

# Our initial experience with robotic hepato-biliary-pancreatic surgery

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## Abstract

**Background** The authors performed Asia's first robotic surgery in March 2000 and a clinical trial was launched in the following year in order to obtain governmental approval for the da Vinci<sup>®</sup> Surgical System.

**Methods** Fifty-two robotic surgeries were performed at Keio University Hospital, of which the authors performed 28 hepato-biliary-pancreatic surgeries.

**Results** In robotic laparoscopic cholecystectomy, articulated monopolar electrocautery scalpels are flexible, enabling precise dissection around the gall bladder and clipless ligation of the cystic artery and cystic ducts. For laparoscopic hepatectomy, hepatic parenchyma was safely resected without hemorrhage by Glisson's pedicles ligation and bipolar hemostatic forceps.

**Conclusions** We review robotic laparoscopic cholecystectomy and hepatectomy and discuss the potential and future outlook for robotic hepato-biliary-pancreatic surgery.

**Keywords** Robotics · da Vinci<sup>®</sup> · Computer technology · Laparoscopic hepatectomy · Laparoscopic cholecystectomy

## Introduction

Endoscopic surgery has greatly improved post-surgical quality of life for patients by minimizing the degree of destruction of the body walls. However, it has also increased the difficulty of surgical procedures for surgeons. Surgical operations using trocars have little flexibility, as surgeons have to convert mentally the two-dimensional images of the endoscope into three dimensions, and the subtle tactile sensations with the forceps need to be felt to their maximum to be able to hold the friable tissues. The advancement of computer technology, however, has increased the flexibility of endoscopic surgery and provided surgeons with three-dimensional images. In addition, tactile sensation has been aggressively researched, and in the near future we should be able to use tactile feedback for endoscopic surgeries. The integration of computer technology in endoscopic surgery, which demands sophisticated skills from surgeons, was an inevitable result.

The authors performed Asia's first robotic laparoscopic cholecystectomy on March 13, 2000, using the da Vinci<sup>®</sup> Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). A clinical trial was launched in the following year in order to obtain governmental approval for this surgical robot. There were 52 robotic surgeries performed during the clinical trial which ended in 2002, in addition to the self-pay surgeries that were performed using the second da Vinci Surgical System to be installed at Keio University Hospital. Of these 52 robotic surgeries, the authors of this report performed 28 hepato-biliary-pancreatic surgeries, including cholecystectomy, choledocholithotomy, choledochojunostomy and hepatectomy (Table 1). In this article, robotic laparoscopic cholecystectomy and hepatectomy will be reviewed and the future outlook for robotic surgery will be discussed.

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**Table 1** Our experience of robotic hepato-biliary-pancreatic surgery

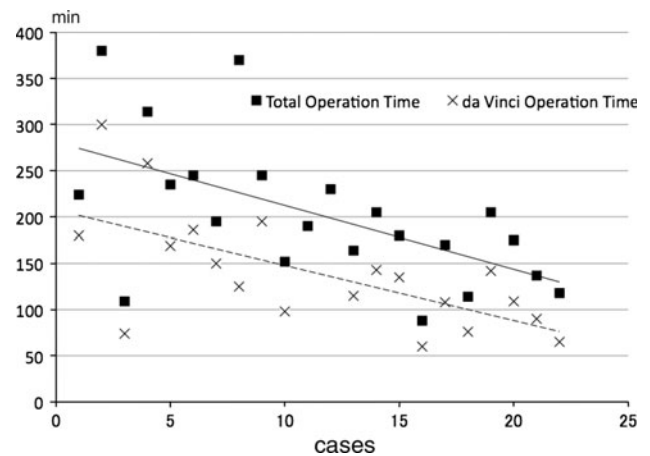
Procedures	Number of cases
Clipless cholecystectomy	22
Choledocholithotomy	1
Choledochojejunostomy	1
Laparoscopic partial hepatectomy	2
Thoracoscopic partial hepatectomy	1
Laparoscopic lateral sectionectomy	1
Total	28

Robotic hepato-biliary-pancreatic surgeries were performed in 28 patients including 22 laparoscopic cholecystectomies and 4 endoscopic hepatectomies

