Impact of Body Mass Index on Mortality in Hospitalized Patients With Coronary Artery Disease

Analysis for RCOP NIS IM6

Ali Salman

## Preamble:

* **Reference Paper:** [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 coronary artery disease (CAD).
* **Data Source**: Cross-sectional analysis of the National Inpatient Sample (NIS) from 2018 to 2020.
* **Patient Selection**: Included all inpatient admissions with a principal diagnosis or a history of CAD.
* **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
* **Primary 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, gender, race
  + Medical History: Previous coronary artery bypass graft, myocardial infarction, percutaneous coronary intervention
  + Comorbidities: Charlson comorbidity index, atrial fibrillation, cerebrovascular disease, heart failure, peripheral vascular disease, dementia, tobacco use disorder, chronic obstructive pulmonary disease, valvular heart disease, liver disease, diabetes mellitus, hypertension, chronic kidney disease, dialysis dependence, anemia, hyperlipidemia, and any cancer.
* **Software:** All analyses were performed using R Version 4.4.1 (R Foundation for Statistical Computing, Vienna, Austria)

## Baseline Table:

| **Characteristic** | **Overall**, N = 3,693,5701 | **Normal weight (BMI 20.0-24.9kg/m²)**, N = 266,9001 | **Class I obesity (BMI 30.0-34.9kg/m²)**, N = 871,7601 | **Class II obesity (BMI 35.0-39.9kg/m²)**, N = 722,2901 | **Class III obesity (BMI ≥40.0kg/m²)**, N = 1,085,3701 | **Overweight (BMI 25.0-29.9kg/m²)**, N = 353,2351 | **Underweight (BMI ≤19.9kg/m²)**, N = 394,0151 | **p-value**2 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age, y | 69 (12) | 76 (11) | 69 (11) | 67 (11) | 64 (11) | 72 (11) | 76 (11) | <0.001 |
| Sex |  |  |  |  |  |  |  | <0.001 |
| Female | 1,616,920 (44) | 100,455 (38) | 319,875 (37) | 299,680 (41) | 570,945 (53) | 130,815 (37) | 195,150 (50) |  |
| Male | 2,076,460 (56) | 166,410 (62) | 551,840 (63) | 422,580 (59) | 514,395 (47) | 222,395 (63) | 198,840 (50) |  |
| Race |  |  |  |  |  |  |  | <0.001 |
| White | 2,703,165 (75) | 191,600 (73) | 652,690 (76) | 537,210 (76) | 784,280 (74) | 254,345 (74) | 283,040 (73) |  |
| Asian or Pacific Islander | 52,325 (1.4) | 8,020 (3.1) | 10,655 (1.2) | 6,380 (0.9) | 6,865 (0.6) | 6,885 (2.0) | 13,520 (3.5) |  |
| Black | 500,665 (14) | 34,105 (13) | 99,630 (12) | 92,615 (13) | 174,955 (16) | 41,910 (12) | 57,450 (15) |  |
| Hispanic | 262,035 (7.3) | 19,275 (7.4) | 67,735 (7.9) | 52,575 (7.4) | 68,870 (6.5) | 32,155 (9.3) | 21,425 (5.5) |  |
| Native American | 19,185 (0.5) | 1,145 (0.4) | 4,435 (0.5) | 3,645 (0.5) | 6,710 (0.6) | 1,460 (0.4) | 1,790 (0.5) |  |
| Other | 76,070 (2.1) | 6,840 (2.6) | 18,110 (2.1) | 14,150 (2.0) | 19,080 (1.8) | 8,870 (2.6) | 9,020 (2.3) |  |
| Income quartile by ZIP |  |  |  |  |  |  |  | <0.001 |
| $1 - $51,999 | 1,163,180 (32) | 79,355 (30) | 259,145 (30) | 222,545 (31) | 372,445 (35) | 106,120 (31) | 123,570 (32) |  |
| $52,000 - $65,999 | 1,024,375 (28) | 69,490 (26) | 239,565 (28) | 205,785 (29) | 312,985 (29) | 94,275 (27) | 102,275 (26) |  |
| $66,000 - $87,999 | 849,875 (23) | 61,125 (23) | 208,045 (24) | 169,480 (24) | 241,895 (23) | 82,280 (24) | 87,050 (22) |  |
| $88,000 or more | 602,210 (17) | 52,990 (20) | 152,800 (18) | 113,750 (16) | 142,615 (13) | 65,175 (19) | 74,880 (19) |  |
| Healthcare payer |  |  |  |  |  |  |  | <0.001 |
