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ORIGINAL ARTICLE

Laparoscopic versus robotic surgery in the setting of combined resection of colorectal cancer and liver metastases: an experience from the I Go MILS registry

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Abstract

Approximately 25% of patients with colorectal cancer (CRC) are diagnosed with distant metastases, with the liver being the most common site. A simultaneous approach to resections in these patients may lead to higher complication rates. Recent research suggests that minimally invasive surgical (MIS) techniques can help reduce this additional morbidity. This study examines a multicenter Italian experience, comparing perioperative outcomes of robotic (RS) and laparoscopic surgery (LS) in this setting. Patients from the prospective multicentre registry of the Italian Group of Minimally Invasive Liver Surgery (I Go MILS) who underwent MIS simultaneous resection for CRC with colorectal liver metastasis between 2015 and 2025 were included. Perioperative outcomes were compared between RS and LS using nearest neighbor matching with 2:1 ratio and caliper of 0.2 to mitigate the selection bias. A total of 505 patients were analyzed, including 415 undergoing LS and 90 undergoing RS. After matching, demographic characteristics were similar. Operative time, conversion rate (11.71% for LS vs 6.67% for RS, $p=0.224$) and length of stay were comparable between the two groups. Robotic surgery enabled more challenging resections compared to laparoscopy and after matching for complexity was associated with lower major complications (21.62% vs 8.89%, $p=0.014$). The robotic approach has demonstrated superior feasibility for technically challenging resections while maintaining similar length of stay, rate of conversion and postoperative complications, after matching for complexity RS was associated with a significantly lower rate of major complications. Robotic surgery can be an alternative to open surgery in complex cases in order to maximise the benefits of minimally invasive surgery and to have better short term postoperative outcomes.

Keywords Minimally invasive · Laparoscopic · Robotic · Colorectal liver metastases · Synchronous

Introduction

Approximately 25% of patients with colorectal cancer (CRC) present with distant metastases at diagnosis, with the liver representing the most common site of metastatic spread [1]. Although the presence of colorectal liver metastases (CRLM) is associated with a poorer prognosis, surgical resection remains the cornerstone of curative treatment and offers the best chance for long-term survival in selected patients [2].

In patients with synchronous CRLM, three main surgical strategies may be adopted: a colon-first approach, a liver-first approach, or a simultaneous resection of the primary tumor and liver metastases [3]. Over recent years, the simultaneous approach has gained increasing acceptance, as it allows definitive treatment of both disease sites in a single operation, potentially reducing overall treatment time and avoiding delays in systemic therapy. However, simultaneous resection is technically demanding and has traditionally been reserved for carefully selected patients, particularly those requiring limited liver resections, due to concerns

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regarding perioperative morbidity and surgical complexity [4–9].

Minimally invasive surgery (MIS) has progressively become the preferred approach for both colorectal and liver surgery, given its well-established benefits in terms of reduced blood loss, faster recovery, and shorter hospital stay, while maintaining oncological adequacy. Laparoscopic surgery (LS) represents the most widely adopted MIS technique and has demonstrated favorable outcomes in liver surgery, including for colorectal liver metastases, particularly in high-volume centers with advanced expertise [10–14]. Nonetheless, the diffusion of advanced laparoscopic liver resections remains limited, as technical complexity, restricted instrument mobility, and challenging ergonomics may hinder its broader adoption, especially for complex resections or in centers with lower procedural volumes.

In this setting, robotic surgery (RS) has emerged as a potential tool to overcome some of the intrinsic limitations of laparoscopy. The robotic platform offers articulated instruments, stable three-dimensional vision, tremor filtration, and improved surgeon ergonomics, which may facilitate precise dissection and vascular control in complex hepatic procedures. In other surgical fields, such as pancreatic surgery and gynaecology, RS has been shown to promote the dissemination of minimally invasive approaches, particularly for technically demanding operations [15–19]. These advantages suggest that RS could similarly support the expansion of MIS in the context of synchronous CRLM, potentially enabling more complex liver resections to be performed safely within a minimally invasive simultaneous strategy.

