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# Defining Benchmark Outcomes for Distal Pancreatectomy

## Results of a French Multicentric Study

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**Objective:** Defining robust and standardized outcome references for distal pancreatectomy (DP) by using Benchmark analysis.

**Background:** Outcomes after DP are recorded in medium or small-sized studies without standardized analysis. Therefore, the best results remain uncertain.

**Methods:** This multicenter study included all patients undergoing DP for resectable benign or malignant tumors in 21 French expert centers in pancreas surgery from 2014 to 2018. A low-risk cohort defined by no significant comorbidities was analyzed to establish 18 outcome benchmarks for DP. These values were tested in high risk, minimally invasive and benign tumor cohorts.

**Results:** A total of 1188 patients were identified and 749 low-risk patients were screened to establish Benchmark cut-offs. Therefore, Benchmark rate for mini-invasive approach was  $\geq 36.8\%$ . Benchmark cut-offs for postoperative mortality, major morbidity grade  $\geq 3a$  and clinically significant pancreatic fistula rates were  $0\%$ ,  $\leq 27\%$ , and  $\leq 28\%$ , respectively. The benchmark rate for readmission was  $\leq 16\%$ . For patients with pancreatic adenocarcinoma, cut-offs were  $\geq 75\%$ ,  $\geq 69.5\%$ , and  $\geq 66\%$  for free resection margins (R0), 1-year disease-free survival and 3-year overall survival, respectively. The rate of mini-invasive approach in high-risk cohort was lower than the Benchmark cut-off ( $34.1\%$  vs  $\geq 36.8\%$ ). All Benchmark cut-offs were respected for benign tumor group. The proportion of benchmark cases was correlated to outcomes of DP.

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The current study included 21 high-volume centers in France. One or more authors from each center were listed in authorship and all individuals met the 3 following guidelines: authors make substantial contributions to conception and design, and/or acquisition of data, and/or analysis and interpretation of data; authors participate in drafting the article or revising it critically for important intellectual content; authors give final approval of the version to be published.

The authors report no conflicts of interest.

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Centers with a majority of low-risk patients had worse results than those operating complex cases.

**Conclusion:** This large-scale study is the first benchmark analysis of DP outcomes and provides robust and standardized data. This may allow for comparisons between surgeons, centers, studies, and surgical techniques.

**Keywords:** benchmark, distal pancreatectomy, outcomes

Distal pancreatectomy (DP) is commonly performed for corporeocaudal pancreatic tumors, especially for pancreatic ductal adenocarcinoma (PDAC). DP is considered a less complex procedure with lower morbidity and mortality rates than reported after pancreaticoduodenectomy (PD).<sup>1,2</sup> However, data from nationwide studies suggest that postoperative mortality after DP may occur in up to 3% of the cases.<sup>3</sup> Recently, minimally invasive distal pancreatectomy (MIDP) have been reported as improving postoperative outcomes as compared to open PD without any difference regarding oncological outcomes.<sup>4-6</sup>

Despite these findings, DP remains a highly complex procedure. Therefore, some authors suggest that centralization of pancreatic surgery should be mandatory to improve outcomes.<sup>7-9</sup> However, the findings of recent nationwide studies indicate that centralization for DP may be unnecessary as there was no evidence to indicate that hospital volume affected DP outcome.<sup>3</sup>

Nevertheless, establishing standardized key metrics in patients who undergo DP seems to be crucial. Among these metrics, mortality alone is no longer sufficient to define surgical standards and other key parameters, such as intraoperative and oncological data, are usually ignored.<sup>8,10</sup> Benchmarking is a quality improvement tool in manufacturing and economy aimed to define the best (benchmark) results and consider them as reference.<sup>11</sup> Benchmark outcomes have been previously investigated for various procedures and the relevance of establishing a benchmark for surgical outcomes was recently defined by an international expert consensus.<sup>12-19</sup>

To date, however, no specific benchmark cut-offs have been established for DP. As DP benchmarking may provide different results than other pancreatic resections, we aimed to investigate the benchmark cut-offs of this procedure in a multicenter survey of a French cohort comprising low-risk patients undergoing DP in high-volume centers.

## METHODS

### Study Population

This study followed a standardized methodology to establish benchmark cut-offs, as reported elsewhere.<sup>19</sup> We included patients aged 18 years or older who underwent planned DP ± splenectomy, by open or minimally invasive approach for resectable malignant or benign pancreatic tumors between 2014 and 2018. Among these patients, we identified a low-risk subgroup to establish a benchmark cohort using preoperative criteria<sup>19</sup> (Supplemental Digital Content, Table S1, <http://links.lww.com/SLA/D931>). We excluded patients who underwent extended DP as defined by the consensus of the International Study Group for Pancreatic Surgery (ISGPS),<sup>20</sup> patients with borderline or locally advanced tumors, palliative resection, or emergency surgery. The centers were assessed for eligibility, and we focused on high-volume centers defined as those performing more than 20 pancreatectomies per year, as previously

validated.<sup>21</sup> The collaborative group included 21 high-volume French centers.

