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Robotic liver resection. Report of the first 50 cases

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ABSTRACT – **Background** – Robotic surgery has gained growing acceptance in recent years, expanding to liver resection. **Objective** – The aim of this paper is to report the experience with our first fifty robotic liver resections. **Methods** – This was a single-cohort, retrospective study. From May 2018 to December 2020, 50 consecutive patients underwent robotic liver resection in a single center. All patients with indication for minimally invasive liver resection underwent robotic hepatectomy. The indication for the use of minimally invasive technique followed practical guidelines based on the second international laparoscopic liver consensus conference. **Results** – The proportion of robotic liver resection was 58.8% of all liver resections. Thirty women and 20 men with median age of 61 years underwent robotic liver resection. Forty-two patients were operated on for malignant diseases. Major liver resection was performed in 16 (32%) patients. Intrahepatic Glissonian approach was used in 28 patients for anatomical resection. In sixteen patients, the robotic liver resection was a redo hepatectomy. In 10 patients, previous liver resection was an open resection and in six it was minimally invasive resection. Simultaneous colon resection was done in three patients. One patient was converted to open resection. Two patients received blood transfusion. Four (8%) patients presented postoperative complications. No 90-day mortality was observed. **Conclusion** – The use of the robot for liver surgery allowed to perform increasingly difficult procedures with similar outcomes of less difficult liver resections.

Keywords – Liver; robotic surgical procedures; liver resection.

INTRODUCTION

Minimally invasive liver resection is a feasible and safe technique and has been used to treat several types of liver neoplasms[1,2]. Robotic surgery has gained growing acceptance in recent years, expanding to liver resection[3-6]. The robotic approach, with its added degrees of freedom, improved visualization, stability of the robotic platform, and better ergonomics improve the surgeon's dexterity during complex minimally invasive procedures.

There is a recent interest in robotic liver surgery and the number and complexity of procedures are rapidly increasing[6-10]. The aim of this paper is to report the experience with our first fifty robotic liver resections.

METHODS

This was a single-cohort, retrospective analysis of a prospective maintained database of all robotic procedures. From May 2018 to December 2020, 50 consecutive patients underwent robotic liver resection in a single center by the senior author (MAM). All patients with indication for minimally invasive liver resection underwent robotic liver resection. The indication for the use of minimally invasive technique followed practical guidelines based on the second international laparoscopic liver consensus conference[11]. Over this period, 38 patients presented contraindication for minimally invasive approach and underwent open liver resection. Main contraindications for the use of a minimally invasive technique were: a) patients with huge tumors which mobilization could result in tumor disruption or jeopardize the oncological aspect of the procedure, b) multiple and small lesions that could be missed with minimally invasive approach, c) lesions in close contact with major hepatic veins that should be preserved (R1 vascular). The patients were informed about the advantages and risks of the robotic technique, and they gave informed consent.

Surgical technique

Patient positioning and port placement

The patient is placed in a supine position and 30º reverse Trendelenburg position. Robotic surgery is performed using the da Vinci Si or Xi robotic platform (Intuitive Surgical Inc., Sunnyvale, CA). This technique uses five trocars. A pneumoperitoneum is created using an open technique in the infra-umbilical area. The pneumoperitoneum is established at 14 mmHg. The remaining trocars are inserted under direct vision and its location will depend on the patient biotype and type of liver resection planned. During this technique, the surgeon is seated at the robotic console and the assistant surgeon stands on the patient's left side. The assistant surgeon performs retraction, suction, clipping, stapling, and changes the robotic instruments.

Intraoperative ultrasound and liver mobilization

Right or left liver is mobilized depending on the type of liver surgery planned. Intraoperative ultrasound is used in all cases to locate the tumor, to determine the liver anatomy, and to stablish relationship between the tumor and major liver vessels and screening for other lesions.

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Pringle Maneuver and hilar dissection

Hepatoduodenal ligament is dissected, and a Foley catheter is passed around to perform intermittent intracorporeal Pringle maneuver in cases where this maneuver was indicated (FIGURE 1.A).

