Improved tumour localisation during minimally-invasive liver surgery using augmented reality: a retrospective study with propensity score analysis

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Abstract

Background - Minimally-invasive liver surgery (MILS) decreases postoperative morbidity but presents specific difficulties, including precise tumour localisation. Conversion to open surgery is sometimes necessary because the tumour cannot be visualised. We previously proposed Hepataug, an augmented reality (AR) software for laparoscopic liver surgery that enables a deformable 3D model of a patient's liver to be merged semi-automatically with the image on the laparoscopic screen during surgery. The aim of this study was therefore to evaluate the contribution of AR to reducing the rate of conversion but without worsening resection margins.

Methods - All patients who underwent MILS between 2017 and 2023 were included and divided into two groups depending on whether AR guidance was used during surgery (AR+ group, n=33) or not (AR- group, n=212). The two groups were compared in terms of perioperative outcomes, and particularly the rate of conversion to laparotomy because of a failure to locate the tumour. A propensity score analysis was implemented using the inverse probability of treatment weighting method.

Results - The conversion rate was zero in the AR+ group, while six patients in the AR- group required necessitated conversion to laparotomy to detect the tumour. AR increased operative time by around 10%, with no significant differences in terms of resection margins and postoperative complications (biliary fistula, Dindo-Clavien grade) between the two groups.

Conclusion - Our study showed that AR could successfully guide the intraoperative localisation of liver tumours and avoid conversion due to an intraoperative non-visualisation of tumours. In addition, AR did not increase postoperative complications or operative times, and could easily be applied during surgery.

Keywords: liver surgery, laparoscopic, augmented reality

Introduction

Minimally-invasive liver surgery (MILS), whether robot-assisted or laparoscopic, is becoming the standard for liver resections, as it significantly reduces the length of hospitalisation and post-operative morbidity – and particularly pulmonary complications – compared to open surgery [1, 2]. However, MILS presents specific difficulties that include precise tumour localisation [3]. Laparoscopic ultrasound (LUS) can improve the accuracy of tumour localisation but is highly operator-dependent. It can only make a limited contribution after resection has started because of the interposition of gas and blood between the LUS probe and the liver parenchyma. In the event of poor tumour visualisation by LUS, conversion to open surgery is sometimes required to facilitate navigation, or resection must be abandoned because no target can be found. Faced with these obstacles, surgeons are increasingly applying preoperative 3D modelling of the liver to visualise tumours and vascular structures [4], but this model cannot yet be superimposed easily on the intraoperative image because of shape and location differences between the preoperative model and the intraoperative image [5].

Our multidisciplinary team has been working on the development of Hepataug, an augmented reality (AR) software for liver surgery that enables the overlaying of a preoperative 3D model of a patient's liver on a laparoscopic screen during surgery. Hepataug can improve tumour localisation, facilitate resection and limit postoperative complications [6, 7]. It has been shown to reduce the R1/R2 resection rate in animal models of difficult-to-access tumours and to overcome the drawbacks of bidirectional vision in monocular laparoscopy [8, 9]. Finally, an observational study by our group on the first 17 patients operated on using Hepataug showed the feasibility and reproducibility of our results, with benefits regarding tumours not visualised by LUS, and particularly small and/or deep tumours [10, 11].

The aim of this study was therefore to show that AR can reduce the rate of conversions related to poor tumour visualisation, but without worsening resection margins and postoperative complications.

Materials and methods

Study population:

All patients who underwent laparoscopic liver surgery in the Digestive Surgery Department at Clermont-Ferrand University Hospital between 2017 and 2023 were included in this study. Our policy was to use AR in MILS as often as possible, depending on the availability of both the surgical and technical teams. Data were extracted from our prospective REDCap database, which was updated at the end of each surgery (with preoperative and intraoperative data) and at the end of the hospital stay (for data concerning postoperative follow-up and pathological analysis) [12, 13]. The patients were divided into two groups according to the intraoperative use of AR guidance (AR+ group) or not (AR- group). AR was used consecutively as often as possible, but this was subject to on the availability of the scientific team members, who alone were able to manipulate and update the Hepataug software. The patients were informed and consented to the use of this technology during surgery.

The study was approved by the local Ethics Committee (IRB00013412, “CHU de Clermont Ferrand IRB #1”, IRB number 2024-CF310) and complied with French policies on individual data protection.

