

Supplementary Online Content

Courcoulas A, Coley RY, Clark JM, et al. Interventions and operations 5 years after bariatric surgery in a cohort from the US National Patient-Centered Clinical Research Network Bariatric Study. *JAMA Surg*. Published online January 15, 2020. doi:10.1001/jamasurg.2019.5470

eFigure. Flow Diagram for Identification of the Cohort

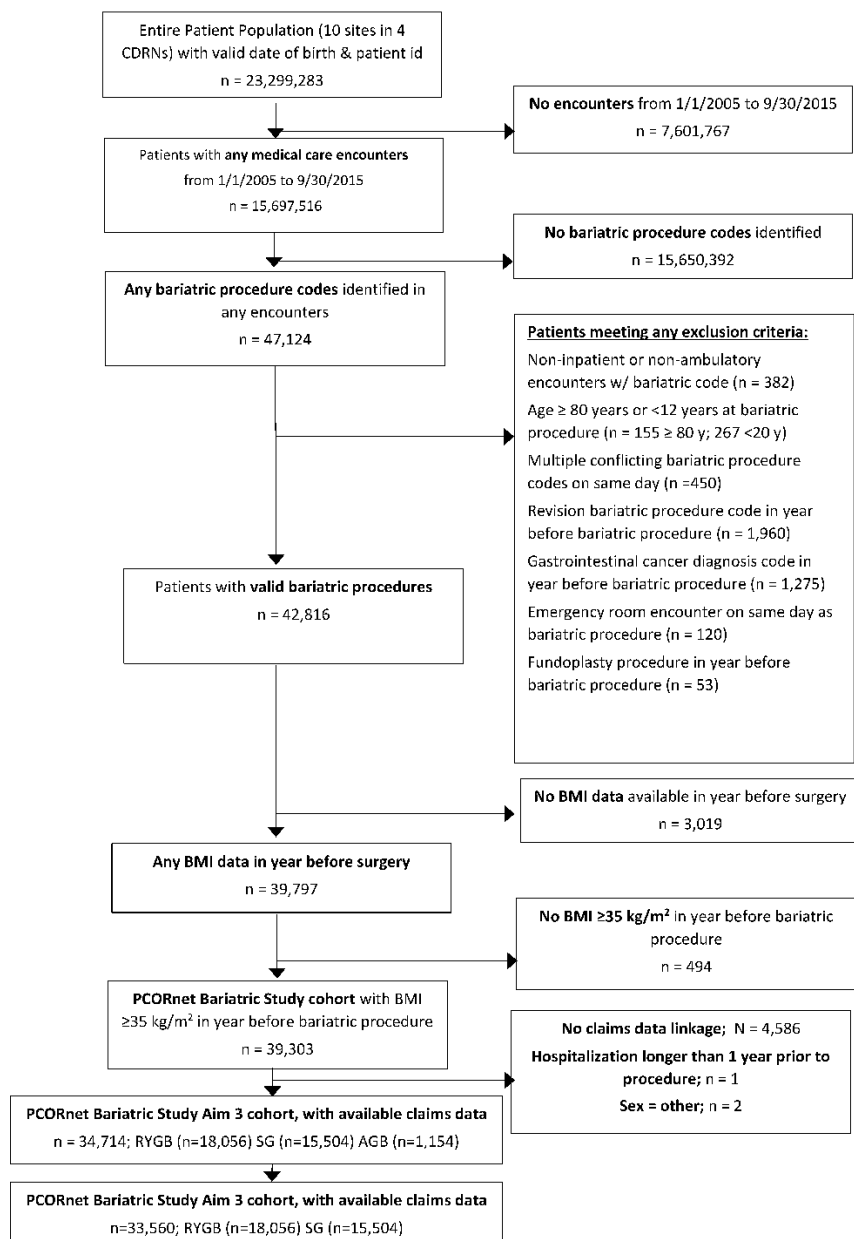
eTable 1. Kaplan-Meier Estimated Cumulative Incidence of Operations, Interventions, and Endoscopy

eTable 2. Causes of Death

eAppendix. Results for Adjustable Gastric Band (AGB)

This supplementary material has been provided by the authors to give readers additional information about their work.

eFigure. Flow Diagram for Identification of the Cohort



eTable 1. Kaplan-Meier Estimated Cumulative Incidence of Operations, Interventions, and Endoscopy^a

| | RYGB (n=18,056) | | | SG (n=15,504) | | |
|------------------------------------|--------------------|----------------------|----------------------|-------------------|-------------------|-------------------|
| | 1 year % | 3 year % | 5 year % | 1 year % | 3 year % | 5 year % |
| OPERATIONS ^b | 4.5 (4.2, 4.8) | 10 (9.5, 10.5) | 13.6 (12.9, 14.3) | 2.3 (2, 2.5) | 5.2 (4.8, 5.6) | 8.3 (7.5, 9.2) |
| REVISION ^c | 1.3 (1.2, 1.5) | 2 (1.8, 2.2) | 2.8 (2.5, 3.2) | 1 (0.8, 1.1) | 2.1 (1.8, 2.3) | 4 (3.3, 4.7) |
| ABDOMINAL WALL HERNIA ^d | 1.4 (1.2, 1.6) | 5.1 (4.7, 5.4) | 7 (6.5, 7.5) | 0.7 (0.6, 0.9) | 2.1 (1.8, 2.4) | 3.2 (2.7, 3.7) |
| OTHER OPERATIONS ^e | 2.8 (2.6, 3.1) | 5.5 (5.1, 5.9) | 7.9 (7.4, 8.5) | 0.9 (0.8, 1.1) | 2.1 (1.8, 2.3) | 3.1 (2.6, 3.7) |
| INTERVENTIONS ^f | | | | | | |
| ENTERAL ACCESS ^g | 0.6 (0.5, 0.7) | 1.1 (0.9, 1.2) | 1.3 (1.1, 1.5) | 0.1 (0, 0.1) | 0.2 (0.1, 0.2) | 0.3 (0.1, 0.4) |
| OTHER INTERVENTIONS ^h | 0.2 (0.1, 0.2) | 0.3 (0.2, 0.4) | 0.4 (0.3, 0.6) | 0.2 (0.1, 0.3) | 0.4 (0.3, 0.5) | 0.5 (0.3, 0.7) |
| ENDOSCOPY ⁱ | 9.7 (9.3, 10.2) | 15.7 (15.1, 16.3) | 20.6 (19.8, 21.3) | 2.7 (2.4, 3) | 4.8 (4.4, 5.2) | 6.8 (6, 7.5) |

a – From Kaplan Meier plots

b - Category includes any operative procedure on the abdomen (includes subcategories of revision, abdominal wall hernia repairs, , and other reoperation-includes internal hernia, paraesophageal/hiatal hernia); **Biliary procedures including cholecystectomy were excluded;**

c - Category includes only subsequent bariatric procedures (e.g. conversion from SG to RYGB) as well as revisional procedures such as gastrectomy;

d- Category includes only repair of ventral hernias and other abdominal wall hernias - does not include internal hernias or paraesophageal/hiatal hernias;

e - Category includes those abdominal operative procedures not captured under the prior categories and represents presumed complications, includes internal hernias or paraesophageal/hiatal hernias;

f – Category includes any enteral access, non-operative procedures on the abdomen;

g – Category includes placement of gastrostomy tubes or other feeding devices, either percutaneously or through other means of access;

h– Category includes invasive but not operative procedures on the abdomen such as paracentesis, or radiologically-guided drainage procedures that do not involve incision

i – Category includes any endoscopic procedure for diagnosis or treatment on the upper GI tract

