**Supplementary Material**

**Supplementary Table A1: Codes used to identify low anterior resection (LAR) procedures**

|  |  |  |
| --- | --- | --- |
| **Code type** | **Code** | **Description** |
| ICD-9 Px | 48.62 | Anterior resection of rectum with synchronous colostomy |
| ICD-9 Px | 48.63 | Other anterior resection of rectum |
| DRG | 329 | Major small and large bowel procedures with major complication or comorbidity (MCC) |
| DRG | 330 | Major small and large bowel procedures with complication or comorbidity (CC) |
| DRG | 331 | Major small and large bowel procedures without MCC or CC |
| DRG | 332 | Rectal resection with MCC |
| DRG | 333 | Rectal resection with CC |
| DRG | 334 | Rectal resection without MCC or CC |

Notes: ICD-9 Px = International Classification of Diseases, Ninth Revision, Clinical Modification, Procedure Code; DRG = Medicare Severity Diagnosis Related Group (MS-DRG) Code. In Premier, patients were included in an ICD-9 procedure code for LAR was recorded as the principal procedure. In Optum, patients were included if both an ICD-9 procedure code (any position) and a DRG code for LAR were observed on the same hospital claim.

**Supplementary Table A2: Codes used to identify colorectal cancer cases**

|  |  |  |
| --- | --- | --- |
| **Code type** | **Code** | **Description** |
| ICD-9 Dx | 153.0 | Malignant neoplasm of hepatic flexure |
| ICD-9 Dx | 153.1 | Malignant neoplasm of transverse colon |
| ICD-9 Dx | 153.2 | Malignant neoplasm of descending colon |
| ICD-9 Dx | 153.3 | Malignant neoplasm of sigmoid colon |
| ICD-9 Dx | 153.4 | Malignant neoplasm of cecum |
| ICD-9 Dx | 153.5 | Malignant neoplasm of appendix vermiformis |
| ICD-9 Dx | 153.6 | Malignant neoplasm of ascending colon |
| ICD-9 Dx | 153.7 | Malignant neoplasm of splenic flexure |
| ICD-9 Dx | 153.8 | Malignant neoplasm of other specified sites of large intestine |
| ICD-9 Dx | 153.9 | Malignant neoplasm of colon, unspecified site |
| ICD-9 Dx | 154.0 | Malignant neoplasm of rectosigmoid junction |
| ICD-9 Dx | 154.1 | Malignant neoplasm of rectum |
| ICD-9 Dx | 154.2 | Malignant neoplasm of anal canal |
| ICD-9 Dx | 154.3 | Malignant neoplasm of anus, unspecified site |
| ICD-9 Dx | 154.8 | Malignant neoplasm of other sites of rectum, rectosigmoid junction, and anus |

Notes: ICD-9 Dx = International Classification of Diseases, Ninth Revision, Clinical Modification, Diagnosis Code. Patients were included if an ICD-9 Dx code for colorectal cancer was coded as the principal diagnosis on the index LAR hospital facility claim.