Despite the increasing use of robotic platforms in both colorectal and liver surgery, evidence directly comparing robotic and laparoscopic approaches in the setting of simultaneous resection for CRC and synchronous CRLM remains limited. Available studies are often characterized by small sample sizes, retrospective designs, and inclusion of highly selected cases from expert centers, thereby limiting the generalizability of their findings and leaving unanswered questions regarding the real-world impact of robotic technology [20].

In this context, large multicenter registry-based analyses may provide unique insights. The Italian I Go MILS (Minimally Invasive Liver Surgery) registry prospectively collects data on minimally invasive liver resections performed across a wide range of institutions, irrespectively of center volume or case complexity. This national registry offers a real-world framework to evaluate the role of different minimally invasive techniques, capturing heterogeneity in surgical expertise, institutional experience, and procedural difficulty.

Therefore, the aim of the present study was to compare robotic and laparoscopic approaches in patients undergoing simultaneous resection for colorectal cancer and synchronous colorectal liver metastases, using data from the Italian I Go MILS registry. By analyzing surgical characteristics, procedural complexity, and perioperative outcomes in a large, heterogeneous national cohort, this study seeks to clarify the relative role of RS and LS in this challenging clinical setting and to assess whether robotic technology may facilitate the safe expansion of minimally invasive simultaneous resections beyond high-volume expert centers.

Methods

Study design

Patients who underwent combined hepatic and colic resection for colorectal liver metastases (CRLM) between 2015 and the first trimester of 2025 were enrolled prospectively in the I Go MILS registry and analysed retrospectively in this study. Patients were divided in two groups according to the surgical approach: robotic surgery group (RS) and laparoscopic surgery group (LS). The characteristics of patients undergoing RS or LS were analyzed to understand if there was a difference in the type of patient allocated to each surgical approach. A propensity score matching was then performed in order to mitigate the confounding factors and to assess if the surgical approach can lead to different short term surgical outcomes.

The primary outcome was to evaluate the short term surgical outcomes of robotic surgery compared to laparoscopic surgery in the setting of combined hepatic and colic resection for CRLM. In particular, the intraoperative performances (i.e. conversion rate, operative time, intraoperative blood transfusions) and the postoperative complications were assessed. The secondary endpoint was to evaluate the criteria of allocation to RS or LS.

The I Go MILS registry

The Italian Group of Minimally Invasive Liver Surgery (I Go MILS) is the nationwide prospective registry established in Italy with the aim of creating a national database to monitor outcomes, assess trends, and promote the dissemination of minimally invasive liver surgery. The Registry is prospective and participation is open to all Italian centers performing MILS, with no restrictions based on annual liver surgery volume or minimally invasive caseload [21, 22]. Consequently, both general surgery units and high-volume hepatobiliary referral centers contribute to the registry.

Patient data are collected and stored in a secure, web-based electronic case report form (eCRF), accessible only to authorized personnel via individual ID and password credentials. Upon enrolment, each patient is assigned a unique identification code automatically generated by the system, ensuring data anonymization. All data are subsequently processed and reported in an anonymous format.

The case report form consists of three distinct modules: enrolment, surgical procedure, and postoperative outcomes. A total of 37 variables are required to complete the CRF. A detailed description of the dataset has been published elsewhere [22].

Variables

The registry collected data on several variables, including demographic features (age, sex, and BMI), liver-related characteristics (presence of portal hypertension, status of the hepatic parenchyma, and tumour size), and surgical details (type of liver resection, technical difficulty, minimally invasive approach, operative time, estimated blood loss, intraoperative transfusions, use of the Pringle manoeuvre, and conversion to open surgery with the corresponding reason). Postoperative outcomes were also recorded, including length of hospital stay, complications, and mortality, as well as the annual surgical volume of the treating centre.

For the analysis, centre case volume was defined as the annual number of minimally invasive liver resections (MILR) performed for CLRM, calculated by dividing the total number of procedures carried out by each centre by its years of participation in the registry. Centres performing at least 10 procedures per year were classified as high-volume. This threshold was defined based on two previous Italian studies, which identified 20 and 24 MILR for any pathology per year as cut-off values [23, 24]. Since our study focuses exclusively on surgeries performed for colorectal liver metastases (CRLM), we considered a threshold of 10 MILR for CRLM per year to be comparable and more appropriate for the specific context analyzed.