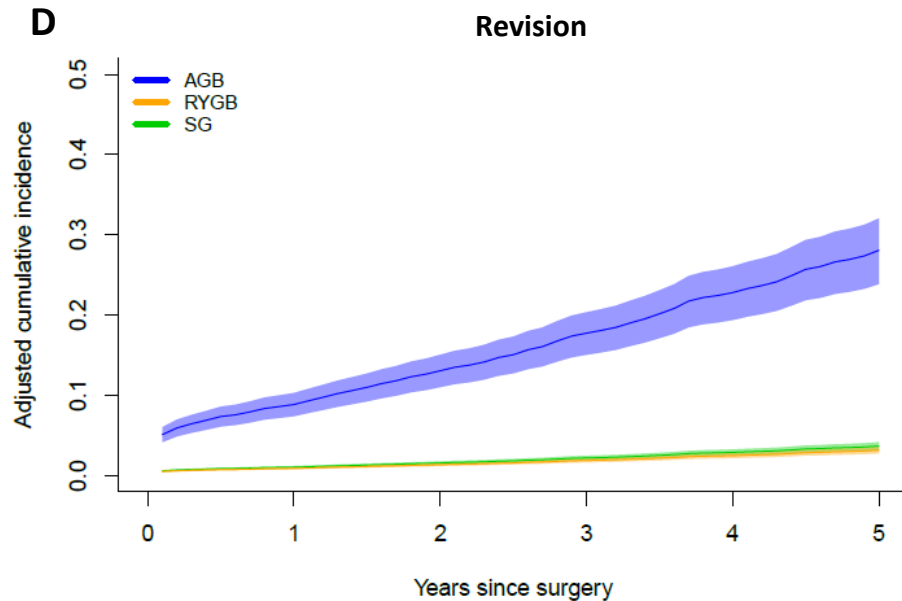
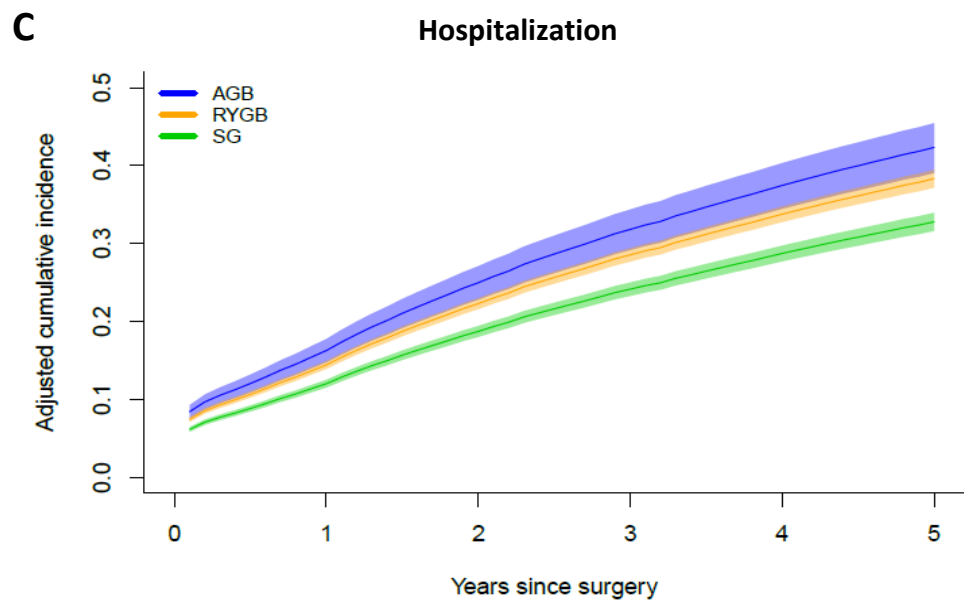
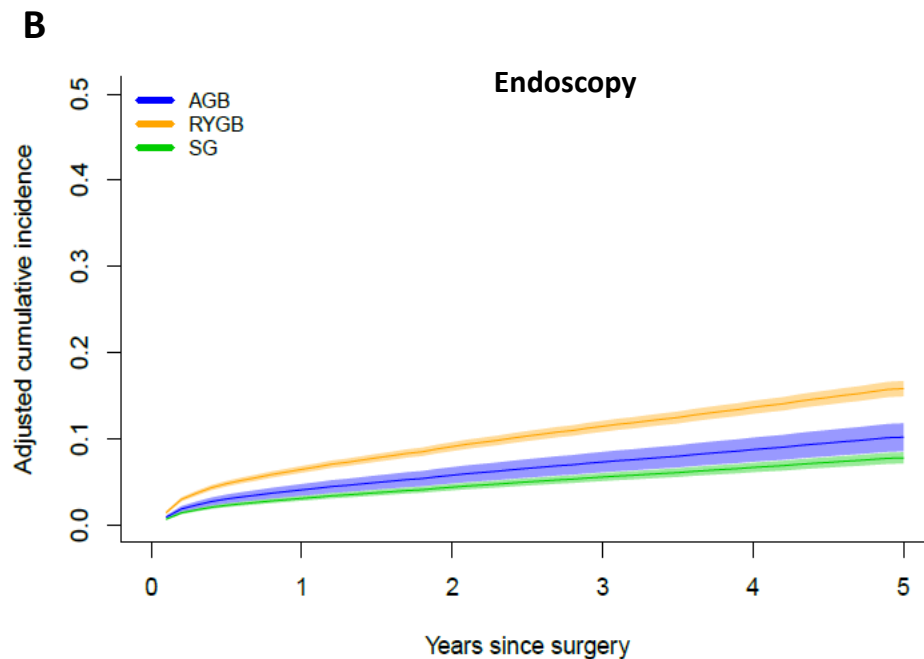
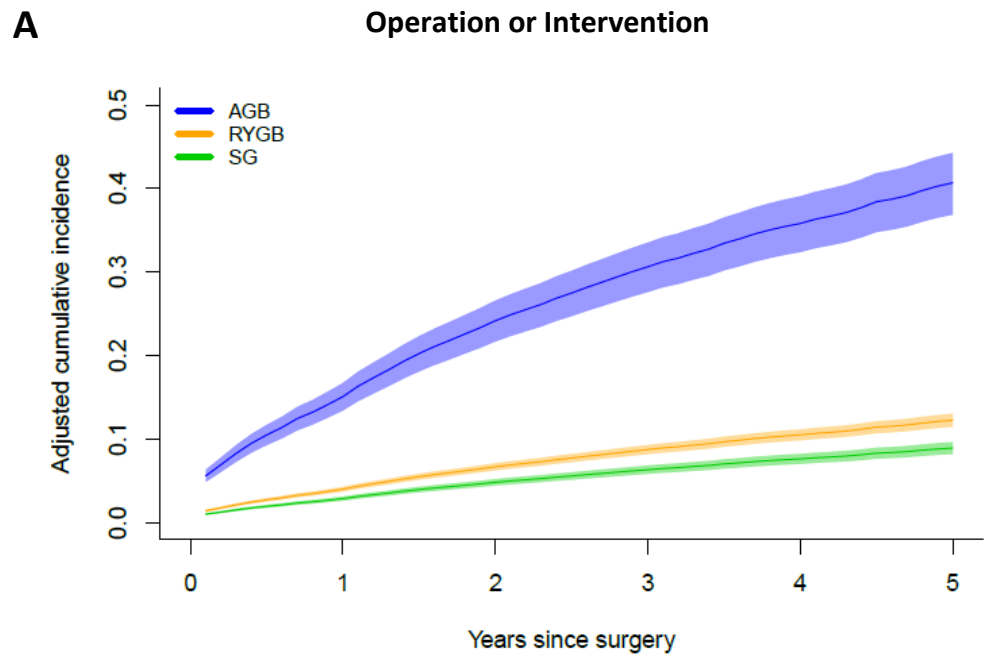
eTable 2. Causes of Death