| Medicaid | 322,300 (8.7) | 15,330 (5.7) | 66,045 (7.6) | 63,840 (8.8) | 128,200 (12) | 23,420 (6.6) | 25,465 (6.5) |  |
| Medicare | 2,581,230 (70) | 218,785 (82) | 597,280 (69) | 473,805 (66) | 699,840 (65) | 265,840 (75) | 325,680 (83) |  |
| No charge | 7,220 (0.2) | 280 (0.1) | 2,135 (0.2) | 1,450 (0.2) | 2,335 (0.2) | 600 (0.2) | 420 (0.1) |  |
| Other | 85,255 (2.3) | 5,425 (2.0) | 22,045 (2.5) | 18,220 (2.5) | 24,045 (2.2) | 8,345 (2.4) | 7,175 (1.8) |  |
| Private | 618,350 (17) | 23,935 (9.0) | 164,200 (19) | 146,770 (20) | 204,370 (19) | 48,475 (14) | 30,600 (7.8) |  |
| Self-pay | 76,355 (2.1) | 3,005 (1.1) | 19,430 (2.2) | 17,680 (2.4) | 25,520 (2.4) | 6,345 (1.8) | 4,375 (1.1) |  |
| Charlson comorbidity index | 3.69 (2.24) | 3.95 (2.42) | 3.49 (2.23) | 3.56 (2.19) | 3.85 (2.15) | 3.73 (2.34) | 3.70 (2.31) | <0.001 |
| Hypertension | 3,341,650 (90) | 227,520 (85) | 798,815 (92) | 668,475 (93) | 1,007,545 (93) | 317,140 (90) | 322,155 (82) | <0.001 |
| Diabetes mellitus | 2,087,065 (57) | 100,760 (38) | 498,745 (57) | 454,870 (63) | 747,095 (69) | 180,495 (51) | 105,100 (27) | <0.001 |
| Chronic kidney disease | 1,354,770 (37) | 98,430 (37) | 303,335 (35) | 259,600 (36) | 437,720 (40) | 130,165 (37) | 125,520 (32) | <0.001 |
| Dialysis dependence | 180,850 (4.9) | 16,535 (6.2) | 41,915 (4.8) | 33,245 (4.6) | 48,045 (4.4) | 20,300 (5.7) | 20,810 (5.3) | <0.001 |
| Liver disease | 221,320 (6.0) | 18,780 (7.0) | 48,250 (5.5) | 40,230 (5.6) | 67,560 (6.2) | 23,525 (6.7) | 22,975 (5.8) | <0.001 |
| Cancer | 202,055 (5.5) | 30,490 (11) | 42,635 (4.9) | 29,105 (4.0) | 35,785 (3.3) | 26,745 (7.6) | 37,295 (9.5) | <0.001 |
| COPD | 1,417,520 (38) | 91,560 (34) | 285,555 (33) | 259,890 (36) | 481,845 (44) | 112,700 (32) | 185,970 (47) | <0.001 |
| Anemia | 265,740 (7.2) | 27,730 (10) | 53,245 (6.1) | 42,205 (5.8) | 74,515 (6.9) | 27,620 (7.8) | 40,425 (10) | <0.001 |
| Peripheral vascular disease | 582,665 (16) | 53,525 (20) | 142,280 (16) | 104,280 (14) | 127,720 (12) | 64,225 (18) | 90,635 (23) | <0.001 |
| Atrial fibrillation | 1,017,110 (28) | 77,730 (29) | 231,395 (27) | 192,880 (27) | 308,780 (28) | 98,005 (28) | 108,320 (27) | <0.001 |
| Prior MI | 889,950 (24) | 62,565 (23) | 221,635 (25) | 179,715 (25) | 245,730 (23) | 85,960 (24) | 94,345 (24) | <0.001 |
| Prior PCI | 923,435 (25) | 62,875 (24) | 246,795 (28) | 198,025 (27) | 246,455 (23) | 93,250 (26) | 76,035 (19) | <0.001 |
| Prior CABG | 645,200 (17) | 58,195 (22) | 170,955 (20) | 131,650 (18) | 145,945 (13) | 75,365 (21) | 63,090 (16) | <0.001 |
| Cerebrovascular disease | 348,870 (9.4) | 30,175 (11) | 88,345 (10) | 63,825 (8.8) | 81,805 (7.5) | 39,635 (11) | 45,085 (11) | <0.001 |
| Dementia | 272,005 (7.4) | 51,075 (19) | 44,965 (5.2) | 26,905 (3.7) | 29,990 (2.8) | 37,600 (11) | 81,470 (21) | <0.001 |
| Heart failure | 1,915,090 (52) | 126,000 (47) | 406,695 (47) | 365,340 (51) | 664,980 (61) | 164,925 (47) | 187,150 (47) | <0.001 |
| Tobbacco use disorder | 26,585 (0.7) | 1,645 (0.6) | 6,570 (0.8) | 5,400 (0.7) | 7,340 (0.7) | 2,560 (0.7) | 3,070 (0.8) | <0.001 |
| Hyperlipidemia | 2,577,040 (70) | 161,330 (60) | 660,670 (76) | 537,115 (74) | 747,645 (69) | 253,555 (72) | 216,725 (55) | <0.001 |
| 1Mean (SD); n (%) | | | | | | | | |
| 2Wilcoxon rank-sum test for complex survey samples; chi-squared test with Rao & Scott's second-order correction | | | | | | | | |