Operative mortality was defined as any death occurring within 90 days after surgery. Postoperative morbidity was assessed using the Dindo–Clavien classification [25], with complications graded as Dindo–Clavien ≥ 3a considered major.

The Kawaguchi et al. classification [26] was used to categorize hepatic resections into three levels of technical difficulty. This system, developed to stratify laparoscopic liver resections based on operative time, blood loss, conversion rate, morbidity, and mortality, groups procedures as follows: low difficulty (wedge resections and left lateral sectionectomy), intermediate difficulty (left hepatectomy and right anterior sectionectomy), and high difficulty (right posterior sectionectomy, right hepatectomy, central hepatectomy, and right or left trisectionectomy). This internationally validated classification was deemed suitable for application within the I Go MILS Registry.

Statistics

Descriptive statistics are expressed as median and interquartile ranges, while the categorical variables are presented with proportions and percentages. Categorical variables were compared using chi-squared test or Fisher's exact test, as appropriate. Continuous variables were analysed using the Mann–Whitney U test.

A propensity analysis with Nearest Neighbor Matching algorithm was used in a 2:1 ratio in order to minimize imbalances between the groups. The variables included in the model were age, BMI, gender, technical complexity, year of enrollment and high volume centre. The caliper was set equal to 0.020, and matching was performed without replacement. In supplementary material it can be found a Love plot showing standardized mean differences for baseline covariates before and after propensity score matching [27, 28].

$p < 0.050$ was considered statistically significant for all tests. Stata® version 14 (StataCorp, College Station, Texas, USA) was used for all analyses.

Results

Before matching

A total of 505 patients undergoing combined liver and colorectal surgery were analysed, including 415 patients undergoing LS and 90 undergoing RS (Fig. 1).

Patients were enrolled from 46 Italian centers of which 24 performed both LS and RS, 5 only RS and 17 only LS. The total number of enrolments per year remained stable throughout the period of the study conversely, the percentage of RS increased progressively during the years (Fig. 2).

As reported in Table 1, age was statistically higher in LS group with median of 72 years old compared to 68 years old of the RS group. The other demographic characteristics were comparable between the two groups: 58.06% of the patients in the LS group were male, 56.90% in the RS group, a median BMI of 25 kg/m2 was found in both cohorts, no statistically significant differences were found for these variables.

In the two groups, the largest hepatic lesion was bigger than 3 cm in a similar rate of patients (32.05% in LS group and 30.00% in the RS group, $p = 0.705$). However, significantly more technically challenging hepatectomies

