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Reduced port minimally invasive distal pancreatectomy: single-port laparoscopic versus robotic single-site plus one-port distal pancreatectomy

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Abstract

Background Minimally invasive surgery appears to be developing in multiple directions, including single-port laparoscopic (SPL), single-port robotic, reduced port laparoscopic, or single-site plus one-port robotic approach. The aim of study was to compare the short-term perioperative variables and outcomes of patients undergoing reduced port minimally invasive distal pancreatectomy (DP) via the SPL, or robotic single-site plus one-port (RSS + 1) approach.

Methods The medical records of 35 patients were retrospectively reviewed, who underwent SPL-DP ($n = 22$) or RSS + 1 DP ($n = 13$) at Korea University Ansan Hospital and Yonsei University Severance Hospital.

Results The mean operation time in SPL group was significantly higher than that of RSS + 1 group (281 vs 192, $p = .001$). The mean blood loss in SPL was significantly larger than that of RSS + 1 group (163 vs 12, $p = .002$). The mean length of free resection margin in SPL group was significantly longer than that of RSS + 1 group (2.1 vs 0.4 cm, $p = .001$). Spleen was significantly preserved in SPL group (54.5 vs 7.7%, $p = .001$). All RSS + 1 cases had tumors located near spleen hilum ($p < .001$). SPL approach had significantly grade IIIa complications ($p = .014$). Moreover, the mean hospital stay in SPL group was significantly longer than that of RSS + 1 group (14.4 vs 7.4 days, $p = .004$). Postoperative pancreatic fistula (POPF) was significantly observed in longer operation time ($p = .043$) and smaller tumor size ($p = .037$) in the univariate analysis. Higher BMI was significantly important factor for prolonged operation time ($p = .034$) in the multivariate analysis. Prolonged hospital stay was related to spleen preservation ($p = .014$) in the multivariate analysis.

Conclusions Both SPL and RSS + 1 are technically feasible and safe. RSS + 1-DP is superior to SPL-DP in terms of operation time, blood loss, severe complications, and hospital stay. SPL-DP shows advantages in terms of single wound site, less trocar usage, higher rate of spleen preservation, and wider range of operative field.

Keywords Single port · Laparoscopic · Robotic · Distal pancreatectomy

Laparoscopic distal pancreatectomy (DP) is regarded as a safe and feasible minimally invasive surgical approach in benign and borderline malignant pancreatic tumors [1]. With advances in laparoscopic techniques and instruments and surgeons' experience, much effort to reduce the number of the trocar site has been made. Minimally invasive surgery appears to be developing in multiple directions, including single-port laparoscopic (SPL) [2–4], single-port robotic [5], reduced port laparoscopic [6], or single-site plus one-port robotic (RSS + 1) approach [7].

The first laparoscopic DP was performed in 1994 by Cuschieri [8], and the first robotic DP was reported by Melvin et al. [9]. In the same year, Giulianotti et al. [10] published their robotic experience on the first series of five DP cases. Daouadi et al. [11] reported that robot-assisted DP

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was as safe and effective as laparoscopic DP but it significantly reduced the conversion to open resection, despite a statistically greater probability of malignancy in the robotic cohort. Short-term results of robotic DP seem to be similar to the laparoscopic approach, but the high cost of robotic approach makes this approach less cost-effective [12].

The single-port surgical approach, which has begun to gain attention with the introduction of natural orifice transluminal endoscopic surgery, has gradually expanded its field from simple to complex surgery. However, the application of this approach has not increased rapidly due to apprehension about the technical difficulty and mental burden of single-port approach and/or the increased operative risk in terms of surgeon's experiences; there have been great concerns regarding operative safety and feasibility compared with the established outcomes of the single-port approach complex surgery, such as hepatectomy or pancreatectomy. The first SPL-DP was reported by Barbaros et al. [13]. In 2014, Han et al. [14] reported their initial experience on SPL-DP, which was similar to conventional laparoscopic DP, except in terms of duration of operation and hospital stay.

The advantages of the robotic platform over the laparoscopic approach include motion stabilization, absence of the fulcrum effect, reduction of operator fatigue, three-dimensional and high-definition vision, seven degrees of freedom, and improved ergonomics for the surgeon. All these features enable the surgeon to assess challenging complex surgical procedures while maintaining all the benefits of a minimally invasive approach and with greater precision and improved functional and cosmetic outcomes [15–17].

To the authors' best knowledge, Kim and colleagues from Yonsei first reported on RSS + 1-DP [18, 19], which is currently available and has the potential to make SPL-DP much easier and ergonomic, providing some room to expand on more minimally invasive surgery. In addition, Peng et al. [20] recently reported that single-port robotic DP using commercial single-port device was safe and efficient in their initial experience. Until now, no clinical investigations compared the perioperative outcomes between SPL-DP and RSS + 1-DP.

The aim of study was to compare the short-term perioperative outcomes in patients undergoing minimally invasive DP via the SPL or the RSS + 1 approach.

