ORIGINAL ARTICLE

Pan-European survey on the implementation of robotic and laparoscopic minimally invasive liver surgery

Maurice J.W. Zwart[1,*], Burak Görgec[1,2,*], Abdullah Arabiyat[3], Carolijn L.M. Nota[4], Marcel J. van der Poel[1], Robert S. Fichtinger[5], Frederik Berrevoet[6], Ronald M. van Dam[5,7], Luca Aldrighetti[8], David Fuks[9], Emir Hoti[10], Bjørn Edwin[11], Marc G. Besselink[1], Mohammed Abu Hilal[2,†], Jeroen Hagendoorn[4,†], Rutger-Jan Swijnenburg[1,†] for the Dutch Liver Collaborative Group and E-AHPBA Innovation & Development Committee

[1]Department of Surgery, Amsterdam UMC, University of Amsterdam, Cancer Center Amsterdam, the Netherlands, [2]Department of Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy, [3]Department of Surgery, The Royal Lancaster Infirmary, University Hospitals of Morecambe Bay, United Kingdom, [4]Department of Surgery, UMC Utrecht Cancer Center/Regional Academic Cancer Center Utrecht (RAKU), Utrecht, [5]Department of Surgery, Maastricht University Medical Center, Maastricht, the Netherlands, [6]Department of General and HPB Surgery and Liver Transplantation, University Hospital Ghent, Ghent, Belgium, [7]Department of General, Visceral and Transplant Surgery, University Hospital Aachen, Aachen, Germany, [8]Department of Surgery, Hepatobiliary Surgery Unit, San Raffaele Hospital, Vita-Salute San Raffaele University, Milan, Italy, [9]Department of Digestive Surgery, Institut Mutualiste Montsouris, Paris, France, [10]Department of Surgery, Saint Vincent's University Hospital, Dublin, Ireland, and [11]Interventional Centre and Department of Hepato-pancreato-biliary Surgery, Oslo University Hospital and Institute for Medicine, University in Oslo, Norway

Abstract

Background: Laparoscopic and robotic minimally invasive liver surgery (MILS) is gaining popularity. Recent data and views on the implementation of laparoscopic and robotic MILS throughout Europe are lacking.

Methods: An anonymous survey consisting of 46 questions was sent to all members of the European-African Hepato-Pancreato-Biliary Association.

Results: The survey was completed by 120 surgeons from 103 centers in 24 countries. Median annual center volume of liver resection was 100 [IQR 50−140]. The median annual volume of MILS per center was 30 [IQR 16−40]. For minor resections, laparoscopic MILS was used by 80 (67%) surgeons and robotic MILS by 35 (29%) surgeons. For major resections, laparoscopic MILS was used by 74 (62%) surgeons and robotic MILS by 33 (28%) surgeons. The majority of the surgeons stated that minimum annual volume of MILS per center should be around 21−30 procedures/year. Of the surgeons performing robotic surgery, 28 (70%) felt they missed specific equipment, such as a robotic-CUSA. Seventy (66%) surgeons provided a formal MILS training to residents and fellows. In 5 years' time, 106 (88%) surgeons felt that MILS would have superior value as compared to open liver surgery.

Conclusion: In the participating European liver centers, MILS comprised about one third of all liver resections and is expected to increase further. Laparoscopic MILS is still twice as common as robotic MILS. Development of specific instruments for robotic liver parenchymal transection might further increase its adoption.

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Correspondence

Rutger-Jan Swijnenburg, Department of Surgery, Amsterdam UMC, Location VUMC, ZH-7F, De Boelelaan 1117, 1081 HV, Amsterdam, the Netherlands. E-mail: r.j.swijnenburg@amsterdamumc.nl

Correspondence

Mohammed Abu Hilal, Department of Surgery, Poliambulanza Foundation Hospital Brescia, Via Bissolati, 57, 25124, Brescia, Italy. E-mail: abuhilal9@gmail.com

* Shared first authorship.

† Shared principal investigators.