Surgical technique:

The patients underwent laparoscopic +/- robotic liver resection after validation by a multidisciplinary consultation meeting. The preoperative work-up included a CT scan and MRI, regardless of the aetiology. In patients considered for AR, a preoperative 3D model of the liver,

including the tumours to be resected, was constructed for each patient from the preoperative CT or MRI scans (Figure 1a).

The surgical technique was initially common to both groups. The pneumoperitoneum was insufflated with a Palmer needle. The trocars were positioned according to the location of the lesion(s) to be resected. The liver was mobilised if necessary, depending on the location of the tumours. LUS was then performed, and the resection limits drawn on the surface with monopolar scissors if the tumour was visible.

After this step, the surgical camera in the AR+ group was positioned to obtain an image of the entire liver and temporarily fixed with a bras-de-martin device for recording. Anatomical landmarks (falciform ligament, inferior ridge and hepatic silhouette) were then drawn by the physicians on the recorded image (Figure 1b), and the AR software Hepataug was started to register the 3D model and the recorded laparoscopic image so as to enable virtual assessment of the tumour location and the resection margins on the laparoscopic image (Figure 1c to 1f). The resection limits were then reassessed from the AR guidance and rectified if necessary.

After definitive margin assessment, resection was started using a similar technique in both groups: parenchymal transection was performed with CUSA® (Integra, France) and haemostasis with bipolar and transcollation (Voyant, Applied, France), using LUS if necessary to adjust transection. Clamping manoeuvres were performed in the event of excessive bleeding and according to the surgeon's preference. At the end of the procedure, the specimen was removed via a suprapubic incision. Drains were not used routinely. The patients were always discharged to the intensive care unit (ICU) in the event of cirrhosis, major liver resection, significant bleeding and/or the use of clamping procedures.

Perioperative clinical data:

The following variables were collected: preoperative patient variables including age, sex, BMI, smoking, alcohol, history (hypertension, diabetes, dyslipidemia, heart failure, respiratory failure, colorectal cancer, NASH, cirrhosis, abdominal surgery, liver surgery); variables concerning the hepatic tumour: benign tumour, cholangiocarcinoma, hepatocellular carcinoma, metastasis, the implementation of neoadjuvant chemotherapy, preoperative biological factors (total bilirubin, prothrombin rate, platelets), number of lesions, segments involved, sum of tumour sizes (greater or less than 3 cm), whether the lesion was deep (close to a suprahepatic vein, hepatic pedicle or vena cava) or superficial (close to the diaphragm, stomach or colon); variables concerning operative data, such as the operation performed, pedicle clamping and its duration, duration of the surgical procedure, blood loss, transfusions, weight of the resected liver; variables concerning postoperative data: duration of hospitalisation, postoperative liver failure according to ISGLS (only clinically relevant grade B and C), biliary fistula, complications according to the Dindo-Clavien classification [14, 15], planned and unplanned transfer to ICU and duration, and postoperative death.

Endpoints:

The primary endpoint was the rate of conversion related to non-visualisation of the intrahepatic tumour in the AR- group (surgical camera + LUS) and in the AR+ group (surgical camera + LUS + AR). The secondary endpoints were the minimum resection margin, operative time and the rate of postoperative complications (biliary fistula, Dindo-Clavien grade).

Statistical analysis:

Categorical data are presented as the number of patients and associated percentages, and continuous data as means ± standard deviation. Comparisons between the separate groups (AR+ and AR-) were performed using univariate logistic regressions. To compensate for baseline

differences between the groups, a propensity score (PS) analysis was implemented using the inverse probability of treatment weighting (IPTW) method [16, 17] which consists in creating a 'pseudo sample' of treated (AR+) and untreated (AR-) patients, weighting each patient by the inverse probability of receiving the treatment they actually received: 1/PS in the AR+ group and 1/(1-PS) in the AR- group. In practice, the probability of being in the AR+ group or not was modelled using multiple logistic regression, and the estimated probability was used as the PS. Baseline variables that might have affected treatment decisions were selected for the PS based on clinical relevance, i.e. history of cirrhosis, history of NASH, history of colorectal cancer, tumour length less than 3 cm, preoperative diagnosis and number of lesions. For the conversion variable, a univariate analysis was conducted using penalised maximum likelihood logistic regression (the Firth logit model) rather than logistic regression [18]. Indeed, the Firth logit model is an appropriate and suitable alternative to reduce any bias affecting maximum likelihood estimates in generalised linear models. It is also useful in logistic regression in circumstances where 'separation' is problematic. There is no weighting option in the Firth logit model, so we were not able to analyse the conversion variable by weighting each patient using IPTW.

