**Supplemental Digital Content**

**Manuscript**

*Gero et al*. Defining Global Benchmarks in Bariatric Surgery. A Multicenter Analysis of Minimally Invasive Roux-en-Y Gastric Bypass and Sleeve Gastrectomy. *Annals of Surgery.* 2019

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**Supplementary Table 1.** Baseline characteristics of patients and procedures.

|  |  |  |
| --- | --- | --- |
|  | **Roux-en-Y gastric bypass**  **n = 4120** | **Sleeve gastrectomy**  **n = 1457** |
| **Patient characteristics** |  |  |
| Age, years | 38.2 ± 11.1 | 37.0 ± 10.8 |
| Sex (female/male) | 3302 (80.1%) / 818 (19.9%) | 1050 (72.1%) / 407 (27.9%) |
| Height, cm | 168.1 ± 9.0 | 167.4 ± 8.7 |
| Weight, kg | 116.9 ± 17.6 | 109.3 ± 19.1 |
| BMI, kg/m2 | 41.3 ± 6.2 | 38.9 ± 5.2 |
| Hypertension, n (%) | 891 (21.6) | 344 (23.6) |
| Gastro-esophageal reflux disease, n (%) | 905 (22.0) | 170 (11.7) |
| Hyperuricemia, n (%) | 112 (2.7) | 60 (4.1) |
| Depression, n (%) | 800 (19.4) | 117 (8.0) |
| Dyslipidemia, n (%) | 935 (22.7) | 388 (26.6) |
| Joint disorders, n (%) | 1200 (29.1) | 269 (18.5) |
| Smoking, n (%) | 733 (17.8) | 224 (15.4) |
| **Operation characteristics** |  |  |
| Approach: laparoscopic / robotic | 4112 (99.8%) / 8 (0.2%) | 1455 (99.9%) / 2 (0.1%) |
| Conversion to open, n (%) | 1 (0.0) | 0 (0.0) |
| Conversion to laparoscopic, n (%) | 5 (0.1) | 1 (0.1) |
| Operation duration, min | 91.3 ± 44.7 | 73.7 ± 34.4 |
| Intraoperative drain placement, n (%) | 1481 (35.9) | 377 (25.9) |
| Anastomotic technique, (%) | circular: 53.5%, linear: 30.5%, hand-sewn: 15.5% | - |
| Staple line over-sewn (%) | - | 52.6% |
| Mesenteric defect closure (%) | 86.3% | - |

**Supplementary Table 2.** Cumulative incidence (%) of the most common reasons for readmission in benchmark patients after bariatric surgery.

1. Roux-en-Y gastric bypass (n= 4120, median follow-up = 1.9 year, [range: 0.25-6 years])

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Until 30 days** | **Until 90 days** | **Until 1 year** | **Until last-follow-up** |
| Abdominal pain of unknown origin | 0.51 (n=21) | 1.02 (n=42) | 2.52 (n=104) | 5 (n=206) |
| Symptomatic cholelithiasis | 0.05 (n=2) | 0.15 (n=6) | 2.45 (n=101) | 4.3 (n=177) |
| Internal hernia / small bowel obstruction | 0.24 (n=10) | 0.39 (n=16) | 1.43 (n=59) | 3.71 (n=153) |
| Dysphagia | 0.49 (n=20) | 1 (n=41) | 1.14 (n=47) | 1.26 (n=52) |
| Weight regain | 0 | 0 | 0 | 0.41 (n=17) |
| Anastomotic leak / perforation | 0.17 (n=7) | 0.17 (n=7) | 0.24 (n=10) | 0.32 (n=13) |
| Gastroesophageal reflux disease | 0.05 (n=2) | 0.12 (n=5) | 0.19 (n=8) | 0.27 (n=11) |

1. Sleeve gastrectomy (n = 1457, median follow-up = 1.6 year, [range: 0.25-6 years])

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Until 30 days** | **Until 90 days** | **Until 1 year** | **Until last-follow-up** |
| Symptomatic cholelithiasis | 0.07 (n=1) | 0.21 (n=3) | 1.3 (n=19) | 1.99 (n=29) |
| Abdominal pain of unknown origin | 0.55 (n=8) | 0.69 (n=10) | 1.44 (n=21) | 1.65 (n=24) |
| Gastroesophageal reflux disease | 0 | 0.07 (n=1) | 0.27 (n=4) | 0.75 (n=11) |
| Staple line leak | 0.48 (n=7) | 0.62 (n=9) | 0.62 (n=9) | 0.62 (n=9) |
| Weight regain | 0 | 0 | 0.07 (n=1) | 0.48 (n=7) |