Introduction

Minimally invasive liver surgery (MILS) was first described by Gagner et al.[1] in 1993 with a laparoscopic approach and by Giulianotti et al.[2] in 2003 with a robotic approach. Over the last three decades, many studies showed the benefits of laparoscopic MILS over open liver surgery, including reduced intraoperative blood loss, shorter hospital stay and less morbidity with equivalent oncological results.[3–5] More recently, an increasing number of studies assessed the use of robotic MILS.[6,7] A systematic review of comparative cohort studies reported reduced morbidity and shorter hospital stay with robotic MILS as compared to open liver surgery.[6] It is suggested that robotic MILS may facilitate more difficult liver resections due to freely articulating and angling instruments, such as resections of the postero-superior segments or those requiring extensive hilar dissection.[8–11] However, there are concerns regarding the additional costs of MILS.[12] Furthermore, the available randomized evidence is limited to colorectal liver metastases, making it difficult to extrapolate conclusions on the merits of MILS for other indications.[5,13] Nonetheless, MILS is increasingly being utilized, which makes it interesting to investigate the general opinions, regional variation, and needs for implementation support, such as training. The present opinions of European liver surgeons on the current and future practice of laparoscopic and robotic MILS are unknown.

This survey aims to provide insights in attitudes and prospects towards laparoscopic and robotic MILS, to investigate whether credentialing for MILS is desired and to identify the need for a dedicated MILS training program. These data could support strategies to analyze and further improve outcomes, such as adapting the prospectively collected registries, starting structured training and proctoring programs and credentialing.

Materials and methods

Target group

The survey was sent by email to all surgeon members (N ≈ 800) of the European-African Hepato-Pancreato-Biliary Association (E-AHPBA) using Google Forms Survey® (Google; Mountain View, CA, USA). Two reminders were sent to non-responders. Due to the anonymity of the society members, the total number of invitees could not be retrieved. The invitation e-mail emphasized that surgeons not performing MILS were especially invited to participate to obtain balanced results.

Survey

The survey was conducted between May 2019 and May 2020 and consisted of 46 questions. The survey started with general information of demographics and liver surgery experience, and continued more specifically on experience, equipment, training, contraindications, preferences, value, and credentialing of MILS. The value of MILS was defined as the overall usefulness of MILS and captures postoperative outcomes, additional costs and comfort for the surgeon. In the current survey, major MILS was defined according to consensus agreements as any resection of three or more segments (anatomically major) or any resection from the posteriorly or superiorly located segments 7, 8, 4a and 1 (technically major).[14,15] The definition of Major MILS was processed in questions and question options rather than providing a separate paragraph elaborating the definition of major MILS to keep the survey as concise as possible for responding surgeons. The survey was overseen by the E-AHPBA innovation and development committee in collaboration with the Dutch Liver Collaborative Group and was rewarded a Blue Seal Endorsement by the E-AHPBA. The E-AHPBA supports educational and scientific activities from its members and therefore introduced the “educational pyramid” (i.e. Platinum, Gold, Silver and blue seal activities) to categorize and provide the most suitable support for a course, meeting or clinically relevant study project. Independent members can apply for a Blue Seal Endorsement and will be considered for a seal of endorsement including temporary use of the endorsement logo and 2 promotional emails and social media posts for the study project. See for the complete survey.

Statistical methods

Data were analyzed using IBM SPSS statistics for Windows version 24 (IBM Corp, Armonk, NY, USA). Normally distributed continuous data were presented as means and standard deviations (SDs). Non-normally distributed continuous data were presented as medians and interquartile ranges (IQRs) or 95% confidence intervals (95%CI). Categorical (binary, nominal, and ordinal) data were presented as frequencies and percentages. Likert-Scale ordinal data were also presented in means and standard deviations, as this allowed more insight into the effect size. Sensitivity analysis regarding views on future implementation was performed for overall annual volume of liver procedures and for center type (i.e. university medical centers, university affiliated centers, or community/independent centers). In addition, stratification (based on the median of the cohort) into total annual volume of both open liver surgery and MILS was performed to better understand the opinions of surgeons in lower-volume (<100 liver resections/year) and higher-volume centers (≥100 liver resections/year). A two-tailed p value $< .05$ was considered statistically significant.

Results

Respondents’ characteristics

A total of 120 surgeons from 103 centers in 24 European countries completed the survey (Fig. 1). Table 1 shows the characteristics of the respondents. The median age of responding surgeons was 46 years [IQR 41–54 years] with 12 years [IQR 7–21 years] of surgical experience as an attending general

Figure 1 European experience with minimally invasive liver surgery

surgeon. Overall, 75 (63%) surgeons were employed at university medical centers, 25 (21%) at university affiliated centers, and 20 (17%) at community/independent centers. The scope of surgical practice was reported as hepato-pancreato-biliary (HPB) by 63 percent of surgeons

Liver surgery experience and practice

Fig. 2 shows the total annual center volume of liver resection and the proportion of MILS per center. The median annual volume of liver resection was 100 procedures [IQR 50–140 procedures] per center. The median annual proportion of MILS was 30% [IQR 16–40%] per center. While the 67 per cent of surgeon indicated to perform laparoscopic MILS only, 5 surgeons (4%) indicated to use a robotic approach only, and 35 surgeons (29%) both approaches. Of all minor liver resections, 65% were performed by a minimally invasive approach. Of all major liver resections, 16% were MILS procedures. Stratification of MILS practice into countries showed that in countries with at least 3 respondents, 77 per cent of centers adopted a combined MILS program (Fig. 3). Table 2 summarizes the liver surgery experience and MILS practice of the responding surgeons.