In our initial cases of anatomical liver resection, complete hilar dissection was performed with individual control of the portal vein, hepatic artery, and bile duct (FIGURE 2). As our experience increased, the technique of intrahepatic control of Glissonian pedicle was used more frequently, especially in patients with previous liver resection, previous hilar dissection or need for segmental liver resection. Hilar dissection was restricted to patients with need for hilar lymphadenectomy (FIGURE 2.D) and hilar cholangiocarcinoma. In some patients, no hilar dissection or Pringle maneuver was used. In other patients, selective hepatic artery clamping was used.

Glissonian approach

Intrahepatic Glissonian approach technique was used according to our previous description[12]. For the intrahepatic Glissonian approach, two small incisions are used following specific anatomical landmarks (FIGURE 3). Removal of liver tissue around the pedicle allows the intrahepatic identification of the Glissonian pedicle. It is then encircled using the Cadière forceps, a robotic wristed instrument, similarly to the open technique of Glissonian approach. FIGURE 4 shows the Machado's points, used as anatomical landmarks for Glissonian approach during anatomical liver resections[12].

Liver transection

After delineation of the area to be resected by either ischemic discoloration, by negative fluorescence imaging (FIGURE 1.B) after indocyanine green injection (anatomic resections) or by simple cautery demarcation guided by intraoperative ultrasound

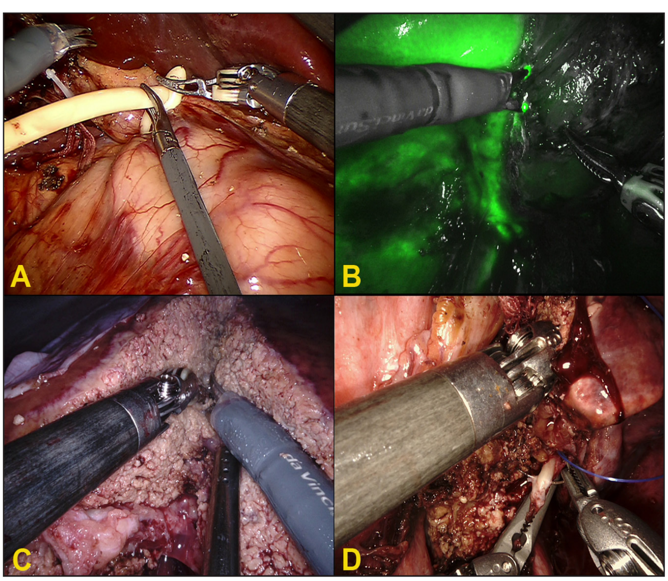

FIGURE 1. Robotic liver resection.
A) Foley catheter is used for intermittent intracorporeal Pringle maneuver.
B) Indocyanine green fluorescence imaging during robotic left hepatectomy. Left liver is ischemic.
C) Liver is transected with a combination of robotic bipolar forceps under continuous saline irrigation and robotic scissors.
D) Intraoperative control of major bleeding from inferior vena cava (IVC) branch. IVC is temporary clamped, and a suture is placed.