**Supplementary Table 3.** Surgical outcomes after BS (median and range of centers’ medians)

A. Roux-en-Y gastric bypass

|  |  |  |  |
| --- | --- | --- | --- |
| **1. Perioperative Course** | *Median (range)* |  |  |
| Operation duration | 92 min (46 - 148) |  |  |
| Conversion to open surgery | 0% (0-0) |  |  |
| Intraoperative blood transfusions | 0 % (0 - 1.3) |  |  |
| Postoperative blood transfusions | 0.9 % (0 - 3) |  |  |
| Postoperative ICU admission | 0 % (0 - 1.3) |  |  |
| ICU stay in patients admitted to ICU | 0 day (0 - 1) |  |  |
| Hospital stay | 2 days (1 - 5) |  |  |
| Hospital cost in CH or USA / in the EU | 16204 (16204 - 18361) / 5402 (5402 - 6121) |  |  |
| Hospital cost in patients with complications in CH or USA / in the EU | 25982 (21717 - 31537) / 8662 (7240 - 10513) |  |  |
|  | *Median (range)* | *Median (range)* | *Median (range)* |
| **2. Morbidity and Mortality** | **Until discharge** | **Until 30-days** | **Until 90-days** |
| Uneventful postoperative course | 96 % (88 – 99.8) | 94 % (83 – 99.7) | 93 % (72 – 99.7) |
| Readmission | - | 2 % (0.09 - 9.5) | 3.7 % (1.5 - 20.5) |
| Reoperation | 1 % (0 - 5.3) | 1.6 % (0 - 4.2) | 1.7 % (0 - 6.2) |
| Any complication | 3.3 % (0.1 - 12) | 5.5 % (0.3 - 16.8) | 6.75 % (0.3 - 28.26) |
| Complication grade ≥ IIIa | 1.6 % (0 - 7) | 2 % (0 - 9.7) | 2.7 % (0 - 21.2) |
| Mortality | 0% (0-0) | 0% (0-0) | 0% (0-0) |
| CCI® In patients with at least 1 Clavien-Dindo Grade ≥II complication until 90-days | 20.92 (0 - 36.71) | 21.35 (0 - 36.71) | 33.63 (20.92 - 36.71) |
| **Signature complications** |  |  |  |
| Anastomotic leak | 0 % (0 - 0.017) | 0.1 % (0 - 3.3) | 0.2 % (0 - 3.3) |
| Stenosis of the anastomosis | 0 % (0 - 0.018) | 0 % (0 - 4) | 0.1 % (0 - 9.2) |
| Postoperative bleeding | 1.6 % (0 - 5.3) | 1.6 % (0 - 5.3) | 1.6 % (0 - 5.3) |
| Small bowel obstruction/internal hernia | 0.09 % (0 - 2.2) | 0.27 % (0 - 2.7) | 0.36 % (0 - 3.5) |
| Wound infection | 0 % (0 - 3.26) | 0 % (0 - 5.4) | 0 % (0 - 5.4) |
| Marginal ulcer | 0 % (0 - 1.6) | 0% (0 - 2.38) | 0.09 % (0 - 7) |
|  |  |  |  |