### Robotic laparoscopic cholecystectomy

The clinical trial consisted mainly of using the da Vinci Surgical System to perform laparoscopic cholecystectomies and gather surgical data, such as time used to set up equipment, operation time, anesthetic time, the amount of hemorrhage, and incidence of complications. Although the original goal of the trial was to confirm the safety of the da Vinci system, the use of robots seemed to offer some advantages to the patients. Open cholecystectomy, which pre-dates laparoscopic cholecystectomy, did not use clips and resected the cystic artery and cystic ducts after ligation. There have been reports of clips transferring to the common bile duct and becoming lithic; therefore, clipless cholecystectomy was performed using the da Vinci system. In addition, the gall-bladder bed was closed with continuous serous suture in order to prevent delayed gastric emptying due to adhesion of the duodenal bulb to the dissected surface of the gall-bladder bed. The surgeon attaches a hooked electrocautery scalpel to the right arm of the robot, and grasping forceps to the left arm, and separates Calot's triangle carefully while an assistant lifts up the gall-bladder bed cranially. A hooked electrocautery scalpel has higher operational flexibility, and detachment/separation seems easier than traditional laparoscopic cholecystectomy. This is because separation is possible from any direction, and it is considered closely related to other reports on the precision of surgical operation of the da Vinci system [1–5]. Once Calot's triangle is sufficiently separated, the cystic ducts and cystic arteries are resected after each ligation with absorbable sutures. The gall-bladder is then separated using a hooked electrocautery scalpel, and the gall-bladder bed is closed with continuous serous sutures.

From the 22 cases of clipless cholecystectomy using the da Vinci system, plotting the operation time and the amount of time the da Vinci system was in use revealed that there was an obvious learning curve (Fig. 1). The



**Fig. 1** Correlation between operation time and the number of cases performed. Total operation time and da Vinci operation time were plotted in 22 robotic laparoscopic cholecystectomies. There was an evident learning curve

authors also felt that their learning curves have not yet reached their plateaus and that they still have to get fully accustomed to the operation of the da Vinci system. In laparoscopic cholecystectomy using the da Vinci system reported by Breintenstein and others, the operation time was approximately 50 min, which is comparable to the operation time of traditional laparoscopic cholecystectomy [1]. Of the 22 cases of clipless cholecystectomy that the authors performed with the da Vinci system, there was no report of complications or intraoperative accidents, and intraoperative hemorrhage was negligible just as in traditional laparoscopic cholecystectomy; the da Vinci system, therefore, was considered safe. The use of the da Vinci system, however, lengthened the operation time two- to threefold (mean operation time; 202 min, mean da Vinci operation time; 139 min.), due in part to the effects of learning. It is reasonable to conclude that although potential long-term advantages are clipless surgeries and closure of the gall-bladder bed, short-term surgical results showed that cholecystectomy with the da Vinci system was, unfortunately, inferior to traditional laparoscopic cholecystectomy in terms of operation time. According to the only clinical trial comparing laparoscopic cholecystectomy using the da Vinci system and traditional laparoscopic cholecystectomy, both surgeries were performed with equal safety. Additionally, the surgical results were equivalent to those of traditional laparoscopic cholecystectomy, although the cost for surgery was very much higher when the da Vinci system was used [1]. In a recent meta-analysis, the da Vinci surgical system was found to be associated with a shorter hospital stay following cholecystectomy, although the duration of surgery was longer [2].

## Robotic laparoscopic hepatectomy

We started performing laparoscopic hepatectomy in 1995, although we had only a few cases per year at the beginning [6]. The surgical skills required for hepatectomy seemed difficult to obtain with the endoscope. With laparoscopic hepatectomy, the benefits are small compared to the risks. The benefit comes only from a shorter incision length; therefore, the surgery cannot become preferable unless risk is decreased as much as possible. Since risk is related to the difficulty of surgical operation, we considered whether the da Vinci system would make this surgical operation easier. Not being able to use the left arm was also influenced by the limited use of the straight forceps through the trocar, and the difficulty of making a flat cut surface was considered to be due to the surgical operation defined by the trocar. Therefore, the flexible forceps of the da Vinci system might help resolve the difficulties of these two surgical procedures. In order to control hemorrhage on transecting the hepatic parenchyma, however, the da Vinci system requires connection to surgical equipment with high hemostatic ability. We requested Intuitive Surgical to install the hemostatic equipment, and bipolar hemostatic forceps and SonoSurg<sup>TM</sup> manufactured by Olympus were attached.

