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Conventional laparoscopic and robot-assisted spleen-preserving pancreatectomy: does da Vinci have clinical advantages?

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Abstract
Background Function-preserving minimally invasive pancreatectomy is thought to be an ideal approach for pancreatic benign and borderline malignant lesions requiring pancreatectomy. However, it is not that easy to accomplish this goal with the conventional laparoscopic approach. It requires extensive surgeon experience and learned techniques. A robot surgical system was recently introduced to overcome these limitations and it may potentially provide precise and safe laparoscopic surgery.
Methods Between March 2006 and July 2010, a total of 45 patients underwent laparoscopic or robot-assisted pancreatectomy performed by a single pancreatic surgeon to preserve the spleen. Twenty-five patients underwent the conventional laparoscopic approach (Lap group) and the other 20 patients underwent robot-assisted surgery (Robot group). The perioperative clinicopathologic variables (age, gender, length of resected pancreas, tumor size, tumor location, amount of bleeding, operation time, length of hospital stay, complications, mortality, and cost) were compared between the two groups, as well as the spleen preservation rate.
Results Younger patients preferred robot-assisted surgery to conventional laparoscopic surgery (44.5 ± 15.9 vs. 56.7 ± 13.9 years, $p = 0.010$), and the mean operation time was longer in the Robot group (258.2 ± 118.6 vs. 348.7 ± 121.8 min, $p = 0.016$). The spleen-preserving rate of the Robot group was considerably superior to that of the Lap group (fail/success, 9/16 vs. 1/19, $p = 0.027$). However, robot surgery cost the patients about USD 8,300 (USD 8,304.8 ± 870.0), which was more than twice the amount for the Lap group (USD 3,861.7 ± 1,724.3). There were no significant differences in other clinicopathologic variables.
Conclusion Robot-assisted pancreatic surgery could provide an increased chance for spleen preservation in spite of higher cost and longer operation time. More experiences are needed to specifically address the role of robot surgery in the advanced laparoscopic era.

Keywords Robot · da Vinci · Laparoscopic · Spleen-preserving · Pancreatectomy

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Introduction

According to accumulated clinical experiences of laparoscopic surgery, it seems that laparoscopic distal pancreatectomy is accepted as a safe and effective modality for treating benign and borderline malignant tumors of the pancreas [1–5]. In the past, when performing distal pancreatectomy, the spleen was removed simultaneously because it

made the procedure simpler since the spleen is close to the distal pancreas. However, with more understanding of the immunological role of the spleen [6–9], many surgeons try to preserve the spleen when the distal part of the pancreas needs to be removed. A patient's quality of life needs to be considered when choosing the surgical approach because long-term survival is highly expected in those patients. Therefore, minimally invasive function-preserving surgery is thought to be an optimal approach.

The surgical procedure for laparoscopic spleen-preserving distal pancreatectomy must require fine and delicate laparoscopic techniques. However, the ligation and division of individual small tributary splenic vessels is not that easy. Even a small break in the branch of splenic vessels may provoke a large amount of intraoperative bleeding, which can potentially obscure the surgical field and prevent the surgeon from conserving both splenic artery and vein for spleen-preserving distal pancreatectomy. This effort may sometimes end up with the inevitable removal of both the spleen and distal pancreas due to uncontrolled bleeding from splenic vessels. A simpler technique with segmental resection of splenic vessels for spleen-preserving distal pancreatectomy has also been introduced [10]; however, the risk of spleen-associated morbidities and potential development of perigastric varices need to be considered. Although much effort has been made to preserve the spleen, the overall spleen preservation rate in laparoscopic distal pancreatectomy is reported to be approximately 40–80% [1, 3, 5, 11–13].

With the development of computer technology, a surgical robotic system has been introduced to compensate for the disadvantages of conventional laparoscopic surgery such as a two-dimensional surgical field, limited range of motion, fulcrum effect, and augmented tremor of effector instrument [14–16]. Therefore, "theoretically" a robotic surgery system may be able to provide safer and more effective laparoscopic surgical procedures. Experience with robot-assisted surgery in the field of general surgery is growing. However, most reports are about the feasibility of robotic surgery and surgeons' feelings or prospects based on their experiences with robot-assisted surgery. Until now, it has been thought that we do not have enough objective data to show the clinical advantage of robot-assisted surgery over conventional laparoscopic surgery.

