Totally Robotic Right Hepatectomy

Surgical Technique and Outcomes

Pier Cristoforo Giulianotti, MD; Fabio Sbrana, MD; Andrea Coratti, MD; Francesco Maria Bianco, MD; Pietro Addeo, MD; Nicolas Christian Buchs, MD; Subhashini M. Ayloo, MD; Enrico Benedetti, MD

Hypothesis: Robotic surgery for performance of right hepatectomy is safe and effective.

Design: Case series from 2 medical institutions.

Setting: University of Illinois at Chicago and Misericordia Hospital, Grosseto, Italy.

Patients: Twenty-four patients underwent right hepatectomy between March 1, 2005, and January 31, 2010, using a robotic surgical system.

Main Outcome Measures: Intraoperative blood loss, operative time, morbidity, mortality, and long-term oncologic follow-up.

Results: The procedure was converted to open surgery in 1 patient (4.2%). The overall mean (SD) operative time was 337 (65) minutes (range, 240-480 minutes), and the mean (SD) intraoperative blood loss was 457 (401) mL (range, 100-2000 mL). Three patients (12.5%) underwent blood transfusion. There were no perioperative deaths and no reoperations. Six patients (25.0%) experienced postoperative morbidity, including transitory liver failure in 2 patients and pleural effusion, bile leak, fluid collection, and deep venous thrombosis in 1 patient each. The patients’ diagnoses included colorectal liver metastases (n=11), noncolorectal liver metastases (n=4), hemangioma (n=4), adenoma (n=2), hepatocellular carcinoma (n=1), hepatoblastoma (n=1), and biliary amartoma (n=1). At a mean follow-up duration of 34 months, no port site metastases were observed in patients with malignant pathologic findings.

Conclusions: The zero mortality and acceptable morbidity of our series indicate that in experienced hands, robotic right hepatectomy is feasible and safe. Robotic surgery offers a new technical option for minimally invasive major hepatic resections. Long-term results seem to confirm oncologic effectiveness of the procedure.

Arch Surg. 2011;146(7):844-850

LAPAROSCOPIC LIVER SURGERY has long been recognized as one of the most challenging procedures in the field of minimally invasive surgery.1 However, as surgeons continue to gain more experience with laparoscopy and as new technological devices become available, the number of laparoscopic liver resections being performed is gradually rising.2 Its benefits have been reported in studies3-6 comparing laparoscopic with open liver surgery and include a significant decrease in intraoperative blood loss, reduced postoperative hospital length of stay, and shortened time to first oral alimentation. Robotics is one of the most recent developments in the field of minimally invasive surgery and has been introduced into clinical practice to overcome some of the technical limitations of laparoscopy.16 Experience with robotic liver resection has not been widely reported to date.16-20

The objective of this study is to describe our experience with robotic right hepatectomy using a robotic surgical system (da Vinci Surgical System; Intuitive Surgical, Inc, Sunnyvale, California). We focus herein on our technique and outcomes.

Methods

Between March 1, 2005, and January 31, 2010, a total of 24 patients underwent robotic right hepatectomy by one of us (P.C.G.) who is an experienced surgeon11 at 2 medical centers, the Department of General Surgery at Misericordia Hospital in Grosseto, Italy (March 2005 to April 2007) and the Division of General, Minimally Invasive and Robotic Surgery at the University of Illinois at Chicago (May 2007 to January 2010). Demographics, intraoperative
outcomes, mortality, 30-day morbidity, and follow-up data were collected prospectively in 2 separate databases kept at each institution and retrospectively analyzed for this study.

INCLUSION AND EXCLUSION CRITERIA

The patients’ clinical status and characteristics of liver lesions were the basis of selection for a robotic approach during the study period. Exclusion criteria included general contraindications to pneumoperitoneum, cardiac or respiratory insufficiency, or American Society of Anesthesiologists classification exceeding 3. Liver resection for benign tumors was considered when symptoms or adenopathy were present or when a malignant neoplasm could not be excluded during the preoperative workup. Resection of liver metastases was considered only in the absence of peritoneal carcinomatosis and nonresectable extrahepatic disease. There was no limit on the size of lesions. However, lesions with extensive subcapsular involvement or those invading major hepatic vessels (portal vein branches, inferior vena cava, and major hepatic veins) were considered contraindications. The need to perform a biliary reconstruction during right hepatectomy was not considered a contraindication during the last 2 years of experience reported in 2010. All patients were fully informed of the risks and benefits of the procedure, and written informed consent was obtained before surgery. All procedures were performed using the robotic surgical system.