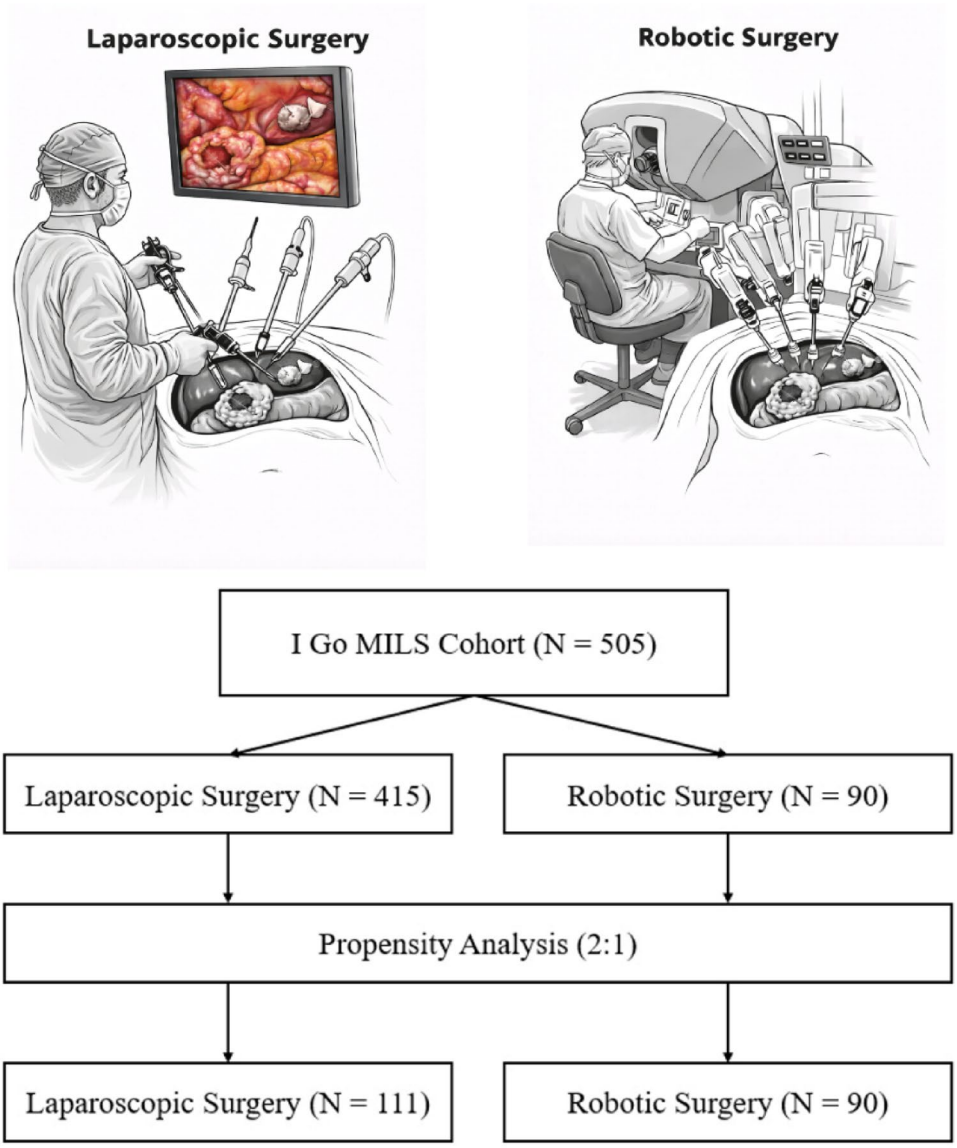

Fig. 1 Flow chart of the study population

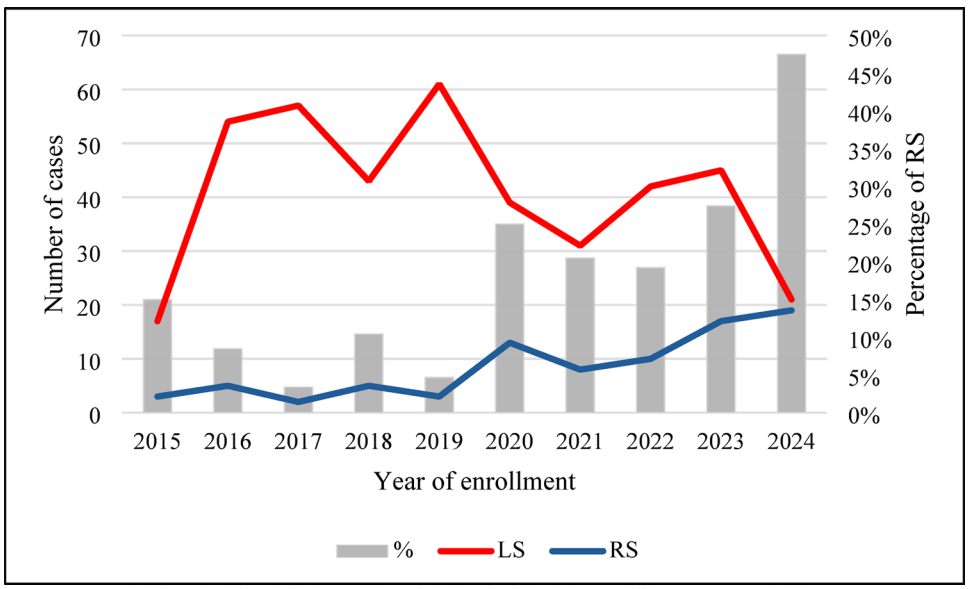

Fig. 2 Number of cases enrolled each year in LS and RS groups and percentage of RS over the total of patients enrolled that year

Table 1 Demographic and clinical characteristics before and after nearest neighbor matching.

