Italian experience in minimally invasive liver surgery: a national survey

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Abstract

This survey provides an overview about current spread of Minimally Invasive Liver Resection (MILR) in Italy. Primary endpoint was to assess evolution of MILR in recent years and its degree of application among centres with different experience in laparoscopic and hepatic surgery. A questionnaire with items describing activity MILR was sent to Italian surgical centers. Diagnosis, technical approaches, resection extent, devices and vascular control, reasons for conversion, morbidity and mortality were recorded. Level of expertise per centre was analysed in terms of learning curve acquisition and relationship with hepatobiliary background. 1497 MILRs from 39 centers (median 27 patients/center, range 1–145, period 1995–2012) were collected. Conversion rate was 10.7 % (180 patients out of 1677, excluded from subsequent analysis), with bleeding representing most frequent cause of conversion (34.4 %). Eleven centers completed learning curve, performing >60 MILR. Benign lesions were 27.5 % and malignant 72.5 %, with hepatocellular carcinoma being the most frequent indication. 92.6 % of cases were performed with a totally laparoscopic technique (1.3 % were hand-assisted, 1.9 % single-port and 4.2 % robotic). Minor resections accounted for 92.9 % (left lateral sectionectomy resulted the most frequent procedure; 23.8 %), while major resections represented 7.1 %. Overall mortality was 0.2 % (3 of 1497 patients) and morbidity 22.8 %. Mean length of stay was 5 days. Correlation between MILR activity and a hepatobiliary background was not clear comparing MILR cases and liver resection volumes per center. MILR has been significantly widespread in Italy in recent years, with several centers having definitely completed the learning curve as attested by clinical results consistent with major series from the Western and Eastern countries. MILR programs in Italy seem to arise from both centers with specific hepatobiliary expertise and centers performing advanced general laparoscopic surgery.

Keywords

Liver Minimally invasive Laparoscopy Liver resection Hepatectomy Survey

The members of Italian Group of Minimally Invasive Liver Surgery (I GO MILS) are listed in the Appendix

Introduction

Since its first application in 1992, the minimally invasive approach for liver resection (Minimally Invasive Liver Resection—MILR) has evolved significantly. Since 2000 it has been more widely introduced into clinical practice, gaining great success. Initially adopted in cases of wedge and minor anatomical resection for benign hepatic lesions, its application was then extended to major liver resection, and has gradually encompassed all kinds of primary [1] and secondary [2] malignant hepatic lesions.

In 2009, a comprehensive review of published series of MILR reported almost 3000 cases worldwide, highlighting the exponential growth in the application of this technique by surgeons experienced in both hepatic and laparoscopic surgery [3].

Several Italian studies have been published regarding minimally invasive liver surgery [1, 4–7], and the present survey aims to investigate whether MILR is still performed in Italy in just those few centers that are specifically committed to developing this type of surgery, or the laparoscopic approach that has spread across the country in recent years in capillary fashion. Similar surveys from Western countries are still lacking in the literature; as far as we know, only two national surveys on laparoscopic surgery for liver resection have been published, showing the gradual development of the minimally invasive approach in Korea [8] and Japan [9].

We therefore aim both to provide an overview on the current spread of the minimally invasive approach for liver resection in Italy, and to comment on the state-of-the-art of laparoscopic liver surgery from the viewpoint of a Western country.

Materials and methods

All Italian surgical centers were contacted through the mailing list of the Italian Chapter of the International Hepato-Pancreato-Biliary Association (IHPBA) and the *Società Italiana di*

Chirurgia [Italian Society of Surgery (SIC)]. The Survey was also announced in the SIC online newsletter.

Centers potentially interested in taking part in the survey were directly contacted through personal e-mail addresses or by phone whenever not already included in other mailing lists, or if it was felt they had not been reached (no answer received 1 month after the announcement).

The e-mail invitation to take part in the survey included a specific questionnaire regarding a series of items to describe the clinical activity of any center performing MILR selected by the promoting group (Luca Aldrighetti, Fulvio Calise, Luciano Casciola). More specific questions were added to give a better picture of the Italian experience in both robot-assisted liver resection, and simultaneous resection of liver metastases and colorectal cancer. All returned questionnaires were screened to eliminate any double counting of patients, even if no apparent duplicate data were found in the total number. A surgeon at each center was then identified for correspondence regarding data, or should there be the need to complete any missing data. No minimal cutoff in the number of cases was established for project inclusion, meaning that even small series were considered.

Only liver resection performed using a minimally invasive technique was taken into account, including totally laparoscopic, hand-assisted, single-port and robotic techniques. Tumor characteristics (benign, malignant), technical approaches (totally laparoscopic, hand-assisted, single-port, robotic), and the extent of resection (minor, major, wedge) were assessed and analyzed in detail. Intraoperative data regarding technical devices, vascular control and the number of resections for each patient were recorded. Reasons for conversion to open surgery, perioperative death, and complications were also recorded.

The centers were divided into two groups, according to the number of MILR performed, in order to study the reasons for conversion: Fully Trained Centers (FTC; more than 60 MILR), and Learning Curve Centers (LCC; less than 60 MILR). The cutoff value was based on the indications of Viganò et al. [10].

Finally, the start-up of MILR activity and the number of cases per year were taken into account for each center. We included all resections performed up to 28 February 2012.

Statistical analysis

All data were expressed as mean plus standard deviation or median and range. $p < 0.05$ was considered significant. Categorical variables were compared using the χ^2 test.

Analysis was carried out using the statistical package SPSS 18.0 (SPSS, Chicago, IL, USA). When required, the weighted mean was used instead of an arithmetic mean. The weighted mean considers the proportional relevance of each sample (i.e. data from each center had a different relevance according to the number of performed cases), rather than treat each sample equally.

Results

Thirty-nine centers from 11 Italian regions returned questionnaires and joined the initiative to establish the Italian National Survey Study Group (INSSG). Between 1 January 1995 and 28 February 2012, a total of 1,677 MILRs were performed in Italy, with a median of 27 patients per center (range 1–145). The complete list of participating centers, specifying their regional distribution, is shown in Fig. 1.

Fig. 1

Regional distribution of the 39 centers participating in the Survey

During the study period, a total of 16,244 liver resections (including open and minimally invasive resections) were performed at INSSG centers. MILR represented 10.3 % of all resections, with significant variety between centers: the MILR/total number of resections ratio per center ranged between 0.9 and 58 %, with a median of 11 % (Fig. 2). One center presented a series consisting only of MILR.

