Robotic, laparoscopic or open hemihepatectomy for giant liver hemangiomas of over 10 cm in diameter

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Abstract

Background To evaluate the clinical efficacy of robotic, laparoscopic, and open hemihepatectomy for giant liver hemangiomas.Methods From April 2011 to April 2017, consecutive patients who underwent hemihepatectomy for giant liver hemangiomas were included into this study. According to the type of operation, these patients were divided into the robotic hemihepatectomy (RH) group, the laparoscopic hemihepatectomy (LH) group, and the open hemihepatectomy (OH) group. The perioperative and short-term postoperative outcomes were compared among the three groups. The study was reported following the STROCSS criteria.Results There were no significant differences in age, sex, tumor location, body surface area (BSA), future liver remnant volume (FLR), standard liver volume (SLV), liver hemangioma volume, FLR/SLV, resected normal liver volume / resected volume, hepatic disease, rates of blood transfusion, liver function after 24 hours of surgery, operative morbidity and mortality among the three groups. Compared with patients in the RH group (n=19), and the LH group (n=13), patients in the OH group (n=25) had significantly longer postoperative hospital stay ($P< 0.05$), time to oral intake ($P < 0.05$), time to get-out-of-bed ($P < 0.05$), a higher VAS score after 24 hours of surgery ($P < 0.05$) and a shorter operative time ($P < 0.05$). There were no significant differences in these postoperative outcomes ($P>0.05$) between the RH group and the LH group. When the setup time in the RH group was excluded, the operative time of the RH group was significantly shorter than the LH group ($P<0.05$). There was no significant difference in the operative time between the RH group and the OH group ($P>0.05$). The intraoperative blood loss of the RH group was the least among the three groups ($P<0.05$) and the intraoperative blood loss of the LH group was less than the OH group ($P<0.05$).Discussion Robotic, laparoscopic, and open hemihepatectomy were safe and efficacious treatments for giant liver hemangiomas. Robotic and laparoscopic hemihepatectomy were significantly better than open hemihepatectomy in intraoperative blood loss, postoperative recovery and pain score. Compared with laparoscopic hemihepatectomy, robotic hemihepatectomy was associated with significantly less intraoperative blood loss and shorter operative time.

Background

Hemangioma is the most common benign lesion of the liver, occurring in the general population with a prevalence which ranged from 0.4 to 7.3% based on autopsy findings[1-2]. The majority of liver hemangioma is asymptomatic and is often discovered incidentally during imaging investigations for various unrelated pathologies. Asymptomatic patients with liver hemangioma of less than 5 cm in diameter require observation and no intervention[3]. Surgical treatment for liver hemangioma is required in lesions larger than 5 cm in diameter, in causing symptoms or complications, or when the diagnosis is uncertain[4]. The main treatments for liver hemangioma include transarterial embolization (TAE), enucleation, liver resection, and transplantation. A giant liver hemangioma is defined as a liver hemangioma with a minimum size of 10 cm[5]. While some surgeons reported that enucleation was safer and quicker[6-7], others concluded that there was no significant difference between enucleation and resection[8-9]. Mark S et al.[10] suggested that liver resection was preferable for lesions that totally occupied an anatomical section of liver. Open liver resection requires a large abdominal incision and long recovery time. More and more operations are now performed with minimally invasive surgery with either laparoscopic or robotic surgery[11]. To our knowledge, no study has been reported to compare robotic, laparoscopic, and open liver resection for giant liver hemangiomas. The present study was undertaken to evaluate the clinical efficacy of robotic, laparoscopic and open hemihepatectomy for giant liver hemangioma.

Methods

Patients

This is a retrospective study on consecutive patients with liver hemangioma who underwent hemihepatectomy from April 2011 to April 2017 in our hospital. The diagnosis of giant liver hemangioma was made by computed tomography and/or magnetic resonance imaging and postoperative histopathology (Fig.1). The main indication for operation was a giant liver hemangioma (>10 cm in diameter) with symptoms (abdominal pain, nausea, or premature satiety after meal). These patients were all suitable to undergo robotic, laparoscopic and open hemihepatectomy. The choice of the operation was determined by the patient after discussion with the operating surgeons. All the operations were carried out by a single team of experienced liver surgeons. The variables selected for analysis were age, sex, tumor size, tumor location, hepatic disease, operative time, intraoperative blood loss, rate of blood transfusion, postoperative hospital stay, time to oral intake, time to get-out-of-bed, liver function after 24 hours of surgery, Visual Analogue Scale (VAS) score after 24 hours of surgery, and operative morbidity/mortality. According to the types of operation, the patients were divided into the robotic hemihepatectomy (RH) group, laparoscopic hemihepatectomy (LH) group, and open hemihepatectomy (OH) group. Comparisons of the variables were then made among the three groups. History taking, physical examination and liver ultrasonography were routinely carried out at a follow-up visit 3 months after surgery. The data in our study that came from a single study center were acquired retrospectively. As we know, potential biases exist in respective study naturally. However, we developed a rigorous and scientific search strategy to lower the power of this bias (Fig.2). This study was approved in writing by the Beijing Special Clinical Application Program (Grant No. Z171100001017239 and Grant No. Z151100004015004).

