Augmented Domain for Hepatic Bruise During Image Based Robotic Liver Surgery

P. Nirmala [1], G. Ramya[2], G.Ramkumar [3], Anitha G[4], R.Thandaiah Prabu[5]

[1]*Professor, Department of Electronics and Communication Engineering, Saveetha School of Engineering, SIMATS, Chennai.*
[2]*Associate Professor, Department of Electrical and Electronics Engineering,*
Saveetha School of Engineering, SIMATS, Chennai.
[3,4,5] *Associate Professor, Department of Electronics and Communication Engineering, Saveetha School of Engineering, SIMATS, Chennai.*

[1]*nirmalajai@gmail.com,* [2]*ramyag.sse@saveetha.com,* [3]*pgrvlsi@gmail.com,*
[4]*anipsg09@gmail.com,* [5]*thandaiah@gmail.com*

Abstract.

Hepatobiliary surgery may now be performed with less trauma to the patient because to the advent of robotic liver resection (RLR). Patients with hepatocellular carcinoma (HCC) may advantage from minimally invasive surgery, which is often accompanied with preexisting liver damage. Hepatectomy's therapeutic benefits are not clearly established despite these important benefits of robots in surgical methods. Thus, we analyzed the surgical outcomes of 57 HCC instances in 46 subjects who had RLR, as well as the long-term outcomes. Robotic anatomic liver resection for HCC feasibility and safety were assessed by the comparison of the outcomes of the AR group with the non-anatomic resection (NAR) group. An aggregate console time of 489 minutes, a blood loss of 190 g, and one open conversion were recorded in this study of 57 people with liver disease (3%). With an 11 percent significant rate of complications and no 90-day fatality, postoperative data revealed that the liver function recovered well. AR was associated with lengthier operating and nursing times, higher loss of blood, and worse postoperative liver function than NAR because of the bigger size and complexity of hepatectomy for more malignant tumors.

Keywords. Hepatic Surgery; Robotic surgery; AR; image-guided surgery; AI

1. INTRODUCTION

A growing number of abdominal surgeries are now being performed with robots, which include urological, gynaecological, and upper/lower gastrointestinal procedures. In Hepatobiliary and pancreatic surgery, however, robotic systems are still restricted due to technical complexity and a lack of adequate tools. RLR (robotic liver resection) is one procedure that is still under development. Short-term outcomes of RLR have been published by many researchers, and the performance was compared to those of traditional laparoscopic or open liver resections in most investigations. As a Hepatobiliary surgical procedure, RLR has yet to be thoroughly tested for its practicality, safety, and effectiveness. Due to its ability to integrate the many benefits of laparoscopic surgery with the maneuverability of an open technique, robotics platforms have gotten a lot of interest in liver resections since their introduction. Laparoscopy has been shown to have comparable oncological outcomes to open surgery in terms of healing time, discomfort, morbidity, and severe bleeding after operation [1] [2]. While technically demanding hepatectomy have their benefits, they also have significant drawbacks, most notably limited mobility, inflexible tools, and a reduced field of view or quality of vision [3].

More studies and meta-analyses have been published in the article demonstrating the well-known benefits of robotic surgery with similar post-operative and oncological outcomes [4]. Beyond the technological advances, the DaVinci system allows surgeons to be directed by before operation and/or after encountered imaging during parenchymal excision using a specific software interface rather than a basic operational field [5]. One way to look at the robot is as a way to place a computer between the surgeon and the patient. Augmented Reality (AR) and other imagery solutions have been created to aid the operator and minimize the inherent limitations of a minimally invasive method, such as the absence of tactile input, which might impair tumor diagnosis or pedicle dissection.

