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ORIGINAL ARTICLE

Minimally invasive robotic-assisted combined colorectal and liver excision surgery: feasibility, safety and surgical technique in a pilot series

Graziano Ceccarelli[1,2] · Aldo Rocca[2,3] · Michele De Rosa[1] · Andrea Fontani[2] · Fabio Ermili[1] · Enrico Andolfi[2] · Walter Bugiantella[1] · Giovanni Battista Levi Sandri[4]

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Abstract

Different strategies may be adopted in patients with synchronous colorectal liver metastases (LM). The role of laparoscopy has been investigated to define the benefits of minimally invasive surgery in a single-stage operation. In our study, we report our experience of 28 Minimally Invasive Robotic-Assisted combined Colorectal and Liver Excision Surgery (MIRACLES). From October 2012 to December 2019, 135 Robotic liver resections and 218 Robotic Colorectal resections were performed in our center. Twenty-eight patients underwent MIRACLES resection with 37 nodules removed. Fifty-two lesions in 28 patients were resected in minimally invasive robot-assisted surgery. Eighteen lesions were located in postero-superior liver segments (eight in segment VII, two in segment VIII, eight in segment IVa). Nine right colectomies, seven left colectomies, ten anterior rectal resections, one Hartmann and one MILES procedures were performed. The median surgical time of MIRACLES procedures was 332 min. Two conversions to open approach were necessary. Four major complications (> III) were observed. No postoperative mortality was recorded. The median hospital stay was 8 days. The median overall survival was 27.5 months. The MIRACLES approach is feasible and safe for colorectal resection and hepatic nodules located in all segments, with a low rate of postoperative complications. Surgical technique is demanding and should be reserved, presently, to tertiary centers.

Keywords Liver resection · Dropout · Recurrence · Propensity score match

Introduction

Colorectal cancer (CRC) is the third common tumor in the world, and in 25% of new cases, synchronous colorectal liver metastases (LM) are diagnosed [1]. A multidisciplinary approach addressing the primary tumor and the metastatic disease is the current strategy of treatment [2, 3]. When the complete surgical resection (R0) is feasible, surgery represents the best potentially curative approach, with a 5-year overall survival reported to be approximately 37–58% [4–6]. Surgical approach to patients affected by Synchronous Colorectal Liver Metastases (SCRLM) has been demonstrated as one of the most challenging key point in the therapeutic strategy (2). Simultaneous resection of the primary cancer associated with liver metastases has been described as a safe and effective choice in selected cases [5–7].

The role of laparoscopy has been investigated to define the benefits of minimally invasive surgery in a single-stage operation [8]. Results showed a favorable outcome compared to the conventional open approach. Safety and feasibility of the robotic approach to liver resections has been clearly established but the Minimally Invasive Robotic-Assisted Combined Colorectal and Liver Excision Surgery procedure has been only occasionally reported in literature [9–11].

✉ Graziano Ceccarelli
grazianoceccarelli1967@gmail.com

1 General and Robotic Surgery Department, San Giovanni Battista Hospital, Foligno, Perugia, Italy

2 San Donato Hospital, General and Robotic Surgery Unit, Arezzo, Italy

3 Department of Medicine and Health Sciences "V. Tiberio", University of Molise, Via Francesco de Sanctis, 1, 86100 Campobasso, Italy

4 Division of General Surgery and Liver Transplantation, Polo Ospedaliero Interaziendale Trapianti (POIT), San Camillo-Forlanini Hospital, Rome, Italy

Herein, we report our experience of twenty-eight Robotic-assisted One-stage Col-orectal And Liver resection (MIRACLES). The primary endpoint of our study was to establish feasibility and safety of the MIRACLES procedure. Details of the technical approach are described.

Methods

We retrospectively reviewed prospectively collected data of our institutional database of robotic-assisted surgical procedures. From October 2012 to December 2019, 135 Robotic liver resection and 218 Robotic Colorectal resections were performed in our Center. 28 patients affected by CRC at stage IV underwent MIRACLES.

Inclusion criteria

Patients age > 18 years, biopsy proven of metastatic disease and no evidences of multiple bilobar liver disease were included. During the multidisciplinary team evaluation, all cases of colorectal tumors associated with synchronous liver metastases were discussed for surgical indication approval. National Comprehensive Cancer Network (NCCN) guidelines were used in treatment planning [12].