Measurements of liver volumes

The volumes of the future liver remnant（FLR）and liver hemangioma were calculated based on computed tomographic (CT) volumetry. The CT data were transferred to a workstation for assessment. Liver volumes were calculated by the integrated software technique. A standard liver volume (SLV) was calculated using the formula: liver volume (cm^3) = 706 × body surface area (m^2) + 2.4. [12] This volume has been validated in a meta-analysis to be a precise and unbiased method to estimate total liver volume. [13] The ratio of FLR volume to total liver volume was estimated using the formula: FLR/SLV. The body surface area (BSA) was calculated using the formula: body surface area (m2) = [body weight (kg) × body height (cm) ÷ 3,600]$^{0.5}$. [14] The resected volume was calculated using the formula: resected volume (cm3) = standard liver volume (cm^3) - future liver remnant volume (cm^3). The resected normal liver volume was calculated using the formula: resected normal liver volume (cm^3) = resected volume (cm^3) - liver hemangioma volume (cm^3). The ratio of resected normal liver volume to resected volume was estimated using the formula: resected normal liver volume / resected volume.

Surgical Techniques

Robotic Hemihepatectomy

The patient was placed in a modified lithotomy and reverse Trendelenburg position, with the first assistant standing between the patient's legs. For right hemihepatectomy, after general anaesthesia with endotracheal intubation, the first trocar was inserted at the umbilical site after creating pneumoperitoneum. Intraabdominal pressure was controlled at 12 to 14mm Hg (1mm Hg=0.133 kPa). The robotic camera was inserted through the umbilical port and the other four ports were introduced under laparoscopic view. The camera port was then placed in the right paraumbilical area. The first and second robotic arm ports were introduced in the left and right upper quadrant areas, respectively. The umbilical port was used as the assistant's port. The third robotic arm port was introduced at the left anterior axillary line (Fig.3). For left hemihepatectomy, the port placement was similar to the port placement of right hemihepatectomy, except for swapping the placement of the camera port and the assistant's port. Selective hemihepatic inflow occlusion was used. The modified Pringle's maneuver was used to occlude inflow of the entire liver when necessary (Fig.4). Liver parenchymal transection was performed using an ultrasound scalpel. Intraparenchymal control of major vessels was achieved with clips or sutures (Fig.5, 6). The corresponding hepatic pedicle and hepatic vein were transected with a linear vascular endo-stapler. The resected specimen was placed in a specimen bag and retrieved from the abdomen through an extension of the umbilical port wound.

Laparoscopic Hemihepatectomy

The patient was placed in a supine position with the patient's legs abducted. The surgeon stood between the patient's legs and the first assistant on the right side of the patient. After general anaesthesia with endotracheal intubation, the first trocar was inserted in the umbilical site after creating pneumoperitoneum. Intraabdominal pressure was controlled at 12 to 14mm Hg (1mm Hg=0.133KPa). Four ports were usually used. The operating ports were placed in a fan-shape around the lesion. Selective hemihepatic inflow occlusion was used for hemihepatectomy. The modified Pringle's maneuver was used to occlude the inflow to the entire liver when necessary. Liver parenchymal transection was performed using an ultrasound scalpel. Intraparenchymal control of major vessels was achieved with clips or sutures. The corresponding hepatic pedicle and hepatic vein were transected using a linear vascular endo-stapler. The resected specimen was placed in a specimen bag and retrieved from the abdomen through an extension of the umbilical port wound.

Open Hemihepatectomy

The patient was placed in a supine position. After general anaesthesia with endotracheal intubation, laparotomy was carried out via a right subcostal incision. After exploration of the abdominal cavity, hepatic vascular inflow occlusion was similar to the technique used in laparoscopic hemihepatectomy. Liver parenchymal transection was done using an electrotome or ultrasound scalpel. Hemostasis was achieved with monopolar cautery, sutures, or clips.

Statistical Analysis

Qualitative variables were compared using the chi-square test. Likehood Ratio test was used for data when the theoretical frequency was less than 5. The data were expressed as mean± standard deviation. Continuous variables were compared using the ANOVA analysis. If ANOVA analysis indicated that there were differences between three groups, SNK (Student-Newman-Keuls) test was used for further verification. A *P*-value of <0.05 was considered to be statistically significant. Statistical analyses were performed using the SPSS software (version 19.0, IBM Corp, Armonk, NY). The study was reported following the STROCSS criteria.

Results

During the study period, 326 patients underwent liver resection for liver hemangioma, and 128 patients had giant liver hemangiomas (defined as a liver hemangioma with a diameter >10 cm). Hemihepatectomies were carried out in 57 of these patients with giant liver hemangiomas. Right hemihepatectomy (RH) was carried out in 19 patients (the RH group), left hemihepatectomy (LH) in 13 patients (the LH group), and open hemihepatectomy (OH) in 25 patients (the OH group). There were no significant differences in age, sex, tumor location, BSA, FLR, SLV, liver hemangioma volume, FLR/SLV, resected normal liver volume / resected volume, and hepatic disease among the three groups (Table 1).