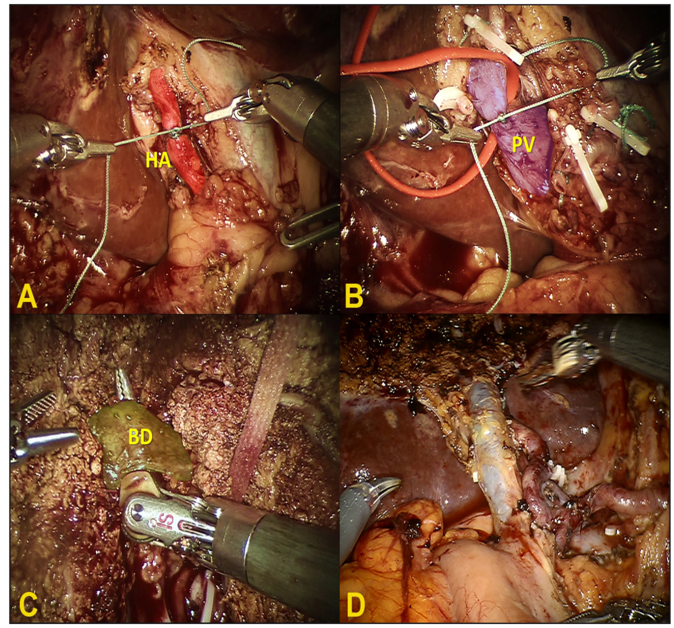

FIGURE 2. Robotic liver resection. Hilar dissection.
A) Right hepatic artery (HA) is dissected and ligated during robotic right hepatectomy.
B) Right portal vein (PV) is dissected and ligated during robotic right hepatectomy.
C) Right bile duct (BD) is identified during liver transection, encircled, and ligated.
D) Final aspect of hilar lymphadenectomy during robotic left hepatectomy for intrahepatic cholangiocarcinoma.

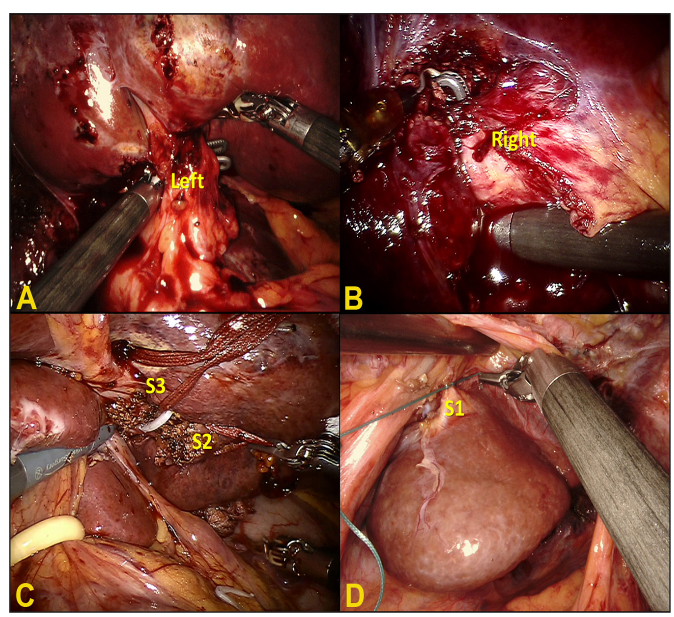

FIGURE 3. Robotic liver resection. Intrahepatic Glissonian approach.
A) Left Glissonian pedicle is encircled during robotic left hepatectomy.
B) Right Glissonian pedicle is encircled during robotic right hepatectomy.
C) Glissonian pedicle from segment 3 (S3) and segment 2 (S2) are encircled during bi-segmentectomy 2–3.
D) Glissonian pedicle from segment 1 (S1) is ligated during segmentectomy 1.