Prior consent was obtained, and full treatment options were submitted to all patients before surgery. Patients, surgical and outcome characteristics of all MIRACLES procedures were prospectively collected.

Exclusion criteria from synchronous approach

Patients with prolonged neoadjuvant chemotherapy, high risk of positive surgical margins (R1) or insufficient liver volume remnant were excluded.

Also patients with ASA score 4, multiple bilobar liver disease, pre-operative prediction of liver vascular resection were not included. Major hepatectomy associated with complex CRC resection was a partial contraindication for the MIRACLES procedure.

MIRACLES procedure

All procedures were performed by the same senior surgeon (GC) in two different centers. Other surgeons involved had the chance to perform different steps of intervention according to their ability and always under GC supervision. The patient is placed in the supine position with open legs, and for right posterior segments, a pillow is positioned under the right flank. Operative table tilt depends on nodule liver location. Pneumoperitoneum is established using a Veress needle at 12 mmHg, with the AirSeal® System insufflation device usually used. As the first step, a laparoscopic intraoperative ultrasound (IOUS) liver examination is routinely carried out to identify already known or undetected liver lesions. Once resectability criteria were met, the operation usually started from the more demanding technical step potential cause of conversion, either liver or rectum, according to difficulty expected. Consequently, trocars were positioned, and the robot was docked in relation to liver and colorectal disease location.

According to location of hepatic nodules and type of resection, we took care of the liver first, to avoid any vascular impairment of the colorectal anastomosis due to Pringle maneuver and minimize the risk of a possible conversion in case of a challenging liver surgery. Alternatively, in case of an easier liver resection, isolation of the colorectal tumor was performed first delaying resection and anastomosis after removal of the liver lesions.

We have been using a four-arm device (robot Da Vinci® Si Sunnyvale, CA, USA) until 2017 and since then, Xi Da Vinci®. The latest allows an easier docking and trocar placement in case of simultaneous resections.

Operative trocars are inserted based on the site of the liver metastasis. One or two additional 10-mm trocars are placed in the upper quadrants for hepatic resection, to allow bedside surgical assistance introducing gauzes or laparoscopic auxiliary instruments. The docking and trocar placement of the two most frequent scenarios, the first in case of right colon and liver resection and, the second in case of left sided/rectal colon cancer and liver resection, are shown in Figs. 1, 2.

Liver resection

When liver resection is the first step, the robot Da Vinci® Si (Sunnyvale, CA, USA) is placed at the head of the patient (right or left shoulder depending on the liver lobe involved; a right shoulder is preferred in case of bilobar disease). The fourth arm is placed on the left patient side for right liver tumors and vice versa. The Pringle maneuver, if needed, is generally performed using the extracorporeal technique [12]. Liver parenchyma transection is performed with the robotic bipolar forceps (Maryland) and curved electrified scissors. We used the clamp-crushing technique and application of laparoscopic clips (hem-o-lock) for vessel control. A vascular stapler was used to seal up left or right hepatic vein.

For lesions in segments 7 and 8, the three robotic trocars are placed at the level of the right costal margin or, in some cases, in an intercostal space. The on-table assistant stays in between the patient's legs using the other trocars for suction, traction, and vessels clipping, or further laparoscopic devices when required, including laparoscopic US probe. The round ligament is generally not sectioned