### Definition of Variables and Study Outcomes

Demographic data [age, sex, weight loss, body mass index (BMI), World Health Organisation score, comorbidities, American Society of Anesthesiologists (ASA) score] and biological and radiological data were exhaustively collected. Clinicopathological (histologic classification, degree of differentiation, and resection

**TABLE 1.** Patients Characteristics

| Variables                                | n (%)       |
|--|-------------|
| Age                                      | 59.9 ± 15.6 |
| Sex                                      |             |
| Male                                     | 511 (43)    |
| Female                                   | 677 (57)    |
| BMI                                      | 25.8 ± 5.1  |
| ASA score                                |             |
| ASA 1                                    | 288 (24.2)  |
| ASA 2-3                                  | 895 (75.5)  |
| ASA 4                                    | 5 (0.4)     |
| Tumor type                               |             |
| Malignant                                | 708 (59.6)  |
| PDAC                                     | 364 (31)    |
| NET                                      | 259 (22)    |
| Metastasis                               | 46 (3.8)    |
| Others                                   | 39 (3.3)    |
| Benign                                   | 480 (40.4)  |
| IPMN                                     | 128 (10.7)  |
| Cystadenoma                              | 138 (11.6)  |
| Pseudocyst                               | 30 (2.5)    |
| Others                                   | 184 (15.5)  |
| Intraoperative data                      |             |
| Procedure                                |             |
| DP without splenectomy                   | 288 (24.3)  |
| DP with splenectomy                      | 614 (51.6)  |
| Warshaw procedure                        | 286 (24.1)  |
| Mini-invasive                            | 565 (47.5)  |
| Laparoscopy                              | 496 (87.8)  |
| Robotic                                  | 69 (12.2)   |
| Open conversion                          | 66 (11.7)   |
| Operation time (min)*                    | 200 ± 77    |
| Intraoperative blood transfusion         | 55 (4.6)    |
| Blood loss (ml)*                         | 223 ± 413   |
| Postoperative data                       |             |
| Intensive care unit stay                 | 222 (18.7)  |
| Hospital stay (d)*                       | 14.8 ± 15.4 |
| Clavien-Dindo grade ≥ IIIa               |             |
| At 3 mo                                  | 92 (11)     |
| At 6 mo                                  | 47 (7.1)    |
| At 9 mo                                  | 44 (7.2)    |
| At 12 mo                                 | 43 (7.3)    |
| CR-POPF (grades B or C)                  | 181 (15.2)  |
| Grade B POPF                             | 151 (12.7)  |
| Grade C POPF                             | 30 (2.5)    |
| Severe postoperative bleeding grade ≥ 3a | 27 (2.3)    |
| 90-day mortality                         | 13 (1.1)    |
| Hospital readmission rate                | 190 (16)    |
| Oncological outcomes for PDAC (n = 364)  |             |
| Resection margin status (R0)             | 306 (84.1)  |
| 1-year overall survival                  | 333 (91.5)  |
| 3-year overall survival                  | 288 (79.1)  |
| 1-year disease-free survival             | 138 (76.4)  |
| Number of lymph nodes resected*          | 16.7 ± 10.4 |

\*Mean ± SD.

IPMN indicates intraductal papillary mucinous neoplasm; NET, neuroendocrine tumor.

margins' status) and operative characteristics (time, blood loss, surgical approach, surgical technique) were also analyzed. Postoperative complications were recorded according to the Clavien-Dindo classification.<sup>22</sup> Major morbidity was defined as Clavien-Dindo  $\geq$  IIIa at 3, 6, 9, and 12 months postoperatively. Pancreas-specific postoperative complications were defined according to the ISGPS guidelines.<sup>23-25</sup> Mortality was defined as in-hospital death or death within 90 days of surgery. For patients with PDAC, we also determined oncological quality indicators, including histopathological data, overall and disease-free survivals. regarding the resection margin status, R0 was defined as free margin  $\geq$  1 mm.