	Before matching			After matching		
	Laparoscopic n = 415	Robotic n = 90	*p*-value	Laparoscopic n = 111	Robotic n = 90	*p*-value
Age (years) median [25–75%]	72 [62–79]	68 [60–74]	< 0.001	66 [58–74]	68 [60–74]	0.692
Sex, Male	236 (56.87%)	56 (62.22%)	0.351	72 (64.86%)	56 (62.22%)	0.698
BMI (Kg/m^2) median [25–75%]	25 [23–28]	26 [23–28]	0.582	25 [23–28]	26 [23–28]	0.906
Underlying liver parenchyma			0.149			0.538
Healthy	313 (75.42%)	61 (67.78%)		77 (69.37%)	61 (67.78%)	
Steatosis	95 (22.89%)	26 (28.89%)		30 (27.03%)	26 (28.89%)	
Chronic hepatocellular dysfunction	4 (0.96%)	3 (3.33%)		2 (1,80%)	3 (3.33%)	
Cirrhosis	3 (0.72%)	0		2 (1.80%)	0	
Diameter of the largest lesion ≥ 3 cm	133 (32.05%)	27 (30.00%)	0.705	33 (29.73%)	27 (30.00%)	0.967
Resection type			0.008			0.546
Wedge resection	199 (47.95%)	33 (36.67%)		52 (46.85%)	33 (36.67%)	
Anatomical segmentectomy	90 (21.69%)	21 (23.33%)		25 (22.52%)	21 (23.33%)	
Left lateral sectionectomy	31 (7.47%)	4 (4.44%)		5 (4.50%)	4 (4.44%)	
Right anterior sectionectomy	32 (7.71%)	8 (8.89%)		10 (9.01%)	8 (8.89%)	
Right posterior sectionectomy	18 (4.34%)	6 (6.67%)		6 (5.41%)	6 (6.67%)	
Left hepatectomy	28 (6.75%)	9 (10.00%)		8 (7.21%)	9 (10.00%)	
Right hepatectomy	16 (3.86%)	6 (6.67%)		5 (4.50%)	6 (6.67%)	
Right/Left trisectionectomy	1 (0.24%)	0		0	0	
ALPPS	0	3 (3.33%)		0	3 (3.33%)	
Technical Complexity			0.005			0.277
Grade I	256 (61.69%)	40 (44.44%)		59 (53.15%)	40 (44.44%)	
Grade II	124 (29.88%)	35 (38.89%)		41 (36.94%)	35 (38.89%)	
Grade III	35 (8.43%)	15 (16.67%)		11 (9.91%)	15 (16.67%)	
High volume center	259 (62.41%)	43 (47.78%)	0.010	53 (47.75%)	43 (47.78%)	0.997

Technical complexity based on Kawaguchi et al. [26]. Categorical variables were compared using chi-squared test or Fisher's exact test, as appropriate. Continuous variables were analysed using the Mann–Whitney U test

[26] were performed with RS rather than LS (grade II and III, 38.89% vs 29,88% and 16.67% vs 8.43%, respectively, $p = 0.005$). A higher percentage of surgeries performed in high volume centres was found in LS group (62.41% vs 47.78%, $p = 0.010$) (Table 1).

Perioperative data are presented in Table 2. A statistically significant longer operative time was found for robotic compared to laparoscopic resections (420 vs 360 min, $p < 0.001$). However, similar blood loss (200 vs. 150 ml, $p = 0.921$), intraoperative transfusions (6.75% vs. 7.78%, $p = 0.727$) and conversion to laparotomy rate (10.60% vs. 6.67%, $p = 0.257$) were detected in LS and RS cohorts.

Regarding postoperative data, in Table 2 it is showed that the same rate of complication was present in the two groups (34.22% in LS and 33.33% in RS groups, $p = 0.873$), in particular the most represented type of complication were the presence of abdominal infections and intestinal complications. Major postoperative complications occurred in 14.46% of patients treated with LS and 8.89% treated with RS ($p = 0.161$). The length of hospital stay was equivalent in the two groups (7 vs 7 days, $p = 0.626$) as well as the postoperative 90-days mortality.