All analyses were performed using Stata software (Version 17, StataCorp, College Station, TX) for a two-sided Type I error alpha=5%.

Results

Between January 2017 and December 2023, 243 patients were included and divided into two groups according to the use of intraoperative AR (n=32, 13.2%, AR+ group) or not (n=211, 86.8%, AR- group) (Figure 2). The missing data rate was lower than 5% except for the following variables: preoperative diagnosis, deep-seated tumour, preoperative total bilirubin,

type of liver surgery, duration of pedicle clamping, transfusion, weight of resected liver, minimum resection margin, Dindo-Clavien grade, and duration of ICU stay (Table 1).

The median age was 65 years. Resections involved a single tumour in 77% of the cases. The aetiology was most frequently HCC (51%) and colorectal cancer metastases (30%). Surgery was non-anatomical in 51% of cases (Table 2). Eight patients (3.3%) required a second operation and three (1.2%) died postoperatively. Thirteen patients (5.3%) required conversion to laparotomy. Of these, six (46.2%) were converted because of a failure to locate the lesion under LUS, and seven (53.8%) because of adhesions or exposure difficulties (Table 3).

After propensity score analysis there was no difference between the AR+ and AR- groups regarding preoperative variables (Table 1). The conversion rate for a failure to locate the lesion was nil and lower in the AR+ group, but not statistically different when compared with the AR- group (n=0% vs. 2.8%, p=0.7). The median minimum margins and rates of postoperative complications did not differ between the two groups. Operative time was slightly longer in the AR+ group (270 vs 245 minutes in the AR- group, p=0.1), and clamping procedures were more frequent in the AR+ group (63% vs. 51% in the AR- group; OR = 1.9; IC95 = [0.75;4.7]; p=0.1). There was no significant difference between the two groups with respect to other perioperative variables (Table 2).

Discussion

To the best of our knowledge, this is the largest study to have assessed the outcome of patients undergoing MILS using AR guidance. After weighted matching based on a propensity score, we can report that a major advantage of AR was better visualisation of the tumours, without compromising the quality of resection, because the minimum margins between the AR+ and AR- groups did not differ. The findings of this clinical study were in line with those of previous animal-model work by our team, which had demonstrated that AR performed on ex-situ animal

livers was able to locate tumours in 100% of cases and enabled resections with adequate margins [8]. US is based on elasticity of the tissues that endows contrast depending on their differing consistencies. In some cases, tumours and liver parenchyma may have the same elasticity and be indistinguishable from each other under LUS, even though they remain visible on a CT or MRI scan. Furthermore, tumours may have decreased in size after systemic treatment and can become invisible. In these cases, AR may be superior to US because tumours and others parameters (vessels, distance between two boundaries) can be implemented through the 3D model and become visible to the surgeon intraoperatively. During our study, all patients in the AR+ group had tumours that were visible after AR.

The installation and processing of AR in our study slightly increased operative time by around 10%, but without having a significant impact on postoperative complications. Golse et al. showed that AR could be set up within less than 10 minutes [19]. With the increasing number of cases and experience of our team, we became used to operating the Hepataug software while continuing the surgical procedure (section of hepatic ligaments, exposition, LUS). Even though it was not assessed during the present study, AR can in turn decrease operative time compared to LUS alone, particularly in the case of deep tumours or those located in posterior-superior segments, which necessitate liver mobilisation to enable access for the LUS probe. This was the topic of a previous publication on animal livers by our team, which showed that AR could ensure more accurate resection margins with less variability than the gold standard US navigation, particularly in difficult-to-access liver zones with deep tumours [8]. This was confirmed by a recent review of the literature that focused on the performance of AR software and showed some benefits, particularly with small lesions [20]. The absence of a significant difference in minimum margin between the AR+ and AR- groups in our study was an indirect indicator of the accuracy of our software. Finally, improved coordination between the surgical

team and the software developers will probably reduce the difference between the two groups in the future.