A hepatectomy known as an anatomic resection (AR) removes the anatomic liver area provided by the matching portal vein branches with utmost precision and completeness. Even tiny tumors with portal vein tumor invasion may be successfully treated with AR, which has a good cure rate for HCC. Ontologically, AR is superior to NAR in individuals with HCC, according to many studies. Consequently, in certain patients with HCC, AR is a suggested method of resection, based on their hepatic functional reserve. Professionals have done most of the laparoscopic liver resections (LLRs) in recent years, despite significant advancements in the procedure. Another question is whether robotic AR is safe or even possible.

2. RELATED STUDY

Using Indocyanine Green (ICG), liver surgeons may boost their ability to see anatomical features by giving a real-time liver mapping. This approach is effective because of its fluorescence qualities. There were 40 successive clients who had robotic-assisted hepatic resection for cancers from June 2014 to November 2017 who received ICG-fluorescence staining. Colorectal liver metastases were the primary surgical reason for 55% of clients, preceded by hepatocarcinoma in 35% of cases. Resection margins of 12 mm were the most common, with a 100% success rate. Twenty percent of people reported tumor recurrence. There were 91 percent and 84 percent overall success rates at one year and two years, respectively. In the first year, 77.2 percent of patients were clear of illness, but in the second year it was 65 percent. In 12 of the 40 patients who underwent the staining procedure, the earlier indicated transaction line had to be redrawn. The ICG-F discovered 52 liver surface lesions, comprising two superficial colorectal tumors ignored by intra-operative ultrasound, whereas 43 tumors were found using white-light liver surface investigation and intra-operative ultrasonography.

Robot-assisted Hepatobiliary treatments are on the rise as a result of recent advancements in robotic surgery. Nevertheless, the lack of tactile input is a drawback to robotic surgery. As hepatocellular tumors and their metastases increase indocyanine green (ICG), a luminous dye, may be useful. A near-infrared camera that is built into certain robotic systems may let surgeons see the buildup of ICG, allowing them to conduct surgery more precisely. Subjects with hepatocellular carcinoma and colorectal cancer metastases, but also those from other sources, were studied by author [7] to see whether preoperative ICG application and intraoperative ICG usage were feasible. ICG preoperative preparation and intraoperative usage in patients having robot-assisted liver resections were investigated in this single-arm, single-center trial. The final study comprised twenty individuals.

Patients with severe liver cirrhosis and those who use it too late before surgery have difficulties. It is possible that intraoperative ICG staining will be helpful for patients having robotic hepatic surgery. There is further work to be done in terms of determining the proper dosage, timing, and level of fluorescence intensity.

Whenever augmented reality (AR) is employed in laparoscopic liver resection operation, the researcher of [8] wants to know how accurate point-based registration (PBR) really is.

An evaluation phantom with divot holes was used in the research; a person-specific liver phantom with CT scan markers was used in the study; and in vivo, the anatomical expertise of the surgeon was relied upon to annotate the PBR sample targets. Picture identification was performed utilizing five randomly chosen locations for target and fiducially registration errors (TRE/FRE). Both TRE and FRE increased throughout the practical experiments, demonstrating that AR is not a robust method for calculating image-to-patient registration. Furthermore, it was found that the amount of data to be recorded had an impact. To avoid large-scale mistakes in AR systems, it's best to minimize both labeling mistakes and the quantity of registration quantities.

The author of article [9] described an AR-assisted liver surgery guidance mechanism that depends on a rigid stereoscopic laparoscope. To create an intraoperative 3D liver surface, unsupervised convolutional network (CNN) architecture uses the stereo picture sets from the laparoscope. V-Net framework for volumetric visual data is used to create 3D models of the person's surgery field using preoperative CT scans. Surgeons may see malignancy, their surgery margins, and the arteries that supply them in real time by overlaying preoperative 3D models on live laparoscopic view using a Go-ICP technique, which is used to enroll the pre-and intraoperative models into a single coordinate system. In persons who had serious hepatectomy for hepatocellular carcinoma, the author [10] investigated if pre-operative 3D assessment offered good long-term life expectancy results than the usual 2D evaluation (HCC). Propensity score matching was used in this retrospective analysis to compare persons who had pre-operative 2D assessment with those who had pre-operative 3D assessment. Long-term survival results following major hepatectomy for HCC were the main objectives in both categories. Overall survival rates were much improved with 3D preoperative examination compared with typical 2D evaluation [11].