STATISTICAL ANALYSIS

The variables analyzed in this study include operative time, intraoperative blood loss, resected tumor size, postoperative hospital length of stay, morbidity, and mortality. Morbidity and mortality were defined as occurring within 1 month of surgery. Continuous data were expressed as the mean (SD). To compare groups, t test was applied to continuous data and Fisher exact test to categorical data when appropriate. P < .05 was considered statistically significant.

SURGICAL TECHNIQUE

Patient Positioning and Port Placement

The patient is placed supine in a 20° reverse Trendelenburg position with the operating table tilted slightly to the left side. Pneumoperitoneum is achieved through a Veress needle in the left hypochondria to insufflate the abdomen to 14 mm Hg.

Six trocars are typically used for the procedure as shown in Figure 1, which illustrates 4 trocars in use and 2 points (marked with red dots) indicating future trocar entry sites. The robotic surgical system’s patient cart is placed at the patient’s head for the docking phase. The first surgeon is seated at the robotic console, while an assistant surgeon who is experienced in advanced laparoscopic surgery stands at the patient’s side. The assistant surgeon is positioned between the patient’s legs to allow for changing of robotic instruments and to perform retraction, clipping, stapling, suction, and laparoscopic ultrasonography. A second assistant surgeon is positioned on the right side of the patient.

Step 1: Hilum Dissection

Retrograde cholecystectomy is performed, and dissection of the hepatic pedicle is started using a combination of monopolar hook and bipolar forceps. The right hepatic artery is dissected first and then sectioned between ligatures (Figure 2). The right portal vein is then completely dissected.
ligatures are applied on the small posterior branches for segment 1 (Figure 3), and the right portal vein is divided between robotic clips and immediately sutured with stitches of polypropylene 5-0 (Figure 4).

Extrahepatic dissection of the right bile duct is accomplished only when the anatomy is clear and the confluence of the biliary duct is low. In this case, once the hilar plate is lowered, the right hepatic duct is isolated and transected 1 cm from the bifurcation (Figure 5). In other cases, the right biliary duct is divided during parenchymal transection.

Step 2: Hepatocaval Dissection

An anterior approach is generally used for robotic right hepatectomy. This phase begins with dissection of the lateral peritoneal reflection along the hepatocaval plane. The inferior surface of the liver is then lifted up using the fourth-arm instrument. The right flank of the inferior vena cava is exposed, and dissection of the inferior vena cava is performed by working along its axes from beneath the liver and sectioning multiple accessory hepatic veins between ligatures or transfixed stitches of polypropylene (Figure 6). If needed, clips can be used to further secure the proximal ligatures. Once the inferior aspect of the right hepatic vein is visible close to the diaphragm, dissection of the inferior vena cava is complete.

Step 3: Parenchymal Transection

To obtain complete visual control of the right hepatic vein, the portion of the falciform ligament that is covering the right hepatic vein is dissected. Parenchymal transection is then carried out along the cholecisto-caval line, following the ischemic demarcation and beginning at the anterior border of the liver. This is performed using a combination of robotic harmonic shears (Intuitive Surgical, Inc) on the right arm and bipolar forceps on the left arm. Optimal exposure of the transection surface is progressively achieved by several polypropylene stay sutures placed at the left resection margins used for retraction by the fourth arm (Figure 7).

Transection of the cortical aspect of the liver continues layer by layer using robotic harmonic shears. Minor bleeding is controlled via bipolar cautery, while the larger vessels are controlled with selective stitches of polypropylene 4-0.

The second phase of parenchymal transection involves the section of the core of the liver parenchyma. This is represented by the part of the liver in which there is higher vascularity because of the venous branches from segments 5 and 8 that are directed toward the middle hepatic vein.
In this phase, endoscopic staplers are used for parenchymal transection. The right hepatic vein is divided inside the parenchyma using a laparoscopic vascular stapler (Figure 8).

The lateral ligaments of the liver are normally taken completely down at the end of the procedure. The specimen is then placed in an endoscopy bag and extracted through a Pfannenstiel minilaparotomy. Two closed suction drains are left in the subhepatic and subdiaphragmatic areas, and pneumoperitoneum is vented through the trocar.

