Initial experience with radical antegrade modular pancreatosplenectomy in a single institution

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INTRODUCTION

Body and tail cancer of the pancreas is an aggressive disease with poor prognosis caused by properties of tumor itself, such as the late presentation of clinical symptoms and the ease of invasion of major vessels or adjacent organs [1-3]. Although distal pancreatectomy (DP) has been the standard procedure for left-sided pancreatic cancer [4,5], the rate of recurrence is high even in patients who undergo surgery that might be caused by the aggressive biology of the cancer [6,7].

Radical antegrade modular pancreatosplenectomy (RAMPS), originally described by Strasberg et al. [5], is a novel approach for left-sided pancreatic cancer that includes the horizontal dissection in a right-to-left fashion and radical dissection of regional lymph nodes based on an anatomical lymphatic drainage [5,8]. Recently studies reported RAMPS could achieve negative tangential margin with oncological feasibility and this procedure has been performed increasingly for locally advanced pancreatic cancer without nodal invasion.

Purpose: Radical antegrade modular pancreatosplenectomy (RAMPS) is expected to be favorable for obtaining the negative tangential margin with oncologic feasibility through the horizontal dissection in a right-to-left fashion for radical lymph node dissections.

Methods: From January 2007 to February 2015, a total of 30 RAMPS and 19 conventional distal pancreatectomy (DP) cases were enrolled. The demographics, perioperative and survival outcomes were compared according to the type of surgery.

Results: The mean operative time, blood loss and length of hospital stay were similar between 2 groups. Morbidities were reported in 14 cases of RAMPS (46.7%) and 8 cases of DP (42.1%) (P = 0.777). The rate of negative tangential margin (96.2%) and the number of harvested lymph nodes (mean ± standard deviation, 21.5 ± 8.3) were significantly higher in RAMPS group (P = 0.011, P = 0.003, respectively). In terms of survival outcomes, there was no significant difference in regard to the overall 3-year disease-free survival (DFS; 30.4% in RAMPS vs. 35.0% in DP, P = 0.354) or overall survival (OS; 29.9% vs. 29.4%, P = 0.429) between the 2 groups. After exclusion of cases with nodal invasion, however, the RAMPS group had a longer DFS than the DP group (55.6% vs. 27.3%, P = 0.048) although OS was similar without significant difference (42.4% vs. 27.3%, P = 0.197).

Conclusion: RAMPS is a safe and oncologically feasible procedure in left-sided pancreatic cancer by obtaining a successful negative tangential margin and radical lymph node dissection. The authors suggest it could also be useful for local control, especially for the limited left-sided pancreatic cancer without nodal invasion.

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Key Words: Radical antegrade modular pancreatosplenectomy, Distal pancreatectomy, Left-sided pancreas cancer
left-sided pancreatic cancer for improving of tumor clearance and survival [5,79]. However, there are only a few reports designed to compare the surgical results according to the types of surgical approach.

This study was performed to assess our experience of RAMPS for pancreatic cancer and compare the surgical outcomes of RAMPS with the conventional open DP.