3. METHODOLOGY

3.1 Patient selection

For tumors that were less than 10 cm in diameter and did not require significant arterial or biliary structures to be repaired, minimally invasive liver resection was the preferred option of technique. When tumors were 10 cm or greater in the centre and there was a suspicion of invasion into the main hepatic veins, we opted for open surgery. We don't have any specific condition among LLR and RLR. In situations where the tumor thrombi had to be removed, open or automated surgery was the only option. Open surgery was not insured by national insurance throughout this research process and was conducted on individuals at their own cost [12] [13]. As a result of this consideration, the resection method was chosen in this research because of its cost-effectiveness and the presence of the device in the clinic. Open, laparoscopic, and robotic hepatectomy techniques all used the same criteria for determining which hepatectomy methods to use based on the patient's hepatic functional reserve and remaining liver volume. There were several factors to consider while dealing with a patient who had had multiple liver resections: the volume of prior resections, the location of the tumor and its size, and preoperative imaging [14] [15].

	Total Cases	**AR**	**NAR**	**P-value**
Age,	71 (20-82)	72 (20-82)	71 (54-82)	0.56
Gender, Male/Female	43/14	18/5	22/12	0.23
Hepatic Function				
Tuberculosis	0.8 (0.4-1.6)	0.9 (0.7-1.2)	0.8 (0.2-1.6)	0.53
Liver Cirrhosis	57% (33)	37% (9)	66% (22)	0.02
malignancy Characteristics				
malignancy size, cm	2.3 (0.7-12.8)	2.4 (0.8-12.6)	1.9 (0.7-10.4)	0.003
malignancy no	1 (1-5)	1 (1-5)	1 (1-6)	0.55
Difficult segments (n)	52% (30)	64% (14)	43% (15)	0.16

Table 1: Background Patient and Tumor Characteristics

3.2 Patient Characteristics

Table 1 lists the features of the 57 HCC patients who had RLR treatment. In a nutshell, the average client age was 71 years old at the time of resection, with men being the majority (n = 42; 74%). All patients had a Child-Pugh class A hepatic functional reserve. The average acceptance rate of indocyanine green at 17 minutes was 15.2%. Thirty-one individuals had postoperative histological evidence of cirrhosis of the liver (54%).

Types of liver surgery	**No**
AR	23
liver parenchyma on the right side	3
liver parenchyma on the left side	2
Right anterior sectionectomy	1

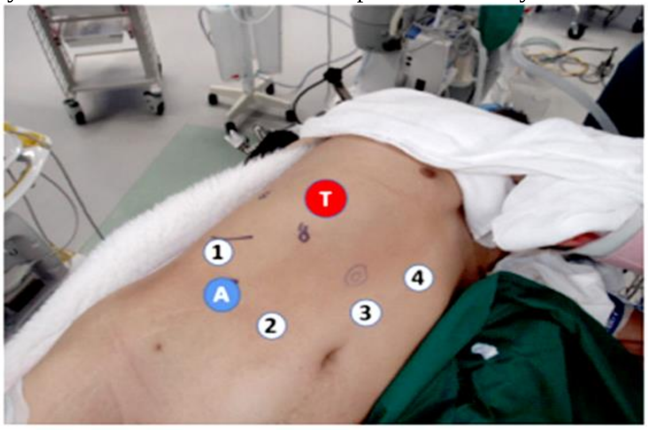
right posterior sectionectomy	2
Left lateral	3
segmentectomy	8
NAR	34
I	3
II	2
III	7
IV	4
V	3
VI	3
VII	2
VIII	10

Table 2: Various Types of robotic liver resection

3.3 Various kinds of liver resection

The 57 RLR patients' liver resection types are shown in Table 2. AR was used in 23 instances (40%) while NAR was used in 34 cases (80%). In 22 patients, there were 23 AR resections, and in 26 patients, there were 34 NAR resections.

