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Robotics in hepatobiliary surgery-initial experience, first reported case series from India

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ABSTRACT

INTRODUCTION: Robotic surgical system's ability to perform complex hepatobiliary surgeries is gaining momentum with outcomes similar to open surgery and advantages of minimal access surgery. The authors present their initial experience of a heterogenous spectrum of robotic hepatobiliary cases and the first reported case series from India.

METHODS: Retrospective review of hepatobiliary cases done robotically from February 2015 to January 2016 was done.

RESULTS: The series has ten patients; with median age of 45 years (range 15–72). Etiologies were choledochal cyst type IVa, benign lower end common bile duct stricture (biliary reconstruction group); incidental gallbladder carcinoma, hepatocellular carcinoma, recurrent pyogenic cholangitis, polycystic liver disease, hemangioma, liver metastases, hydatid cyst (resection group). Median operative duration was 510 min; one patient needed intra-operative blood transfusion and there were no conversions to open surgery. One patient developed bile leak which was managed by biliary stenting and another thrombotic thrombocytopenic purpura during post-operative period. Median length of hospital stay was 6 days with average cost of robotic surgery being $1700 USD more for major hepatectomy and $900 USD more for biliary reconstruction compared to open procedure.

CONCLUSION: This initial series adds to existing data on the feasibility of robotic hepatobiliary cases with inherent advantages of minimal invasive surgery, however with limitation of availability and use of devices like cavitron ultrasonic surgical aspirator (CUSA) and higher operative cost.

1. Introduction

Robotic surgical platform has improved liver surgeons ability and expertise in performing minimal invasive liver surgery, although hepatectomy traditionally has always presented a challenge to surgeons because of the complex vascular and biliary anatomy. Liver surgery has become more refined since the definition of segmental anatomy by French surgeon and anatomist Claude Couinaud [1]. Laparoscopy for liver resection was first documented in the early 1990s, proving over the years to be as safe as conventional open hepatectomy while retaining oncologic integrity [2–7]. However, disadvantages of laparoscopy being limited degrees of instrument motion, unstable camera platform, poor ergonomy and the ability to control bleeding; all factors that hinder in achieving the operative complexity and dexterity required for complex hepatobiliary surgery, thus slowing it's broader adoption [7–10]. Robot-assisted approaches have been devised and implemented to overcome the shortcomings of conventional laparoscopy; the stability of the robotic platform combined with three dimensional magnified high definition vision, increased degrees of freedom of the instruments and tremor filtering provide better dexterity enabling the surgeon to mimic movements of open surgery. Precise dissection and suturing are possible, even on narrower operative fields, allowing for easier dissection of the hepatic hilum, biliary reconstruction even with small bile ducts and effective hemostasis and biliostasis along with better access to superior and posterior segments of liver [8–12].There are still limitations due to non-availability of full range of instruments and devices like cavitron ultrasonic surgical aspirator (CUSA) used for open or laparoscopic liver resection and higher cost remains an issue. The authors describe their initial experience doing hepatobiliary cases using a robotic surgical platform along the lines of PROCESS criteria [13] for case series.

2. Materials and methods

The series involved retrospective review of hepatobiliary cases done robotically using the Da Vinci surgical system at a private tertiary teaching hospital from February 2015 to January 2016.

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3. Results

There were ten patients, 4 females and 6 males with median age of 45 years (range 15–72); their characteristics are listed in Table 1 with no loss to follow-up. Median (IQR) operative duration was 510 (370–660) minutes, liver resection patients had median (IQR) operative time of 480 (240–600) minutes; one intra-operative blood transfusion was required and all procedures were completed robotically without conversion to open surgery. One patient of incidental gallbladder cancer who needed lymph node clearance around porta hepatis developed bile leak from cystic duct stump, which was managed by biliary stenting and another developed thrombotic thrombocytopenic purpura (TTP) during post-operative period, requiring ten sessions of plasmapheresis and prolonged hospital stay. Median hospital length of stay was 6 days with range of 4–28 days. Operative cost compared to open was $900 higher for biliary reconstruction and $1700 USD higher for major hepatectomy in the robotic group.

The three groups of patients were:

1. Liver Resection

There were 6 resections in our series, five anatomical and one non anatomical; three left lobe resections, one Segment 4b/5, Segment 5 and one non anatomical segment 6/7 resection.

a) Left Hepatectomy

The etiologies for all left lobe resections were benign with no underlying cirrhosis namely recurrent pyogenic cholangitis, polycystic liver disease and hemangioma.

The first resection was for recurrent pyogenic cholangitis in a 46 year old male, magnetic resonance cholangiopancreatography showed mild dilation of common bile duct/left hepatic duct and left lateral segmental duct stricture with multiple pseudotumor in left lateral segment. Total robotic left lobe liver resection was performed after treatment for cholangitis, as described in prior report [14].