This clinical research is an interim result of our clinical experiences. We retrospectively evaluated the perioperative surgical outcomes of conventional laparoscopic and robot-assisted distal pancreatectomy for benign and borderline malignant tumors of the pancreas. We wanted to know if there is any clinical advantage to robot-assisted distal pancreatectomy in terms of spleen preservation by comparing this technique with conventional laparoscopic distal pancreatectomy.

Materials and methods

This study was approved by the Yonsei University Institutional Review Board. We reviewed the medical records from January 2006 to July 2010 of patients who underwent laparoscopic or robot-assisted distal pancreatectomy for benign and borderline malignant tumors of the pancreas with the intent to preserve the spleen. Robot-assisted central pancreatectomy is also thought to be another type of spleen-preserving procedure but we excluded three such cases from this study.

The robot surgical system (da Vinci) was first introduced to our institution in 2005 [17], and the first robot-assisted laparoscopic distal pancreatectomy was performed in September 2007 (data not shown). This study is based on retrospective observation of our recent experiences with laparoscopic and robot-assisted distal pancreatectomy. Surgical indications are basically the same for both approaches. Patients with growing benign-looking or suspected borderline malignant lesions in the left side of the pancreas were all informed of their disease and the general characteristics of each surgical approach [conventional laparoscopic (Lap group) and robot-assisted distal pancreatectomy (Robot group)], including expected complications, mortality, merits, demerits, and cost. After understanding the given information, patients chose which surgical approach to undergo.

The clinicopathologic variables were collected from the retrospective review of the medical records and were compared between the two groups. Continuous variables were expressed as the mean ± standard deviation and categorical variables were expressed as frequency (percent). We created a new variable called "cumulative spleen-preserving rate (CSPR)" to compare the ability of the spleen-preserving rate and to estimate the quality of the two different surgical systems in preserving the spleen. These variables were defined as the overall spleen-preserving rate in later cases for spleen-preserving distal pancreatectomy. The differences were evaluated using χ^2 (Fisher's exact test) and the Mann–Whitney U test. Time-dependent clinical changes of the cumulative spleen-preserving rate and operation time were analyzed in linear estimation regression analysis. The variables were considered significant when $p < 0.05$.

Results

Comparison between conventional laparoscopic (Lap) and robot-assisted (Robot) distal pancreatectomy with intent for spleen preservation

Between March 2006 and July 2010, laparoscopic or robot-assisted distal pancreatectomy with intent to preserve the

spleen was performed on 45 patients by a single pancreatic surgeon. When comparing the perioperative outcomes between the Lap and Robot groups, we found that younger patients preferred the new emerging technique of robot-assisted surgery to conventional laparoscopic surgery (44.5 ± 15.9 vs. 56.7 ± 13.9 years, $p = 0.010$), and the mean operation time was longer in the Robot group (258.2 ± 118.6 vs. 348.7 ± 121.8 min, $p = 0.016$). The spleen-preserving rate of the Robot group was considerably superior to that of the Lap group (fail/success, 1/19 vs. 9/16, $p = 0.027$). However, robot surgery cost the patients more than USD 8,000 (USD 8,304.8 ± 870.0), which was more than twice the cost for the Lap group (USD 3,861.7 ± 1,724.3). The total difference in cost was derived mainly from a high surgery fee in the Robot group (USD 2,222.1 ± 627.5 vs. USD 5,726.6 ± 380.5, $p < 0.001$).There were no significant differences in other clinicopathologic variables such as gender, body mass index, the length of resected pancreas, tumor size, amount of bleeding, transfusion, start of diet, complications, length of hospital stay, and segmental resection of both splenic vessels ($p > 0.1$) (Table 1).

Cumulative spleen-preserving rate in conventional laparoscopic approach

The overall spleen preservation rate was 77.8% (35 of 45 patients) in our series. When plotting the CSPR, a higher and stable spleen-preserving rate was noted in the Robot group, which is in contrast to a relatively unstable and lower spleen-preserving rate observed in the Lap group. However, the spleen-preserving rate became more stable after about ten consecutive cases using the conventional laparoscopic approach (Fig. 1).

