Updates in Surgery (2023) 75:1457–1469
https://doi.org/10.1007/s13304-023-01597-2

ORIGINAL ARTICLE

# Ten years of Italian mini-invasiveness: the I Go MILS registry as a tool of dissemination, characterization and networking

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Received: 11 July 2023 / Accepted: 15 July 2023 / Published online: 24 July 2023


**Abstract**

Purposes of this study are to evaluate the main changes that have occurred in the Italian MILS activity in the last decade in terms of indications, approaches and outcomes as reported in the national registry and to provide specific details on the main areas of development of MILS. Data from patients undergoing minimally invasive liver resections at centers included in the I Go MILS Registry from its start-up (November 2014) to March 2023 were analyzed for the purposes of this study. The registry is intention-to-treat and prospective. Global recruitment trends stratified by indication to surgery and type of approach were analysed. 7413 MILS procedures were performed across all centers (median number of procedures per center: 63). Years (2020–2023) displayed a significantly higher proportion of treated patients diagnosed with hepatocellular carcinoma (HCC) (38.2% vs. 28.9% and 33.9%, $p<0.001$) and cholangiocarcinoma (6.7% vs. 6.5% and 4.2%, $p<0.001$) compared to the preceding triennial periods. Additionally, technical complexity demonstrated an increased prominence in Years (2019–2023) with a significantly higher percentage of grade III cases compared to the earlier periods (39.3% vs. 21.7% and 25.6%, $p<0.001$). Annual case trends focusing on laparoscopic and robotic techniques demonstrated a steadily increase in the use of these techniques for complex case mix of indications. Overall, attitude and attention to MILS approach has evolved, so that currently indications to hepatic mini-invasiveness have expanded and surgical technique has been refined: Areas mainly involved in increasing growth trends are hepatocellular carcinoma, possible applications of MILS in transplant setting, intrahepatic cholangiocarcinoma and robotic approach.

**Keywords** Laparoscopy · Robotics · Registry · Liver surgery · Evolution

## Introduction

The last decade has marked the establishment and consolidation of the role of minimally invasive approach (MILS—Minimally Invasive Liver Surgery) in every center with an active program of liver surgery [1–3]. This implementation process has gone through a phase of acquisition of progressive technical expertise and the creation of specific training opportunities [4–6], but had also a benefit from the growing availability and technological improvements in dedicated and advanced instrumentations [7–10]: modern operating rooms are indeed equipped for intraoperative navigation (indocyanine green, 3D reconstructions, augmented reality), for precise dissection of vascular intrahepatic structures and for adequately addressing the task of parenchymal transection. This favorable scenario contributed to a safe dissemination of MILS in Italy and worldwide, so that the estimated MILS/total liver resection ratio in Europe is presently 30% [3]. Together with this evolution in the real-life clinical setting, high quality randomized trials, large cohort studies and meta-analyses strongly supported the adoption of laparoscopic approach in hepatobiliary surgery showing the perioperative advantages of MILS for patients—crosswise distributed among different indications (i.e., hepatocellular carcinoma, colorectal metastases, cholangiocarcinoma and benign diseases)—and confirmed its adequacy from the oncological perspective [11–17].

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Even before the recommendation to prospectively register MILS activity was indicated through international guidelines [18], this specific need was perceived in Italy and leaded to the early creation of the I Go MILS (Italian Group of MILS) national registry specifically dedicated to minimally invasive liver activity. The initiative was born in 2013 and become active with the first enrollments since 2014: it was designed and built to respond to specific tasks of registries, providing snapshots of the activity and trends over the years, developing original studies based on the national series collected in an intention-to-treat modality and to analyze the quality of MILS in Italy [1, 2, 19, 20].

The main purpose of this study is therefore to evaluate the main changes that have occurred in the Italian MILS activity in the last decade in terms of indications, approaches and outcomes as reported in the national registry. Secondary purposes are to provide specific details on the main areas of development of MILS in terms of general features and perioperative results indications and to describe the current availability of human and technological resources dedicated to minimally invasive liver surgery on a national basis.

## Materials and methods

Data from patients undergoing minimally invasive liver resections at centers included in the I Go MILS Registry from its start-up (November 2014) to March 2023 were analyzed for the purposes of this study. As reported elsewhere [1, 2], the I Go MILS registry is intention-to-treat and prospective. To specifically fulfill primary and secondary endpoints, global recruitment trends stratified by indication to surgery and type of approach were analysed. The whole period of recruitment was stratified in three periods (i.e., years 2014–2016; years 2017–2019; years 2020–2023) to evaluate characteristics of recruited cases and perioperative outcomes. The filling out of a specific online questionnaire was also requested aimed at providing an overview of MILS approach in the whole scenario of liver resection activity and at studying recent implementation areas and human and technological availabilities.

### Registry centers

Each center with minimally invasive activity, regardless of the level of expertise and the number of expected recruitments, was admitted to the registry, having the possibility to enroll patients after the approval by the local ethical committee. A specific written consent for inclusion in the study and for data storage was waived from patients. Details regarding data protection and collection are reported elsewhere. No superimposition regarding surgical techniques and inclusion to MILS was provided to centers, as per registry nature [1, 2].

### eCRF for data logging and registry variables

Case registration was developed through an eCRF (electronic platform for clinical trials management) accessible through personal passwords for investigator and allowing to enter data and to consult previously entered outcomes (data entered from other centers are not accessible for consultation). Data for analysis required for individual studies are provided only upon specific request to the scientific director and approval by the scientific board of the I Go MILS Group. Each patient is assigned an automatically generated numeric code after enrollment and all data are stored in anonymized mode.

The case report form—as already described elsewhere—is composed of three separate modules: enrollment, surgery and postoperative data [1, 2]. The total number of variables required to complete the CRF is 37.

### Outcomes evaluation

Total number of inclusions per year, as well as inclusions per approach were evaluated: the yearly case count and the corresponding annual case increase, both in absolute terms and as a percentage, for laparoscopic and robotic procedures were analyzed. Preoperative characteristics including diagnosis, location, size and number of lesions were recorded. Level of technical difficulty was graded according to Kawaguchi classification, defining three degrees of complexity based on type and site of resection [21]. Mortality was calculated as any death occurring during hospitalization or within 30 days from surgery. Postoperative complications were graded according to Dindo–Clavien classification of surgical complications [22].

### Additional questionnaire

Centers involved in the I Go MILS Registry were asked to complete an additional questionnaire to provide details regarding evolution and changes in MILS in recent years, as well as availability of intraoperative navigation tools and technological resources. Surgeons were asked to complete one questionnaire per center. Centers and respondents identity was not blinded and was explicitly required, to avoid overlapping data (contact data from the respondent were required to consider the questionnaire valid). The questionnaire was open and shared on Google Forms, hence the results were automatically exported in Excel for storage and subsequent analysis. The survey was sent out on 25 June 2023 with 7 days available to respond.

### Statistics

All variables were compared using the $\chi^2$ or Fisher's exact test for categorical data, the Mann–Whitney *U* test for non-normally distributed continuous data, and Student's *t*-test for normally distributed continuous variables. All data are expressed as a mean plus or minus the standard deviation or median and range. Time series analysis using an exponential smoothing model was used to forecast the trends in the implementation of robotic liver resection. Significance was defined as $p < 0.05$. All analyses were performed using the statistical package SPSS 18.0 (SPSS, Chicago, IL, USA).

## Results

### Participants

All data analyzed derived from the "I Go MILS Registry," which included a total of seventy-nine Italian HPB centers. Among these centers, 13 (16.5%) were specialized liver transplant centers. Between November 1, 2014, and March 31, 2023, a total of 7413 MILS procedures were performed across all centers. The median number of procedures per center was 63 (range 2–1387). Median ratio between MILS and total liver resections is 41%, showing an increasing trend compared to 30% of ratio reported 5 years ago and 15% reported 10 years ago. A median of 3 surgeons per center perform laparoscopic liver resections (compared to 1 surgeon 5 years ago). Indocyanine green vision is available in 89% of centers, 3D reconstructions in 52% of centers and augmented reality in 10.7% of centers.