Materials and methods

Patient and data

This study is a bi-institutional collaborative study between Korea University and Yonsei University in the Republic of Korea. The medical records of patients who consecutively underwent SPL-DP at the Department of Surgery, Korea University Ansan Hospital and RSS + 1-DP at the Department of Surgery, Yonsei University Severance Hospital between January 2012 and January 2018 for benign and low-grade malignant pancreatic tumor were retrospectively reviewed. Clinicopathologic data including demographic characteristics, clinical presentation, perioperative results, complications, and pathologic findings were collected. The postoperative pancreatic fistula (POPF) was defined by the revised 2016 International Study Group of Pancreatic Fistula guidelines [21]. Additionally, the Clavien–Dindo classification (CDC) [22] was surveyed for overall complications and the comprehensive complication index (CCI) [23] was obtained using the CCI calculator available online (http://www.assessurgery.com). Tumor location was reviewed based on preoperative abdominal computed tomography results. Postoperative pain intensity was registered at postoperative days (POD) 1 and 3. All patients were asked to rate their present intensity of pain by (1) placing a vertical mark on a 10-cm visual analogue scale (VAS), which ranged from "no pain" on the left to "worst pain" on the right end, (2) choosing a number between 0 and 10, where 0 was "no pain" and 10 was "worst pain," and (3) describing their present pain, from no pain, mild, moderate, severe, and excruciating [24].

Indications for splenectomy in the SPL and RSS + 1-DP groups were pancreatic neoplasm located in the splenic hilum, intraoperative intractable bleeding from the spleen during spleen preservation, and highly suspicious malignancy in the preoperative imaging study.

Surgical techniques of SPL-DP and RSS + 1-DP

The SPL technique was performed using a pure SPL technique, which was described in detail in 2014 [14]. Additionally, we created new channels on the body of the glove port with purse-string sutures and sterile Fixomull stretch (BSN Medical, Hamburg, Germany) for laparoscopic stapling device using an SPL technique. The remnant pancreas was reinforced with nonabsorbable 3–0 continuous barbed sutures using an SPL technique. The RSS + 1-DP technique was described in our recent studies [18, 19].

Statistical analysis

Each variable's distributional characteristics were assessed for normality. Continuous data were reported in terms of mean ± standard deviation and/or median with interquartile range based on variance. The chi-squared test or Fisher's exact test was used to compare categorical variables, and independent *t* test or Mann–Whitney test was used to compare continuous variables. The *p* value was adjusted under Bonferroni correction after Mann–Whitney test. The POPF risk factor analysis was performed in the univariate logistic

regression analysis and variables with p value < 0.2 were analyzed in the multivariate logistic regression method. Statistical analyses were performed using SPSS (version 21.0 for Mac, SPSS Inc., Chicago, IL, USA). The institutional review board of the ethics committees (IRB) of Korea University Ansan Hospital and Yonsei University Severance Hospital approved the study protocol. The written informed consent was waived by the IRB owing to the study's retrospective nature.

Results

Clinicopathologic characteristics

Twenty-two patients underwent SPL-DP for pancreatic neoplasm in Korea University Ansan Hospital (SPL group) and 13 patients underwent RSS + 1-DP for pancreatic neoplasm in Yonsei University Severance Hospital (RSS + 1 group). Table 1 shows that the mean age in the SPL group was significantly higher than that in the RSS + 1 group (58.3 vs 46.1 years, $p = .023$). The mean body mass index (BMI) in the SPL group was higher than that in the RSS + 1 group (23.9 vs 20.9 kg/m^2, $p = .034$). There was no statistically significant difference in male -to-female ratio, American Association of Anesthesiologist (ASA) score, and the presence of previous abdominal operation history between the two groups. The pathologic examination demonstrated some differences between the two groups. The proportions of intraductal papillary mucinous neoplasm (18.2 vs 0%), and mucinous cystic neoplasm (27.3 vs 0%) were higher in the SPL group. However, the proportion of neuroendocrine tumor (18.2 vs 30.8%) and solid pseudopapillary tumor (4.5 vs 30.8%) were higher in the RSS + 1 group.

Perioperative characteristics

The perioperative characteristics were compared between the groups in Table 2. The mean operation time in the SPL group was significantly higher than that in the RSS + 1 group (281 vs 192, $p = .001$). The mean blood loss in the SPL group was significantly larger than that in the RSS + 1 group (163 vs 12 mL, $p = .002$), but there was no transfusion in either group. The spleen was significantly preserved in the SPL group (54.5 vs 7.7%, $p = .001$), which was explained by the observation that pancreatic neoplasms in the RSS + 1 group were mainly located in the pancreas tail abutting splenic hilum (38.1 vs 100.0%, $p < .001$). The mean number of trocars in the SPL group was significantly lower than that in the RSS + 1 group (1.1 vs 2, $p < .001$). The mean tumor size in the SPL group was similar to that in the RSS + 1 group (3.0 vs 2.7 cm). The mean length of free resection margin in the SPL group was significantly longer than that in the RSS + 1 group (2.1 vs 0.4 cm, $p = .001$). There were no