B. Sleeve gastrectomy

|  |  |  |  |
| --- | --- | --- | --- |
| **A. Perioperative Course** | *Median (range)* |  |  |
| Operation duration | 72 min (35 - 125) |  |  |
| Conversion to open surgery | 0% (0 - 0) |  |  |
| Intraoperative blood transfusions | 0% (0 - 0) |  |  |
| Postoperative blood transfusions | 0.6 % (0 - 1.8) |  |  |
| Postoperative ICU admission | 0 % (0 - 1.7) |  |  |
| ICU stay in patients admitted to ICU | 2 days (1 - 6) |  |  |
| Hospital stay | 2 days (1 - 5) |  |  |
| Hospital cost in CH or USA / in the EU | 16204 CHF (16204 - 16204) / 5402 EUR (5402 - 5402) |  |  |
| Hospital cost in patients with complications in CH or USA / in the EU | 24608 CHF (21717 - 34606) / 8203 EUR (7240 - 11536) |  |  |
|  | *Median (range)* | *Median (range)* | *Median (range)* |
| **B. Morbidity and Mortality** | **Until discharge** | **Until 30-days** | **Until 90-days** |
| Uneventful postoperative course | 98 % (88 - 100) | 96 % (83 - 100) | 95 % (83 - 98) |
| Readmission | - | 1.8 % (0 - 10.6) | 2.5% (0 - 10.6) |
| Reoperation | 0.7 % (0 - 3.8) | 1.1 % (0 - 7.1) | 1.4 % (0.5 - 7.1) |
| Any complication | 2 % (0 - 11.4) | 3.7 % (0 - 16.5) | 4.3 % (1.3 - 16.5) |
| Complication grade ≥ IIIa | 1.1 % (0 - 5) | 1.2 % (0 - 7.1) | 2.3 % (0.9 - 7.7) |
| Mortality | 0% (0 - 0) | 0% (0 - 0) | 0% (0 - 0) |
| CCI® In patients with at least 1 Clavien-Dindo Grade ≥II complication until 90 days | 4.3 (0 - 33.7) | 28.6 (0 - 39.7) | 33.73 (20.9 - 54.2) |
| **Signature complications** |  |  |  |
| Staple line leak | 0% (0 - 0) | 0% (0 - 4.6) | 0 % (0 - 10.8) |
| Dysphagia/Stenosis of the gastric tube | 0 % (0 - 7.6) | 0 % (0 - 7.6) | 0 % (0 - 7.6) |
| Postoperative bleeding | 1.17% (0 - 3.8) | 1.17 % (0 - 3.8) | 1.17 % (0 - 3.8) |
| Small bowel obstruction | 0 % (0 - 1.1) | 0 % (0 - 1.1) | 0 % (0 - 1.1) |
| Wound infection | 0 % (0-0) | 0 % (0-0) | 0 % (0-0) |

**Supplementary Table 4.** Comparison of outcomes in non-benchmark Roux-en-Y gastric bypass (RYGB) cases operated during the study period in one participating center with the identified global benchmarks for RYGB.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **1. Perioperative Course** | **Global benchmark cutoff (n=4120, 15 centers)** | **Outcomes in non-benchmark cases (n=468, 1 center)** |  |  |
| Operation duration (benchmark cutoff / median, range) | ≤120 min | 117 min (55-450) |  |  |
| Intraoperative blood transfusions | 0% | 0.00% |  |  |
| Postoperative blood transfusions | ≤2% | 4.70% |  |  |
| Postoperative ICU admission | ≤0.14% | 0.43% |  |  |
| ICU stay in patients admitted to ICU (benchmark cutoff / median, range) | ≤1 day | 7 days (4-11) |  |  |
| Hospital stay (benchmark cutoff / median, range) | ≤4 days | 5 days (3-36) |  |  |
|  |  |  |  |  |
|  | **Global benchmark cutoff (n=4120, 15 centers)** | **Outcomes in non-benchmark cases (n=468, 1 center)** | **Global benchmark cutoff (n=4120, 15 centers)** | **Outcomes in non-benchmark cases (n=468, 1 center)** |
| **2. Morbidity and Mortality** | **Inpatient stay** | **Inpatient stay** | **90-day postoperative** | **90-day postoperative** |
| Uneventful postoperative course | >94% | 86.7% | >90% | 66% |
| Readmission | - | - | ≤5.5% | 19.6% |
| Reoperation | ≤2% | 2.80% | ≤4% | 11.5% |
| Any complication | ≤6% | 13.3% | ≤10% | 34% |
| Complication grade ≥ IIIa | ≤3.5% | 3.80% | ≤5.5% | 19.6% |
| Mortality | 0% | 0% | 0% | 0% |
| CCI® In patients with at least 1 Clavien-Dindo Grade ≥II complication (benchmark cutoff / median, inter-quartile range) | ≤26.2 | 20.9 (20.9 -33.7) | ≤33.7 | 33.7 (20.9 - 42.3) |
| **Signature complications** |  |  |  |  |
| Anastomotic leak | 0% | 0.21% | ≤1.3% | 0.64% |
| Stenosis of the anastomosis | 0% | 0% | ≤1.2% | 10.90% |
| Postoperative bleeding | ≤2.2% | 5.30% | ≤2.2% | 6.40% |
| Small bowel obstruction/internal hernia | ≤1.4% | 0.21% | ≤2.1% | 0.43% |
| Wound infection | ≤0.5% | 2.35% | ≤0.5% | 6.20% |
| Marginal ulcer | 0% | 0% | ≤1.5% | 2.13% |