**Supplementary Table A3: Codes used to identify surgical complications**

| **Complication type** | **Code type** | **Code** | **Description** |
| --- | --- | --- | --- |
| Anastomotic leak | ICD-9 Dx | 567.22 | Peritoneal abscess |
| ICD-9 Dx | 569.81 | Fistula of intestine, excluding rectum and anus |
| ICD-9 Dx | 997.4 | Complications of surgical and medical care, not elsewhere classified; Digestive system complications not elsewhere classified |
| ICD-9 Dx | 997.49 | Complications of surgical and medical care, not elsewhere classified; Digestive system complications not elsewhere classified; Other digestive system complication |
| Infection | ICD-9 Dx | 038.0 | Streptococcal septicemia |
| ICD-9 Dx | 038.10 | Staphylococcal septicemia, unspecified |
| ICD-9 Dx | 038.11 | Methicillin susceptible Staphylococcus aureus septicemia |
| ICD-9 Dx | 038.12 | Methicillin resistant Staphylococcus aureus septicemia |
| ICD-9 Dx | 038.19 | Other staphylococcal septicemia |
| ICD-9 Dx | 038.2 | Pneumococcal septicemia [Streptococcus pneumoniae septicemia] |
| ICD-9 Dx | 038.40 | Septicemia due to gram-negative organism, unspecified |
| ICD-9 Dx | 038.42 | Septicemia due to escherichia coli [E. coli] |
| ICD-9 Dx | 038.43 | Septicemia due to pseudomonas |
| ICD-9 Dx | 038.44 | Septicemia due to serratia |
| ICD-9 Dx | 038.49 | Other septicemia due to gram-negative organisms |
| ICD-9 Dx | 038.8 | Other specified septicemias |
| ICD-9 Dx | 038.9 | Unspecified septicemia |
| ICD-9 Dx | 567.0 | Peritonitis in infectious diseases classified elsewhere |
| ICD-9 Dx | 567.1 | Pneumococcal peritonitis |
| ICD-9 Dx | 567.21 | Peritonitis (acute) generalized |
| ICD-9 Dx | 567.22 | Peritoneal abscess |
| ICD-9 Dx | 567.29 | Other suppurative peritonitis |
| ICD-9 Dx | 567.38 | Other retroperitoneal abscess |
| ICD-9 Dx | 567.39 | Other retroperitoneal infections |
| ICD-9 Dx | 567.89 | Other specified peritonitis |
| ICD-9 Dx | 567.9 | Unspecified peritonitis |
| ICD-9 Dx | 569.5 | Abscess of intestine |
| ICD-9 Dx | 785.52 | Septic shock |
| ICD-9 Dx | 790.7 | Bacteremia |
| ICD-9 Dx | 995.91 | Sepsis |
| ICD-9 Dx | 995.92 | Severe sepsis |
| ICD-9 Dx | 998.51 | Infected postoperative seroma |
| ICD-9 Dx | 998.59 | Other postoperative infection |
| Bleeding | ICD-9 Dx | 285.1 | Acute posthemorrhagic anemia |
| ICD-9 Dx | 998.11 | Hemorrhage complicating a procedure |
| ICD-9 Dx | 998.12 | Hematoma complicating a procedure |
| ICD-9 Dx | 998.13 | Seroma complicating a procedure |

Notes: ICD-9 Dx = International Classification of Diseases, Ninth Revision, Clinical Modification, Diagnosis Code.

**Supplementary Table A4: Codes used to define surgical approach**

| **Covariate** | **Code type** | **Code** | **Description** |
| --- | --- | --- | --- |
| Laparoscopic surgery | ICD-9 Px | 54.21 | Laparoscopy |
| Robotic surgery | ICD-9 Px | 17.41 | Open robotic assisted procedure |
| ICD-9 Px | 17.42 | Laparoscopic robotic assisted procedure |
| ICD-9 Px | 17.43 | Percutaneous robotic assisted procedure |
| ICD-9 Px | 17.44 | Endoscopic robotic assisted procedure |
| ICD-9 Px | 17.45 | Thoracoscopic robotic assisted procedure |
| ICD-9 Px | 17.49 | Other and unspecified robotic assisted procedure |
| Conversion to open | ICD-9 Dx | V64.41 | Laparoscopic surgical procedure converted to open procedure |

Notes: ICD-9 Px = International Classification of Diseases, Ninth Revision, Clinical Modification, Procedure Code; ICD-9 Dx = International Classification of Diseases, Ninth Revision, Clinical Modification, Diagnosis Code.

**Supplementary Table A5: Characteristics of eligible Premier (N = 7,479) low anterior resection (LAR) patients for covariates unique to the Premier database.**

|  |  |
| --- | --- |
| **Characteristic** | **Premier cohort** **N (%)** |
| Race* White
* African American
* Other
 | 5,430 (73%)552 (7%)1,497 (20%) |
| Marital Status* Married
* Single
* Other
 | 3,863 (52%) 2,692 (36%)924 (12%) |
| Surgeon type* Colorectal surgeon
* Other
 | 2,329 (31%)5,150 (69%) |
| Hospital size* 1-300
* 301-500
* >500
 | 2,063 (28%)2,741 (37%)2,675 (36%) |
| Teaching hospital* Teaching hospital or academic affiliation
* Non-teaching hospital
 | 3,378 (45%)4,101 (55%) |
| Hospital location* Urban
* Rural
 | 6,782 (91%)697 (9%) |

Notes: Race, marital status, surgeon type, hospital size, teaching hospital status, and hospital location were available in the Premier database but not Optum.