To examine the time trends of MILS throughout the study period, data with missing information regarding the exact operation date were excluded ($n = 233$), resulting in a total of 7180 MILS procedures being assessed. The study timeline was divided into three-year periods: November 1, 2014, to December 31, 2016, which accounted for 879 MILS procedures (12.2%); January 1, 2017, to December 31, 2019, which accounted for 2578 MILS procedures (35.9%); and January 1, 2020, to December 31, 2023, which accounted for 3723 MILS procedures (51.8%).

### Annual trend of pure laparoscopic liver resections

The pure laparoscopic approach to liver resections accounted for a total of 5960 cases. Table 1 displays the yearly case increase and the corresponding percentage for each year from 2014 to 2023.

In 2014, there were only 10 cases recorded, serving as the baseline for the analysis. Subsequently, the number of cases steadily increased over the years. In 2015, there was a significant jump in cases, with an increase of 173 cases, representing a percentage increase of 1730%. The trend continued in 2016, where an additional 414 cases were observed, showing a substantial yearly case increase of 226.30%. From 2017 to 2019, the yearly case increases were more modest, ranging from 5.59% to 12.59%. However, in 2020, the growth slowed down, with only 14 additional cases reported (a 1.77% increase). The upward trend resumed in 2021, with 115 more cases compared to the previous year, corresponding to a yearly case increase of 14.26%. Finally, in 2023, the largest yearly case increase was observed, with 308 additional cases reported, representing a substantial percentage increase of 33.44%. Main reasons contributing to the increase in MILS activity are widened criteria for MILS access (68% of centers), wider technological availability (68% of centers) and higher number of surgeons performing MILS (52% of centers). Inclusion to MILS approach is based on: difficulty scores (47% of centers), specific criteria for MILS inclusion (42% of centers) or specific criteria for open approach inclusion (15.9% of centers).

**Table 1** Annual trend of laparoscopic liver resections

| Laparoscopic approach | | | |
|---|---|---|---|
| Year | Cases $n = 5960$ | Yearly case increase | Yearly case increase, percentage (%) |
| 2014 | 10 | | |
| 2015 | 183 | +173 | 1730 |
| 2016 | 597 | +414 | 226.30 |
| 2017 | 667 | +70 | 11.71 |
| 2018 | 751 | +84 | 12.59 |
| 2019 | 793 | +42 | 5.59 |
| 2020 | 807 | +14 | 1.77 |
| 2021 | 922 | +115 | 14.26 |
| 2022 | 1230 | +308 | 33.44 |

The yearly case count and the corresponding annual case increase, both in absolute terms and as a percentage, for laparoscopic procedures from 2014 to 2022 is displayed

The data shows the consistent growth of the laparoscopic approaches, with notable variations in yearly case increases ($p < 0.001$)

### Annual trend of pure robotic liver resections

A pure robotic approach was applied for a total of 1080 cases. Table 2 presents the yearly case increase and the corresponding percentage for each year from 2014 to 2023.

In 2014, there were no recorded cases of the robotic approach. However, in the subsequent years, the utilization of robotic procedures increased steadily. In 2015, there were 27 cases, indicating an increase of 27 cases compared to the previous year (N/A percentage since it was the first year of recording). The trend continued in 2016, with an additional 18 cases reported, representing a yearly case increase of

**Table 2** Annual trend of robotic liver resections

| Robotic approach | | | |
|---|---|---|---|
| Year | Cases $n=1080$ | Yearly case increase | Yearly case increase, percentage (%) |
| 2014 | 0 | | |
| 2015 | 27 | +27 | N/A |
| 2016 | 45 | +18 | 66.67 |
| 2017 | 74 | +29 | 64.44 |
| 2018 | 103 | +29 | 39.19 |
| 2019 | 125 | +22 | 21.36 |
| 2020 | 129 | +4 | 3.2 |
| 2021 | 162 | +33 | 25.58 |
| 2022 | 415 | +253 | 156.17 |

The yearly case count and the corresponding annual case increase, both in absolute terms and as a percentage, for robotic procedures from 2014 to 2022 is displayed

The data shows the consistent growth of the robotic approach, with notable variations in yearly case increases ($p<0.001$)

66.67%. In 2017, there was a further increase of 29 cases, resulting in a 64.44% yearly case increase. From 2018 to 2019, the yearly case increases were more modest, ranging from 21.36% to 39.19%. In 2021, the number of cases rose to 162, with an additional 33 cases compared to the previous year, reflecting a yearly case increase of 25.58%. Finally, in 2023, the largest yearly case increase was observed, with 253 additional cases reported, representing a substantial percentage increase of 156.17%.

Figure 1 presents a visual analysis of annual case trends from the IGoMILS registry, focusing on the utilization of various minimally invasive approaches such as hybrid, laparoscopic, single-port, and robotic techniques.

## Snapshot from the pure robotic cohort: baseline characteristics and outcomes

Table 3a displays the results of Minimal Invasive Liver Surgery (MILS) with a particular emphasis on the following aspects: pure robotic liver resections, MILS for Hepatocellular Carcinoma (HCC), MILS for Cholangiocarcinoma, and MILS in centers with dedicated transplant programs. An annual case trends analysis from the registry, specifically focusing on the reported diagnosis in the final pathology of the patients is shown in Fig. 2.

The pure robotic cohort consisted of a total of 1080 cases. The median age of the patients was 68 years (range 43–76). Male patients accounted for 59.2% of the cohort. The median BMI was 25.5 kg/m2 (range 21.2–28.9). Among the patients, 44.2% had a history of previous hepatic resection, 42.1% had gastrointestinal surgery, and 48.2% had other previous surgeries. Cirrhosis was present in 24.0% of the cases. Regarding the diagnosis, 18.5% had benign lesions, 36.5% had hepatocellular carcinoma (HCC), 27.9% had colorectal cancer (CCR) metastases, 6.2% had cholangiocarcinoma, and 6.8% had other diagnoses. Multiple lesions were observed in 24.5% of cases, and 45.1% had the largest lesion with a diameter ≥ 3 cm. The resection types included wedge resection (49.7%), anatomical segmentectomy (20.7%), left lateral sectionectomy (11.3%), right anterior sectionectomy (0.7%), right posterior sectionectomy (2.3%), left hepatectomy (4.9%), right hepatectomy (4.5%), and right/left trisectionectomy

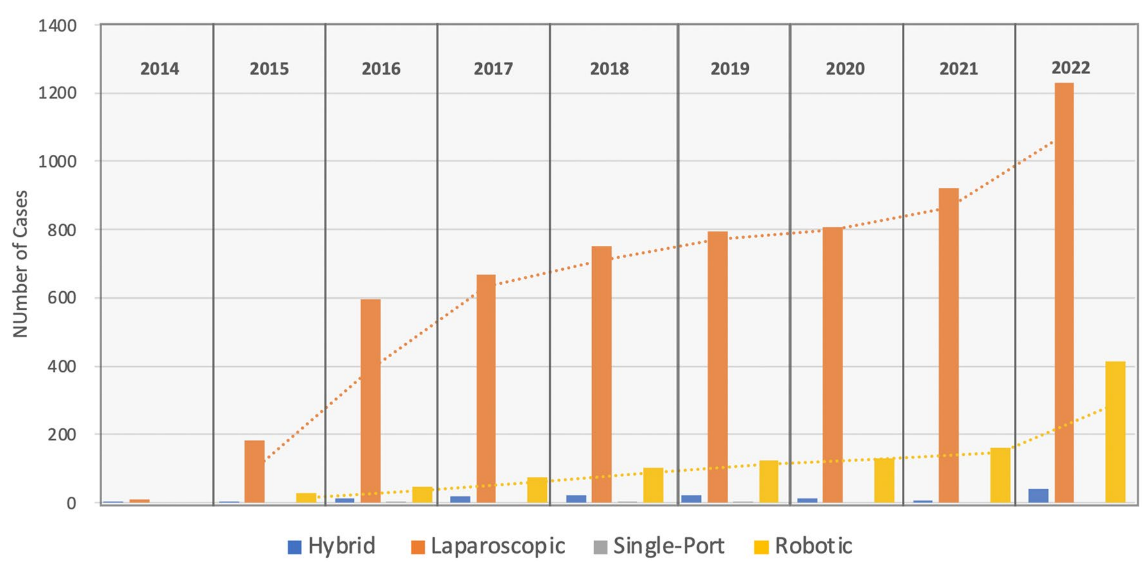


**Fig. 1** Analysis of annual case trends from the IGoMILS registry based on the application of different minimally invasive approaches (hybrid, laparoscopic, single-port, robotic)