## Benchmark Definition

Eighteen intraoperative and postoperative variables were used to define benchmark outcomes in the subgroup of patients with low preoperative risk. As recommended by the International Expert Delphi Consensus,<sup>19</sup> we defined benchmarks as the 75th percentile of the median outcome parameters of the participating centers. For variables with a lower value associated with worse outcomes (R0 status, number of lymph nodes, and survival data), benchmark was defined as the 25th percentile. To evaluate the robustness of this methodology, we tested benchmark cut-offs in patients undergoing MIDP, DP for benign tumors and high-risk patients.

To evaluate the correlation between the proportion of benchmark cases and outcomes after DP, we also stratified centers according to the rates of benchmark and nonbenchmark cases.

## Statistical Analysis

Categorical variables were presented as percentage values and absolute numbers (of patients) and were analyzed using the  $\chi^2$  or the Fisher exact test. Continuous variables were expressed as mean  $\pm$  SD or median. Differences between the groups were analyzed using the Mann-Whitney *U* test. A 2-tailed *P* value  $<$  0.05 was considered to indicate statistical significance. All statistical analyses were performed using Stata, version 13 STATA 13 (StataCorp, College Station, TX, USA)..

## RESULTS

### Patients' Characteristics

We collected data from 1188 patients who underwent DP at 21 high-volume centers in France over the study period. The mean age of the patients was 59.9 years, and 57% were female. The mean BMI was 25.8 kg/m<sup>2</sup> and 61% of patients had an ASA score of 2. The mean operation time was 200  $\pm$  77 min. Regarding surgical approach, nearly half of the patients (47%) underwent mini-invasive DP, but the procedure was converted to open DP for 11% of these patients (Table 1).

Regarding indications, most patients underwent DP for malignant tumors (60%). Among these patients with oncological indication, the majority underwent DP for PDAC (31%) or neuroendocrine tumors (22%). Among patients with PDAC (*n* = 364), the majority (53%) had T3 disease.

The most common surgical procedure was DP with splenectomy (51%), followed by spleen-preserving DP with resection (Warshaw procedure—24%) or preservation (Kimura procedure—24%) of spleen vessels. Postoperatively, 13 deaths occurred within 90 days after DP and the mortality rate was 1.1%. Furthermore, 17% of patients experienced major complications (Clavien-Dindo score  $\geq$  IIIa), mostly attributed to a clinically relevant postoperative pancreatic fistula (CR-POPF). For patients with PDAC, the rate of positive margins (R1) was 15%

and the mean number of resected lymph nodes was 16  $\pm$  10. Further baseline data of the cohort are shown in Table 1.

## Benchmark Analysis

Based on data of 749 low-risk patients, 18 benchmark cut-offs were established. The data are presented in Table 2. The benchmark rate for the minimally invasive approach was  $\geq$  36.8%. The benchmark cut-off value for postoperative mortality was 0%. Regarding morbidity, major morbidity grade  $\geq$  3 and CR-POPF rates were  $\leq$  27% and  $\leq$  28%, respectively. Notably, the benchmark rate for readmission was  $\leq$  16%. Cut-off values for patients with PDAC were  $\geq$  75%,  $\geq$  88%, and  $\geq$  66% for free resection margins (R0), 1-year, and 3-year overall survival, respectively.

## Validation of Benchmark Cut-offs

To evaluate the validity of the benchmark cut-off values, 3 groups of patients were established. The related patient characteristics and perioperative data are shown in Table 3. High-risk patients were more likely to be older (*P*  $<$  0.001), have more comorbidities (*P*  $<$  0.001), and a higher BMI (*P*  $<$  0.001) than low-risk patients. In addition, DP in high-risk patients was associated with a high rate of intraoperative blood transfusion (6.6% vs 3.5%, *P* = 0.012) and increased blood loss (296  $\pm$  531 vs 181  $\pm$  318, *P*  $<$  0.001). Postoperative mortality was significantly higher in the high-risk group than in the low-risk group (2.1% vs 0.5%, *P* = 0.045). However, major complications and CR-POPF rates were comparable between groups. When analyzing oncological data, survival rates were significantly worse in high-risk patients (59.2% vs 95.1% for 1-year survival rate, *P* = 0.002).