**Supplementary Table 5.** Results of a literature review to identify published outcome data from the participating centers on consecutive RYGB cohorts or on non-benchmark RYGB patients. The median rate of 30-day complications requiring re-intervention in these 10 studies covering a total of 3993 patients was 10.75%, more than the double of the benchmark cutoff for the same outcome indicator identified by the current study: 5%.

*CD: Clavien-Dindo grade of postoperative complications; PMID: Pubmed ID; RYGB: Roux-en-Y gastric bypass*

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|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Center** | **Cohort**  **(publication date)** | **CD>II**  **at 30-day (%)** | **N** | **Title** |
| Basel | Consecutive RYGB (2013) | 4.5 | 110 | Early results of the Swiss Multicentre Bypass or Sleeve Study (SM-BOSS): a prospective randomized trial comparing laparoscopic sleeve gastrectomy and Roux-en-Y gastric bypass.1 |
| Offenbach | Consecutive RYGB (inpatient complications only) (2013) | 5 | 1345 | Early Post-operative Complications: Incidence, Management, and Impact on Length of Hospital Stay. A Retrospective Comparison Between Laparoscopic Gastric Bypass and Sleeve Gastrectomy2 |
| Zurich | Consecutive RYGB (2019) | 15 | 135 | Predictors of a Healthy Eating Disorder Examination-Questionnaire (EDE-Q) Score 1 Year After Bariatric Surgery3 |
| Brussels | Secondary RYGB after gastric band (2018) | 12.9 | 1219 | Roux-en-Y gastric bypass, sleeve gastrectomy, or one anastomosis gastric bypass as rescue therapy after failed adjustable gastric banding: a multicenter comparative study4 |
| Taunton | Secondary RYGB after gastric band (2018) | 14.15 | 113 | Single-stage conversions from failed gastric band to sleeve gastrectomy versus Roux-en-Y gastric bypass: results from the United Kingdom National Bariatric Surgical Registry.5 |
| Bruges | Secondary RYGB after gastric band (2016) | 5.1 | 885 | A one-step conversion from gastric banding to laparoscopic Roux-en-Y gastric bypass is as safe as a two-step conversion: A comparative analysis of 885 patients.6 |
| Wien | Secondary RYGB after sleeve gastrectomy (2010) | 12.5 | 73 | Conversion from Sleeve Gastrectomy to Roux-en-Y Gastric Bypass—Indications and Outcome7 |
| Weston | Secondary RYGB after sleeve gastrectomy (2016) | 3.3 | 30 | Reasons and outcomes of conversion of laparoscopic sleeve gastrectomy to Roux-en-Y gastric bypass for nonresponders8 |
| Arnhem | Secondary RYGB or duodenal switch after sleeve gastrectomy (2015) | 9 | 43 | Secondary surgery after sleeve gastrectomy: Roux-en-Y gastric bypass or biliopancreatic diversion with duodenal switch9 |
| Nice | Secondary RYGB after sleeve gastrectomy (2016) | 14 | 40 | Laparoscopic conversion of sleeve gastrectomy to Roux-en-Y gastric bypass: indications and preliminary results10 |
| **Overall** | **Median** | **10.75** |  |  |
| **75th percentile** | **13.72** |  |  |

**Supplementary Figure 1.** Study flowchart.

*RYGB: Roux-en-Y gastric bypass, SG: sleeve gastrectomy, FU: follow-up*

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**Supplementary Figure 2.** Rate of “uneventful postoperative course” in benchmark patients per included bariatric center (anonymized). Red dashed line: Benchmark cut-off at 90-days