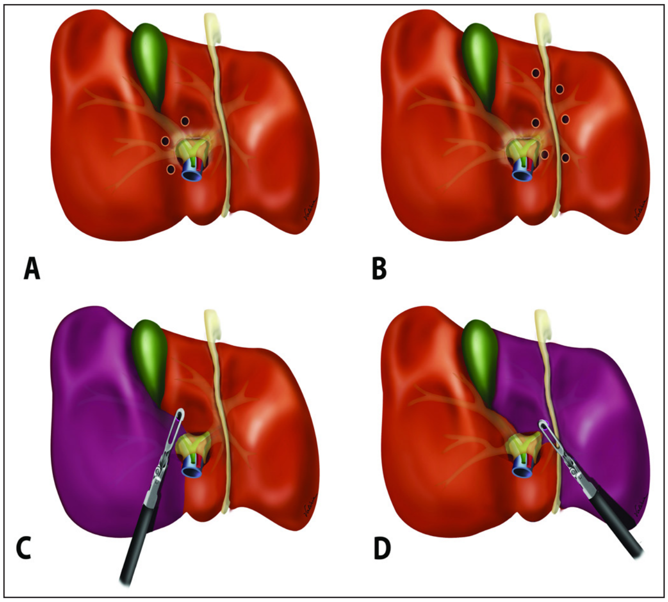

FIGURE 4. Schematic drawings of robotic Glissonian approach during liver resection.
A) Machado's points used for intrahepatic access to Glissonian pedicles from right liver.
B) Machado's points used for intrahepatic access to Glissonian pedicles from left liver.
C) Schematic drawing of caudal view for intrahepatic access of right Glissonian pedicle.
D) Schematic drawing of caudal view for intrahepatic access of left Glissonian pedicle.

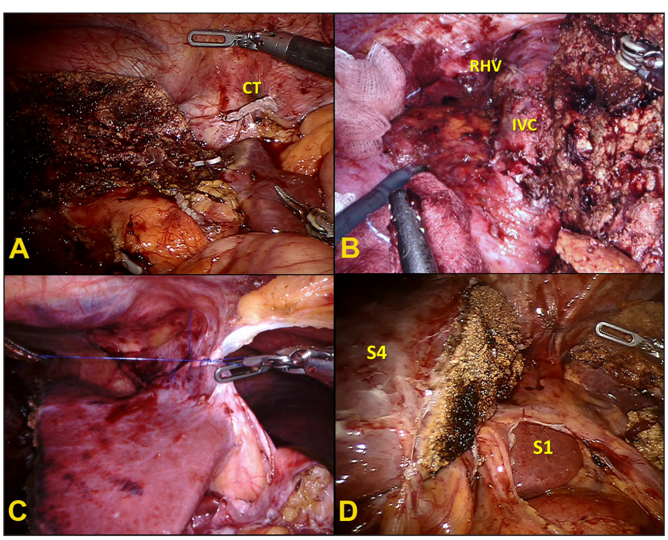

FIGURE 5. Robotic liver resection. View after liver resection.
A) Final view after robotic left trisegmentectomy with caudate lobe preservation. CT: common trunk, containing middle and left hepatic veins.
B) Final view after robotic bi-segmentectomy 7–8. IVC: inferior vena cava; RHV: right hepatic vein.
C) Final view after robotic right hepatectomy. Falciform ligament is sutured to the abdominal wall to maintain the left liver (remnant) in its original position avoiding hepatic vein kinking.
D) Final view after robotic bi-segmentectomy 2–3. S1: segment 1; S4: segment 4.

(wedge resections), the liver is transected (FIGURE 5). Our technique of liver transection is the use of the robotic bipolar forceps under continuous saline irrigation (FIGURE 1.C) with or without Pringle or selective inflow control. The liver tissue is then transected with robotic scissors. Large hepatic veins or pedicles encountered during liver transection are divided between hem-o-locks. Main hepatic veins are divided with vascular stapler or suture ligated (FIGURE 1.D).

Variables

The primary endpoint was safety of the procedures. Safety was assessed as the occurrence of intraoperative events or during hospitalization complications such as biliary fistulas, transfusion, liver failure, infection and 90-day mortality. To further account for the severity of complications, the Clavien-Dindo classification was used[13]. Secondary outcomes were surgical efficacy endpoints such as conversion rate, operative time, blood loss, need for transfusions, and length of hospitalization.

RESULTS

We have performed robotic liver resection on 50 consecutive patients. Over the same period, 38 patients underwent open liver resection, thus, the proportion of robotic liver resection was 58.8% of all liver resections. Thirty women and 20 men with median age of 61 years (range: 30–88) underwent robotic liver resection (TABLE 1). Forty-two patients were operated on for malignant diseases, 34 for liver metastases, three for hepatocellular carcinoma, three for intrahepatic cholangiocarcinoma, one for hilar cholangiocarcinoma and one for hemangioendothelioma. Robotic liver resection was performed in eight patients for benign diseases, three for intrahepatic lithiasis, four for biliary cystadenoma and one due to a large focal nodular hyperplasia with extrinsic gastric compression (TABLE 1). Major liver resection, defined as resection of three or more adjacent liver segments, was performed in 16 (32%) patients. Anatomical bi-segmentectomies were performed in six patients, anatomical segmentectomies were performed in

TABLE 1. Demographics of 50 patients undergoing robotic liver resection.

