

# APPLICATION OF DA VINCI SURGICAL ROBOTIC SYSTEM IN HEPATOBILIARY SURGERY

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**ABSTRACT** The development of minimally invasive surgery has brought a revolutionary change to surgery techniques, and endoscopic surgical robots, especially Da Vinci robotic surgical system, has further broadened the scope of minimally invasive surgery, which has been applied in a variety of surgical fields including hepatobiliary surgery. Today, the application of Da Vinci surgical robot can cover most of the operations in hepatobiliary surgery which has proved to be safe and practical. What's more, many clinical studies in recent years have shown that Da Vinci surgical system is superior to traditional laparoscopy. This paper summarises the advantage and disadvantage of Da Vinci surgical system and outlines the current status of and future perspectives on the robot-assisted hepatobiliary surgery based on the cases reports in recent years of the application of Da Vinci surgical robot.

**KEYWORDS:** Da Vinci Surgical Robot; Hepatobiliary Surgery; Minimally invasive surgery

## Introduction

In the 1980s, surgical operation entered the era of "Minitrauma" through the application of laparoscopy. At present, however, the minimally invasive technique is restricted to be expanded to more complicated surgical operations due to a deficiency in stereoscopic two-dimensional images, limited manipulation space and other limitations of conventional laparoscopy. To overcome the deficiencies of laparoscopy, surgical robot emerged in response to the proper time and conditions and was rapidly applied in clinical applications. Its entirely new concept and effects are known as a revolution in the history of surgical. It has gradually become the primary trend of minimally invasive surgery. Da Vinci robot-assisted surgical system is the most advanced robot-assisted surgical system in the world at present. It was

developed by Intuitive Surgical and was launched to the market [1] after Food and Drug Administration (FDA) authentication in 2000. It has been applied in a variety of surgical fields including hepatobiliary surgery.

## 1. Overview of Da Vinci

### 1.1 Structure, the latest technology and application status of Da Vinci.

In fact, Da Vinci is a kind of "endoscopic surgical instrument control system". It is mainly composed of three sub-systems, namely surgeon console, patient cart and 3D vision chart. During the surgery process, the vision chart will undoubtedly reflect the visual operative field on the console. Thus the surgeons can carry out the surgery on the console. The system will transmit in vitro actions of the surgeon to the robot arm, and transfer to surgical instrument's action inside the patient body thus to complete the surgery [1]. At present, the one mainly applied on clinical applications is the third generation of Da Vinci (Da Vinci Si); on April 1, 2014, the fourth generation of Da Vinci (Da Vinci Xi) with more clear visual operative field and flexible operation passed FDA authentication and was put into service. Moreover, micro-Doppler technology, blood vessels surveying and mapping technology, water moving from the blood vessels, micro melting technology (CO2 laser technology), laser scanning confocal microscopy and other advanced auxiliary microscopy

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techniques have been developing rapidly [2]. According to the latest data of Intuitive Surgical, until Dec. 31, 2013, the global installed capacity of Da Vinci is 2,966, including 2,083 in the United States, 476 in Europe, 407 in Asia and other areas.

### 1.2 Overview of preponderances and deficiencies

Compared to laparotomy and traditional laparoscopic surgery, Da Vinci has many preponderances [1-3, 14, 21]:

1. Advanced imaging technology" The application of high definition 3D camera and imaging device achieved real 3D effects of surgery field. It can enlarge the surgery field to 10 20 times and can zoom in and zoom out arbitrarily in this range. By applying fluorescence imaging technique and based on different preferendum of organ tissue to dye, judging ability differing from the general macroscopic observation can be obtained; micro-Doppler technology can distinguish blood vessels with the minimum diameter of 1mm; confocal microtechnique can form images on cellular level etc.
2. Innovative wrist: The robot arm can imitate functions of man's hands. It has seven DOFs and can rotate 360 with tiny joints. Laser positioning can automatically calculate the optimal operation state of robot arm; the motion direction of motion arm is consistent with operating direction of the operator with hand-eye coordination; the surgeon can control 2-3 motion arms among the 3 5 motion arms and can switch at any time; while replacing the instrument, due to the memory function of the system, it can automatically replace the instrument and arrive the original position thus to assist in completing sophisticated all kinds of difficult surgeries.
3. Sophisticated and stable operation: The system can automatically filter out physical vibration, exclude adverse effects caused by hand trembling of the surgeon to improve controllability, accuracy and stability.
4. Small-size trauma, few haemorrhage and rapid recovery: Sophisticated and stable operation can reduce surgical trauma and blood loss thus to reduce the occurrence of perioperative complications and complications thus to reduce surgical pain, decrease the use of postoperative painkillers and shorten the HLOS. It can improve ward bed turnover rate of the hospital to realise the possibility of "Day surgery".
5. Easy to master and study: Da Vinci supports double consoles for simultaneous operation of two surgeons. It can optimise certain operation steps to improve the efficiency and save operation time; it can be used by well-experienced Robodoc to teach new Robodoc simultaneously; also, MIMIC and other companies developed Da Vinci surgical simulation trainer to be used on simulation of the learning process, rectify faulty operation and save the costs.
6. Expand application scope of the surgery: It can breakthrough the forbidden area of certain conventional surgeries and broaden the development of the age appropriately; for obese patients and patients with severe abdominal adhesion, the surgical field is over better than that of laparotomy surgery.

7. Manpower saving and more comfort surgery process: Reduce the surgeries participating in the surgery. The surgeons do not need to be crowded around the operating table; the surgeons can sit next to the console to reduce fatigue and concentrated energy. Generally speaking, Da Vinci has broken through "the four limits", namely limits to human eyes, hands, minimally invasive and labour. It has brought revolutionary changes for surgery.

At present, Da Vinci is still under development phase and deficiencies [1, 9, 20, 21]:

1. High cost and expensive surgery expense.
2. The development of pseudo tactile devices is still not mature. The fingers of surgeon have no tactile perception, and can hardly judge texture, elasticity, the presence of pulsation and other properties of tissues accurately.
3. The volume is huge. It requires specialised operating and maintenance personnel with the long preoperative installation.
4. Longer operating time prolonged anaesthesia.
5. Security: Wireless communication between the intraoperative console and the instrument is subject to disturbance; it is reported that robot arm halt, arms in human tissue loosening, damage to human body healthy organs and patients with a current tap. (Well-known freelancer Timothy Lenoir believed that: The application of robot will lose the creativeness of surgeon during the surgery process. The mainstream does not identify it.)

### 1. 2. Application of Da Vinci in the operation of hepatobiliary surgery.

Since from Da Vinci being applied to hepatobiliary surgery, it has been developing rapidly. Currently, it has covered most of the operations of hepatobiliary surgery.

#### 2.1 Hepatic surgery

The liver has complicated, various anatomical structure and rich blood supply. Hepatectomy is one of the principal methods for liver benign of a malignant tumour and severe hepatolith. The abdominal incisional of open hepatectomy is long. For a malignant tumour, it has severe extrusion and traction to the liver which may cause the tumour cell entering blood vessels, postoperative relapse or distant metastasis in short time. In consequence, laparoscopic hepatectomy is a dream of liver surgeon [3]. However, laparoscopic hepatectomy is a surgery with great difficulty and high risk. It only has been carried out in few specialised medical centres. The occurrence of Da Vinci has significantly dragged precise liver resection under minimally invasive. There are many case reports on hepatectomy with Da Vinci (Table 1). The application of Da Vinci on hepatectomy is safe and feasible with advantages such as low open abdominal rate, few hemorrhage during operation, small trauma, rapid recovery and short HLOS et. which have increased the hepatectomy scope (such as focus on rear-upper section of liver), and reflected the concept of precise liver resection better [3]. Also, hepatectomy under the robot-assisted under the Da Vinci surgical system increasingly become mature which has laid a foundation for liver transplantation under the assistance of the