Robotic liver surgery equipment

Robotic MILS was performed by 40 of the 120 responding surgeons (33.3%). The predominantly used instrument for liver parenchymal transection was a robotic bipolar device, as indicated by 12 of the 40 surgeons (30%) (Fig. 4). Considering all instruments for robotic MILS, 34 out of 40 surgeons indicated that the predominantly used instrument was still a robotic bipolar device. Most of the respondents were dissatisfied with the available robotic instruments for liver resection (n = 28). Of these 28 respondents, 13 indicated that they would like to have a robotic CUSA.

Preferences and opinions

When asked about the current value of MILS, 68 surgeons (57%) stated that MILS is of superior value in comparison to open liver surgery for both minor and major liver resections, while 35 surgeons (29%) believed MILS to be of superior value for minor liver resections only (Table 3 and Fig. 5).

When asked about future value of MILS, 88 per cent of respondents believed that in the coming years MILS would be of superior value as compared to the open approach. In five years'

Table 1 Respondents' characteristics

Characteristics	N = 120
Age, years	45 (40–54)[a]
Surgical experience as an attending surgeon, years	12 (7–21)[a]
Employment at type of medical center	
University	75 (63%)[b]
University affiliated	25 (21%)[b]
Community/Independent	20 (17%)[b]
Scope of surgical practice	
Hepato-pancreato-biliary surgery	76 (64%)[b]
Liver surgery	13 (11%)[b]
Surgical oncology	12 (10%)[b]
Gastrointestinal surgery	12 (10%)[b]
Other categories	5 (4%)[b]
All categories applied	2 (2%)[b]

[a] Median (interquartile range).
[b] Numbers (proportions).

time, the respondents expect 61–70% of liver surgery to be performed minimally invasive, of which 21–30% robotically. Centers performing laparoscopic MILS only and centers performing both robotic and laparoscopic MILS demonstrated similar views on the current and future value of MILS. However, robotic surgeons expect an increasing implementation of MILS in general (p = .043) and specifically robotic MILS (p < .001).

Technical concerns and contraindications

Of all technical concerns regarding MILS, operative time (41%), risk of intraoperative bleeding (41%), and ability to achieve R0 resection (33%) were remarked most often (Supplementary Material 1). The most mentioned benefit of robotic MILS over laparoscopic MILS was its use for hilar dissection (71%). The most mentioned disadvantages of robotic MILS compared to laparoscopic MILS were costs (81%) and the current available parenchymal transection instruments (45%).

Most surgeons (67%) mentioned that contraindications for minor MILS were limited to general contraindications for minimally-invasive surgery, such as increased intracranial pressure, abnormalities of cardiac output and pulmonary gas exchange. For the other surgeons (33%), the most mentioned contraindications for minor MILS were involvement or near involvement (<5 mm) of hilar vessels (n = 42 (35%)), and 'large tumor size >10 cm' (29%).

Similarly, the 72 per cent of responding surgeons also indicated general contraindications for major MILS. Additionally,

