**Name of Journal: World Journal of Gastroenterology**

**ESPS Manuscript NO: 32562**

**Manuscript Type: ORIGINAL ARTICLE**

***Observational Study***

**Consequences of metabolic syndrome on postoperative outcomes after pancreaticoduodenectomy**

Zarzavadjian Le Bian A *et al*. Pancreaticoduodenectomy in patients with metabolic syndrome

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**Institutional review board statement:** The study was reviewed and approved by the *“Groupe de Réflexion Ethique”*, Centre Hospitalier Simone Veil, Eaubonne, France.

**Conflict-of-interest statement:** All authors have no conflict of interest.

**Data sharing statement:** No additional data are available.

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**Manuscript source:** Unsolicited manuscript

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**Telephone:** +33-6-85109112

**Received:** January 13, 2017

**Peer-review started:** January 14, 2017

**First decision:** February 23, 2017

**Revised:** March 3, 2017

**Accepted:** March 15, 2017

**Article in press:**

**Published online:**

**Abstract**

***Aim***

To analyze immediate postoperative outcomes after pancreaticoduodenectomy regarding metabolic syndrome.

***Methods***

In two academic centers, postoperative outcomes of patients undergoing pancreaticoduodenectomy from 2002 to 2014 were prospectively recorded. Patients presenting with metabolic syndrome [defined as at least three criteria among overweight (BMI ≥ 28kg/m²), diabetes mellitus, arterial hypertension and dyslipidemia] were compared to patients without metabolic syndrome.

***Results***

Among 270 consecutive patients, 29 (11%) presented with metabolic syndrome. In univariable analysis, patients with metabolic syndrome were significantly older (69.4 *vs* 62.5 years, *p* = 0.003) and presented more frequently with soft pancreas (72% *vs* 22%, *p* = 0.0001). In-hospital morbidity (83% *vs* 71%) and mortality (7% *vs* 6%) did not differ in the two groups so as pancreatic fistula rate (45% *vs* 30%, *p* = 0.079) and its severity of pancreatic fistula (*p* = 0.257). In multivariable analysis, soft pancreas texture (*p* = 0.001), pancreatic duct diameter < 3 mm (*p* = 0.025) and BMI > 30 kg/m² (*p* = 0.041) were identified as independent risk factors of pancreatic fistula after pancreaticoduodenectomy, but not metabolic syndrome.

***Conclusion***

In spite of logical reasoning and appropriate methodology, present series suggests that metabolic syndrome did not jeopardize postoperative outcomes after pancreaticoduodenectomy. Therefore, definition of Metabolic Syndrome seems to be inappropriate and fatty pancreas needs to be assessed with an international consensual histopathological classification.

**Key words**: Metabolic syndrome; Pancreaticoduodenectomy; Soft pancreas; Postoperative outcomes

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**Core tip:** As metabolic syndrome is related to fatty pancreas and fatty pancreas is related to pancreatic fistula, postoperative morbi-mortality should theoretically increase in patient with metabolic syndrome and undergoing pancreaticoduodenectomy. In two academic centers, postoperative outcomes of 270 consecutive patients undergoing pancreaticoduodenectomy were retrospectively compared in regards of metabolic syndrome. In multivariable analysis, soft pancreas texture (*p* = 0.001), pancreatic duct diameter < 3 mm (*p* = 0.025) and BMI > 30 kg/m² (*p* = 0.041) were identified as independent risk factors of pancreatic fistula after pancreaticoduodenectomy, but not metabolic syndrome. The present series suggests that metabolic syndrome did not jeopardize postoperative outcomes after pancreaticoduodenectomy.

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**INTRODUCTION**

In spite of recent advances in pancreatic surgery, pancreaticoduodenectomy (PD) is still seen as a demanding procedure, ideally performed by experienced teams in high volume centres[1]. Indeed, when a decrease in postoperative mortality after PD has been observed over the last decades, it has not been associated with a similar reduction in morbidity rates that still ranges from 30% to more than 70%. Still, PD represents nowadays the main curative option for lesion located in the pancreatic head. Pancreatic fistula (PF) is the most common complication following PD and is responsible for a significant mortality and morbidity[2]. An extensive literature analysis identified several preoperative risk factors such as fatty pancreas infiltration, intra-abdominal obesity, all possibly related to metabolic syndrome (MS).