We tested benchmark cut-offs established among the low-risk patient group in cohorts of patients who underwent mini-invasive DP, those who underwent DP for benign tumors, and those in the high-risk cohort (Table 4). The rate of MIDP in the high-risk group reached the benchmark cutoff (34.1% vs  $\geq$  36.8%). Furthermore, the median length of hospital stay in high-risk patients reached the benchmark cut-off of 13 days. Despite the higher rates of postoperative complications in high-risk patients, all defined outcome parameters were consistent with the benchmark cut-off values. Similarly, we assessed the benchmark cut-offs in a subgroup of

**TABLE 2. Outcome Benchmark After DP in Low-risk Patients**

|   | Benchmark Cut-off (%) |
|---|-----------------------|
| <i>n</i> (%)                                  | 749 (63)              |
| Intraoperative data                           |                       |
| Mini-invasive                                 | $\geq$ 36.8           |
| Open conversion                               | $\leq$ 20.0           |
| Operation time (min)                          | $\leq$ 232            |
| Intraoperative blood transfusion              | $\leq$ 5.9            |
| Postoperative data                            |                       |
| Intensive care unit stay                      | $\leq$ 25             |
| Hospital stay (d)                             | $\leq$ 13             |
| Postoperative morbidity                       |                       |
| Clavien-Dindo grade $\geq$ IIIa at 3 mo       | $\leq$ 27.3           |
| CR-POPF (grades B or C)                       | $\leq$ 28.6           |
| Grade B POPF                                  | $\leq$ 27.8           |
| Grade C POPF                                  | $\leq$ 5.3            |
| Severe postoperative bleeding grade $\geq$ 3a | $\leq$ 2.8            |
| 90-day mortality                              | 0.0                   |
| Hospital readmission rate                     | $\leq$ 16.7           |
| Oncological outcomes for PDAC                 |                       |
| Resection margin status                       | R0 $\geq$ 75.9        |
| 1-year overall survival                       | $\geq$ 88.3           |
| 3 years overall survival                      | $\geq$ 66.7           |
| 1-year disease-free survival                  | $\geq$ 69.5           |