**Table 3** a Baseline characteristics of the entire patient cohort from the IGoMILS registry, categorized according to resection type (robotic), diagnosis at final pathology (HCC and Cholangiocarcinoma) and transplant activity. b Perioperative outcomes of the entire patient cohort from the IGoMILS registry, categorized according to resection type (robotic), diagnosis at final pathology (HCC and Cholangiocarcinoma) and transplant activity

| 3a | Robotic<br>*N* = 1080 | HCC<br>*N* = 2553 | Cholangiocarcinoma<br>*N* = 455 | Transplant center<br>*N* = 2126 |
|---|---|---|---|---|
| Age (years) | 68 (43–76) | 69 (49–76) | 65 (41–72) | 68 (46–73) |
| Sex, male | 639 (59.2) | 1617 (63.3) | 261 (57.4) | 1263 (59.4) |
| BMI (Kg/m$^2$) | 25.5 (21.2–28.9) | 25.8 (23.2–28.7) | 24.5 (22.7–27.4) | 25.3 (21.5–28.7) |
| Previous surgery | 477 (44.2) | 1186 (46.5) | 46 (10.1) | 723 (34.0) |
| Hepatic resection | 201 (42.1) | 498 (42.0) | 5 (10.9) | 164 (22.7) |
| Gastrointestinal | 230 (48.2) | 218 (18.4) | 38 (82.6) | 320 (44.3) |
| Other | 46 (9.6) | 470 (39.6) | 3 (6.5) | 239 (33.0) |
| Cirrhosis | 259 (24.0) | 1067 (41.8) | 108 (23.7) | 766 (36.0) |
| Diagnosis | | NA | NA | |
| Benign | 200 (18.5) | | | 438 (20.6) |
| HCC | 394 (36.5) | | | 964 (45.3) |
| CCR metastases | 301 (27.9) | | | 370 (17.4) |
| Cholangiocarcinoma | 67 (6.2) | | | 122 (5.7) |
| Other | 74 (86.8) | | | 232 (10.9) |
| Multiple lesions | 265 (24.5) | 815 (31.9) | 143 (31.4) | 756 (35.6) |
| Diameter of the largest lesion ≥ 3 cm | 487 (45.1) | 1437 (56.3) | 239 (52.5) | 978 (46.0) |
| Resection type | | | | |
| Wedge resection | 537 (49.7) | 1302 (51.0) | 29 (6.4) | 1186 (55.8) |
| Anatomical segmentectomy | 224 (20.7) | 615 (24.1) | 203 (44.6) | 440 (20.7) |
| Left lateral sectionectomy | 122 (11.3) | 286 (11.2) | 55 (12.1) | 265 (12.5) |
| Right anterior sectionectomy | 8 (0.7) | 20 (0.8) | 21 (4.6) | 33 (1.5) |
| Right posterior sectionectomy | 25 (2.3) | 60 (2.4) | 23 (5.0) | 34 (1.6) |
| Left hepatectomy | 53 (4.9) | 105 (4.1) | 47 (10.3) | 89 (4.2) |
| Right hepatectomy | 49 (4.5) | 80 (3.1) | 43 (9.4) | 54 (2.5) |
| Right/left trisectionectomy | 62 (5.7) | 85 (3.3) | 34 (7.5) | 25 (1.2) |
| Technical complexity* | | | | |
| Grade I | 659 (61.0) | 1588 (62.2) | 84 (18.5) | 1451 (68.2) |
| Grade II | 258 (23.9) | 646 (25.3) | 208 (45.7) | 394 (18.5) |
| Grade III | 163 (15.1) | 319 (12.5) | 163 (35.8) | 281 (13.2) |
| Approach | NA | | | |
| Hybrid | | 64 (2.5) | 6 (1.4) | 62 (2.9) |
| Laparoscopic | | 2093 (82.0) | 370 (83.5) | 1869 (87.9) |
| Single-Port | | 2 (0.08) | 0 (0.0) | 2 (0.09) |
| Robotic | | 394 (15.4) | 67 (15.1) | 193 (9.1) |

| 3b | Robotic<br>*N* = 1080 | HCC<br>*N* = 2553 | Cholangiocarcinoma<br>*N* = 455 | |
|---|---|---|---|---|
| Conversion | 19 (1.8) | 213 (8.3) | 50 (11.0) | 163 (7.7) |
| Hemorrhage | 6 (31.6) | 41 (19.2) | 12 (24.0) | 54 (33.1) |
| Adhesions | 5 (26.3) | 34 (16.0) | 8 (16.0) | 57 (35.0) |
| Oncologic reasons | 3 (15.8) | 116 (54.5) | 23 (46.0) | 24 (14.7) |
| Iatrogenic injury | 1 (5.3) | 5 (2.3) | 5 (10.0) | 11 (6.7) |
| Anaesthesiological reasons | 4 (21.0) | 17 (8.0) | 7 (14.0) | 17 (10.4) |
| R1 margin | 102 (9.4) | 206 (8.1) | 39 (8.6) | 195 (9.2) |
| Blood loss, mL | 200 (100–450) | 320 (250–550) | 350 (210–550) | 370 (150–620) |
| Operative time, min | 330 (150–420) | 240 (120–350) | 270 (180–360) | 280 (180–410) |
| Any complications | 299 (27.7) | 556 (21.8) | 103 (22.6) | 432 (20.3) |

**Table 3** (continued)

| 3b | Robotic $N = 1080$ | HCC $N = 2553$ | Cholangiocarcinoma $N = 455$ | |
|---|---|---|---|---|
| Major complications | 56 (5.2) | 174 (6.8) | 39 (8.6) | 198 (9.3) |
| 90-days Mortality | 6 (0.6) | 10 (0.4) | 3 (0.7) | 17 (0.8) |
| LOS (days) | 4 (3–7) | 5 (3–8) | 5 (4–8) | 5 (4–9) |