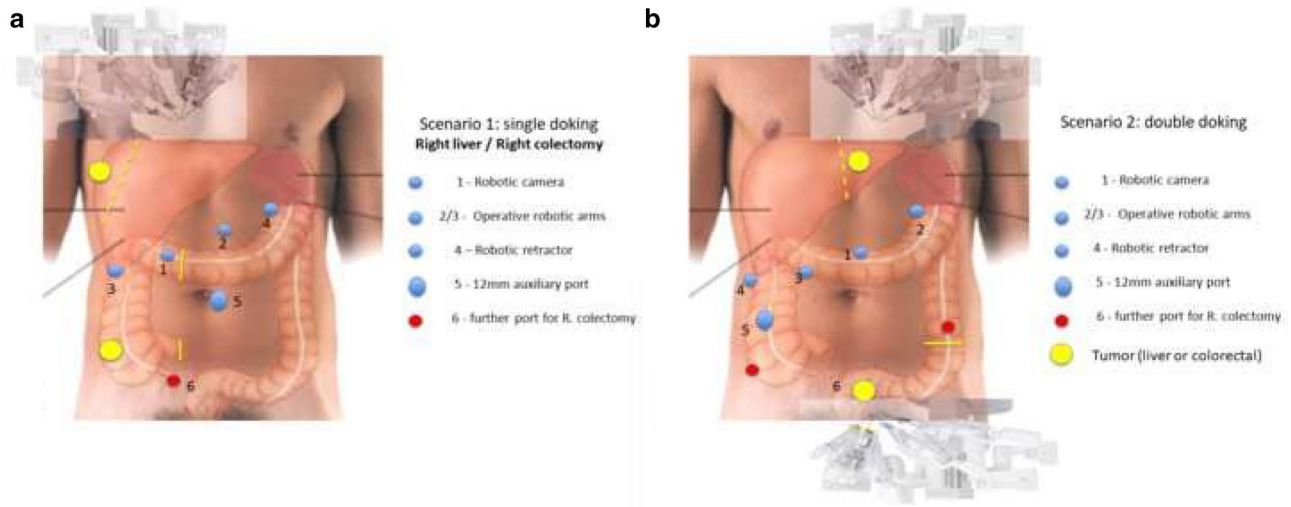

Fig. 1 The docking and trocar placement of the two most frequent scenarios. **a** right colon and liver resection. **b** left sided/rectal colon cancer and liver resection

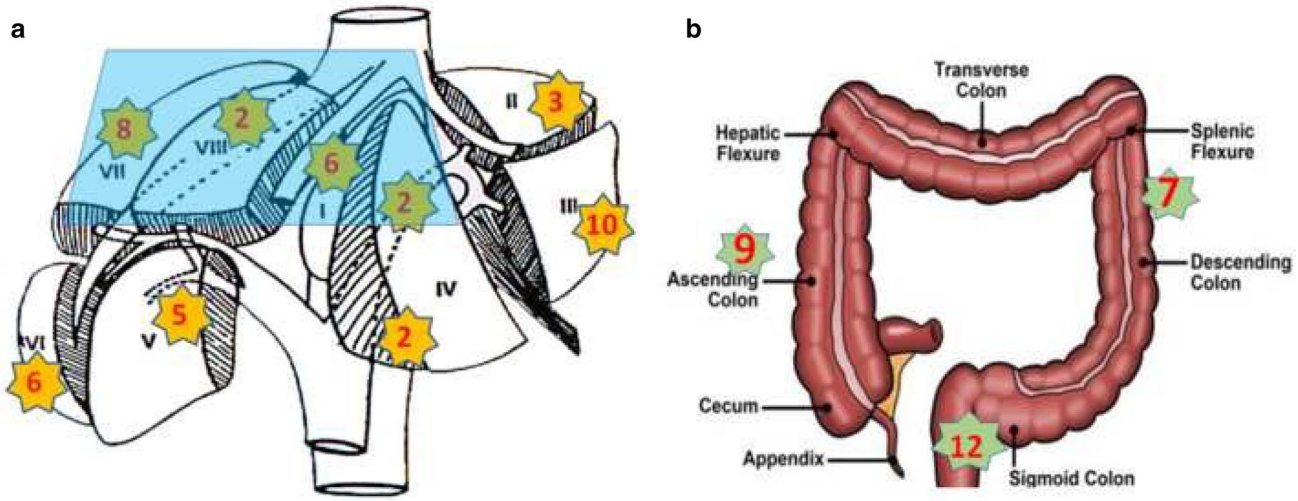

Fig. 2 **a** Anatomical location of liver nodules resected. Segment IV is represented as IVa and IVb. The Nodules in the unfavourable segments liver are highlighted. **b** Colo-rectal tumor distribution

to grant a stable counter-traction. A whole is achieved in the falciform ligament to insert the robotic instrument. The triangular and coronal ligaments are sectioned only in case of left hepatectomy and for segments 2, 7, and 8 resections.

Liver hemostasis is also obtained by monopolar coagulation, applying fibrin sealant if necessary on the resection surface.

Biliostasis is assessed by prolonged observation and stitches when necessary. Occasionally, we have used real-time indocyanine green (ICG) dye for a better definition of sub-capsular liver tumors through accumulation of ICG. It might be also useful for recognizing extra-hepatic bile duct anatomy and liver segmental borders, implementing the accuracy and the easiness of resections.

Colorectal resection

Colorectal resections are performed according to the standard techniques. The two specimens (liver and colon–rectum) are extracted with different endoscopic bags generally by a Pfannenstiel incision or troughs an enlargement of one trocar (for specimen of 3 cm or less) [12]. We routinely leave two abdominal drains, at the liver transection plane and colonic anastomosis, respectively.