**TABLE 3.** Comparison of Patient Characteristics and Outcomes Between Low-risk Patients and Validation Cohorts

| Variable                                 | Low-risk Patients, n (%) | Mini-invasive, n (%) | P      | High-risk Patients, n (%) | P      | Benign Group, n (%) | P      |
|--|--------------------------|----------------------|--------|---------------------------|--------|---------------------|--------|
| Age*                                     | 57.6 ± 15.1              | 57.7 ± 16.9          | 0.444  | 64 ± 15.7                 | <0.001 | 56.4 ± 16.2         | 0.384  |
| Sex                                      |                          |                      |        |                           |        |                     |        |
| Male                                     | 272 (36.3)               | 215 (38)             | 0.676  | 239 (54.4)                | <0.001 | 173 (36.0)          |        |
| Female                                   | 477 (63.7)               | 350 (62)             |        | 200 (45.6)                |        | 307 (64)            | 0.875  |
| BMI*                                     | 24.8 ± 4.1               | 25.7 ± 5             | 0.026  | 27.5 ± 6.2                | <0.001 | 25.2 ± 5.3          | <0.001 |
| ASA score                                |                          |                      |        |                           |        |                     |        |
| ASA 1                                    | 268 (35.8)               | 170 (30)             | <0.001 | 20 (4.6)                  | <0.001 | 143 (30.4)          | <0.001 |
| ASA 2                                    | 481 (64.2)               | 344 (60.8)           |        | 247 (56.3)                |        | 275 (58.4)          |        |
| ASA 3                                    | 0                        | 49 (8.7)             |        | 167 (38)                  |        | 52 (11)             |        |
| ASA 4                                    | 0                        | 2 (0.4)              |        | 5 (1.1)                   |        | 1 (0.2)             |        |
| Intraoperative data                      |                          |                      |        |                           |        |                     |        |
| Laparoscopy                              | 361 (48.1)               | 496 (87.7)           | —      | 135 (30.8)                | —      | 252 (52.5)          | —      |
| Open conversion                          | 36 (9.9)                 | 62 (12.5)            | —      | 26 (19.3)                 | —      | 24 (9.5)            | —      |
| Mini-invasive                            | 412 (55)                 | 565 (100)            | —      | 153 (34.9)                | —      | 275 (57.3)          | —      |
| Open conversion                          | 43 (10.4)                | 70 (11.8)            | —      | 27 (17.6)                 | —      | 26 (9.5)            | —      |
| Operation time (min)*                    | 198 ± 73                 | 193 ± 74             | 0.102  | 204 ± 86                  | 0.446  | 191 ± 71            | 0.107  |
| Intraoperative blood transfusion         | 26 (3.5)                 | 11 (2)               | 0.104  | 29 (6.6)                  | 0.012  | 25 (5.2)            | 0.134  |
| Blood loss (ml)*                         | 181 ± 318                | 176 ± 334            | 0.355  | 296 ± 531                 | <0.001 | 190 ± 348           | 0.951  |
| Postoperative data                       |                          |                      |        |                           |        |                     |        |
| Intensive care unit stay                 | 118 (15.7)               | 79 (14.1)            | 0.413  | 105 (23.9)                | 0.001  | 70 (14.6)           | <0.001 |
| Hospital stay (d)*                       | 14.0 ± 14.4              | 12.1 ± 10.7          | <0.001 | 16.1 ± 17                 | <0.001 | 13.6 ± 12.4         | <0.001 |
| Clavien-Dindo grade ≥ IIIa               |                          |                      |        |                           |        |                     |        |
| At 3 mo                                  | 64 (12.1)                | 38 (9.3)             | 0.185  | 28 (9.3)                  | 0.599  | 51 (14.4)           | 0.085  |
| At 6 mo                                  | 31 (7.4)                 | 20 (6.2)             | 0.511  | 16 (6.5)                  | 0.836  | 17 (6.5)            | 0.000  |
| At 9 mo                                  | 31 (7.9)                 | 22 (7.5)             | 0.819  | 13 (6)                    | 0.607  | 18 (7.5)            | 0.000  |
| At 12 mo                                 | 27 (7.1)                 | 16 (5.6)             | 0.437  | 16 (7.8)                  | 0.910  | 23 (10)             | 0.002  |
| CR-POPF (grades B or C)                  | 110 (14.7)               | 74 (13.2)            | 0.452  | 71 (16.2)                 | 0.459  | 67 (13.9)           | 0.737  |
| Grade B POPF                             | 92 (12.3)                | 57 (10.2)            | 0.238  | 59 (13.5)                 | 0.533  | 58 (12.1)           | 0.930  |
| Grade C POPF                             | 18 (2.4)                 | 17 (3)               | 0.481  | 12 (2.7)                  | 0.711  | 9 (1.9)             | 0.542  |
| Severe postoperative bleeding grade ≥ 3a | 15 (2)                   | 12 (2.1)             | 0.858  | 12 (2.7)                  | 0.404  | 7 (1.5)             | 0.486  |
| 90-day mortality                         | 4 (0.5)                  | 2 (0.4)              | 0.585  | 9 (2.1)                   | 0.045  | 3 (0.6)             | 0.762  |
| Hospital readmission rate                | 105 (14)                 | 81 (14.4)            | 0.814  | 85 (19.4)                 | 0.013  | 72 (15)             | 0.319  |
| Oncological outcomes for PDAC (n = 364)  |                          |                      |        |                           |        |                     |        |
| Resection margin status (R0)             | 169 (85.8)               | 105 (85.4)           | 0.583  | 137 (83)                  | 0.507  | —                   | —      |
| Survival at 1 y                          | 189 (95.1)               | 115 (92.6)           | 0.979  | 103 (59.2)                | 0.002  | —                   | —      |
| Survival at 3 y                          | 160 (81.2)               | 93 (75.6)            | 0.562  | 95 (57.5)                 | 0.003  | —                   | —      |
| Disease-free survival                    | 84 (48.3)                | 51 (44.7)            | 0.556  | 54 (35.5)                 | 0.020  | —                   | —      |
| Number of lymph nodes resected*          | 17.1 ± 11.6              | 14.2 ± 9             | 0.031  | 14.3 ± 9.6                | 0.015  | —                   | —      |

\*Mean ± SD.

IPMN indicates intraductal papillary mucinous neoplasm; NET, neuroendocrine tumor; PDAC, pancreatic ductal adenocarcinoma.

patients who underwent DP for benign tumors. All the benchmark cut-offs were fulfilled in this subgroup.

### Correlation Between the Rate of Benchmark Cases and Outcomes After DP

The proportion of benchmark cases varied significantly between centers, ranging from 9% to 74% (Fig. 1). Interestingly, we found no correlation between the hospital volume and the proportion of benchmark cases ( $r = 0.127$ ,  $P = 0.583$ ). The rate of CR-POPF was not correlated with the proportion of benchmark cases in the low-risk cohort ( $r = -0.209$ ,  $P = 0.363$ ) (Fig. 2). This trend was observed in patients that underwent MIDP, those with benign tumors and high-risk patients. Regarding major complications, the proportion of benchmark cases tended to be correlated with the rate of severe complications (Clavien-Dindo ≥ IIIa) in the low-risk cohort ( $r = 0.358$ ,  $P = 0.112$ ). Interestingly, this correlation was significant in the MIDP ( $r = 0.479$ ,  $P = 0.028$ ), benign ( $r = 0.449$ ,  $P = 0.041$ ), and high-risk cohorts ( $r = 0.466$ ,  $P = 0.033$ ) (Fig. 3). In other words, centers with a majority of low-risk patients had worse results than those operating complex cases.