Two AR procedures were performed on one of the victims. Twenty-one of the 26 patients receiving NAR have only had one NAR, four have had numerous NARs, and one has had both a NAR and an AR. AR and NAR were performed on two individuals who had numerous tumors in the same procedure. The AR group included these two patients. Major anatomic sectionectomy were performed in 16 of the 23 (70 percent) patients with AR-treated liver tumors. Both tumor thrombi in the right portal vein were eliminated by excision and restoration of the portal venous system.



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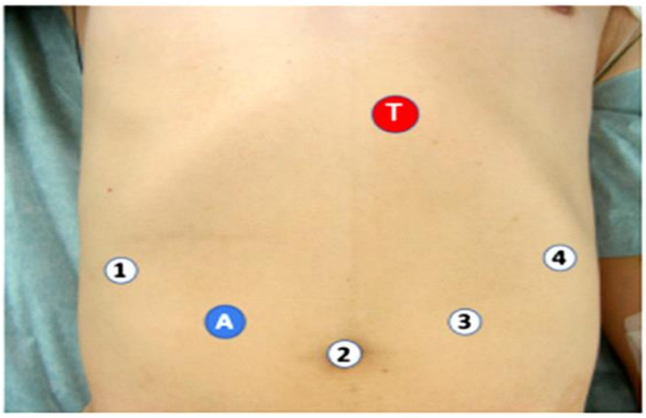

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Figure 1: Positioning of the Patient's Body and the Point.

Operative treatments other than hepatic resection were done in 14 percent of the instances when hepatectomy was undertaken. The AR was used in two of the eight non-hepatectomy surgeries. Recurrent resections with RLR were done in 21 of the 57 instances handled with RLR (37%), in 12 of the 46 individuals (26%). Eight patients had open surgery, two underwent laparoscopic surgery, and eleven underwent robotic surgery.

3.4 Representative Procedures During Robotic AR

Figures 2-4 depict robotic AR methods utilized in robotic anatomic segmentectomy VIII. Anterior portion Glissonian pedicle root may be easily accessed by the cystic plate cholecystectomy, which is the initial surgery (G-ant). The hilar plate is attached to the liver parenchyma by many pieces of fibrous tissue, which we refer to as the pillar. When anchoring are divided, the area between the hepatic cells enclosed by Laennec's capsule and Glissonian pedicle sheaths is readily created and entered. Extrahepatic separation of the G-ant is made possible by Laennec's capsule-based layer dissection at Gates IV and V in accordance with the Gate hypothesis [Figure 2A and B]. With comparison to the open operation, the enlarged caudal view of the hilum in laparoscopic and robotic techniques seems to be more effective for precise layer dissection and pedicle isolation. Additionally, adjustable tools are quite beneficial during robotic dissection of the hilar pedicles. In the next step, the G-ventral ant's surface is dissected, and the G-ant segment V (G-V) pedicle is outlying outside the body. As a consequence, the G-VIII pedicle is isolated from the rest of the G-ant tape by passing the right stump beneath G-V and then switching cranially over G-V [Figure 2C].

The subtraction procedure is used to isolate deeper pedicles. Before beginning parenchymal dissection, the isolated S-VIII becomes ischemic by clamping G-VIII [Figure 2D]. After clamping G-VIII, an intravenous infusion of ICG clearly shows that S-VIII is stained negatively in the Firefly mode [Figure 3B]. A parenchymal dissection begins with a tracking and exposing of the MHV's root in a cranial-caudal direction [Figure 4A] when confirmation of the S-discoloration VIII's is confirmed. To further dissect along the RHV from cranial to caudal, the root of the vein is revealed in a similar fashion. The S-VIII split many MHV tributaries. G-VIII, which had been outlying at the hilum, is now left vulnerable after parenchymal resection. This is done in such a way that G-VIII and G-ant aren't jeopardized [Figure 4B]. It is possible to separate many G-VIII branches on their own. During anatomic segmentectomy VIII, the Pringle technique is seldom used.