* Classification of complexity according to Kawaguchi-Gayet classification

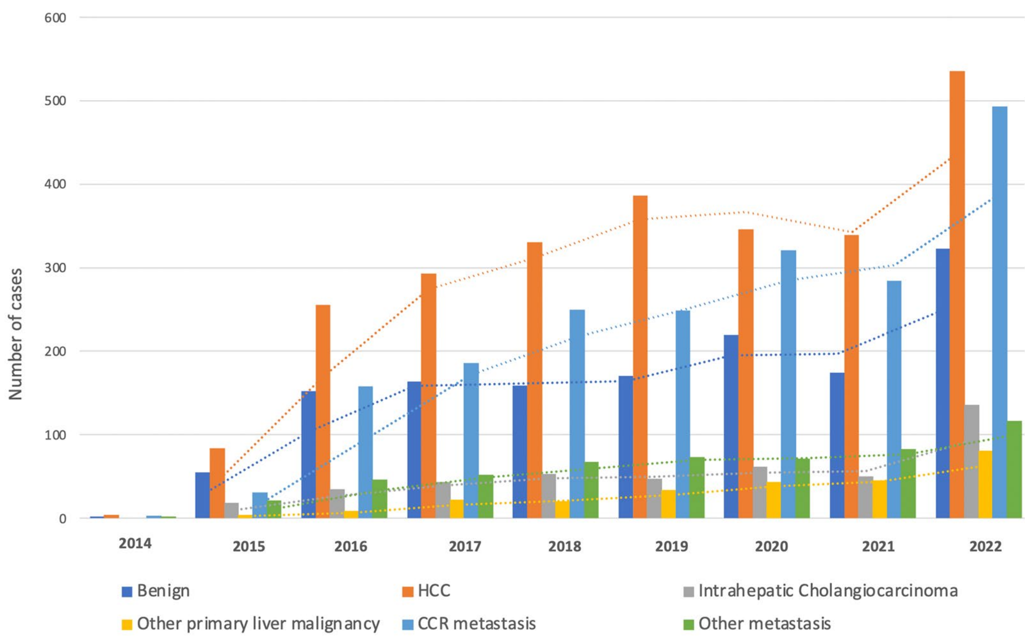


**Fig. 2** Analysis of annual case trends from the IGoMILS registry based on the diagnosis reported at final pathology

(5.7%). Technical complexity was graded as grade I in 61.0% of cases, grade II in 23.9%, and grade III in 15.1%. The majority of cases were performed using the robotic approach.

Table 3b focuses on the conversion rates and surgical outcomes of robotic liver resections. Among the 1080 cases, the conversion rate was 1.8%. The most common reasons for conversion included hemorrhage (31.6%), adhesions (26.3%), oncologic reasons (15.8%), iatrogenic injury (5.3%), and anesthesiological reasons (21.0%). R1 margins, indicating incomplete resection, were observed in 9.4% of cases. The median blood loss was 200 mL (range 100–450), while the median operative time was 330 min (range 150–420). Any complications were observed in 27.7% of cases, with major complications occurring in 5.2% of cases. The 90-day mortality rate was 0.6%, and the median length of hospital stay was 4 days (IQR: 3–7). Figure 3 displays the results of a time series analysis utilizing an exponential smoothing model to forecast future trends in the implementation of robotic activity over the next seven years. According to the model, by September 3030, there is a predicted overall increase of 120.3% in pure robotic resections.

## Baseline characteristics according to triennial trends (2014–2016; 2017–2019 and 2020–2023)

In the time case analysis of the evolving triennial trends in MILS, several statistically significant findings emerged across different time periods (Table 4). The incidence of previous surgeries, particularly previous hepatic resections, exhibited a significant increase in Years (2019–2023) compared to both Years (2014–2016) and Years (2017–2019) (41.3% vs. 18.2% and 26.1%, $p = 0.003$). Conversely, the prevalence of cirrhosis was significantly lower in Years (2020–2023) in comparison to the earlier time periods (23.7% vs. 26.7% and 26.8%, $p < 0.001$).

Regarding the final pathology diagnosis, Years (2020–2023) displayed a significantly higher proportion of treated patients diagnosed with hepatocellular carcinoma

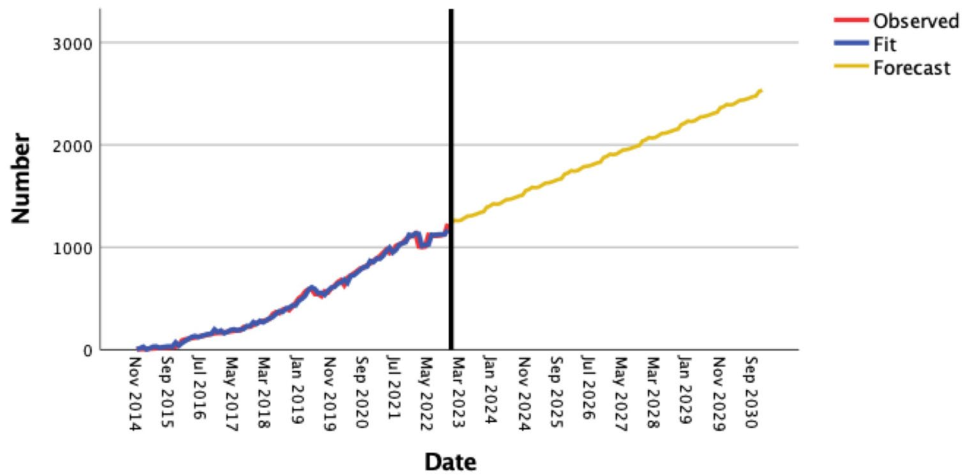


**Fig. 3** Time series analysis using an exponential smoothing model to forecast the trends in the implementation of robotic liver resection. The *x*-axis represents time, while the *y*-axis represents the number of robotic liver resections performed. The data points on the graph are actual historical values, and the line represents the predicted values based on the exponential smoothing model. By September 3030, the model predicts an increase of robotic liver resections by 120.3%

(HCC) (38.2% vs. 28.9% and 33.9%, $p < 0.001$) and cholangiocarcinoma (6.7% vs. 6.5% and 4.2%, $p < 0.001$) compared to the preceding triennial periods. Additionally, technical complexity demonstrated an increased prominence in Years (2019–2023) with a significantly higher percentage of grade III cases compared to the earlier periods (39.3% vs. 21.7% and 25.6%, $p < 0.001$). This was evidenced by an escalating trend in the performance of right/left trisectionectomies (3.6% vs. 5.5% vs. 8.6%, $p < 0.001$) and right hepatectomies (5.7% vs. 6.7% vs. 10.6%, $p < 0.001$) reaching its apex in the last triennial period.

Furthermore, the laparoscopic approach was more commonly utilized in Years (2014–2019) with a significantly higher proportion of patients undergoing this technique compared to the last triennial period (89.9% and 85.8% vs. 79.5%, $p < 0.001$). Notably, there was a significant progression in the implementation of the robotic platform observed in the last triennial period (Years 2020–2023) (19.0% vs. 11.7% vs. 8.2%, $p < 0.001$).

### Perioperative outcomes according to triennial trends (2014–2016; 2017–2019 and 2020–2023)

The analysis of surgical outcomes across different time periods is presented in Table 5. Significant differences were observed in the conversion rates, with Years (2019–2023) exhibiting a lower percentage of conversions (6.9% vs. 8.2% vs. 10.0%, $p = 0.001$). The most common reason for conversion was adherence (31.0%), followed by hemorrhage (29.1%). Additionally, a significant difference was observed in the occurrence of major complications ($p = 0.028$), with Years (2019–2023) demonstrating a lower percentage of major complications compared to the preceding triennial periods (4.5% vs. 5.8% and 5.5%).

## Discussion

Data arising from the ten-year experience of the I Go MILS registry document on the one hand the large-scale consequences of the implementation of minimally invasive techniques in the field of liver resection and, on the other side, the effects of availability of growing body of evidence regarding the benefits of these techniques. Interestingly indeed, areas mainly involved in increasing growth trends are the same ones where clinical research efforts have focused in recent years: surgery of hepatocellular carcinoma in patients with impaired liver function, MILS for intrahepatic cholangiocarcinoma, robotic approach and finally possible applications of MILS in transplant setting.

Overall, attitude and attention to MILS approach has evolved, so that currently indications to hepatic mini-invasiveness have expanded to include complex resection; surgical technique has been refined to maintain principles of anatomical resections, intraoperative safety and oncological principles.

