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Conversion during minimally invasive left pancreatectomy: a nationwide study of causes and consequences

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SHORT RUNNING HEAD

Causes and consequences of conversion during MILP

CONFLICT OF INTEREST DISCLOSURES

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DATA SHARING STATEMENT

Considering French legislation and current standards, the data are only accessible upon submission of a research project to the Sorbonne Ethics Committee (CER).

KEY WORDS

Left pancreatectomy, Laparoscopy, Robot, minimally invasive, conversion

ABSTRACT

Objectives: To identify risk factors for conversion, develop a predictive Conversion Risk Score (CRS), and assess the association between conversion and severe postoperative complications.

Background: Conversion occurs in 15-30% of minimally invasive left pancreatectomies (MILP). Risk factors and potential negative impacts on postoperative outcomes are poorly described.

Methods: Retrospective, nationwide, multicenter study including all MILP (laparoscopy and robot) performed between 2010 and 2021. Risk factors for conversion were identified by multivariate mixed model, and a CRS was developed on a "training-set" and validated (calibration diagrams and ROC curves) on a "validation-set." The association between severe complications and conversion was assessed using a propensity score based on the main risk factors for severe complications: age, sex, BMI, ASA score, tumor malignancy, multi-organ resection, operative duration, blood loss, splenectomy.

Results: 2104 patients included from 55 centers. Conversion occurred in 15.6% of MILP. Its risk factors were male sex (OR=1.67;p=0.048), BMI≥25kg/m^2 (OR=2.15;p=0.004), history of laparotomy (OR=2.9;p<0.001), initial pancreatitis (OR=3.58;p=0.007), tumor size≥40mm (OR=2.12;p=0.003), planned splenectomy (OR=2.63;p<0.001), unplanned splenectomy (OR=4.05;p=0.028), portal vein resection (OR=36.3;p=0.002), multi-organ resection

(OR=12.97;$p<0.001$). A predictive CRS was created based only on preoperatively available variables (the first six), with scores ranging from 0 to 7, corresponding to a conversion risk of 2% to 100%. No association was observed with tumor malignancy, robotic approach, or pancreatectomy volume. Conversion was significantly associated with severe complications [OR=1.80(1.16-2.54)], independent of other risk factors for complications.

Conclusions: Conversion during MILP can be predicted by CRS, aiding surgeons in decision-making, given its significant association with severe complications.

INTRODUCTION

While the minimally invasive approach has been established as the gold standard for various surgical procedures [1,2], its application has also been extended and validated for minimally invasive left pancreatectomy (MILP) [3,4], resulting in reduced intraoperative blood loss and shorter hospital stay [5]. The robot-assisted approach seems to provide comparable outcomes to laparoscopy, but its relevance is still under evaluation [6–8]. Nevertheless, the choice between open and minimally invasive approaches requires careful patient selection to prevent intraoperative complications and conversion. The conversion rates reported in the literature are highly variable, ranging from 15% to 30% [4,9–12]. Existing data on risk factors for conversion during MILP are notably inconsistent, potentially including tumor size and malignancy [13], extent of pancreatic resection [14,15], unplanned splenectomy [9], increased body mass index (BMI), low preoperative albumin levels, current smoking habits, chronic pancreatitis [16], male sex, multi-organ resection, laparoscopy (compared to robotic approaches) [17], volume of the center [18], and learning curve [19]. These divergent findings make it challenging for surgeons to confidently select patients for a minimally invasive approach in daily practice. To date, no robust predictive score has been proposed to guide surgeons preoperatively during the decision-making process. Given the data suggesting an association between conversion and severe postoperative morbidity [20,21], attempts to reduce the risk of conversion seem relevant. However, several risk factors are common to both conversion and postoperative complications [17], leading to a potential bias in accurately evaluating the consequences of conversion.

Given these considerations, the present study has two interrelated objectives. First, to identify and assess preoperative risk factors for conversion during MILP and to create a clinically applicable predictive Conversion Risk Score (CRS). Second, to investigate the association between conversion during MILP and severe postoperative complications.

METHODS

Population

This multicenter retrospective study included patients undergoing minimally invasive left pancreatectomy (MILP) [22] in both private and public hospitals, both academic and non-academic. The participating centers were contacted through the *Association Française de Chirurgie*. All adult patients (≥18 years) who underwent MILP (laparoscopic and robot-assisted) between January 2010 and December 2021 were included, regardless of indication. Patients who had undergone previous pancreatectomy were excluded. Patients who underwent pancreatic surgical biopsy or necrosectomy, as well as those who underwent pancreatectomy by initial laparotomy or using a hybrid procedure, defined as planned surgery combining a first-stage minimally invasive procedure followed by a planned open approach (except for specimen extraction), including hand-assisted procedures, were also excluded.

This study was approved by the Ethics and Research Committee of Paris Sorbonne University (CER-2022-055) and performed in accordance with the ethical principles of the Declaration of Helsinki. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed [23].