1. Roux-en-Y gastric bypass

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1. Sleeve gastrectomy

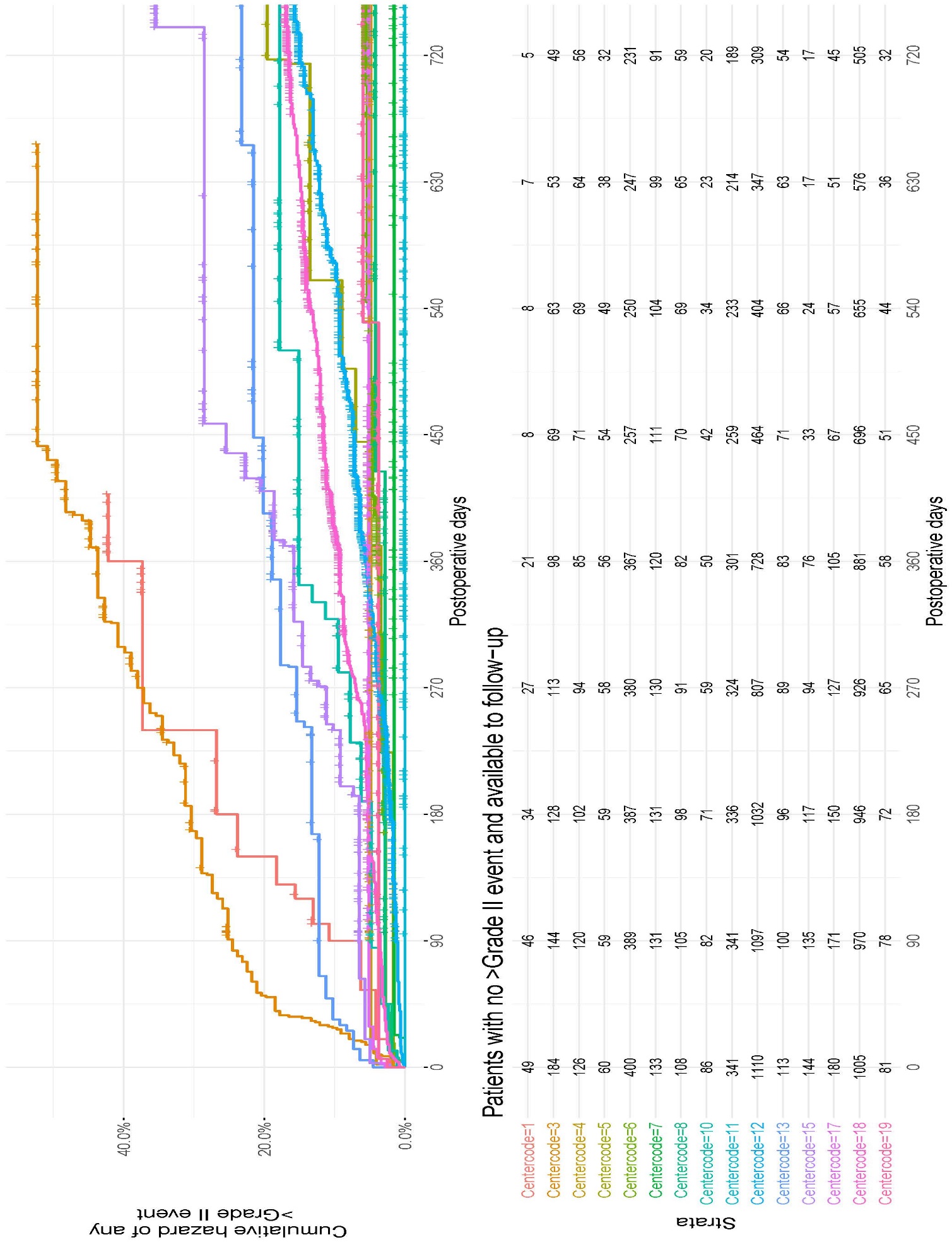
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**Supplementary Figure 3.** Cumulative hazard of Clavien-Dindo grade > II events in benchmark patients during the first two years after bariatric surgery (Roux-en-Y gastric bypass and sleeve gastrectomy).