### DISCUSSION

To date, this cohort represents one of the largest reported series establishing benchmark outcomes after DP. The previous application of benchmarks in pancreatic surgery has shown interesting results when analyzing the criteria for quality after PD.<sup>17,18</sup> Even if DP is associated with a lower grade of major postoperative morbidity and mortality than other pancreatic procedures, it remains a complex procedure and its best achievable results should be determined.

Among the surgical benchmark values, the benchmark mortality rate was 0%. This finding confirms that postoperative mortality after DP tended toward 0 in high-volume centers.<sup>2,26</sup> Compared to previously reported data on PD performed with or without portal venous resection, these results were particularly better.<sup>17,18</sup> Concerning oncological benchmark values, the 1-year disease-free survival after DP for PDAC was ≥ 69.5% and the minimal harvested lymph node number was 9, confirming that oncological results after DP were better than those after PD even if the number of harvested lymph nodes was lower.<sup>27,28</sup>

The benchmark values were then compared to the median outcome values in different subgroups, that is, patients with high-risk morbidity due to poor preoperative general status

**TABLE 4.** Examples of Benchmark Comparisons in 3 Different DP Cohorts: High-risk Patients, Mini-invasive and Benign Tumors

|  | Benchmarks (%) | Mini-invasive (%) | Benign Tumors (%) | High Risk (%) |
|--|----------------|-------------------|-------------------|---------------|
| n (%)                                    | 749 (63)       | 565 (47.5)        | 480 (40)          | 439 (37)      |
| <b>Intraoperative data</b>               |                |                   |                   |               |
| Mini-invasive                            | ≥ 36.8         | 100               | 54.4              | 34.14         |
| Open conversion                          | ≤ 20.0         | 16                | 7.1               | 3.5           |
| Operation time (min)                     | ≤ 232          | 210               | 210               | 205           |
| Intraoperative blood transfusion         | ≤ 5.9          | 0.0               | 0.0               | 4.3           |
| <b>Postoperative data</b>                |                |                   |                   |               |
| Intensive care unit stay                 | ≤ 25           | 5.0               | 10.0              | 14.6          |
| Hospital stay (d)                        | ≤ 13           | 9                 | 11.5              | 13            |
| <b>Postoperative morbidity</b>           |                |                   |                   |               |
| Clavien-Dindo grade ≥ IIIa at 3 mo       | ≤ 27.3         | 16.7              | 16.7              | 14.3          |
| CR-POPF (grades B or C)                  | ≤ 28.6         | 12.9              | 13.6              | 17.4          |
| Grade B POPF                             | ≤ 27.8         | 11.1              | 13.6              | 13.6          |
| Grade C POPF                             | ≤ 5.3          | 0.0               | 13.6              | 0.0           |
| Severe postoperative bleeding grade ≥ 3a | ≤ 2.8          | 0                 | 0                 | 0             |
| 90-day mortality                         | 0.0            | 0                 | 0                 | 0             |
| Hospital readmission rate                | ≤ 16.7         | 11.8              | 13.3              | 14.3          |
| <b>Oncological outcomes for PDAC</b>     |                |                   |                   |               |
| Resection margin status                  | R0 ≥ 75.9      | 100               | —                 | 100           |
| 1-year overall survival                  | ≥ 88.3         | 100               | —                 | 93.3          |
| 3 years overall survival                 | ≥ 66.7         | 97.4              | —                 | 66.7          |
| 1-year disease-free survival             | ≥ 69.5         | 80.7              | —                 | 80            |

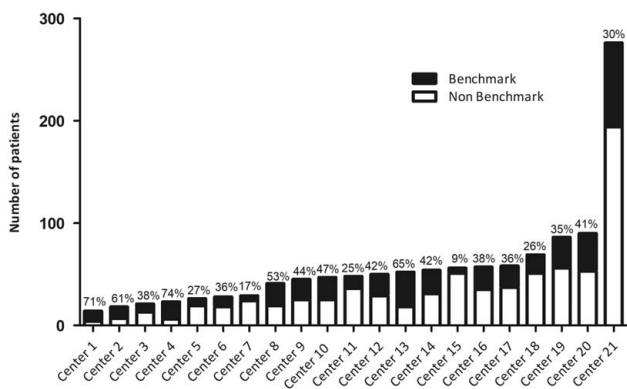
Variables are expressed as a median.