Creation of the Predictive Conversion Risk Score (CRS)

The first aim was to build a predictive CRS based on preoperative factors to assess the risk of conversion during MILP. To calculate this score, univariate and multivariate analyses were performed on a training set randomly derived from the entire cohort. Based on these results, only preoperative variables that were significantly associated with the risk of conversion were selected. Their coefficients, obtained using the multivariate mixed model, were rounded to the nearest integer to obtain values without decimals, which are easier to use in clinical practice. The CRS was then validated on a validation set, randomly derived from the entire cohort, using ROC curve analysis and calibration diagrams.

Propensity Score Matching

The association between conversion and severe postoperative morbidity (according to Dindo-Clavien classification ≥3) [24] was assessed using propensity score matching based on the main risk factors for postoperative complications after MILP [25–27]: Age, Sex, BMI, ASA score, Malignancy, Multi-organ resection, Operative time, Blood loss, and Splenectomy (planned and unplanned). Multiple logistic regression analysis was applied to generate a propensity score, and the “nearest-neighbor matching method” was used, which involves pairing each point with the closest one, to achieve 1:1 matching using the “MatchIt” package in R software. Correct balance of the propensity score variables was verified by ensuring that the standardized mean differences were <0.1 **(Supplement 1, Supplemental Digital Content 1, http://links.lww.com/SLA/F424)**.

Main variables and outcomes

The primary endpoint was conversion, defined according to the last standardized terminology for minimally invasive pancreatic resection, as any procedure that started as minimally invasive but terminated by an unplanned or unintended laparotomy [28].

Tumor malignancy included all indications for cancer (pancreatic duct adenocarcinoma, sarcoma, and metastases) and conditions requiring lymph node dissection (pancreatic neuroendocrine tumor).

Statistical Analysis

Quantitative variables were expressed as mean (± SD) or median (IQR) based on the normality of their distribution, assessed both graphically and using the Shapiro-Wilk test. These variables were compared in univariate analyses using the Mann-Whitney U test or Student's t-test, depending on their respective applicability. Qualitative variables were expressed as numbers and percentages and compared in univariate analyses using the Chi-square test or Fisher's exact test, depending on the sample size and test conditions.

For missing data representing less than 15% of observations and defined as "missing at random," multiple imputation using Predictive Mean Matching (PMM) sampling was conducted with ten iterations, and the results were pooled from these ten imputed datasets [(29)]. If the missing data exceeded 15% or were not "missing at random," the variable was omitted.

The training and validation sets were randomly created from the entire cohort using R software's *"sample"* function (sampling without replacement). The size of the sets was chosen according to the cohort size and the representativeness of the primary endpoint. The commonly applied ratios in this type of study are 70%/30% or 80%/20% [(30–33)]. However, to avoid the risk of overfitting during model validation, a larger size was allocated to the validation set, with ratios of 70% (training set) and 30% (validation set). No statistical tests were performed to compare and verify the correct distribution of variables to avoid inflation of alpha risk. Therefore, the quality of the distribution between the two sets was determined using an "eyeball test" **(Supplement 2, Supplemental Digital Content 2, http://links.lww.com/SLA/F425)**.

In multivariate analyses, the center effect was converted into a random effect variable and addressed using a generalized linear mixed model (GLMM) [(34)] to satisfy the conditions for applying logistic regression. Variables incorporated into the GLMM were selected based on a p-value <0.10 in the univariate analyses, as well as variables with well-established associations with the outcome in the literature. Variables linked to the type of center were not included in the multivariate model since the center effect was already accounted for by the GLMM to avoid redundancy and collinearity, which could compromise model convergence. The quantitative variables in the multivariate analysis were discretized into binary variables (cut-off points obtained from an analysis of distribution curve breakpoints using an ROC curve) to make the predictive score more efficient for clinical use at the risk of losing power. The predictive score was subsequently based on the coefficients derived from the GLMM for variables with $p < 0.05$.

In the analysis following propensity score matching, the center effect was again converted into a random effect variable and addressed using a GLMM.

All tests were two-sided with a type I error rate of 5%. Analyses were performed using R software version 4.2.3 on macOS.

RESULTS

Cohort characteristics (Figure 1)

Overall, 55 centers included 2104 MILP: 13.4% (n=281) by robotic approach and 86.6% (n=1823) by laparoscopy. **Table 1 and 2** details the characteristics of the entire cohort. The average age of the patients was 59.9 (±14.9) years, with a slight female predominance of 57.2% (n=1203). The average BMI was 25.9 (±4.9) kg/m^2 and 17.4% (n=357) had an ASA score ≥3. Malignant tumors accounted for 58.0% (n=1221), including 30.1% (n=633) pancreatic neuroendocrine tumors and 23.8% (n=500) pancreatic ductal adenocarcinomas. Pancreatic lesions were mainly discovered incidentally (47.1%; n=990).

Conversion to laparotomy was performed in 15.6% (n=329) of the patients: 34.3% (n=113) for exposure and technical issues, 26.1% (n=86) for hemorrhage, 20.1% (n=66) for inflammatory adhesions, 18.5% (n=61) for oncological reasons, and 0.9% (n=3) for anesthetic issues. Regarding patients operated on by the robot-assisted approach, all conversions were performed using an open approach. Splenectomy was performed in 46.3% (n=974) of the cases, including 4.1% (n=86) that were performed emergently. Colectomy or duodenojejunal flexure resection, partial gastrectomy, hepatectomy, and nephrectomy were performed in 1.8% (n=37), 1.5% (n=32), 0.1% (n=3), and 0.3% (n=7) of the patients, respectively. Anterior and posterior radical antegrade modular pancreatosplenectomy (RAMPS) [35] were performed in 26.2% (n=552) and 1.7% (n=35) of the patients, respectively.