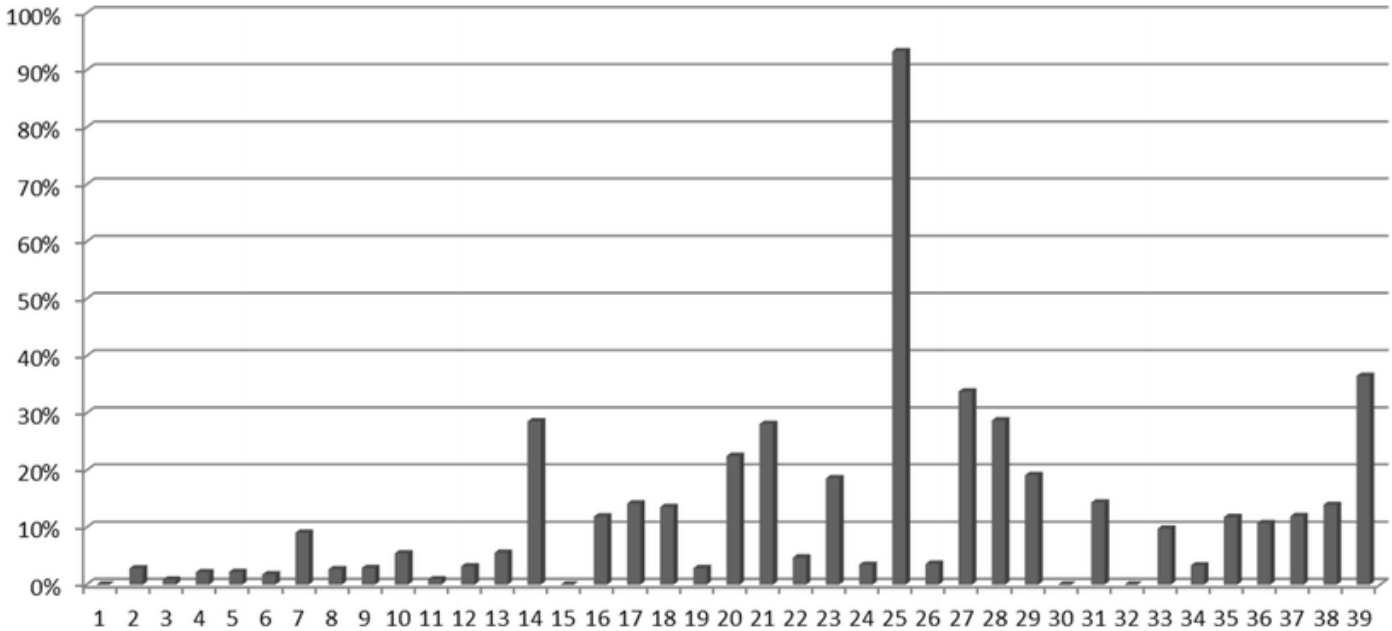

Fig. 2

A progressive number has been assigned to each center (*X* axis) according to the increasing number of laparoscopic cases. The MILR/open resection ratio per center is represented. For centers 1, 15, 30 and 32 a ratio was not assessable

Analysis showed that over time the volume of Italian cases increased progressively with an almost linear trend (Fig. 3). Moreover, once adopted no center abandoned the MILR approach. Figure 4 shows the number of MILR cases per center, indicating that 11 out of 39 centers exceeded 60 MILR procedures, considered the cutoff value for completion of the learning curve in laparoscopic liver surgery as described by Viganò et al. [10].

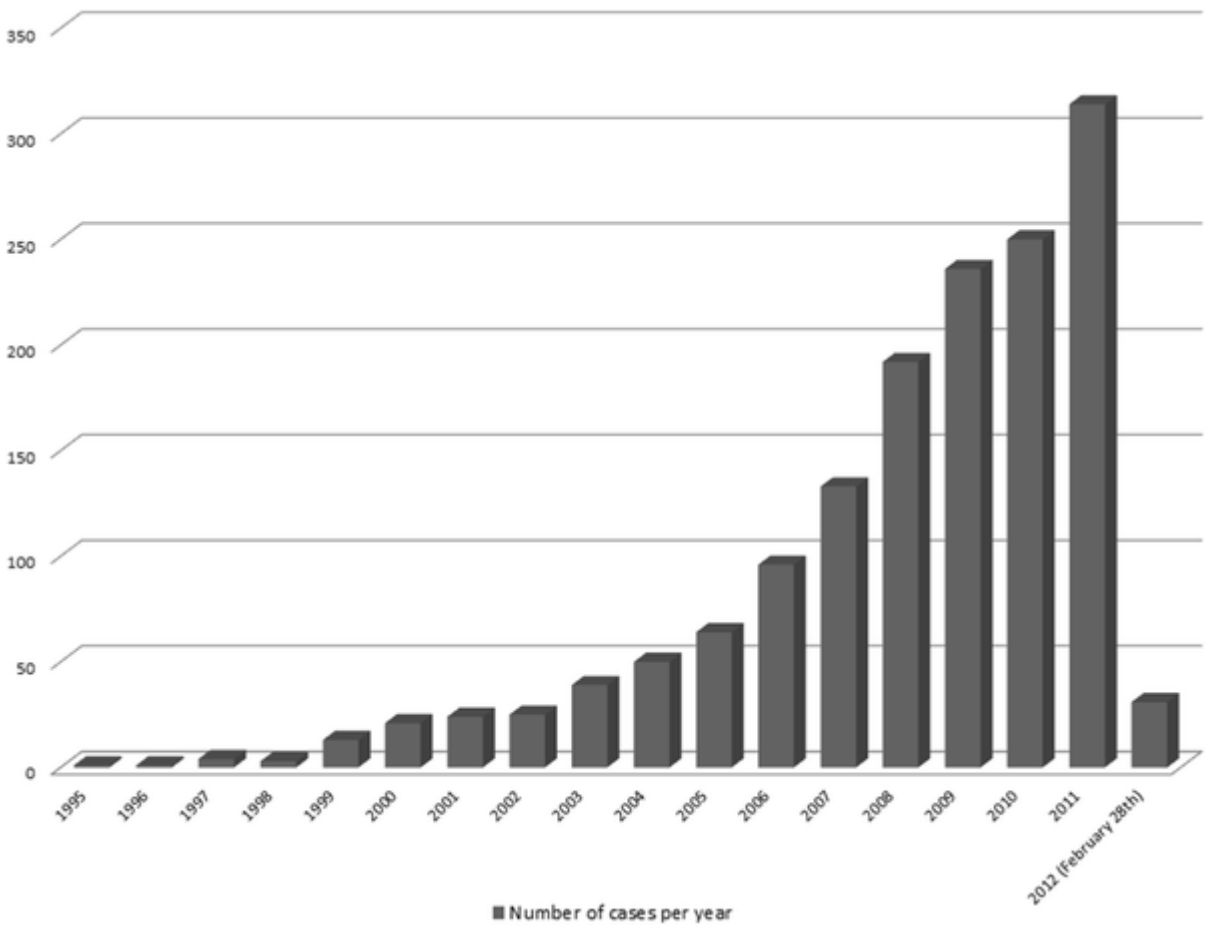

Fig. 3

In Italy there has been exponential growth in MILR over the years (1995–2012) with a progressive increase and an almost linear trend