| All (n=33,560; 464 deaths) | | | RYGB (n=18,056; 364 deaths) | | | SG (n=15,504; 100 deaths) | | |
|----------------------------|--------------------------|--------------|-----------------------------|--------------------------|--------------|---------------------------|--------------------------|--------------|
| Rank | Cause of Death | Total Number | Rank | Cause of Death | Total Number | Rank | Cause of Death | Total Number |
| 1 | None | 144 | 1 | None | 106 | 1 | None | 38 |
| 2 | Cardiac | 63 | 2 | Malignancy | 51 | 2 | Cardiac | 21 |
| 3 | Malignancy | 66 | 3 | Cardiac | 42 | 3 | Endocrine | 20 |
| 4 | Endocrine | 53 | 4 | Coronary artery disease | 38 | 4 | Malignancy | 15 |
| 5 | Coronary artery disease | 49 | 5 | Diabetes | 34 | 5 | Respiratory | 13 |
| 6 | Diabetes | 42 | 6 | Endocrine | 33 | 6 | Coronary artery disease | 11 |
| 7 | Sepsis | 33 | 7 | Sepsis | 27 | 7 | Alcohol/substance | 9 |
| 8 | Alcohol/Substance | 31 | 8 | Accidental injury | 23 | 8 | Renal | 9 |
| 9 | Hypertension | 31 | 9 | Hypertension | 23 | 9 | Diabetes | 8 |
| 10 | Respiratory | 29 | 10 | Alcohol/substance | 22 | 10 | GI | 8 |
| 11 | Renal | 30 | 11 | Trauma | 21 | 11 | Hypertension | 8 |
| 12 | Accidental injury | 29 | 12 | Renal | 21 | 12 | Congestive heart failure | 7 |
| 13 | GI | 24 | 13 | GI | 16 | 13 | Sepsis | 6 |
| 14 | Trauma | 24 | 14 | Respiratory | 16 | 14 | Accidental injury | 6 |
| 15 | Congestive heart failure | 21 | 15 | Self harm | 15 | 15 | Pulmonary embolism | 5 |
| 16 | Self harm | 18 | 16 | Liver | 15 | 16 | Other | 4 |
| 17 | Liver | 17 | 17 | Congestive heart failure | 14 | 17 | Self harm | 3 |

| | | | | | | | | | | |
|----|---------------------------|----|--|----|------------|----|--|----|---------------|---|
| 18 | Neurologic | 15 | | 18 | Neurologic | 12 | | 18 | Trauma | 3 |
| 19 | Other | 12 | | 19 | Other | 8 | | 19 | Flu/pneumonia | 3 |
| 20 | Stroke/Intracranial bleed | 8 | | 20 | Vascular | 8 | | 20 | Vascular | 3 |

eAppendix. Results for Adjustable Gastric Band (AGB)

eAppendix Figure 1: Cumulative Incidence Operation or Intervention, Endoscopy, Hospitalization, and Revision*



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*Adjusted cumulative incidence based on cox proportional hazards model results—solid colored lines—with 95% pointwise confidence intervals—shading around lines

eAppendix Table 1. Baseline Characteristics

| | RYGB (n=18,056) | | | SG (n=15,504) | | | AGB (n=1,154) | | | All (n=34,714) | | |
|-----------------------------------|-----------------|--------|-------|---------------|--------|-------|---------------|--------|-------|----------------|--------|-------|
| | Mean | Median | SD | Mean | Median | SD | Mean | Median | SD | Mean | Median | SD |
| Age | 45.8 | 46 | 11.44 | 44.1 | 44 | 11.47 | 46.3 | 46 | 12.15 | 45.1 | 45 | 11.51 |
| Sex – N (%) | | | | | | | | | | | | |
| Female | 14481 (80.2) | | | 12493 (80.6) | | | 912 (79) | | | 27886 (80.3) | | |
| Male | 3575 (19.8) | | | 3011 (19.4) | | | 242 (21) | | | 6828 (19.7) | | |
| Race – N (%) | | | | | | | | | | | | |
| Asian | 186 (1.03) | | | 227 (1.5) | | | 9 (0.8) | | | 422 (1.2) | | |
| Black | 2246 (12.4) | | | 3574 (23.1) | | | 217 (18.8) | | | 6037 (17.4) | | |
| Missing | 1950 (10.8) | | | 2675 (17.3) | | | 91 (7.9) | | | 4716 (13.6) | | |
| Multiple | 10 (0.1) | | | 10 (0.1) | | | 1 (0.1) | | | 21 (0.1) | | |
| Native | 161 (0.9) | | | 129 (0.8) | | | 9 (0.8) | | | 299 (0.9) | | |
| Other | 154 (0.9) | | | 73 (0.5) | | | 12 (1) | | | 239 (0.7) | | |
| Pacific Islander | 72 (0.4) | | | 80 (0.5) | | | 0 (0) | | | 152 (0.4) | | |
| White | 13277 (73.5) | | | 8736 (56.4) | | | 815 (70.6) | | | 22828 (65.8) | | |
| Hispanic Ethnicity – N (%) | | | | | | | | | | | | |

| | RYGB (n=18,056) | | | SG (n=15,504) | | | AGB (n=1,154) | | | All (n=34,714) | | |
|-------------------------------|-----------------|--------|-------|---------------|--------|-------|---------------|--------|-------|----------------|--------|-------|
| Missing | 1970 (10.9) | | | 1124 (7.3) | | | 250 (21.7) | | | 3344 (9.6) | | |
| No | 12432 (68.9) | | | 9399 (60.6) | | | 762 (66) | | | 22593 (65.1) | | |
| Yes | 3654 (20.2) | | | 4981 (32.1) | | | 142 (12.3) | | | 8777 (25.3) | | |
| | Mean | Median | SD | Mean | Median | SD | Mean | Median | SD | Mean | Median | SD |
| BMI | 49.7 | 48.1 | 8.09 | 48.5 | 46.8 | 7.65 | 46.4 | 45 | 6.40 | 49 | 47.4 | 7.88 |
| Weight | 127.9 | 123.6 | 25.58 | 123.6 | 118.9 | 24.53 | 121.5 | 118.4 | 21.71 | 125.7 | 121.4 | 25.10 |
| Procedure Year – N (%) | | | | | | | | | | | | |
| 2005-2009 | 4038 (22.4) | | | 412 (2.7) | | | 333 (28.9) | | | 4783 (13.8) | | |
| 2010 | 2840 (15.7) | | | 1085 (7) | | | 266 (23.1) | | | 4191 (12.1) | | |
| 2011 | 3300 (18.3) | | | 2886 (18.6) | | | 317 (27.5) | | | 6503 (18.7) | | |
| 2012 | 2573 (14.3) | | | 2978 (19.2) | | | 119 (10.3) | | | 5670 (16.3) | | |
| 2013 | 1824 (10.1) | | | 2651 (17.1) | | | 60 (5.2) | | | 4535 (13.1) | | |
| 2014 | 1907 (10.6) | | | 2921 (18.8) | | | 46 (4) | | | 4874 (14) | | |
| 2015 | 1574 (8.7) | | | 2571 (16.6) | | | 13 (1.1) | | | 4158 (12) | | |
| Comorbidities – N (%) | | | | | | | | | | | | |
| Anxiety | 3891 (21.6) | | | 3248 (21) | | | 238 (20.6) | | | 7377 (21.3) | | |