**Supplementary Table A6: Association between incidence of major surgical complications and length of stay, discharge disposition, and 90-day readmission; commercially-insured and Medicare-insured sub-groups**

|  |  |  |  |
| --- | --- | --- | --- |
| **Patient group** | **Adjusted mean hospital length of stay in days (ratio of means [MR]; p value; mean incremental difference [MID])\*** | **Adjusted risk of non-home discharge (odds ratio [OR]; p value; risk difference [RD])\*** | **Adjusted risk of 90-day readmission (odds ratio [OR] or hazard ratio [HR], p value, risk difference [RD])\*** |
| **Premier cohort (N = 3,081)****Commercially insured patients** |  |  |  |
| *Anastomotic leak* |  |  |  |
| * Yes (N=265, 8.6%)
 | 11.1 (MR=1.95; p<0.001; MID=5.4)  | 16.3% (OR=1.85; p<0.001; RD=5.5%)  | 28.0% (OR=1.40; p<0.001; RD=6.1%)  |
| * No (N=2,816, 91.4%)
 | 5.7 (Reference) | 10.8% (Reference) | 21.9% (Reference) |
| *Infection\*\** |  |  |  |
| * Yes (N=132, 4.3%)
 | 13.7 (MR=2.35; p<0.001; MID=7.9)  | 10.3% (OR=6.38; p<0.001; RD=8.0%) | 32.7% (OR=2.05; p<0.001; RD=13.1%) |
| * No (N=2,949, 95.7%)
 | 5.8 (Reference) | 2.4% (Reference) | 19.6% (Reference) |
| *Bleeding* |  |  |  |
| * Yes (N=235, 7.6%)
 | 8.3 (MR=1.36; p<0.001; MID=2.2)  | 4.5% (OR=1.79; p=0.0377; RD=1.7%) | 26.9% (OR=1.53; p=0.0035; RD=7.4%) |
| * No (N=2,846, 92.4%)
 | 6.1 (Reference) | 2.8% (Reference) | 19.6% (Reference) |
| **Premier cohort (N = 3,422)****Medicare patients** |  |  |  |
| *Anastomotic leak* |  |  |  |
| * Yes (N=411, 12.0%)
 | 12.9 (MR=1.71; p<0.001; MID=5.3)  | 26.4% (OR=1.68; p<0.001; RD=7.3%)  | 29.6% (OR=1.37 p=0.005; RD=6.0%)  |
| * No (N=3,011, 88.0%)
 | 7.5 (Reference) | 19.1% (Reference) | 23.5% (Reference) |
| *Infection\*\** |  |  |  |
| * Yes (N=289, 8.5%)
 | 15.3 (MR=2.06; p<0.001; MID=7.9)  | 39.6% (OR=3.86; p<0.001; RD=21.6%) | 33.3% (OR=1.65; p<0.001; RD=9.9%) |
| * No (N=3,133, 91.5%)
 | 7.4 (Reference) | 18.0% (Reference) | 23.4% (Reference) |
| *Bleeding* |  |  |  |
| * Yes (N=485, 14.2%)
 | 10.1 (MR=1.28; p<0.001; MID=2.2)  | 23.5% (OR=1.35; p=0.0259; RD=4.1%) | 24.5% (OR=1.01; p=0.932; RD=0.2%) |
| * No (N=2,937, 85.8%)
 | 7.8 (Reference) | 19.4% (Reference) | 24.3% (Reference) |
| **Optum cohort (N = 1,407)****Commercially insured patients** |  |  |  |
| *Anastomotic leak* |  |  |  |
| * Yes (N=145, 10.3%)
 | 11.0 (MR=1.98; p<0.001; MID=5.5)  | 2.1% (OR=1.44; p=0.003; RD=0.6%)  | 34.2% (HR=1.46; p=0.02; RD=9.3%)  |
| * No (N=1,262, 89.7%%)
 | 5.6 (Reference) | 1.5% (Reference) | 25.0% (Reference) |
| *Infection\*\** |  |  |  |
| * Yes (N=67, 4.8%)
 | 13.7 (MR=2.35; p<0.001; MID=7.9)  | 4.0% (OR=3.51; p=0.06; RD=2.6%) | 48.2% (HR=2.36; p<0.001; RD=23.4%) |
| * No (N=1340, 95.2%)
 | 5.8 (Reference) | 1.4% (Reference) | 24.8% (Reference) |
| *Bleeding* |  |  |  |
| * Yes (N=109, 7.7%)
 | 8.6 (MR=1.45; p<0.001; MID=2.7)  | 3.1% (OR=2.58; p=0.12; RD=1.7%) | 35.2% (HR=1.50; p=0.02; RD=10.0%) |
| * No (N=1,298, 92.3%)
 | 6.0 (Reference) | 1.4% (Reference) | 25.2% (Reference) |
| **Optum cohort (N = 852)****Medicare patients** |  |  |  |
| *Anastomotic leak* |  |  |  |
| * Yes (N=108, 12.7%)
 | 12.5 (MR=1.87; p<0.001; MID=5.8)  | 14.2% (OR=2.31; p=0.003; RD=1.1%)  | 31.9% (HR=1.16 p=0.44; RD=3.7%)  |
| * No (N=744, 87.3%)
 | 6.7 (Reference) | 13.1% (Reference) | 28.2% (Reference) |
| *Infection\*\** |  |  |  |
| * Yes (N=65, 7.6%)
 | 15.3 (MR=2.06; p<0.001; MID=7.9)  | 24.4% (OR=2.62; p=0.003; RD=12.1%) | 37.0% (HR=1.41; p=0.13; RD=9.0%) |
| * No (N=787, 92.4%)
 | 7.4 (Reference) | 12.3% | 28.0% (Reference) |
| *Bleeding* |  |  |  |
| * Yes (N=123, 14.4%)
 | 8.9 (MR=1.24; p<0.001; MID=1.8)  | 21.4% (OR=3.86; p<0.001; RD=9.8%) | 36.1% (HR=1.40; p=0.06; RD=8.5%) |
| * No (N=729, 85.6%)
 | 7.2 (Reference) | 11.6% (Reference) | 27.5% (Reference) |