The presence of hepatocellular carcinoma as the most frequent indication in minimally invasive series is constant in all eras [1, 2, 16, 23]: in fact, the specific advantages of this approach in HCC have been widely acknowledged. Nevertheless, surgical aptitude has changed so that minimally invasive approach is more frequently considered in patients showing hepatic functional impairment and/or high disease burden. On the one hand indeed, portal hypertension and Child B conditions are not considered anymore an absolute contraindication to surgery, especially in MILS setting, while on the other, there is a growing trend of inclusion to MILS of complex and repeated hepatic resections [24–27]: the advantages of mini-invasiveness are indeed proportionally wider in more complex situations, providing a rationale for the expansion

**Table 4** Baseline characteristics of the entire patient cohort from the IGoMILS registry, categorized into three different timeframes: 2014–2016, 2017–2019, and 2020–2023

| | Years (2014–2016) N = 879 | Years (2017–2019) N = 2578 | Years (2020–2023) N = 3723 | *p* value |
|---|---|---|---|---|
| Age (years) | 66 (43–81) | 66 (45–83) | 69 (41–84) | 0.467 |
| Sex, male | 494 (56.2) | 1529 (59.3) | 2183 (58.6) | 0.270 |
| BMI (Kg/m$^2$) | 25.3 (21.1–28.9) | 25.6 (20.9–28.4) | 25.8 (20.2–29.1) | 0.312 |
| Previous surgery | 160 (18.2) | 672 (26.1) | 1537 (41.3) | 0.003 |
| Hepatic resection | 41 (25.6) | 186 (27.7) | 463 (30.1) | |
| Gastrointestinal | 103 (64.4) | 475 (70.7) | 998 (64.9) | |
| Other | 16 (10.0) | 11 (1.6) | 76 (4.9) | |
| Cirrhosis | 235 (26.7) | 692 (26.8) | 882 (23.7) | < 0.001 |
| Diagnosis | | | | < 0.001 |
| Benign | 269 (30.6) | 641 (24.9) | 710 (19.1) | |
| HCC | 254 (28.9) | 875 (33.9) | 1424 (38.2) | |
| CCR metastases | 188 (21.4) | 682 (26.4) | 991 (26.6) | |
| Cholangiocarcinoma | 37 (4.2) | 167 (6.5) | 251 (6.7) | |
| Other | 131 (14.9) | 213 (8.3) | 347 (9.3) | |
| Multiple lesions | 254 (28.9) | 786 (30.5) | 1157 (31.1) | 0.445 |
| Diameter of the largest lesion ≥ 3 cm | 218 (24.8) | 711 (27.6) | 1008 (27.1) | 0.271 |
| Resection type | | | | < 0.001 |
| Wedge resection | 414 (47.1) | 998 (38.7) | 1194 (32.1) | |
| Anatomical segmentectomy | 195 (22.2) | 543 (21.1) | 711 (19.1) | |
| Left lateral sectionectomy | 53 (6.0) | 266 (10.3) | 321 (8.6) | |
| Right anterior sectionectomy | 47 (5.3) | 153 (5.9) | 151 (4.1) | |
| Right posterior sectionectomy | 39 (4.4) | 104 (4.0) | 219 (5.9) | |
| Left hepatectomy | 49 (5.6) | 197 (7.6) | 412 (11.1) | |
| Right hepatectomy | 50 (5.7) | 174 (6.7) | 394 (10.6) | |
| Right/left trisectionectomy | 32 (3.6) | 143 (5.5) | 321 (8.6) | |
| Technical complexity* | | | | < 0.001 |
| Grade I | 467 (53.1) | 1264 (49.0) | 1515 (40.7) | |
| Grade II | 221 (25.1) | 653 (25.3) | 745 (20.0) | |
| Grade III | 191 (21.7) | 661 (25.6) | 1463 (39.3) | |
| Approach | | | | < 0.001 |
| Hybrid | 16 (1.8) | 63 (2.4) | 58 (1.6) | |
| Laparoscopic | 790 (89.9) | 2211 (85.8) | 2959 (79.5) | |
| Single-port | 1 (0.1) | 2 (0.1) | 0 (0.0) | |
| Robotic | 72 (8.2) | 302 (11.7) | 706 (19.0) | |

*Kawaguchi classification: Grade I = wedge resection/left lateral sectionectomy, Grade II = anterolateral segmentectomies/left hepatectomy, Grade III = posterosuperior segmentectomy, right posterior sectionectomy, right hepatectomy, central hepatectomy or extended left/right hepatectomy

of indications as well as to push towards MILS as far as technically feasible [28].

In centers with a program of liver transplantation, the minimally invasive approach is today a fundamental tool that is experiencing a constant and fruitful evolution: indeed it may be chosen as a bridge treatment option before liver transplantation, as the approach of choice in living donors, and—in pioneering series – to perform recipient hepatectomy and advanced transplant programs for oncological indications [29–32]. Today, it is hence fascinating to observe how two areas initially considered antipodes (i.e., transplantation and minimally invasiveness) are currently different aspects of a complex mosaic of therapeutic options for patients with liver diseases.

Cholangiocarcinoma was the latest indication to break down the barriers of minimally invasiveness. Due to the frequent need for complex resections and the indication to perform a formal lymphadenectomy, cholangiocarcinoma surgery represents itself a niche field in the setting of hepatic surgery. Among centers dealing specifically with

**Table 5** Perioperative outcomes of the entire patient cohort from the IGoMILS registry, categorized into three different timeframes: 2014–2016, 2017–2019, and 2020–2023

| | Years (2014–2016) N = 879 | Years (2017–2019) N = 2578 | Years (2020–2023) N = 3723 | *p* value |
|---|---|---|---|---|
| Conversion | 88 (10.0) | 211 (8.2) | 258 (6.9) | 0.001 |
| Hemorrhage | 23 (26.1) | 52 (24.6) | 75 (29.1) | |
| Adhesions | 15 (17.0) | 73 (35.6) | 80 (31.0) | |
| Oncologic reasons | 42 (47.7) | 49 (23.2) | 45 (17.4) | |
| Iatrogenic injury | 6 (6.8) | 32 (15.2) | 31 (12.0) | |
| Anaesthesiological reasons | 2 (2.3) | 15 (7.1) | 27 (10.5) | |
| R1 margin | 116 (13.2) | 253 (9.8) | 369 (9.9) | 0.002 |
| Blood loss, mL | 200 (50–350) | 250 (50–300) | 200 (50–350) | 0.672 |
| Operative time, min | 250 (180–420) | 300 (160–450) | 300 (170–460) | 0.243 |
| Any complications | 180 (20.5) | 558 (21.6) | 822 (22.1) | 0.084 |
| Major complications | 51 (5.8) | 143 (5.5) | 167 (4.5) | 0.028 |
| 90-days mortality | 3 (0.3) | 8 (0.3) | 7 (0.2) | 0.265 |
| LOS (days) | 5 (4–8) | 5 (3–9) | 5 (4–9) | 0.482 |

cholangiocarcinoma, concerns regarding the oncological adequacy and short-term benefits of MILS been overcome only in recent years. In the past, some authors raised skepticism about the possibility of obtaining an adequate lymphadenectomy by the minimally invasive technique: unfortunately, the presence of these report—invalidated by the presence of obsolete series in which patients subjected to lymph node sampling at low-volume centers had also been included – has significantly slowed the spread of this approach [33, 34]. Maintaining oncological adequacy as a fundamental principle, it is currently known that image magnification and the availability of adequate dissection tools are advantages in MILS over open surgery in these patients [35]. In particular, robotic approach increases surgical performance in nodal dissection, overcoming laparoscopic capability of achieving an adequate lymphadenectomy with at least 6 lymph nodes retrieved [36].

Robotic surgery constitutes the main area of present study and interest of MILS community. It has certainly developed later in liver surgery compared to other areas of abdominal surgery due to the still limited diffusion and availability of the robotic platform and also to concerns of surgeons regarding the lack of ultrasonic dissector generally used in open and laparoscopic surgery [3]. Data from the current series demonstrates that the robotic approach is actively growing, with reasonable estimates of further explosion in the coming years. On the one hand indeed, alternative technical solutions including hybrid robotic-laparoscopic approach have been developed, allowing to maximize the benefits of both approaches [37] (i.e., the dexterity of robotics and the precision of laparoscopic ultrasonic dissection) and, on the other hand, reports of superiority of robotics in situations of greater technical complexity have been published [38, 39]. It is in fact possible that—thanks to a better control of intraoperative adverse events—the robotic technique is burdened by a lower risk of laparotomic conversion in difficult resections: the patient is hence exposed to a lower risk of postoperative morbidity and mortality which seems correlated to the conversion itself [40]. It is therefore reasonable that in the short-term future, the need to focus on the topic of robotic training will be perceived, as well as the necessity to outline the settings in which robot-assisted surgery determines specific advantages (and hence cost-effectiveness) compared to laparoscopy, while preserving the benefits of mini-invasiveness.