RESULTS

In this study, 24 patients who underwent robotic right hepatectomy were analyzed. The first group of 13 patients (54.2%) underwent robotic right hepatectomy at the Department of General Surgery at Misericordia Hospital in Grosseto, Italy (March 2005 to April 2007), while the second group of 11 patients (45.8%) underwent robotic right hepatectomy at the Division of General, Minimally Invasive and Robotic Surgery at the University of Illinois at Chicago (May 2007 to January 2010). Of 24 procedures performed, all but 1 (95.8%) were successfully completed robotically. One conversion to open surgery was necessary owing to adhesion of the colorectal metastases to the inferior vena cava, making it impossible to safely evaluate the oncologic margin.

Demographics of the patients are summarized in Table 1. Of 24 patients undergoing robotic right hepatectomy, 14 (58.3%) were women. The median age was 55 years (age range, 21-84 years). Eighteen patients (75.0%) had undergone previous abdominal surgery. Indications included malignant tumors in 17 patients (70.8%) and benign tumors in 7 patients (29.2%) (Table 2). Five patients (20.8%) had secondary procedures performed in addition to right hepatectomy (Table 3). The overall mean (SD) operative time was 337 (65) minutes (range, 240-480 minutes), and the overall mean (SD) intraoperative blood loss was 457 (401) mL (range, 100-2000 mL). Blood transfusions were required in 3 patients (12.5%).

There was no mortality in our series. Morbidity occurred in 6 patients (25.0%). Of these, 5 were in the first group of 13 cases, and 1 was in the second group of 11 cases (P = .17). Transitory liver failure (50-50 criteria22) was observed in 2 patients who received preoperative chemotherapy. One bile leak occurred and was treated by percutaneous drainage.

All patients were ambulating by the end of the first or second postoperative day. Oral alimentation was restarted at a mean of 2 (1) days after surgery. There was no incision-related morbidity.

The overall mean (SD) postoperative hospital length of stay was 9.0 (3.0) days (range, 3-23 days). Comparing the 2 groups of patients, the postoperative hospital length of stay was significantly shorter in the US group than in the Italian group (5.5 [2.0] vs 11.0 [5.0] days, P = .003). Three patients in the Italian group had a postoperative hospital length of stay exceeding 20 days because of liver failure, pleural effusion requiring thoracic drainage, and deep venous thrombosis.

Table 1. Demographics Among 24 Patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male-female ratio</td>
<td>10:14</td>
</tr>
<tr>
<td>Age, median (range), y</td>
<td>55 (21-84)</td>
</tr>
<tr>
<td>American Society of Anesthesiologists class</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Previous abdominal surgery</td>
<td>18</td>
</tr>
<tr>
<td>Colorectal resections</td>
<td></td>
</tr>
<tr>
<td>Left colectomy</td>
<td>5</td>
</tr>
<tr>
<td>Right colectomy</td>
<td>2</td>
</tr>
<tr>
<td>Abdominoperineal amputation</td>
<td>1</td>
</tr>
<tr>
<td>Rectal anterior resection</td>
<td>4</td>
</tr>
<tr>
<td>Nephrectomy</td>
<td>2</td>
</tr>
<tr>
<td>Appendectomy</td>
<td>3</td>
</tr>
<tr>
<td>Cholecystectomy</td>
<td>3</td>
</tr>
<tr>
<td>Gastric bypass</td>
<td>1</td>
</tr>
<tr>
<td>Hysterectomy</td>
<td>2</td>
</tr>
<tr>
<td>Ventral hernia repair</td>
<td>1</td>
</tr>
<tr>
<td>Previous chemotherapy</td>
<td>11</td>
</tr>
</tbody>
</table>

aThree laparoscopic and 1 robotic.
bTwo laparoscopic.
ments 3 and 2 after right hepatectomy at 10 and 20 months. Among patients with colorectal liver metastases, 9 of 11 are alive and disease free at a mean follow-up duration of 34 months (range, 1-57 months). No port site or peritoneal metastases were observed in patients with malignant pathologic findings.

The mean surgical margin was 30 mm (range, 3-70 mm). Only 1 patient had a margin less than 1 cm. The overall median size of lesions was 52 (28) mm (range, 10-110 mm). Intraoperative blood loss, mean (SD) [range], mL 457 (401) [100-2000]. Blood transfusion 3.