MS is defined by the association of three criteria among increased waist circumference or overweight/obesity, arterial hypertension, decreased serum HDL cholesterol, increased serum triglycerides and diabetes mellitus (DM) or increased fasting glucose[3]. With a rising incidence[4], it has become a contemporary concern. Yet, MS has been linked to fatty pancreas when obesity is involved[5] and fatty pancreas is also associated with DM (without MS)[6]. Interestingly, fatty pancreas and increased body mass index (BMI) are associated to increased rate of pancreatic fistula (PF)[7-9]. Additionally, both impaired performance status of these patients as a consequence of advanced age, central obesity, diabetes mellitus and cardiovascular co-morbidities, as well as the impact of the underlying liver status, may have impact after pancreatic surgery. Therefore, theoretically, MS could adversely affect the postoperative course in patients undergoing PD. These issues are still largely unclear and currently, only one study has analyzed the influence of MS on postoperative outcomes in pancreatectomy[10], showing increased postoperative morbidity.

Therefore, the present series aimed to characterize the outcomes in MS patients who underwent PD in order to determine the influence of the MS on the postoperative course.

**MATERIAL AND METHODS**

***Patient’s selection***

From February 2002 to December 2014, data of all consecutive patients undergoing PD at Institut Mutualiste Montsouris (Paris, France) and Hôpital Antoine Béclère (Clamart, France) were retrieved from a prospectively collected database. Surgical approach and pancreatic reconstruction [pancreaticojejunostomy (PJ) or pancreaticogastrostomy (PG)] was left to the surgeon’s discretion. The diagnosis of MS was considered when three or more of the following criteria were present[3]: central obesity; dyslipidemia (triglycerides 1.7 mmol/l or above, or high-density lipoprotein cholesterol less than 1.03 mmol/l in men or less than 1.29 mmol/l in women); type II diabetes or glucose intolerance with fasting glucose 5.6 mmol/l or above; and arterial hypertension (blood pressure above 135/85 mmHg). Because of the retrospective nature of the study, it was assumed that central obesity was reached when the patient’s body mass index was greater than 28 kg/m2 {as normal WHO BMI < 25 kg/m²[11]}, that patients receiving statin or fenofibrate medication had dyslipidemia, that patients treated for hypertension had arterial hypertension. In spite of recent results[12], level of serum uric acid was not considered as it was not routinely performed.

***Preoperative evaluation and postoperative outcomes***

Preoperative investigations included complete blood tests as well as routine cardiorespiratory evaluation. Computed tomography (CT) and/or magnetic resonance imaging were performed to assess tumor characteristics.

All resections were performed with curative intent. All intraoperative parameters, including blood loss with subsequent blood transfusion and duration of surgery, were recorded. The pancreatic parenchyma consistency, soft or hard, was evaluated intra-operatively by the surgeon by manual palpation of the pancreatic remnant. Pancreatic duct diameter was measured using a scale.

Postoperative complications were stratified according to the Clavien–Dindo classification[13], which defines major complications by a score of 3 or more. Specific pancreatic complications were detailed as follows: PF was defined according to the ISGPF definition[14]; haemorrhage was defined as a drop of haemoglobin level > 3 g/dl after the end of surgery compared to postoperative baseline level and/or any postoperative transfusion of packed red blood cell units for a falling haemoglobin and/or the need for invasive re-intervention[15] and biliary leakage was defined by a bilirubin concentration in the drainage fluid more than threefold higher than that in serum[16]. Both complications and operative mortality were considered as those occurring within 90 d of surgery, or at any time during the postoperative hospital stay.

***Statistical analysis***

Patient baseline characteristics are expressed as median (range) for continuous data, and as numbers with percentages for categorical data. Fisher’s exact test was used to compare differences in categorical variables, and the Wilcoxon rank sum test for continuous variables. Variables achieving statistical significance at the 0·1 level in univariable analysis were considered for multivariable analysis. A backward variable procedure was used to identify independent predictive factors. A *p*-value of 0.05 was considered statistically significant and odds ratios (OR) with 95% confidence intervals (CI) were calculated. All statistical analyses were performed with PASW (SPSS) 18.0 (SPSS Inc, Chicago, IL).

**RESULTS**

***Patients’ characteristics***

From 2002 to 2014, 270 patients underwent PD. There were 169 (63%) males with a median age of 64.5 years (range 30.6–88.7). Among these patients, 29 (11%) were diagnosed with MS, defining the MS group. Patients’ characteristics depending on MS are detailed in Table 1.