The perception of the need to have advanced instrumentation and dedicated operating theaters available to offer patients suffering from liver disease safe surgery has created the background to the current diffusion of advanced intraoperative navigation tools in many Italian centers: while the availability and the expertise in performing intraoperative ultrasound is a mandatory and considered a consolidated prerequisite, an increasing number of centers report the availability of vision systems based on fluorescence with indocyanine green, three-dimensional reconstruction methods of preoperative images and the possibility of using of augmented reality. It is therefore possible that in these technologies will become soon an integral part of the instruments available for liver surgeons, both for the purpose of training the new generations and to improve the fine surgical planning and therefore optimize the results.

The creation of the Italian registry has condensed around the same initiative different needs born within the MILS area: beside addressing the task of providing an effective tool to snapshot the state of the art and to directly detect changes of trends on a national and local basis, the registry has contributed to the creation of a community that fulfills the desire to provide peers a technical and cultural background. Furthermore, it has laid the foundations for a school of minimally invasive liver surgery and the consequent increase in the number of surgeons performing MILS in each center. Finally it has allowed an analysis of the quality of Italian MILS surgery and the evaluation of benchmarks values for morbidity according to complexity.

Thanks to the early timing of the I Go MILS registry creation, it had an active inclusion and participation in the era of greater growth and differentiation of MILS in Italy and in the world: it is reasonable this prospectively maintained dataset will keep representing an effective tool for the Italian hepatobiliary community from the cultural, scientific and technical perspective.

**Acknowledgements** List of collaborators of the Italian Group of Minimally Invasive Liver Surgery (I Go MILS): Rebecca Marino, Nadia Russolillo, Andrea Ruzzenente, Enrico Gringeri, Francesco Ardito, Carlo Sposito, Riccardo De Carlis, Marco Colasanti, Pasquale Bonsignore, Stefano Di Sandro, Giuliano La Barba, Mario Giuffrida, Matteo Cescon, Matteo Barabino, Ugo Boggi, Mohammed Abu Hilal, Giovanni Vennarecci, Giorgio Rossi, Gian Luca Grazi, Antonio Frena, Leonardo Vincenti, Alberto Brolese, Fulvio Calise, Luca Morelli, Fausto Zamboni, Raffaele Romito, Guido Torzilli, Stefano Berti, Guido Griseri, Marco Filauro, Marco Massani, Giacomo Batignani, Riccardo Memeo, Giuseppe Navarra, Giuseppe Tisone, Andrea Coratti, Graziano Ceccarelli, Marco Vivarelli, Giulio Belli, Christian Cotsoglou, Pietro Mezzatesta, Adelmo Antonucci, Luigi Veneroni, Michele Colledan, Amilcare Parisi, Silvio Guerriero, Marco Spada, Antonio Floridi, Giovanni Sgroi, Paola Tarchi, Dario Lorenzin, Alberto Patriti, Dario Ribero, Pietro Maida, Luigi Boni, Andrea Percivale, Umberto Montin, Stefano Mancini, Marcello Spampinato.

**Data availability statement** Data from the present study will be made available upon reasonable request.

## Declarations

**Conflict of interest** There is no personal conflicts of interest of any of the authors. The first author had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

**Research involving human participants and/or animals** The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

**Informed consent** IRB approval was obtained from institutional ethical committees (I Go MILS Registry protocol) of each participating center and informed consent from subjects was waived.

## References

1. Aldrighetti L, Belli G, Boni L, Cillo U, Ettorre G, De Carlis L, Pinna A, Casciola L, Calise F, Italian Group of Minimally Invasive Liver Surgery (I GO MILS) (2015) Italian experience in minimally invasive liver surgery: a national survey. Updates Surg 67(2):129–140. https://doi.org/10.1007/s13304-015-0307-2
2. Aldrighetti L, Ratti F, Cillo U, Ferrero A, Ettorre GM, Guglielmi A, Giuliante F, Calise F, Italian Group of Minimally Invasive Liver Surgery (I GO MILS) (2017) Diffusion, outcomes and implementation of minimally invasive liver surgery: a snapshot from the I Go MILS (Italian Group of Minimally Invasive Liver Surgery) Registry. Updates Surg 69(3):271–283. https://doi.org/10.1007/s13304-017-0489-x
3. Zwart MJW, Görgec B, Arabiyat A, Nota CLM, van der Poel MJ, Fichtinger RS, Berrevoet F, van Dam RM, Aldrighetti L, Fuks D, Hoti E, Edwin B, Besselink MG, Abu Hilal M, Hagendoorn J, Swijnenburg RJ, Dutch Liver Collaborative Group and E-AHPBA Innovation & Development Committee (2022) Pan-European survey on the implementation of robotic and laparoscopic minimally invasive liver surgery. HPB (Oxford) 24(3):322–331. https://doi.org/10.1016/j.hpb.2021.08.939
4. Halls MC, Alseidi A, Berardi G, Cipriani F, Van der Poel M, Davila D, Ciria R, Besselink M, D'Hondt M, Dagher I, Alrdrighetti L, Troisi RI, Abu HM (2019) A comparison of the learning curves of laparoscopic liver surgeons in differing stages of the IDEAL paradigm of surgical innovation: standing on the shoulders of pioneers. Ann Surg 269(2):221–228. https://doi.org/10.1097/SLA.0000000000002996
5. Wakabayashi G, Cherqui D, Geller DA, Buell JF, Kaneko H, Han HS, Asbun H, O'Rourke N, Tanabe M, Koffron AJ, Tsung A, Soubrane O, Machado MA, Gayet B, Troisi RI, Pessaux P, Van Dam RM, Scatton O, Abu Hilal M, Belli G, Kwon CH, Edwin B, Choi GH, Aldrighetti LA, Cai X, Cleary S, Chen KH, Schön MR, Sugioka A, Tang CN, Herman P, Pekolj J, Chen XP, Dagher I, Jarnagin W, Yamamoto M, Strong R, Jagannath P, Lo CM, Clavien PA, Kokudo N, Barkun J, Strasberg SM (2015) Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. Ann Surg 261(4):619–629. https://doi.org/10.1097/SLA.0000000000001184
6. Ratti F, Fiorentini G, Cipriani F, Paganelli M, Catena M, Aldrighetti L (2019) Safety of minimally invasive liver resections during live surgery: a propensity score based assessment. HPB (Oxford) 21(3):328–334. https://doi.org/10.1016/j.hpb.2018.08.015
7. Wakabayashi T, Cacciaguerra AB, Abe Y, Bona ED, Nicolini D, Mocchegiani F, Kabeshima Y, Vivarelli M, Wakabayashi G, Kitagawa Y (2022) Indocyanine green fluorescence navigation in liver surgery: a systematic review on dose and timing of administration. Ann Surg 275(6):1025–1034. https://doi.org/10.1097/SLA.0000000000005406
8. Berardi G, Colasanti M, Meniconi RL, Ferretti S, Guglielmo N, Mariano G, Burocchi M, Campanelli A, Scotti A, Pecoraro A, Angrisani M, Ferrari P, Minervini A, Gasparoli C, Wakabayashi G, Ettorre GM (2021) The applications of 3D imaging and indocyanine green dye fluorescence in laparoscopic liver surgery. Diagnostics (Basel) 11(12):2169. https://doi.org/10.3390/diagnostics11122169
9. Schneider C, Allam M, Stoyanov D, Hawkes DJ, Gurusamy K, Davidson BR (2021) Performance of image guided navigation in laparoscopic liver surgery—a systematic review. Surg Oncol 38:101637. https://doi.org/10.1016/j.suronc.2021.101637
10 Gavriilidis P, Edwin B, Pelanis E, Hidalgo E, de'Angelis N, Memeo R, Aldrighetti L, Sutcliffe RP (2022) Navigated liver surgery: state of the art and future perspectives. Hepatobiliary Pancreat Dis Int 21(3):226–233. https://doi.org/10.1016/j.hbpd.2021.09.002
11. Ciria R, Ocaña S, Gomez-Luque I, Cipriani F, Halls M, Fretland ÅA, Okuda Y, Aroori S, Briceño J, Aldrighetti L, Edwin B, Hilal MA (2020) A systematic review and meta-analysis comparing the short- and long-term outcomes for laparoscopic and open liver resections for liver metastases from colorectal cancer. Surg Endosc 34(1):349–360. https://doi.org/10.1007/s00464-019-06774-2
12. Fretland ÅA, Dagenborg VJ, Bjørnelv GMW, Kazaryan AM, Kristiansen R, Fagerland MW, Hausken J, Tønnessen TI, Abildgaard A, Barkhatov L, Yaqub S, Røsok BI, Bjørnbeth BA, Andersen