Operation time for laparoscopic and robot-assisted spleen-preserving distal pancreatectomy

The operation time was much longer in the robot-assisted pancreatectomy group. This significant time difference is still observed when cases of successful spleen-preserving distal pancreatectomy were considered in both groups (251.3 ± 130.2 vs. 349.9 ± 124.9, $p = 0.026$); however, the operation time of successful spleen-preserving distal pancreatectomy became shorter in both groups as more experience was accumulated (Lap vs. Robot, $R^2 = 0.5937$, $p < 0.001$ vs. $R^2 = 0.2028$, $p = 0.053$, Fig. 2).

Discussion

Laparoscopic experiences and techniques have increased tremendously over the last 20 years. The clinical application of laparoscopic resection of the pancreas started late compared to other surgeries such as of the esophagus, stomach, and small bowel, and colorectal diseases [18]. While a few reports show that conventional laparoscopic central pancreatectomy and pancreatoduodenectomy can be performed safely [19, 20], it is thought that only a few expert surgeons can perform such advanced laparoscopic pancreatic surgery. However, most surgeons may agree with the opinion that laparoscopic distal pancreatectomy with or without removing the spleen is safe and effective treatment for benign and borderline malignant tumors of the pancreas. Recently, the role of the spleen has been emphasized [6], and spleen-preserving distal pancreatectomy is thought to be quite adequate surgery for benign and borderline malignant pancreatic tumors. Traditionally, distal pancreatectomy with concomitant splenectomy has been performed in our institution for most cases of benign and borderline malignant pancreatic lesions. However, in 2006 we changed our policy to the one that preserves the spleen in benign and borderline malignant cases requiring distal pancreatectomy. For spleen preservation, a fine and delicate laparoscopic technique is required because even a small break in the tributary vessels from the splenic artery and vein can potentially obscure a clear surgical field, which might result in intraoperative bleeding subsequently resulting in performing a splenectomy.

With the development of computer science and technology, a robot surgical system was introduced in the field of general surgery [15, 21]. The robot (da Vinci) surgical system has unique characteristics for providing safe and effective laparoscopic surgery [22]. It provides stable three-dimensional views, wrist-like movement of the effector instrument (seven degrees of freedom) without fulcrum effect, no tremor, and scale adjustment for instruments. These properties are theoretically thought to fulfill the requirements for safe laparoscopic spleen-preserving distal pancreatectomy. Many clinical experiences with robot surgery have been accumulated; however, objective and concrete clinical data showing the clinical advantages of robot surgery over conventional laparoscopic surgery seem to be lacking. Most reports are about the technical feasibility of and surgeons' experiences with robot surgery. Therefore, we wanted to find whether there are any clinical advantages to robot-assisted surgery over conventional laparoscopic surgery for spleen-preserving laparoscopic pancreatectomy. Although this study is based on a retrospective case series with selection bias, potential clinical advantages of robot surgery for spleen-preserving laparoscopic distal pancreatectomy should be considered.

We observed the important clinical advantage of the robotic surgical system in spleen-preserving pancreatectomy. According to our results, the robot surgical system (da Vinci) had a superior spleen-preserving rate compared to conventional laparoscopy (19/20 vs. 16/25, $p = 0.0270$).

Table 1 Clinical comparative analysis between conventional laparoscopic and robot-assisted pancreatectomy groups

Clinicopathologic variables	Pancreatectomy		*p* value
	Lap ($N = 25$)	Robot ($N = 20$)	
Age (years)	56.5 ± 13.9	44.5 ± 15.9	0.020
Gender			
Female	14	12	ns
Male	11	8	
BMI (kg/m^2)	23.4 ± 2.6	24.2 ± 2.9	ns
Diagnosis			
SCT	3	4	
MCT	2	5	
IPMT	10	2	
NET	3	3	
SPT	4	4	
Pancreatitis (pseudocyst)	1	1	
IPAS	1	1	
Benign stricture	1	–	
Tumor size (cm)	3.0 ± 1.4	3.5 ± 1.3	ns
Length of resected pancreas (cm)	8.5 ± 3.8	7.9 ± 2.8	ns
Bleeding amount (ml)	420.2 ± 445.5	372.0 ± 341.5	ns
Intraoperative transfusion 1			
No	21	16	ns
Yes	4	4	
Intraoperative transfusion 2 (ml)	420.0 ± 168.1	320.2 ± 339.5	ns
Operation time (min)	258.2 ± 118.6	348.7 ± 121.8	0.024
Length of hospital stay (day)	7.3 ± 3.0	7.1 ± 2.2	ns
Diet start (day)	1.2 ± 0.5	1.2 ± 0.5	ns
Complication			
No	21	18	ns
Yes	4	2	
Mortality			
No	25	20	ns
Yes	–	–	
Spleen-preserving			
Fail	9	1	0.027
Success	16	19	
Splenic vessels conservation			
Conservation	12	15	ns
Segmental resection	3 (1)*	3	
Total cost (USD)	3,861.7 ± 1,724.3	8,304.8 ± 870.0	<0.001
Operation cost (USD)	2,222.1 ± 627.5	5,752.6 ± 380.5	<0.001