**Table 1** The case reports on hepatectomy with Da Vinci recently.

Author	Operation Method	No. of patients (n)*	OR time (min)	Blood Loss (ml)	Length of stay (days)	Complication
Giulianotti [4][5]	Right Hemihepatectomy	24 (1)	337 (240-480)	457 (100-2000)	9 (3-23)	6
Ji [6]	Hemihepatectomy	9	338 (150-720)	280	6.7	1
Lai [8]	Hemihepatectomy	10	364.8±98.1	407(100-600)	6.7±3.5	3
Choi [7]	Right Hemihepatectomy	6 (1)	724 (648-812)	629 (100-1500)	18.7 (9-46)	2
	Left Hemihepatectomy	14 (1)	518 (315-763)	328 (150-900)	11.5 (7-32)	5
Gu [9]	Segmental Hepatectomy	8	199.6±110.5	703.3±1260.7	11.0±3.6	0
	Hemihepatectomy	1				
	Hepatectomy	6	130-260		Malignant	
Zhou [10]	Right anterior lobe Hepatectomy	3	170-260	NR	11.9±3.2	1
	Anatomical Hepatectomy	3(1)	410-650			
	Left Hemihepatectomy	3	280-340		Benign 9.9±7.1	

\* the cases of conversion to laparotomy.

robot. In 2011, Giulianotti et al. of the United States completed the world's first living right liver transplantation under the assistance of Da Vinci system. In March 2013, Italy was the first country applying Da Vinci on completing specific part of liver transplantation alone in the world. On Feb. 27, 2014, Zhongshan Hospital affiliated to Fudan University completed the first adults-children liver transplantation under the assistance of Da Vinci surgical robot in Asia. It is visible that left liver lobe has been removed from hepatic surgery initially to carry out right liver resection, living donor liver transplantation and donor liver insection etc.

#### Operation of biliary tract.

Laparoscopic cholecystectomy has become mature. However, for patients with chronic atrophic cholecystolithiasis, sequential choledocholithiasis with the history of epigastric operation, obesity patients with gallbladder carcinoma. It is challenging to perform cholecystectomy under conventional laparoscopy. For malignant biliary diseases (such as gallbladder carcinoma, hilar cholangiocarcinoma, intrahepatic cholangiocarcinoma etc.), the application of conventional laparoscopy has been restricted significantly due to the complexity of traditional laparoscopy. Da Vinci can identify the convergence of auditory tube and common bile duct. It can observe the capillaries in a cystic artery or even the gallbladder film layer. The application of "fluorescence imaging technique" can make the anatomical structure more clearly. Combining with the tremendous flexible robotic arm, the operative difficulties have been reduced. Another essential surgical technique of biliary tract surgery is hepatic duct jejunum Roux-en-Y. Applying common bile duct jejunum, Roux-en-Y anastomose under the assistance of robot is simple which is propitious to excellent bile intestinal anastomosis in the complicated operation of biliary tract [22]. There are many case reports on biliary operation with Da Vinci (Table 2). Applying diversified benign and malignant disease surgeries under the assistance of Da Vinci surgical robot is safe, reliable and efficient.

#### Pancreatic operation

Pancreatic operation has been universally recognized as one of the most challenging problems to be overcome in the field of minimally invasive surgical field:

1. Pancreaticoduodenectomy: Excision extension covers certain pancreas, adjacent duodenum, bottom end of bile duct, upper part of the stomach and jejunum, as well as common bile duct, pancreatic duct, stomach and jejunum anastomosis. Since Gagner applied the first case of laparoscope pancreaticoduodenectomy in 1994, pancreaticoduodenectomy developed in the minimally invasive field due to its high open abdominal rate, tedious process, long operation time and high postoperative complications occurrence rate.
2. Pancreatic middle section excision: Lesions is to be eradicated with specific pancreas reserved. Conventional laparoscopy is very difficult with few reports.
3. Distal pancreatectomy: For patients with clear pancreatic tail lesions border, without involvement on splenic arteriovenous and benign lesion, spleen-preserving should be taken into consideration. Spleen distal pancreatectomy of conventional laparoscopy technology is prone to causing massive haemorrhage as well as open abdominal surgery.
4. Beger surgery: It is required to eradicate the pancreas head, reserve and protect blood supply for common bile duct and duodenum to avoid postoperative complications, high difficulty and requirements.