MH, Flatmark K, Aas E, Edwin B (2018) Laparoscopic versus open resection for colorectal liver metastases: the OSLO-COMET randomized controlled trial. Ann Surg 267(2):199–207. https://doi.org/10.1097/SLA.0000000000002353
13. Ratti F, Rawashdeh A, Cipriani F, Primrose J, Fiorentini G, Abu Hilal M, Aldrighetti L (2021) Intrahepatic cholangiocarcinoma as the new field of implementation of laparoscopic liver resection programs. A comparative propensity score-based analysis of open and laparoscopic liver resections. Surg Endosc 35(4):1851–1862. https://doi.org/10.1007/s00464-020-07588-3
14. Ardito F, Aldrighetti L, Guglielmi A, Jovine E, Cillo U, Ferrero A, De Carlis L, Belli G, Dalla Valle R, Slim A, Mazzaferro V, Navarra G, Ettorre GM, Calise F, Pinna AD, Giuliante F, Italian Group of Minimally Invasive Liver Surgery (I Go MILS) (2020) Surgical management of hepatic benign disease: have the number of liver resections increased in the era of minimally invasive approach? Analysis from the I Go MILS (Italian Group of Minimally Invasive Liver Surgery) Registry. J Gastrointest Surg 24(10):2233–2243. https://doi.org/10.1007/s11605-019-04260-7
15. Viganò L, Cimino M, Aldrighetti L, Ferrero A, Cillo U, Guglielmi A, Ettorre GM, Giuliante F, Dalla Valle R, Mazzaferro V, Jovine E, De Carlis L, Calise F, Torzilli G, Italian Group of Minimally Invasive Liver Surgery (I Go MILS) (2020) Multicentre evaluation of case volume in minimally invasive hepatectomy. Br J Surg 107(4):443–451. https://doi.org/10.1002/bjs.11369
16. Giuliante F, Ratti F, Panettieri E, Mazzaferro V, Guglielmi A, Ettorre GM, Gruttadauria S, Di Benedetto F, Cillo U, De Carlis L, Dalla Valle R, Ferrero A, Santambrogio R, Ardito F, Aldrighetti L, IgoMILS – Small HCC Group (2023) Short and long-term outcomes after minimally invasive liver resection for single small hepatocellular carcinoma: an analysis of 714 patients from the IGoMILS (Italian group of minimally invasive liver surgery) registry. HPB (Oxford) 25(6):674–683. https://doi.org/10.1016/j.hpb.2023.02.007
17. Rocca A, Cipriani F, Belli G, Berti S, Boggi U, Bottino V, Cillo U, Cescon M, Cimino M, Corcione F, De Carlis L, Degiuli M, De Paolis P, De Rose AM, D'Ugo D, Di Benedetto F, Elmore U, Ercolani G, Ettorre GM, Ferrero A, Filauro M, Giuliante F, Gruttadauria S, Guglielmi A, Izzo F, Jovine E, Laurenzi A, Marchegiani F, Marini P, Massani M, Mazzaferro V, Mineccia M, Minni F, Muratore A, Nicosia S, Pellicci R, Rosati R, Russolillo N, Spinelli A, Spolverato G, Torzilli G, Vennarecci G, Viganò L, Vincenti L, Delrio P, Calise F, Aldrighetti L (2021) The Italian Consensus on minimally invasive simultaneous resections for synchronous liver metastasis and primary colorectal cancer: a Delphi methodology. Updates Surg 73(4):1247–1265. https://doi.org/10.1007/s13304-021-01100-9
18. Abu Hilal M, Aldrighetti L, Dagher I, Edwin B, Troisi RI, Alikhanov R, Aroori S, Belli G, Besselink M, Briceno J, Gayet B, D'Hondt M, Lesurtel M, Menon K, Lodge P, Rotellar F, Santoyo J, Scatton O, Soubrane O, Sutcliffe R, Van Dam R, White S, Halls MC, Cipriani F, Van der Poel M, Ciria R, Barkhatov L, Gomez-Luque Y, Ocana-Garcia S, Cook A, Buell J, Clavien PA, Dervenis C, Fusai G, Geller D, Lang H, Primrose J, Taylor M, Van Gulik T, Wakabayashi G, Asbun H, Cherqui D (2018) The Southampton consensus guidelines for laparoscopic liver surgery: from indication to implementation. Ann Surg 268(1):11–18. https://doi.org/10.1097/SLA.0000000000002524
19. Russolillo N, Aldrighetti L, Cillo U, Guglielmi A, Ettorre GM, Giuliante F, Mazzaferro V, Dalla Valle R, De Carlis L, Jovine E, Ferrero A, I Go MILS Group (2020) Risk-adjusted benchmarks in laparoscopic liver surgery in a national cohort. Br J Surg 107(7):845–853. https://doi.org/10.1002/bjs.11404
20. Cucchetti A, Aldrighetti L, Ratti F, Ferrero A, Guglielmi A, Giuliante F, Cillo U, Mazzaferro V, De Carlis L, Ercolani G, I Go MILS Group (2022) Variations in risk-adjusted outcomes following 4318 laparoscopic liver resections. J Hepatobiliary Pancreat Sci 29(5):521–530. https://doi.org/10.1002/jhbp.1141
21. Kawaguchi Y, Fuks D, Kokudo N, Gayet B (2018) Difficulty of laparoscopic liver resection: proposal for a new classification. Ann Surg 267(1):13–17. https://doi.org/10.1097/SLA.0000000000002176
22. Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, de Santibañes E, Pekolj J, Slankamenac K, Bassi C, Graf R, Vonlanthen R, Padbury R, Cameron JL, Makuuchi M (2009) The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg 250(2):187–196. https://doi.org/10.1097/SLA.0b013e3181b13ca2
23. Levi Sandri GB, Colasanti M, Aldrighetti L, Guglielmi A, Cillo U, Mazzaferro V, Dalla Valle R, De Carlis L, Gruttadauria S, Di Benedetto F, Ferrero A, Ettorre GM, I Go MILS Group on HCC (2022) Is minimally invasive liver surgery a reasonable option in recurrent HCC? A snapshot from the I Go MILS registry. Updates Surg 74(1):87–96. https://doi.org/10.1007/s13304-021-01161-w
24. Cipriani F, Ratti F, Fornoni G, Marino R, Tudisco A, Catena M, Aldrighetti L (2023) Conversion of minimally invasive liver resection for HCC in advanced cirrhosis: clinical impact and role of difficulty scoring systems. Cancers (Basel) 15(5):1432. https://doi.org/10.3390/cancers15051432
25. Serenari M, Lenzi J, Cucchetti A, Cipriani F, Donadon M, Ardito F, Fazio F, Nicolini D, Iaria M, Famularo S, Perri P, Ansaloni L, Zanello M, Lai Q, Conci S, Molfino S, Ferrari C, Germani P, Zago M, Romano M, Zimmitti G, Antonucci A, Fumagalli L, Troci A, Ferraro V, Memeo R, Crespi M, Chiarelli M, Ercolani G, Hilal MA, Zanus G, Pinotti E, Tarchi P, Griseri G, Baiocchi GL, Ruzzenente A, Rossi M, Jovine E, Maestri M, Grazi GL, Romano F, Dalla Valle R, Ravaioli M, Vivarelli M, Ferrero A, Giuliante F, Torzilli G, Aldrighetti L, Cescon M, HE.RC.O.LE.S. Group (2023) The effect of a liver transplant program on the outcomes of resectable hepatocellular carcinoma: a nationwide multicenter analysis. Ann Surg 277(4):664–671. https://doi.org/10.1097/SLA.0000000000005439
26. Morise Z, Aldrighetti L, Belli G, Ratti F, Belli A, Cherqui D, Tanabe M, Wakabayashi G, ILLS-Tokyo Collaborator group (2020) Laparoscopic repeat liver resection for hepatocellular carcinoma: a multicentre propensity score-based study. Br J Surg 107(7):889–895. https://doi.org/10.1002/bjs.11436
27. Serenari M, Ratti F, Zanello M, Guglielmo N, Mocchegiani F, Di Benedetto F, Nardo B, Mazzaferro V, Cillo U, Massani M, Colledan M, Dalla Valle R, Cescon M, Vivarelli M, Colasanti M, Ettorre GM, Aldrighetti L, Jovine E (2020) Minimally invasive stage 1 to protect against the risk of liver failure: results from the hepatocellular carcinoma series of the associating liver partition and portal vein ligation for staged hepatectomy Italian registry. J Laparoendosc Adv Surg Tech A 30(10):1082–1089. https://doi.org/10.1089/lap.2020.0563
28. Ratti F, Cipriani F, Fiorentini G, Catena M, Paganelli M, Aldrighetti L (2020) Reappraisal of the advantages of laparoscopic liver resection for intermediate hepatocellular carcinoma within a stage migration perspective: propensity score analysis of the differential benefit. J Hepatobiliary Pancreat Sci 27(8):510–521. https://doi.org/10.1002/jhbp.736
29. Serenari M, Ratti F, Guglielmo N, Zanello M, Mocchegiani F, Lenzi J, Colledan M, Mazzaferro V, Cillo U, Ferrero A, Cescon M, Di Benedetto F, Massani M, Grazi G, Valle RD, Vivarelli M, Ettorre GM, Aldrighetti L, Jovine E, ALPPS Italian Registry (2023) Evolution of minimally invasive techniques and surgical outcomes of ALPPS in Italy: a comprehensive trend analysis over 10 years from a national prospective registry. Surg Endosc 37(7):5285–5294. https://doi.org/10.1007/s00464-023-09937-4
30. Settmacher U, Ali-Deeb A, Coubeau L, Cillo U, Line PD, Guba M, Nadalin S, Rauchfuß F (2023) Auxilliary liver transplantation