\* All measures of association presented in Table 2 were adjusted for patient, procedure, and provider characteristics, as described in the methods section.

\*\* Infection was defined as septicemia and/or surgical site infection, as described in Appendix Table A3.

**Supplementary Table A7: Association between incidence of major surgical complications and measures of economic burden; commercially-insured and Medicare-insured sub-groups**

|  |  |  |  |
| --- | --- | --- | --- |
| **Patient group** | **Index LAR adjusted mean total hospital cost (cost ratio [CR]; p value; mean incremental difference [MID])\*** | **Index LAR adjusted mean expenditure total (cost ratio [CR]; p value; mean incremental difference [MID])\*** | **Index LAR + 90d post-discharge adjusted mean expenditure total (cost ratio [CR]; p value; mean incremental difference [MID])\*** |
| **Premier cohort (N = 3,081)****Commercially insured patients**  |  |  |  |
| *Anastomotic leak* |  |  |  |
| * Yes (N=265, 8.6%)
 | $31,281 (CR=1.72, p<0.001; MID=$13,074) | N/A | N/A |
| * No (N=2,816, 91.4%)
 | $18,206 (Reference) |  |  |
| *Infection\*\** |  |  |  |
| * Yes (N=132, 4.3%)
 | $41,312 (CR=2.26, p<0.001; MID=$22,993) | N/A | N/A |
| * No (N=2,949, 95.7%)
 | $18,320 (Reference) |  |  |
| *Bleeding* |  |  |  |
| * Yes (N=235, 7.6%)
 | $27,690 (CR=1.47, p<0.001; MID=$8,899) | N/A | N/A |
| * No (N=2,846, 92.4%)
 | $18,792 (Reference) |  |  |
| **Premier cohort (N = 3,422)****Medicare patients** |  |  |  |
| *Anastomotic leak* |  |  |  |
| * Yes (N=411, 12.0%)
 | $32,136 (CR=1.47, p<0.001; MID=$10,334) | N/A | N/A |
| * No (N=3,011, 88.0%)
 | $21,801 (Reference) |  |  |
| *Infection\*\** |  |  |  |
| * Yes (N=289, 8.5%)
 | $40,243 (CR=1.88, p<0.001; MID=$18,805) | N/A | N/A |
| * No (N=3,133, 91.5%)
 | $21,438 (Reference) |  |  |
| *Bleeding* |  |  |  |
| * Yes (N=485, 14.2%)
 | $28,241 (CR=1.27, p<0.001; MID=$5,995) | N/A | N/A |
| * No (N=2,937, 85.8%)
 | $22,246 (Reference) |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **Optum cohort (N = 1,407)****Commercially insured patients** |  |  |  |
| *Anastomotic leak* |  |  |  |
| * Yes (N=145, 10.3%)
 | N/A | $46,742 (CR=1.60; p<0.001; MID=$17,558)  | $78,837 (HR=1.38, p<0.001; MID=$21,552) |
| * No (N=1,262, 89.7%%)
 |  | $29,185 (Reference) | $57,285 (Reference) |