(high-risk cohort), patients who underwent surgery for benign disease, and patients who underwent a minimally invasive procedure. Along with the results in the high-risk patients cohort, our study confirmed that postoperative courses were associated with a longer length of stay and a higher rate of severe complications, though without overcoming the benchmark cut-off. In this subgroup, the cut-off for mortality remained at 0%, as in the low-risk cohort. Thus, the benchmark cut-off of mortality seemed to be poorly affected by patient preoperative general status and once again differed from the results observed after PD. This observation confirmed that these 2 procedures had to be considered separately. However, the oncological outcomes were significantly worse for patients with PDAC in this subgroup than for those in the benchmark group, possibly due to lower exposure to adjuvant chemotherapy.<sup>29</sup> Another explanation is that poor performance status could be associated with a more advanced disease. To avoid patient heterogeneity, we excluded all patients with borderline or locally advanced tumors, and those who received preoperative chemotherapy.

The benchmark rate for the use of a minimally invasive approach was ≥ 36.8%. MIDP is nowadays a well-evaluated procedure and prospective multicenter studies confirmed both its safety and its oncological equivalence to open DP.<sup>5,30</sup> In the current study, about half of the patients underwent a minimally invasive first approach and its use slightly increased over time. Nevertheless, the median length of stay after DP remained particularly high. This could be explained by the fact that more than half of the patients underwent open DP. In the recent LEOPARD study, the laparoscopic approach was associated with a reduced hospital stay compared with the open group. However, even in the MIDP subgroup, the median length of stay was high.<sup>30</sup> These findings suggest differences in local routine and standard approaches between centers.

We found that the benchmark cut-off of admission in the intensive care unit was still high, but both definition and use of intensive care unit vary between centers. Unsurprisingly, we found that high-risk patients were more likely to be admitted to intensive care units compared to other subgroups. Moreover, postoperative outcomes after DP in high-risk patients were particularly worse, suggesting a correlation between the occurrence of severe complications and admission to the intensive care unit. Similarly, a recent study from the multi-institutional National Surgical Quality database demonstrated that patients without immediate postoperative admission to the intensive care unit had a very low risk of failure-to-rescue.<sup>31</sup>

Although outcomes after PD are strongly correlated to hospital volume, this was not so obvious for DP.<sup>3</sup> In this study, the rates of severe postoperative complications correlated with the proportion of benchmark cases but not with the volume of pancreatectomies. In other words, the rate of major complications increased with the increase in the rate of low-risk cases. Thus, centers operating on a high proportion of difficult cases, had better outcomes. As suggested in previous studies, the difference observed in postoperative outcomes between centers might be due to better management of postoperative complications in centers used to manage with more complex patients.<sup>17,32</sup> Therefore, the distinction between low-risk and high-risk patients allows to establish the case-mix of centers which may be used as a novel tool of quality of care. For this, an international expert



**FIGURE 1.** The proportion of benchmark cases across the 21 centers.

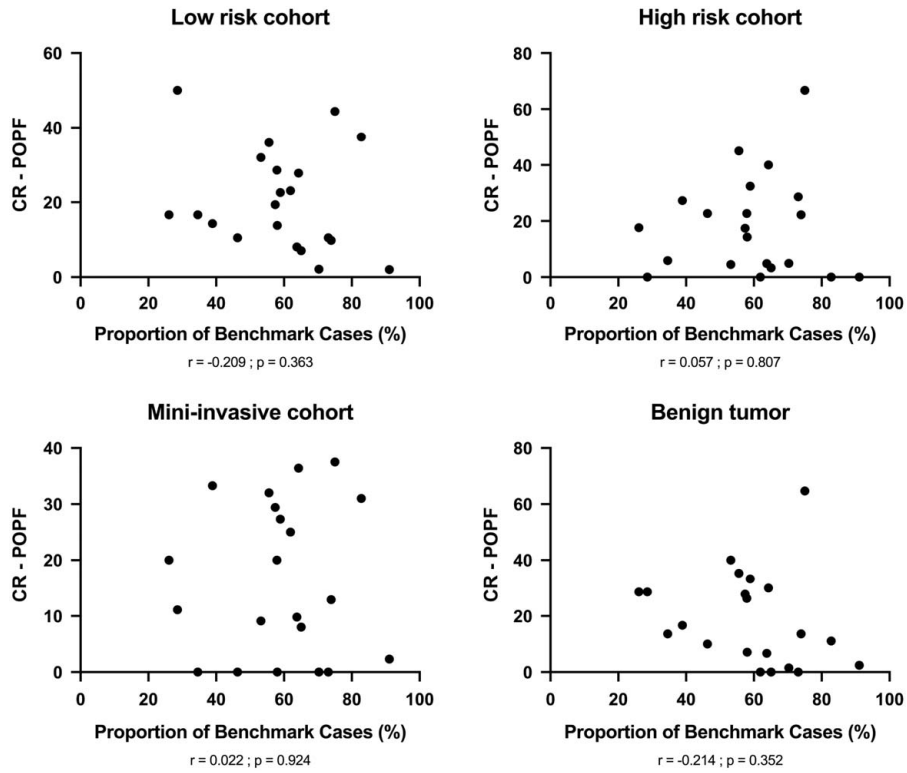


FIGURE 2. Correlation between the proportion of benchmark cases and clinically relevant postoperative pancreatic fistula rates.