Results

Forty-five patients were considered at the multidisciplinary meeting for a MIRACLES procedure. Eight patients were excluded because of major liver resections needed to achieve R0 and nine for major comorbidities. Twenty-eight patients underwent a MIRACLES resection out of a total of 135 liver resections managed with a robotic approach: median age was 65 (54–73) with a median BMI of 27.5 [15–43]. According to the American Society of Anaesthesiologists Classification, six patients were ASA 1, twelve ASA 2 and ten ASA 3 (Table 2).

Fifty-two (52) hepatic lesions in twenty-eight patients were resected with the robotic approach. Type of liver resections is shown in Fig. 2 and Table 1.

The location of all colorectal tumors is illustrated in Fig. 1b.

The location of all nodules is illustrated in Fig. 1a.

Eighteen lesions were located in the unfavorable segments (VI–VIII–IVa). Nine right colectomies (32.1%), seven left colectomies (25%), ten anterior rectal resections (35.7%), one Hartmann procedure (3.6%), and one MILES procedure (3.6%) were performed. A laparoscopic approach for four resections (two left colectomies, one right colectomy, one Hartmann) was used. Patient characteristics and details of the surgical procedures are summarized in Tables 1, 2, 3, 4.

The median surgical time of the MIRACLES procedure was 332 min [280–385]. The estimated blood loss was 143 cc [50–600]. Hepatic pedicle control was always prepared, intermittent clamping (10′ plus 5′) by Pringle maneuver was used in 9 of the 28 patients, with a median clamping time of 21 min [5–109].

In three patients, we performed an anterior rectal resection for upper rectal cancer and we were able to associate more complex liver resections of segment VII and one trisectionectomy of segments IVa, V, VI. In case of middle and low rectal resections, easier liver resections of anterior segments were always associated. We performed two low rectal resections associating, in one case a synchronous resection of segments VI–VII without complications, and in another case, a multiple wedges resections (I, VI, IVb) followed by a re-intervention in post-operative day 7 for an anastomotic leakage (Table 5).

Table 1 Patients characteristics

Gender	
Male	18
Female	10
Age	65 [54–73]
BMI	27.5 [15–43]
ASA	2 (1–3)
Type of liver resection	
Wedge	20
Segmentectomy	5
Left Lateral Sectionectomy	1
Right bi segmentectomy	1
Left Hepatectomy	1
Type of colon Resection	
Right Hemicolectomy	9 (1 laparoscopic)
Left Hemicolectomy	7 (2 laparoscopic)
Rectal anterior resection	10
Hartmann Procedure	1 (laparoscopic)
MILES Procedure	1
Specimen extraction site	
Pfannenstiel	17
Umbilical trocar	7
Suprapubic mini-laparotomy	4

Data are expressed in median, IQR

Table 2 Perioperative data according to Clavien-Dindo classification

Age	BMI	ASA	CLAVIEN
75	24,91	1	1
31	19,59	1	3b
51	31,31	1	1
39	29,11	1	1
53	40,83	1	1
39	21,60	1	3b
66	23,62	2	1
83	26,60	2	1
70	29,4	2	1
55	27,73	2	2
54	23,12	2	1
85	25,00	2	1
77	29	2	2
64	24,00	2	1
68	30,38	2	1
63	27,77	2	1
70	25,6	2	1
59	26,70	2	1
63	27,40	2	1
63	31,00	3	3a
80	27,50	3	1
63	31,50	3	1
80	25,60	3	1
69	43,00	3	2
56	29,00	3	1
53	15,77	3	1
77	28,65	3	1.2
66	25,24	3	4b
72	23,52	3	2

Table 3 Operative data are expressed in median and IQR

Operation time (min)	332 [280–385]
Blood loss (cc)	143 [50–600]
Pringle maneuver	9/28
Conversion	2
Complication grade according to Clavien dindo classification	
I-II	24
IIIa	1
IIIb	2
IV	1
Mortality	0
Length of stay (days)	8 [7–13]

Table 4 Tumor Characteristics

Nodule diameter	24.8 [7–66]
Radicality	
R0	27
R1	1
TNM	
T1	1
T2	1
T3	24
T4	1

Nodule diameter is expressed in mm

Two conversions to open approach were necessary because of an intraoperative diagnosis by ultrasound of further lesions not seen in pre-operative work-up and a perihilar location of the metastasis.