Secondary procedures
- Partial diaphragmatic resection 6
- Extensive adhesiolysis 1
- Ventral hernia repair 1

Mortality 0

Morbidity
- Transitory liver failure 3
- Pleural effusion 2
- Bile leak 1
- Fluid collection 1
- Deep venous thrombosis 1

Postoperative hospital length of stay, mean (SD), d 9.0 (3.0)
- Italy 11.0 (5.0)
- US 5.5 (2.0)

Although reports of laparoscopic minor liver resections have increased with experience and availability of new technological devices, the fear of major intraoperative bleeding and technical difficulties because of a lack of advanced laparoscopic skills have limited the use of minimally invasive surgery for major liver resections. In a large systematic review of the literature, Nguyen et al2 found that, of 2804 laparoscopic liver resections performed between 1992 and 2008, only 253 (9.0%) were right hepatectomies. Likewise, Dagher et al23 in a 2009 multicenter study on laparoscopic major liver resections reported 136 minimally invasive (hand-assisted and totally laparoscopic) right hepatectomies performed over 11 years at 6 international (3 European, 1 US, and 1 Australian) centers.

Studies10-12,14,24 have shown that in experienced hands, laparoscopic major right liver resection offers reductions in intraoperative blood loss, blood transfusion rates, and postoperative hospital length of stay. However, it is performed in only a few centers worldwide.

The experience with robotic surgery for major liver resection reported thus far in the literature remains limited. An initial study19 of robotic anatomic liver resection was published by our group in 2003. That same year, Vibert et al27 reported a case of an extended robotic right hepatectomy in which the robot was used to perform the hilum dissection and part of the parenchymal transection.

In 2009, Patriti et al19 reported their initial experience with 7 patients in whom synchronous colorectal liver metastases were treated using robotic surgery. In this series, only 1 patient underwent right hepatectomy, although a right subcostal incision was made for completing the hemostasis and extracting the specimen.

From a technical point of view, the use of a robotic surgical system can improve certain steps of minimally invasive liver resections. The robotic system can improve certain steps of minimally invasive liver resections.
invasive right liver resection. Magnified 3-dimensional vision allows for better definition of the vascular anatomy and improved recognition of the fine branches that originate from the right portal trunk and are directed toward segment 1. Furthermore, by taking advantage of the wristed instruments, it is possible to use simple ligatures to control major vessels instead of the stapler, which can be cumbersome in small spaces.

In our experience, extraparenchymal dissection and selective control in elements of the right portal pedicle were possible in all cases, with no intraoperative accidents. Furthermore, in 1 case of high intraportal bifurcation, intraparenchymal dissection (an anterior split) enabled safe recognition and control of portal branches.

Hepatocaval dissection can also be improved by the use of a robotic surgical system. The dissection can be completed by working along the main axis from beneath the liver and increasing progressively the traction on the fourth arm. In a limited workspace, the availability of instruments with wristed technology can allow for precise dissection and suturing of the accessory hepatic vein.

It is important to note that with this type of advanced procedure, it is mandatory to have an experienced assistant surgeon present. He or she can assist in suctioning and retracting the tissue to obtain optimal exposure.

Intraoperative bleeding during parenchymal transection is a primary reason for conversion to open surgery during laparoscopic major liver resections.14,23 The reported conversion rate for laparoscopic right hepatectomy varies from 33% in the early experience by Dulucq et al12 to a more limited rate of 14% reported by Gayet et al.12 In our experience, only 1 conversion to open surgery occurred. This was because of inability to carefully evaluate the oncologic margin. Conversion to open surgery was considered mandatory to avoid compromising the oncologic outcome of the operation.

Some authors have adopted the use of the Pringle maneuver for major liver resection to prevent possible bleeding.14,25 In our experience, the Pringle maneuver was not necessary. The mean intraoperative blood loss was 457 (401) mL (range, 100-2000 mL), and 3 patients underwent blood transfusion. These overall intraoperative blood loss and blood transfusion data are comparable to those reported in other series of laparoscopic right hepatectomy.12,15,23 In particular, Dagher et al.15 in their series of 20 laparoscopic right hepatectomies reported a blood transfusion rate of 15%, with a mean intraoperative blood loss of 523 (526) mL. A similar rate was reported by Gayet et al.12 in their series of 42 laparoscopic right liver resections, with a 14% blood transfusion rate.