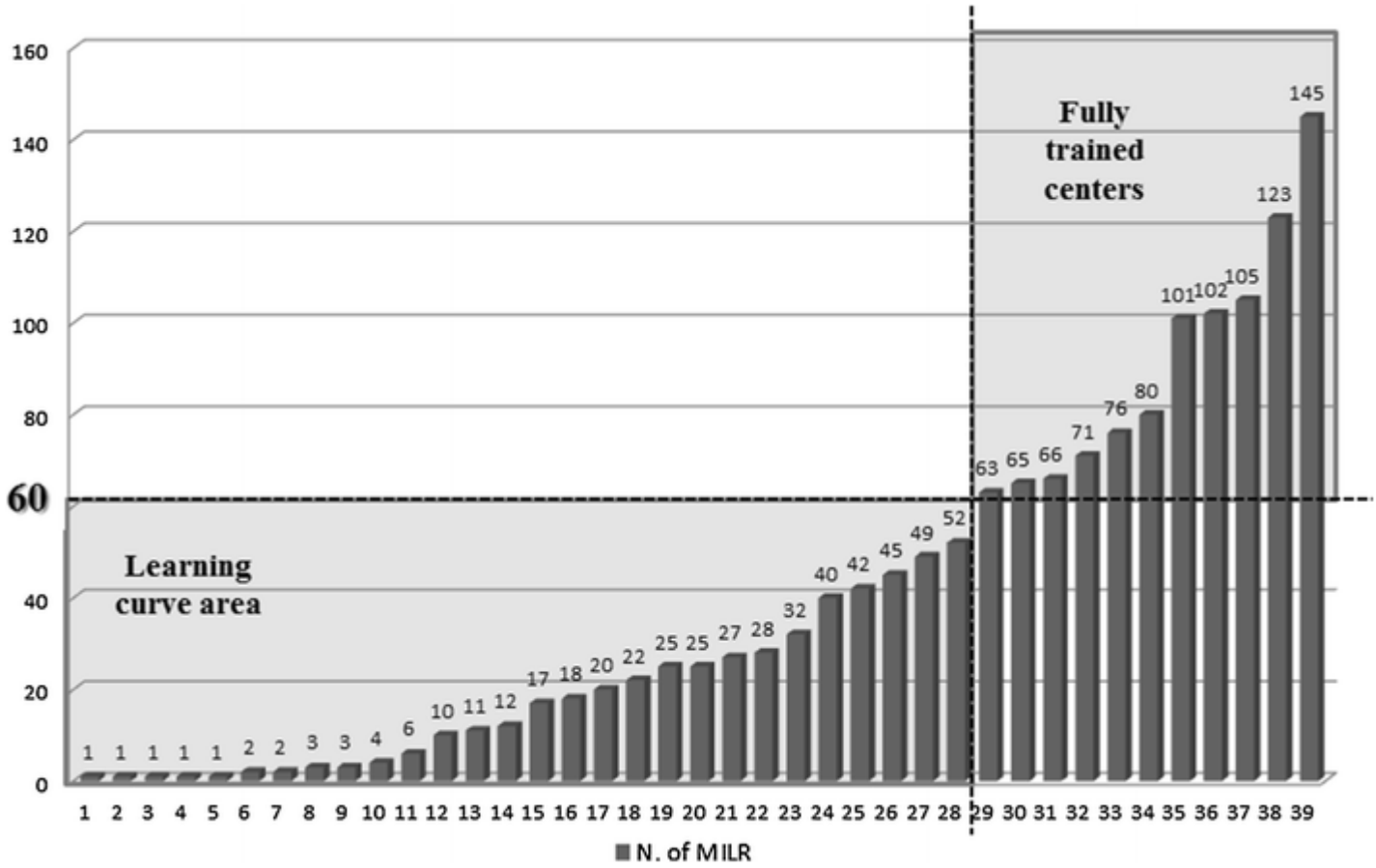

Fig. 4

Number of minimally invasive cases per center. A progressive number was assigned to each center (*X* axis) according to the increasing number of laparoscopic cases. According to Viganò, the break line between learning curve area and fully trained area was set at 60 cases

Figure 5 shows the number of open and minimally invasive series per center, assigning to each of them a progressive number according to the number of cases in the minimally invasive series.