Da Vinci makes some steps of pancreas surgery more easy under minimally invasive environment, mainly including separation of the pancreas, lymph node dissection, free excision of hook, free blood vessel, protection and selective ligation to rebuild the digestive tract (pancreas and intestine, gallbladder-intestine and gastrointestinal anastomosis) etc.. There are many reports of pancreatic operation with Da Vinci (Table 3). Applying pancreatic operation under the assistance of Da Vinci is safe and feasible with advantages such as intraoperative bleeding, short postoperative recovery time and. Boggi etc. completed pancreas

**Table 2** The case reports on operation of biliary tract with Da Vinci recently.

Author	Operation Method	No. of patients	OR time (min)	Blood Loss (ml)	Length of stay (days)	Complication
Ayloo [11]	Cholecystectomy	179	95.7 (37-268)		0.9 (0.2-8.2)	6
Sudan [12]	Biliopancreatic diversion with duodenal switch (BPDDS)	59	306±80	NR	4.6±4.3	5
Gu [9]	Cholecystectomy	7	212.9±64.2	257.1±127.2	6.8±2.5	1
Zhou [10]	Resection of extrahepatic duct & gallbladder bridge type biliary revascularization	3	390-460			
	Resection of extrahepatic duct & biliary-enteric Roux-en-Y anastomosis	14	350-510			
	Resection of extrahepatic duct & revascularization of hepatic portal bile duct	1	350			
	Partial resection of cholangiocarcinoma & external drainage of intrahepatic bile duct	5	190-290			
	Partial resection of cholangiocarcinoma & Y-internal drainage of hepatic portal	10	210-280			
	Resection of cholangiocarcinoma & biliary-enteric Roux-en-Y anastomosis	1	330		Malignant	
	Resection of gallbladder carcinoma & biliary-enteric Roux-en-Y anastomosis	2	410-490	NR	11.9±5.1	1
	Cholecystectomy	9	170-430		Benign 9.7±7.4	
	Cholecystectomy & external drainage of intrahepatic bile duct	1	220			
	Cholecystectomy & Y-internal drainage of hepatic portal	4	210-280			
	Resection of intrahepatic bile duct cystadenoma & hilar cholangiocarcinoma and hepatic hilar plasty	1	300			
	Cholecystectomy & T-tube drainage	2	210-250			
	Calculus remove from intrahepatic bile duct & drainage with T-tube	9	260-360			
	Choledocholithotomy	21	120-370			
	Choledochotomy	1	280			
	Plastic operation of choledochal stricture	1	160			
	Biliary tract Reconstruction	3	180-300			

**Table 3** My caption

Author	Operation Method	No. of patients (n)*	OR time (min)	Blood Loss (ml)	Length of stay (days)	Complication
Giulianotti[13]	Pancreaticoduodenectomy	60 (13)				
	Distal splenopancreatectomy	23				
	Distal pancreatectomy	23	Italy:312(55-660) USA:351(73-630)	Italy:261(100-600) USA:342(5-2000)	Italy:21.8(6-85) USA:9.3(3-30)	35
	Middle pancreatectomy	3				
	Total pancreatectomy	1				
	Pancreatic enucleation	3				
	Others	21				
Kang[14,15]	Distal pancreatectomy	20	348.7±121.8	372.0±341.5	7.1±2.2	2
	Middle pancreatectomy	5	432.0±65.7	275.0±221.7	14.6±7.7	1
Narula[16]	Pancreaticoduodenectomy	8 (3)	420(360-510)	NR	9.6	0
Waters[17]	Distal pancreatectomy	17 (2)	298(191-418)	279(20-1200)	3.8(2-6)	3
Zeh[18]	Pancreaticoduodenectomy	50 (8)	568(536-629)	350(150-625)	10(8-13)	28
	Pancreaticoduodenectomy	31 (1)	450.4±102.1	506.5±266.5	34.4±7.8	19
	Beger's procedure	7 (1)	284.2±35.8	321.7±244.2	26.3±7.7	4
Gu[9]	Middle pancreatectomy	16	215.6±45.7	145.6±118.4	22.7±8.0	10
	Distal pancreatectomy	42 (1)	161.0±68.7	278.0±331.5	20.9±10.9	16
	Pancreatic enucleation	6	116.7±37.2	61.7±69.1	27.8±11.8	4
Zhou[10]	Pancreaticoduodenectomy	16 (4)	420-870			
	Distal splenopancreatectomy	3	280-360			
	Distal pancreatectomy	3	270-340	NR	Malignant 13.1±6.7 Benign 12.9±4.5	2
	Middle pancreatectomy	1 (1)	410			
	Enucleation of pancreatic insulinoma	1	260			