There were no significant differences in the rates of blood transfusion (*P*0.05, Table 2) among the three groups. The operative time of the OH group was significantly shorter than the RH group and the LH group (190.2±51.8 *vs* 256.3±57.7 and 268.4±93.6min, *P*0.05, Table 2, 4), while there was no significant difference between the RH group and the LH group (*P*0.05, Table 4). When the setup time in the RH group was excluded, the operative time of the RH group was significantly shorter than the LH group (216.3±57.7 *vs* 268.4±93.6min, *P*0.05, Table 2, 4), while there was no significant difference between the RH group and the OH group (190.2±51.8 *vs* 216.3±57.7, *P*0.05, Table 4). The intraoperative blood loss of the RH group was significantly the least among the three groups (319.5±206.0 *vs* 476.9±210.8 and 628.0±231.0ml, *P* 0.05, Table 2, 4), and the intraoperative blood loss of the LH group was significantly less than the OH group (476.9±210.8 *vs* 628.0±231.0ml, *P*0.05, Table 2, 4). When compared with patients in the RH group and the LH group, patients in the OH group had significantly longer postoperative hospital stay (7.2±2.3 *vs* 5.5±2.1 and 4.7±1.7d), time to oral intake (3.1±1.1 *vs* 2.2±1.1 and 1.9±0.9d), time to get-out-of-bed (2.8±0.9 *vs* 1.8±0.7 and 1.7±0.8d), and a significantly higher VAS score after 24 hours of surgery (4.9±1.3 *vs* 2.5±1.0 and 2.3±0.9) (*P* < 0.05 each) (Table 3, 4), while there were no significant differences in these variables between the RH group and the LH group (*P*0.05, Table 4). There was no significant difference in liver function after 24 hours of surgery among the three groups ($P>0.05$, Table 3). No postoperative death occurred in this study and 3 patient (5.3%) developed complications, which included gastric retention (n=1) and biliary leakage (n=2) (Table 3). The data for the follow-up visits at 3 months after operation were available for all the 57 patients. Four patients (7.0%) had persistent or recurrent preoperative symptoms, with 2 patients with abdominal pain, 1 with nausea, and 1with premature satiety after meals (Table 5).

Discussion

Hemangioma is a common benign lesion of the liver. It originates from the mesodermal layer and represents a congenital, non-neoplastic hamartomatous proliferation of vascular endothelial cells[15]. Asymptomatic patients with liver hemangioma of less than 5 cm in diameter require only monitoring through imaging examinations at every 6 months or annually to assess the progression of disease[3,11]. The common indications for surgical treatment in symptomatic patients with liver hemangioma larger than 5 cm in diameter are pain, rapid growth in size, uncertainty of whether it is malignant, local compression, spontaneous or traumatic rupture, and Kasabach-Merritt syndrome[5,10]. Since the first resection of liver hemangioma reported by Hermann Pfannenstiel in 1898, the treatments of liver hemangioma include TAE, enucleation, liver resection, and transplantation[16-17]. TAE can be used to reduce the size of giant liver hemangiomas and decrease the risk of bleeding during resection. However, vascular recanalization leading to recurrence is common[18-20]. Symptomatic patients with unresectable lesions or multiple hemangiomas are indicated for liver transplantation[21]. Hemangioma is a well-circumscribed, hypervascular and compressible lesion with a clear sheath of compressed liver parenchyma between the haemangiomatous tissues and the normal liver[22]. Enucleation can be performed to remove the liver hemangioma with its surrounding fibrous capsule which is composed of compressed liver parenchyma. Several authors reported that enucleation of giant hemangioma was safer and quicker than liver resection, with better preservation of liver parenchyma, less morbidity, and less blood loss[6-7]. On the other hand, Wang et al.[23] concluded that the operative time, blood loss, and blood transfusion requirement for anatomic liver resections were similar to those of enucleation. When a liver hemangioma is giant or when it is at a dangerous anatomical location adjacent to the inferior vena cava or a major hepatic vein, enucleation may cause massive intraoperative blood loss. In such patients, liver resection may be a better approach[24-25]. In hepatic resection, the FLR volume, SLV and TLV have been used to predict postoperative hepatic dysfunction[26]. Although the safety limit of FLV remains controversial, several studies showed that a FLR/TLV ratio of ≤20% to be associated with increased complications and a higher likelihood of postoperative hepatic dysfunction in noncirrhotic patients. In our study, the FLR/SLV ratio was between 33.2 to 41.2%, and the resected normal liver volume / resected volume was only between 14.2 to 17.4%. These ratios suggested there were adequate remnant liver volumes and small loss of normal hepatic parenchyma in our patients. To balance between the risk of massive intraoperative bleeding and preservation of normal hepatic parenchyma, our team prefers to perform hemihepatectomy rather than enucleation for patients without cirrhosis and hepatitis whenever technically possible. To decrease excessive intraoperative blood loss in hemihepatectomy, our team routinely uses selective hemihepatic inflow occlusion for hemihepatectomy and the modified Pringle's maneuver to occlude the inflow of the entire liver when necessary.