After matching

After matching, the LS group comprised 111 patients and the RS group 90 patients. Age, BMI, ratio of male patients and rate of operations performed in high volume hospitals were similar.

We found the major hepatic lesion bigger than 30 mm in 29.73% of the patients in LS group and in 30.00% of the patients in RS group without a statistically significant difference between the two ($p = 0.967$).

The technical difficulty [26] of the hepatic resections were comparable between the two groups with a *p*-Value of 0.277.

Operative time was of 405 min in LS group and 420 min in RS group ($p = 0.589$), median intraoperative blood loss was of 200 ml in LS group and 150 ml in RS group ($p = 0.793$), the rate of intraoperative blood transfusion was 7.21% and 7.78% in LS and RS groups ($p = 0.878$), the rate of conversion to laparotomy was 11.71% for LS and 6.67% for RS ($p = 0.224$).

Regarding postoperative complications, RS and LS groups showed a similar rate of total complications (33.33% vs 40,54%, respectively, $p = 0.293$) and mortality but RS had

Table 2 Intraoperative and postoperative data before and after nearest neighbor matching.

	Before matching			After matching		
	Laparoscopic n = 415	Robotic n = 90	*p*-Value	Laparoscopic n = 111	Robotic n = 90	*p*-Value
Operative time, min median [25–75%]	360 [270–480]	420 [340–510]	< 0.001	405 [321–510]	420 [340–510]	0.589
Blood loss, mL median [25–75%]	200 [100–300]	150 [100–300]	0.921	200 [50–350]	150 [100–300]	0.793
Pringle Maneuvre	227 (54.70%)	40 (44.44%)	0.077	63 (56.76%)	40 (44.44%)	0.082
Intraoperative RBC transfusion	28 (6.75%)	7 (7.78%)	0.727	8 (7.21%)	7 (7.78%)	0.878
Conversion	44 (10.60%)	6 (6.67%)	0.257	13 (11.71%)	6 (6.67%)	0.224
Hemorrhage	4 (0,96%)	2 (2.22%)		1 (0.90%)	2 (2.22%)	
Adhesions	6 (1.45%)	2 (2.22%)		0	2 (2.22%)	
Oncologic reasons	31 (7,47%)	2 (2.22%)		10 (9.01%)	2 (2.22%)	
Iatrogenic injury	1 (0.24%)	0		1 (0.90%)	0	
Anaesthesiological reasons	4 (0.96%)	0		1 (0.90%)	0	
Postoperative complications	142 (34.22%)	30 (33.33%)	0.873	45 (40.54%)	30 (33.33%)	0.293
Bleeding	7 (1.69%)	3 (3.33%)		3 (2.70%)	3 (3.33%)	
Bile leak	14 (3.37%)	2 (2.22%)		4 (3.60%)	2 (2.22%)	
Intestinal complications	30 (7,23%)	2 (2.22%)		10 (9.01%)	2 (2.22%)	
SSI	12 (2,89%)	6 (6.67%)		1 (0.90%)	6 (6.67%)	
Abdominal infections	30 (7,23%)	7 (7.78%)		11 (9.91%)	7 (7.78%)	
Pneumonia	11 (2.65%)	4 (4.44%)		3 (2.70%)	4 (4.44%)	
Liver failure	11 (2.65%)	3 (3.33%)		3 (2.70%)	3 (3.33%)	
Postoperative major complication (CD > 2)	60 (14.46%)	8 (8.89%)	0.161	24 (21.62%)	8 (8.89%)	0.014
Lenght of Hospital Stay, days	7 [6–10]	7 [6–10]	0.626	8 [6–12]	7 [6–10]	0.305
90-days mortality	3 (0.72%)	2 (2.22%)	0.193	2 (1.80%)	2 (2.22%)	0.832

RBC: red blood cells, CD: Clavien-Dindo classification. Categorical variables were compared using chi-squared test or Fisher's exact test, as appropriate. Continuous variables were analysed using the Mann–Whitney U test

a significant lower rate of major complications (8.89% vs 21.62%, respectively, $p = 0.014$).

