Impact of BMI on In-Hospital Outcomes in Colorectal Cancer Patients

Analysis for RCOP NIS Gastro2

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## Preamble:

* **Reference Papers:**
  + [Salman et al. 2024](https://journals.lww.com/coronary-artery/abstract/9900/obesity_paradox_in_coronary_artery_disease_.331.aspx)
  + [Persaud et al.2019](https://www.ahajournals.org/doi/full/10.1161/STROKEAHA.119.024638)
  + [Sreenivasan et al. 2022](https://doi.org/10.1016/j.amjcard.2022.04.011)
* **Study Objective**: Examine the impact of body mass index (BMI) on outcomes among inpatient admissions with colorectal cancer.
* **Data Source**: Cross-sectional analysis of the National Inpatient Sample (NIS) from 2018 to 2020.
* **Patient Selection**: Included all inpatient admissions with colorectal cancer.
* **BMI Categories**:
  + Underweight: BMI ≤19.9 kg/m²
  + Normal Weight: BMI 20.0 to 24.9 kg/m²
  + Overweight: BMI 25.0 to 29.9 kg/m²
  + Class I Obesity: BMI 30.0 to 34.9 kg/m²
  + Class II Obesity: BMI 35.0 to 39.9 kg/m²
  + Class III Obesity: BMI ≥40.0 kg/m²
* **Outcomes**:
  + In-hospital all-cause mortality
  + Total hospital length of stay (days)
  + Total charge, inflation adjusted to 2020 ($)
* **Statistical Analysis**: Multiple logistic and linear regression to determine the independent association of BMI categories with in-hospital mortality and length of stay, respectively, adjusted for:
  + Demographics: Age, sex, race, residential income, and insurance.
  + Medical History: Cardiac arrhythmia, Anemia, Cerebrovascular disease, Chronic kidney disease, Chronic obstructive pulmonary disease, Diabetes, Dementia, Heart failure, Hypertension, Hyperlipidemia, Myocardial infarction, Peripheral vascular disease, Rheumatoid disease, Valvular heart disease
  + Comorbidities: Charlson comorbidity index.
* **Software:** All analyses were performed using R Version 4.4.1 (R Foundation for Statistical Computing, Vienna, Austria)