One patient had polycystic liver disease with large cysts replacing the whole left lobe and multiple large cysts in the right lobe, he presented with symptoms of abdominal pain, intermittent fever and early satiety. Patient underwent robotic left hepatectomy and deroofing of liver cysts in the right lobe. On post-operative day five patient had seizures and persistent drop in platelet count, was diagnosed with TTP needing 10 sessions of plasmapheresis and prolonged hospital stay of 28 days.

Another patient of left lobe resection had a 12 cm hemangioma of left lobe liver.

Port placement were done starting with umbilical camera port, two 8 mm robotic ports in the left upper quadrant, 5 mm assist port in left paramedian location, 8 mm robotic port in right upper quadrant and a 12 mm assist port in right paramedian position. All left lobe resections were performed after inflow ligation and pringle maneuver was not used in any patient. Transection was performed with a combination of bipolar device and harmonic scalpel (Fig. 1). Outflow was stapled using an endo-GIA vascular stapler after completion of transection. Pedicles and bile duct stump were suture ligated with 5-0 prolene or PDS. Flat jackson pratt drain was used in all procedures and specimen was extracted via pfannenstiel or a midline incision.

b) Bisegmentectomy

Completion radical cholecystectomy with anatomical segment 4b and 5 resection was performed in one patient who had incidentally diagnosed gallbladder cancer (stage 2b) after laparoscopic cholecystectomy. Cystic duct margin being free, no CBD excision was performed. This patient developed post-operative bile leak from cystic duct stump, probably due to loosening of cystic duct clip during lymph node clearance at the porta hepatis.

c) Monosegmentectomy

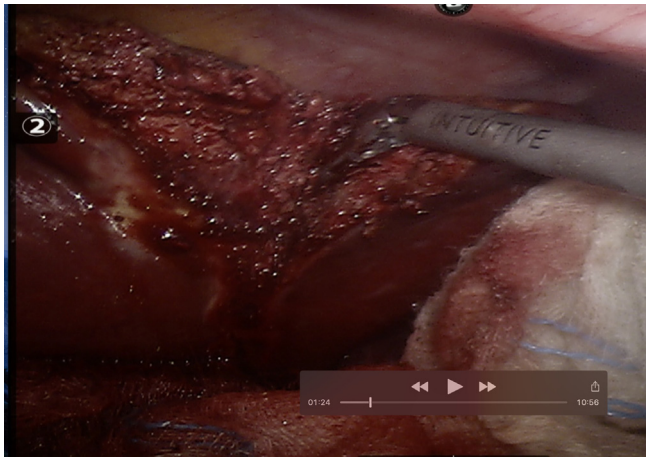

Fig. 1. Intraoperative image showing liver parenchymal transection with harmonic scalpel and bipolar grasper.

Segment 5 resection was performed for a 2.7 cm HCC found on imaging for abdominal pain in a 72 year old male.

d) Non-anatomical

The patient had a PET avid liver segment 6/7 lesion with history of cervical cancer, non anatomical resection was performed. The patient had received chemotherapy. This patient required 1unit of prbc transfusion intraoperatively secondary to bleeding due to post chemotherapy steatotic liver.

2) Biliary resection and reconstructions

One patient with choledochal cyst (type IVa) who underwent choledochal cyst excision and roux-en-y hepatico-jejunostomy, another patient with benign distal common bile duct stricture, underwent roux-en-y hepatico-jejunostomy. The patient with choledochal cyst was a 35 y/o female found to have a type Iva choledochal cyst during workup for recurrent upper abdominal pain associated with nausea/vomiting and fever. Computed tomography showed fusiform dilation of common hepatic duct and bile duct with maximum diameter of 4.2 cm, dilated cystic duct and distended gallbladder. MRCP confirmed the finding. Robotic excision of choledochal cyst was performed followed by creation of roux limb and hepatico-jejunostomy (Fig. 2). Patient had uneventful intra-operative and post-operative course with hospital discharge after five days. Pathology findings were consistent with inflamed choledochal cyst.

The patient with benign distal biliary stricture was a 57 y/o male who was found to have biliary stricture during workup for abdominal pain and jaundice. He had undergone spincterotomy and stent placement few months before and presented to us with recurrent symptoms of cholangitis. Imaging including CT and MRI showed diffuse dilation of intra and extrahepatic biliary system with tapering at distal bile duct. Patient underwent robotic roux-en-y hepatico-jejunostomy and cholecystectomy. Patient's intra-operative and post-operative course were uneventful with hospital stay of six days.

In both patients of biliary reconstruction ports were placed lower to have easy access to both supra and infra colic compartments. Robotic arms provided easy and better precision of intracorporial suturing.

3) Liver cyst resection

Two patients underwent liver cyst resections, one for polycystic liver disease and the other for hydatid cyst. The patient with polycystic liver disease was a 59 year old female who underwent partial excision of large left lateral segment cyst and deroofing of adjoining cyts in segment IV.