With regard to morbidity and mortality, our study reports 25.0% (6 of 24) morbidity and zero mortality. The morbidity rate was higher in the first group of patients because of 2 transitory liver failures and can be attributed less to surgical technique and more to extensive preoperative chemotherapy20 that both patients received. The mean postoperative hospital length of stay at the 2 institutions were significantly different (11.0 vs 5.5 days), despite that a standardized technique was used and almost all patients experienced early ambulation, oral alimentation, and bowel movements. We believe that this difference can be attributed not only to increased (although not statistically significant) morbidity in the Italian group but also to cultural and health care management variations between the 2 countries involved. However, the short postoperative hospital length of stay seen in the US group compares favorably to that in some US series of open major liver resection.27,28

Regarding long-term oncologic outcomes, 3 of 17 patients with malignant disease had liver recurrences, and 2 died of systemic recurrence. However, type of recurrence does not seem to be associated with surgical technique (far away from the section line). A controlled trial is needed to compare the long-term oncologic results of robotic right hepatectomy with those of open surgery.

In conclusion, minimally invasive surgery has a clear role in major liver resections at experienced centers, offering the patient decreased abdominal wall morbidity, shorter postoperative hospital length of stay, and minimal need for blood transfusion. The acceptable morbidity and low blood transfusion rate in our series indicate that robotic right hepatectomy is feasible and safe in experienced hands. This technique may represent a future minimally invasive approach to major liver surgery.

Accepted for Publication: June 7, 2010.
Correspondence: Pier Cristoforo Giulianotti, MD, Division of General, Minimally Invasive and Robotic Surgery, Department of Surgery, University of Illinois at Chicago, 840 S Wood St, Ste 433E, Chicago, IL 60612 (piercg@uic.edu).

Author Contributions: Study concept and design: Giulianotti. Acquisition of data: Sbrana, Coratti, Bianco, Addeo, and Buchs. Analysis and interpretation of data: Coratti, Bianco, Buchs, and Ayloo. Drafting of the manuscript: Giulianotti, Bianco, Addeo, and Buchs. Critical revision of the manuscript for important intellectual content: Giulianotti, Sbrana, Coratti, Bianco, Addeo, Ayloo, and Benedetti. Study supervision: Giulianotti, Sbrana, Coratti, Addeo, Ayloo, and Benedetti.

Financial Disclosure: None reported.

REFERENCES

Advances in surgical technique are driven by patient demand and by a genuine motivation to improve the objective and quality-of-life outcomes for those who require surgical attention. Although many would have thought (or aspired to believe) that laparoscopy was a transient interest with little to offer, it is safe to say that minimally invasive surgery is here to stay. The early experience with laparoscopic cholecystectomy and gynecological procedures led to the development of improved instrumentation, powerful optics, and training programs to allow minimally invasive therapy in cases that were thought to be reserved for open surgical management. With experience and conviction, surgeons treated various conditions in the abdominal and thoracic cavities via laparoscopy, noting its clinical benefits and technical challenges. Perhaps the last anatomical holdout was the hepatobiliary system. While appropriately feared for its risk of sudden and exhaustive hemorrhage, laparoscopic liver surgery had been reserved for excision of small exophytic lesions or resection of left lateral segments.

In this issue of *Archives*, Giulianotti et al. present their series of 24 patients who underwent right hepatic lobectomy performed robotically with reasonable operative time, minimal morbidity, and no mortality. The indications vary from benign processes to metastatic disease. Their outcomes are exceptional and worthy of praise. The authors conclude that this method of therapy “is feasible and safe.”

While the authors are to be commended on their superior results, it is important to highlight that, in the absence of 2 qualified surgeons at an institution invested in technology and advanced instrumentation, the application of this procedure is neither prudent nor ethical. The advantages of laparoscopy notwithstanding, one must not forget that technology does not replace surgical skill and that “the next great thing” does not excuse poor judgment. Before widely and universally accepting laparoscopic right hepatic lobectomy as the standard of care or adopting this technique into their own practice, surgeons must not only perform a careful analysis of the environment in which they work but also ask, “Do I possess this skill set?” There is no shame in open surgery.

Matthew Cooper, MD

**Author Affiliation:** Department of Surgery, University of Maryland School of Medicine, Baltimore.

**Correspondence:** Dr Cooper, Department of Surgery, University of Maryland School of Medicine, 29 S Greene St, Ste 200, Baltimore, MD 21201 (mcooper@smail.umaryland.edu).

**Financial Disclosure:** None reported.