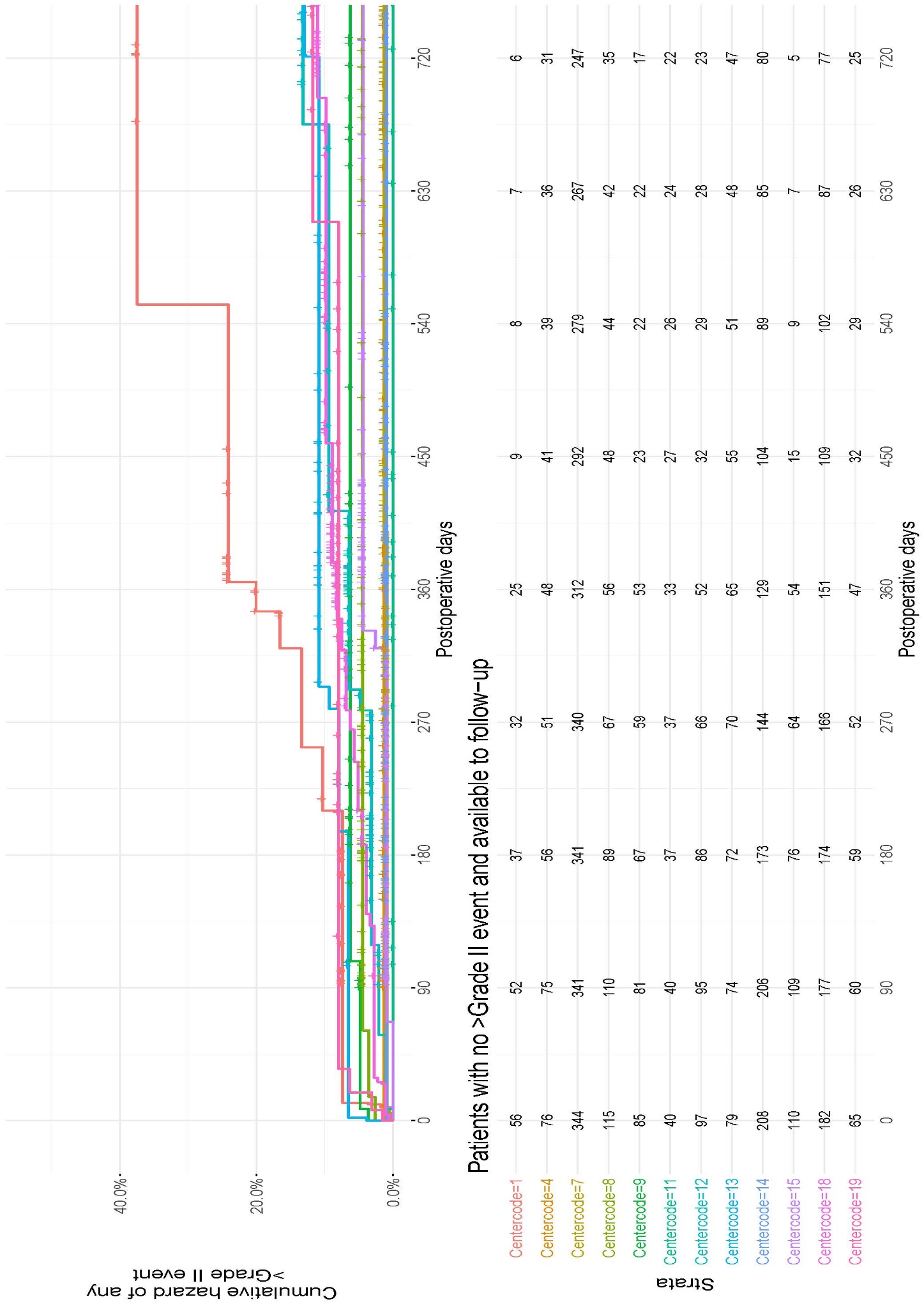
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**Supplementary Figure 4.** Cumulative hazard of Clavien-Dindo grade > II events in benchmark patients during the first two years after, stratified by centers

1. Roux-en-Y gastric bypass

****

1. Sleeve gastrectomy

****

**Supplementary Figure 5.** Correlation of center volume and cumulative morbidity (CCI®) at 90-days postoperatively.

A. Elective bariatric caseload over 5-years and mean CCI® in benchmark RYGB cases over the first 90-days postoperatively (r = -0.37, P = 0.17).

B. Benchmark RYGB cases over 5-years and mean CCI® in benchmark RYGB cases over the first 90-days postoperatively (r = -0.24, P = 0.38).

C. Elective bariatric caseload over 5-years and mean CCI® in benchmark SG cases over the first 90-days postoperatively (r = -0.34, P = 0.28).

D. Benchmark SG cases over 5-years and mean CCI® in benchmark SG cases over the first 90-days postoperatively (r = -0.41, P = 0.19).