The length of hospital stay was 8 days for LS and 7 days for RS cohort, but no significant difference was detected ($p = 0.305$).

Discussion

The present study demonstrates that robotic surgery (RS) and laparoscopic surgery (LS) achieve comparable short-term outcomes in the setting of simultaneous resection for colorectal cancer and synchronous colorectal liver metastases (CRLM), despite a clear tendency to allocate more technically demanding liver resections to the robotic platform.

The pre-matching analysis indeed indicates that perioperative outcomes are similar between RS and LS, even though procedures with higher hepatic complexity were preferentially performed robotically. Interestingly, most laparoscopic procedures were carried out in high-volume centers. This finding suggests that, while advanced laparoscopic liver surgery remains largely concentrated in expert institutions, robotic technology may allow low- and medium-volume centers to safely manage complex cases that might otherwise require referral or conversion to open surgery. In this perspective, RS may contribute to an "equalization" of access to minimally invasive liver surgery (MILS), expanding its benefits beyond highly specialized centers.

The optimal surgical strategy for synchronous CRLM remains a matter of debate. Although the simultaneous approach is increasingly adopted, international guidelines still lack precise recommendations. Most consensus statements suggest simultaneous resection primarily for patients requiring limited hepatectomy, while not excluding major hepatectomies in selected cases [2, 4, 29]. Within this evolving landscape, the present multicenter Italian registry study suggests that RS facilitates the implementation of MILS and enables surgeons to safely perform more complex hepatic resections during simultaneous procedures, without increasing postoperative morbidity.

Despite this imbalance in technical complexity, perioperative outcomes were remarkably similar between RS and LS. Operative time, estimated blood loss, transfusion rate, conversion to open surgery, and length of hospital stay did not differ significantly between the two approaches. Postoperative outcomes were also comparable in the overall cohort. However, in the matched analysis, RS was associated with a reduced risk of severe postoperative morbidity, suggesting a potential protective effect of the robotic platform when procedural complexity and institutional factors are adequately balanced. The impact of the learning curve in both RS and LS was not investigated in this study; however,

it may represent a factor influencing clinical outcomes and should therefore be considered also in the specific context of synchronous resections for CRLM. New studies are needed to assess this topic.

These findings are consistent with the growing body of literature comparing robotic and laparoscopic approaches in liver surgery and, more specifically, in CRLM. A recent meta-analysis by Safiejko et al. [30], including 3210 patients undergoing minimally invasive liver resection for CRLM, reported a significantly lower conversion rate for RS compared with LS (6.7% vs 12.4%, $p<0.001$), with no differences in 30-day mortality, overall complications, length of hospital stay, or short-term oncological outcomes. Importantly, survival at 1, 2, and 3 years was comparable between the two techniques, supporting oncological non-inferiority of RS. Similarly, the network meta-analysis by Mkabaah et al. [31], including 6582 patients, confirmed that both laparoscopic and robotic approaches are superior to open surgery in terms of postoperative outcomes, with no significant differences between the two minimally invasive techniques in major complications, R0 resection rate, disease-free survival, or overall survival. Notably, RS was associated with a lower need for blood transfusion, whereas LS showed a modest advantage in length of hospital stay.

When focusing specifically on simultaneous resections, the systematic review by Suarez-Benitez et al. [20], including 165 patients undergoing combined robotic colorectal and liver resection, reported highly favorable outcomes, with a conversion rate of 3.9%, a major complication rate of 9.3%, a 30-day mortality of 0.9%, and an R0 resection rate of 99%. Although based mainly on retrospective series, these data further support the technical feasibility and safety of the robotic platform in highly demanding combined procedures.