| | RYGB (n=18,056) | SG (n=15,504) | AGB (n=1,154) | All (n=34,714) |
|--------------------|------------------------|----------------------|----------------------|-----------------------|
| Depression | 6361 (35.2) | 4288 (27.7) | 343 (29.7) | 10992 (31.7) |
| Diabetes | 8018 (44.4) | 4094 (26.4) | 347 (30.1) | 12459 (35.9) |
| DVT ^a | 122 (0.7) | 56 (0.4) | 11 (1) | 189 (0.5) |
| Dyslipidemia | 9782 (54.2) | 6991 (45.1) | 562 (48.7) | 17335 (49.9) |
| Eating disorder | 3421 (19) | 450 (2.9) | 123 (10.7) | 3994 (11.5) |
| GERD ^b | 7925 (43.9) | 4463 (28.8) | 453 (39.3) | 12841 (37) |
| Hypertension | 11220 (62.1) | 7897 (50.9) | 666 (57.7) | 19783 (57) |
| Kidney disease | 1976 (10.9) | 1168 (7.5) | 77 (6.7) | 3221 (9.3) |
| NAFLD ^c | 4534 (25.1) | 1688 (10.9) | 198 (17.2) | 6420 (18.5) |
| Osteoarthritis | 438 (2.4) | 325 (2.1) | 22 (1.9) | 785 (2.3) |
| PE ^d | 258 (1.4) | 108 (0.7) | 17 (1.5) | 383 (1.1) |
| Sleep apnea | 10017 (55.5) | 6067 (39.1) | 583 (50.5) | 16667 (48) |

^aDVT – Deep vein thrombosis; ^bGastroesophageal reflux disease; ^cNon-alcoholic fatty liver disease; ^dPulmonary embolism

eAppendix Table 2. Adjusted Hazard Ratio (HR) and Event Probability

| Hazard Ratio (95% CI) for comparison of different events across procedures | | | | | |
|---|--------------|----------|----------|----------|---------|
| Outcome | Procedures | Estimate | Lower CI | Upper CI | P-value |
| Operation or Intervention (Oorl) <i>excluding endoscopy</i> | SG vs. RYGB | 0.715 | 0.646 | 0.793 | <0.001 |
| | AGB vs. RYGB | 3.989 | 3.553 | 4.479 | <0.001 |
| | AGB vs. SG | 5.576 | 4.849 | 6.412 | <0.001 |
| Endoscopy | SG vs. RYGB | 0.471 | 0.426 | 0.52 | <0.001 |
| | AGB vs. RYGB | 0.624 | 0.531 | 0.734 | <0.001 |
| | AGB vs. SG | 1.325 | 1.103 | 1.592 | <0.01 |
| Revision | SG vs. RYGB | 1.165 | 0.976 | 1.392 | 0.09 |
| | AGB vs. RYGB | 10.271 | 8.625 | 12.231 | <0.001 |
| | AGB vs. SG | 8.814 | 7.159 | 10.851 | <0.001 |
| Hospitalization | SG vs. RYGB | 0.822 | 0.781 | 0.866 | <0.001 |
| | AGB vs. RYGB | 1.139 | 1.032 | 1.258 | <0.01 |
| | AGB vs. SG | 1.385 | 1.245 | 1.542 | <0.001 |
| Mortality | SG vs. RYGB | 0.942 | 0.725 | 1.225 | 0.66 |

| | | | | | |
|---|--------------|---------------------|---------------------|---------------------|------|
| | AGB vs. RYGB | 1.218 | 0.804 | 1.846 | 0.35 |
| | AGB vs. SG | 1.292 | 0.814 | 2.053 | 0.28 |
| Estimated % of patients with outcome event at specified timepoints [Estimate (95% CI)] | | | | | |
| Outcome | Procedure | 1 year | 3 year | 5 year | |
| Operation or Intervention (Oral) <i>excluding</i> endoscopy | RYGB | 4.02 (3.74 4.3) | 8.76 (8.22 9.3) | 12.27 (11.49 13.05) | |
| | SG | 2.89 (2.65 3.14) | 6.35 (5.85 6.85) | 8.94 (8.23 9.65) | |
| | AGB | 15.1 (13.44 16.73) | 30.64 (27.62 33.53) | 40.68 (36.88 44.26) | |
| Endoscopy | RYGB | 6.46 (6.08 6.84) | 11.46 (10.83 12.08) | 15.83 (14.94 16.71) | |
| | SG | 3.1 (2.84 3.36) | 5.57 (5.12 6.02) | 7.8 (7.15 8.43) | |
| | AGB | 4.08 (3.41 4.75) | 7.31 (6.14 8.47) | 10.2 (8.57 11.79) | |
| Revision | RYGB | 0.9 (0.78 1.02) | 1.88 (1.65 2.12) | 3.16 (2.75 3.56) | |
| | SG | 1.05 (0.9 1.19) | 2.19 (1.91 2.47) | 3.67 (3.18 4.16) | |
| | AGB | 8.86 (7.4 10.29) | 17.75 (15.05 20.36) | 28.07 (23.87 32.04) | |
| Hospitalization | RYGB | 14.44 (13.94 14.95) | 28.55 (27.69 29.4) | 38.33 (37.17 39.46) | |
| | SG | 12.04 (11.55 12.53) | 24.15 (23.29 25.0) | 32.79 (31.62 33.94) | |
| | AGB | 16.28 (14.78 17.76) | 31.82 (29.18 34.36) | 42.34 (39.06 45.44) | |

| | | | | |
|-----------|------|------------------|------------------|------------------|
| Mortality | RYGB | 0.17 (0.13 0.21) | 0.45 (0.36 0.54) | 0.89 (0.71 1.06) |
| | SG | 0.16 (0.12 0.2) | 0.43 (0.33 0.52) | 0.84 (0.65 1.02) |
| | AGB | 0.21 (0.11 0.3) | 0.55 (0.31 0.79) | 1.08 (0.62 1.54) |