The traditional open approach requires a large abdominal incision which is often associated with a long recovery time. Since the first truly laparoscopic anatomical liver resection in the form of a left lateral sectionectomy was reported in 1996 by Azagra et al, laparoscopic liver resection rapidly progressed and became popular[27]. The main advantages of minimally invasive liver resection are its significantly shorter postoperative hospital stay and lower morbidity[28-30]. Robotic surgery is a further development of the minimally invasive technique. The robotic system provides magnified three-dimensional imaging, tremor filtering and motion scaling. The Endowrist technology with seven degrees of freedom allows smooth and precise movements which are required in liver resection[31].

The current study aimed to evaluate the clinical efficacy of robotic, laparoscopic, and open hemihepatectomy for giant liver hemangioma carried out by a single team of experienced liver surgeons. This study showed that hemihepatectomy was an effective treatment for giant liver hemangiomas. Furthermore, robotic and laparoscopic hemihepatectomy had the following advantages over open hemohepatectomy in our study: less intraoperative blood loss, shorter postoperative hospital stay and earlier time to get-out-of bed, earlier oral intake, and a lower VAS score after 24 hours of surgery. The modified Pringle's maneuver made control of bleeding as easy in the RH group and the LH group as in the OH group. The minimal manipulation and the small incision were correlated with less bleeding, faster postoperative recovery and better pain control. All physicians in our teams were skilled in performing open, robotic and laparoscopic hemihepatectomy. Due to limited two-dimensional vision in laparoscopic surgery, giant liver hemangiomas resulting in limited manipulating space in the LH group, the long setup time in robotic surgery, and the longer operative time was in LH and RH groups. If the setup time in the RH group was excluded, the operative time was significantly shorter in the RH group than the LH group, while there was no significant difference between the RH and the OH groups. The intraoperative blood loss was significantly greater in the LH group than the RH group. Precise movements and three-dimensional view of the operative field in robotic hemihepatectomy was probably the reasons for the less bleeding and shorter operation time than in laparoscopic hemihepatectomy. Our study also showed that no significant difference existed among the three groups in the rates of blood transfusion, and in the liver function after 24 hours of surgery. Yu et al.[32] reported that the levels of ALT and AST after operations for the laparoscopic liver resection group was lower than that of the open liver resection group. Our study also showed no significant differences in postoperative hospital stay, time to oral intake, time to get-out-of bed and the VAS scores between the RH and LH groups. Furthermore, most people's symptoms, such as abdominal pain and nausea was relieved after hemihepatectomy.

The major limitations of this study are the small sample size and the short duration of follow-up, which may generate bias in the interpretation of results. Further multicenter randomized controlled clinical studies with larger sample size and longer follow-up are needed.

Conclusion

Hemihepatectomy was a safe and effective treatment for giant liver hemangiomas. Robotic and laparoscopic hemihepatectomies were superior to open hemihepatectomy in intraoperative blood loss, postoperative pain, time to diet, time to get-out-of bed, and postoperative hospital stay. Although robotic and laparoscopic hemihepatectomies were both safe and effective, robotic hemihepatectomy was associated with significantly less intraoperative blood loss and shorter operative time. Robotic hemihepatectomy was a more effective treatment for giant liver hemangioma.

Abbreviations

RH: Robotic hemihepatectomy

LH: Laparoscopic hemihepatectomy

OH: Open hemihepatectomy

BSA: Body surface area

FLR: Future liver remnant volume

SLV: Standard liver volume

TAE: Transarterial embolization

VAS: Visual Analogue Scale

CT: computed tomographic

SNK: Student-Newman-Keuls

Declarations

Ethics approval and consent to participate

This study was approved in writing by the Beijing Special Clinical Application Program (Grant No. Z171100001017239 and Grant No. Z151100004015004).

Consent for publication

The manuscript is approved for publication by all the authors.

Availability of data and materials

All data generated or analyzed during this study are available from all the included studies from PubMed and CNKI databases.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

MGH and RL conceived and designed the study. MGH, XZ, CGL and KC perform the surgeries. MGH and KC wrote the paper. MGH, RL, DDS and KC reviewed and edited the manuscript. All authors read and approved the manuscript.