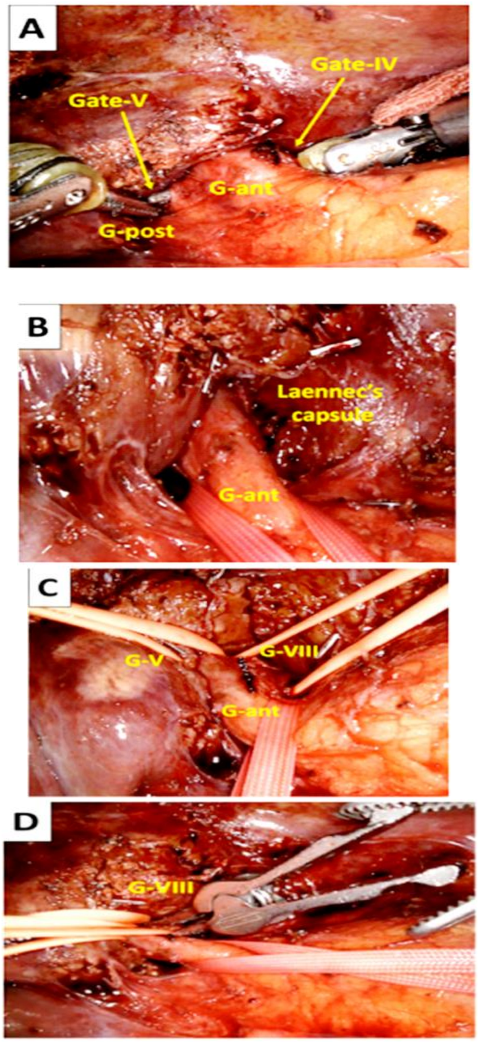
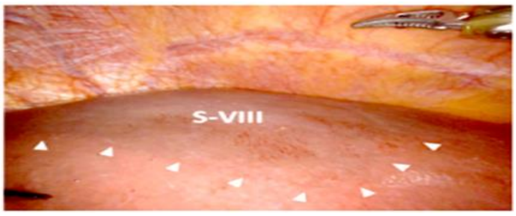


Figure 2: Hilar Dissection in Robotic Anatomic Segmentectomy



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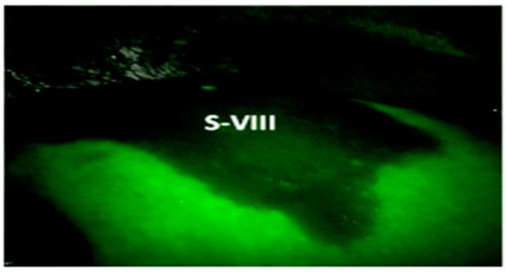

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Figure 3: Discoloration of the segment. (A) Normal endoscopic view. (B) The intravenous infusion of indocyanine green