There was no significant difference after weighted matching on any of the variables studied, except a slight increase in operative time but without a significant impact on postoperative complications. The use of AR in liver surgery has been developing rapidly over the past few years, initially using *in vivo* and *ex vivo* animal models [21, 22]. A recent systematic review reported that in 32 selected studies, a total of 183 patients underwent surgery using AR, 31 through an open approach and 152 using minimally-invasive surgery [23]. Our study therefore constitutes a major contribution to the emergence of AR in liver surgery, because we report 32 cases of patients undergoing laparoscopic surgery using this technology, or in fact 21% of all the cases reported in the literature.

Our study has therefore shown that AR was able to detect almost all tumours within the liver, thus decreasing the rate of conversion or abortion of resection. Furthermore, AR can enhance the rapidity and accuracy of LUS by generating a first tracking of the tumour, particularly in deep lesions and when LUS is performed by inexperienced surgeons. AR is operator-independent, and does not necessitate as long a learning curve as LUS. Setting up Hepataug slightly increased the operative time, but without having significant effects on postoperative complications. This had already been noted during a previous study by our team [8].

The second most common indication for liver resection in our study was colorectal liver metastases (CRLM). CLRM need parenchymal sparing because the risk of intrahepatic recurrence is high. In these cases, a second, third or even fourth repeated hepatectomy must be performed if possible as this strategy increases survival [24]. AR can therefore be used to improve the accuracy of liver resections and thus decrease postoperative complications and peritoneal adhesions, in order to improve long-term survival [25]. This was the case in our study, because there were no conversions in the AR+ group.

Our study had some limitations. Although it adds substantial value to the existing literature, it remains a retrospective, monocentric study, and surgeons and patients were not randomly assigned to the groups making the interpretation of results difficult. The primary endpoint was not significant, probably due to a lack of power and the small number of cases concerned. Nevertheless, it remains entirely relevant because there were no cases of conversion in the AR+ group. Surprisingly, conversion for reasons other than a failure to locate tumours was also nil in the AR+ group. AR can improve surgical exposure and reduce the risk of conversion in open procedures. However, it remains possible that patients at a lower risk of conversion were unintentionally selected for AR use, to avoid the risk of moving the AR team unnecessarily. It would also have been interesting to study the impact of bias linked to the 'surgeon' effect, for instance the number of resection margin reassessments through AR. We did not have this variable in our database and were therefore unable to add it to our statistical analysis models. Also, given the small number of complications, our regression model could not contain too many explanatory variables. Nevertheless, this was not essential in this study, since complications were the second endpoint of our work, and we were clearly able to show that the use of AR does not increase the risk of complications in any way.

Conclusion

Our study demonstrated that our AR software, Hepataug, could successfully guide the intraoperative localisation of liver tumours in 100% of cases, without conversion due to the intraoperative non-visualisation of tumours. AR did not increase postoperative complications and could easily be implemented during surgery. A forthcoming prospective multicentre study may provide more powerful evidence that AR offers benefits to both patients and surgeons in the context of liver resection.

Disclosures

Mr. Martinet-Kosinski, Prof. Le Roy, Dr. Espinel Lopez, and Prof. Buc have no conflicts of interest to disclose.

Prof. Bartoli is Chief Scientific Officer at Surgical Augmented Reality (SurgAR).