The postoperative mortality and severe morbidity rates were 1.3% (n=28) and 17.8% (n=375), respectively. Postoperative pancreatic fistula (POPF) grades B and C [36] occurred in 18.7% (n=393) of patients. The mean length of hospital stay was 11.8 (±9.6) days, and reoperation occurred in 5.6% (n=118) of the patients due to hemorrhage in 3% (n=59), sepsis in 2% (n=44), intestinal obstruction in 0.2% (n=4), evisceration in 0.2% (n=4), oncological needs in 0.1% (n=3), drainage issues in 0.1% (n=3), and digestive ischemia in 0.05% (n=1).

Creation of a clinical predictive Conversion Risk Score (CRS)

Identification of risk factors of conversion, in the training set

The results of univariate and multivariate analyses of the preoperative and intraoperative risk factors for conversion are provided in **Table 3**. Independent risk factors for conversion in the multivariate analysis were male sex (OR=1.67; 95% CI=1.01-2.80), overweight with BMI ≥25kg/m^2 (OR=2.15; 95% CI=1.28-3.68), history of abdominal laparotomy (OR=5.68; 95% CI=2.59-12.62), initial pancreatitis (OR=3.58; 95% CI=1.42-9.13), tumor size ≥40 mm (OR=2.12; 95% CI=1.34-3.38), portal vein resection (OR=36.3; 95% CI=4.74-422.45), planned splenectomy (OR=2.63; 95% CI=1.51-4.67), unplanned splenectomy (OR=4.05; 95% CI=1.16-14.39), and multi-organ resection (OR=12.97; 95% CI=3.95-45.84). In multivariate analysis, there was no significant difference according to age, ASA score, tumor malignancy, robot-assisted approach, right pancreatic section at the head-neck junction, or RAMPS.

Finally, no significant association was found between the risk of conversion and the activity volume of each center, both in terms of the number of pancreatic surgeries performed using a minimally invasive approach per center and the number of MILP performed.

Within the subgroup of patients who underwent MILP for pancreatic ductal adenocarcinoma (n=500), a similar univariate and multivariate analysis was performed (**Supplement 3, Supplemental Digital Content 3, http://links.lww.com/SLA/F426**), revealing the same variables associated with conversion, except for age, pancreatic consistency, transection to the right of the isthmus, and splenectomy. Neither resectable (n=461), borderline (n=34), nor locally advanced (n=5) status, nor the administration of neoadjuvant treatment with chemotherapy alone (n=48) or chemoradiotherapy (n=15) was independently associated with conversion, particularly when accounting for multiorgan resection or portal vein resection.

Development of the predictive CRS, in the training set

Based on the results obtained from the multivariate analysis (**Table 3**), only preoperatively available variables associated with the risk of conversion were selected: male sex, overweight (BMI ≥25kg/m^2), history of abdominal laparotomy, initial pancreatitis, tumor size ≥40 mm, and planned splenectomy. A predictive CRS was then created (**Table 4**) and a coefficient of 1 or 2 was assigned to each variable, resulting in a total score ranging from 0 to 7 points.

Validation of the CRS, in the validation set

The area under the curve (AUC) of the predictive CRS obtained was AUC=0.75 in the training set and AUC=0.74 in the validation set **(Figure 2)**. The concordance between the predicted probabilities and the actual observations was confirmed using a calibration diagram in the validation set **(Figure 2)**, with a mean absolute error (MAE) of 0.014, a mean squared error (MSE) of 0.0003, and a quantile of absolute error of 0.029, demonstrating good calibration of the model without overestimation or underestimation of the risk of conversion.

The predictive CRS developed showed an almost linear relationship with the score achieved, with a risk of conversion ranging from 2% (for a CRS=0/7) to 100% (for a CRS ≥6/7) (**Figure 2**).

Consequences of conversion on postoperative outcomes

The propensity score, based on the main risk factors for severe postoperative complications, was used to compare patients with severe complications (n=375) to those without severe complications (n=375). A significant association between conversion and severe postoperative complications was demonstrated (OR=1.80; 95%CI=1.16-2.54) **(Supplement 4, Supplemental Digital Content 4, http://links.lww.com/SLA/F427)**. No significant difference was observed between severe complications and indications for conversion: emergency/hemorrhage (6.4% vs. 4.8%; p=0.906), exposure and technical issues (7.7% vs. 4.5%; p=0.102), inflammatory adhesion (4.0% vs. 4.0%; p=0.352), and oncological reasons (4.3% vs. 4.0%; p=0.246).