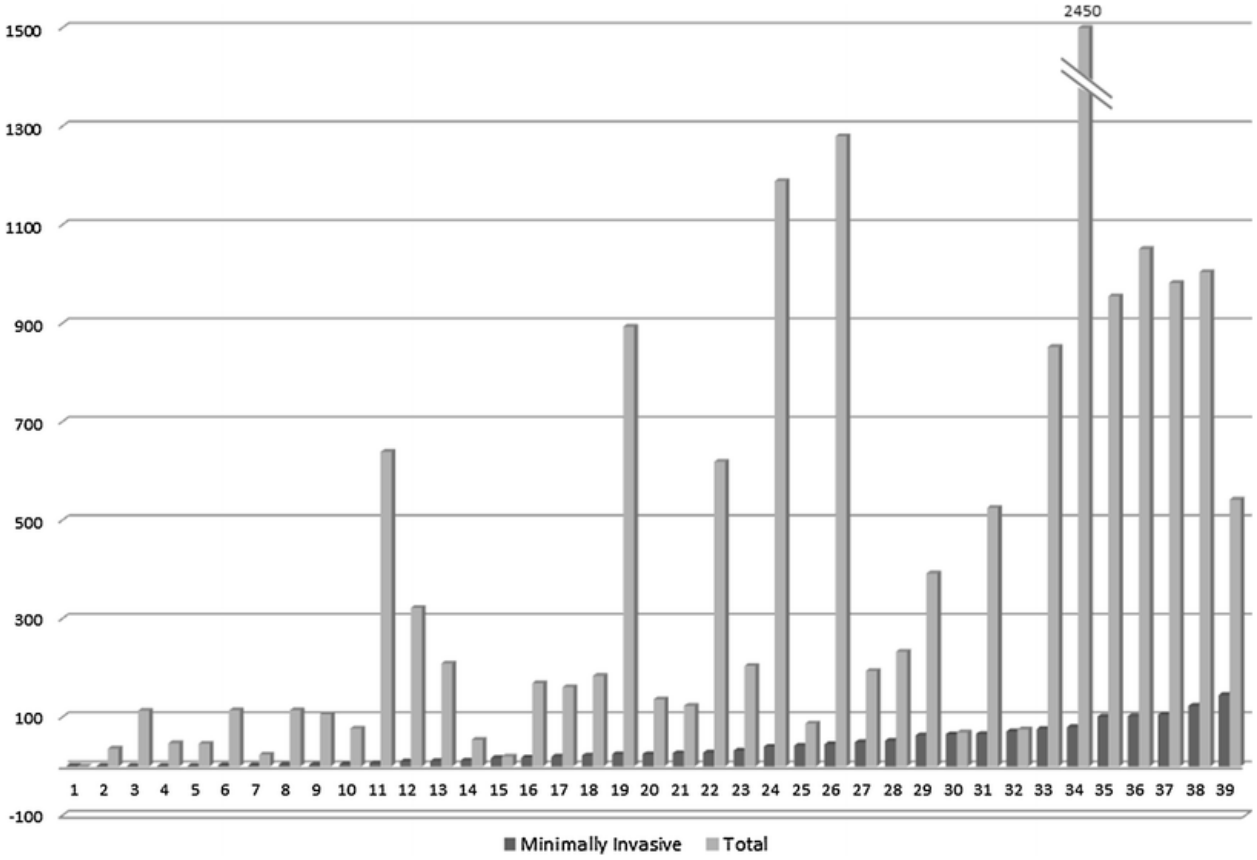

Fig. 5

Number of minimally invasive and open cases per center. A progressive number was assigned to each center (*X* axis) according to the increasing number of laparoscopic cases

The mean interval between the start-up of advanced laparoscopic surgery and the first MILR was 9 years, when most centers had already gained significant experience in hepatic surgery.

Four centers simultaneously began a program of advanced laparoscopic surgery and liver resection. Moreover, in most centers the number of MILR seemed to have reached a fixed proportion of total annual resections after a 4-year mean of activity.

Conversions

The series conversion rate was 10.7 % (180 patients out of 1677), with an incidence among INSSG centers ranging from 0 to 34.4 %. The most common causes of conversion were: intraoperative hemorrhage in 62 (34.4 %), concerns for oncological radicality in 47 (26.1 %) and technical difficulties in 43 cases (23.8 %). Other less frequent reasons were severe adhesions from previous surgery in 14 cases (7.7 %), anesthesiological problems in five cases (2.7 %) and injury to adjacent organs in one case (0.5 %). In eight cases (4.8 %) the reason for conversion was not documented.

When considering only the 11 FTC centers that had completed the learning curve, the median rate of conversion was 8.3 % (range 3.8–30.9 %), which corresponded to that of the overall series (8.3 %, range 0–50.0 %), and to that of Learning Curve Centers (8.3 %, range 0–50.0 %). Conversion related to oncological concerns was significantly more frequent ($p = 0.02$) in FTC groups (median 25 %, range 10–63.1 %) than in LCC groups (median 0 %, range 0–100 %). Other reasons for conversion did not significantly differ between FTC and LCC groups, as shown in Table 1.

Table 1

Reasons for conversion in FTC (fully trained centers) and LCC (learning curve centers)

Causes of conversion[a]	FTC—fully trained centers [11] (%)	LCC—learning curve centers [28] (%)	Significance (*p* value)
Concerns for oncological radicality	25	0	0.02
Adhesions from previous surgery	0	0	0.94
Intraoperative hemorrhage	50	37.5	0.45
Injury to adjacent organs	0	0	0.70
Technical difficulties	12.5	0	0.2
Anesthesiological problems	0	0	0.2

[a]Median value of percentages among participating centers

MILR procedures requiring conversion to open surgery were excluded from the analysis: 1,497 liver resections completed with the minimally invasive approach were eventually taken into account and constituted the study population.

Indications

MILR was performed in 1,085 cases for malignant lesions (72.5 %), the most frequent indication being 608 cases of hepatocellular carcinoma (56.0 % of all malignant lesions). MILR was performed on 432 occasions for liver metastases (39.8 % of the overall series), with the primary tumor most frequently located in the colon or the rectum (302 cases, 69.9 % of metastases). In 115 cases (38.1 % of colorectal metastases), primary colorectal cancer and liver metastases were simultaneously resected using a minimally invasive approach. Metastases from lung, breast, kidney, melanoma, gastrointestinal stromal tumor (GIST), squamous cell anal cancer, neuroendocrine tumor and mesothelioma accounted

for 30.1 % of MILRs performed for secondary lesions. A final histological diagnosis of intrahepatic cholangiocellular carcinoma was made in the remaining 45 patients (4.1 %). Benign lesions represented the remaining 27.5 % (412 resections) of MILRs: final diagnosis was focal nodular hyperplasia in 91 (22.0 %), liver adenoma in 88 (21.4 %), and hemangioma in 86 cases (20.9 %).

Benign cystic disease was present in 43 patients (10.4 %), including simple or complicated cysts, hydatid cysts, and cystoadenomas requiring formal liver resection. Cyst wall deroofings were not included in the analysis.

In a minority of cases, liver resection was carried out for intrahepatic lithiasis (16 cases, 3.9 %), and regenerative or inflammatory nodules (14 cases, 3.4 %). In 74 cases of benign neoplasms the histological diagnosis was not documented (18.0 %).

Finally, laparoscopic left lateral sectionectomy was performed in four cases for living-donor liver procurement. A breakdown of diagnoses is shown in Fig. 6.