according to the RAPID procedure in noncirrhotic patients: technical aspects and early outcomes. Ann Surg 277(2):305–312. https://doi.org/10.1097/SLA.0000000000005726
31. Di Benedetto F, Petrowsky H, Magistri P, Halazun KJ (2020) Robotic liver resection: hurdles and beyond. Int J Surg 82S:155–162. https://doi.org/10.1016/j.ijsu.2020.05.070
32. Cherqui D, Ciria R, Kwon CHD, Kim KH, Broering D, Wakabayashi G, Samstein B, Troisi RI, Han HS, Rotellar F, Soubrane O, Briceño J, Alconchel F, Ayllón MD, Berardi G, Cauchy F, Luque IG, Hong SK, Yoon YY, Egawa H, Lerut J, Lo CM, Rela M, Sapisochin G, Suh KS (2021) Expert consensus guidelines on minimally invasive donor hepatectomy for living donor liver transplantation from innovation to implementation: a joint initiative from the international laparoscopic liver society (ILLS) and the Asian-Pacific hepato-pancreato-biliary association (A-PHPBA). Ann Surg 273(1):96–108. https://doi.org/10.1097/SLA.0000000000004475
33. Aliseda D, Sapisochin G, Martí-Cruchaga P, Zozaya G, Blanco N, Goh BKP, Rotellar F (2023) Association of laparoscopic surgery with improved perioperative and survival outcomes in patients with resectable intrahepatic cholangiocarcinoma: a systematic review and meta-analysis from propensity-score matched studies. Ann Surg Oncol 30(8):4888–4901. https://doi.org/10.1245/s10434-023-13498-0
34. Guerrini GP, Esposito G, Tarantino G, Serra V, Olivieri T, Catellani B, Assirati G, Guidetti C, Ballarin R, Magistri P, Di Benedetto F (2020) Laparoscopic versus open liver resection for intrahepatic cholangiocarcinoma: the first meta-analysis. Langenbecks Arch Surg 405(3):265–275. https://doi.org/10.1007/s00423-020-01877-0
35. Ratti F, Fiorentini G, Cipriani F, Paganelli M, Catena M, Aldrighetti L (2019) Perioperative and long-term outcomes of laparoscopic versus open lymphadenectomy for biliary tumors: a propensity-score-based, case-matched analysis. Ann Surg Oncol 26(2):564–575. https://doi.org/10.1245/s10434-018-6811-0
36. Ratti F, Cipriani F, Ingallinella S, Tudisco A, Catena M, Aldrighetti L (2022) Robotic approach for lymphadenectomy in biliary tumours: the missing ring between the benefits of laparoscopic and reproducibility of open approach? Ann Surg. https://doi.org/10.1097/SLA.0000000000005748
37. Aldrighetti L, Catena M, Ratti F (2022) Maximizing performance in complex minimally invasive surgery of the liver: the RoboLap approach. J Gastrointest Surg 26(8):1811–1813. https://doi.org/10.1007/s11605-022-05340-x
38. Cipriani F, Fiorentini G, Magistri P, Fontani A, Menonna F, Annecchiarico M, Lauterio A, De Carlis L, Coratti A, Boggi U, Ceccarelli G, Di Benedetto F, Aldrighetti L (2022) Pure laparoscopic versus robotic liver resections: multicentric propensity score-based analysis with stratification according to difficulty scores. J Hepatobiliary Pancreat Sci 29(10):1108–1123. https://doi.org/10.1002/jhbp.1022
39. Chong CC, Fuks D, Lee KF, Zhao JJ, Choi GH, Sucandy I, Chiow AKH, Marino MV, Gastaca M, Wang X, Lee JH, Efanov M, Kingham TP, D'Hondt M, Troisi RI, Choi SH, Sutcliffe RP, Chan CY, Lai ECH, Park JO, Di Benedetto F, Rotellar F, Sugioka A, Coelho FF, Ferrero A, Long TCD, Lim C, Scatton O, Liu Q, Schmelzle M, Pratschke J, Cheung TT, Liu R, Han HS, Tang CN, Goh BKP, International Robotic and Laparoscopic Liver Resection study group investigators (2022) Propensity score-matched analysis comparing robotic and laparoscopic right and extended right hepatectomy. JAMA Surg 157(5):436–444. https://doi.org/10.1001/jamasurg.2022.0161
40. Halls MC, Cipriani F, Berardi G, Barkhatov L, Lainas P, Alzoubi M, D'Hondt M, Rotellar F, Dagher I, Aldrighetti L, Troisi RI, Edwin B, Abu HM (2018) Conversion for unfavorable intraoperative events results in significantly worse outcomes during laparoscopic liver resection: lessons learned from a multicenter review of 2861 cases. Ann Surg 268(6):1051–1057. https://doi.org/10.1097/SLA.0000000000002332



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