DISCUSSION

This is the first study to develop an easy-to-use predictive CRS during MILP, based on clinical and preoperative parameters through a statistically valid and well-established methodology. The preoperatively available risk factors identified and included in the CRS were male sex, overweight, history of laparotomy, initial pancreatitis, tumor size, and planned splenectomy. The score obtained has an almost linear association with the risk of conversion, ranging from 2% for a score of 0/7 to 100% for a score of ≥6/7. Other easily understandable intraoperative factors associated with the risk of conversion were also identified: portal vein resection, unplanned splenectomy, and multi-organ resection.

Various risk factors for conversion during MILP have been published with considerable heterogeneity across articles [12,13,15,16,18,20,37–40]. In the present study, the extent of pancreatectomy, often found as a risk factor in the literature [12,14,15,38], was higher in the converted group but was not significant in multivariate analysis for two reasons. On one hand, the number of pancreatectomies requiring resection on the right side of the isthmus, in general and in this cohort, was too low (0.5%; n=11) to identify an association with conversion risk. In contrast, portal vein resection (frequently associated with resection extended to the right) was significantly associated with conversion in multivariate analysis and could mask the association between the extent of pancreatectomy and conversion. No association between neoadjuvant treatment, borderline or locally advanced status, and conversion was observed in the univariate and multivariate analyses within the pancreatic ductal adenocarcinoma subgroup. First, we suggest that sub-characteristics of resectability (vascular resection, multiorgan resection, splenectomy) are captured in the multivariate model and the predictive score, rather than borderline or locally advanced status itself. Second, the number of borderline and locally advanced tumors, as well as pre-treated patients (neoadjuvant chemotherapy alone or chemoradiotherapy) remains limited. This suggests that patients undergoing MILP are already highly selected by their surgeons. The results, based on a small subset of patients, may also reflect a lack of statistical power. Therefore, making any suggestion regarding MILP for borderline and locally advanced tumors is challenging.

However, in our opinion, caution should remain the guiding principle when considering MILP for borderline and locally advanced tumors. Unplanned splenectomy performed during MILP is a risk factor for conversion, which is consistent with the literature [9]. In contrast, to the best of our knowledge, no published study has demonstrated that spleen preservation is a protective factor against conversion. While it may appear counterintuitive, a planned splenectomy actually increases the risk of conversion, highlighting the technical and exposure challenges associated with splenopancreatectomy, compared to spleen-preserving left pancreatectomy, particularly when utilizing the Warshaw technique. This finding also aligns with the trend that the risk of conversion seems to increase with the extent of resection, as indicated by variables such as multi-organ resection, RAMPS, pancreatic section to the right of the neck, and tumor size. Moreover, among patients who underwent spleen preservation, no significant difference in the risk of conversion was found according to whether or not the splenic vessels were resected. Although the Kimura vs. Warshaw categorization was based primarily on the surgeon's preoperative intentions, it cannot be ruled out that some procedures intended by Kimura might have been performed as Warshaw for technical reasons, potentially biasing this lack of association with conversion.

The robotic approach appears to be associated with a lower risk of conversion compared to laparoscopy, as noted by several authors [7,41]. The recent 2024 recommendation on Robotic Hepato-Pancreato-Biliary Surgery by Hobeika et al. [8] reaffirms the advantage of the robot-assisted approach in reducing the risk of conversion in left pancreatectomy. This observation aligns with our univariate analysis, which demonstrated a significant difference in conversion rates between robotic and laparoscopic approaches. However, the number of MILPs performed using the robot-assisted approach in this cohort remains limited (n=281, 13.4%), reducing the statistical power and the ability to detect significance in multivariate analyses. Furthermore, among the 55 participating centers, fewer than half (n=26) performed

MILP using the robot-assisted approach, and only 6 centers averaged more than one robotic MILP per year. This limited volume of robot-assisted surgery prevents a robust analysis of the robotic volume threshold. It is therefore likely that the benefits of the robot-assisted approach on conversion, clearly suggested in the univariate analysis, are obscured in the multivariate analysis by other variables strongly associated with conversion. This limitation can be attributed to the heterogeneity of practices and the varying levels of experience across centers, which are not fully accounted for in the GLMM model, despite the inclusion of the center effect. Despite the advantages of robotics in terms of ergonomics and expanded indications, these results also suggest that conversion is primarily a matter of patient selection for minimally invasive approaches [(8)].

In the study by Lof et al., there was a significant difference between the number of conversions and the surgeon's experience and learning curve, with a breakpoint of approximately 40 MILP (95%CI=11-68) [(18)]. Data per surgeon were not available in this cohort; however, no threshold per center was identified in this study as being associated with the risk of conversion.

The developed CRS raises questions about the threshold at which proposing a minimally invasive approach to the patient seems unreasonable. In the literature and in our cohort, the risk of conversion during MILP is approximately 15-30% [(20,40)]. In our study, a score of 4/7 correlated with a 35% conversion risk. Thus, it can be suggested that a score of 4/7 or higher indicated a conversion risk above the range reported in the literature. However, it is clear that this threshold can be adjusted for each surgeon, depending on their expertise and progress along the learning curve. Therefore, surgeons can incorporate an additional corrective variable to further refine the results obtained by the general predictive CRS proposed or set a stricter target according to their own conversion rates.