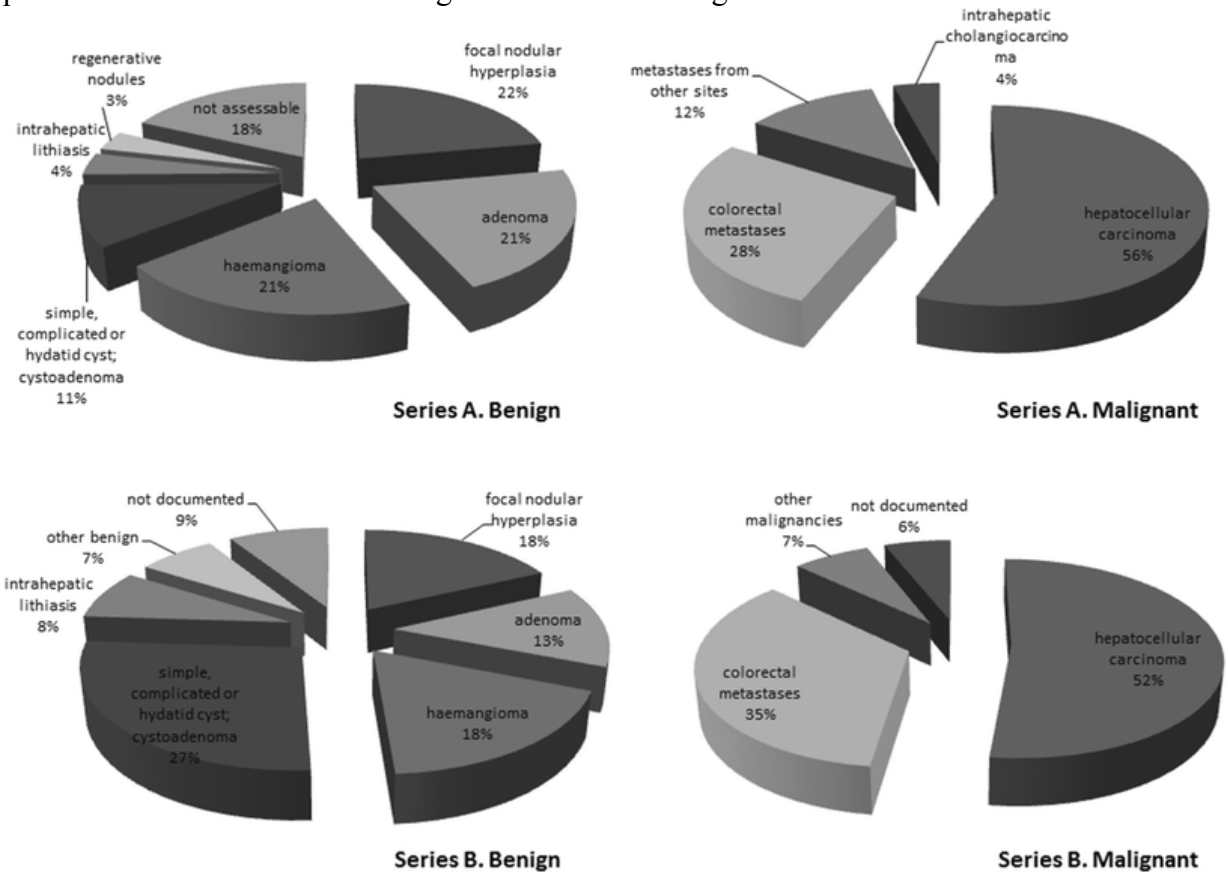

Fig. 6

Breakdown of diagnoses (benign and malignant) of the National Survey (Series A) compared with data of the World Review (Series B)

Extent of liver resection

According to the Brisbane 2000 system of nomenclature [11], 1391 minor liver resections were performed (92.9 % of total resections), with left lateral sectionectomy being the most widely performed procedure (357 cases, 25.7 % of minor resections and 23.8 % of total resections) (Fig. 7).

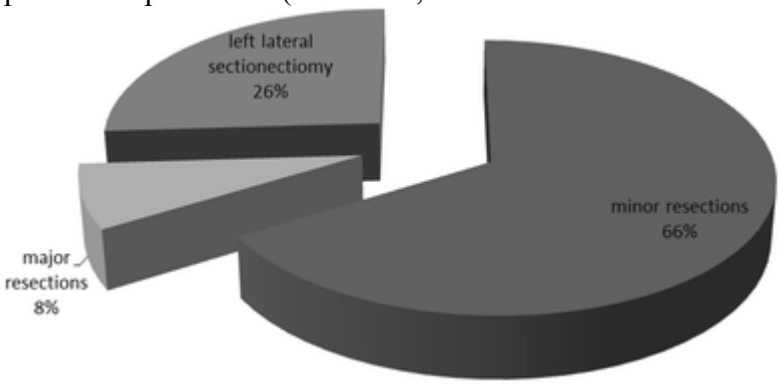

Fig. 7

Minor resection was performed in 1391 cases (92.9 % of total resections), with left lateral sectionectomy being the most widely performed procedure (357 cases, 23.8 % of total resections). Major resection accounted for 7.1 % of the total

Wedge resection or single segmentectomy was performed in 870 cases (62.5 % of all minor resections) involving the so-called “laparoscopic segments”: Sg2, Sg3, Sg4b, Sg5, Sg6 (784 cases, 90.1 %). Indeed, wedge resection or single segmentectomy involving posterosuperior segments was less frequently performed (80 patients, 9.1 %), with right sectionectomy being reported in an even smaller number of cases: right posterior sectionectomy in 33 cases, and right anterior sectionectomy in nine cases (2.4 and 0.6 % of all minor resections, respectively). Segment 1 resection was performed in six cases. Major liver resection totaled 106 (7.1 % of the entire MILR series) (Fig. 7). There were 63 left and 43 right hepatectomies (59.4 and 40.6 % of all major resections, respectively). There were no central or extended right/left hepatectomies. Multiple simultaneous resections were performed in 254 cases (16.9 % of all resections). Biliary or vascular reconstruction, which, although technically feasible, is generally considered a contraindication to the minimally invasive approach, was never performed.

Minimally invasive approaches

The majority of centers used a traditional multi-port totally laparoscopic approach (92.6 %—1.386 cases) (Fig. 8).

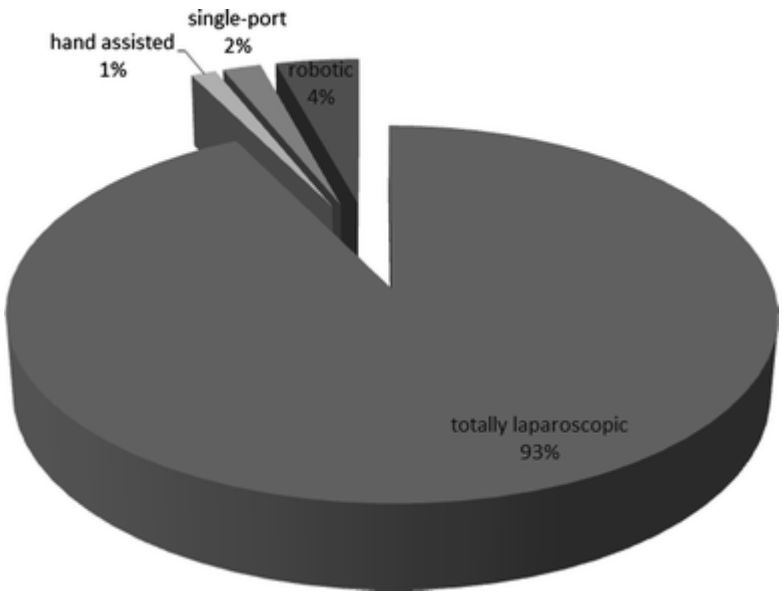

Fig. 8

Use of minimally invasive approaches among centers

The hand-assisted approach and the single-port technique were reported only in 19 and 29 cases, respectively (1.3 and 1.9 % of the entire series), with left lateral sectionectomy being the most frequent indication. Moreover, 63 robot-assisted liver resections were carried out, accounting for 4.2 % of all liver resections, and including 16 segmentectomies/sectionectomies involving the right posterior segment. No major resection was performed using the robotic technique.