METHODS

Patient population and data selection
From January 2007 to February 2015, 67 pancreatosectomies for resectable left-sided pancreatic malignancy were performed at the Department of Surgery of Seoul St. Mary’s Hospital. The authors had traditionally performed the conventional DP with splenectomy for left-sided pancreatic cancer and RAMPS was initially performed in May 2010; since then, it was consecutively applied. We preoperatively evaluated using abdominal computed tomography scans and magnetic resonance cholangiopancreatography to determine an accurate location of the cancer, and a positron emission tomography scan was used to detect distant metastasis. One cancer, which exceeded T4 stage or required major arterial resection including the celiac axis or the superior mesenteric artery, was excluded from this study. If there were direct invasions of adjacent organs including the stomach, adrenal gland, or kidney, we concomitantly resected the invaded organs, and these cases were included. Thirty cases of RAMPS and 19 cases of conventional open DP were enrolled. All patients underwent the adjuvant concurrent chemoradiotherapy according to the policy of our institution, but none of the patients who underwent neoadjuvant chemotherapy or radiation therapy were included in the study. All data were retrospectively reviewed: age, sex, American Society of Anesthesiologists (ASA) class, perioperative results, tumor characteristics and survival data from the outpatient department. Tumor characteristics were collected from the permanent pathology report. The transection surface at the neck of pancreas and all tangential margins of the specimen, which were not covered with peritoneum, i.e., the posterior surface and the superior and inferior border of specimen, were both painted with ink in the operating room after retrieving the specimen from the back table. The resection margin at the neck of pancreas was sent for processing as a frozen section to clarify the cleanness of proximal margin. The anterior surface of pancreas was not inked, and the tumor penetration of the anterior peritoneum of pancreas was not considered as positive if there was no evidence of tumor invasion to adjacent organs. Postoperative complications were graded from 0 to 5 using the system proposed by DeOliveira et al. [10]. Complications were also divided into two groups; the minor complications were defined as grade 1 or 2, and the major complications were defined as grades 3 to 5. We evaluated the incidence of digestive trouble including prolonged diarrhea defined as loose stools lasted for at least 4 weeks. The definition of a postoperative pancreatic fistula (POPF) was based on the definition of the International Study Group of the Pancreatic Fistula [11]. Postoperative mortality was defined as the mortality that developed within 30 days of the operation or was within the same time of hospital stay. We compared these perioperative outcomes according to the type of surgery: RAMPS group versus DP group. For oncological analysis, the cumulative overall survival (OS) rate and the disease-free survival (DFS) rate were calculated using the Kaplan-Meier method. Additionally, the positivity of nodal status might implicate the progression of malignancy towards systemic disease, and the locoregional treatment including surgery has the limitations of curative effects. To more objectively evaluate the effect of surgery influencing the survival rate, cases without node invasion were carefully selected and the survival outcomes of these cases were reanalyzed according to the type of surgery.

Operative technique
Conventional DP was performed as follows. The patient had an upper midline incision and the lesser sac was entered through a gastrocolic ligament in order to expose the distal anterior pancreas. The dissection proceeded from left to right. The mobilization of spleen was initially performed, and then, the pancreas was dissected to the confluence of the superior mesenteric vein (SMV), portal vein (PV) and splenic vein (SV) which facilitated the full mobilization of distal pancreas. After splenic vessels were ligated at the origin, the pancreas neck transection was performed by electrocautery allowing an adequate margin from the tumor of at least 1 cm. The pancreas stump was closed with a continuous suture using prolene #4-0.

RAMPS was performed according to the procedure introduced by Strasberg and Fields [9]. A long midline incision was made and the pancreas neck was elevated from the PV and SMV. We created a window between the pancreas and a confluence of the SMV, the PV and the SV. The pancreas neck was transected and the repair of resection margin was performed in the same way as conventional DP. The range of medial-to-lateral lymph node dissection was upward to the diaphragmatic crus, downward to the left renal vein, and to the left lateral portion of aorta on the posterior side. The dissection continued more laterally from right to the left on Gerota’s fascia and divided the inferior mesenteric vein. In each case, the surgeon decided to perform the type of RAMPS, whether anterior or posterior, that would increase the chance of obtaining a negative tangential margin based on the principles described by Strasberg et al [5]. We concomitantly resected the adrenal gland in case of posterior RAMPS (Fig. 1) and the en bloc resection of surrounding organs.
was performed in case of extensive disease in which the tumor invaded adjacent organs. A closed suction drain was placed in the pancreas stump, and the abdomen was closed in layers.

**Statistical analysis**

Fisher exact test was conducted for categorical data and the Mann-Whitney U-test was used for continuous variables. Descriptive statistics were recorded as the means ± standard deviation and the 95% confidence interval of difference in proportions was calculated with a level of significance of 0.05.