eAppendix Table 3. Heterogeneity of Treatment Effects

| Age: | | | | | | | | | | |
|--|-----------|-------------|--------------|--------------|-------------|--------------|--------------|-----------------|--------------|--------------|
| Evidence of heterogeneous treatment effect of procedures on event time given age at baseline | | | | | | | | | | |
| | | Age < 65 | | | Age >65 | | | | | |
| | | Adjusted HR | Lower 95% CI | Upper 95% CI | Adjusted HR | Lower 95% CI | Upper 95% CI | p-value for HTE | | |
| SG vs. RYGB | | 0.711 | 0.64 | 0.79 | 0.783 | 0.562 | 1.089 | 0.58 | | |
| AGB vs RYGB | | 4.148 | 3.681 | 4.675 | 2.677 | 1.826 | 3.925 | 0.03 | | |
| AGB vs SG | | 5.833 | 5.052 | 6.734 | 3.42 | 2.194 | 5.33 | 0.02 | | |
| Estimated percent of patients with event at 1, 3, and 5 years | | | | | | | | | | |
| | | 1 year | | | 3 years | | | 5 years | | |
| | | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI |
| RYGB | Age < 65 | 3.95 | 3.67 | 4.23 | 8.61 | 8.06 | 9.15 | 12.06 | 11.28 | 12.84 |
| | Age >= 65 | 5.61 | 4.59 | 6.62 | 12.1 | 9.99 | 14.16 | 16.82 | 13.94 | 19.61 |
| SG | Age < 65 | 2.83 | 2.58 | 3.07 | 6.2 | 5.7 | 6.7 | 8.74 | 8.01 | 9.45 |
| | Age >= 65 | 4.42 | 3.18 | 5.64 | 9.61 | 6.98 | 12.15 | 13.42 | 9.81 | 16.9 |
| AGB | Age < 65 | 15.39 | 13.66 | 17.09 | 31.17 | 28.04 | 34.16 | 41.32 | 37.39 | 45.01 |
| | Age >= 65 | 14.32 | 9.54 | 18.85 | 29.2 | 20.09 | 37.28 | 38.92 | 27.36 | 48.64 |

| Gender: | | | | | | | | | | | |
|--|--------|-------------|--------------|--------------|-------------|--------------|--------------|-----------------|--------------|--------------|-----------------|
| Evidence of heterogeneous treatment effect of procedures on event time given gender | | | | | | | | | | | |
| | | Female | | | Male | | | | | | |
| | | Adjusted HR | Lower 95% CI | Upper 95% CI | Adjusted HR | Lower 95% CI | Upper 95% CI | p-value for HTE | | | |
| SG vs. RYGB | | 0.699 | 0.625 | 0.782 | 0.784 | 0.642 | 0.959 | 0.30 | | | |
| AGB vs RYGB | | 4.18 | 3.686 | 4.741 | 3.27 | 2.53 | 4.225 | 0.08 | | | |
| AGB vs SG | | 5.981 | 5.14 | 6.959 | 4.168 | 3.119 | 5.571 | 0.02 | | | |
| Estimated percent of patients with event at 1, 3, and 5 years | | | | | | | | | | | |
| | | 1 year | | | 3 years | | | 5 years | | | |
| | | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI | |
| RYGB | Female | 4.04 | 3.75 | 4.34 | 8.81 | 8.23 | 9.39 | 12.34 | 11.52 | 13.17 | |
| | Male | 3.93 | 3.46 | 4.4 | 8.58 | 7.6 | 9.54 | 12.02 | 10.66 | 13.36 | |
| SG | Female | 2.84 | 2.58 | 3.11 | 6.25 | 5.7 | 6.79 | 8.8 | 8.02 | 9.57 | |
| | Male | 3.1 | 2.57 | 3.62 | 6.79 | 5.68 | 7.89 | 9.56 | 8 | 11.09 | |
| AGB | Female | 15.85 | 13.99 | 17.67 | 32.01 | 28.65 | 35.2 | 42.35 | 38.16 | 46.26 | |
| | Male | 12.29 | 9.48 | 15.02 | 25.41 | 19.98 | 30.48 | 34.21 | 27.22 | 40.52 | |
| BMI: | | | | | | | | | | | |
| Evidence of heterogeneous treatment effect of procedures on event time given BMI at baseline | | | | | | | | | | | |
| | | BMI < 50 | | | BMI 50-60 | | | BMI >= 60 | | | |
| | | Adjusted HR | Lower 95% CI | Upper 95% CI | Adjusted HR | Lower 95% CI | Upper 95% CI | Adjusted HR | Lower 95% CI | Upper 95% CI | p-value for HTE |
| SG vs. RYGB | | 0.708 | 0.632 | 0.795 | 0.746 | 0.61 | 0.913 | 0.775 | 0.543 | 1.105 | <0.01 |
| AGB vs RYGB | | 4.205 | 3.71 | 4.767 | 3.106 | 2.354 | 4.097 | 3.814 | 2.001 | 7.269 | <0.001 |
| AGB vs SG | | 5.935 | 5.103 | 6.903 | 4.161 | 3.03 | 5.714 | 4.923 | 2.45 | 9.893 | <0.001 |

| Estimated percent of patients with event at 1, 3, and 5 years | | | | | | | | | | |
|---|-----------|----------|--------------|--------------|----------|--------------|--------------|----------|--------------|--------------|
| | | 1 year | | | 3 years | | | 5 years | | |
| | | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI |
| RYGB | BMI < 50 | 3.9 | 3.6 | 4.19 | 8.5 | 7.92 | 9.08 | 11.91 | 11.08 | 12.74 |
| | BMI 50-60 | 4.29 | 3.83 | 4.74 | 9.32 | 8.4 | 10.24 | 13.04 | 11.74 | 14.32 |
| | BMI >= 60 | 4.78 | 3.95 | 5.6 | 10.36 | 8.63 | 12.05 | 14.45 | 12.06 | 16.76 |
| SG | BMI < 50 | 2.78 | 2.51 | 3.04 | 6.1 | 5.56 | 6.65 | 8.59 | 7.82 | 9.37 |
| | BMI 50-60 | 3.22 | 2.66 | 3.77 | 7.05 | 5.86 | 8.22 | 9.9 | 8.24 | 11.53 |
| | BMI >= 60 | 3.72 | 2.57 | 4.86 | 8.12 | 5.66 | 10.52 | 11.39 | 7.97 | 14.67 |
| AGB | BMI < 50 | 15.4 | 13.63 | 17.14 | 31.18 | 27.97 | 34.25 | 41.34 | 37.31 | 45.1 |
| | BMI 50-60 | 11.61 | 3.56 | 18.99 | 24.1 | 7.79 | 37.53 | 32.53 | 10.9 | 48.92 |
| | BMI >= 60 | 18.6 | 14.88 | 22.15 | 36.85 | 30.27 | 42.81 | 48.11 | 40.16 | 55.01 |

| Diabetes: | | | | | | | | | | |
|---|-------------|-------------|--------------|--------------|-------------|--------------|--------------|-----------------|--------------|--------------|
| Evidence of heterogeneous treatment effect of procedures on event time given diabetes | | | | | | | | | | |
| | | No diabetes | | | Diabetes | | | | | |
| | | Adjusted HR | Lower 95% CI | Upper 95% CI | Adjusted HR | Lower 95% CI | Upper 95% CI | p-value for HTE | | |
| SG vs. RYGB | | 0.678 | 0.6 | 0.765 | 0.796 | 0.68 | 0.931 | 0.09 | | |
| AGB vs RYGB | | 3.981 | 3.47 | 4.567 | 3.958 | 3.277 | 4.78 | 0.96 | | |
| AGB vs SG | | 5.875 | 4.999 | 6.903 | 4.976 | 3.97 | 6.236 | 0.21 | | |
| Estimated percent of patients with event at 1, 3, and 5 years | | | | | | | | | | |
| | | 1 year | | | 3 years | | | 5 years | | |
| | | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI |
| RYGB | No diabetes | 4.11 | 3.78 | 4.45 | 8.96 | 8.29 | 9.62 | 12.54 | 11.59 | 13.47 |
| | Diabetes | 3.9 | 3.55 | 4.25 | 8.51 | 7.8 | 9.21 | 11.92 | 10.92 | 12.91 |
| SG | No diabetes | 2.81 | 2.53 | 3.08 | 6.16 | 5.58 | 6.74 | 8.68 | 7.86 | 9.49 |

| | | | | | | | | | | |
|-----|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | Diabetes | 3.12 | 2.68 | 3.55 | 6.83 | 5.9 | 7.75 | 9.61 | 8.31 | 10.89 |
| AGB | No diabetes | 15.4 | 13.48 | 17.27 | 31.17 | 27.69 | 34.49 | 41.34 | 36.97 | 45.4 |
| | Diabetes | 14.58 | 12.03 | 17.05 | 29.67 | 24.94 | 34.11 | 39.5 | 33.54 | 44.93 |