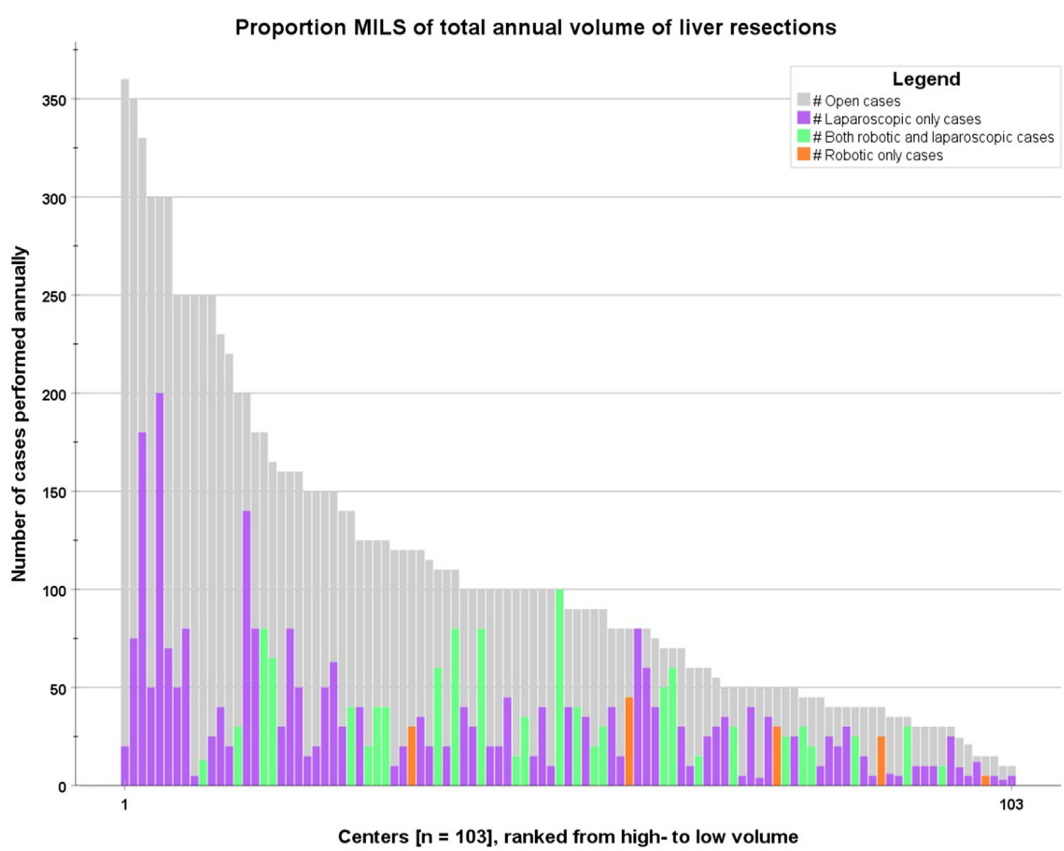

Figure 2 Proportion MILS of the total annual volume of liver resections per center

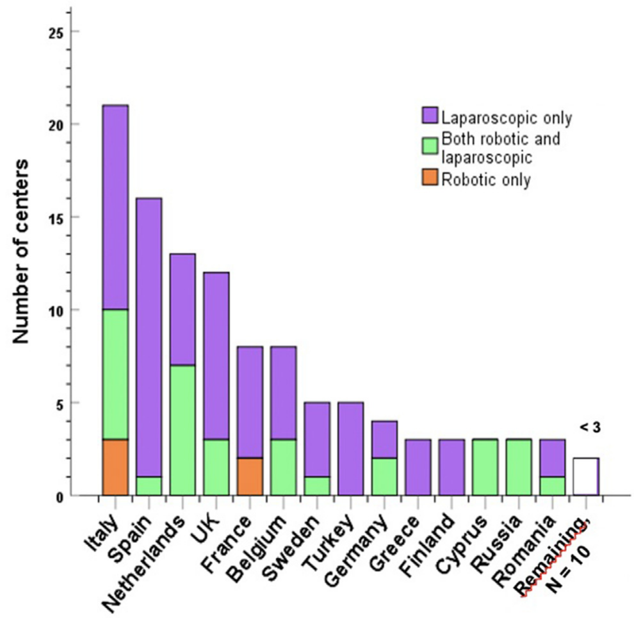

Figure 3 Minimally invasive approach of choice per country

Table 2 Surgical experience

	N = 120
Annual volume of liver surgery (minimally invasive and open) per center	100 (50–140)[a]
Rate of MILS per center	30 (16–40)[a]
Type of minimally invasive resections	
Laparoscopic	80 (67%)[b]
Robotic	5 (4%)[b]
Both laparoscopic and robotic	35 (29%)[b]
Use of MILS for minor and major liver resection per center	
Rate of MILS in minor liver resections	66 (36–76)[a]
Rate of MILS in major liver resections	16 (6–46)[a]
Use of other types of MIS HPB surgery per center	
No, only open	0 (0%)[b]
No, we perform only MILS	5 (4%)[b]
Yes, MILS and minimally invasive distal pancreatectomy	74 (62%)[b]
Yes, MILS and minimally invasive pancreatoduodenectomy	40 (33%)[b]
Team for MILS per center	
Minor	n = 120
One surgeon with resident	32 (27%)[b]
One surgeon with fellow	46 (38%)[b]
Two surgeons	36 (30%)[b]
Other	6 (5%)[b]
Major	n = 110
One surgeon with resident	16 (15%)[b]
One surgeon with fellow	25 (23%)[b]
Two surgeons	67 (61%)[b]
Two surgeons with resident	2 (2%)[b]

Abbreviations: MILS = Minimally invasive liver surgery.
[a] Median (interquartile range).
[b] Numbers of respondents (proportions).

the most mentioned contraindications for major MILS were involvement or near involvement (<5 mm) of hilar vessels (28%) and ASA score >3 (25%).