## Baseline Table:

| **Characteristic** | **Overall** N = 204,320*1* | **Normal weight (BMI 20.0-24.9kg/m²)** N = 38,225*1* | **Underweight (BMI ≤19.9kg/m²)** N = 49,675*1* | **Overweight (BMI 25.0-29.9kg/m²)** N = 27,295*1* | **Class I obesity (BMI 30.0-34.9kg/m²)** N = 34,075*1* | **Class II obesity (BMI 35.0-39.9kg/m²)** N = 23,465*1* | **Class III obesity (BMI ≥40.0kg/m²)** N = 31,585*1* | **p-value***2* |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age, y | 65 (56, 74) | 67 (58, 77) | 67 (57, 77) | 67 (57, 77) | 65 (55, 74) | 62 (53, 71) | 61 (52, 69) | <0.001 |
| Sex |  |  |  |  |  |  |  | <0.001 |
| Female | 99,600 (49%) | 15,915 (42%) | 25,165 (51%) | 11,945 (44%) | 15,865 (47%) | 12,085 (52%) | 18,625 (59%) |  |
| Male | 104,715 (51%) | 22,310 (58%) | 24,505 (49%) | 15,350 (56%) | 18,210 (53%) | 11,380 (48%) | 12,960 (41%) |  |
| Race |  |  |  |  |  |  |  | <0.001 |
| Asian or Pacific Islander | 6,180 (3.1%) | 1,560 (4.2%) | 2,845 (5.9%) | 735 (2.7%) | 515 (1.5%) | 235 (1.0%) | 290 (0.9%) |  |
| Black | 31,865 (16%) | 6,160 (16%) | 9,190 (19%) | 3,635 (14%) | 4,250 (13%) | 3,325 (14%) | 5,305 (17%) |  |
| Hispanic | 18,820 (9.4%) | 3,905 (10%) | 3,830 (7.9%) | 3,165 (12%) | 3,510 (11%) | 2,145 (9.3%) | 2,265 (7.4%) |  |
| Native American | 1,035 (0.5%) | 150 (0.4%) | 225 (0.5%) | 105 (0.4%) | 205 (0.6%) | 145 (0.6%) | 205 (0.7%) |  |
| Other | 5,165 (2.6%) | 1,170 (3.1%) | 1,460 (3.0%) | 685 (2.6%) | 775 (2.3%) | 490 (2.1%) | 585 (1.9%) |  |
| White | 136,845 (68%) | 24,530 (65%) | 31,065 (64%) | 18,480 (69%) | 24,010 (72%) | 16,635 (72%) | 22,125 (72%) |  |
| Income quartile |  |  |  |  |  |  |  | <0.001 |
| $1 - $51,999 | 58,360 (29%) | 10,890 (29%) | 14,400 (30%) | 7,420 (28%) | 9,175 (27%) | 6,705 (29%) | 9,770 (31%) |  |
| $52,000 - $65,999 | 53,430 (27%) | 9,305 (25%) | 12,735 (26%) | 7,070 (26%) | 8,785 (26%) | 6,455 (28%) | 9,080 (29%) |  |
| $66,000 - $87,999 | 48,310 (24%) | 8,860 (24%) | 11,145 (23%) | 6,620 (25%) | 8,405 (25%) | 5,750 (25%) | 7,530 (24%) |  |
| $88,000 or more | 40,690 (20%) | 8,355 (22%) | 10,425 (21%) | 5,755 (21%) | 7,090 (21%) | 4,245 (18%) | 4,820 (15%) |  |
| Insurance payer |  |  |  |  |  |  |  | <0.001 |
| Medicaid | 26,420 (13%) | 5,365 (14%) | 7,610 (15%) | 3,310 (12%) | 3,510 (10%) | 2,440 (10%) | 4,185 (13%) |  |
| Medicare | 108,820 (53%) | 21,355 (56%) | 28,590 (58%) | 15,350 (56%) | 17,420 (51%) | 10,985 (47%) | 15,120 (48%) |  |
| Other | 10,415 (5.1%) | 2,215 (5.8%) | 2,665 (5.4%) | 1,310 (4.8%) | 1,710 (5.0%) | 1,070 (4.6%) | 1,445 (4.6%) |  |
| Private | 58,500 (29%) | 9,240 (24%) | 10,770 (22%) | 7,315 (27%) | 11,435 (34%) | 8,935 (38%) | 10,805 (34%) |  |
| No. of comorbidities |  |  |  |  |  |  |  | 0.006 |
| No comorbidities | 250 (0.1%) | 25 (<0.1%) | 40 (<0.1%) | 20 (<0.1%) | 55 (0.2%) | 35 (0.1%) | 75 (0.2%) |  |
| One comorbidity | 295 (0.1%) | 20 (<0.1%) | 75 (0.2%) | 15 (<0.1%) | 70 (0.2%) | 45 (0.2%) | 70 (0.2%) |  |
| Two or more comorbidities | 203,775 (100%) | 38,180 (100%) | 49,560 (100%) | 27,260 (100%) | 33,950 (100%) | 23,385 (100%) | 31,440 (100%) |  |
| Cardiac arrhythmia | 44,385 (22%) | 7,905 (21%) | 9,460 (19%) | 6,250 (23%) | 7,310 (21%) | 5,385 (23%) | 8,075 (26%) | <0.001 |
| Anemia | 34,315 (17%) | 7,165 (19%) | 8,780 (18%) | 4,680 (17%) | 5,320 (16%) | 3,495 (15%) | 4,875 (15%) | <0.001 |
| Cerebrovascular disease | 6,730 (3.3%) | 1,285 (3.4%) | 1,870 (3.8%) | 930 (3.4%) | 1,115 (3.3%) | 650 (2.8%) | 880 (2.8%) | 0.007 |
| Chronic kidney disease | 31,595 (15%) | 5,085 (13%) | 6,425 (13%) | 4,235 (16%) | 5,305 (16%) | 3,905 (17%) | 6,640 (21%) | <0.001 |
| Chronic obstructive pulmonary disease | 38,585 (19%) | 5,520 (14%) | 10,095 (20%) | 4,010 (15%) | 6,130 (18%) | 4,730 (20%) | 8,100 (26%) | <0.001 |
| Diabetes | 56,340 (28%) | 7,220 (19%) | 6,050 (12%) | 7,575 (28%) | 11,790 (35%) | 9,385 (40%) | 14,320 (45%) | <0.001 |
| Dementia | 7,385 (3.6%) | 1,875 (4.9%) | 2,910 (5.9%) | 1,000 (3.7%) | 720 (2.1%) | 410 (1.7%) | 470 (1.5%) | <0.001 |
| Heart failure | 28,735 (14%) | 3,870 (10%) | 5,665 (11%) | 3,465 (13%) | 4,645 (14%) | 3,680 (16%) | 7,410 (23%) | <0.001 |
| Hypertension | 121,920 (60%) | 20,005 (52%) | 21,815 (44%) | 17,010 (62%) | 23,110 (68%) | 16,860 (72%) | 23,120 (73%) | <0.001 |
| Hyperlipidemia | 67,435 (33%) | 10,355 (27%) | 10,390 (21%) | 9,765 (36%) | 14,650 (43%) | 10,245 (44%) | 12,030 (38%) | <0.001 |
| Myocardial infarction | 12,230 (6.0%) | 1,970 (5.2%) | 2,685 (5.4%) | 1,785 (6.5%) | 2,365 (6.9%) | 1,615 (6.9%) | 1,810 (5.7%) | <0.001 |
| Peripheral vascular disease | 13,180 (6.5%) | 2,420 (6.3%) | 3,535 (7.1%) | 1,720 (6.3%) | 2,270 (6.7%) | 1,555 (6.6%) | 1,680 (5.3%) | <0.001 |
| Rheumatoid disease | 3,825 (1.9%) | 650 (1.7%) | 830 (1.7%) | 435 (1.6%) | 625 (1.8%) | 540 (2.3%) | 745 (2.4%) | 0.002 |
| Valvular heart disease | 9,260 (4.5%) | 1,630 (4.3%) | 2,115 (4.3%) | 1,365 (5.0%) | 1,735 (5.1%) | 1,045 (4.5%) | 1,370 (4.3%) | 0.044 |
| *1*Median (Q1, Q3); n (%) | | | | | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | | | | | |

## Outcomes Table:

| **Characteristic** | **Normal weight (BMI 20.0-24.9kg/m²)** N = 38,225*1* | **Underweight (BMI ≤19.9kg/m²)** N = 49,675*1* | **Overweight (BMI 25.0-29.9kg/m²)** N = 27,295*1* | **Class I obesity (BMI 30.0-34.9kg/m²)** N = 34,075*1* | **Class II obesity (BMI 35.0-39.9kg/m²)** N = 23,465*1* | **Class III obesity (BMI ≥40.0kg/m²)** N = 31,585*1* | **p-value***2* |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Died during hospitalization | 2,035 (5.3%) | 3,765 (7.6%) | 1,005 (3.7%) | 670 (2.0%) | 455 (1.9%) | 1,145 (3.6%) | <0.001 |
| Length of stay (days) | 6.0 (4.0, 11.0) | 6.0 (3.0, 11.0) | 6.0 (3.0, 11.0) | 5.0 (3.0, 8.0) | 5.0 (3.0, 8.0) | 5.0 (3.0, 9.0) | <0.001 |
| Inflation-adjusted total charge ($) | 60,660 (32,487, 114,574) | 56,083 (29,423, 110,997) | 67,339 (35,059, 120,194) | 67,317 (39,405, 115,412) | 67,982 (39,782, 112,523) | 68,570 (39,024, 125,641) | <0.001 |
| *1*n (%); Median (Q1, Q3) | | | | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | | | | |

## Multivariable Logistic Regression:

### All-Cause Mortality:

| **Characteristic** | **OR***1* | **95% CI***1* | **p-value** |
| --- | --- | --- | --- |
| BMI category |  |  |  |
| Normal weight (BMI 20.0-24.9kg/m²) | — | — |  |
| Underweight (BMI ≤19.9kg/m²) | 1.52 | 1.33, 1.74 | <0.001 |
| Overweight (BMI 25.0-29.9kg/m²) | 0.76 | 0.64, 0.92 | 0.004 |
| Class I obesity (BMI 30.0-34.9kg/m²) | 0.47 | 0.38, 0.58 | <0.001 |
| Class II obesity (BMI 35.0-39.9kg/m²) | 0.48 | 0.38, 0.62 | <0.001 |
| Class III obesity (BMI ≥40.0kg/m²) | 0.91 | 0.75, 1.10 | 0.3 |
| Age, y | 1.02 | 1.01, 1.02 | <0.001 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 1.15 | 1.04, 1.28 | 0.007 |
| Race |  |  |  |
| Asian or Pacific Islander | — | — |  |
| Black | 0.85 | 0.66, 1.11 | 0.2 |
| Hispanic | 0.77 | 0.58, 1.03 | 0.074 |
| Native American | 1.20 | 0.63, 2.29 | 0.6 |
| Other | 1.07 | 0.76, 1.52 | 0.7 |
| White | 0.73 | 0.57, 0.93 | 0.010 |
| Income quartile |  |  |  |
| $1 - $51,999 | — | — |  |
| $52,000 - $65,999 | 0.88 | 0.77, 1.01 | 0.059 |
| $66,000 - $87,999 | 0.90 | 0.78, 1.03 | 0.12 |
| $88,000 or more | 0.86 | 0.74, 0.99 | 0.033 |
| Insurance payer |  |  |  |
| Medicaid | — | — |  |
| Medicare | 1.06 | 0.88, 1.27 | 0.5 |
| Other | 1.42 | 1.11, 1.81 | 0.005 |
| Private | 1.21 | 1.01, 1.45 | 0.039 |
| Charlson comorbidity index | 1.24 | 1.21, 1.27 | <0.001 |
| Cardiac arrhythmia |  |  |  |
| No | — | — |  |
| Yes | 1.69 | 1.50, 1.91 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 0.73 | 0.63, 0.83 | <0.001 |
| Cerebrovascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.45 | 1.17, 1.80 | <0.001 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 0.70 | 0.60, 0.82 | <0.001 |
| Chronic obstructive pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | 0.85 | 0.75, 0.97 | 0.017 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 0.80 | 0.70, 0.91 | 0.001 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 0.92 | 0.73, 1.15 | 0.5 |
| Heart failure |  |  |  |
| No | — | — |  |
| Yes | 1.37 | 1.18, 1.59 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 0.82 | 0.73, 0.92 | 0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 0.62 | 0.55, 0.71 | <0.001 |
| Myocardial infarction |  |  |  |
| No | — | — |  |
| Yes | 1.10 | 0.90, 1.34 | 0.3 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.05 | 0.88, 1.27 | 0.6 |
| Rheumatoid disease |  |  |  |
| No | — | — |  |
| Yes | 0.79 | 0.54, 1.17 | 0.2 |
| Valvular heart disease |  |  |  |
| No | — | — |  |
| Yes | 0.76 | 0.60, 0.98 | 0.032 |
| *1*OR = Odds Ratio, CI = Confidence Interval | | | |

## Multivariable Linear Regression:

### Length of Stay:

| **Characteristic** | **Beta** | **95% CI***1* | **p-value** |
| --- | --- | --- | --- |
| BMI category |  |  |  |
| Normal weight (BMI 20.0-24.9kg/m²) | — | — |  |
| Underweight (BMI ≤19.9kg/m²) | 0.20 | -0.08, 0.48 | 0.2 |
| Overweight (BMI 25.0-29.9kg/m²) | -0.12 | -0.42, 0.17 | 0.4 |
| Class I obesity (BMI 30.0-34.9kg/m²) | -1.4 | -1.6, -1.1 | <0.001 |
| Class II obesity (BMI 35.0-39.9kg/m²) | -1.5 | -1.8, -1.2 | <0.001 |
| Class III obesity (BMI ≥40.0kg/m²) | -0.45 | -0.78, -0.12 | 0.007 |
| Age, y | -0.01 | -0.02, 0.00 | 0.14 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 0.09 | -0.07, 0.26 | 0.3 |
| Race |  |  |  |
| Asian or Pacific Islander | — | — |  |
| Black | 0.10 | -0.49, 0.69 | 0.7 |
| Hispanic | -0.35 | -0.94, 0.25 | 0.3 |
| Native American | -0.16 | -1.8, 1.4 | 0.8 |
| Other | 0.48 | -0.40, 1.4 | 0.3 |
| White | -0.74 | -1.3, -0.19 | 0.009 |
| Income quartile |  |  |  |
| $1 - $51,999 | — | — |  |
| $52,000 - $65,999 | -0.12 | -0.33, 0.10 | 0.3 |
| $66,000 - $87,999 | 0.07 | -0.17, 0.31 | 0.6 |
| $88,000 or more | 0.13 | -0.13, 0.40 | 0.3 |
| Insurance payer |  |  |  |
| Medicaid | — | — |  |
| Medicare | -0.76 | -1.1, -0.39 | <0.001 |
| Other | -0.75 | -1.2, -0.27 | 0.002 |
| Private | -1.1 | -1.5, -0.82 | <0.001 |
| Charlson comorbidity index | 0.02 | -0.02, 0.07 | 0.3 |
| Cardiac arrhythmia |  |  |  |
| No | — | — |  |
| Yes | 1.9 | 1.7, 2.2 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 0.87 | 0.65, 1.1 | <0.001 |
| Cerebrovascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.8 | 1.2, 2.4 | <0.001 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 0.75 | 0.47, 1.0 | <0.001 |
| Chronic obstructive pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | -0.01 | -0.22, 0.21 | >0.9 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 0.01 | -0.21, 0.23 | >0.9 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 0.70 | 0.22, 1.2 | 0.004 |
| Heart failure |  |  |  |
| No | — | — |  |
| Yes | 1.2 | 0.91, 1.5 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | -0.45 | -0.66, -0.25 | <0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | -0.77 | -0.95, -0.60 | <0.001 |
| Myocardial infarction |  |  |  |
| No | — | — |  |
| Yes | -0.14 | -0.48, 0.20 | 0.4 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 0.44 | 0.02, 0.85 | 0.038 |
| Rheumatoid disease |  |  |  |
| No | — | — |  |
| Yes | 0.15 | -0.37, 0.68 | 0.6 |
| Valvular heart disease |  |  |  |
| No | — | — |  |
| Yes | -0.04 | -0.47, 0.39 | 0.9 |
| *1*CI = Confidence Interval | | | |