Regarding preferred technique distribution, the traditional multi-port totally laparoscopic approach was the standard technique in all centers; the single-port approach and the hand-assisted technique were performed in four and eight centers, respectively. Robotic liver resection was carried out in three centers.

Intraoperative outcomes and technical features

Intraoperative details are shown in Table 2. Thirty-one centers routinely performed MILR primarily through ultrasound or radiofrequency-energy-based devices that resulted therefore as first choice. Alternatives consisted of radiofrequency-based MILR and parenchymal transection through vascular staplers: this last technique was reported in one center. Most centers only used staplers to transect the main portal branches and hepatic veins.

Table 2

Intraoperative details

Intraoperative details	
Intraoperative mortality, *n* (%)	0 (0 %)
Intraoperative blood loss, median (range)	125 mL (50–625)
Operating times, weighted mean (range)	145 min (45–315)

Intraoperative details	
Pringle maneuver	
Performing centers, *n* (%) (continuous/intermittent)	22 (56.4 %) (3/19)
Cases performed, *n* (%)	199 (13.7 %)
Total length	22 min (7–52)
Surgical drain placement, *n* (%)	1392 (93.0 %)

In the present series, 22 centers (56.4 %) performed the Pringle maneuver in continuous or intermittent fashion in 3 and 19 centers, respectively. The number of LLR performed using the Pringle maneuver was 199 (13.7 %). The mean time of ischemia per center ranged between 9 and 57 min, while the weighted mean time of vascular occlusion was 22 min.

Finally, in the majority of patients the abdominal drain was placed at th`(1392 cases, 93.0 %).

Postoperative outcome

Postoperative details are listed in Table 3. There were no intraoperative deaths, and three postoperative deaths (mortality rate 0.2 %). In the present series, 342 postoperative complications were reported (morbidity rate 22.8 %); ascites occurred in 81 patients (23.6 % of all complications, 5.4 % of all MILR); pleural effusion was reported in 74 cases (21.6 % of all complications, 4.9 % of all MILR); postoperative hemorrhage occurred in 61 patients (17.8 % of all complications, 4.0 % of all MILR); postoperative bile leakage was reported in 35 cases (10.2 % of all complications, 2.3 % of all MILR). A complete list of complications can be found in Table 2, together with their stratification by severity according to the Clavien–Dindo grading system [12]. There were 174 grade II complications (50.8 %), 125 grade I (36.5 %), 42 grade III (12.2 %) requiring surgical, endoscopic, or radiological interventions, and 2 grade IV. During the postoperative course, patients returned to unrestricted diet a weighted mean of 2 days after surgery. Postoperative hospital stay ranged between 2 and 12 days. The weighted mean hospital stay was 6 (range 3–15) days, whereas the weighted mean postoperative course lasted 5 (range 3–12) days.

Table 3

Postoperative details

Postoperative details	
Postoperative mortality, *n* (%)	3 (0.2 %)
Postoperative morbidity	
Type of complication, *n* (total resections)	
Ascites	81 (5.4 %)
Pleural effusion	74 (4.9 %)
Hemorrhage	61 (4.0 %)

Postoperative details	
Bile leakage	35 (2.3 %)
Fever	29 (1.9 %)
Urinary tract infection	11 (0.7 %)
Intra-abdominal infection	11 (0.7 %)
Jaundice	5 (0.3 %)
Pneumonia	5 (0.3 %)
Bowel perforation	4 (0.2 %)
Arrhythmia	3 (0.2 %)
Bowel obstruction	1 (0.06)
Pulmonary embolism	1 (0.06)
Hypertensive peak	1 (0.06)
Pneumothorax	1 (0.06)
Acute respiratory failure	1 (0.06)
Acute cardiac failure	1 (0.06)
Peripheral paresthesia	1 (0.06)
Grade of severity (Clavien–Dindo classification), *n* (all complications)	
Grade I	125 (36.5 %)
Grade II	174 (50.8 %)
Grade III	42 (12.2 %)
Grade IV	2 (0.5 %)
Grade V	3 (0.2 %)
Postoperative course	5.6 postoperative days [2–12]

Discussion

The worldwide diffusion of MILR has been possible thanks to recent developments in surgery and technology. Surgical indications for the treatment of liver tumors have resulted in an increased number of candidates for hepatectomy. Patient awareness regarding the benefits of MILR has grown: the World Review of laparoscopic liver resection (Nguyen, 2009) that enrolled 2804 liver resections performed over a 16-year period (1992–2008) confirmed these data [3]. Before the present study, two national surveys regarding minimally invasive liver surgery in Korea [8] and in Japan [9] were published, focusing the

interest of surgeons practicing laparoscopic and hepatic surgery on this approach. In particular, the Korean study, which reports the outcome of 416 patients in 19 centers from 2001 to 2008, and the present survey, which records 1677 MILR over an 18-year period in Italy, show results that are comparable as regards the type of resection, lesion distribution, and postoperative outcome. The occurrence of similar results in Eastern and Western countries might be related to the application of the same well-established MILR indications, as indicated by the Louisville Statement [13]: single lesions, both malignant or benign, located in laparoscopic segments (Sg2, Sg3, Sg4b, Sg5, Sg6) and requiring segmentary resections or left lateral sectionectomy, while major liver resections (i.e. right or left hepatectomies) are instead to be reserved for experienced surgeons, already facile with more limited laparoscopic resections.

Analysis of the volume of cases over the years shows the exponential progressive increase of MILR in Italy, with an almost linear growing trend similar to the ever-growing volume of MILR procedures performed yearly in other Eastern and Western countries, as reported by Nguyen [3]. In the present series, MILR accounted for 10.3 % of the total number of liver resections performed during the same period (n = 16,244). These data are consistent with the literature, which reports a range between 19 and 24.3 % [5, 14]. In each series included in this analysis, the MILR/total number of liver resections ratio seems to stabilize after an initial training period (mean 4 years following start-up of the minimally invasive surgery program). This finding reflects, on the one hand, satisfaction and awareness of the benefits associated with this approach, especially for certain procedures (e.g. the laparoscopic approach is more or less considered the gold standard for left lateral sectionectomy) [4, 15], and on the other hand the difficulty to further expand the pool of candidates for MILR without affecting surgical indication. A remarkable sign of trust in the potential of MILR is also represented by the fact that no center abandons minimally invasive programs once they have been adopted.