Variable of interest	Patients (n=50)
Age, years, median (range)	61 (30–88)
Sex, male/female, n (%)	20/30 (40%/60%)
Type of operation	
Minor, n (%)	34 (68%)
Major, n (%)	16 (32%)
Malignancy	
Benign, n (%)	8 (16%)
Malignant, n (%)	42 (84%)
Tumor type	
Primary, n (%)	16 (32%)
Secondary, n (%)	34 (68%)
Liver parenchyma	
Normal, n (%)	46 (92%)
Cirrhosis, n (%)	4 (8%)

n: number.

11 patients. Associating Liver Partition and Portal vein ligation for Stage hepatectomy (ALPPS) procedure was performed in two patients (TABLE 2).

TABLE 2. Types of robotic liver resection.

Procedure	Patients (n=50)
Left liver	
S1	3
S2	–
S3	3
S4	4
S2–S3	4
Left hemihepatectomy	5
Right liver	
S5–S6	1
S6–S7	1
S7–S8	1
S5	–
S6	6
S7	2
S8	2
Right hemihepatectomy	6
Bilateral	
Right trisectionectomy	2
Left trisectionectomy	1
Mesohepatectomy	2
ALPPS	2
Other types/combination of segments	5

ALPPS: Associating Liver Partition and Portal vein ligation for Stage hepatectomy.

Intrahepatic Glissonian approach was used in 28 patients for anatomical liver resection. Five major liver resections were performed with dissection of the hilar pedicle for anatomical liver resection, two right and three left hepatectomies. In two of these patients, hepaticojejunostomy was performed and in one case, the portal vein was resected and reconstructed. Hilar lymphadenectomy was performed in three cases.

In 16 patients, the robotic liver resection was a redo hepatectomy. In 13 patients, it was the second hepatectomy, in two patients it was the third and in one patient it was the fourth liver resection. In ten patients, previous liver resection was performed by open approach and in six by minimally invasive technique. In two patients, robotic liver resection was performed after open pancreatoduodenectomy and no hilar dissection or Pringle maneuver was performed due to the presence of hepaticojejunostomy. Simultaneous colon resection was done in three patients.

One patient was converted to open resection due to invasion of the hepatic hilum that preclude a safe and oncological operation. Two patients received blood transfusion (TABLE 3). Four (8%) patients presented postoperative complications, two clinical complications, acute renal failure (Clavien-Dindo IVa) and cardiac arrhythmia (Clavien-Dindo II) were conservatively managed and two surgical complications (subphrenic abscess and biliary fistula). Biliary fistula (Clavien-Dindo II) was managed by late removal of the drain while the abscess needed drainage under general anesthesia (Clavien-Dindo IIIb). Median hospital stay was 4 days. Mortality was nil.

TABLE 3. General outcomes of 50 patients undergoing robotic liver resection.

Variable of interest	Patients (n=50)
Operative time, minutes, median (SD)	293 (143)
Patients transfused (RBC), n (%)	2 (4%)
Blood loss	
<100 mL, n (%)	31 (62%)
101–600 mL, n (%)	17 (34%)
601–1000 mL, n (%)	2 (20%)
>1000 mL, n (%)	0 (0%)
Conversion, n (%)	1 (2%)
Hospital stay, days, median (range)	4 (1–15)
Malignant tumor in pathology, n (%)	42 (84%)
Positive margins*, n (%)	1 (2.4%)

SD: standard deviation, RBC: red blood cell. *Benign tumors excluded.