Table 1 Clinicopathologic characteristics of patients undergoing SPL or RSS + 1

Variables	All ($n = 35$)	SPL ($n = 22$)	RSS + 1 ($n = 13$)	p Value
Demographics				
Sex (male/female)	11:24	8:14	3:10	0.478
Age (years)	53.0 ± 16.9	58.3 ± 15.0	46.1 ± 14.0	0.023*
BMI (kg/m^2)	23.3 ± 3.3	23.9 ± 3.6	20.9 ± 4.0	0.034
	24.0 [4.1]	24.6 [3.5]	19.0 [6.2]	
ASA score				0.386
1	11 (31.4)	5 (22.7)	6 (46.2)	
2	19 (54.3)	13 (59.1)	6 (46.2)	
3	5 (14.3)	4 (18.2)	1 (7.7)	
Op history	9 (25.7)	5 (22.7)	4 (30.8)	0.698
Histopathology				0.048
NET	8 (22.9)	4 (18.2)	4 (30.8)	
IPMN	4 (11.4)	4 (18.2)	0 (0)	
MCN	6 (17.1)	6 (27.3)	0 (0)	
SPN	5 (14.3)	1 (4.5)	4 (30.8)	
SCN	3 (8.6)	2 (9.1)	1 (7.7)	
Others	9 (25.7)	5 (22.7)	4 (30.8)	

Values are presented as mean ± standard deviation, median [interquartile range], or n (%)

ASA American Society of Anesthesiologists, *BMI* body mass index, *IPMN* intraductal papillary mucinous neoplasm, *MCN* mucinous cystic neoplasm, *NET* neuroendocrine tumor, *Op* abdominal operation, *RSS + 1* robotic single-site plus one distal pancreatectomy, *SCN* serous cystic neoplasm, *SPL* single-port laparoscopic distal pancreatectomy, *SPN* solid pseudopapillary neoplasm

*Statistically significant (Bonferroni correction)

Table 2 Perioperative characteristics of patients undergoing SPL or RSS + 1

Variables	All ($n=35$)	SPL ($n=22$)	RSS + 1 ($n=13$)	p Value
Operation time (min)	252 ± 75	281 ± 52	192 ± 69	0.001*
	270 [154]	275 [90]	170 [67]	
Co-operation	5 (14.3)	5 (22.7)	0 (0)	0.134
Spleen preservation	12 (34.3)	12 (54.5)	1 (7.7)	0.001*
Trocar number	1.4 ± 0.7	1.1 ± 0.2	2.0 ± 0.7	< 0.001*
	1.0 [1.0]	1.0 [0]	2.0 [0]	
Blood loss (mL)	86 ± 130	163 ± 197	12 ± 22	0.002*
	50 [130]	100 [250]	0 [28]	
Conversion	2 (5.7)	1 (4.5)	1 (7.7)	> 0.999
Tumor size (cm)	2.8 ± 1.6	3.0 ± 1.8	2.7 ± 1.2	0.678
	2.3 [2.2]	2.5 [3.2]	2.3 [2.3]	
Resection margin (cm)	1.4 ± 1.6	2.1 ± 1.8	0.4 ± 0.6	0.001*
	0.5 [3.3]	1.0 [3.4]	0.2 [0.4]	
Tumor location				< 0.001*
Body	14 (40.0)	14 (63.6)	0 (0)	
Tail	21 (60.0)	8 (38.1)	13 (100)	
Pain score POD 1	2.5 ± 1.2	2.6 ± 0.9	2.3 ± 1.2	0.395
	2.0 [1.0]	2.5 [1.0]	2.0 [1.0]	
Pain score POD 3	2.7 ± 1.9	2.3 ± 1.5	2.5 ± 1.9	0.985
	2.0 [3.0]	2.0 [1.0]	2.0 [2.0]	
Complications	13 (37.1)	8 (36.4)	5 (38.5)	> 0.999
CCI	4.7 ± 8.5	8.3 ± 11.7	3.3 ± 4.4	0.566
	0 [8.7]	0 [22.2]	0 [8.7]	
CDC grade				0.014
I	6 (17.1)	1 (4.5)	5 (38.5)	
II	2 (5.7)	2 (9.1)	0 (0)	
IIIa	5 (14.3)	5 (22.7)	0 (0)	
POPF				0.274
< Grade A	31 (88.6)	18 (81.8)	13 (100)	
Grade B >	4 (11.4)	4 (18.2)	0 (0)	
Hospital stay duration (days)	12.6 ± 12.3	14.4 ± 12.3	7.4 ± 1.9	0.004*
	9.0 [3.0]	10.0 [6.0]	8.0 [3.0]	
Follow-up duration (months)	13.3 ± 9.9	23.4 ± 18.6	7.8 ± 7.1	0.005
	12.4 [15.0]	19.0 [19.5]	6.0 [12.5]	