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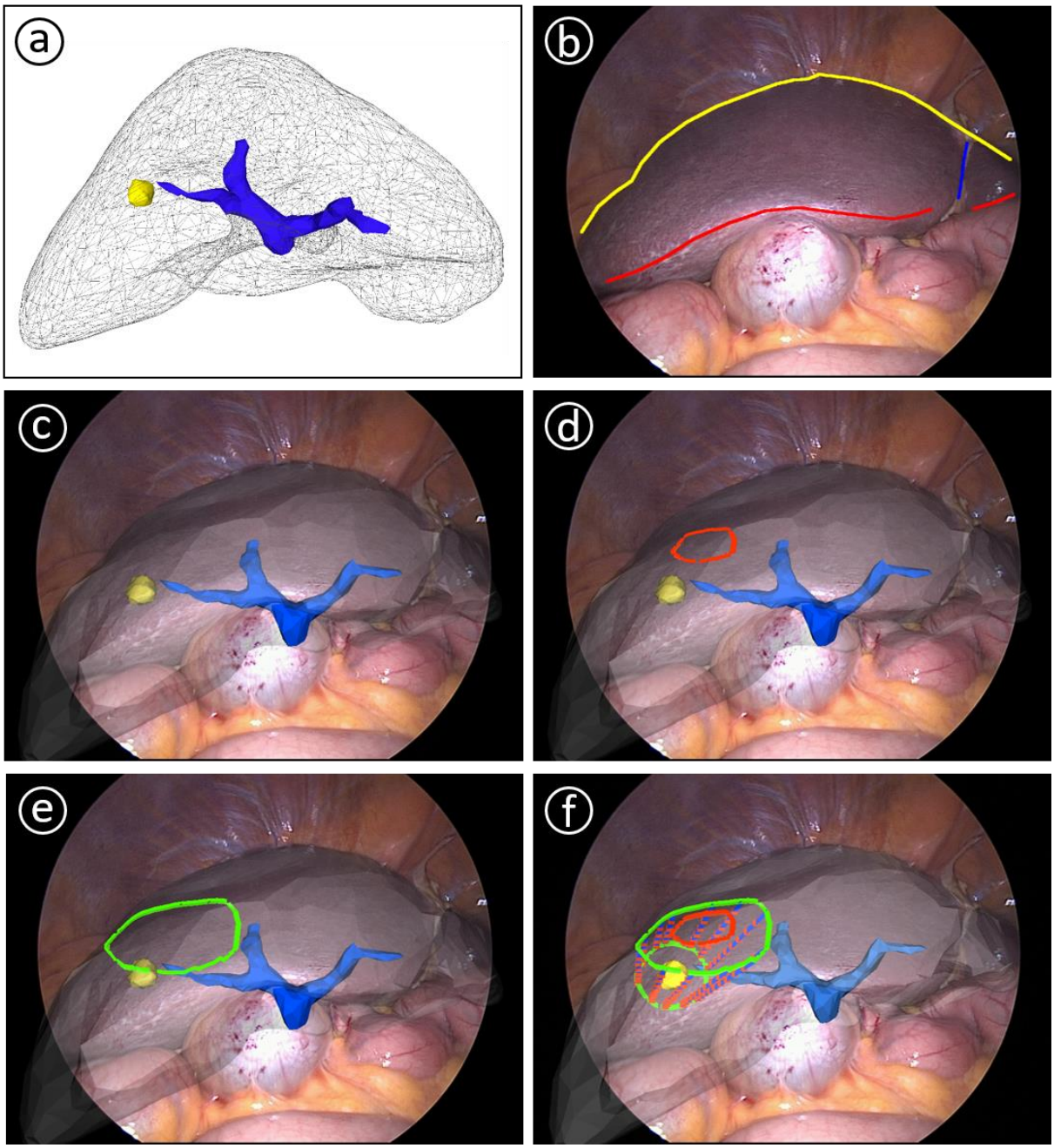

Figure 1: AR procedure, from a preoperative 3D model to a final intraoperative AR. a) preoperative 3D liver model built from a preoperative CT-scan or MRI, with the intrahepatic tumour (yellow) and portal venous system (blue); b) tracing of anatomical landmarks on the intraoperative laparoscopic image: silhouette (yellow line), anterior ridge (red line) and falciform ligament (blue line); c) intraoperative image augmented using Hepataug software; d) tumour projection at the surface of the liver (red circle); (e) projection of one centimetre tumour

margins at the surface of the liver (green circle); (f) ideal resection cylinder: the red and blue dotted line represents the resection depth from the surface (large green circle) to the inferior margin (small green circle).