**RESULTS**

**Patient demographics and perioperative outcomes**

During the study period, 30 RAMPS and 19 conventional DP were included. The demographics and perioperative outcomes according to the type of surgery are shown in Table 1. There were 20 men (40.8%) and 29 women (59.2%), and the mean age was 63.1 ± 8.3 years. There was no significant difference in terms of sex, age, BMI and ASA class. The mean operative time was 277.8 ± 55.6 minutes in RAMPS group and 253.3 ± 41.0 minutes in DP group (P = 0.127) and the mean estimated blood loss was 300 ± 220 mL in RAMPS group and 260 ± 180 mL in DP group (P = 0.086). The mean length of postoperative hospital stay was 6.4 ± 4.3 days in RAMPS group and 8.2 ± 3.3 days in DP group (P = 0.174). No postoperative mortality was observed in either group and postoperative complications were reported in 14 patients (46.7%) in RAMPS group and 8 patients (24.1%) in DP group (P = 0.777): 4 fluid collections, 5 atelectases, 2 wound infections, 2 postoperative ileuses, 2 prolonged diarrheas, and 6 POPFs. The grades of six cases of POPF (12.2%) were as follows: 4 POPFs (8.2%) were grade A, and 2 (4.1%) were grade B, whereas grade C POPF was not found. There was no significant difference in the incidence of POPF (13.3% in RAMPS group and 10.5% in DP group, P > 0.999). According to the grading system by DeOliveira et al. [10], 19 minor complications (11 cases in RAMPS group and 8 cases in DP group) and one major complication in RAMPS group were observed without a significant difference (P = 0.769 and P > 0.999, respectively).

**Oncological outcomes**

Of the 49 patients, 43 patients (87.8%) had been diagnosed with pancreas ductal adenocarcinoma (PDAC) in the permanent pathology. Four patients having neuroendocrine carcinoma in the pathologic report which usually has a better prognosis than PDAC, were excluded from the tumor analysis or survival assay. Two patients who had metastatic renal cell carcinoma were also excluded. Tumor differentiation is shown in Table 2. The distribution of tumor differentiation, the T stage and nodal status of cancer had no significant difference between the 2 groups (P > 0.999, P = 0.071, and P = 0.349, respectively): 14 cases in RAMPS group (53.8%) and 6 cases in DP group (35.3%) were positive for lymph node metastasis. The mean count of retrieving lymph nodes was 18.4 ± 8.8 with a significant difference between the 2 groups (P = 0.003): 21.5 ± 8.3 in RAMPS group and a 13.7 ± 7.4 mean count in DP group. The mean tumor size was 4.5 ± 1.5 cm: 4.6 ± 1.6 cm in RAMPS group and 4.5 ± 1.5 cm in DP group (P = 0.913). R0 resectability was achieved in 33 patients (76.7%) and a negative tangential margin was obtained in 36 patients (73.7%). In terms of negative tangential margin status, a significant difference was observed between the 2 groups (P = 0.011): 25 patients (96.2%) in RAMPS group, and 11 patients (64.7%) in DP group.

**Survival and follow-up outcomes**

Survival results are presented in Tables 3, 4. The median follow-up time was 33 months (range, 8–97 months), and 15 patients (34.9%) are still alive; 13 of 15 patients (86.7%) are alive without disease and 2 patients (13.3%) are alive with recurrent tumor. The mortality occurred from 7 to 51 months after surgery and the median survival was 26.0 ± 21.8 months: 27.5 ± 14.9 months in RAMPS group and 26.0 ± 29.2 months in DP group (P = 0.769). In the current study, 13 deaths (50%) and 8 recurrences (30.8%) developed in RAMPS group while 15 deaths (88.2%) and 8 recurrences (47.1%) occurred in DP group. The overall 1-, 2- and 3-year cumulative DFS after surgery was 86.1%, 60.9%, and 35.0% in RAMPS group whereas it was 52.4%, 52.4%, and 35.0% in DP group, respectively (P = 0.354). The 1-, 2- and 3-year OS after surgery was 64.7%, 44.8%, and 29.9% in RAMPS group whereas it was 58.8%, 35.3%, and 29.4% in DP group, respectively (P = 0.429) (Fig. 2).
After the exclusion of cases with nodal invasion, 23 N0 cases (12 cases in RAMPS group and 11 cases in DP group) were reanalyzed. Among them, the overall 1-, 2-, and 3-year DFSs in RAMPS group were 100%, 83.3%, and 55.6% whereas there were 54.5%, 54.5%, and 27.3% in DP group, respectively (P = 0.048). The overall 1-, 2-, and 3-year OSs were 70.7%, 56.6%, and 42.4% in RAMPS group whereas they were 63.6%, 36.4%, and 27.3% in DP group, respectively (P = 0.197). Survival outcomes according to the type of surgery in N0 cases are shown in Fig. 2.