Values are presented as mean ± standard deviation, median [interquartile range], or n (%)

CCI comprehensive complication index, *CDC* Clavien–Dindo classification, *POD* postoperative day, *POPF* postoperative pancreatic fistula, *RSS + 1* robotic single-site plus one robotic distal pancreatectomy, *SPL* single-port laparoscopic distal pancreatectomy

*Statistically significant (Bonferroni correction)

significant differences in the mean pain VAS score on POD 1 (2.6 vs 2.3, $p=.395$) and POD 3 (2.3 vs 2.5, $p=.985$), mean CCI (8.3 vs 3.3, $p=.566$), and complication rate (36.4 vs 38.5%, $p>.99$) between the two groups. However, SPL had significantly higher CDC grade complications ($p=.014$). There was no significant difference in POPF between the two groups ($p=.274$); however, the SPL group had slightly higher POPF grade than the RSS + 1 group ($p=.120$). Moreover, the mean hospital stay in the SPL group was significantly longer than that of RSS + 1 group (14.4 vs 7.4 days, $p=.004$). The mean follow-up period in SPL group was slightly longer than that in the RSS + 1 group (23.4 vs 7.8 months, $p=.005$).

Multivariate logistic regression analysis

The results of the analysis of the overall complications and POPF risk factors are shown in Table 3. Overall complications were related with previous abdominal operation history ($p=.043$) but were not significant in the multivariate

Table 3 Complications and postoperative pancreatic fistula risk factor analysis after SPL or RSS + 1

	Univariate analysis				Multivariate analysis			
	p Value	HR	95% CI		*p* Value	HR	95% CI	
Overall complications								
Age	0.152	0.966	0.921	1..013	0.705	0.989	0.933	1.048
Male sex	0.493	0.600	0.139	2.581				
BMI	0.364	0.920	0.769	1.101				
Operation history	0.043*	5.429	1.059	27.833	0.053	5.504	0.975	31.061
ASA score	0.148	0.429	0.136	1.350	0.357	0.503	0.116	2.172
Operation time	0.833	1.001	0.991	1.011				
Tumor size	0.415	0.826	0.521	1.308				
Resection margin length	0.529	1.183	0.701	1.997				
Blood loss	0.672	1.001	0.997	1.005				
Splenectomy	0.260	0.438	0.104	1.844				
Co-operation	0.866	1.152	0.166	7.990				
Location near splenic hilum	> 0.999							
Conversion	> 0.999							
Robotic approach	0.901	1.094	0.266	4.504				
Pain score POD1	0.199	1.659	0.766	3.594	0.174	1.844	0.764	4.455
Pain score POD3	0.634	0.897	0.575	1.401				
POPF								
Age	0.982	0.999	0.940	1.063				
Male sex	0.157	0.242	0.034	1.727	0.413			
BMI	0.994	0.999	0.784	1.274				
Operation history	0.753	0.688	0.066	7.108				
ASA score	0.916	0.925	0.216	3.956				
Operation time	0.043*	1.023	1.001	1.045	0.397	1.256	0.741	2.128
Tumor size	0.037*	0.164	0.030	0.899	0.407			
Resection margin length	0.176	1.630	0.803	3.312	0.358			
Blood loss	0.223	1.003	0.998	1.007				
Splenectomy	0.208	0.286	0.041	2.013				
Co-operation	0.695	1.625	0.143	18.477				
Location near splenic hilum	> 0.999							
Conversion	> 0.999							
Robotic approach	0.405	2.667	0.265	26.861				
Pain score POD1	0.212	1.843	0.706	4.811				
Pain score POD3	0.553	0.807	0.398	1.638				

ASA American Society of Anesthesiologists, *BMI* body mass index, *CI* confidence interval, *HR* hazard ratio, *POD* postoperative day, *RSS + 1* robotic single-site plus one robotic distal pancreatectomy, *SPL* single-port laparoscopic distal pancreatectomy

*Statistically significant

analysis ($p = .053$). POPF development was related with longer operation time ($p = .043$) and smaller tumor size ($p = .037$), but based on the multivariate analysis, there was no statistically different risk factor of POPF in patients between the two groups.

Table 4 shows the factors that increased the duration of operation and hospital stay. In terms of operation time, higher BMI ($p = .008$), SPL approach ($p = .014$), and larger amount of blood loss ($p = .027$) were significantly correlated with longer operation time, but in the multivariate analysis, only higher BMI and higher amount of blood loss were significantly important factors ($p = .034$). Prolonged hospital stay was related to spleen preservation ($p = .008$), higher complication rates ($p = .013$), grade IIIa complications ($p = .003$), POPF ($p = .032$), grade B POPF ($p = .002$), and higher CCI ($p = .001$). In the multivariate analysis, there are statistically significant differences in spleen preservation ($p = .014$) and complications ($p = .020$).