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Minggen Hu and Kuang Chen contributed equally to this study

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Tables

TABLE 1. Characteristics of Patients in the RH ,LH and OH Groups

	RH group *n=19*	*LH group* *n=13*	*OH group* *n=25*	*P value*
Age (year)	49.2±10.6	46.5±8.9	45.6±10.1	0.494
Sex				
Male	2 (10.5%)	1 (7.7%)	8 (32%)	0.094
Female	17 (89.5%)	12 (92.3%)	17 (68%)	
Location*				
Right	15	8	19	0.530
Left	4	5	6	
Body surface area (BSA , cm2)	1.6±0.2	1.6±0.2	1.6±0.2	0.821
Futrue liver remnant volume (FLR, cm3)	463.9±151.2	442.9±152.8	374.8±135.7	0.115
Standard liver volume (SLV, cm3)	1120.1±137.8	1110.1±108.1	1144.9±108.8	0.646
Liver hemangioma volume (cm3)	553.2±122.3	556.2±179.8	667.5±202.6	0.061
FLR/SLV (%)	41.2±11.4	40.1±14.0	33.2±13.4	0.099
Resected normal liver volume / resected volume (%)	16.1±7.2	17.4±7.0	14.2±8.2	0.437
Hepatic disease†	0(0%)	0(0%)	0(0%)	1.000

*Location refers to the location of the largest liver hemangioma for patients with multiple lesions.

†Hepatic disease refers to hepatitis and liver cirrhosis

TABLE 2. Comparison of intraoperative variables in the RH ,LH, and OH Groups

	RH group *n=19*	*LH group* *n=13*	*OH group* *n=25*	*P value*
Operative time(min)	256.3±57.7	268.4±93.6	190.2±51.8	0.001
Operative time(min) (remove setup time)	216.3±57.7	268.4±93.6	190.2±51.8	0.004
Intraoperative blood loss(ml)	319.5±206.0	476.9±210.8	628.0±231.0	0.000
Rate of blood transfusion	5(26.3%)	4(30.8%)	8(32.0%)	0.916

TABLE 3. Comparison of postoperative variables in the RH ,LH, and OH Groups

	RH group *n=19*	*LH group* *n=13*	*OH group* *n=25*	*P value*
Postoperative hospital stay(d)	5.5±2.1	4.7±1.7	7.2±2.3	0.002
Time to oral intake(d)	2.2±1.1	1.9±0.9	3.1±1.1	0.002
Time to off-bed activity(d)	1.8±0.7	1.7±0.8	2.8±0.9	<0.001
Liver function				
ALT(U/L)	261.0±164.7	225.4±154.8	305.6±252.9	0.508
AST(U/L)	269.4±162.8	215.8±121.8	271.0±228.8	0.658
ALB(g/L)	35.9±3.1	35.2±7.6	35.4±4.9	0.880
TBil (μmmol/L))	22.3±12.4	17.5±8.3	25.3±16.2	0.245
VAS score	2.5±1.0	2.3±0.9	4.9±1.3	<0.001
Mortality	0(0%)	0(0%)	0(0%)	1.000
Morbidity	1(5.3%)	1(7.7%)	1(4.0%)	0.890

ALT indicates alanine aminotransferase; AST indicates aspartate transaminase; ALB indicates albumin; TBil indicates total bilirubin.

TABLE 4. SNK(Student-Newman-Keuls) *test for operative and postoperative variables in the RH ,LH, and OH Groups

			RH group n=19	*LH group n=13*	*OH group n=25*	*Significance*
Subset for α=0.05	Operative time(min)	1			190.1600	1.000
		2	256.2632	268.3846		0.582
	Operative time(min)	1	216.2632		190.1600	1.000
	(remove setup time)	2		268.3846		0.239
	Intraoperative blood loss(ml)	1	319.4737			1.000
		2		476.9231		1.000
		3			628.0000	1.000
	Postoperative hospital stay(d)	1			7.2400	1.000
		2	5.5263	4.6923		0.246
	Time to oral intake(d)	1			3.0800	1.000
		2	2.1579	1.9231		0.508
	Time to off-bed activity(d)	1			2.8000	1.000
		2	1.8421	1.6923		0.573
	VAS score	1			4.8800	1.000
		2	2.5236	2.3077		0.565

*Groups are in the same subset indicate no difference between these groups

†Means for groups in homogeneous subsets are displayed

TABLE 5.Improvement of symptoms after operation

Symptom	*Preoperative status*	*Postoperative status*	*P value*
abdominal pain	45(78.9%)	2(3.5%)	<0.001
nausea	19(33.3%)	1(1.8%)	<0.001
premature satiety after meal	16(28.1%)	1(1.8%)	<0.001