Another problem with laparoscopic hepatectomy is that it is difficult to obtain sufficient surgical margins on the bottom of the tumor due to the problem of operating the forceps when partially resecting the superficial tumor [7]. Therefore, the da Vinci system was applied to thoracoscopic partial hepatectomy through the diaphragm on a hepatocellular carcinoma (HCC) located in segment 8. The first thoracoscopic partial hepatectomy was satisfactory without major hemorrhage and had a good surgical margin on the bottom of the tumor, since operation of the forceps was better and SonoSurg and bipolar hemostatic forceps had high hemostatic abilities. After having performed two partial resections of the lateral sector, we have accomplished pure laparoscopic anatomical lateral sectionectomy for HCC located in the lateral sector using the da Vinci system (Fig. 2). This surgery was reported with a video presentation at the annual meeting of the American Hepato-Pancreato-Biliary Association in Washington, DC, USA in 2004 and was considered to be the first laparoscopic hepatectomy with the da Vinci system in the world. Pure laparoscopic anatomical lateral sectionectomy using the da Vinci system was performed by first resecting the hepatic parenchyma with SonoSurg and bipolar hemostatic forceps to expose the umbilical parts of the portal vein from Glisson's pedicles, and then resecting each carefully after ligation (Figs. 3, 4, 5, 6). After ligation and resection of S3 Glisson's pedicles, the hepatic parenchyma was carefully transected with hemostatic instruments to expose S2 Glisson's pedicles and the root of the left hepatic vein (Fig. 7). There are no major

intrahepatic vessels up to approximately 1 cm below the liver surface; therefore, transection of the hepatic parenchyma can be safely performed without hemorrhage using SonoSurg and bipolar hemostatic forceps. With traditional laparoscopic hepatectomy of the lateral sector, S2 Glisson's pedicles and the root of the left hepatic vein are ligated together with automatic stapling instruments before resection [8]. That laparoscopic hepatectomy also used the da Vinci system, and therefore ligation of the Glisson's pedicles and the left hepatic vein as well as continuous suture was possible. In that case, however, it was the first assistant who used the stapler, while we ligated S2 Glisson's pedicles and the root of the left hepatic vein separately with the stapler, and resected both together (Figs. 7, 8). The resected lateral sector was then placed in a plastic bag and removed through the small incision on the pubis.

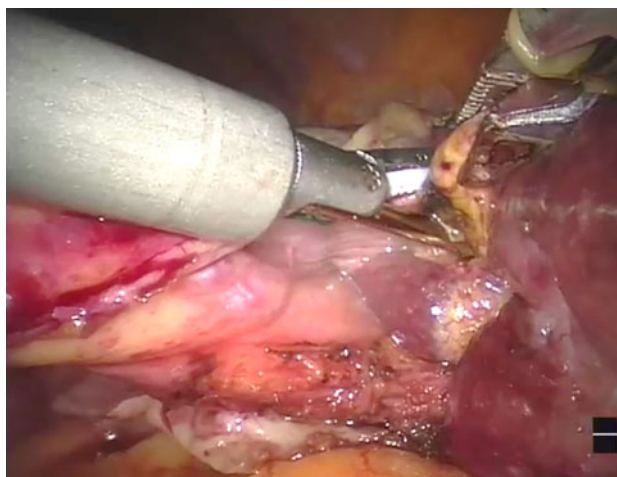
The 4 cases of endoscopic hepatectomy using the da Vinci system were completed easily and safely without major hemorrhage, although they took longer than traditional endoscopic hepatectomy (Table 2). As expected beforehand, flexible forceps made the operation on the dissected surface of the hepatic parenchyma much easier and the left arm was used almost freely. Using articulated forceps medial to the trocar made the surgical operation less problematic than traditional laparoscopic hepatectomy. SonoSurg and bipolar hemostatic forceps have high hemostatic abilities, and endoscopic hepatectomy using the da Vinci system seemed useful for these 4 cases of partial resection or resection of the lateral sector. The da Vinci system, which has articulated forceps enabling precise operations, performs superbly in a relatively small surgical area; therefore, it might be suitable for a hepatectomy that is surrounded by the ribs. It is preferable, however, for other surgeries that require transection of the deeper hepatic parenchyma, such as hepatic lobectomy or sectionectomy, to utilize instruments that can expose intrahepatic vessels, such as the CUSA<sup>TM</sup> Ultrasonic Aspiration System (Valleylab, Boulder, CO, USA), as well as forceps to hold the liver, and equipment to cleanse and irrigate. Based on the literature search, there are still only a few reports on laparoscopic hepatectomy using the da Vinci system, including one with 3 cases by Yonsei University in South Korea [9], one with 7 cases from Italy of simultaneous resection of colon cancer that had metastasized to the liver [10], one with 13 cases from China [11], and one with 70 cases from USA [12].