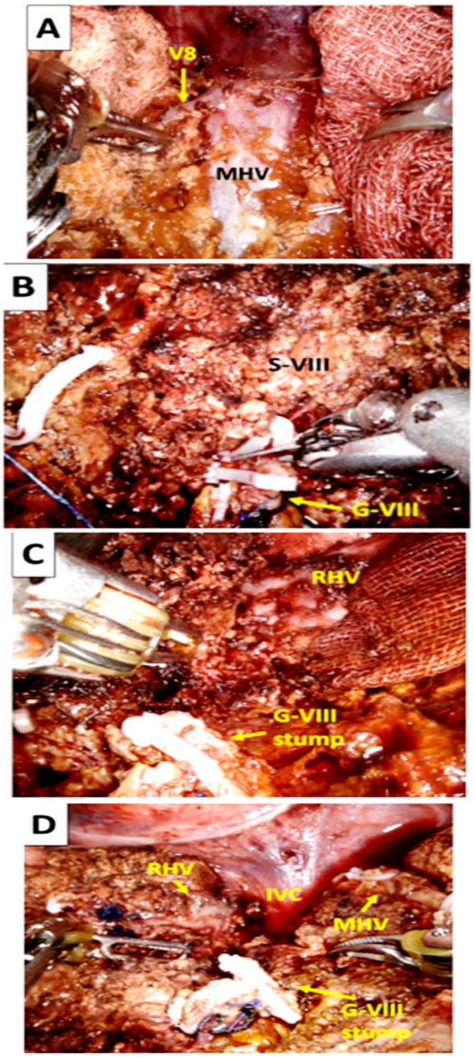


Figure 4: (A) HV base and front wall of the main liver vein (B) HV base in the middle of the cranial-to-caudal (C) HV base of the right liver vein (RHV) is exposed cranially. (D) The final surgical image after a robotic anatomic segmentectomy

4. Results and Discussions

Data from the AR and NAR categories are included in Table 1, which compares all 57 instances. Preoperative serum TB, Alb, AST, ALT, and PT values in both groups of patients were similar in age, sex, and gender distribution. AR patients had a more accurate assessment of liver functional reserve, as measured by blood PC and ICGR15, than those in the NAR group (all of whom had Child-Pugh class A disease). More people in the NAR group had (histological verified) liver damage comparing with AR group, and this difference was statistically significant. The AR group had considerably larger tumors than the NAR group (2.5 cm vs. 1.8 cm; P 0.001), however the tumor count per instance was the same in both categories (n = 1). There was a substantial difference in hepatic functional reserve between individuals who received AR and NAR, and bigger tumors were more likely to be removed during AR. There was a superior contrast among the AR and NAR class in terms of tumor stages (P 0.03), with the AR group having a larger percentage of patients with tumor phases I or II.

4.1 Short-term results of RLR for HCC

There were 57 patients with HCC who received RLR, and Table 2 demonstrates the short-term results of the AR and NAR class. Both groups had equal frequencies of concomitant extrahepatic procedures. There was a significant difference between the AR and NAR groups when it came to estimated blood loss (EBL): 346 g in the AR class and 138 g in the NAR class (P = 0.009).

Pringle's technique was used in 12% of the 57 instances studied; the AR group had a considerably greater rate of use (26%) than the NAR group (3%). One patient who had been treated for bleeding with AR (4 percent) had open conversion.

	Overall	**AR**	**NAR**	**P**
Minimum operating time,	634 (60-2234)	845 (332-2184)	458 (61-1147)	<0.0002
aggregate console time	489 (48-1954)	713 (255-1967)	274 (48-854)	<0.0002
Concurrent proc	13%	10%	19%	0.34
Blood loss	190 (9-6930)	346 (48-6920)	138 (8-4986)	0.008
Pringle maneuver	13%	28%	4%	0.009
Open conversion	3%	5%	0%	0.23
Postoperative laboratory data				
Maximum Tuberculosis	1.6	1.4	1.5	0.17
Maximum AST	436	879	294	0.002
Minimum PT	66	59	68	0.006
Minimum PC	7.6	8.3	7.6	0.48
Pathological data				
R0	97%	95%	99%	0.23
Rest in Hospital	16	17	16	0.24
Postoperative complications				