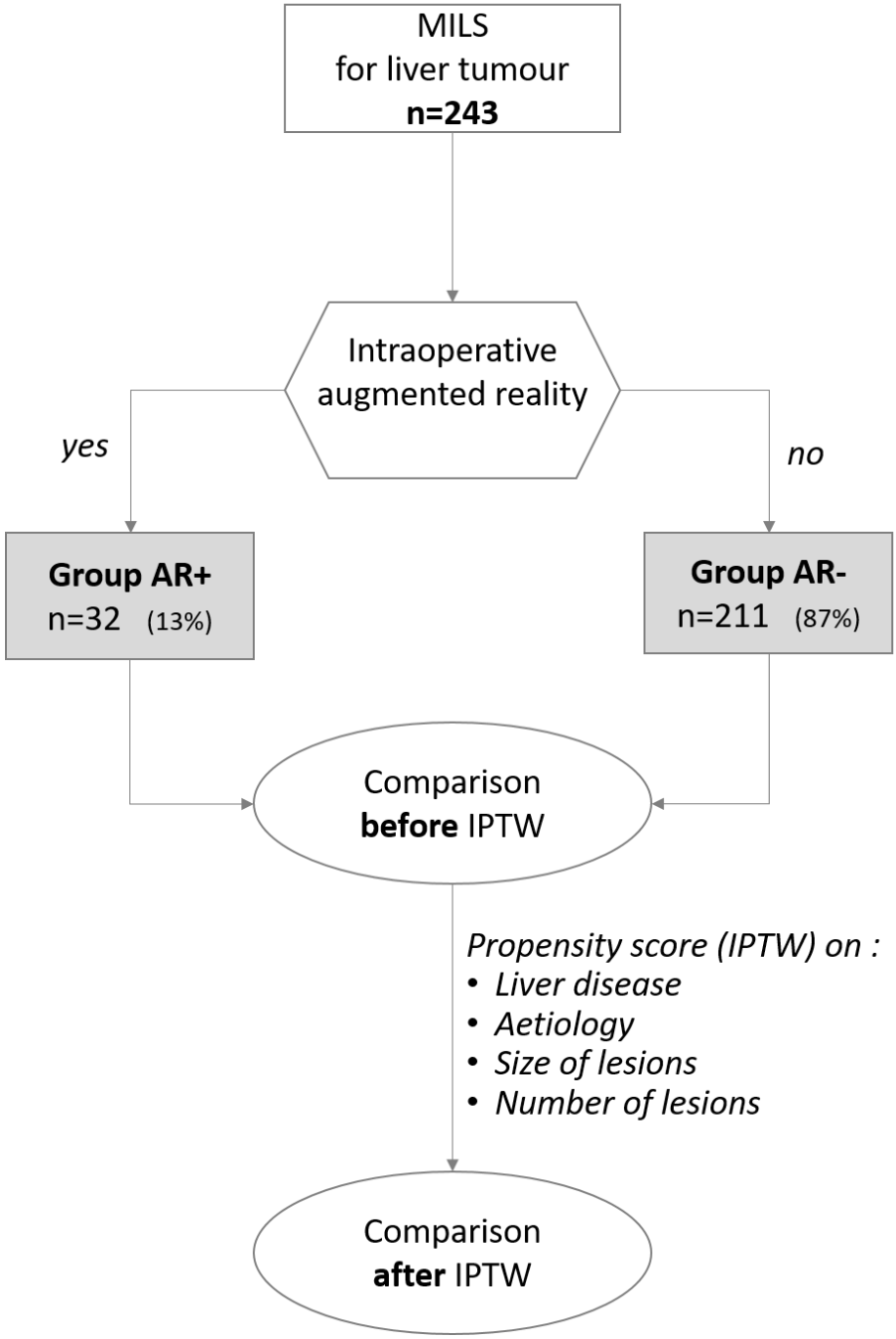

Figure 2: Flowchart (IPTW= Inverse Probability of Treatment Weighting).