### Inflation Adjusted Total Charge:

| **Characteristic** | **Beta** | **95% CI***1* | **p-value** |
| --- | --- | --- | --- |
| BMI category |  |  |  |
| Normal weight (BMI 20.0-24.9kg/m²) | — | — |  |
| Underweight (BMI ≤19.9kg/m²) | 2,081 | -1,885, 6,047 | 0.3 |
| Overweight (BMI 25.0-29.9kg/m²) | 4,276 | -81, 8,633 | 0.054 |
| Class I obesity (BMI 30.0-34.9kg/m²) | 2,572 | -1,350, 6,495 | 0.2 |
| Class II obesity (BMI 35.0-39.9kg/m²) | 1,598 | -2,815, 6,011 | 0.5 |
| Class III obesity (BMI ≥40.0kg/m²) | 15,970 | 11,110, 20,831 | <0.001 |
| Age, y | -370 | -567, -172 | <0.001 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 2,843 | 265, 5,420 | 0.031 |
| Race |  |  |  |
| Asian or Pacific Islander | — | — |  |
| Black | -24,494 | -33,899, -15,089 | <0.001 |
| Hispanic | -677 | -10,373, 9,019 | 0.9 |
| Native American | -30,258 | -49,364, -11,153 | 0.002 |
| Other | 5,693 | -10,776, 22,162 | 0.5 |
| White | -31,021 | -39,772, -22,271 | <0.001 |
| Income quartile |  |  |  |
| $1 - $51,999 | — | — |  |
| $52,000 - $65,999 | 1,634 | -1,564, 4,832 | 0.3 |
| $66,000 - $87,999 | 6,114 | 2,371, 9,858 | 0.001 |
| $88,000 or more | 14,318 | 9,688, 18,949 | <0.001 |
| Insurance payer |  |  |  |
| Medicaid | — | — |  |
| Medicare | -3,071 | -8,674, 2,532 | 0.3 |
| Other | -12,702 | -18,936, -6,469 | <0.001 |
| Private | -4,268 | -9,354, 818 | 0.10 |
| Charlson comorbidity index | -2,013 | -2,697, -1,329 | <0.001 |
| Cardiac arrhythmia |  |  |  |
| No | — | — |  |
| Yes | 26,694 | 22,652, 30,737 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 6,359 | 3,187, 9,530 | <0.001 |
| Cerebrovascular disease |  |  |  |
| No | — | — |  |
| Yes | 27,096 | 17,341, 36,852 | <0.001 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 8,646 | 4,111, 13,181 | <0.001 |
| Chronic obstructive pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | 3,085 | -639, 6,810 | 0.10 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 1,960 | -1,185, 5,104 | 0.2 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 198 | -5,809, 6,204 | >0.9 |
| Heart failure |  |  |  |
| No | — | — |  |
| Yes | 17,578 | 12,383, 22,772 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | -6,085 | -9,156, -3,013 | <0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | -8,110 | -10,734, -5,485 | <0.001 |
| Myocardial infarction |  |  |  |
| No | — | — |  |
| Yes | 7,508 | 923, 14,092 | 0.025 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 10,094 | 4,233, 15,955 | <0.001 |
| Rheumatoid disease |  |  |  |
| No | — | — |  |
| Yes | 1,465 | -6,552, 9,483 | 0.7 |
| Valvular heart disease |  |  |  |
| No | — | — |  |
| Yes | -83 | -6,551, 6,385 | >0.9 |
| *1*CI = Confidence Interval | | | |