(*); segmental resection of splenic artery only with conservation of splenic vein [23]

USD = U.S. dollar, 1 USD = 1,209.8 Korean won as of July 2010

ns = non significant, $p > 0.05$

The unique properties of the robot surgical system played an important role during the spleen-preserving procedures. The articulated movement without tremor under a stable three-dimensional operative view is thought to facilitate safety and efficacy during spleen-preserving laparoscopic procedures. A steady and higher rate of CSPR was noted in the Robot group compared to a relatively unstable and lower CSPR in the Lap group (Fig. 1). However, it was also noted that the spleen-preserving rate gradually increased after a number of cases in the Lap group. One of the weakest points of the current study is the small sample size of both groups. Therefore, we wonder if the currently achieved statistical significance would hold up over time as laparoscopic and robotic experiences increase. In fact, as shown by the CSPR of Lap group (Fig. 1), the spleen-preserving rate of the Lap group steadily increased after 15 cases. In the end, the statistical difference in the ability to preserve the spleen between the two procedures might be

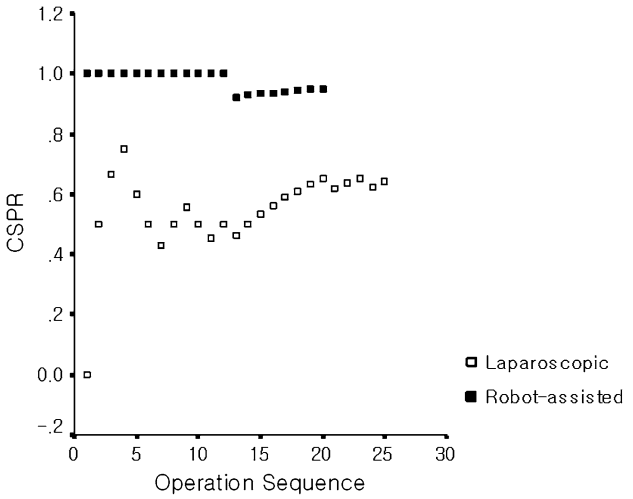

Fig. 1 Cumulative spleen-preserving rate (CSPR). Note the stable and high rate of spleen preservation in the Robot group. An increasing spleen-preserving rate was also observed following about 15 cases in the Lap group

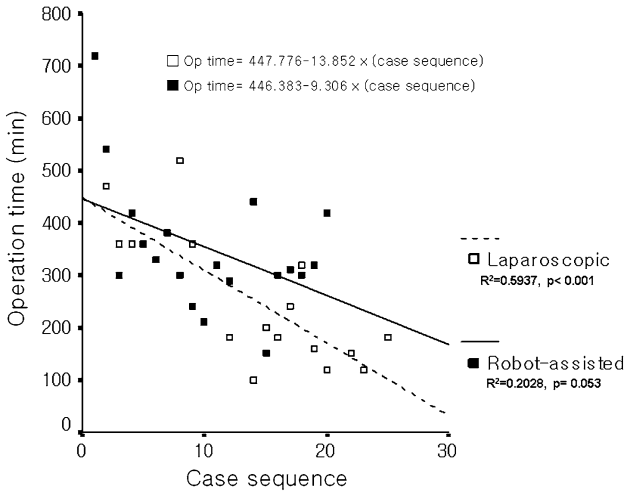

Fig. 2 The change in operation time according to case sequence (among the cases with successful spleen-preserving procedure). Operation time became shorter in both groups as experience increased

negated with accumulating experience. Therefore, we can also expect that the surgeons' experiences with conventional laparoscopic surgery might be comparable to the clinical outcomes with the recent robotic surgical system as experiences accumulate. The robot surgical system might be a useful approach for surgeons to perform spleen-preserving distal pancreatectomy before achieving enough experience with the demanding laparoscopic procedure.