Table 1
Characteristics of patients.

	Age/Sex	Diagnosis	Operation	Duration (Mins)	Intra-operative blood Transfusion	Length of Stay (days)
1	45/Female	Incidental gallbladder carcinoma	Completion radical cholecystectomy (Anatomical Segment IVB/V resection)	480	0	7
2	46/Male	Recurrent pyogenic cholangitis	Left hepatectomy	540	0	7
3	35/Female	Choledochal cyst type IV	Choledochal cyst excision + Roux en-Y hepaticojejunostomy	550	0	6
4	44/Male	Polycystic liver disease	Deroofing liver cysts right + left hepatectomy	600	0	28
5	15/Male	Hydatid cyst seg VII	Partial cystectomy	480	0	7
6	59/Female	Polycystic liver disease	Left lateral segment partial cystectomy + cyst deroofing	370	0	4
7	57/Male	Distal benign biliary stricture	Hepaticojejunostomy Roux-en-y + Cholecystectomy	600	0	6
8	43/Female	Cervical cancer w/liver lesion seg 6/7	Seg 6/7 lesion excision + cholecystectomy	240	1	5
9	55/Male	Hemangioma	Left Hepatectomy	660	0	6
10	72/Male	Hepatocellular Carcinoma	Segment 5 resection	450	0	4

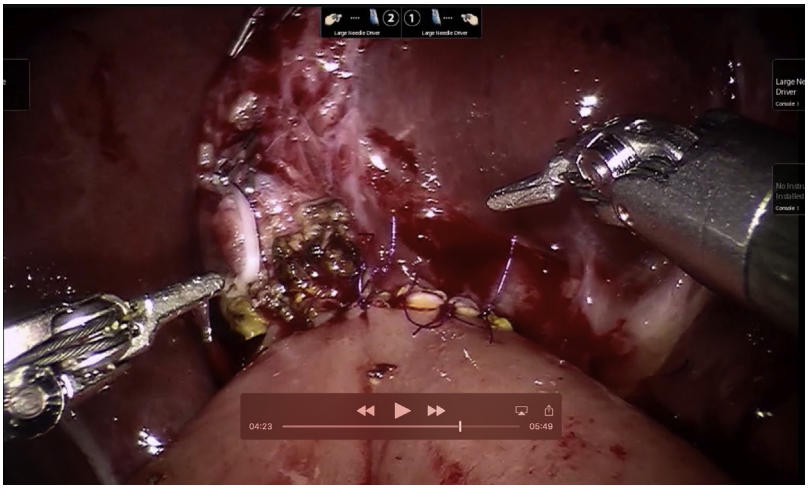

Fig. 2. Intraoperative image showing Roux en-Y hepatico-jejunostomy creation after choledochal cyst excision.

The other patient was a 15 year old boy who underwent partial cystectomy of segment VII hydatid cyst. Both the patients had uneventful intra-operative and post-operative course, with hospital discharges in four and seven days.

4. Discussion

The authors report the first case series of robotic hepatobiliary cases from India, adding to the many series reporting on the safety, limited conversion rates, reasonable blood loss, and minimal post-operative morbidity, even for major hepatectomy [9–12,14,15]; since the first reported use of robotic surgical system for liver surgery by Vibert E et al. [16] in 2003 where they used it for pedicle dissection and initial hepatotomy.

Liver surgery is technically demanding due to its complex vascular and biliary anatomy; the challenges include access to the vena cava and major hepatic veins, hilar dissection and parenchymal transection. Robotic surgery enables overcoming these challenges and patients may be spared large incisions required for liver mobilization in an open approach. Robotic-assisted laparoscopic surgery overcomes the limitation of conventional laparoscopic instruments in performing liver surgery including depth perception, rigid instruments and difficulty of suturing and access to postero-superior segments of liver [10–12,15]. Hepatic resections for hilar cholangiocarcinoma, caudate lobectomy and bile duct anastomosis are difficult via pure laparoscopic approach and generally not performed [5–7], but the use of robotic surgical system may allow these to be approached in a minimally invasive manner.

The limitation of our paper is that it is a small retrospective series with a heterogenous case mix. Although our group was heterogenous, when compared to series in literature the median (IQR) operative time was 510 (370–660) minutes and 480 (240–600) minutes for biliary reconstruction and liver resection group respectively, with 10% intra-operative transfusion, 20% post-operative morbidity, 0% mortality. There were no conversions to open surgery, resection margins were negative in all tumor cases and median stay was 6 days.