An additional major strength of the present study is the size of the cohort, which, to the best of our knowledge, represents the largest series currently available specifically addressing minimally invasive simultaneous resections for CRLM. The large sample size enhances the robustness of the analyses and allows meaningful comparisons even in complex surgical scenarios. Furthermore, the registry-based nature of the study, relying on data from the national I Go MILS registry, constitutes a key methodological advantage. By including cases independently of institutional volume, the registry reflects real-world practice characterized by substantial heterogeneity in expertise and case mix. This feature is particularly relevant when assessing the role of robotic surgery, as it enables evaluation of its impact beyond highly specialized centers and supports the hypothesis that robotic technology may facilitate the safe dissemination of MILS on a national scale.

The lower rate of severe postoperative complications observed in the matched robotic cohort deserves further consideration. This finding may be partially related to intraoperative factors, whereby the technical advantages of the robotic platform may allow a more controlled and safer management of intraoperative adverse events, ultimately translating into improved postoperative outcomes. However, this interpretation remains speculative and will require future dedicated analyses focusing on intraoperative events and their relationship with postoperative morbidity.

Economic considerations remain a critical issue. Multiple studies based on large administrative databases have consistently demonstrated higher costs associated with robotic procedures compared with laparoscopy, without clear improvements in clinical outcomes [32–34]. Cost-effectiveness analyses have shown unfavorable incremental cost-effectiveness ratios for RS under current economic models, suggesting that its routine use in standard cases should be carefully weighed against economic sustainability. In this context, the role of RS may be best justified in complex cases where it enables a minimally invasive approach that might otherwise not be feasible.

One potential limitation of this study is the limited granularity of data regarding colorectal resection. Specifically, details on the type of colectomy performed (e.g., right- versus left-sided) and the use of a diverting stoma were not systematically available, due to the structure of the database. These factors may play a role in influencing postoperative outcomes, particularly in the setting of simultaneous surgery, where the risk of complications can be affected by the complexity and location of the colorectal resection as well as by the need for protective stomas. The absence of these variables precluded a more detailed risk stratification and may have introduced residual confounding. Nevertheless, given the large sample size, we believe that this limitation is unlikely to substantially alter the main interpretation of our findings. Future multicenter studies, ideally prospective or randomized, could further explore these aspects.

The technical difference between performing the hepatic resection before or after the colorectal resection was not analyzed due to lack of data. It can be speculated that if the colorectal resection is performed first, the anastomosis may be exposed to venous stasis due to the Pringle maneuver, which is often required during the hepatic resection. In addition, a low central venous pressure is commonly induced during the hepatic phase in order to reduce bleeding. Both of these conditions could be detrimental to the colorectal anastomosis, potentially increasing the risk of dehiscence. Despite that, there is no specific recommendation in the literature favoring one approach over the other; both strategies are considered acceptable, and there is no evidence of

a difference in clinical outcomes. Further studies are necessary to answer this specific question.

Another potential limitation of this study is the use of the Kawaguchi score [26] to classify the difficulty of liver resections. This scoring system has been validated only for laparoscopic procedures; however, it has already been applied in the literature in studies comparing robotic and laparoscopic surgery [35, 36]. Although a difficulty scoring system specifically designed for robotic liver resections has been proposed [37], it was not compatible with the variables available in the I Go MILS database and would have made comparisons with laparoscopic cases more difficult to interpret. For these reasons, we opted to use the Kawaguchi score.

In conclusion, robotic surgery appears to offer superior feasibility whenever technically challenging hepatic resections are required in the setting of simultaneous surgery for colorectal cancer and synchronous liver metastases, while maintaining perioperative outcomes comparable to laparoscopy. When adjusted analyses are applied, RS may be associated with a reduced risk of severe postoperative morbidity. Rather than replacing laparoscopy, robotic surgery should be regarded as a complementary tool that allows extension of minimally invasive liver surgery to more complex procedures and to a broader range of centers, thereby potentially maximizing patient access to the benefits of MILS.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13304-026-02684-w.

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by G. Traina and F. Ratti. The first draft of the manuscript was written by G. Traina and F. Ratti and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability The data underlying this study were derived from a multicenter registry. Due to data-sharing agreements amongparticipating centers and patient confi dentiality requirements, the dataset is not publicly available. De-identifi eddata may be made available from the corresponding author upon reasonable request, subject to approval by thestudy steering committee and participating institutions.

Declarations

Conflict of interest The authors declare no conflict of interest.

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