Figures

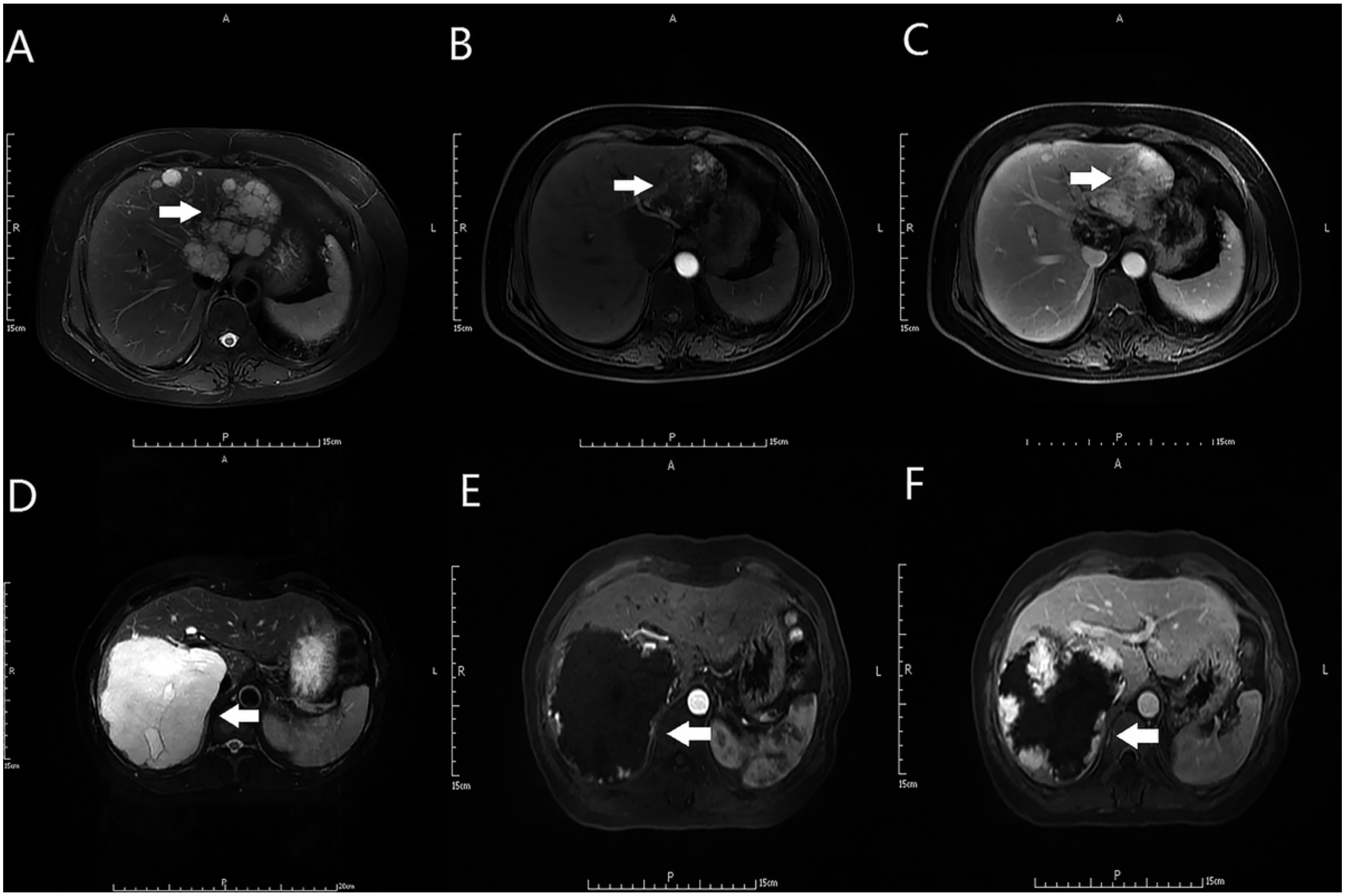

Figure 1

Magnetic resonance imaging of giant liver hemangiomas A and D T2-weighted magnetic resonance showed giant liver hemangiomas on left and right liver(A and D, arrow). B and E Magnetic resonance in arterial phase showed giant liver hemangiomas on left and right liver(B and E, arrow). C and F Magnetic resonance in delayed phase showed giant liver hemangiomas on left and right liver(C and F, arrow).