**DISCUSSION**

In conventional DP, the left-to-right dissection and the late ligation of splenic vessels followed by the mobilization of pancreas were usually performed. Contrary to this, the right-to-left dissection of the plane and the early ligation of
splenic vessels were used in RAMPS. Because the surgeon can gradually dissect the inferior border of pancreas under direct view in a state of being apart from the tumor, RAMPS might be favorable to achieve a negative tangential margin. The body and tail of pancreas is located within the pararenal space, which lies between the peritoneum and anterior renal fascia. The kidney and adrenal gland are placed within the perirenal space, which lies behind the anterior renal fascia and in front of the peritoneum.

Table 2. Oncologic outcome and survival analysis

| Characteristic                        | Total (n = 43) | RAMPS groupa (n = 26) | DP groupb (n = 17) | P-value |
|---------------------------------------|----------------|-----------------------|-------------------|---------|
| Tumor differentiation                |                |                       |                   | >0.999  |
| Well differentiated                  | 5 (11.6)       | 3 (11.5)              | 2 (11.8)          |         |
| Moderately differentiated            | 34 (79.1)      | 21 (80.8)             | 13 (76.5)         |         |
| Poorly differentiated                | 4 (9.3)        | 2 (7.7)               | 2 (11.8)          |         |
| T stage                              |                |                       |                   | 0.071   |
| T2                                   | 5 (11.6)       | 1 (3.8)               | 4 (23.5)          |         |
| T3                                   | 38 (88.4)      | 25 (96.2)             | 13 (76.5)         |         |
| N stage                              |                |                       |                   | 0.349   |
| N0                                   | 23 (53.5)      | 12 (46.2)             | 11 (64.7)         |         |
| N1                                   | 20 (46.5)      | 14 (53.8)             | 6 (35.3)          |         |
| TNM staging                          |                |                       |                   | 0.069   |
| Stage IB                             | 3 (7)          | 0 (0)                 | 3 (17.6)          |         |
| Stage IIA                            | 20 (46.5)      | 12 (46.2)             | 8 (47.1)          |         |
| Stage IIB                            | 20 (46.5)      | 14 (53.8)             | 6 (35.3)          |         |
| Tumor size (cm)                      | 4.5 ± 1.5      | 4.6 ± 1.6             | 4.5 ± 1.5         | 0.013   |
| Count of retrieving lymph node       | 18.4 ± 8.8     | 21.5 ± 8.3            | 13.7 ± 7.4        | 0.003   |
| R0 resection                         | 33 (76.7)      | 22 (84.6)             | 11 (64.7)         | 0.018   |
| Negative tangential margin           | 36 (83.7)      | 25 (96.2)             | 11 (64.7)         | 0.011   |
| Recurrence                           | 16 (37.2)      | 8 (30.8)              | 8 (47.1)          | 0.043   |
| Metastasis                           | 22 (51.2)      | 11 (42.3)             | 11 (64.7)         | 0.215   |

Values are presented as number (%) or mean ± standard deviation.
RAMPS, radical antegrade modular pancreatosplenectomy; DP, distal pancreatectomy.

aTwo patients who had neuroendocrine carcinoma and two who had metastatic renal cell carcinoma were excluded in this analysis.
bTwo patients who had neuroendocrine carcinoma were excluded in this analysis.

Table 3. Disease-free survival and overall survival according to surgical procedure in 43 PDAC patients: RAMPS vs. DP

| Surgical procedure | No. | Disease-free survival (%) | Overall survival (%) |
|--------------------|-----|---------------------------|----------------------|
|                    |     | 1 yr | 2 yr | 3 yr | P-value | 1 yr | 2 yr | 3 yr | P-value |
| RAMPS              | 26  | 86.1 | 60.9 | 30.4 | 0.354   | 64.7 | 44.8 | 29.9 | 0.429   |
| DP                 | 17  | 52.4 | 52.4 | 35.0 |         | 58.8 | 35.3 | 29.4 |         |
| Total              | 43  | 72.6 | 58.3 | 33.3 |         | 62.2 | 41.7 | 29.6 |         |

PDAC, pancreas ductal adenocarcinoma; RAMPS, radical antegrade modular pancreatosplenectomy; DP, distal pancreatectomy.