Comorbidity index:

Evidence of heterogeneous treatment effect of procedures on event time given comorbidity score

| | Comorbidity < 0 | | | Comorbidity = 0 | | | Comorbidity > 0 | | | p-value for HTE |
|-------------|-----------------|--------------|--------------|-----------------|--------------|--------------|-----------------|--------------|--------------|-----------------|
| | Adjusted HR | Lower 95% CI | Upper 95% CI | Adjusted HR | Lower 95% CI | Upper 95% CI | Adjusted HR | Lower 95% CI | Upper 95% CI | |
| SG vs. RYGB | 0.689 | 0.587 | 0.809 | 0.702 | 0.61 | 0.807 | 0.813 | 0.665 | 0.995 | <0.001 |
| AGB vs RYGB | 3.039 | 2.494 | 3.705 | 4.668 | 3.979 | 5.475 | 4.338 | 3.447 | 5.459 | <0.001 |
| AGB vs SG | 4.411 | 3.512 | 5.54 | 6.65 | 5.519 | 8.013 | 5.333 | 4.059 | 7.007 | <0.001 |

Estimated percent of patients with event at 1, 3, and 5 years

| | | 1 year | | | 3 years | | | 5 years | | |
|------|-----------------|----------|--------------|--------------|----------|--------------|--------------|----------|--------------|--------------|
| | | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI |
| RYGB | Comorbidity < 0 | 3.81 | 3.4 | 4.23 | 8.33 | 7.47 | 9.18 | 11.68 | 10.47 | 12.87 |
| | Comorbidity = 0 | 4.07 | 3.72 | 4.42 | 8.88 | 8.17 | 9.58 | 12.43 | 11.43 | 13.42 |
| | Comorbidity > 0 | 4.27 | 3.73 | 4.8 | 9.3 | 8.18 | 10.4 | 13.01 | 11.46 | 14.53 |
| SG | Comorbidity < 0 | 2.64 | 2.26 | 3.02 | 5.82 | 5 | 6.62 | 8.2 | 7.05 | 9.33 |
| | Comorbidity = 0 | 2.87 | 2.54 | 3.21 | 6.32 | 5.61 | 7.02 | 8.9 | 7.9 | 9.88 |
| | Comorbidity > 0 | 3.49 | 2.87 | 4.1 | 7.63 | 6.32 | 8.93 | 10.72 | 8.89 | 12.51 |
| AGB | Comorbidity < 0 | 11.14 | 9.07 | 13.17 | 23.23 | 19.19 | 27.06 | 31.44 | 26.19 | 36.32 |
| | Comorbidity = 0 | 24.18 | 16.88 | 30.84 | 46.17 | 33.88 | 56.17 | 58.7 | 44.55 | 69.24 |
| | Comorbidity > 0 | 12.42 | 9.62 | 15.13 | 25.67 | 20.29 | 30.69 | 34.53 | 27.62 | 40.78 |

GERD:

| Evidence of heterogeneous treatment effect of procedures on event time given GERD | | | | | | | |
|---|-------------|--------------|--------------|-------------|--------------|--------------|-----------------|
| | No GERD | | | GERD | | | |
| | Adjusted HR | Lower 95% CI | Upper 95% CI | Adjusted HR | Lower 95% CI | Upper 95% CI | p-value for HTE |
| SG vs. RYGB | 0.716 | 0.633 | 0.811 | 0.724 | 0.622 | 0.843 | 0.91 |
| AGB vs RYGB | 4.383 | 3.798 | 5.059 | 3.486 | 2.93 | 4.148 | 0.04 |
| AGB vs SG | 6.12 | 5.179 | 7.232 | 4.816 | 3.901 | 5.945 | 0.06 |

| Estimated percent of patients with event at 1, 3, and 5 years | | | | | | | | | | |
|---|---------|----------|--------------|--------------|----------|--------------|--------------|----------|--------------|--------------|
| | | 1 year | | | 3 years | | | 5 years | | |
| | | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI |
| RYGB | No GERD | 3.84 | 3.53 | 4.15 | 8.38 | 7.76 | 9 | 11.75 | 10.86 | 12.63 |
| | GERD | 4.3 | 3.94 | 4.66 | 9.36 | 8.63 | 10.08 | 13.09 | 12.06 | 14.11 |
| SG | No GERD | 2.77 | 2.49 | 3.04 | 6.08 | 5.5 | 6.65 | 8.56 | 7.74 | 9.38 |
| | GERD | 3.13 | 2.71 | 3.55 | 6.87 | 5.98 | 7.74 | 9.66 | 8.42 | 10.88 |
| AGB | No GERD | 15.78 | 13.75 | 17.76 | 31.87 | 28.19 | 35.35 | 42.18 | 37.6 | 46.43 |
| | GERD | 14.21 | 11.94 | 16.42 | 29 | 24.78 | 32.99 | 38.68 | 33.35 | 43.58 |

| Race/Ethnicity: | | | | | | | | | | | | | |
|--|--------------------|--------------|--------------|--------------------|--------------|--------------|----------|--------------|--------------|--------------------|--------------|--------------|-----------------|
| Evidence of heterogeneous treatment effect of procedures on event time given comorbidity score | | | | | | | | | | | | | |
| | White non-Hispanic | | | Black non-Hispanic | | | Hispanic | | | Other non-Hispanic | | | |
| | Adj HR | Lower 95% CI | Upper 95% CI | Adj HR | Lower 95% CI | Upper 95% CI | Adj HR | Lower 95% CI | Upper 95% CI | Adj HR | Lower 95% CI | Upper 95% CI | p-value for HTE |
| SG vs. RYGB | 0.687 | 0.599 | 0.786 | 0.694 | 0.564 | 0.854 | 0.628 | 0.523 | 0.755 | 0.682 | 0.367 | 1.266 | <0.001 |
| AGB vs RYGB | 1.635 | 1.383 | 1.933 | 2.532 | 1.928 | 3.326 | 3.173 | 2.297 | 4.382 | 0.657 | 0.09 | 4.818 | <0.001 |
| AGB vs SG | 2.382 | 1.949 | 2.91 | 3.649 | 2.729 | 4.878 | 5.05 | 3.607 | 7.069 | 0.963 | 0.127 | 7.312 | <0.001 |