MS patients were significantly older (69.4 *vs* 62.5 years, *p =* 0.003) than non-MS patients. MS group presented more frequently with jaundice (31% *vs* 20%, *p =* 0.004) and required biliary stenting more often than the Non-MS group (59% *vs* 34%, *p =* 0.008). Tumor characteristics (such as indications for PD)(Table 1)and indication for neoadjuvant treatment were comparable in the two groups.

***Surgical procedures***

Intraoperative blood loss, operative time and resection of adjacent organs were similar in both groups (Table 2). In 65 (24%) patients, the PD was completed laparoscopically. Resection of the portal vein was required in 44 (16%) patients. During surgical examination, soft pancreatic parenchyma was more frequently observed in patients with MS (72% *vs* 22%, *p =* 0.0001). Pancreaticogastrostomy (PG) and pancreaticojejunostomy (PJ) were performed in 109 (40%) and 161 (60%) patients, respectively, with no difference in the two groups.

***Pathology and postoperative outcomes***

Among 232 (86%) patients who underwent PD for malignancy, R0 resection was achieved in 183 (79%) patients with no difference between the two groups. Seventeen (6%) patients died during the early postoperative period, three had MS. Postoperative complications are detailed in Table 3. Statistical analysis revealed no significant difference between MS and Non-MS groups regarding overall (*p =* 0.195), minor (*p =* 0.639) and major (*p =* 0.123) complications. Pancreatic fistula and its severity were comparable in the two groups even though there was a non-significant tendency towards higher PF in the MS group. Multivariate analysis (Table 4) demonstrated soft pancreas texture (*p =* 0.001), pancreatic duct diameter < 3 mm (*p =* 0.025) and BMI > 30 kg/m² (*p =* 0.041) as independent risk factors however MS was not. Delayed gastric emptying and haemorrhage rate were comparable in the two groups. Overall, median in-hospital stay reached 23 d with no difference in the two groups.

**DISCUSSION**

This study has been initially designed from a simple statement: because of demonstrated links between MS/obesity/DM[3,5-7] and fatty pancreas, and between fatty pancreas/obesity and PF after PD[7-9], common sense compels to guess that MS should be related to an increased rate of PF after PD. Also, as PF is also related to increased in-hospital mortality[17], the question of the link between MS and perioperative mortality seems pertinent. Regarding these queries, conclusions of this study may lead to change preoperative and intraoperative managements in patients presenting with MS like previous studies have changed management in liver resections[18].

First, and considering pancreatic texture, soft pancreas (at intraoperative evaluation) has been previously related to fatty pancreas[19] and obesity[20]. In this analysis, soft pancreas, pancreatic duct diameter < 3 mm and obesity (BMI > 30 kg/m²) are demonstrated as independent risk factors of PF. Such results are in accordance with previous reports[7-9,21,22] and consequently are strengthening the background, coherence and methodology of this study. Indeed, compared to fatty pancreas as a predictive criterion (an histopathological finding requiring the specimen and available at least one week after the procedure), BMI can be assessed in the clinic, soft pancreas and duct dilatation are defined during the surgical procedure, enabling to modify the surgical strategy and to adapt the postoperative management. Interestingly, due to the subjectivity of evaluation (depending on the surgeon), soft pancreas texture may be argued as being unreliable. Also and considering PF, no other independent risk factor was identified, including DM and MS.

Regarding the influence of MS on PF and postoperative mortality, no link was demonstrated in this study. So far, several studies evaluating individually components of MS (mainly DM and obesity) are well known but only one analysis regarding MS and pancreatic resection has been reported[10]. This previous report showed an increased morbidity (including severe morbidity, but without increased rate of PF) regarding all pancreatic resections[10]. Currently, in scientific literature, DM is demonstrated as being associated to soft pancreas[6] but not to an increased rate of PF in PD[23]. On the contrary, obesity has already been related to an increased risk of PF[7-9] and to soft pancreas[20]. Unfortunately, in all these studies MS was not evaluated as an independent risk factor. On the subject of postoperative mortality (and regardless PF), MS did not show any effect in this study. Because of MS and potential frailties (DM, arterial hypertension and their vascular consequences), a higher mortality rate could have been expected in MS group. In accordance with such hypothesis, MS has been recently linked to postoperative mortality after various surgical procedures such as liver resections[17,24,25], vascular procedures[26] and urology[27], and is known to be responsible for reduced life expectancy[28]. Also, with a well-known link between PF and postoperative mortality in PD[17], an increased rate of PF related to MS in this study would have resulted in an increased mortality. The analysis has refuted this hypothesis. Comparison of the PF Grade according to ISGPF Classification did not show any difference as well. These results suggest that MS does not lead to major complications. Consequently, without increased rate of PF and postoperative mortality, MS should not be seen as a contraindication to perform a PD.