Table 1 : preoperative data

	All [N=243]	MD (n)	Group RA- [N=211]	Group RA+ [N=32]	Before IPTW OR	Before IPTW IC95	Before IPTW p-value	After IPTW OR	After IPTW IC95	After IPTW p-value
Age (mean (SD))	65 (14)	0	64.1 (14.2)	67.5 (11.8)	1.02	[0.99 ; 1.05]	0.1	1.01	[0.97 ; 1.04]	0.7
Sex (% - Women)	66 (27%)	0	61 (28%)	5 (15%)	0.45	[0.16 ; 1.2]	0.1	1.53	[0.50 ; 4.68]	0.5
BMI (mean (SD))	28 (9)	0	27.4 (5.4)	31.8 (20.7)	1.03	[0.99 ; 1.08]	0.1	1.03	[0.96 ; 1.11]	0.3
Smoking (%)	159 (65%)	0	137 (65%)	22 (68%)	1.18	[0.53 ; 2.64]	0.6	1.06	[0.43 ; 2.67]	0.9
Alcohol consumption (%)	111 (46%)	1	92 (44%)	19 (59%)	1.87	[0.88 ; 3.99]	0.07	1.20	[0.49 ; 2.89]	0.7
High blood pressure (%)	129 (53%)	0	110 (52%)	19 (58%)	1.25	[0.59 ; 2.64]	0.5	1.24	[0.51 ; 2.9]	0.6
Diabetes (%)	16 (7%)	0	15 (7%)	1 (3%)	0.42	[0.05 ; 3.3]	0.4	0.35	[0.04 ; 2.7]	0.3
Dyslipidaemia (%)	76 (31%)	0	64 (30%)	12 (39%)	1.38	[0.63 ; 2.99]	0.4	1.1	[0.46 ; 2.74]	0.8
Heart failure (%)	6 (2%)	0	5 (2%)	1 (3%)	1.32	[0.15 ; 11.7]	0.8	1.53	[0.17 ; 13.8]	0.7
Respiratory failure (%)	0 (0%)	0	0 (0%)	0 (0%)						
History of colorectal cancer(%)	68 (28%)	0	65 (31%)	3 (9%)	0.23	[0.06 ; 0.79]	**0.01**	0.47	[0.13 ; 1.67]	0.2
History of cirrhosis (%)	59 (24%)	0	49 (23%)	10 (31%)	1.50	[0.66 ; 3.38]	0.3	1.29	[0.52 ; 3.19]	0.6
History of MASH (%)	33 (13%)	0	27 (13%)	6 (19%)	1.57	[0.59 ; 4.17]	0.4	1.15	[0.41 ; 3.24]	0.8
History of abdominal surgery (%)	175 (73%)	2	154 (74%)	21 (66%)	0.68	[0.31 ; 1.50]	0.4	1.03	[0.41 ; 2.61]	0.9
History of liver surgery (%)	38 (16%)	9	30 (15%)	8 (26%)	2	[0.82 ; 4.89]	0.06	2.25	[0.82 ; 6.20]	0.1
Pre-operative diagnosis (%)		16								
Benin	32 (14%)		29 (15%)	3 (11%)	1.			1.		
Hepatocellular carcinoma	116 (51%)		95 (48%)	21 (71%)	2.01	[0.55 ; 7.2]	0.3	0.78	[0.21 ; 2.89]	0.7
Cholangiocarcinoma	11 (5%)		10 (5%)	1 (4%)	0.96	[0.09 ; 10.3]	0.9	0.31	[0.03 ; 3.46]	0.3
Colorectal cancer metastases	69 (30%)		64 (32%)	4 (14%)	0.60	[0.13 ; 2.87]	0.5	0.43	[0.08 ; 2.17]	0.3
Neoadjuvant chemotherapy (%)	60 (25%)	0	57 (27%)	3 (9%)	0.28	[0.08 ; 0.90]	**0.04**	0.31	[0.05 ; 1.67]	0.1
Total tumour size < 3cm (%)	62 (26%)	9	54 (26%)	8 (26%)	0.96	[0.41 ; 2.3]	0.8	0.77	[0.27 ; 2.21]	0.6
Number of lesions (%)		6								
1	184 (77%)		159 (77%)	25 (79%)	1.			1.		
< 5	46 (20%)		41 (20%)	5 (15%)	0.78	[0.28 ; 2.15]	0.5	0.34	[0.11 ; 1.08]	0.06
> 5	7 (3%)		5 (2%)	2 (6%)	2.5	[0.47 ; 13.8]	0.3	3.2	[0.42 ; 24.6]	0.2
Deep-seated tumour (%)	29 (26%)	132	26 (28%)	3 (15%)	0.45	[0.12 ; 1.65]	0.2	0.57	[0.13 ; 2.44]	0.5
Pre-operative total bilirubin (mean (SD))	12 (17)	70	11.7 (17.5)	11.7 (8.2)	1	[0.98 ; 1.03]	0.9	0.99	[0.97 ; 1.02]	0.9
Preoperative platelets (mean (SD))	231 (82)	10	234 (82)	213 (83)	0.99	[0.99 ; 1.01]	0.2	0.99	[0.99 ; 1.01]	0.6
Preoperative prothrombin level (mean (SD))	92 (10)	7	92.2 (9.4)	90 (14)	0.98	[0.94 ; 1.01]	0.3	0.99	[0.96 ; 1.03]	0.7

IPTW: Inverse Probability of Treatment Weighting ; OR: Odds ratio ; IC95: 95% confidence interval ; SD: standard deviation ; MD: Missing Data