| *Infection\*\** |  |  |  |
| * Yes (N=67, 4.8%)
 | N/A | $55,645 (CR=1.87; p<0.001; MID=$25,914) | $95,326 (CR=1.65; p<0.001; MID=$37,652) |
| * No (N=1340, 95.2%)
 |  | $29,731 (Reference) | $57,674 (Reference) |
| *Bleeding* |  |  |  |
| * Yes (N=109, 7.7%)
 | N/A | $37,051 (CR=1.21; p<0.001; MID=$6,516) | $69,249 (CR=1.18; p=0.002; MID=$10,527) |
| * No (N=1,298, 92.3%)
 |  | $30,535 (Reference) | $58,722 (Reference) |
| **Optum cohort (N = 852)****Medicare patients** |  |  |  |
| *Anastomotic leak* |  |  |  |
| * Yes (N=108, 12.7%)
 | N/A | $44,046 (CR=1.51; p<0.001; MID=$14,863)  | $64,377 (HR=1.34, p<0.001; MID=$16,253) |
| * No (N=744, 87.3%)
 |  | $29,183 (Reference) | $48,125 (Reference) |
| *Infection\*\** |  |  |  |
| * Yes (N=65, 7.6%)
 | N/A | $50,198 (CR=1.71; p<0.001; MID=$20,789) | $72,428 (CR=1.50; p<0.001; MID=$24,144) |
| * No (N=787, 92.4%)
 |  | $29,409 (Reference) | $48,283 (Reference) |
| *Bleeding* |  |  |  |
| * Yes (N=123, 14.4%)
 | N/A | $38,159 (CR=1.27; p<0.001; MID=$8,159) | $60,869 (CR=1.25; p<0.001; MID=$12,310) |
| * No (N=729, 85.6%)
 |  | $30,001 (Reference) | $48,559(Reference) |

\* All measures of association presented in Table 2 were adjusted for patient, procedure, and provider characteristics, as described in the methods section.

\*\* Infection was defined as septicemia and/or surgical site infection, as described in Appendix Table A3.

**Supplementary Table A8: Concurrent incidence of complications** **among eligible Premier (N = 7,479) and Optum (N = 2,259) patients who underwent low anterior resection (LAR)**

|  |  |  |
| --- | --- | --- |
| **Complication** | **Premier cohort** **N (%)** | **Optum cohort** **N (%)** |
| Anastomotic leak* + bleeding
* + infection\*
* + bleeding + infection\*,\*\*
 | 776 (10.4%)155 (2.1%)183 (2.4%)60 (0.8%) | 253 (11.2%)46 (2.0%)68 (3.0%)15 (0.7%) |
| Infection\** + bleeding
* + anastomotic leak
* + bleeding + anastomotic leak
 | 490 (6.6%)139 (1.9%)183 (2.4%)60 (0.8%) | 132 (5.8%)33 (1.5%)68 (3.0%)15 (0.7%) |
| Bleeding* + anastomotic leak
* + infection\*
* + anastomotic leak + infection\*,\*\*
 | 833 (11.1%)155 (2.1%)139 (1.9%)60 (0.8%) | 232 (10.3%)46 (2.0%)33 (1.5%)15 (0.7%) |

\* Infection was defined as septicemia and/or surgical site infection, as described in Appendix Table A3.