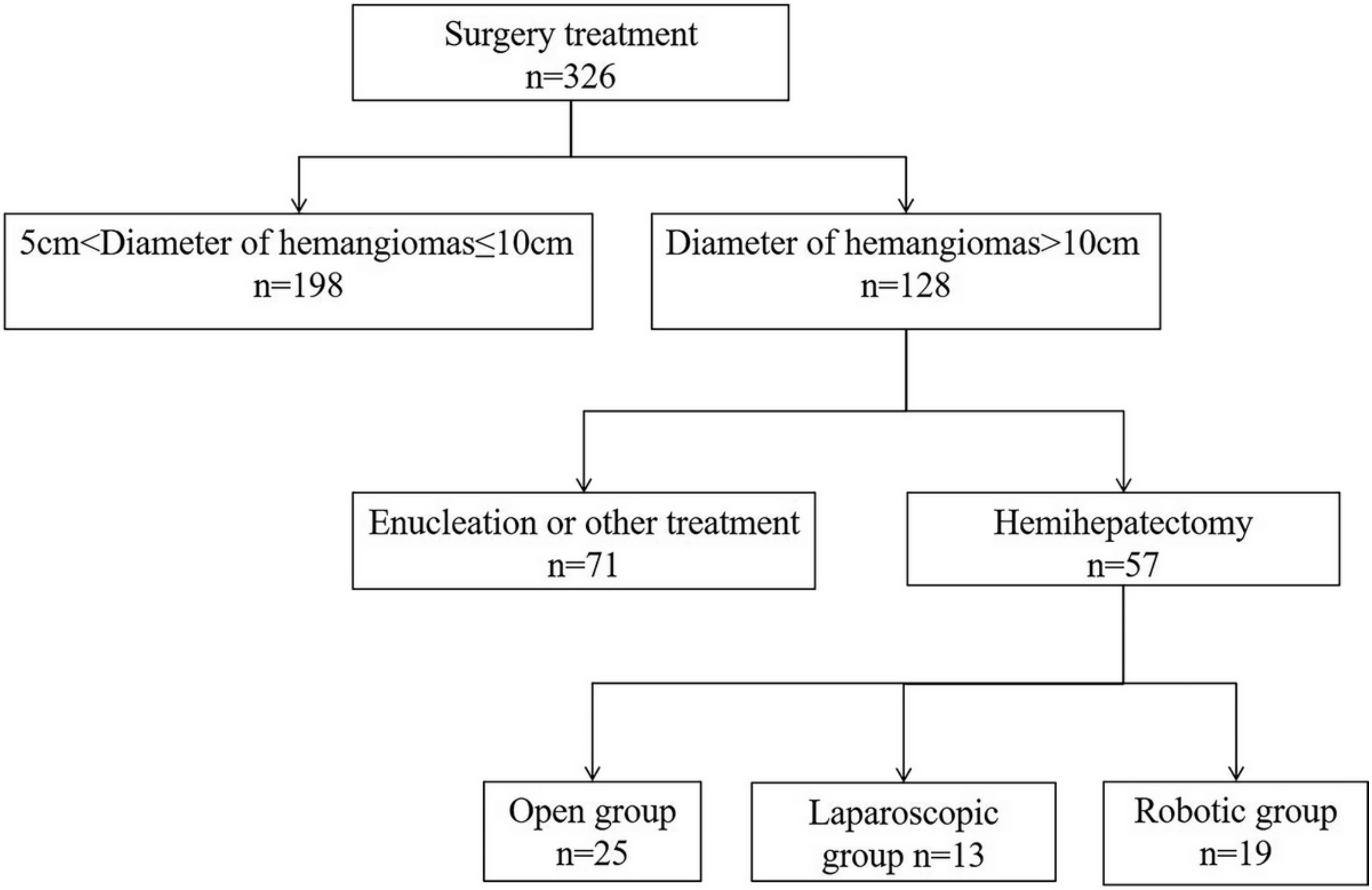

Figure 2

Search strategy

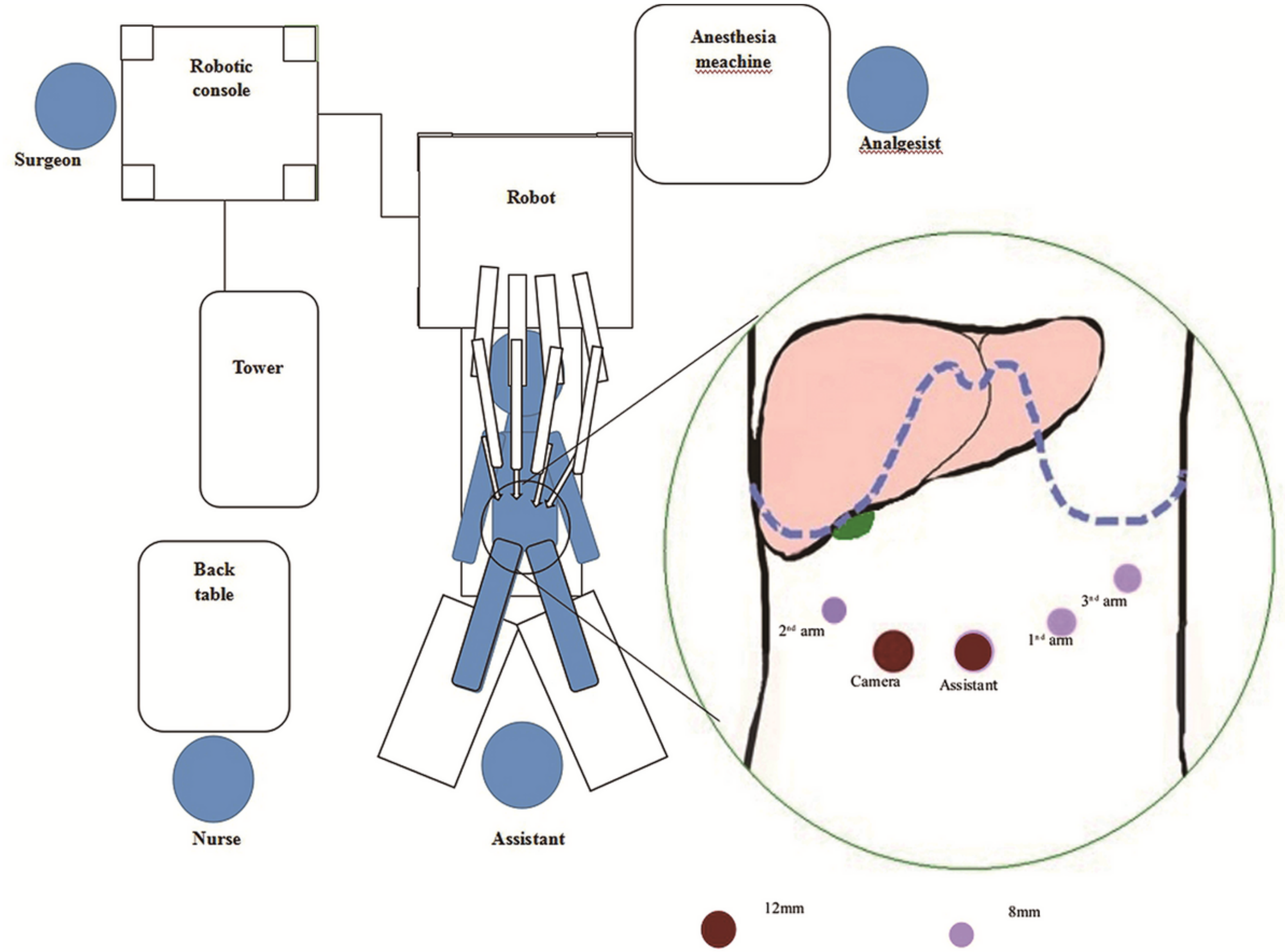

Figure 3

Operating room setup and port placement for robotic right hemihepatectomy

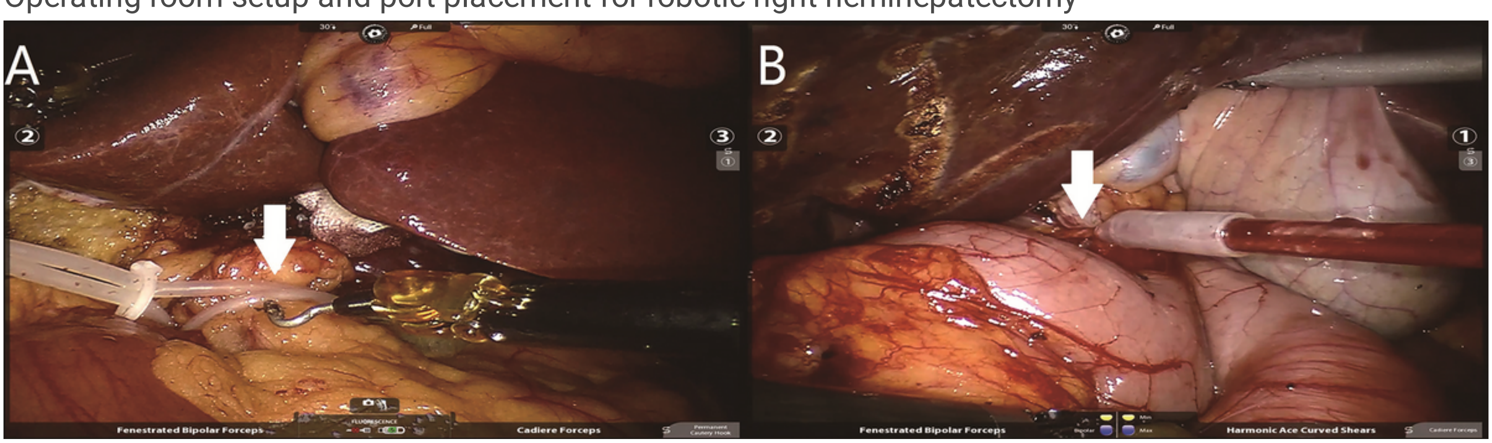

Figure 4

: Modified Pringle maneuver A, B Hepatoduodenal ligament was encircled and ready to be occluded by the catheter (8F) or rope: hepatoduodenal ligament (A and B, arrow).

Figure 5

The main procedures of robotic left hemihepatectomy. A The left hepatic artery (A, arrow) was dissected and sectioned by clips and ultrasound scalpel. B The left branch of portal vein (B, arrow) was dissected and sectioned by clips and ultrasound scalpel. C The ischemic demarcation line (C, arrow) was incised by using the monopolar hook. D The branchs of middle hepatic vein (D, arrow) were dissected and sectioned by clips and ultrasound scalpe. E The left hepatic vein was dissected and sectioned by using a linear vascular endo-stapler (E,arrow). F Hepatic cross section after hemihepatectomy and the middle hepatic vein (F,arrow)

Figure 6

The main procedures of robotic right hemihepatectomy. A The right hepatic artery (A, arrow) was dissected and sectioned by clips and ultrasound scalpel. B The right branch of portal vein (B, arrow) was dissected and sectioned by clips and ultrasound scalpel. C The ischemic demarcation line (C,arrow) was incised by using the monopolar hook with application of indocyanine green (ICG) fluorescence imaging. D The branchs of middle hepatic vein (D, arrow) were dissected and sectioned by clips and ultrasound scalpe. E The right hepatic vein was dissected and sectioned by using a linear vascular endo-stapler (E, arrow). F Hepatic cross section after hemihepatectomy and branchs of middle hepatic vein (F, arrow)