DISCUSSION

Since May 2018, all our minimally invasive liver surgeries are performed using the robotic platform and their data has been recorded on a prospective maintained database. Our experience with this new system increased over this period and so the indications for more complex cases[7-10]. The robotic approach, with its added degrees of freedom and stability of the robotic platform, may offer options for minimally invasive performance of complex liver resections that were a relative contraindication of laparoscopy[15-17]. Procedures that require excellent accuracy and dexterity are the best candidates for robotic surgery. Vascular structures, such as portal vein[8,9], hepatic artery and hepatic veins, are magnified in robotic vision. The magnified vision camera can expose the anatomic structure of the hilum. The da Vinci robot provides 20x magnified 3D vision, improving the precision of hilar dissection allowing vascular sutures, venous reconstruction[9], and biliary anastomosis[10] at difficult angles with the non-dominant hand, when necessary. An excellent visualization is key to the control of the intraoperative bleeding during mobilization and transection of the liver.

The first robotic liver resection in Brazil was performed by our team in 2008[14]. However, high-cost and absence of specific instruments for this complex procedure paused its use in our center for 10 years. Since May 2018, with the development of new instruments, acquisition of a new robotic platform and a new hospital policy with significant cost reduction for the use of the robotic platform, inspired us to employ the robot in all minimally invasive robotic surgery. Our previous and significant experience in laparoscopic liver surgery was important to decrease our learning curve. In our first 50 consecutive cases, there was just one conversion that occurred in the beginning of our experience. The morbidity rate was low (8%) with no mortality even though almost one third of procedures were major liver resections. The proportion of robotic liver resections was 56.8% among all liver resections. Laparoscopy was completely replaced by the robotic approach. Open approach was reserved for the patients with contraindications for minimally invasive technique[11]. In brief, every patient with a straightforward liver resection can and should be operated by minimally invasive approach. There is no consensus for contraindication for minimally invasive approach. Patients that until recently had a contraindication for minimally invasive approach are now being operated on by robotic approach[9,10]. Therefore, indication for the use of the robotic technique is changing fast and the proportion of minimally invasive liver resection will certainly increase with more experience with this new technology. The three techniques, open, laparoscopic, and robotic will coexist in the future, but with a different proportion than is seen today. In our opinion, the robotic technique will prevail, at least for liver resection.

Cost has always been considered to be the greatest limitation for the use of the robotic platform. However, recent studies with cost analysis have concluded that robotic hepatectomy has a lower overall cost. Robotic approach has greater intraoperative costs but this is outbalanced by a lower postoperative cost conferred by lower complication rate and shorter hospital stay[15,17-20]. This robotic effect on outcome, according to Luberice et al.[7], is independent of difficulty level of the liver resection. It has been noted by us since the inception of our robotic program and shown by these authors with their analysis of Iwate criteria of laparoscopic liver resection difficulty applied to robotic hepatectomy[7].

Robotic approach is useful for a precise dissection of the hepatic hilum. Individual dissection and identification of the portal triad seems faster and easier than with laparoscopy[3]. The intrahepatic Glissonian approach is our preferred method of inflow control for anatomical resections because it permits a rapid control of the portal pedicles while allowing segmental liver resections[12,21]. The use of this approach in laparoscopic liver resection needed an adaptation in the technique[12,21]. Instead of encircling the Glissonian pedicle for individual control of the correspondent portal pedicle (as in open intrahepatic Glissonian technique), laparoscopic Glissonian approach was achieved with blind insertion of a vascular clamp around the target pedicle using specific anatomical landmarks[12,21]. The use of the robotic platform permitted the safe encircling of the Glissonian pedicle in the same way that it was originally described for open liver resection, precluding the hilar dissection, even though robotic facilitates such dissection. Fluorescence imaging after indocyanine green injection is an important tool to define the limits of liver resection and to check liver perfusion and bile leaks after resection[22]. Individual dissection of the hilar elements was used for inflow control in five major liver resections, two right and three left hepatectomies. In two of these patients, hepaticojejunostomy was performed and in one case, the portal vein was resected and reconstructed. Hilar lymphadenectomy was performed in three patients.