Of course, potential disadvantages of a robotic surgery for minimally invasive pancreatectomy were also observed. The total operation time was much longer in the Robot group. Considering that laparoscopic spleen-preserving distal pancreatectomy is known to be a time- and labor-

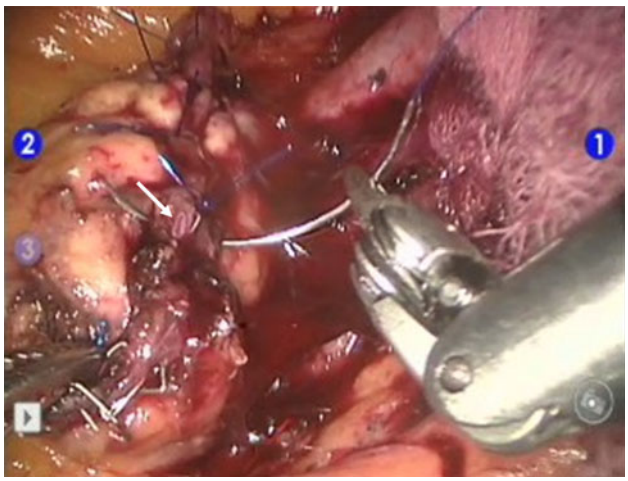

Fig. 3 Serial interrupted sutures were placed along the pancreatic stump. From time to time, the pancreatic duct (*white arrow*) was well visualized and the surgeon applied a transfixation suture which is usually done in open surgery

consuming procedure, it seemed that the total operation time was much longer for the Robot group because most cases preserved the spleen (258.2 ± 118.6 min. vs. 348.7 ± 121.8, $p = 0.024$). This time difference is still observed, even in cases of successful spleen-preserving distal pancreatectomy, but it is thought that a difference of about 100 min may not be so critical in the clinical setting. Also, additional time may be necessary in robot-assisted surgery because we always applied serial interrupted figure-of-eight sutures at the pancreatic stump, which was never done in the conventional laparoscopic group (Fig. 3). However, the operation time for successful spleen-preserving distal pancreatectomy was shown to decrease with experience in both surgical approaches (Fig. 2). Another potential negative of robot-assisted surgery is the total loss of tactile sensation, but it is not thought to be a serious problem. Our experiences show that three-dimensional visual feedback can compensate for the loss of tactile sensation. The feeling of softness or hardness and the strength of grasping and traction of tissue could be estimated based on visual compensation. Therefore, we think the handicap of tactile loss is no longer a major obstacle for using a robot surgical system. The high cost for the robot surgery may be the largest obstacle to the clinical application of the da Vinci surgical system. The cost for robot surgery is very high in Korea (almost 2.5 times the amount of conventional laparoscopic surgery, USD 5,752.6 ± 380 vs. USD 2,222.1 ± 672.5, $p < 0.001$). Therefore, the total economic burden of robot-assisted surgery was almost twice as much as conventional laparoscopic pancreatic surgery (USD 8,304.8 ± 870 vs. USD 3,861.71 ± 724.3, $p < 0.001$; Table 1). That is why this robot-assisted surgery could not be freely used for the general population in

Korea. If the financial burden of this surgery were lower, we would more readily use this procedure, given its potential clinical advantages shown in the current study. Minimally invasive surgery has its own purposes and clinical goals. Both conventional laparoscopic and robot-assisted pancreatic surgery are thought to belong to the same category of minimally invasive surgery. Therefore, their clinical goals and end results may be inevitably similar to each other. The robot surgical system was introduced to overcome the current limitations of conventional laparoscopic surgery; therefore, these two surgical options are thought to be very harmonizing for properly managing patients requiring minimally invasive surgery.

In summary, the high cost of the robotic surgical system is still a challenging issue, but the robot surgical system may enhance the spleen preservation rate in patients with benign and borderline malignant tumors requiring pancreatectomy. In addition, the robot enables surgeons to perform far advanced laparoscopic surgery safely and precisely. We need more experience to address the real role of the robot in advanced laparoscopic pancreatic surgery, not only for safety reasons but also for the real clinical benefits to the patient.

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