The rate of conversion to open surgery (10.7 %) and the reasons for conversion (hemorrhage, concern for oncological radicality and technical challenges) were substantially consistent with the literature; centers which had completed the learning curve (with a cutoff value of 60 minimally invasive resections, as indicated by Viganò) [10] experienced a conversion rate similar to those with fewer than 60 cases. A possible explanation to this finding might be that in experienced centers the complexity of enrolled cases increases as the gathered experience progresses, resulting in stability of the conversion rate: during the training period, patients with limited technical challenges are

candidates for the minimally invasive approach, while laparoscopy is proposed to a greater variety of patients once learning has been completed (e.g. posterior segments, intraparenchymal lesions, previous abdominal surgery).

It has been suggested that surgeons should have extensive experience in open liver surgery and technical skill in advanced laparoscopic surgery before undertaking MILR [9]. In the present survey, a strong correlation between MILR activity and a hepatobiliary background was not clear when MILR case and total liver resection volumes were compared per center (Fig. 5). It seems that some Italian centers with great hepatobiliary expertise have developed laparoscopic liver resection programs slowly, probably due to the complexity of treated cases, with few good MILR candidates. Other centers with extensive laparoscopic experience in major gastrointestinal surgery might have recruited perfect candidates for the laparoscopic approach (i.e. single peripheral metastases from colorectal cancer). This situation will probably change in the near future, since it is reasonable to think that MILR cases will be primarily managed within major hepatobiliary programs.

As reported in previous series, the possibility to carry out liver resection using laparoscopy must not influence or—even worse—create the indication for liver resection, expanding the pool of candidates for surgery thanks to the widespread application of minimally invasive techniques. The possibility to remove a benign lesion using minimally invasive hepatic resection should not represent an indication for surgery; a correct management flowchart for benign lesions first of all implies the definition of surgical indication, followed by the type of required hepatic resection, and finally the approach to be used.

In Italy, MILR is usually performed following well-accepted indications for liver resection. Indeed, although benign diseases were also treated by laparoscopic approaches (412 cases, 27.5 %), most LLR procedures were performed for malignant diseases: 1,085 (72.5 %). The world review by Nguyen [3] and the Korean survey [8] showed a different relative distribution between benign and malignant diagnosis, with a significantly higher amount of benign cases (45 and 50.0 % in the first, 40.4 and 59.6 % in the second, respectively).

The higher incidence of benign lesions in the Korean experience is possibly related to geographical and ethnical factors that constitute the pathophysiological explanation for the prevalence of intrahepatic lithiasis in Eastern countries. The Italian survey recorded MILR for intrahepatic lithiasis in a minority of cases (3.8 %), in contrast with the Korean

experience, where intrahepatic duct stones represented the most frequent benign diagnosis resulting in 27.4 % of all MILR.

As regards malignant lesions, hepatocellular carcinoma was the most frequent indication among primary and secondary neoplasms in the present series (56 %), and was the most frequent overall indication accounting for 40.6 % of all MILR. Many previous series [16–18], including a recent meta-analysis [19] comparing the outcome of hepatic resection for HCC using open or minimally invasive surgery, showed how laparoscopy positively affects the postoperative course, reducing the morbidity rate in cirrhotic patients. In the near future, short-term outcome improvements might extend the indication criteria for resection: selected Child-Pugh class B patients, who have been traditionally excluded from open surgery owing to poor short-term outcome caused by hepatic decompensation, might be considered for laparoscopic surgery. Furthermore, laparoscopic resection may represent an alternative to ablation procedures, as a “bridge treatment” before liver transplantation.

Liver metastases represented the second most frequent indication among malignancies, followed by a low percentage of intrahepatic cholangiocellular carcinoma (39.8 and 4.1 % of malignant diagnosis, respectively).

The proportion of patients affected by liver metastases in this study, as well as in other laparoscopic series, does not resemble the distribution of diagnoses within major open series in the literature [20] where liver metastases are the most frequent indication. This discrepancy between MILR and open series might be a consequence, on the one hand, of the frequently reiterative and parenchymal sparing specific features of liver metastasis surgery. On the other hand we find the growing number of cirrhotic patients with borderline hepatic function who undergo laparoscopic resection.

Minor resection was performed in 1,391 cases (92.9 % of total resections), mainly involving the so-called laparoscopic segments: Sg2, Sg3, Sg4b, Sg5, Sg6 (784 cases, 90.1 %), which are considered easier for laparoscopic devices than the posterosuperior segments (Sg1, Sg4a, Sg7, Sg8). Laparoscopy is possibly following a similar course to that of open liver resection during the ’80 s and ’90 s. Left lateral sectionectomy was the most widely performed procedure in the entire series (357 cases, 25.7 % of minor resections and 23.8 % of total resections), and this finding was confirmed when analyzing single-institution series, indicating that left lateral sectionectomy is frequently approached with laparoscopy, and may become a standard procedure in the near future as indicated by Azagrà [21].

Major liver resection represented 7.1 % of total laparoscopic resections. The feasibility and safety of major hepatectomies using the laparoscopic approach have been discussed in literature [22], although hepatectomies are associated with technical challenges represented by the safe control of hepatic veins, vena cava dissection, and frequently by tumor burden. The relatively small number of major liver resections found in the present Survey is substantially consistent with previous data reported both in the World Review [3] and in the Japanese Survey [9] (15.8 and 12.5 %, respectively), while it differs significantly from data in the Korean Survey (25.2 %) [8]. Our findings reflect the small number of candidates for major resection that can undergo the laparoscopic approach. Indeed, major resection for gallbladder or Klatskin tumors is not yet considered suitable for the minimally invasive approach, likewise major resection for large primary liver tumors, or neoplasms involving major vascular pedicles (i.e. hepatic or portal vein thrombosis). Furthermore, many patients affected by liver metastases are candidates for simultaneous multiple resection, in accordance with the recent trend toward performing parenchyma-sparing surgery rather than major hepatectomies whenever technically feasible [23, 24].
While in the literature the term “minimally invasive surgery” usually indicates the traditional multi-port laparoscopic approach, other techniques have been developed to deal with different tasks: hybrid (laparoscopic-assisted surgery and hand-assisted surgery) approaches and the totally-laparoscopic technique, with single-port or robot-assisted surgery, represent alternatives to the conventional approach. Most Italian centers used a multiple-port totally-laparoscopic approach (92.6 % of the entire series), whereas hand-assisted and single-port resection was performed less frequently (1.3 and 1.9 % of MILR, respectively). These percentages show that the hand-assisted approach might be indicated for technically challenging cases, such as hemihepatectomy, resection of posterosuperior segments, or as an alternative to the conversion to open surgery as reported in the literature [13, 25]. In order to further minimize invasiveness, the single-port access was used mainly in cases of left lateral sectionectomy, that seems the most suitable MILR for such an approach as the transection plane may be appropriately accomplished even without full instrument triangulation [26]. Three centers performed robot-assisted hepatectomies, accounting for 4.2 % of all liver resections, including 16 segmentectomies/sectionectomies involving the right posterior segments. It is reasonable to believe that the robot-assisted technique for liver resection will spread more extensively throughout Italian centers in the near future, covering a higher rate of the national MILR pool, and allowing wider application of the minimally invasive approach to the