Proposing such a score is clinically relevant since this study also demonstrated a significant association between conversion during MILP and the risk of severe postoperative complications, independent of other known risk factors for postoperative complications. This result is consistent with the trends observed in colorectal surgery [42,43]. In addition, there was no difference between severe complications and the indication for conversion (notably emergently for hemorrhage or not), although the study may be underpowered to examine this specific question. It remains likely that emergency conversion is associated with higher complications and a “loss of chance” for the patient [20]. It is also important to note that while the benefits of the minimally invasive approach in left pancreatectomies are evident regarding pain, cosmetic results, and abdominal wall complications, they remain clinically moderate, mainly on length of stay, functional recovery, and intraoperative blood loss, and null regarding POPF, which remains the Achilles’ heel of pancreatic surgery [3,44,45]. All these results support the idea that it is essential to carefully select patients to avoid exposing them to the risk of conversion, which could negatively affect postoperative outcomes.

This study had several limitations. First, the AUC of the predictive CRS in the validation set was moderate, approximately 0.74. Nevertheless, such a moderate AUC score reflects the great heterogeneity of data in the literature on MILP conversion risk factors and the numerous factors influencing the conversion risk. Second, it is challenging to achieve a higher AUC score since some variables, such as surgeons’ skill, experience, and learning curve, are difficult to capture. Our choice was also to include only variables that are clearly identifiable preoperatively for the clinical relevance of the CRS and not to include other risk factors identified intraoperatively (multiorgan resection, unplanned splenectomy, portal vein resection) that would have improved the score's parameters. Nevertheless, the calibration diagram provided a good indicator of the performance of this score after bootstrapping. Third, the design of this study only allowed us to assess the significant association between conversion and severe complications, and no other postoperative outcomes, including oncological results. However, severe complications are more clinically significant than the length of hospital stay or rehospitalization rate. Finally, although this has already been demonstrated in colorectal procedures [46], our study was not designed to compare postoperative outcomes between MILP with conversion and left pancreatectomy by open approach from the outset to confirm the deleterious impact of conversion on postoperative outcomes.

In conclusion, this study is the largest of its kind, and its national multicenter design and robust methodology provide strong results with wide clinical applicability. MILP conversion can be accurately predicted using a simple score based on six preoperatively available parameters and can help surgeons in their decision-making during preoperative consultation regarding the choice of the surgical approach. Identifying the causes of conversion and proposing such a score is clinically relevant since conversion is associated with a higher risk of severe complications.

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Figure 1: Flowchart of the study