Training

According to 118 respondents (98%), the minimum annual volume of MILS including both minor and major MILS per center should be 21–30 resections per year (Table 4). Of all respondents, 78 surgeons (65%) provided a formal MILS training to senior residents and fellows. Of surgeons who did not provide MILS training (35%), the most reported reason was that the surgeons had not surpassed their own learning curves (19%). Training in MILS was reported as the most essential element for performing minor MILS by 100 respondents (83.3), while training in major open liver surgery was mentioned most frequently as essential for performing major MILS (82%).

Subgroup analysis

Responses were stratified based on the lowest (<100 liver resections/year) and the highest two volume quartiles (≥100 liver resections/year) centers. The median annual overall liver volume including both open liver resection and MILS was 50 [35–70] in the lower-volume group versus 140 [110–200] in the higher-volume group ($p < .001$). Higher center volume was associated with significantly lower use of MILS, (Rho −.266; $p = .040$).

Comparing centers who perform both robotic and laparoscopic MILS and centers who perform laparoscopic MILS only showed a higher implementation of MILS in the centers performing both approaches as compared to centers performing laparoscopy only (44% vs. 32%; $P = .022$).

Discussion

This survey on views and implementation of MILS among a group of European liver surgeons found that MILS consisted of about one third of liver resections in participating centers and was mostly performed laparoscopically, although the use of robotic liver surgery seems to be increasing. The development of additional choice of instruments for robotic parenchymal transection might help to further increase the adoption of robotic MILS.

Several studies have reported on implementation of MILS on a nationwide scale.[16–21] A Brazilian survey from 2016 reported that 91% of the centers implemented MILS with the majority of the centers having an implementation rate of less than 9%.[16] Of note, robotic MILS was not employed in Brazil. A nationwide

Table 3 Preferences and opinions

	All N = 120	Laparoscopy N = 82	Robotic N = 38	p-value
Overall ***current*** value of MILS compared to open liver surgery in patients eligible for both approaches				
Inferior value of MILS	3 (3%)[b]	2 (2%)[b]	1 (3%)[b]	x = 1.777, p = .620
Equivalent value of MILS	14 (12%)[b]	9 (11%)[b]	5 (13%)[b]	
Superior value of MILS	103 (86%)[b]	71 (87%)[b]	32 (84%)[b]	
Superior value of minor MILS, unclear for major	35 (29%)[b]	27 (33%)[b]	8 (21%)[b]	
Superior value of minor and major MILS	68 (57%)[b]	44 (54%)[b]	24 (63%)[b]	
Overall ***future*** value of MILS compared to open liver surgery in patients eligible for both approaches				
Inferior value of MILS	0 (0%)[b]	0 (0%)	0 (0%)	x = 1.078, p = .299
Equivalent value of MILS	15 (13%)[b]	12 (15%)	3 (8%)	
Superior value of MILS	105 (88%)[b]	70 (85%)	35 (92%)	
In 5 years from now, what percentage of liver resections (minor and major combined) will be minimally invasive	56 (46–66)[a]	56 (36–66)[a]	66 (56–76)[a]	.043
In 5 years from now, what percentage of MILS (minor and major combined) will be robotic	26 (16–46)[a]	26 (16–36)[a]	46 (26–56)[a]	<.001
For which procedures would the robot be beneficial over conventional laparoscopic-, or open surgery				
Wedge resections/partial segment resection	8 (13%)[b]			
Left lateral resections (S2, S3)	5 (8%)[b]			
Resection of anterior segments (S4b, S5, S6)	8 (13%)[b]			
Resection postero-superior segments (S4a, S7, and S8)	37 (60%)[b]			
Central hepatectomy	32 (52%)[b]			
Left hemihepatectomy	5 (8%)[b]			
Right hemihepatectomy	10 (16%)[b]			
Trisectionectomy/extended left hemihepatectomy + hepaticojejunostomy	36 (58%)[b]			
Trisectionectomy/extended right hemihepatectomy + hepaticojejunostomy	37 (60%)[b]			

