Impact of Hospital Location and Teaching Status on Outcomes of Colectomy in Colon Cancer Patients

Analysis for RCOP NIS Surgery7

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## Preamble:

* **Reference Papers:**
  + [Dolmatova et al. 2016](https://doi.org/10.1016/j.amjcard.2016.05.062)
  + [Sohail et al. 2025](https://www.jacc.org/doi/abs/10.1016/S0735-1097%2825%2902161-8)
  + [Salman et al. 2025](https://doi.org/10.1097/MCA.0000000000001479)
* **Study Objective**: To evaluate the impact of hospital location/teaching status (urban teaching, urban non-teaching, rural) on clinical and resource utilization outcomes among adult patients undergoing colectomy for colon cancer in the United States.
* **Data Source**: Cross-sectional analysis using the National Inpatient Sample (NIS) database from 2018 to 2020, a representative sample of all-payer inpatient hospitalizations in the U.S.
* **Patient Selection**: The study cohort included adult patients (aged ≥18 years) who were hospitalized with a diagnosis of colon cancer and underwent a colectomy. Colon cancer was identified using ICD-10-CM diagnosis codes (C18.0–C18.9), and colectomy procedures were identified using ICD-10-PCS codes. Patients were included only if they had non-missing data on hospital location and teaching status. To ensure accurate attribution of outcomes to the index hospital, patients who were transferred into or out of the hospital were excluded.
* **Outcomes of Interest**:
  + In-hospital Mortality
  + Length of Stay (LOS) in days
  + Inflation-adjusted Total Charges (converted to 2020 U.S. dollars using Consumer Price Index data)
  + Any Major Complication — defined as the presence of at least one of the following:
    - Postoperative infection
    - Postoperative wound complications
    - Postoperative bleeding
    - Acute kidney injury
    - Postoperative ileus
    - Venous thromboembolism
    - Acute myocardial infarction
* **Statistical Analysis**: Univariable and multivariable analyses were conducted to assess the association between hospital location/teaching status and the outcomes of interest:
  + **Univariable Analysis:**
    - Continuous variables: Design-based Kruskal-Wallis test.
    - Categorical variables: Pearson’s X² test with Rao & Scott adjustment to account for survey design.
  + **Multivariable Analysis:**
    - Logistic regression for binary outcomes (e.g., mortality, complications).
    - Linear regression for continuous outcomes (e.g., length of stay, total charges).
  + **Adjustments:** Models controlled for the following covariates:
    - **Demographics and Socioeconomic Factors**: Age, Sex, Race, Residential income, Expected primary payer.
    - **Clinical Factors:** A summary measure of comorbidity (Elixhauser comorbidity index).
    - **Hospital-Level Factors:** Hospital region and Hospital bedsize.
* **Software:** All statistical analyses were performed using R Statistical Language (Version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria), incorporating survey-weighted procedures via the *survey* package to account for the complex sampling design of NIS.