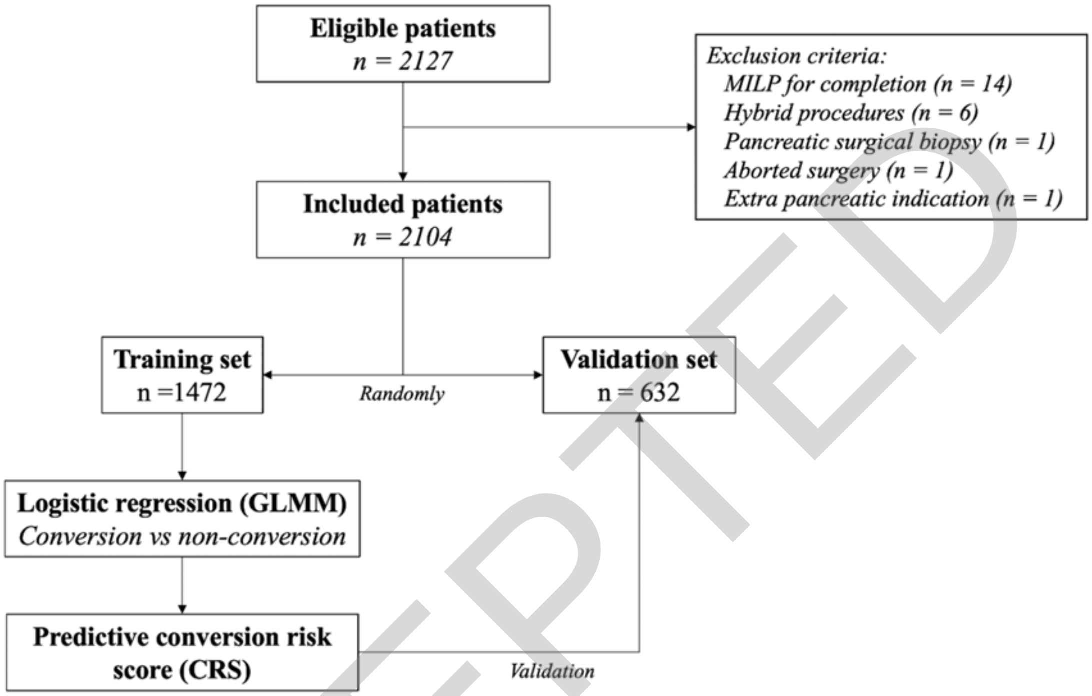
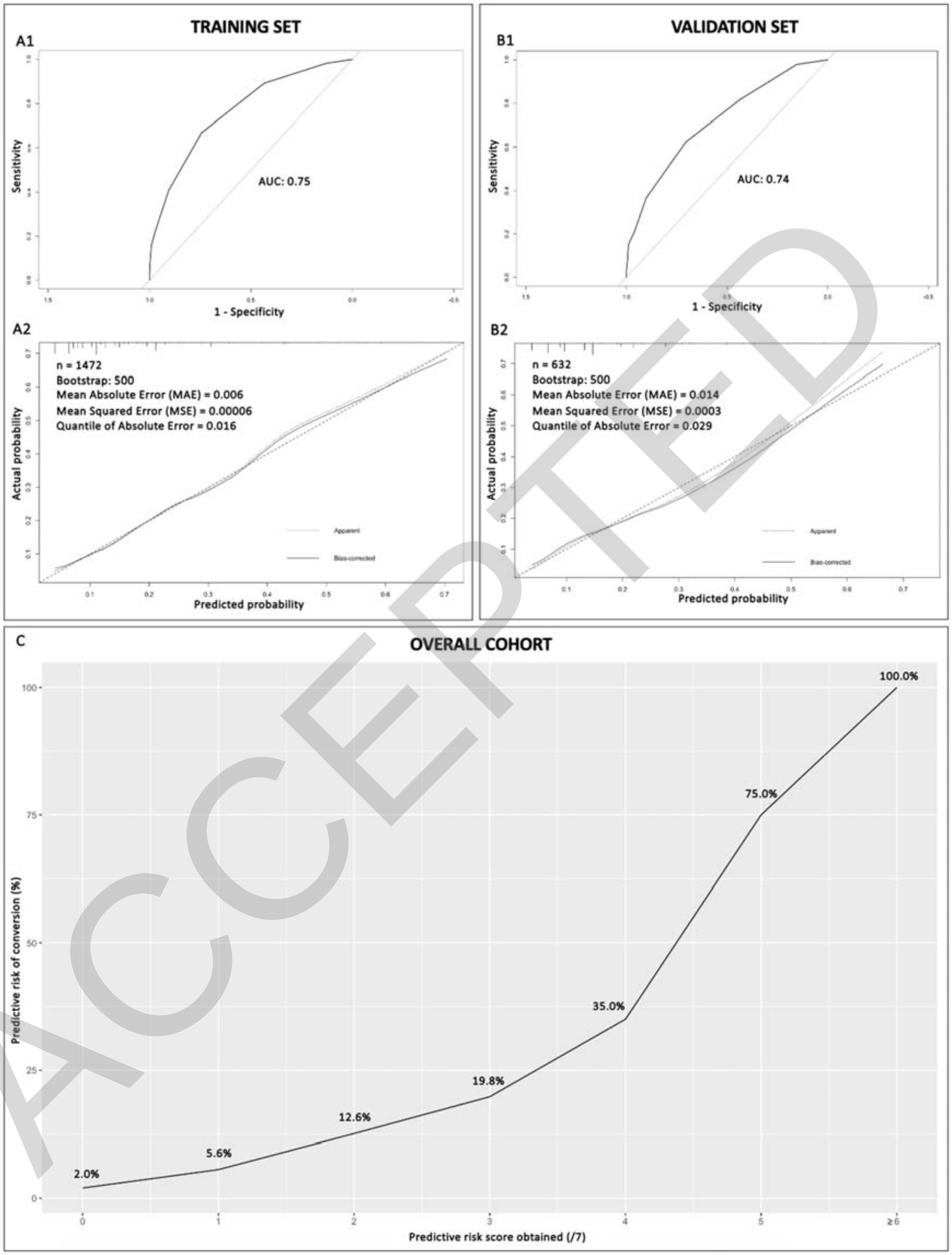


Figure 2: ROC curve with AUC for predictive CRS based on model rounded coefficients in training set (A1) and in validation set (B1), with its calibration diagrams in the training set (A2) and validation set (B2), and probability of conversion depending on the predictive CRS obtained in the entire cohort (C)



TRAINING SET
A1
Sensitivity
AUC: 0.75
1 - Specificity
A2
n = 1472
Bootstrap: 500
Mean Absolute Error (MAE) = 0.006
Mean Squared Error (MSE) = 0.00006
Quantile of Absolute Error = 0.016
Actual probability
Predicted probability
VALIDATION SET
B1
Sensitivity
AUC: 0.74
1 - Specificity
B2
n = 632
Bootstrap: 500
Mean Absolute Error (MAE) = 0.014
Mean Squared Error (MSE) = 0.0003
Quantile of Absolute Error = 0.029
Actual probability
Predicted probability
C
OVERALL COHORT
Predictive risk of conversion (%)
2.0%
5.6%
12.6%
19.8%
35.0%
75.0%
100.0%
Predictive risk score obtained (/7)