## Future outlook for robotic surgeries

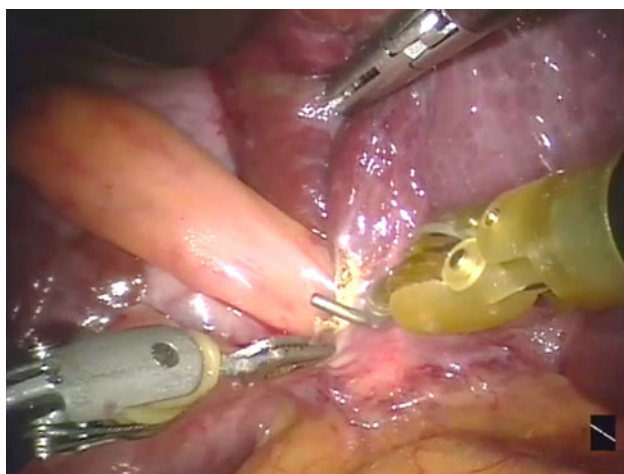
Even from the authors' limited experience, it was clear that the da Vinci system made precise separation and hemostasis easier. It magnifies the view as in microsurgery, and thus would be very useful for surgeries that require



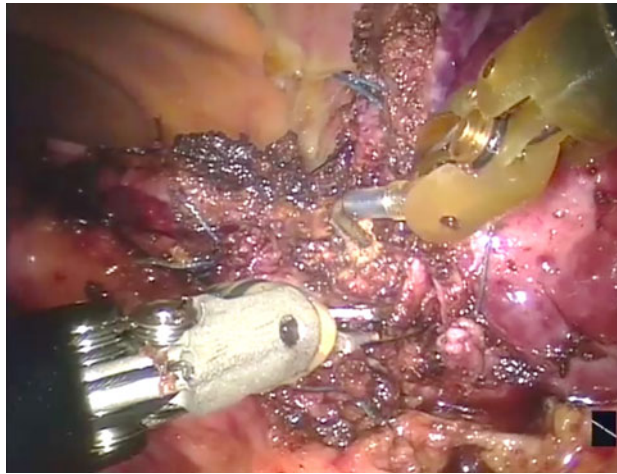
**Fig. 2** HCC located in lateral sector of the cirrhotic liver. A conventional laparoscope was placed in order to insert da Vinci trocars and to perform intraoperative ultrasonography



**Fig. 4** Parenchymal transection with SonoSurg and bipolar hemostatic forceps. The operator used SonoSurg with the left hand and bipolar hemostatic forceps with the right hand



**Fig. 3** Preparation of umbilical portal vein. The hepatic parenchyma was carefully transected with a hooked articulated monopolar electrocautery scalpel



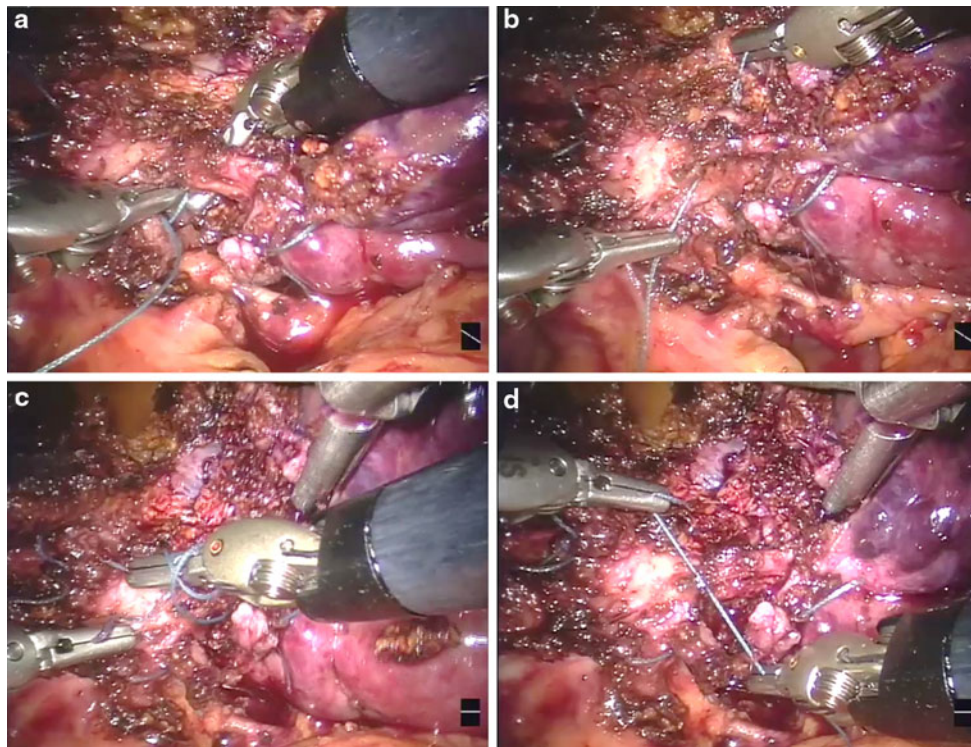
**Fig. 5** Preparation of the Glisson's pedicles with a hooked electrocautery scalpel and bipolar hemostatic forceps. Precise preparation is possible from any direction with articulated electrocautery scalpel and forceps