Abbreviations: MILS = Minimally invasive liver surgery.
[a] Median (interquartile range).
[b] Numbers (proportions).

questionnaire study from 2017 investigated the use of liver surgery in Japan and showed that 14.3% of liver surgery was performed as MILS with all procedures being performed laparoscopically.[19] The Italian I GO MILS group performed a nationwide survey among 39 centers and reported an implementation rate of 10.3% of MILS in the period 1995–2012 including 3 centers performing robotic MILS.[21] The consecutive *I GO MILS Registry* analysis of the period 2014–2017 showed that 5 more centers were started performing robotic MILS.[22] Of note, no implementation rate of MILS has been analyzed in this study. On an international level, a survey study mentioned no robotic MILS was performed in 448 liver centers across the world before 2014,[20] while the INSTALL-2 study showed that the proportion of robotic MILS as part of the overall MILS practice was 5% in the period 2014–2018.[23] The higher implementation rate in the current study as compared to previous studies may be explained by difference in time period and the implementation of the Southampton guidelines in 2017 which states that MILS should be considered as standard of care for minor liver resections.[24]

In the present study, the majority of responding surgeons felt that training was essential for performing both minor and major MILS. However, formal training in MILS for senior residents and fellows was only provided by 65% of respondents. Of centers who did not provide formal training, 55% stated to have not completely passed their own learning curves. Therefore, 78% reported specific training in MILS as an essential item for performing major MILS. The learning curve for MILS can be quite long and previous studies reported learning curves of 7–160 procedures, partly determined by the technique used and the outcome investigated (laparoscopic = 7–160 procedures,[25–29] robotic = 7–30 procedures[29–33]).

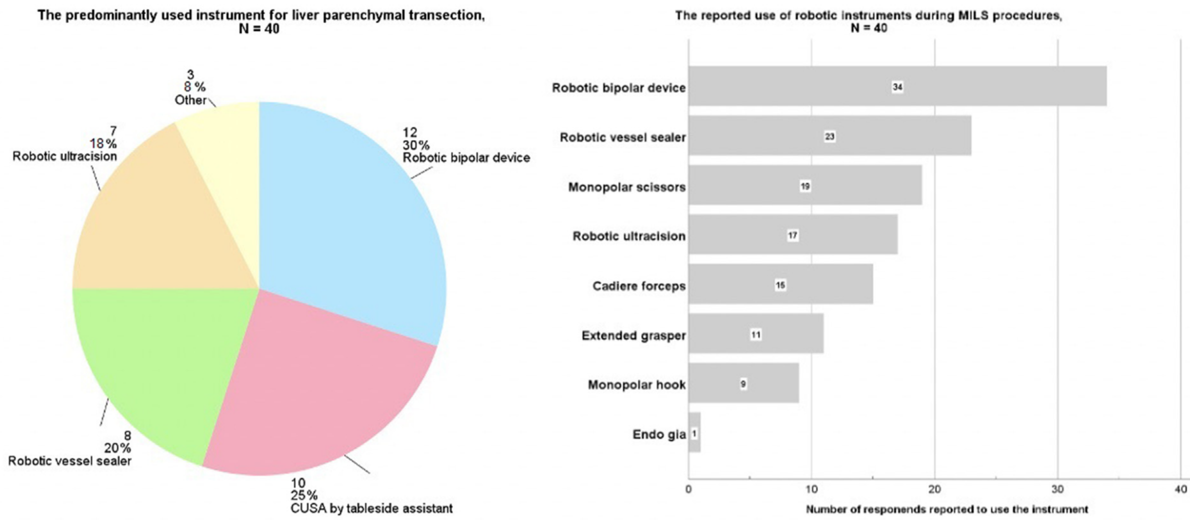

Figure 4 Robotic liver surgery equipment

The use of robotic MILS is thought to provide some advantages over laparoscopic MILS for certain procedures (91%), such as resection in postero-superior segments (60%) and extended hemihepatectomy (~59%). However, implementation of and experience with the robotic approach (i.e. the da Vinci system) is limited to only 33% of our respondents. Of these, 70% was dissatisfied with the available robotic instruments, with a wish for an robotic CUSA as the most mentioned reason. As this study did not assess the type of da Vinci system used (S, Si, X, Xi; with/without robotic ultrasound, Firefly etc.), dissatisfaction with instruments may reflect the use of older systems. We suggest that, apart from the development of a robotic CUSA, more standardized techniques of robotic parenchymal transection need to be defined. Moreover, 81% of respondents stated that robotic MILS could be more expensive than laparoscopic MILS.