Perioperative data according to Clavien–Dindo classification are reported in Tables 2, 3. No postoperative mortality was recorded. Median hospital stay was 8 days.

Only one positive margin R1 1/28 was recorded. Tumor characteristics are reported in Tables 4, 5.

At time of our data analysi,s 21 patients are still alive.

Five have recurrence: three in the liver (one also in the lung), one in the pelvis, and one with abdominal carcinosis. The median overall survival is 27.5 months.

Overall survival curve is shown in Fig. 3.

Discussion

In the present study, we report our experience of 28 patients with CRC and synchronous LM treated by MIRACLES procedure.

The optimal treatment strategy for resectable synchronous colorectal LM is still a matter of debate [13–15]. Several studies have proven that simultaneous resection of both colorectal and liver disease for primary CRC with LM is a safe and feasible strategy, compared with the classical staged approach [16, 17].

No significant difference concerning long-term outcomes of overall survival and recurrence-free survival was detected between the simultaneous and the delayed strategy group in a meta-analysis of 2880 patients [18]. It was also shown that operative time and hospital stay in the simultaneous strategy group were significantly better compared to delayed surgery, as well as blood loss and short-term complications [18].

In the last decades, there has been a shift towards a minimally invasive surgical approach with laparoscopy. Laparoscopic simultaneous resection of primary colorectal tumor and liver metastases has been described to be feasible and safe [19–22].

Furthermore, patients treated with laparoscopic liver procedures seem to have a better quality of life during the first year after surgery compared with the open approach [23]. The rate of major complications does not seem to increase, even when simultaneous metastatic liver disease

Table 5 Anterior rectal resections details

Primary resection	Liver resection	Pathological finding	TNM	Duration
Anterior rectal resection + Adhesiolysis	Wedge resection VIIS	Upper rectal adenocarcinoma	PT3N1MXG2	310
Anterior rectal resection	Wedge resection III	Upper rectal adenocarcinoma	T3 N1B M1 G3	270’
Anterior rectal resection	Wedge resection IVA, V, VI, VIIS	Upper rectal adenocarcinoma	T3N2M1 G3	540’
Anterior rectal resection	Wedge resection III	Rectal adenocarcinoma	TXN0MX	420’
Anterior rectal resection	Wedge resection VI–VII	Rectal adenocarcinoma	T3N2M1G3	420’
Miles resection + Cholecystectomy	Wedge resection VI + III	Rectal adenocarcinoma	PT3N2AM1 G2	310
Anterior rectal resection	Wedge resection IV	Rectal adenocarcinoma	T4BN0M1 G3	335’
Laparoscopic Hartmann resection	Wedge III	Rectal adenocarcinoma	T3N1BM1A G2	285’
Anterior rectal resection + Cholecystectomy	Wedge resection I, VI, IV B	Rectal adenocarcinoma	T3N1BM1A G3	345’
Anterior rectal resection + Cholecystectomy	Segmentectomy VI	Rectal adenocarcinoma	PT3N2BM1 G2-3	380
Anterior rectal resection + Cholecystectomy	Subsegmentectomy VS	Rectal adenocarcinoma	PT3N1AM1G2	370
Anterior rectal resection	wedge resection IIIS + VS	Rectal adenocarcinoma	T3N2M1 G3	400

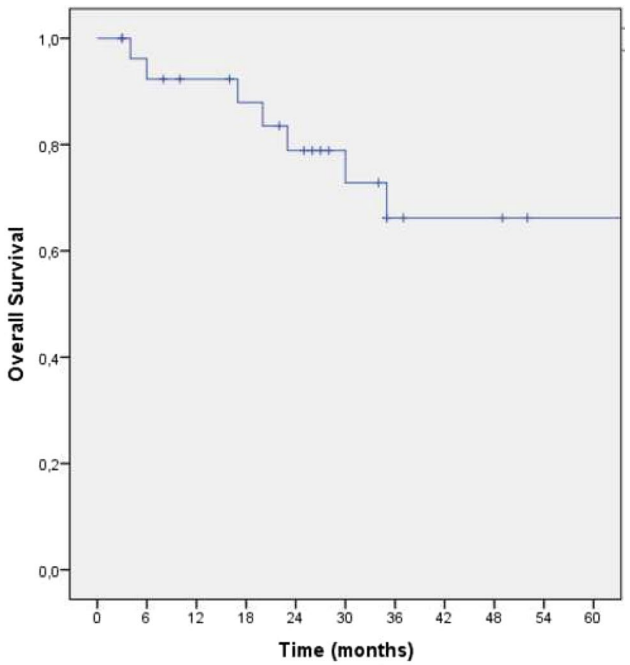

Fig. 3 Kaplan Meir Curve of the overall survival

is performed associated with rectal surgery in a laparoscopic scenario [24].