Lessons learned

Our initial experience with robotic liver surgery raised some issues that may be important for any surgeon who intend to embark in this new technology. Previous experience in both open and laparoscopic liver surgery is essential for better results. Trocar placement may vary depending on the biotype of the patient and it is different from laparoscopic hepatectomy. Correct trocar placement is one of the most important steps for successful robotic procedure. The constant mobilization of the operating table, common during laparoscopic liver resection, is not possible in most robotic platforms. The supine position and reverse Trendelenburg position should be correctly stablished before robot docking. New platforms (da Vinci Xi) have operating tables integrated with the robot, but its availability is still scarce in our country. Another important issue is that there are some surgical instruments commonly used in liver surgery that are not available in the robotic systems so far, such as CUSA, cavitron ultrasonic surgical aspirator (used for liver transection) and other which are expensive and its use may be limited in developing countries, such as integrated staplers and robotic ultrasound. Therefore, we may overcome this issue by using laparoscopic available instruments, CUSA, laparoscopic ultrasound probe and staplers. However, these instruments are controlled by the bedside surgeon, so adequate experience in advanced liver surgery is also a prerequisite for the bedside surgeon. Conversion to open approach is less common than laparoscopy since bleeding is easier to fix with the use of wristed instruments that allows precise suturing whenever necessary (FIGURE 1.D). Indeed, several patients with major bleeding during this initial experience were easily controlled by suture. Nevertheless, if emergency conversion is needed, it may be hazardous once the undocking may take an extra time. Fortunately, the only patient converted in the present series was electively converted due to technical difficulty.

CONCLUSION

The use of the robot for liver surgery allowed to perform increasingly difficult procedures with similar outcomes of less difficult liver resections.

Authors' contribution

Machado MAC, Lobo-Filho MM, Mattos BH and Makdissi FF participate in the operative procedures. Ardengh AO collected the data. Machado MA wrote the manuscript draft. Ardengh AO, Lobo-Filho MM, Mattos BH and Makdissi FF supervised and commented on the manuscript. All authors discussed the results and contributed to the final manuscript.

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RESUMO – **Contexto** – A cirurgia robótica tem tido aceitação crescente nos últimos anos, expandindo-se para a ressecção hepática. **Objetivo** – Relatar a experiência com as primeiras cinquenta ressecções hepáticas robóticas. **Métodos** – Trata-se de análise retrospectiva de dados coletados prospectivamente. De maio de 2018 a dezembro de 2020, 50 pacientes consecutivos foram submetidos à ressecção hepática robótica em um único centro. Todos os pacientes com indicação de ressecção hepática minimamente invasiva foram submetidos à hepatectomia robótica. A indicação de técnica minimamente invasiva seguiu as diretrizes práticas baseadas na segunda conferência internacional de consenso laparoscópico hepático. **Resultados** – A proporção de ressecções hepáticas robóticas foi de 58,8% de todas as ressecções hepáticas. Trinta mulheres e 20 homens com idade mediana de 61 anos foram submetidos à ressecção hepática robótica. Quarenta e dois pacientes foram operados por doenças malignas. Ressecção hepática maior foi realizada em 16 (32%) pacientes. A abordagem Glissoniana intra-hepática foi usada em 28 pacientes para ressecção anatômica. Em 16 pacientes, a ressecção hepática robótica foi uma re-hepatectomia. Em 10, a hepatectomia prévia foi aberta e em seis foi por via minimamente invasiva. Ressecção simultânea do cólon foi feita em três pacientes. Um paciente foi convertido para ressecção aberta. Dois pacientes receberam transfusão sanguínea. Quatro (8%) pacientes apresentaram complicações pós-operatórias. Mortalidade em 90 dias foi nula. **Conclusão** – O uso do robô permitiu realizar procedimentos progressivamente mais complexos com resultados semelhantes às hepatectomias menos complexas.

Palavras-chave – Fígado; cirurgia robótica; hepatectomia.

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