The COMET randomized trial compared MILS versus open liver surgery for colorectal liver metastases and demonstrated lower complication rates, faster recovery, cost effectiveness and

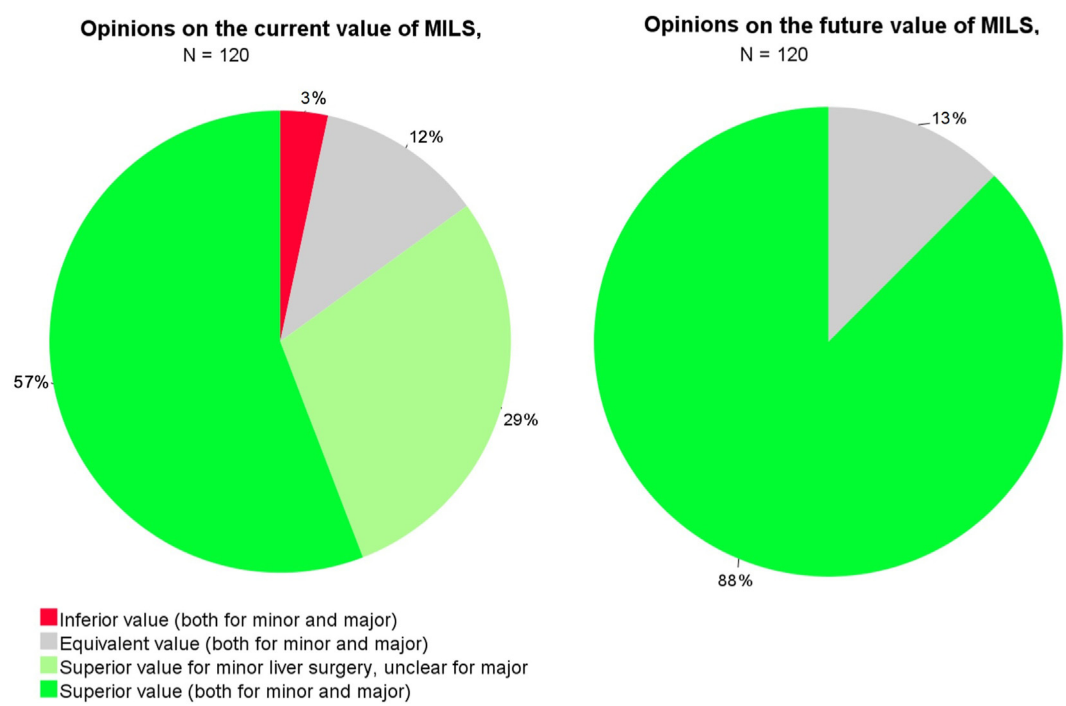

Figure 5 Preferences and opinions

Table 4 Training and credentialing

	N = 120	
What should be the minimal annual center case volume for MILS	21–30	
A formal training for senior residents/fellows in laparoscopic/robotic MILS	78 (65%)[a]	
No formal training, reasons for	42 (35%)[a]	
Not completely passed own learning curve	23 (19%)[a]	
Most residents/fellows will not pursue a career in MILS	14 (12%)[a]	
Other	5 (4%)[a]	
Which items are, in your opinion, essential (absolutely required) for performing minimally invasive liver surgery, separated by type	Minor resections	Major resections
Specific training in OPEN minor liver surgery	79 (66%)[a]	NA
Specific training in OPEN major liver surgery	NA	98 (82%)[a]
Training in minimally invasive surgery	100 (83%)[a]	93 (78%)[a]
Specific training in minor MILS	74 (62%)[a]	92 (77%)[a]
High-volume liver surgery center	80 (67%)[a]	90 (75%)[a]
High-volume MILS center[b]	58 (48%)[a]	85 (71%)[a]
At least two surgeons trained in minor MILS	56 (47%)[a]	69 (58%)[a]
Multidisciplinary assessment of patients for minor MILS	57 (48%)[a]	63 (53%)[a]
Specific accreditation in minor MILS	9 (8%)[a]	21 (18%)[a]
Other	2 (2%)[a]	1 (1%)[a]

Abbreviations: MILS = minimally invasive livers surgery; NA = Not applicable.
[a] Numbers (proportions).
[b] >40 MILS annually.