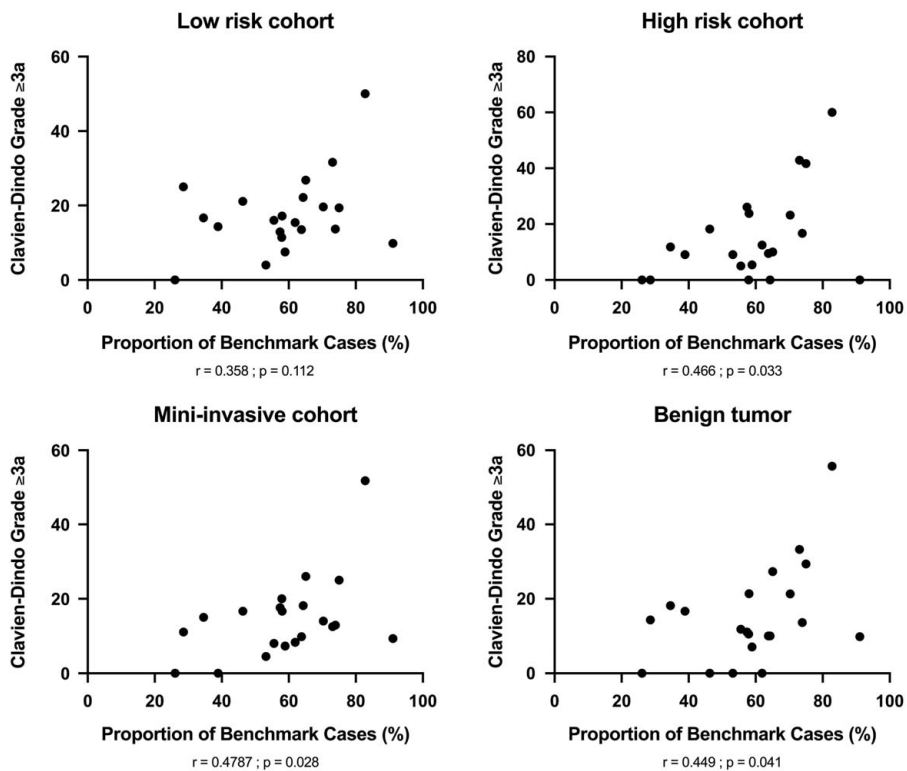


FIGURE 3. Correlation between the proportion of benchmark cases and major complications rates (Clavien-Dindo  $\geq 3a$ ).

Delphi consensus recommended to establish benchmarks in low-risk patients according to medical and surgical comorbidities.<sup>19</sup> The definition of these parameters are consistent with the results of previous studies that identified diabetes, cardiac, pulmonary, and renal diseases as predictors of major morbidity after pancreatectomy.<sup>9</sup>

This study has limitations owing to its retrospective design. First, the definition of low-risk profile focused only on preoperative feature and did not include intraoperative parameters. However, these data could impact outcomes after DP. Second, the perioperative management could be different between centers. However, only high-volume centers were included in the current study precisely in order to minimize the possible inhomogeneity in the perioperative management. We believe that high-volume status is a proxy for structural differences such as staffing level, availability of advanced technology, and processes of care. These hospital attributes would provide a similar environment to manage major complications. Also, postoperative complications were recorded according to Clavien-Dindo classification, which provides uniformity of the complications recording process. Moreover, specific complications of pancreatic surgery were defined according to international guidelines of ISGPS. Third, the average number of patients included per center was low and most centers contributed <10 DPs per year. This could be explained by the selection criteria of the current study focusing only on patients undergoing “simple” resection to define the benchmarking cases. Despite these limitations, our study used a large, high-quality, national database and was the first to define the benchmark cut-off after DP.

## CONCLUSIONS

In conclusion, this large-scale study is the first benchmark analysis of DP outcomes and provides robust and standardized data. This may allow for comparisons between surgeons, centers, studies, and surgical techniques. Furthermore, it may improve patient allocation to high-volume expert centers for high-risk profiles. The proportion of benchmark cases may reflect the results more accurately than the center volume or morbidity or mortality rates.

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