This study and its results are worth a commentary as it failed to reach significance in spite of a consistent reasoning. When methodology may be commented - this small sample was recorded during a decade and retrospectively analyzed -, results suggest it is appropriate. So, failure to reach significance (MS increasing PF and mortality) needs to be rationalized. As previously described, fatty pancreas, soft pancreas (evaluated and depending on surgeons), MS and its independent criteria (mainly obesity and DM) composed a group of interrelated affections. Considering PD, several reports have supported all these affections as being independent risk factors of PF (except DM that is not a risk factor of PF in spite of being a risk factor of fatty pancreas). Also, regarding influence of DM on PF, a recent meta-analysis[23] showed a protective effect of DM, with more fatty pancreas and soft pancreas in patients without DM. These results lead to two remarks. First, when the targeted disease is insulin resistance, definition of MS does not discriminate between types of DM: DM type 1 and 2, lack of insulin and insulin resistance, respectively. Yet, a lesion in the head of pancreas may result in atrophy of pancreas, endocrine pancreatic insufficiency and lack of insulin known as DM type 1. And such a lesion may lead to hard pancreas during PD with decreased PF rate (as previously described). This conclusion and discrepancies regarding DM and PF in current scientific literature should lead to reassess current definition of MS. Also, this study (showing only obesity as an independent factor of PF among MS criteria) and divergences in literature suggest that the understanding of fatty pancreas and soft pancreas are unresolved, probably incorrect. Indeed, manual palpation is subjective and enables an appropriate assessment for mild or massive pancreatic steatosis by simple inspection in surgical setting[29]. Yet, fatty pancreas is defined using pathological examination[30] and can be uneven in pancreas[31] compelling to propose another method to assess fatty pancreas as the role of pathologist in fatty pancreas is not standardized. In preoperative setting, MRI is currently considered as being as effective as histology when assessing fatty infiltration[32]. Still, a consensual and standardized histopathological examination assessing fatty infiltration[30] and fibrosis[33] of pancreatic parenchyma is required, as it has been proposed in Non-Alcoholic Fatty Liver Disease (NAFLD)[34]. Also, like in NAFLD, microcirculation disorders should be investigated in fatty pancreas: in NAFLD, microcirculation has been reported as being altered[35] potentially leading to an increased mortality after hepatectomy[36]. Ischemic process related to microcirculation disorders in fatty pancreas could explain an increased rate of pancreatic fistula and pancreatic insufficiency.

Finally, results of this study should be mitigated owing to usual flaws. This series has been recorded retrospectively (in spite of a prospective inclusions). The length of the study – more than a decade - was required to reach a proper number, so management may have changed during the timeline. In the same way, different surgeons from two centres have been recorded and may have improved. Then, in-hospital mortality may be discussed due to a high rate (6%). Indeed, this rate seems to be overestimated as it is calculated as overall in-hospital mortality: in-hospital 30-d mortality and in-hospital 90-d mortality reached 4% and 6%, respectively. These results are in accordance with previous occidental studies[37], obviously, not as impressive as expert centre outcomes[38] including in France[39]. Yet, we believe that despite its retrospective design and mortality rate, this report, the first of its kind, should lead to reassess concepts of fatty pancreas and MS.

This study confirmed soft pancreas, pancreatic duct diameter < 3 mm and obesity as independent factors of PF after PD. Also, the supposed link between MS and PF after PD was not observed in the present series. Further investigations should be designed, mainly in order to confirm these results and to homogenize concepts of MS and fatty pancreas.

**comments**

***Background***

With a rising incidence in western countries and association with various digestive disorders, metabolic syndrome (MS) has become a hot topic in digestive surgery including in pancreatic resection (due to fatty pancreas).

***Research frontiers***

Theoretically, as MS is related to fatty pancreas and fatty pancreas is related to pancreatic fistula, pancreatic fistula occurrence should increase in patients presenting with MS and undergoing pancreaticoduodenectomy. Also, as pancreatic fistula is related to an increased postoperative mortality, postoperative mortality should be increased. Yet, no analysis of perioperative outcome after pancreaticoduodenectomy has been reported.