Tsung et al. [17] performed a matched series comparison of surgical and postsurgical outcomes between robotic (n = 57), laparoscopic (n = 114), and open hepatic resections (n = 21). The robotic and laparoscopic group had similar EBL, transfusion rate, R0 negative margin rate, postoperative peak bilirubin, postoperative ICU admission rate, LOS, and 90-day mortality. Among the robotic surgery group, a significantly greater overall room time (342 vs 261.5 min, $p < 0.001$) and OR time (253 vs 198.5 min, $p = 0.001$) were experienced. However, a greater proportion of robotic hepatectomies were accomplished in a purely minimally invasive manner (93.0% vs 49.1%, $p < 0.001$).Total complication rates did not significantly differ between the robotic and laparoscopic cases (19% vs 26%, respectively, $p = 0.34$,).The robotic versus laparoscopic groups were also similar in the rate of conversion to open (7% vs 8.8%, $p = 0.67$).The robotic hepatectomy series included 21 major liver resections which were compared to an open cohort. Differences were seen in EBL (200 vs 500 mL, $p = 0.005$) and LOS (5 vs 8 days, $p = 0.02$) in favor of the robotic cohort.

Qui et al. [18] published a meta-analysis reviewing 29 studies involving 537 patients undergoing robot assisted liver resection (RALR). The most common RALR procedure was a wedge resection and segmentectomy (28.67%), followed by right hepatectomy (17.88%), left lateral sectionectomy (13.22%), and bisegmentectomy (9.12%). The conversion and complication rates were 5.59 and 11.36%, respectively. Nine studies, involving 774 patients, were included in meta-analysis. RALR had a longer operative time compared with laparoscopic liver resection (LLR) [mean difference (MD) 48.49; 95% confidence interval (CI) 22.49–74.49 min; $p = 0.0003$]. There were no significant differences between the two groups in blood loss, hospital stay, postoperative overall morbidity and surgical margin status; cost was greater with robotic surgery.

Transchart H et al. [19] compared traditional laparoscopic liver resection (TLLR) with robot assisted laparoscopic liver resection (RLLR) with twenty-eight patients in each group. Despite matching, more tumors were solitary in the TLLR group ($p = 0.02$) and more were localized in the superior and posterior segments in the RLLR group ($p = 0.003$). The median duration of surgery was 210 and 176 min in the RLLR and TLLR groups, respectively ($p = 0.12$). Conversion rate, blood loss, morbidity, and length of stay were similar in both groups.

A *meta*-analysis by Nicole RJ et al. [20] which included 49 pertinent studies showed minimally invasive approaches for hepatectomy to be as safe and efficacious as conventional laparotomy, with similar total operative times. Minimally invasive approaches afford shorter LOH, decreased EBL, and decreased postoperative morbidity. Specifically, these approaches resulted in fewer incisional hernias, wound infections, ascites or cirrhotic decompensation events and retained oncologic integrity. All approaches to liver resection resulted in similar mortality rates.

Another meta-analysis demonstrated the value for malignant tumors as well; no differences in the long-term survival and tumor recurrence for patients between open and laparoscopic procedures were observed, but the blood loss and postoperative complication rates were lower in minimally invasive procedures [21].

Bile leaks and massive hemorrhage are two important perioperative considerations in hepatic surgery owing to the unique anatomic structure of the liver, with minimally invasive approaches showing decreased intra-operative blood loss and equitable postoperative bile leak rates. The observed lower EBL is likely multifactorial, owing to both hepatic vein tamponade from pneumoperitoneum and improved dissection via field magnification. Robotic surgery has a perceived risk of delay in open conversion in cases of hemorrhage due to separation of the console surgeon from the patient and robotic setup. This can be overcome by having a qualified surgeon assist in these complex cases.

In our experience robotic system can be safely used to perform major hepatectomies, with greater ease of hemostasis and biliary pedicle suturing which is difficult in laparoscopy needing a long learning curve. Access to superior segments, 7 and 8 which is a challenge in laparoscopy is far easier using the robotic platform as shown in two of our cases in this series. However the greatest hurdle in adoption of this technology remains cost, with increase in operative cost ranging from 900 to 1700 USD than open surgery.

5. Conclusion

The authors present this series of robotic hepatobiliary cases with different sets of diagnoses and procedures, highlighting the utility of robotics in hepatobiliary surgery with application in both benign and malignant disorders. Versatility of the system allows ease of use for both liver resections and biliary reconstruction, with benefits of minimal invasive surgery; but wider use of this technology is limited by higher cost at present.

Conflicts of interest

The authors have no conflict of interest to disclose.

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Ethical approval

None.

Author contribution

Sanjay Goja: Conception of the work; data analysis and interpretation. Drafting the work, critical revision for important intellectual content and final approval of the version to be published.

Manoj K Singh: Data acquisition, analysis and interpretation, drafting and final approval.

Arvinder Soin: Conception, critical revision and final approval of the version to be published.

Consent

Written informed consent was obtained from patients for publication of this case series and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Guarantor

Dr Sanjay Goja.

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