Table 1: *Overall preoperative and intraoperative characteristics of the cohort*

Variables	**Cohort**
n	2104
Age, mean (SD), years	59.9 (14.9)
Male sex (%)	901 (42.8)
BMI, mean (SD), kg/m2	25.9(4.9)
ASA score 3 and 4 (%)	357 (17.4)
Surgical history - Laparotomy (%) [a] - Laparoscopy (%)	 167 (7.9) 607 (28.8)
Medical history - Diabetes mellitus (%) - Cardiorespiratory disease (%) - Chronic pancreatitis (%) - Chronic kidney disease (%) - Chronic liver disease (≥ F3) (%)	 443 (21.1) 220 (10.5) 103 (4.9) 95 (4.5) 42 (2.0)
Main modes of discovery - Incidentally (%) - Abdominal pain (%) - Pancreatitis (%) - Diabetes (%) - General status deterioration (%) - Digestive disorders (%) - Others (hypoglycemia, pulmonary embolism, fever, etc.) (%)	 990 (47.1) 535 (25.4) 244 (11.6) 109 (5.2) 93 (4.4) 23 (1.1) 110 (5.2)
Robot-assisted approach (%)	281 (13.4)
“Soft” consistency of the pancreas (%)	1114 (67.6)
Dilated main pancreatic duct at the section level (> 3 mm) (%)	392 (30.1)
Location of the pancreatic section - Isthmus (%) - Left side of isthmus (%) - Right side of isthmus (%)	 1383 (65.7) 710 (33.7) 11 (0.5)
Operative time, mean (SD), min	217.4 (90.3)
Blood loss, mean (SD), mL	227.7 (379.2)
Conversion (%)	329 (15.6)
Portal vein resection (%)	25 (1.2)
MILP with splenectomy - Planned (%) - Emergency/unplanned (%)	 888 (42.2) 86 (4.1)
MILP with spleen preservation - With splenic vessels preservation (Kimura procedure) (%) - With splenic vessels resection (Warshaw procedure) (%)	 539 (25.6) 591 (28.1)
Colectomy or duodenojejunal flexure resection (%)	37 (1.8)
Partial gastrectomy (%)	32 (1.5)
Hepatectomy (%)	3 (0.1)

Cholecystectomy (%)	143 (6.8)
Total nephrectomy (%)	7 (0.3)
RAMPS	
- Anterior (%)	552 (26.2)
- Posterior (%)	35 (1.7)

All percentages are given with a denominator excluding missing data.
RAMPS= Radical Antegrade Modular Pancreatosplenectomy
[a]*All the laparotomies performed except caesarean sections, hernia repairs and appendectomies.*

Table 2: Overall postoperative characteristics of the cohort

Variables	**Cohort**
n	2104
Mortality (%)	28 (1.3)
Complications - Overall (%) - Severe (Dindo Clavien ≥ III) (%)	 1064 (50.6) 375 (17.8)
POPF (Grade B + C) (%)	393 (18.7)
PPH (%)	122 (5.8)
Delayed gastric emptying (%)	123 (5.8)
ICU admission (%)	142 (6.7)
Re-operation (%)	118 (5.6)
Delay before reoperation, mean (SD), days	13.7 (15.3)
Re-admission (%)	320 (15.2)
Length of hospital stay, mean (SD), days	11.8 (9.6)
Surgical indications: Malignant tumors - pNETs (%) - Pancreatic ductal adenocarcinoma (%) [a] - Metastasis (extra-pancreatic cancer) (%) - Carcinoma/Sarcoma (%) - Others (%) Surgical indications: Benign tumors - IPMN (%) - Mucinous cystadenoma (%) - Serous cystadenoma (%) - Solid pseudopapillary neoplasms (%) - Chronic pancreatitis (%) - Others (auto-immune pancreatitis, pseudocyst, traumatism) (%)	1221 (58.0) 633 (30.1) 500 (23.8) 63 (3.0) 23 (1.1) 2 (0.1) 883 (42.0) 287 (13.6) 271 (12.9) 88 (4.2) 72 (3.4) 39 (1.9) 126 (6.0)
Tumor size, mean (SD), mm	32.5 (21.8)
Positive resection margins (%) [b]	83 (16.6)
Lymph nodes harvested, mean (SD) [b]	15.5 (9.1)
Lymph nodes involved (N+ status) (%) [b]	255 (51.0)

All percentages are given with a denominator excluding missing data

ICU= Intensive care unit; pNETs= pancreatic neuroendocrine tumors; POPF= Postoperative pancreatic fistula; PPH= Postoperative pancreatic hemorrhage; IPMN= Intraductal Papillary Mucinous Neoplasm

[a] *Pancreatic duct adenocarcinoma including invasive IPMN*
[b] *Concerns only pancreatic duct adenocarcinoma*

Table 3: *Univariate and multivariate analyses comparing preoperative and intraoperative data between converted and non-converted patients in the training-set.*