***Innovations and breakthroughs***

When this analysis showed independent factors of pancreatic fistula in accordance with previous reports, the supposed link between MS and pancreatic fistula after pancreaticoduodenectomy was not observed in the present series. Further investigations should be designed, mainly in order to confirm these results and to homogenize concepts of MS and fatty pancreas.

***Applications***

MS should not be seen as a contraindication to pancreaticoduodenectomy.

***Terminology***

MS is defined by the association of three criteria among increased waist circumference or overweight/obesity, arterial hypertension, decreased serum HDL cholesterol, increased serum triglycerides and diabetes mellitus or increased fasting glucose.

***Peer-review***

This is an interest paper. It is based on important considerations and the findings are interesting. There are some points to be addressed before considering it for publication.

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**P-Reviewer:** Luchini c **S-Editor:** Ma YJ **L-Editor:** **E-Editor:**

**Specialty type:** Gastroenterology and hepatology

**Country of origin:** France

**Peer-review report classification**

Grade A (Excellent): 0

Grade B (Very good): B

Grade C (Good): 0

Grade D (Fair): 0

Grade E (Poor): 0

**Table 1 Demographic characteristics *n* (%)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Non-MS group**  **(*n* = 241)** | **MS group**  **(*n* = 29)** | ***p*-value** |
| **Preoperative characteristics** |  |  |  |
| Male gender | 148 (61) | 21 (72) | 0.170 |
| Age (yr), mean (range) | 62.5 (30.6-88.7) | 69.4 (52.1-80.3) | 0.003 |
| > 75 yr | 8 (28) | 42 (17) | 0.141 |
| ASA score ≤ 2 | 204 (85) | 22 (76) | 0.171 |
| Median BMI (kg/m2) | 23.5 | 27.2 | 0.001 |
| > 30 kg/m2 | 11 (5) | 6 (21) | 0.0001 |
| Diabetes | 26 (11) | 18 (62) | 0.0001 |
| Hypertension | 66 (28) | 28 (97) | 0.0001 |
| Dyslipidemia | 33 (14) | 25 (86) | 0.0001 |
| Cardio-respiratory comorbidity |  |  |  |
| Coronary heart disease | 17 (7) | 4 (14) | 0.181 |
| COPD | 7 (3) | 1 (3) | 0.608 |
| Alcohol | 34 (14) | 3 (10) | 0.401 |
| Tobacco | 45 (19) | 3 (10) | 0.190 |
| **Initial presentation** |  |  |  |
| Jaundice | 47 (20) | 9 (31) | 0.004 |
| Biliary stenting | 80 (34) | 17 (59) | 0.008 |
| Abdominal pain | 74 (31) | 4 (14) | 0.179 |
| Baseline CA 19-9, mean (range) | 312.8 (0-5300) | 430.4 (35.2-1054) | 0.710 |
| Tumor diameter > 30 mm | 80 (34) | 6 (21) | 0.838 |
| **Indications** |  |  |  |
| Malignant disease | 211 (86) | 27 (93) | 0.516 |
| Adenocarcinoma | 141 (59) | 17 (59) | 0.842 |
| Malignant ampuloma | 25 (10) | 2 (7) | 0.557 |
| Cholangiocarcinoma | 21 (9) | 5 (17) | 0.142 |
| Endocrine tumor | 10 (4) | 2 (7) | 0.499 |
| Other | 14 (6) | 1 (3) | 0.148 |
| Benign disease | 30 (12) | 2 (7) | 0.385 |
| IPMN | 22 (9) | 1 (3) | 0.302 |
| Other | 8 (3) | 1 (3) | 0.742 |

MS: Metabolic syndrome; ASA: American society of anesthesiologists; BMI: Body mass index; COPD: Chronic obstructive pulmonary disease; IPMN: Intraductal papillary mucinous neoplasm.

**Table 2 Intraoperative characteristics *n* (%)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Non-MS group**  **(*n* = 241)** | **MS group**  **(*n* = 29)** | ***p*-value** |
| Soft pancreatic texture | 53 (22) | 21 (72) | 0.0001 |
| Pancreatic duct diameter < 3 mm | 84 (35) | 13 (45) | 0.295 |
| Vein resection | 39 (16) | 5 (17) | 0.560 |
| Visceral resection | 21 (9) | 3 (10) | 0.490 |
| Median surgery duration (mn) | 430 | 462 | 0.285 |
| Median blood loss (ml) | 400 | 600 | 0.287 |
| Perioperative transfusion | 16% | 29% | 0.002 |

MS: Metabolic syndrome.