thorough dissection of the lymph nodes around vessels. However, it does not seem to provide any direct benefit to patients when it comes to laparoscopic cholecystectomy, for which the traditional technique provides sufficient benefit with its minimally invasive procedure. On the contrary, the da Vinci system is not advantageous since it increases cost without offering additional medical benefits to patients. With this technique, however, even less experienced surgeons can intuitively separate the Calot's triangle or surroundings of the gall-bladder, which is highly inflammatory; therefore, it might provide some advantages by improving surgery safety. A comparison study of laparoscopic cholecystectomy using the da Vinci system showed that less experienced surgeons completed

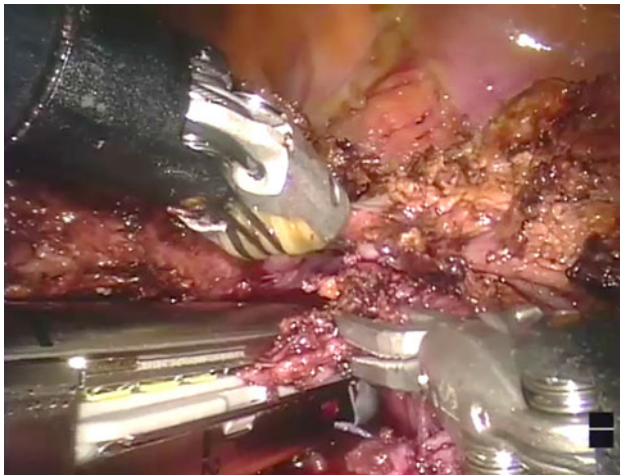
laparoscopic cholecystectomy in the same amount of time as more experienced surgeons [1]. As can be easily imagined, less experienced surgeons required more time to complete traditional laparoscopic cholecystectomy.

One report suggests that a three-dimensional view will help supplement the lack of tactile sensation [13]. A three-dimensional view is not necessary for experienced surgeons since they can effortlessly convert two-dimensional images to three in the brain. However, it also reports that when experienced surgeons have more surgeries with three-dimensional images, they are able to see more detailed anatomy and improve their surgical operation. The authors also had experience with ligation using the da Vinci system. There is no tactile sensation with the da