Table 4 Analysis of factors that increased operation time or hospital stay after SPL or RSS + 1

	Univariate analysis				Multivariate analysis			
	p Value	HR	95% CI		*p* Value	HR	95% CI	
Prolonged operation time								
Age	0.131	1.037	0.989	1.086	0.373	1.044	0.950	1.148
Female sex	0.332	0.484	0.111	2.098				
BMI	0.008*	1.385	1.090	1.760	0.034*	1.508	1.031	2.206
Operation history	0.216	0.367	0.075	1.797				
ASA score	0.121	2.403	0.792	7.285	0.547	0.495	0.050	4.887
Tumor size	0.313	0.798	0.515	1.237				
Resection margin length	0.212	1.443	0.811	2.566				
Blood loss	0.027*	1.013	1.001	1.025	0.172	1.013	0.994	1.033
Splenectomy	0.198	0.385	0.090	1.650	0.529	0.324	0.010	10.819
Co-operation	0.196	4.571	0.456	45.857	0.479	3.688	0.099	137.056
Location near splenic hilum	0.059	0.246	0.057	1.056	0.270	6.455	0.234	177.919
Conversion	> 0.999							
Robotic approach	0.014*	0.140	0.029	0.674	0.654	0.555	0.042	7.281
Prolonged hospital stay								
Age	0.181	0.962	0.909	1.018	0.070	0.891	0.787	1.010
Male sex	0.470	0.533	0.097	2.939				
BMI	0.792	1.029	0.830	1.276				
Operation history	0.847	1.200	0.189	7.628				
ASA score	0.607	0.711	0.194	2.604				
Operation time	0.139	1.010	0.997	1.023	0.148	1.045	0.984	1.110
Tumor size	0.559	1.162	0.702	1.925				
Resection margin length	0.352	22.953	0.031	16925.361				
Blood loss	0.766	0.999	0.994	1.005				
Splenectomy	0.008*	0.045	0.005	0.454	0.014*	0.027	0.002	0.484
Co-operation	0.245	3.333	0.438	25.394				
Location near the splenic hilum	0.863	0.863	0.161	4.620				
Complications	0.013*	18.000	1.835	176.560	0.020*	30.43	1.700	544.868
CDC grade	0.036*				0.062	4.476	0.928	21.581
I	> 0.999							
II	> 0.999							
IIIa	0.003*	84.000	4.306	1638.785				
POPF	0.032*	9.750	1.223	77.724	0.384	5.900	0.109	320.508
POPF grade	0.066				0.697			
Grade A	> 0.999				> 0.999			
Grade B	0.002*	19.500	1.607	236.612	0.379	6.066	0.109	336.268
CCI	0.001*	1.227	1.083	1.391	0.075	1.212	0.981	1.498
Conversion	> 0.999							
Robotic approach	> 0.999							
Pain score POD1	0.065	2.488	0.946	6.543	0.622	2.059	0.117	36.268
Pain score POD3	0.958	1.014	0.608	1.690				

ASA American Society of Anesthesiologists, *BMI* body mass index, *CCI* comprehensive complication index, *CDC* Clavien–Dindo classification, *CI* confidence interval, *HR* hazard ratio, *POD* postoperative day, *POPF* postoperative pancreatic fistula, *RSS + 1* robotic single-site plus one robotic distal pancreatectomy, *SPL* single-port laparoscopic distal pancreatectomy

*Statistically significant

Discussion

The RSS + 1 approach was associated with a significantly shorter operation time, blood loss, postoperative hospital stays, and lower CDC grade of complications, but the SPL approach was associated with significantly fewer trocars, better spleen preservation, larger free resection margin, and wider operation field for more centrally located pancreatic neoplasm. There were no significant differences in the incidence of overall complications, CCI, and POPF, but more grave complications were significantly more common in the SPL group. The advantages of robotic approach to distal pancreatic neoplasms are closely related with the merits of minimally invasive surgery in our study. Reduction of postoperative hospital stay is one of the main objectives of minimally invasive pancreatic surgery, as it can balance the increased costs of laparoscopic or robotic equipment, as demonstrated recently for minimally invasive liver surgery [25]. For hepatobiliary surgery in particular, progress made in the last 5 years in robotically assisted minimally invasive surgery has been astounding [26]. Robotic DP was known to be associated with significantly better spleen preservation rate and reduced operative time, blood loss, transfusion requirement, and postoperative hospital stay for patients undergoing spleen preservation compared with conventional laparoscopic DP, but it offered fewer benefits for patients undergoing splenectomy [27, 28]. The advantages of the laparoscopic approach using a single port to distal pancreatic neoplasm are significantly more focused on the benefits of SPL itself, such as widening of the operation field and extension of the surgical scope that robotic surgery do not have.