\* the cases of conversion to laparotomy.

transplantation under the assistance of Da Vinci for the first time to make Da Vinci surgical covering all surgical methods of pancreatic operation. However, it is not hard to see that the surgery has less transfer laparotomy rate, operation time apparent delay, postoperative complications probability and equal probability. Thus the patients shall select Da Vinci surgical robot with cautious and perform sufficient evaluation [9]. Therefore, the application effects of Da Vinci surgical robot on pancreatic operation application has been consistently improving. Also, a large number of clinical randomised controlled researchers have to be performed simultaneously.

### Splenic operations

Since from 1991 the first case of laparoscopic splenectomy being reported by Delaitre et al. (laparoscopic splenectomy, LS), LS has been extensively applied in the clinic. Traditional LS has certain limitations: (1) Traditional LC has potential risks on missing accessory spleen; (2) Big spleen increased LS difficulties etc.. Giulianotti[19] researchers believed that Da Vinci surgical robot has more preponderances due to better visual field and more accurate operation which is safe and feasible; In case of high LC risks, applying splenectomy with Da Vinci surgical robot is beneficial. The researchers of Gelmini R et al. [20] and Maeso S et al. [21] show that compared with traditional LS, splenectomy with Da Vinci surgical robot has no significant difference

regarding transfer open abdominal rate, drainage tube removal, food ingestion and incidence rate of postoperative complications. However, the operation time is long, and the surgery expense is higher. Thus, there is no significant clinical benefit for spleen removal with a Da Vinci surgical robot. Traditional LS is a golden standard for clinical splenectomy. Consequently, a large number of clinical researchers are required to demonstrate which surgery method has more superiority.

### Conclusion

Due to complicated anatomical structure, particular anatomical position, conventional laparoscopic instrument and limitation of the technology, hepatic surgery minimally invasive has encountered bottlenecks. Da Vinci surgical robot has broken through the existing bottlenecks of laparoscopy and expanded the application of hepatobiliary surgery in the minimally invasive field. Da Vinci surgical robot is still at the stage of development. Especially in China, there is few clinical record experience accumulated lacking large sample controlled clinical trial. It can not substitute for conventional laparoscopy and laparotomy surgery. However, it can be foreseen that with continuous improvement and continuous mature of Da Vinci surgical robot, the existing deficiencies will be conquered consistently to promote the minimally invasive surgical technique developing to be more difficult

and complicated. Also, Da Vinci surgical robot provides conditions for remote surgery. In 2011, Marescaux cooperated with a work team of IRCAD and completed a surgical operation across the Atlantic Ocean successfully for the first time by applying asynchronous transfer mode and remote control system of Zeus under an average delay of 155ms. It has become a milestone in the global surgical field. The development of Da Vinci surgical robot will accelerate the progress of telemedicine and provide a new platform for mutual aid, communication and cooperation. Also, researchers on surgical robots which can complete surgical operations independently have been promoted to agenda. It is believed that with the development of technology, surgical robot can achieve simple surgery relatively in the future.

## Authors' Statements

### Competing Interests

Written informed consent was obtained from the patient for publication of this case report and any accompanying images.

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