable results to those reported in literature, except for longer operative times especially when ARR was performed. This is easily justified by the use of the Da Vinci Si system, which has proven to be linked with longer operative times when compared with the Xi during ARR [43, 44]. The Xi system was specifically designed for multiquadrant surgery with improved arm's dexterity and a boom able to rotate, and even when a new targeting is needed, the new system offers a less complicated setup. Despite the system, we were still able to complete every procedure with a full robotic approach, without having to resort to a hybrid laparoscopic/robotic technique. An additional feature that could implement the use of the robotic system for multivisceral resections is the Integrated Table Motion, that enables to change patient's position without having to undock the robot or disconnect the instruments from the robotic arms, allowing for a smoother surgical workflow. Ultimately, the Firefly® technology on the da Vinci® platform is an integrated fluorescence system that uses near-infrared light to visualize tissue uptake of indocyanine green (ICG). This feature can prove valuable in multiple circumstances, such as: real-time identification of superficially located liver metastases [3], evaluation of colorectal anastomosis perfusion, identification of vascular anatomy, lymph node mapping, and identification of pancreatic neuroendocrine tumors [45–47].

Conclusions

Robotic combined multivisceral resections proved to be safe and feasible when performed in high volume centers by expert surgeons. Combined procedures can offer several advantages due to exposure to a single anesthesia, reduced hospitalization, decreased morbidity, and better cost effectiveness. The regular multidisciplinary use of the robotic platform practiced in many Institutions has advantages not only in terms of cost-effectiveness, but also for overall patient care. Preoperative evaluation of both the clinical case and technical steps of the procedure is of outmost importance. The technical feasibility of a procedure, also due to technological advancements, should not overshadow the risks of combining two major surgeries in frail patients, an experienced team capable to evaluate each case and to manage possible complications remains essential.

The heterogeneity of reports does not allow for a standardization of the procedure. The author's common ground remains their extensive experience in robotic surgery along with the multidisciplinary approach to combined multiorgan resections. The focus of this study was to investigate the feasibility of robotic combined procedures and eventually try and standardize a method, not a specific surgical technique, which is indeed difficult to do since patient's and tumor's characteristics are very diversified. Further studies and accumulation of experience could help standardize also the surgical technique for the different combinations of procedures, thus expanding the indications of robotic surgery.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethics approval All procedures performed in the study involving human participants were in accordance with ethical standards of Institutional and National research committee.

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

Consent for publication All authors consent for publication of the study.

Availability of data and material All relevant data generated or analysed during this study are included in this published article.

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