The duration of operation and hospital stay in the SPL group was much longer than that in the RSS + 1 group, which was similar to the findings of other studies on robotic DP [27, 28]. However, in our study, there were significant differences in the mean age, mean BMI, and pathologic reports between the two groups. The operation time was influenced and prolonged by the SPL approach, higher BMI, and larger blood loss in our study. Resection of pancreatic tumors near the splenic hilum is thought to be easily performed by laparoscopy or robotic DP with planned splenectomy; however, tumors near the neck or the body of the pancreas sometimes require division of the pancreatic neck portion, which is a more complex and relatively difficult procedure. Simultaneous splenectomy is performed with DP mainly for technical reasons, such as to make resection easier, to shorten operation time, and to minimize bleeding from dissection of the splenic vessels. The use of laparoscopy was reported to improve the spleen preservation rate compared with laparotomy [29], although spleen-preserving laparoscopic DP relatively needs more time and effort. A major limitation regarding the laparoscopic technique is its less effective control of bleeding from the splenic vessels, because splenic vessel bleeding is a major risk factor for failed spleen preservation. The distance from the umbilicus to the spleen in the SPL approach is different from that of the conventional laparoscopic approach. Although bleeding around the spleen is also a major risk factor for failed spleen preservation in the SPL approach, spleen-sacrificing SPL-DP is still more time consuming and labor consuming. From that point of view, we can explain why SPL-DP has a much longer operation time even if the docking time of the robotic approach is not considered. The operative time in robotic approach is influenced by the docking method and the surgeon's experience in robotic pancreatic surgery. However, a surgeon with enough experience and the latest version of the da Vinci Xi, which has narrower arms and a more straightforward docking method, contributes to a decrease in operative time. Expert surgical experience is important in achieving superior robotic DP surgical outcomes. It would be important to know the number of minimally invasive distal pancreatectomies performed in the institution and the average experience of each of the surgeons. A recent study has reported improvements in complications and length of hospital stay after 30 cases of learning curves in laparoscopic DP [30].

However, we do not believe that SPL-DP should increase more clinical experiences to obtain the learning curve and improve satisfactory perioperative outcomes. The robotic approach has been introduced to overcome the limitations of conventional laparoscopic surgery, and it may be useful for pancreatic surgery, which requires delicate laparoscopic surgical techniques. However, many laparoscopic surgeons have overcome the limitations of conventional laparoscopic techniques as a result of their surgical experiences [31]. It is necessary for the SPL approach to develop a brand-new single-port system to untangle the complexity of the arrangement of the laparoscopic instruments and expand the number of working laparoscopic instruments in the single-port. The RSS + 1 pancreas approach is a modified surgical platform of a complete minimally invasive surgical technique, but SPL pancreatic surgery is a developing, time-consuming, and technical-demanding technique in minimally invasive surgery.

Prolonged duration of hospital stay was related with complications in our study. The index of complications including CDC grade, CCI, and POPF grade indicated that more severe complications are associated with longer duration of hospital stay. Additionally, significant relationship was noted between spleen preservation and longer duration of hospital stays. There is no evidence that a higher spleen preservation rate is associated with longer duration of hospital stays until now. However, spleen preservation was frequently observed

in the SPL approach, which was directly related with longer operation time.

The gateway in comparison between laparoscopic and robotic surgery is the problem of cost. The meta-analyses between laparoscopic and robotic DP by Gavriilidis et al. [32] could not demonstrate that the robotic approach was more expensive because of a small number of cost-analysis studies and differences in medical costs between countries. In our study, the mean operation cost in the SPL group was significantly lower than that in the RSS + 1 group ($2262 ± 587 vs. $7409 ± 0, $p < .001$). The mean total cost in the SPL group was $10,661 ± 3070, of which patients were only charged $4402 ± 1121, as a benefit from the National Health Insurance Service. Zhou et al. [33] in a meta-analysis of two studies that reported the costs, reported no statistical difference between the laparoscopic and robotic groups, which was explained by the shorter hospital stay in the robotic group.

Our study has several limitations, including the small sample size, different laparoscopic pancreatic surgical experiences of the two surgeons, different volumes of laparoscopic pancreatic surgery in each hospital, heterogeneous pancreatic disease, and limitation of the study design. However, despite the limitations, our results can be used as groundwork for the future direction of reduced port minimally invasive surgery. It may be that the baseline itself is different when comparing SLP and RSS + 1 surgeries. However, this study is not an comparison study of conventional laparoscopic and robotic systems currently being performed. Our study is a comparison between reduced port robotic surgery and SPL surgery, which will be conducted predominantly in the recent future. As reduced port robotic surgery had a number of advantages over SPL surgery, we should provide opportunities for single-port surgery, including laparoscopic and robotic, to be developed as a new low-entry barrier surgical platform by technical advances, rather than not having SPL surgery.

Conclusions

Both SPL and RSS + 1 are technically feasible and safe. RSS + 1-DP is superior to SPL-DP in terms of operation time, blood loss, severe complications, and hospital stay. The SPL approach shows advantages in terms of single wound site, fewer trocar usage, higher rate of spleen preservation, and wider range of operative field.

Compliance with ethical standards

Disclosure Drs. Hyung Joon Han and Chang Moo Kang have no conflict of interest or financial ties to disclose.