4.2 Survival Data

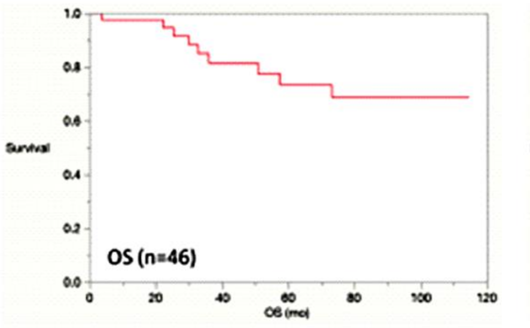
In 46 patients with HCC, the combined OS and DFS rates after the initial RLR were evaluated. A total of 98, 82, and 74% of patients had OS, whereas DFS was at a rate of 80 (42%), 42, and 31% following the first RLR [Figure 5]. In the absence of a median OS rate, the study was deemed a failure. After operation, patients' median DFS was 25.9 months long. At the earlier years following the initial RLR, for 21 malignant hepatoma cases who had robotic AR, the life expectancy rate were 95, 86, and 86 percent and the Disorder-free rates were 75, 37, and 37 percent, respectively. At the earlier years after the first RLR, the life expectancy rates were 100, 81, and 71%, and the Disorder-free rates were 74, 41, and 29%, respectively. For 25 malignant hepatoma cases who received robotic NAR as the first RLR [Figure 6]. There was no big contrast among OS and DFS rates between the AR and NAR populations.

4.3 Discussion

A ten-year retrospective analysis of 57 RLR surgeries involving 46 HCC patients performed at a single hospital examined the surgical outcomes. Moreover, all 23 autonomous liver resections were performed using the identical procedures as were used in the open liver resections and LLRs. This accurate hilar dissection may have been facilitated by robotics, which has intrinsic functional advantages such as tool articulation and an operating area that is stable. Nevertheless, a lack of parenchymal dissection equipment persists. Hemihepatectomy hemiparesis necessitates harmonic shears for parenchymal excision on a single direction, but they may be challenging to use or need skill in circumstances when the resection plane is curved or complicated. Clamp-crush methods, such as those used with articulated forceps or vessel sealers, are widely used in AR operations that require the Pringle manoeuvre. Instruments for parenchymal resection need to be improved.

Most operations were performed because of HCC in our 94 RLRs' experience (n = 57; 61%). Despite the fact that the majority of HCC patients were in the early stages, the cases and tumors features were not pleasing; there were high frequencies of basic cirrhosis (55%), tumors placed in tough regions (50%), repeat liver resections (32%). All the results of the RLR procedure for HCC and other malignancies have been judged satisfactory (in the short and long term). We found that the duration of hospitalization for AR patients was greater than that previously reported for HCC patients in our study. But reliable comparisons are difficult owing to the disparities across the research in people, malignancies and processes. We contrasted the results of the AR and NAR in order to further assess the viability and protection of robotic AR in the treatment of HCC. In comparison to NAR, we found that AR led to longer operational durations, a longer LCST, greater EBL, a higher rate of administration of the Pringle manoeuvre, a higher postoperative AST, and a lower PT. In light of the AR group's more extensive and sophisticated hepatectomy, these results appear credible. AR and NAR patients had considerably greater tumors stages, but the major complication rates and death rates were not mathematical dissimilar between classes, and R0 resects rates were also not statistically different between the two groups of patients. Even though robotic AR requires extensive training and experience, it may be a safe and effective method of removing HCC from the liver in chosen individuals.

It has been shown that even with slight HV injuries, severe CO_2 gas embolism and considerable hypotension may develop. In addition, the AirSeal system was not associated with any systemic issues when it was discontinued. Since the main HVs are frequently exposed during parenchymal dissection in AR, our results and the mechanical activities of the Air Seal system suggest that we should keep away from utilizing this system. Significant issues associated with AirSealsystems do not only affect RLR patients. As a result of AR exposing a large HV, we encountered CO_2 embolism during LLR. Surgical-site problems, on the other hand, were very rare. Nevertheless, an evaluation of surgical-site risk of complications across open, laparoscopic and robotic AR utilizing comparable procedures is necessary.