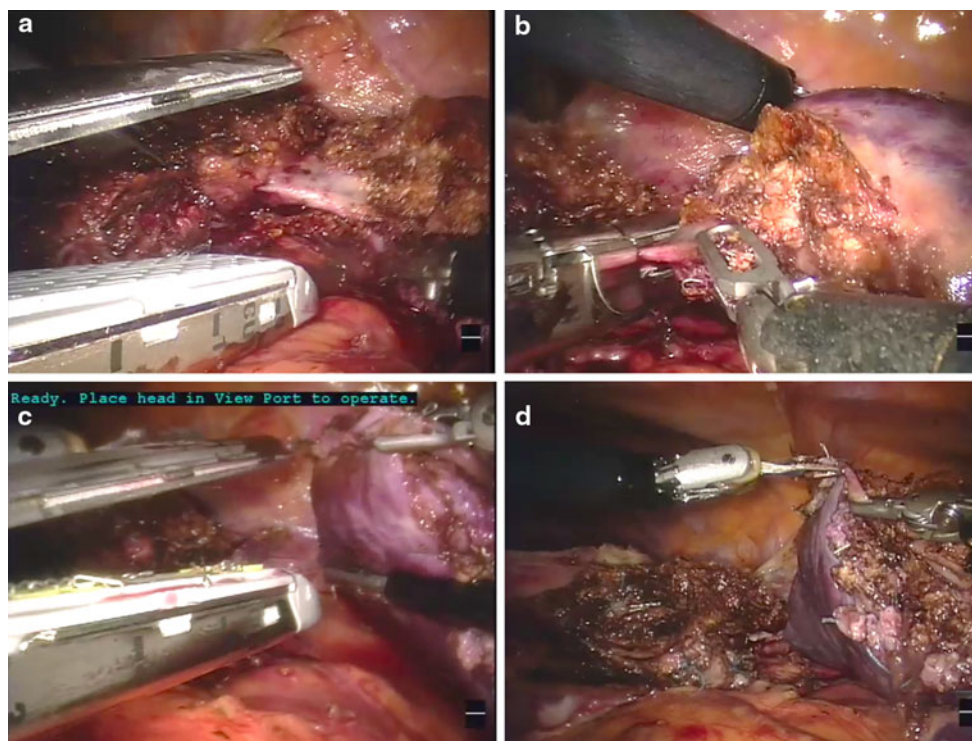
**Fig. 6** Ligation of the Glisson's pedicles to segment 3. Ligation is easy and smooth with articulated forceps



**Fig. 7** Stapling the Glisson's pedicles to segment 2 while grasping the left hepatic vein. The Glisson's pedicles to segment 2 and the root of left hepatic vein were grasped and divided separately

Vinci system, and we therefore found it hard to feel proper ligation and often broke sutures accidentally. Once we experienced ligation with the three-dimensional view, however, it allowed us to see sutures stretching too thin before breaking and tactile sensation naturally developed in the mind, and we no longer broke sutures prematurely. Three-dimensional images provide more information than two-dimensional images, and that information most likely helps improve surgical techniques.

One type of hepato-biliary-pancreatic surgery in which the da Vinci system will be the most beneficial is pancreatoduodenectomy. It will work well for dissection of the lymph nodes around the vessels and for pancreatojejunostomy, and will help reconstruct digestive tracts safely under pure laparoscopic procedure. Among the hepato-biliary-pancreatic surgeries that the authors have performed with the da Vinci system, surgical skills evidently improved with regard to suture ligation for closure of choledochotomy and choledochojunostomy. A certain efficacy was also observed in laparoscopic hepatectomy; however, the da Vinci system does not seem greatly beneficial considering the extensive setup of the equipment and increased cost. Any surgeons who are experienced in endoscopic ligation and hepatectomy can obtain surgical skills comparable to the da Vinci system. The da Vinci system should provide advantages to surgeons who are less experienced in these surgical procedures. As a result, the surgeon's experience and the cost of the da Vinci system should be equivalent, and if charges for surgery rise with the use of the da Vinci system, they should rise based on the experience of the surgeon as well. Nevertheless, it would still be beneficial if surgical skills are improved to minimize operation time even with the extra time to set up the system. If health insurance systems were to add surgical charges based on operation time or the time that surgical suites are occupied, the da



**Fig. 8** Stapling the left hepatic vein at the end of resection. The first assistant used an automatic stapler by the patient side and the resected lateral sector was then placed in a plastic bag and removed

**Table 2** Our experience of robotic endoscopic hepatectomy

Case	Disease	Procedure	Operation time (min)	Blood loss	Complications
1	HCC (S2)	Laparoscopic partial hepatectomy	323	Negligible	No
2	Hemangioma (S3)	Laparoscopic partial hepatectomy	160	Negligible	No
3	HCC (S8)	Thoracoscopic partial hepatectomy	235	Negligible	No
4	HCC (S2)	Laparoscopic lateral sectionectomy	370	Negligible	No

Four cases of robotic endoscopic hepatectomy were completed purely endoscopically with negligible blood loss and no complications  
HCC hepatocellular carcinoma

Vinci system would be beneficial for those surgeries that decrease in operation time.

The da Vinci system is an infant and is only about to start walking. As technology advances, if tactile sensation can be learned and equipment set-up can be completed more easily, these technologies will be helpful for patients as well as surgeons.

## Conclusion

The use of the da Vinci<sup>®</sup> system in laparoscopic cholecystectomy and hepatectomy was discussed. Although robotic surgery is a field with guaranteed potential for growth, some areas still need to be resolved from the

perspectives of mechanical engineering technology and medical economics.

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