| | | 1 year | | | 3 years | | | 5 years | | |
|------|--------------------|----------|--------------|--------------|----------|--------------|--------------|----------|--------------|--------------|
| | | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI | Estimate | Lower 95% CI | Upper 95% CI |
| RYGB | White non-Hispanic | 3.95 | 3.61 | 4.28 | 8.6 | 7.92 | 9.26 | 12.05 | 11.1 | 13 |
| | Black non-Hispanic | 4.45 | 3.82 | 5.08 | 9.65 | 8.34 | 10.94 | 13.5 | 11.69 | 15.28 |
| | Hispanic | 4.05 | 3.54 | 4.56 | 8.81 | 7.75 | 9.87 | 12.35 | 10.87 | 13.81 |
| | Other non-Hispanic | 4.07 | 2.66 | 5.46 | 8.85 | 5.84 | 11.76 | 12.4 | 8.24 | 16.38 |
| SG | White non-Hispanic | 3.05 | 2.69 | 3.4 | 6.67 | 5.93 | 7.41 | 9.4 | 8.35 | 10.43 |
| | Black non-Hispanic | 2.96 | 2.48 | 3.44 | 6.48 | 5.46 | 7.48 | 9.13 | 7.71 | 10.53 |
| | Hispanic | 2.68 | 2.28 | 3.08 | 5.89 | 5.04 | 6.73 | 8.3 | 7.11 | 9.49 |
| | Other non-Hispanic | 2.65 | 1.31 | 3.97 | 5.81 | 2.9 | 8.63 | 8.2 | 4.12 | 12.11 |
| AGB | White non-Hispanic | 15.41 | 13.42 | 17.37 | 31.16 | 27.52 | 34.61 | 41.35 | 36.8 | 45.57 |
| | Black non-Hispanic | 16.32 | 10.17 | 22.04 | 32.79 | 21.3 | 42.6 | 43.32 | 28.96 | 54.79 |
| | Hispanic | 15.79 | 13 | 18.49 | 31.84 | 26.73 | 36.6 | 42.18 | 35.82 | 47.9 |
| | Other non-Hispanic | 2.65 | 0 | 7.66 | 5.82 | 0 | 16.28 | 8.21 | 0 | 22.42 |

eAppendix Table 4. Kaplan-Meier Estimated Cumulative Incidence of Operations, Interventions and Endoscopy ^a

| | RYGB (n=18,056) | | | SG (n=15,504) | | | AGB (n=1,154) | | |
|------------------------------------|----------------------|-------------------|----------------------|-------------------|-------------------|-------------------|----------------------|----------------------|----------------------|
| | 1 year % (95% CI) | 3 year % | 5 year % | 1 year % | 3 year % | 5 year % | 1 year % | 3 year % | 5 year % |
| OPERATIONS ^b | 4.5 (4.2, 4.8) | 10 (9.5, 10.5) | 13.6 (12.9, 14.3) | 2.3 (2, 2.5) | 5.2 (4.8, 5.6) | 8.3 (7.5, 9.2) | 20.5 (18.1, 22.8) | 33.5 (30.6, 36.3) | 43.4 (39.9, 46.6) |
| REVISION ^c | 1.3 (1.2, 1.5) | 2 (1.8, 2.2) | 2.8 (2.5, 3.2) | 1 (0.8, 1.1) | 2.1 (1.8, 2.3) | 4 (3.3, 4.7) | 6.2 (4.8, 7.6) | 17.7 (15.3, 20) | 28.6 (25.4, 31.8) |
| ABDOMINAL WALL HERNIA ^d | 1.4 (1.2, 1.6) | 5.1 (4.7, 5.4) | 7 (6.5, 7.5) | 0.7 (0.6, 0.9) | 2.1 (1.8, 2.4) | 3.2 (2.7, 3.7) | 0.3 (0, 0.6) | 1.2 (0.5, 1.8) | 2.1 (1.1, 3.1) |
| OTHER OPERATIONS ^e | 2.8 (2.6, 3.1) | 5.5 (5.1, 5.9) | 7.9 (7.4, 8.5) | 0.9 (0.8, 1.1) | 2.1 (1.8, 2.3) | 3.1 (2.6, 3.7) | 16.2 (14, 18.3) | 19.4 (17, 21.7) | 22.8 (20.1, 25.5) |
| INTERVENTIONS ^f | | | | | | | | | |
| ENTERAL ACCESS ^g | 0.6 (0.5, 0.7) | 1.1 (0.9, 1.2) | 1.3 (1.1, 1.5) | 0.1 (0, 0.1) | 0.2 (0.1, 0.2) | 0.3 (0.1, 0.4) | 0.3 (0, 0.6) | 0.4 (0, 0.7) | 0.9 (0.2, 1.7) |
| OTHER INTERVENTIONS ^h | 0.2 (0.1, 0.2) | 0.3 (0.2, 0.4) | 0.4 (0.3, 0.6) | 0.2 (0.1, 0.3) | 0.4 (0.3, 0.5) | 0.5 (0.3, 0.7) | 0.1 (0, 0.3) | 0.1 (0, 0.3) | 0.6 (0, 1.2) |

| | | | | | | | | | |
|-------------------------------|--------------------|----------------------|----------------------|-----------------|-------------------|-----------------|-------------------|---------------------|----------------------|
| ENDOSCOPY ⁱ | 9.7 (9.3, 10.2) | 15.7 (15.1, 16.3) | 20.6 (19.8, 21.3) | 2.7 (2.4, 3) | 4.8 (4.4, 5.2) | 6.8 (6, 7.5) | 2.9 (1.9, 3.8) | 10.5 (8.6, 12.3) | 16.9 (14.3, 19.5) |
|-------------------------------|--------------------|----------------------|----------------------|-----------------|-------------------|-----------------|-------------------|---------------------|----------------------|

a – From Kaplan Meier plots

b - Category includes any operative procedure on the abdomen (includes subcategories of revision, abdominal wall hernia repairs, , and other reoperation-includes internal hernia, paraesophageal/hiatal hernia); **Biliary procedures including cholecystectomy were excluded;**

c - Category includes only subsequent bariatric procedures (e.g. conversion from SG to RYGB) as well as revisional procedures such as gastrectomy;

d- Category includes only repair of ventral hernias and other abdominal wall hernias - does not include internal hernias or paraesophageal/hiatal hernias;

e - Category includes those abdominal operative procedures not captured under the prior categories and represents presumed complications, includes internal hernias or paraesophageal/hiatal hernias;

f – Category includes any enteral access, non-operative procedures on the abdomen;

g – Category includes placement of gastrostomy tubes or other feeding devices, either percutaneously or through other means of access;

h– Category includes invasive but not operative procedures on the abdomen such as paracentesis, or radiologically-guided drainage procedures that do not involve incision

i – Category includes any endoscopic procedure for diagnosis or treatment on the upper GI tract