“nonlaparoscopic segments” (right posterosuperior segments, cranial and posterior portion of S4, cranial portion of S1), as well as to major hemihepatectomies [7, 27].
Different methods have been used to transect the liver parenchyma in MILR, mainly ultrasound or radiofrequency-energy-based devices. Alternatives, consisting of radiofrequency-based MILR and vascular staplers to perform the entire transection, are less common. The more extensive application of technological devices in MILR than in conventional open liver resection—where the Kelly clamp-crush technique, or ultrasonic dissection plus bipolar forceps or ligations are still the most common methods of parenchymal transection—is understandable, as precise and complete progressive hemostasis is more critical during parenchymal transection in MILR than in open resection. Indeed, any—even minimal—bleeding from portal and hepatic vessels may be more challenging to control laparoscopically, as it impairs optimal vision, hinders the safe progression of resection, and may ultimately require conversion to open surgery.
The Pringle maneuver was performed in 22 centers (56.4 %). However, only 199 LLR were performed using the Pringle maneuver (13.7 %). These results confirm that MILR may be performed even without routine vascular control, as suggested by previous data in the literature [14]. On the other hand, routine encircling of the hepatic pedicle for a possible Pringle maneuver has yet to be recommended as a precautionary measure whenever approaching MILR.
Finally, the placing of an abdominal drain at the end of liver resection persists (1392 cases, 93.0 %), although this contrasts with evidence from the Cochrane systematic review [28], and the growing tendency toward fast-track and Enhanced Recovery After Surgery (ERAS) programs [29], which substantially ban the routine use of surgical drains.
Data concerning mortality rate (0.2 %) are in accordance with data reported in the literature, where a postoperative mortality rate <1.0 % is reported for MILR, thus confirming the safety of this approach, even in the field of liver resection [3].
In this survey, 342 postoperative complications were reported (22.8 %), with 10–15 % morbidity being reported in the literature [3]. During the postoperative course, patients returned to unrestricted diet a weighted mean of 2 days after surgery. Postoperative hospital stay ranged between 2 and 12 days, with the likelihood of wide variability due both to the heterogeneity of MILR, and to differing postoperative patient management between centers. However, the weighted mean hospital stay was 6 (range 3–15) days, whereas weighted mean postoperative course lasted 5 (range 3–12) days. No significant

discrepancy was noted between these data, or previous results from multiple series, systematic reviews, and meta-analyses reported in the literature.

Conclusion

In recent years, the minimally invasive approach for liver resection has been spread significantly in Italy, with several centers having definitely completed the learning curve, as attested by clinical results consistent with major series from Western and Eastern countries.

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Research involving human participants and/or animals

This articles does not contain any studies with human partecipants or animal performed by any of the authors.

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Appendix

The list of the members of the Italian Group of Minimally Invasive Liver Surgery is given below:
Fantini Corrado, S. M. Loreto Nuovo Hospital, Naples; Cipriani Federica, San Raffaele Hospital, Milan; Ratti Francesca, San Raffaele Hospital, Milan; Cassinotti Elisa, Fondazione Macchi, Varese; Gringeri Enrico, Policlinico Universitario, Padua; Santoro Roberto, San Camillo – Forlanini Hospital, Rome; Di Sandro Stefano, Niguarda Ca' Granda Hospital, Milan; Giuliani Antonio, Cardarelli Hospital, Naples; Reggiani Paolo, Hospital Maggiore - Policlinico, Milan; Santambrogio Roberto, San Paolo Hospital, Milan; Spampinato Marcello, Hospital Policlinico, Abano Terme; **Morino Mario**, Le Molinette Hospital, Turin; Filauro Marco, Galliera Hospital, Genoa; Navarra Giuseppe, Hospital Policlinico Martino, Messina; Ercolani Giorgio, S. Orsola Hospital, Bologna; Patriti Alberto, San Matteo degli Infermi Hospital, Spoleto; Capussotti Lorenzo, Mauriziano Umberto I Hospital, Turin; Casaccia Marco, San Martino Hospital, Genoa; Nuzzo Gennaro, Hospital Policlinico Gemelli, Rome; Guerrieri Mario, Ospedali Riuniti, Ancona; Bassi Nicolò, S. Maria di Ca' Foncello Hospital, Treviso; Brolese Alberto, S. Chiara Hospital, Trento; Sgroi Giovanni, Treviglio – Caravaggio Hospital, Treviglio; Buonanno Maurizio, Rummo Hospital, Benevento; Jovine Elio, Maggiore Hospital, Bologna; Spada Marco, IsMeTT, Palermo;

Corcione Francesco, Monaldi Hospital, Naples; Dalla Valle Raffaele, Maggiore Hospital, Parma; Colledan Michele, Ospedali Riuniti, Bergamo; Gerunda Giorgio, Hospital Policlinico, Modena; Mezzatesta Pietro, La Maddalena Hospital, Palermo; Di Somma Carmine Gianfranco, San Martino Hospital, Genoa; Guglielmi Alfredo, Hospital Policlinico G.B. Rossi, Verona; Di Carlo Isidoro, Cannizzaro Hospital, Catania; Gruttadauria Salvatore, Hospital Policlinico Vittorio Emanuele, Catania; Antonucci Adelmo, Hospital Policlinico, Monza; Caldarera Goffredo, Garibaldi Hospital, Catania; Scuderi Vincenzo, San Lazzaro Hospital, Alba; De Werra Carlo, Federico II University, Naples; Maida Piero, Ospedale Evangelico Villa Betania, Naples.

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