References

1. Jusoh AC, Ammori BJ (2012) Laparoscopic versus open distal pancreatectomy: a systematic review of comparative studies. Surg Endosc 26:904–913. https://doi.org/10.1007/s00464-011-2016-3
2. Benzing C, Krenzien F, Atanasov G, Seehofer D, Sucher R, Zorron R, Pratschke J, Schmelzle M (2015) Single incision laparoscopic liver resection (SILL)—a systematic review. GMS Interdisc Plast Reconstr Surg DGPW 4:Doc17. https://doi.org/10.3205/iprs000076
3. Kang BM, Kim HJ, Kye BH, Lee SC, Lee KY, Park SJ, Lee SH, Lim SW, Lee YS, Kim JH, Lee J, Kim MK, Kim JG (2018) Multicenter, randomized single-port versus multiport laparoscopic surgery (SIMPLE) trial in colon cancer: an interim analysis. Surg Endosc 32:1540–1549. https://doi.org/10.1007/s00464-017-5842-0
4. Lee Y, Kim HH (2017) Single-incision Laparoscopic gastrectomy for gastric cancer. J Gastric Cancer 17:193–203. https://doi.org/10.5230/jgc.2017.17.e29
5. Autorino R, Kaouk JH, Stolzenburg JU, Gill IS, Mottrie A, Tewari A, Cadeddu JA (2013) Current status and future directions of robotic single-site surgery: a systematic review. Eur Urol 63:266–280. https://doi.org/10.1016/j.eururo.2012.08.028
6. Inaki N, Tsuji T, Doden K, Sakimura Y, Tawara H, Matsui R, Yamamoto D, Kitamura H, Bando H, Yamada T (2016) Reduced port laparoscopic gastrectomy for gastric cancer. Transl Gastroenterol Hepatol 1:38. https://doi.org/10.21037/tgh.2016.04.04
7. Bae SU, Jeong WK, Baek SK (2017) Reduced-port robotic total mesorectal resection for rectal cancer using a single-port access: a technical note. Wideochir Inne Tech Maloinwazyjne 12:378–384. https://doi.org/10.5114/wiitm.2017.69727
8. Cuschieri A (1994) Laparoscopic surgery of the pancreas. J R Coll Surg Edinb 39:178–184
9. Melvin WS, Needleman BJ, Krause KR, Ellison EC (2003) Robotic resection of pancreatic neuroendocrine tumor. J Laparoendosc Adv Surg Tech A 13:33–36. https://doi.org/10.1089/109264203321235449
10. Giulianotti PC, Coratti A, Angelini M, Sbrana F, Cecconi S, Balestracci T, Caravaglios G (2003) Robotics in general surgery: personal experience in a large community hospital. Arch Surg 138:777–784. https://doi.org/10.1001/archsurg.138.7.777
11. Daouadi M, Zureikat AH, Zenati MS, Choudry H, Tsung A, Bartlett DL, Hughes SJ, Lee KK, Moser AJ, Zeh HJ (2013) Robot-assisted minimally invasive distal pancreatectomy is superior to the laparoscopic technique. Ann Surg 257:128–132. https://doi.org/10.1097/SLA.0b013e31825fff08
12. Souche R, Herrero A, Bourel G, Chauvat J, Pirlet I, Guillon F, Nocca D, Borie F, Mercier G, Fabre JM (2018) Robotic versus laparoscopic distal pancreatectomy: a French prospective single-center experience and cost-effectiveness analysis. Surg Endosc. https://doi.org/10.1007/s00464-018-6080-9
13. Barbaros U, Sumer A, Demirel T, Karakullukcu N, Batman B, Icscan Y, Saricam G, Serin K, Loh WL, Dinccag A, Mercan S (2010) Single incision laparoscopic pancreas resection for pancreatic metastasis of renal cell carcinoma. JSLS 14:566–570. https://doi.org/10.4293/108680810x12924466008448
14. Han HJ, Yoon SY, Song TJ, Choi SB, Kim WB, Choi SY, Park SH (2014) Single-port laparoscopic distal pancreatectomy: initial experience. J Laparoendosc Adv Surg Tech A 24:858–863. https://doi.org/10.1089/lap.2014.0151
15. Barbash GI, Glied SA (2010) New technology and health care costs—the case of robot-assisted surgery. N Engl J Med 363:701–704
16. Giulianotti PC, Sbrana F, Bianco FM, Elli EF, Shah G, Addeo P, Caravaglios G, Coratti A (2010) Robot-assisted laparoscopic