better quality of life in the MILS group as compared to the open group.[13,34,35] Similarly, the LapOpHuva randomized trial assessed short-term outcomes for MILS versus open liver surgery in patients with colorectal liver metastases and showed a significantly shorter hospital stay after MILS as compared to the open approach.[5] The INSTALL-2 survey found that most ‘difficult’ laparoscopic MILS procedures reached the ‘assessment’ phase (IDEAL stage 3) in centers performing ˃100 laparoscopic MILS annually.[23] Although more trials on the value of MILS are needed, in the current study high-volume MILS (annual volume >21–30 per center) was mentioned as the essential item for performing major MILS, whereas the actual median annual volume of MILS per center was 30 procedures/year in the current study. In specialized MILS centers, no correlation between MILS volume and both morbidity and mortality was found.[23] In contrast, a nationwide retrospective cohort study showed that a MILS volume of 24 or less procedures/year was associated with significantly higher morbidity as compared to centers performing >24 procedures/year.[36]

This survey emphasizes the need for structured and tailored training programs in MILS on a national as well as an international scale. Currently, such training programs are scarce, lack uniformity, and it is unknown whether these training programs are feasible and will lead to beneficial outcomes. In the Netherlands, several training programs(LAELAPS-1, 2, 3)[37–39] for minimally invasive pancreatic surgery were shown to be feasible and effective. Based on findings from a nationwide analysis of the implementation and outcomes of MILS in the Netherlands,[40] the LAELIVE training program was initiated by the Dutch Liver Collaborative Group for both anatomically and technically major laparoscopic MILS including detailed technique description and proctoring on-site. LAELIVE may serve as a format for a European training program in laparoscopic and robotic MILS similar to how LAELAPS[37–39] served as a format for the European LEARNBOT training program in minimally invasive pancreatic surgery [Netherlands Trial Register″ NL8898]. A step-by-step approach may be valuable to establish an effective and sustainable MILS training program and credentialing for MILS. Such a program could include an online assessment, training course on the robotic system and equipment, simulation training with the need to achieve a threshold competence score, several formal case observations during which the surgeon visits an expert liver surgical center and formal clinical training on site with a proctor. Furthermore, as this survey showed that one third of all liver resections was performed by a minimally invasive approach in participating centers, there is more need for insights in the application and perioperative outcomes of MILS. In several countries, independent nationwide registries have been initiated to provide insight in daily clinical practice, quality of care and outcomes of MILS such as the European Registry of Minimally invasive Liver Surgery (E-MILS Registry). It is essential to sustain such national and international MILS registries by encouraging the participation of all centers performing MILS, regardless of volume of MILS performed in a center.

The outcomes of this survey should be interpreted in the light of several limitations. First, this survey undoubtedly contains a degree of selection bias towards centers performing MILS since all participants performed MILS. Second, the total number of surgeons who actually received receiving this survey is unknown due to the confidentiality of the members of societies. For example, more than 20 centers perform MILS in the Netherlands, yet this survey has 13 respondents from the Netherlands.[36] Therefore, the exact participation is unknown. Third, the 83 per cent of respondents worked in a university- or university affiliated center. We aimed to adjust for this by stratifying results for hospital volume. While this sensitivity analysis demonstrated similar outcomes in both groups regarding volume criteria, contraindications and future perspectives on MILS volume, it also showed a higher estimated future use of robotics by surgeons from university affiliated hospitals. Fourth, in the current study the cut-off value to categorize a center as lower- or higher-volume center was 100 liver resections per year based on descriptive data without asking responding surgeons whether they would consider their liver surgery practice low- or high-volume. This cut-off may be controversial since there is limited previously published data regarding the optimal cut-off to define a high-volume center. Further studies might be needed to reach a uniform definition of a high-volume liver surgical center. Fifth, both overall annual center as well as individual annual surgeon volume of MILS are probably relevant. However, information about individual surgeon volume was not available. These data may be valuable to improve insights on the current practice of MILS.

In conclusion, MILS seems well implemented in Europe with laparoscopy still being the most common approach. The current undesirable mismatch in actual volume and stated required volume of MILS and the lack of dedicated training programs hampers broad implementation of MILS. Furthermore, robotic MILS is gaining popularity for certain indications, although its role, capabilities and costs should be further assessed. Development of robotic instruments with an added value compared to the current laparoscopic instruments is warranted to increase adoption of robotic MILS. Future studies are required to compare outcomes between laparoscopic and robotic MILS.

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Conflict of interest
None to declare

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Appendix A. Supplementary data

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