Table 2 : Outcomes

	All [N=243]	MD (n)	Group RA- [N=211]	Group RA+ [N=32]	Before IPTW OR	Before IPTW IC95	Before IPTW p-value	After IPTW OR	After IPTW IC95	After IPTW p-value
Cause of conversion (%)		0					0.7			
No conversion	230 (95%)		198 (94%)	32 (100%)	1					
Failure to locate	6 (2.4%)		6 (2.8%)	0 (0%)	0.46	[0.02 ; 8.32]	0.6			
Other causes	7 (2.9%)		7 (3.3%)	0 (0%)	0.40	[0.02 ; 7.11]	0.5			
Type of liver surgery (%)		22								
Atypical resection	120 (51%)		105 (51%)	15 (52%)	1			1		
Minor resection	112 (47%)		101 (49%)	10 (34%)	0.69	[0.30 ; 1.61]	0.3	0.76	[0.29 ; 1.98]	0.6
Major resection	4 (2%)		0 (0%)	4 (14%)						
Pedicle clamping (%)	128 (53%)	0	108 (51%)	20 (63%)	1.59	[0.74 ; 3.4]	0.2	1.9	[0.75 ; 4.7]	0.1
Duration of pedicle clamping (mean (SD))	41 (27)	117	41.1 (25)	43.2 (38)	1.01	[0.99 ; 1.01]	0.8	0.99	[0.98 ; 1.01]	0.7
Surgical duration (mean (SD))	248 (116)	1	245 (117)	270 (105)	1.01	[0.99 ; 1.01]	0.2	1.0	[0.99 ; 1.01]	0.1
Blood loss (mean (SD))	388 (501)	8	396 (520)	335 (349)	0.99	[0.99 ; 1.01]	0.5	1.0	[0.99 ; 1.01]	0.1
Transfusion (%)	4 (2%)	17	4 (2%)	0 (0%)						
Weight of resected liver (mean (SD))	267 (296)	130	266 (314)	270 (181)	0.99	[0.99 ; 1.01]	0.9	1.0	[0.99 ; 1.01]	0.9
Minimum resection margin (mean (SD))	6 (8)	160	6.4 (7.7)	4.6 (4.7)	0.96	[0.83 ; 1.11]	0.6	0.96	[0.84 ; 1.09]	0.5
Surgical complication (%)	43 (18%)	2	39 (19%)	4 (13%)	0.6	[0.20 ; 1.87]	0.4	0.45	[0.12 ; 1.66]	0.2
Biliary fistula (%)	12 (5%)	0	11 (5%)	1 (3%)	0.59	[0.07; 4.7]	0.6	0.46	[0.06 ; 3.7]	0.4
Post-operative liver failure (%)	5 (2%)	0	4 (2%)	1 (3%)	1.63	[0.18 ; 15]	0.7	1.99	[0.21 ; 19]	0.8
Dindo-Clavien grade (%)		136								
0-I-II	103 (95%)		88 (94%)	15 (100%)						
III-IV-V	6 (5%)		6 (6%)	0 (0%)						
Re-intervention (%)	8 (3.3%)	6	7 (3%)	1 (3%)	0.95	[0.1 ; 7.9]	0.9	1.13	[0.15 ; 11]	0.8
Length of hospitalisation (mean (SD))	6 (6)	0	6.2 (5.9)	5.5 (2.9)	0.97	[0.90 ; 1.05]	0.5	0.98	[0.92 ; 1.04]	0.4
UCI transfer (%)		0								
Planned	91 (91%)		78 (91%)	13 (93%)	1			1		
Unplanned	9 (9%)	0	8 (9%)	1 (7%)	0.75	[0.08 ; 6.5]	0.8	1.19	[0.12 ; 11]	0.8
Duration ICU (mean (SD))	3 (3)	143	3.3 (3)	3.2 (2.3)	0.99	[0.81 ; 1.2]	0.9	0.95	[0.77 ; 1.18]	0.7
Death (%)	3 (1.2%)	3	2 (1%)	1 (3%)	3.45	[0.30 ; 39]	0.3	4.12	[0.35 ; 48]	0.3

IPTW: Inverse Probability of Treatment Weighting; OR: Odds ratio; IC95: 95% confidence interval; SD: standard deviation; MD: Missing Data; ICU: Intensive Care Unit

Table 3: chart of causes of conversions

Causes of conversion (n)	AR+ group	AR- group
Failure to locate the tumour(s)	0	6
Technical difficulties	0	3
Tumoral adhesions	0	1
Peritoneal adhesions	0	2
Liver abscess	0	1
Total	0	13