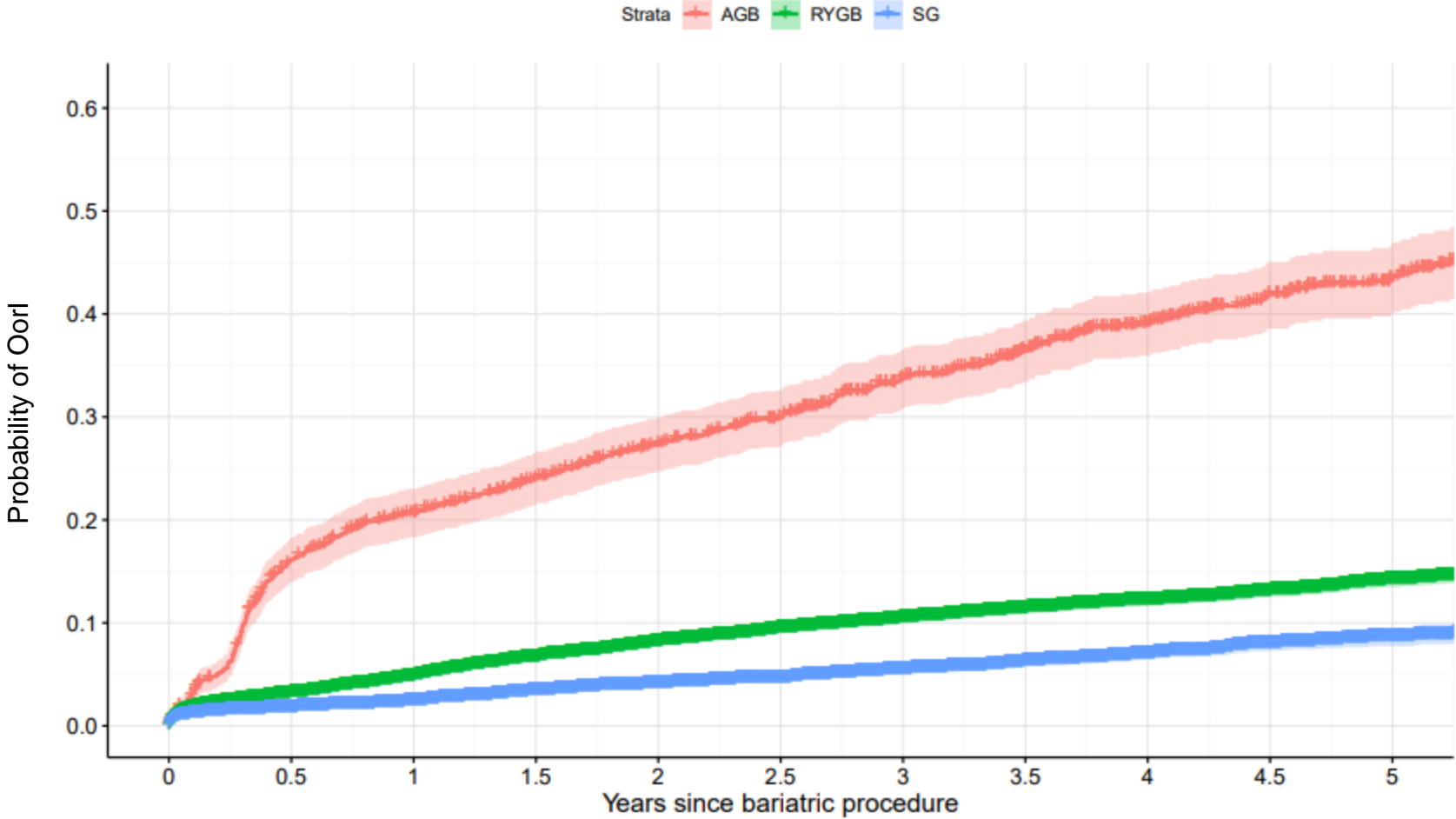
eAppendix Table 5. Causes of Death*

| All (n=34,714; 491 deaths) | | | AGB (n=1,154; 27 deaths) | | | RYGB (n=18,056; 364 deaths) | | | SG (n=15,504; 100 deaths) | | |
|----------------------------|--------------------------|--------------|--------------------------|---------------------------|--------------|-----------------------------|-------------------------|--------------|---------------------------|--------------------------|--------------|
| Rank | Cause of Death | Total Number | Rank | Cause of Death | Total Number | Rank | Cause of Death | Total Number | Rank | Cause of Death | Total Number |
| 1 | None | 147 | 1 | Cardiac | 9 | 1 | None | 106 | 1 | None | 38 |
| 2 | Cardiac | 72 | 2 | Endocrine | 7 | 2 | Malignancy | 51 | 2 | Cardiac | 21 |
| 3 | Malignancy | 69 | 3 | Diabetes | 7 | 3 | Cardiac | 42 | 3 | Endocrine | 20 |
| 4 | Endocrine | 60 | 4 | Coronary artery disease | 5 | 4 | Coronary artery disease | 38 | 4 | Malignancy | 15 |
| 5 | Coronary artery disease | 54 | 5 | Stroke/intracranial bleed | 4 | 5 | Diabetes | 34 | 5 | Respiratory | 13 |
| 6 | Diabetes | 49 | 6 | Sleep apnea | 4 | 6 | Endocrine | 33 | 6 | Coronary artery disease | 11 |
| 7 | Sepsis | 36 | 7 | Respiratory | 4 | 7 | Sepsis | 27 | 7 | Alcohol/substance | 9 |
| 8 | Alcohol/Substance | 34 | 8 | Sepsis | 3 | 8 | Accidental injury | 23 | 8 | Renal | 9 |
| 9 | Hypertension | 34 | 9 | Alcohol/substance | 3 | 9 | Hypertension | 23 | 9 | Diabetes | 8 |
| 10 | Respiratory | 33 | 10 | Malignancy | 3 | 10 | Alcohol/substance | 22 | 10 | GI | 8 |
| 11 | Renal | 33 | 11 | GI | 3 | 11 | Trauma | 21 | 11 | Hypertension | 8 |
| 12 | Accidental injury | 29 | 12 | Trauma | 3 | 12 | Renal | 21 | 12 | Congestive heart failure | 7 |
| 13 | GI | 27 | 13 | Hypertension | 3 | 13 | GI | 16 | 13 | Sepsis | 6 |
| 14 | Trauma | 27 | 14 | Renal | 3 | 14 | Respiratory | 16 | 14 | Accidental injury | 6 |
| 15 | Congestive heart failure | 22 | 15 | None | 3 | 15 | Self harm | 15 | 15 | Pulmonary embolism | 5 |

| | | | | | | | | | | | | | | |
|----|------------------------------|----|--|----|-----------------------------|---|--|----|-----------------------------|----|--|----|---------------|---|
| 16 | Self harm | 18 | | 16 | Medical Complication | 2 | | 16 | Liver | 15 | | 16 | Other | 4 |
| 17 | Liver | 17 | | 17 | Neurologic | 2 | | 17 | Congestive heart failure | 14 | | 17 | Self harm | 3 |
| 18 | Neurologic | 17 | | 18 | Indeterminate | 1 | | 18 | Neurologic | 12 | | 18 | Trauma | 3 |
| 19 | Other | 13 | | 19 | Other | 1 | | 19 | Other | 8 | | 19 | Flu/pneumonia | 3 |
| 20 | Stroke/Intracranial bleed | 12 | | 20 | Congestive heart failure | 1 | | 20 | Vascular | 8 | | 20 | Vascular | 3 |

* Note that about one third (n=163) of the cohort have more than one cause of death contributing to the list of causes

eAppendix Figure 2. Kaplan-Meier Plot for Operation or Intervention (Oorl)



Number at risk

| | | | | | | | | | | | |
|------|-------|-------|-------|-------|-------|-------|------|------|------|------|------|
| AGB | 1154 | 939 | 860 | 789 | 720 | 658 | 563 | 481 | 382 | 301 | 220 |
| RYGB | 18056 | 15945 | 14379 | 12872 | 11637 | 10305 | 9047 | 7613 | 6261 | 4779 | 3541 |
| SG | 15504 | 12864 | 11103 | 9349 | 8095 | 6590 | 5264 | 3802 | 2517 | 1333 | 691 |