Table 4. Disease-free survival and overall survival according to surgical procedure in 23 PDAC patients without nodal invasion: RAMPS vs. DP

| Surgical procedure | No. | Disease-free survival (%) | Overall survival (%) |
|--------------------|-----|---------------------------|----------------------|
|                    |     | 1 yr | 2 yr | 3 yr | P-value | 1 yr | 2 yr | 3 yr | P-value |
| RAMPS              | 12  | 100 | 83.3 | 55.6 | 0.048   | 70.7 | 56.6 | 42.4 | 0.197   |
| DP                 | 11  | 54.5 | 54.5 | 27.3 |         | 63.6 | 36.4 | 27.3 |         |
| Total              | 23  | 79.5 | 70.7 | 42.4 |         | 67.5 | 47.2 | 34.4 |         |

PDAC, pancreas ductal adenocarcinoma; RAMPS, radical antegrade modular pancreatosplenectomy; DP, distal pancreatectomy.
of a layer named the posterior renal fascia. In conventional DP, the dissection plane is usually placed just behind the posterior capsule of pancreas and in front of the anterior renal fascia. The operator usually lifts up the spleen located in the rib cage, and that motion causes an expressive force on the posterior part of pancreas. Therefore, the dismounting of the posterior aspect of pancreas can commonly occur in conventional DP, and it causes failure of obtaining a negative tangential margin. Making the correct posterior dissection plane is very important for the pancreatic cancer because the posterior margin is the most common site of remnant tumor cells which means R1 resection. Therefore, the right-to-left dissection of RAMPS is advantageous in order to secure the sufficient margin, especially in the posterior plane rather than the conventional DP. In our study, the negative rate of tangential margin was 90.2% in RAMPS group which was higher than those in DP group (64.7%, \( P = 0.011 \)). These results were better than the reported negative tangential margin rate of conventional DP and also comparable with previous reports using RAMPS, i.e., 91% in the study of Strasberg et al. [5,7] and 91.7% in the study of Chang et al. [6].

Radical dissection and sufficient harvest of lymph nodes are another main goal of RAMPS. In RAMPS procedure, the lymph nodes dissection has been performed on the basis of anatomic lymph node drainage of distal pancreas reviewed by O’Morchoe [8]. The regional lymph nodes including gastrasplicnic nodes, infrapancreatic nodes and splenic nodes were removed and the three lymph node groups including the gastroduodenal node and lymph nodes along the superior and inferior border of the pancreas were also eliminated in RAMPS. In our study, the mean counts of retrieved lymph nodes were higher in RAMPS group with a significant difference (\( P = 0.003 \)). We suppose our results might suggest the superiority of the RAMPS over the conventional DP in terms of oncologic feasibility including the negative rate of tangential margin and the radical dissection of lymph nodes.

Additionally, pancreatic cancer easily invades adjacent organs...
and major blood vessels. In RAMPS, the operator can achieve the en bloc resection without a transection of the tumor or separation of main mass from adjacent organs through gradual dissection. Although our data did not contain the actual invasion rate of adjacent organs on the permanent pathologic reports, authors suppose RAMPS could provide more opportunities for local treatment and curative resection for locally advanced pancreatic cancer with organ invasion.

In our study, the overall 1-, 2-, and 3-year DFS and OS after surgery showed no significant difference between the 2 groups. However, the N1 status would suggest the advancement of malignant cells beyond pancreas that progresses toward systemic disease. In such cases, the locoregional treatment including surgery has the limited effect for eradication of disease, and the great possibility of recurrence cannot be avoided even after achieving radical surgery. Therefore, we excluded the case having nodal invasion and recalculated the DFS and OS. The re-estimated DFS was significantly higher in RAMPS group although the recalculated OS had similar results between the 2 groups. The authors suppose, with prudence, that the advantage of RAMPS including the obtained negative tangential margin and radical lymph node dissection can be helpful in providing more curative chances for patients who have localized pancreatic cancer to have the cancer confined within the pancreas or adjacent tissues.

Although the RAMPS operation has many advantages as previously described, there are still many concerns about the invasiveness of operation due to its radical nature and unaccustomed procedures. However, our results for the RAMPS were comparable with the perioperative outcomes for conventional DP. 18 patients (46.2%) experienced postoperative morbidity without nodal invasion. Therefore, authors suggest the surgical approach for RAMPS would be safe and oncologically feasible in left-sided pancreatic cancer. Further prospective, well-designed trials with a large number of samples are required to confirm our results.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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