## Baseline Table:

| **Characteristic** | **Overall** N = 179,770*1* | **Urban, teaching** N = 131,295*1* | **Rural** N = 15,605*1* | **Urban, non-teaching** N = 32,870*1* | **p-value***2* |
| --- | --- | --- | --- | --- | --- |
| Age, y | 66 (13) | 65 (13) | 68 (12) | 67 (13) | <0.001 |
| Sex |  |  |  |  | 0.8 |
| Female | 87,945 (49%) | 64,225 (49%) | 7,705 (49%) | 16,015 (49%) |  |
| Male | 91,820 (51%) | 67,065 (51%) | 7,900 (51%) | 16,855 (51%) |  |
| Race |  |  |  |  | <0.001 |
| White | 127,530 (73%) | 90,235 (70%) | 13,005 (86%) | 24,290 (75%) |  |
| Asian or Pacific Islander | 6,370 (3.6%) | 5,100 (4.0%) | 95 (0.6%) | 1,175 (3.6%) |  |
| Black | 20,400 (12%) | 16,335 (13%) | 1,310 (8.7%) | 2,755 (8.5%) |  |
| Hispanic | 15,735 (9.0%) | 12,320 (9.6%) | 385 (2.6%) | 3,030 (9.4%) |  |
| Other | 5,515 (3.1%) | 4,230 (3.3%) | 255 (1.7%) | 1,030 (3.2%) |  |
| Median ZIP Code Income Quartile |  |  |  |  | <0.001 |
| $1 - $51,999 | 45,390 (26%) | 30,005 (23%) | 7,945 (52%) | 7,440 (23%) |  |
| $52,000 - $65,999 | 47,655 (27%) | 32,455 (25%) | 5,565 (37%) | 9,635 (30%) |  |
| $66,000 - $87,999 | 43,740 (25%) | 33,800 (26%) | 1,455 (9.6%) | 8,485 (26%) |  |
| $88,000 or more | 40,430 (23%) | 33,370 (26%) | 230 (1.5%) | 6,830 (21%) |  |
| Primary Expected Payer |  |  |  |  | <0.001 |
| Private | 61,025 (34%) | 46,830 (36%) | 4,065 (26%) | 10,130 (31%) |  |
| Medicaid | 13,945 (7.8%) | 10,675 (8.1%) | 995 (6.4%) | 2,275 (6.9%) |  |
| Medicare | 96,190 (54%) | 67,655 (52%) | 9,680 (62%) | 18,855 (57%) |  |
| Other | 8,465 (4.7%) | 6,020 (4.6%) | 835 (5.4%) | 1,610 (4.9%) |  |
| Hospital Region |  |  |  |  | <0.001 |
| Midwest | 38,500 (21%) | 27,530 (21%) | 5,170 (33%) | 5,800 (18%) |  |
| Northeast | 31,400 (17%) | 26,405 (20%) | 1,820 (12%) | 3,175 (9.7%) |  |
| South | 73,270 (41%) | 50,565 (39%) | 6,785 (43%) | 15,920 (48%) |  |
| West | 36,600 (20%) | 26,795 (20%) | 1,830 (12%) | 7,975 (24%) |  |
| Hospital Bed Size |  |  |  |  | <0.001 |
| Large | 92,770 (52%) | 64,490 (49%) | 10,830 (69%) | 17,450 (53%) |  |
| Medium | 51,440 (29%) | 38,295 (29%) | 3,095 (20%) | 10,050 (31%) |  |
| Small | 35,560 (20%) | 28,510 (22%) | 1,680 (11%) | 5,370 (16%) |  |
| Elixhauser Comorbidity Index | 4.20 (2.14) | 4.17 (2.13) | 4.16 (2.06) | 4.30 (2.18) | 0.009 |
| Route of Colectomy |  |  |  |  | <0.001 |
| Laparoscopic | 53,090 (30%) | 39,800 (30%) | 3,620 (23%) | 9,670 (29%) |  |
| Open | 94,170 (52%) | 65,715 (50%) | 10,750 (69%) | 17,705 (54%) |  |
| Robotic | 32,510 (18%) | 25,780 (20%) | 1,235 (7.9%) | 5,495 (17%) |  |
| Metastatic Cancer | 47,445 (26%) | 36,245 (28%) | 3,460 (22%) | 7,740 (24%) | <0.001 |
| Diabetes Mellitus | 43,075 (24%) | 30,925 (24%) | 4,125 (26%) | 8,025 (24%) | 0.001 |
| Congestive Heart Failure | 14,750 (8.2%) | 10,520 (8.0%) | 1,375 (8.8%) | 2,855 (8.7%) | 0.11 |
| Chronic Pulmonary Disease | 26,590 (15%) | 18,895 (14%) | 2,670 (17%) | 5,025 (15%) | <0.001 |
| Renal Failure | 17,505 (9.7%) | 12,720 (9.7%) | 1,455 (9.3%) | 3,330 (10%) | 0.4 |
| Coagulopathy | 6,225 (3.5%) | 4,655 (3.5%) | 385 (2.5%) | 1,185 (3.6%) | 0.008 |
| Obesity | 33,130 (18%) | 24,410 (19%) | 2,725 (17%) | 5,995 (18%) | 0.4 |
| Hypertension | 104,465 (58%) | 75,080 (57%) | 9,545 (61%) | 19,840 (60%) | <0.001 |
| Liver Disease | 10,240 (5.7%) | 7,895 (6.0%) | 645 (4.1%) | 1,700 (5.2%) | <0.001 |
| Deficiency Anemia | 18,925 (11%) | 13,450 (10%) | 1,405 (9.0%) | 4,070 (12%) | <0.001 |
| Fluid and Electrolyte Disorders | 40,950 (23%) | 28,855 (22%) | 3,690 (24%) | 8,405 (26%) | <0.001 |
| Peripheral Vascular Disease | 10,010 (5.6%) | 7,305 (5.6%) | 825 (5.3%) | 1,880 (5.7%) | 0.7 |
| *1*Mean (SD); n (%) | | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | | |

## Univariable Analysis:

| **Characteristic** | **Overall** N = 179,770*1* | **Urban, teaching** N = 131,295*1* | **Rural** N = 15,605*1* | **Urban, non-teaching** N = 32,870*1* | **p-value***2* |
| --- | --- | --- | --- | --- | --- |
| In-hospital Mortality | 3,700 (2.1%) | 2,475 (1.9%) | 395 (2.5%) | 830 (2.5%) | 0.001 |
| Length of Stay (days) | 4.0 (3.0, 8.0) | 4.0 (3.0, 8.0) | 5.0 (3.0, 7.0) | 5.0 (3.0, 8.0) | <0.001 |
| Inflation-Adjusted Total Charges ($) | 74,921 (49,611, 119,006) | 77,202 (51,538, 121,026) | 53,371 (37,987, 80,332) | 78,498 (50,715, 131,906) | <0.001 |
| Any Major Complication | 24,760 (14%) | 17,800 (14%) | 2,030 (13%) | 4,930 (15%) | 0.007 |
| Postoperative Infection | 2,435 (1.4%) | 1,710 (1.3%) | 220 (1.4%) | 505 (1.5%) | 0.3 |
| Postoperative Wound Complication | 1,415 (0.8%) | 925 (0.7%) | 165 (1.1%) | 325 (1.0%) | 0.015 |
| Postoperative Bleeding | 2,005 (1.1%) | 1,410 (1.1%) | 185 (1.2%) | 410 (1.2%) | 0.5 |
| Acute Kidney Injury | 17,165 (9.5%) | 12,405 (9.4%) | 1,295 (8.3%) | 3,465 (11%) | 0.002 |
| Postoperative Ileus | 1,035 (0.6%) | 690 (0.5%) | 155 (1.0%) | 190 (0.6%) | 0.006 |
| Venous Thromboembolism | 3,850 (2.1%) | 2,830 (2.2%) | 260 (1.7%) | 760 (2.3%) | 0.11 |
| Acute Myocardial Infarction | 1,280 (0.7%) | 895 (0.7%) | 135 (0.9%) | 250 (0.8%) | 0.4 |
| *1*n (%); Median (Q1, Q3) | | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | | |

## Multivariable Logistic Regression:

### In-hospital Mortality:

| **Characteristic** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Hospital Location and Teaching Status |  |  |  |
| Urban, teaching | — | — |  |
| Rural | 1.32 | 1.00, 1.74 | 0.053 |
| Urban, non-teaching | 1.27 | 1.04, 1.54 | 0.019 |
| Age, y | 1.04 | 1.03, 1.05 | <0.001 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 1.24 | 1.06, 1.46 | 0.009 |
| Race |  |  |  |
| White | — | — |  |
| Asian or Pacific Islander | 0.96 | 0.59, 1.56 | 0.9 |
| Black | 1.06 | 0.82, 1.37 | 0.6 |
| Hispanic | 0.90 | 0.66, 1.22 | 0.5 |
| Other | 0.78 | 0.45, 1.33 | 0.4 |
| Median ZIP Code Income Quartile |  |  |  |
| $1 - $51,999 | — | — |  |
| $52,000 - $65,999 | 0.91 | 0.74, 1.12 | 0.4 |
| $66,000 - $87,999 | 0.77 | 0.61, 0.97 | 0.027 |
| $88,000 or more | 0.72 | 0.56, 0.93 | 0.012 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 1.63 | 1.07, 2.49 | 0.023 |
| Medicare | 1.49 | 1.12, 1.97 | 0.006 |
| Other | 2.44 | 1.57, 3.78 | <0.001 |
| Hospital Region |  |  |  |
| Midwest | — | — |  |
| Northeast | 1.47 | 1.11, 1.93 | 0.007 |
| South | 1.13 | 0.90, 1.42 | 0.3 |
| West | 1.13 | 0.86, 1.48 | 0.4 |
| Hospital Bed Size |  |  |  |
| Large | — | — |  |
| Medium | 1.19 | 0.99, 1.43 | 0.069 |
| Small | 1.18 | 0.95, 1.46 | 0.13 |
| Elixhauser Comorbidity Index | 1.52 | 1.47, 1.57 | <0.001 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |

### Any Major Complication:

| **Characteristic** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Hospital Location and Teaching Status |  |  |  |
| Urban, teaching | — | — |  |
| Rural | 1.02 | 0.89, 1.16 | 0.8 |
| Urban, non-teaching | 1.12 | 1.02, 1.22 | 0.014 |
| Age, y | 1.01 | 1.00, 1.01 | <0.001 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 1.64 | 1.53, 1.75 | <0.001 |
| Race |  |  |  |
| White | — | — |  |
| Asian or Pacific Islander | 1.11 | 0.92, 1.33 | 0.3 |
| Black | 1.47 | 1.33, 1.63 | <0.001 |
| Hispanic | 1.13 | 1.01, 1.28 | 0.039 |
| Other | 1.19 | 0.98, 1.44 | 0.082 |
| Median ZIP Code Income Quartile |  |  |  |
| $1 - $51,999 | — | — |  |
| $52,000 - $65,999 | 0.97 | 0.88, 1.06 | 0.5 |
| $66,000 - $87,999 | 1.04 | 0.94, 1.14 | 0.5 |
| $88,000 or more | 1.01 | 0.91, 1.12 | 0.8 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 1.45 | 1.28, 1.66 | <0.001 |
| Medicare | 1.11 | 1.01, 1.22 | 0.033 |
| Other | 1.32 | 1.12, 1.56 | <0.001 |
| Hospital Region |  |  |  |
| Midwest | — | — |  |
| Northeast | 1.12 | 1.00, 1.25 | 0.044 |
| South | 0.91 | 0.83, 1.00 | 0.055 |
| West | 0.88 | 0.79, 0.99 | 0.028 |
| Hospital Bed Size |  |  |  |
| Large | — | — |  |
| Medium | 1.00 | 0.92, 1.08 | >0.9 |
| Small | 1.03 | 0.94, 1.13 | 0.6 |
| Elixhauser Comorbidity Index | 1.45 | 1.43, 1.47 | <0.001 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |

## Multivariable Linear Regression:

### Length of Stay:

| **Characteristic** | **Beta** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Hospital Location and Teaching Status |  |  |  |
| Urban, teaching | — | — |  |
| Rural | 0.03 | -0.16, 0.23 | 0.7 |
| Urban, non-teaching | 0.25 | 0.08, 0.42 | 0.003 |
| Age, y | 0.00 | -0.01, 0.00 | 0.2 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 0.41 | 0.30, 0.52 | <0.001 |
| Race |  |  |  |
| White | — | — |  |
| Asian or Pacific Islander | 0.88 | 0.53, 1.2 | <0.001 |
| Black | 0.87 | 0.65, 1.1 | <0.001 |
| Hispanic | 0.68 | 0.42, 0.94 | <0.001 |
| Other | 0.38 | 0.05, 0.71 | 0.026 |
| Median ZIP Code Income Quartile |  |  |  |
| $1 - $51,999 | — | — |  |
| $52,000 - $65,999 | 0.01 | -0.15, 0.18 | 0.9 |
| $66,000 - $87,999 | -0.09 | -0.26, 0.08 | 0.3 |
| $88,000 or more | -0.34 | -0.51, -0.16 | <0.001 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 2.0 | 1.7, 2.4 | <0.001 |
| Medicare | 0.10 | -0.07, 0.26 | 0.3 |
| Other | 1.4 | 1.1, 1.7 | <0.001 |
| Hospital Region |  |  |  |
| Midwest | — | — |  |
| Northeast | 1.0 | 0.82, 1.2 | <0.001 |
| South | 0.37 | 0.21, 0.54 | <0.001 |
| West | -0.03 | -0.22, 0.16 | 0.7 |
| Hospital Bed Size |  |  |  |
| Large | — | — |  |
| Medium | -0.06 | -0.21, 0.09 | 0.4 |
| Small | -0.08 | -0.24, 0.08 | 0.3 |
| Elixhauser Comorbidity Index | 0.83 | 0.80, 0.87 | <0.001 |
| Abbreviation: CI = Confidence Interval | | | |

### Inflation-adjusted Total Charge:

| **Characteristic** | **Beta** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Hospital Location and Teaching Status |  |  |  |
| Urban, teaching | — | — |  |
| Rural | -27,956 | -31,494, -24,418 | <0.001 |
| Urban, non-teaching | 2,729 | -1,246, 6,704 | 0.2 |
| Age, y | -363 | -470, -255 | <0.001 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 7,342 | 5,446, 9,238 | <0.001 |
| Race |  |  |  |
| White | — | — |  |
| Asian or Pacific Islander | 16,990 | 9,393, 24,588 | <0.001 |
| Black | 6,245 | 2,655, 9,834 | <0.001 |
| Hispanic | 23,741 | 18,416, 29,066 | <0.001 |
| Other | 12,232 | 5,565, 18,899 | <0.001 |
| Median ZIP Code Income Quartile |  |  |  |
| $1 - $51,999 | — | — |  |
| $52,000 - $65,999 | 664 | -2,279, 3,606 | 0.7 |
| $66,000 - $87,999 | -2,382 | -5,513, 749 | 0.14 |
| $88,000 or more | 1,407 | -2,454, 5,269 | 0.5 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 16,925 | 11,385, 22,466 | <0.001 |
| Medicare | 616 | -2,085, 3,316 | 0.7 |
| Other | 7,991 | 2,940, 13,042 | 0.002 |
| Hospital Region |  |  |  |
| Midwest | — | — |  |
| Northeast | 20,810 | 16,246, 25,375 | <0.001 |
| South | 18,295 | 15,051, 21,539 | <0.001 |
| West | 46,572 | 41,286, 51,859 | <0.001 |
| Hospital Bed Size |  |  |  |
| Large | — | — |  |
| Medium | -4,252 | -8,076, -427 | 0.029 |
| Small | -9,345 | -13,106, -5,585 | <0.001 |
| Elixhauser Comorbidity Index | 11,774 | 11,071, 12,476 | <0.001 |
| Abbreviation: CI = Confidence Interval | | | |