**Table 3 Postoperative outcomes *n* (%)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Non-MS group**  **(*n* = 241)** | **MS group**  **(*n* = 29)** | ***p*-value** |
| Postoperative complications | 170 (71) | 24 (83) | 0.195 |
| Clavien I-II complications | 77 (32) | 9 (31) | 0.639 |
| Clavien III-IV complications | 78 (32) | 12 (41) | 0.123 |
| Postoperative mortality | 15 (6) | 2 (7) | 0.302 |
| Pancreatic fistula | 72 (30) | 13 (45) | 0.079 |
| Grade of pancreatic fistula |  |  | 0.257 |
| A | 16 (22) | 4 (31) |  |
| B | 22 (31) | 5 (38) |  |
| C | 34 (47) | 4 (31) |  |
| Delayed gastric emptying | 12 (5) | 1 (3) | 0.583 |
| Abdominal collection | 54 (22) | 7 (24) | 0.496 |
| Haemorrhage | 44 (18) | 6 (21) | 0.800 |
| Biliary fistula | 16 (7) | 1 (3) | 0.762 |
| Gastroenteric anastomosis fistula | 5 (2) | 1 (3) | 0.814 |
| Pulmonary complications | 35 (15) | 8 (28) | 0.057 |
| Reoperation | 59 (24) | 5 (17) | 0.921 |
| Hospital stay (d), median | 22 | 25 | 0.972 |

MS: Metabolic syndrome.

**Table 4 Risk factors of pancreatic fistula *n* (%)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | **Univariate analysis** | | | **Multivariable analysis** | | |
|  | **No pancreatic fistula**  **(*n* = 185)** | **Pancreatic fistula**  **(*n* = 85)** | | ***p*-value** | **HR** | | **95%CI** | ***p*-value** |
| **Preoperative characteristics** |  |  | |  |  | |  |  |
| Male gender | 108 (58) | 61 (72) | | 0.023 | 1.45 | | 0.038-9.204 | 0.418 |
| Age > 75 yr | 33 (18) | 17 (20) | | 0.394 |  | |  |  |
| ASA score ≤ 2 | 161 (87) | 65 (76) | | 0.125 |  | |  |  |
| BMI > 30 kg/m2 | 6 (3) | 11 (13) | | 0.005 | 2.02 | | 1.034-3.284 | **0.041** |
| Diabetes | 33 (18) | 11 (13) | | 0.193 |  | |  |  |
| Hypertension | 57 (31) | 37 (44) | | 0.041 | 1.03 | | 0.005-14.58 | 0.250 |
| Dyslipidemia | 33 (18) | 25 (29) | | 0.132 |  | |  |  |
| Metabolic syndrome | 16 (9) | 13 (15) | | 0.137 |  | |  |  |
| Coronary heart disease | 10 (5) | 11 (13) | | 0.049 | 3.51 | | 0.108-2.071 | 0.865 |
| COPD | 7 (4) | 1 (1) | | 0.443 |  | |  |  |
| Alcohol | 21 (11) | 16 (19) | | 0.083 | 0.25 | | 0.024-3.578 | 0.725 |
| Tobacco | 28 (15) | 20 (23) | | 0.125 |  | |  |  |
| Malignant disease | 165 (89) | 73 (86) | | 0.825 |  | |  |  |
| **Surgical procedures** |  |  | |  |  | |  |  |
| Pancreatogastrostomy | 76 (41) | 33 (39) | | 0.893 |  | |  |  |
| Soft pancreatic texture | 42 (23) | 32 (38) | | 0.001 | 3.37 | | 1.124-3.217 | **0.001** |
| Pancreatic duct diameter < 3 mm | 55 (30) | 42 (49) | | 0.003 | 1.45 | | 1.045-2.452 | **0.025** |
| Vein resection | 38 (20.5) | 6 (7.0) | | 0.002 | 2.25 | | 0.045-4.393 | 0.486 |
| Arterial resection | 2 (1.0) | 0 (0) | | 0.925 |  | |  |  |
| Visceral resection | 17 (9) | 7 (8) | | 0.499 |  | |  |  |
| Perioperative Transfusion | 27 (15) | 14 (16) | | 0.528 |  | |  |  |

MS: Metabolic syndrome; ASA: American society of anesthesiologists; BMI: Body mass index; COPD: Chronic obstructive pulmonary disease.