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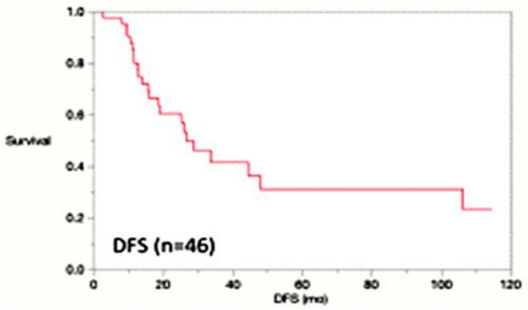
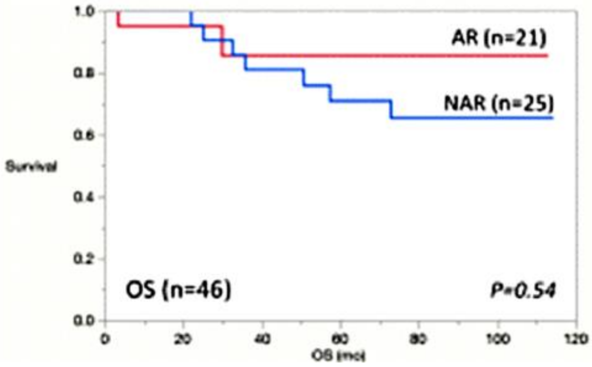


Figure 5: (A) cumulative life expectancy after first RLR; (B) disorder-free survival after first RLR



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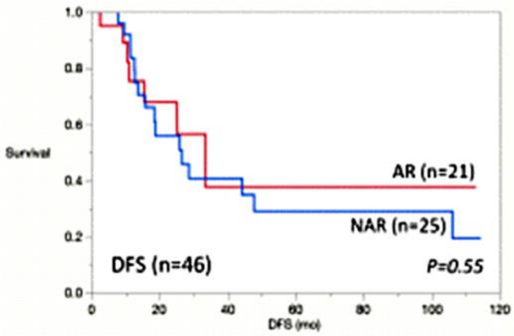

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Figure 6: (A) Analysis of cumulative life expectancy between the AR and NAR; (B) The AR and NAR were compared in terms of disorder-free survival.

RLR and LLR has never been the subject of a randomized control study. Methods and indications for surgery are same at our facility. Because RLR is not covered by any insurer, as well as because there aren't any machines available in the hospital, randomized trials are not feasible. Future randomized research, as well as studies using propensity-score matching, is necessary. Despite its strengths, this research has certain drawbacks. Because of the limited number of participants, this research has some limitations. Second, as previously noted, the lack of health insurance for RLR had a significant impact on the choice of methods.

5. CONCLUSION AND FUTURE SCOPE

Hepatobiliary surgery may now be performed with less trauma to the patient because to the advent of robotic liver resection (RLR). People with hepatocellular carcinoma (HCC) may profit from minimally invasive surgical, which is often accompanied with pre-existing liver disease. Hepatectomy's therapeutic benefits are not clearly established despite the inherent advantages of robots in surgical methods. Thus, we analyzed the surgical outcomes of 57 HCC instances in 46 patients who had RLR, as well as the long-term outcomes. A total console time of 487 minutes, a blood loss of 194 g, and one spontaneous conversion were recorded in this study of 57 people with liver disease (2%). With an 11 percent significant rate of complications and no 90-day mortality, post operative data revealed that the liver function recovered well. Because of the larger size and complexity of hepatectomy for more sophisticated malignancies, AR was related than NAR. In spite of this, the rates of significant complications, mortality, duration of hospital stay, and R0 resection were equal across the two sets of studies. Hepatocellular carcinoma (HCC) hepatectomy have had similar long-term outcomes to those previously described. In the end, RLR may be a safe and effective method of hepatectomy for patients with HCC. GPA and HV root-first one-way resection may be used to standardize robotic AR for HCC, which is safe and effective for the patient. In order to determine the value of robotic AR in the therapy of Cancer, further research comparing RLR, LLR, and open resection is required.

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