pancreatic surgery: single-surgeon experience. Surg Endosc 24:1646–1657. https://doi.org/10.1007/s00464-009-0825-4
17. Goh BK, Chan CY, Soh HL, Lee SY, Cheow PC, Chow PK, Ooi LL, Chung AY (2017) A comparison between robotic-assisted laparoscopic distal pancreatectomy versus laparoscopic distal pancreatectomy. Int J Med Robot. https://doi.org/10.1002/rcs.1733
18. Kang CM (2018) Robotic single-site plus ONE-port distal pancreatectomy. Ann Pancreat Cancer 1
19. Kim SH, Kang CM, Lee WJ (2017) Robotic single-site plus ONE port distal pancreatectomy. Surg Endosc 31:4258–4259. https://doi.org/10.1007/s00464-017-5476-2
20. Peng CM, Liu HC, Hsieh CL, Yang YK, Cheng TC, Chou RH, Liu YJ (2018) Application of a commercial single-port device for robotic single-incision distal pancreatectomy: initial experience. Surg Today. https://doi.org/10.1007/s00595-018-1647-6
21. Bassi C, Marchegiani G, Dervenis C, Sarr M, Abu Hilal M, Adham M, Allen P, Andersson R, Asbun HJ, Besselink MG, Conlon K, Del Chiaro M, Falconi M, Fernandez-Cruz L, Fernandez-Del Castillo C, Fingerhut A, Friess H, Gouma DJ, Hackert T, Izbicki J, Lillemoe KD, Neoptolemos JP, Olah A, Schulick R, Shrikhande SV, Takada T, Takaori K, Traverso W, Vollmer CR, Wolfgang CL, Yeo CJ, Salvia R, Buchler M (2017) The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery 161:584–591. https://doi.org/10.1016/j.surg.2016.11.014
22. Dindo D, Demartines N, Clavien P-A (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240:205–213. https://doi.org/10.1097/01.sla.0000133083.54934.ae
23. Slankamenac K, Graf R, Barkun J, Puhan MA, Clavien PA (2013) The comprehensive complication index: a novel continuous scale to measure surgical morbidity. Ann Surg 258:1–7. https://doi.org/10.1097/SLA.0b013e318296c732
24. Kremer E, Atkinson JH, Ignelzi RJ (1981) Measurement of pain: patient preference does not confound pain measurement. Pain 10:241–248
25. Cleary SP, Han HS, Yamamoto M, Wakabayashi G, Asbun HJ (2016) The comparative costs of laparoscopic and open liver resection: a report for the 2nd International Consensus Conference on Laparoscopic Liver Resection. Surg Endosc 30:4691–4696. https://doi.org/10.1007/s00464-016-4801-5
26. Fong Y, Woo Y, Giulianotti PC (2017) Robotic surgery: the promise and finally the progress. Hepatobiliary Surg Nutr 6:219–221. https://doi.org/10.21037/hbsn.2017.04.04
27. Chen S, Zhan Q, Chen JZ, Jin JB, Deng XX, Chen H, Shen BY, Peng CH, Li HW (2015) Robotic approach improves spleen-preserving rate and shortens postoperative hospital stay of laparoscopic distal pancreatectomy: a matched cohort study. Surg Endosc 29:3507–3518. https://doi.org/10.1007/s00464-015-4101-5
28. Guerrini GP, Lauretta A, Belluco C, Olivieri M, Forlin M, Basso S, Breda B, Bertola G, Di Benedetto F (2017) Robotic versus laparoscopic distal pancreatectomy: an up-to-date meta-analysis. BMC Surg 17:105. https://doi.org/10.1186/s12893-017-0301-3
29. Kooby DA, Gillespie T, Bentrem D, Nakeeb A, Schmidt MC, Merchant NB, Parikh AA, Martin RC 2nd, Scoggins CR, Ahmad S, Kim HJ, Park J, Johnston F, Strouch MJ, Menze A, Rymer J, McClaine R, Strasberg SM, Talamonti MS, Staley CA, McMasters KM, Lowy AM, Byrd-Sellers J, Wood WC, Hawkins WG (2008) Left-sided pancreatectomy: a multicenter comparison of laparoscopic and open approaches. Ann Surg 248:438–446. https://doi.org/10.1097/SLA.0b013e318185a990
30. de Rooij T, Cipriani F, Rawashdeh M, van Dieren S, Barbaro S, Abuawwad M, van Hilst J, Fontana M, Besselink MG, Abu Hilal M (2017) Single-surgeon learning curve in 111 laparoscopic distal pancreatectomies: does operative time tell the whole story? J Am Coll Surg 224:826–832.e821. https://doi.org/10.1016/j.jamcollsurg.2017.01.023
31. Kang CM (2015) Is robot-assisted minimally invasive distal pancreatectomy superior to the laparoscopic technique? Ann Surg 261:e153–e154. https://doi.org/10.1097/sla.0000000000000682
32. Gavriilidis P, Lim C, Menahem B, Lahat E, Salloum C, Azoulay D (2016) Robotic versus laparoscopic distal pancreatectomy—the first meta-analysis. HPB 18:567–574. https://doi.org/10.1016/j.hpb.2016.04.008
33. Zhou J-Y, Xin C, Mou Y-P, Xu X-W, Zhang M-Z, Zhou Y-C, Lu C, Chen R-G (2016) Robotic versus laparoscopic distal pancreatectomy: a meta-analysis of short-term outcomes. PLoS ONE 11:e0151189