Variables	Non-converted	Converted	Univariate analysis	Multivariate analysis	
			p value	p value	OR (CI 95%)
n	1241	231	-	-	-
Age, mean (SD), years	59.4 (15.2)	61.9 (13.3)	0.020*	0.701	-
Male sex (%)	488 (39.3)	138 (59.7)	<0.001*	0.048	1.67 (1.01-2.80)
BMI, mean (SD), kg/m^2	25.8 (4.8)	27.4 (4.8)	<0.001*	0.004	2.15 (1.28-3.68) [b]
ASA score = 3 or 4 (%)	200 (16.5)	48 (21.4)	0.076*	0.635	-
Surgical history of laparotomy (%)	73 (5.9)	50 (21.6)	<0.001*	<0.001	5.68 (2.59-12.62)
Medical history					
- Diabetes mellitus (%)	246 (19.8)	60 (26.0)	0.034*	0.056	-
- Cardiorespiratory disease (%)	122 (9.8)	35 (15.2)	0.016*	0.559	-
- Chronic pancreatitis (%)	53 (4.3)	17 (7.4)	0.043*	0.164	-
- Chronic renal failure (%)	48 (3.9)	9 (3.9)	0.984	-	-
- Chronic hepatopathy (%)	25 (2.0)	5 (2.2)	0.882	-	-
Surgical indication: Malign tumors (%)	723 (58.3)	150 (64.9)	0.058*	0.529	-
Tumor size, mean (SD), mm	32.0 (21.2)	38.2 (23.2)	<0.001*	0.003	2.12 (1.34-3.38) [b]
Main modes of discovery					
- Incidentally (%)	605 (48.8)	97 (42.0)	0.059*	0.540	-
- Abdominal pain (%)	328 (26.4)	45 (19.5)	0.026*	0.627	-
- Pancreatitis (%)	121 (9.8)	49 (21.2)	<0.001*	0.007	3.58 (1.42-9.13)
- Diabetes mellitus (%)	59 (4.8)	15 (6.5)	0.267	-	-
- General status deterioration (%)	51 (4.1)	9 (3.9)	0.880	-	-
- Digestive disorders (%)	14 (1.1)	5 (2.2)	0.335	-	-
- Others (%)	63 (5.1)	11 (4.8)	0.841	-	-
Robot-assisted approach (%)	181 (14.6)	15 (6.5)	0.001*	0.796	-
Dilated MPB (≥3mm) (%)	221 (17.8)	51 (22.1)	0.228	-	-
Soft pancreatic consistency (%)	668 (53.8)	103 (44.6)	0.001*	0.094	-
Section on the head-neck junction (%)	3 (0.2)	4 (1.7)	0.002*	0.507	-
Portal vein resection (%)	10 (0.8)	11 (4.8)	<0.001*	0.002	36.3 (4.7-422.5)
MILP with planned splenectomy (%)	485 (39.1)	139 (60.2)	<0.001*	<0.001	2.63 (1.51-4.67)
MILP with unplanned splenectomy (%)	33 (2.7)	26 (11.3)	<0.001*	0.028	4.05 (1.16-14.39)
MILP with spleen preservation			0.856	-	-
- Kimura technique (%)	348 (28.0)	31 (13.4)			
- Warshaw technique (%)	375 (30.2)	35 (15.2)			
Cholecystectomy (%)	72 (5.8)	20 (8.7)	0.134	-	-
Multiorgan resection				<0.001 [a]	12.97 (3.95-45.84)
- Colectomy/Duodenojejunal flexure resection (%)	10 (0.8)	15 (6.5)	<0.001*		

- Partial gastrectomy (%)	9 (0.7)	14 (6.1)	**_<0.001*_**		
- Hepatectomy (%)	3 (0.2)	0	*0.454*		
- Nephrectomy (%)	0	5 (2.2)	**_<0.001*_**		
Anterior RAMPS (%)	307 (24.7)	64 (27.7)	*0.166*	-	-
Posterior RAMPS (%)	15 (1.2)	6 (2.6)	*0.093**	*0.633*	-

IPMN= Intraductal Papillary Mucinous Neoplasm; MPD= Main Pancreatic Duct; OR= Odds Ratio; pNETs= pancreatic Neuroendocrine Tumors; RAMPS= Radical Antegrade Modular Pancreatosplenectomy;

** Variables included in multivariate analysis.*

[a] *Due to the absence of observation in one of the two groups for the variable "hepatectomy" and "nephrectomy", all the associated organ resection were grouped in multi-organ resection variable, that included: gastrectomy, colectomy or small bowel resection, hepatectomy and nephrectomy.*

[b] *The choice of the cut-offs to obtained an odds ratio were obtained from a ROC curve and were: BMI ≥ 25kg/m2 and Tumor size ≥40mm*

Table 4: *Predictive conversion risk score (CRS) in the training set only based on preoperative risk factors.*

Variables	**Proportion in training set (%)**	**Proportion in non-converted group (%)**	**Proportion in converted group (%)**	**GLMM Coefficient** [a]	**Score assigned** [b]
Male gender	42.5	39.3	59.7	0.52	**1**
BMI ≥ 25kg/m^2	52.2	51.7	66.2	0.76	**1**
History of laparotomy	8.4	5.9	21.6	1.74	**2**
Tumor size ≥40mm	31.3	29.5	42.7	0.75	**1**
Initial pancreatitis	11.5	9.8	21.2	1.28	**1**
Planned splenectomy	42.4	39.1	60.2	0.97	**1**
					= 7

The others risk factors associated with conversion in multivariate analysis (such as portal vein resection, unplanned splenectomy and multiorgan resection) were not included in the CRS given that they are difficult to predict preoperatively.

[a] *Coefficients obtained from the generalized linear mixed model (GLMM)*

[b] *Coefficients rounded to 1 or 2 based on coefficients obtained from the generalized linear mixed model (GLMM)*