\*\*Subset of N’s reported in rows above

**Supplementary Table A9: Association between incidence of major surgical complications and length of stay, discharge disposition, and 90-day readmission; sensitivity analysis with anastomotic leak and/or infection as a composite complication measure**

|  |  |  |  |
| --- | --- | --- | --- |
| **Patient group** | **Adjusted mean hospital length of stay in days (ratio of means [MR]; p value; mean incremental difference [MID])\*** | **Adjusted risk of non-home discharge (odds ratio [OR]; p value; risk difference [RD])\*** | **Adjusted risk of 90-day readmission (odds ratio [OR] or hazard ratio [HR], p value, risk difference [RD])\*** |
| **Premier cohort (N = 7,479)** |  |  |  |
| *Anastomotic leak and/or infection\*\** |  |  |  |
| * Yes (N=1,083, 14.5%)
 | 12.2 (MR=1.89; p<0.001; MID=5.8)  | 18.5% (OR=2.58; p<0.0001; RD=8.7%) | 29.3% (OR=1.53; p<0.0001; RD=7.8%) |
| * No (N=6,396, 85.5%)
 | 6.4 (Reference) | 9.8% (Reference) | 21.4% (Reference) |
| **Optum cohort (N = 2,259)** |  |  |  |
| *Anastomotic leak and/or infection\*\** |  |  |  |
| * Yes (N=317; 14.0%)
 | 11.4 (MR=1.96; p<0.001; MID=5.6) | 8.3% (OR=1.73; p=0.03; RD=2.9%) | 35.1% (HR=1.46; p<0.001; RD=9.4%) |
| * No (N=1,942; 86.0%)
 | 5.8 (Reference) | 5.5% (Reference) | 25.7% (Reference) |

\* All measures of association presented in Table A9 were adjusted for patient, procedure, and provider characteristics, as described in the methods section.

\*\* Infection was defined as septicemia and/or surgical site infection, as described in Appendix Table A3.

**Supplementary Table A10: Association between incidence of major surgical complications and measures of economic burden; sensitivity analysis with anastomotic leak and/or infection as a composite complication measure**

|  |  |  |  |
| --- | --- | --- | --- |
| **Patient group** | **Index LAR adjusted mean total hospital cost (cost ratio [CR]; p value; mean incremental difference [MID])\*** | **Index LAR adjusted mean expenditure total (cost ratio [CR]; p value; mean incremental difference [MID])\*** | **Index LAR + 90d post-discharge adjusted mean expenditure total (cost ratio [CR]; p value; mean incremental difference [MID])\*** |
| **Premier cohort (N = 7,479)** |  |  |  |
| *Anastomotic leak and/or infection* |  |  |  |
| * Yes (N=1,083, 14.5%)
 | $32,755 (CR=1.67, p<0.001; MID=$13,108) | N/A | N/A |
| * No (N=6,396, 85.5%)
 | $19,647 (Reference) |  |  |
| **Optum cohort (N = 2,259)** |  |  |  |
| *Anastomotic leak and/or infection* |  |  |  |
| * Yes (N=317; 14.0%)
 | N/A | $45,714 (CR=1.60; p<0.001; MID=$17,113) | $73,523 (CR=1.38; p<0.001; MID=$20,406) |
| * No (N=1,942; 86.0%)
 |  | $28,601 (Reference) | $53,116 (Reference) |

\* All measures of association presented in Table A10 were adjusted for patient, procedure, and provider characteristics, as described in the methods section.

\*\* Infection was defined as septicemia and/or surgical site infection, as described in Appendix Table A3.