No differences exist between open and laparoscopic liver surgery in terms of oncological results, nodule location, or nodule size, with less post-operative pain and shorter hospital stay observed in minimally invasive cohorts [25–27].

More recently, the robotic approach has shown to be a feasible option for liver surgery also in the treatment of synchronous colorectal and liver metastasis [9–28]. The application of robotic technology to colorectal and liver procedures has been justified by the technical advantages over conventional laparoscopy, through a more significant range of articulation, abolition of a possible tremor, improved ergonomics and high-quality maneuvers to be performed in narrow spaces such as the pelvic cavity and particularly the posterior segments.

A recent study has shown that operative time and length of stay are similar comparing 185 laparoscopic colorectal resections with 70 robotic with a robotic approach [29].

Similar results in terms of operative times and length of stay are reported in two studies comparing laparoscopic and robotic approach [30, 31].

In a previous paper, we have been able to assess feasibility and safety of the robot-assisted surgery in elderly and very elderly patients in oncologic than in general abdominal surgery [28].

The largest systematic review recently published including more than 1000 patients, despite the limitations due to retrospective nature of most of the studies included, showed that robotic technique for liver resections is a safe and feasible alternative to laparoscopic surgery for both minor and major resections in terms of blood loss, operative time, hospital stay and complete tumor excision. Median operative time was 295.5 min (range 45–1186), and median blood loss was 224.5 mL (range 0–5000), while complication and conversion rate was 17.6% and 5.9%, respectively [32].

A synchronous mini-invasive treatment for colorectal liver metastasis approach may, therefore, be feasible by laparoscopic than robotic approach enhancing the benefits of the simultaneous treatment and adding all advantages over conventional open approach for both colorectal and liver resections.

A systematic review by Garritano et al. has identified 20 studies involving laparoscopic and robotic-assisted resection for synchronous liver metastatic colorectal neoplasms. It concluded that the one-stage procedure, compared to the staged one, allows shorter postoperative course but no definitive conclusions could be drawn concerning oncological outcomes [22].

Upper rectal resection associated to minor liver resections are reported in literature and considered quite safe when compared to open approach.

To date, there is no evidence in the literature to consider major liver resections as a safe procedure when associated with complex rectal procedures. The association of extended hepatic resection and high-risk CR operations, because of high post-operative morbidity, should be primarily considered for future study designs [8–18].

In our series, the MIRACLES procedure has shown to be:

- technically feasible provided a careful and appropriate position of the trocars,
- safe in terms of no intraoperative major complications, a low rate of conversions to open (7%), a low rate of complications (14% >= Clavien III grade) and 0% of mortality.

Also the median post-operative course was low (8 days) and in the range of all minimally invasive combined approaches reported in literature [7, 10, 20, 22].

A stoma diversion in MIRACLES procedure was evaluated case by case.

In our series, from a total of 52 liver lesions in 28 patients, 18 were located in posterior segments (IVa, VII, VIII, and I segments). As previously described, the use of robot has allowed an optimal access to all liver segments, facilitating parenchymal-sparing surgery also for lesions located in the postero-superior segments [33–36].

Conclusions

Therefore, we were able to confirm, in a larger series, the feasibility and safety of the MIRACLES procedure, warning though that we have still a long way to go before being able to assess that the MIRACLES procedure might be considered a standard procedure. This approach requires an expert surgical team in both minimally invasive robotic colorectal and liver surgery and a multidisciplinary team to properly select patients eligible to this procedure. But the road of feasibility and safety has been traveled: we do wish that multicenter studies of cooperative centers might definitively assess the efficacy of this astonishing procedure that technology and surgical skills are nowadays offering for the sake of our patients.

Author contributions GC, AR, GBLS were responsible for the conception, design, analysis and writing of the study; GBLS, MR, AF, FE, LM, EA and WB were involved with the collection and interpretation of data; GC, AR and GBLS participated in data management, review and editing of the manuscript.

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Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to declare about the present study.

Ethical approval All procedures performed were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in this study.

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