## Outcomes Table:

| **Characteristic** | **Overall**, N = 3,693,5701 | **Normal weight (BMI 20.0-24.9kg/m²)**, N = 266,9001 | **Class I obesity (BMI 30.0-34.9kg/m²)**, N = 871,7601 | **Class II obesity (BMI 35.0-39.9kg/m²)**, N = 722,2901 | **Class III obesity (BMI ≥40.0kg/m²)**, N = 1,085,3701 | **Overweight (BMI 25.0-29.9kg/m²)**, N = 353,2351 | **Underweight (BMI ≤19.9kg/m²)**, N = 394,0151 | **p-value**2 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Died during hospitalization | 108,960 (3.0%) | 13,855 (5.2%) | 16,395 (1.9%) | 13,240 (1.8%) | 27,475 (2.5%) | 11,190 (3.2%) | 26,805 (6.8%) | <0.001 |
| Length of stay (days) | 4.0 (2.0, 7.0) | 5.0 (3.0, 9.0) | 4.0 (2.0, 6.0) | 4.0 (2.0, 6.0) | 4.0 (2.0, 7.0) | 4.0 (2.0, 8.0) | 5.0 (3.0, 9.0) | <0.001 |
| Inflation-adjusted total charge ($) | 49,814 (26,900, 95,686) | 49,340 (27,125, 93,565) | 52,773 (27,789, 102,334) | 50,213 (26,849, 95,516) | 47,440 (26,022, 90,658) | 53,730 (28,587, 105,184) | 47,178 (26,253, 88,784) | <0.001 |
| 1n (%); Median (IQR) | | | | | | | | |
| 2chi-squared test with Rao & Scott's second-order correction; Wilcoxon rank-sum test for complex survey samples | | | | | | | | |

## Multivariable Logistic Regression:

### All-Cause Mortality:

| **Characteristic** | **OR**1 | **95% CI**1 | **p-value** |
| --- | --- | --- | --- |
| Body mass index (BMI) |  |  |  |
| Normal weight (BMI 20.0-24.9kg/m²) | — | — |  |
| Class I obesity (BMI 30.0-34.9kg/m²) | 0.54 | 0.51, 0.57 | <0.001 |
| Class II obesity (BMI 35.0-39.9kg/m²) | 0.56 | 0.53, 0.59 | <0.001 |
| Class III obesity (BMI ≥40.0kg/m²) | 0.78 | 0.74, 0.82 | <0.001 |
| Overweight (BMI 25.0-29.9kg/m²) | 0.75 | 0.70, 0.79 | <0.001 |
| Underweight (BMI ≤19.9kg/m²) | 1.38 | 1.31, 1.45 | <0.001 |
| Age, y | 1.03 | 1.03, 1.03 | <0.001 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 1.13 | 1.09, 1.16 | <0.001 |
| Race |  |  |  |
| White | — | — |  |
| Asian or Pacific Islander | 1.25 | 1.13, 1.38 | <0.001 |
| Black | 0.97 | 0.92, 1.01 | 0.15 |
| Hispanic | 1.08 | 1.02, 1.15 | 0.014 |
| Native American | 1.18 | 0.96, 1.45 | 0.12 |
| Other | 1.12 | 1.02, 1.24 | 0.017 |
| Prior CABG |  |  |  |
| No | — | — |  |
| Yes | 0.92 | 0.88, 0.95 | <0.001 |
| Prior MI |  |  |  |
| No | — | — |  |
| Yes | 0.76 | 0.73, 0.79 | <0.001 |
| Prior PCI |  |  |  |
| No | — | — |  |
| Yes | 0.79 | 0.76, 0.82 | <0.001 |
| Charlson comorbidity index | 1.16 | 1.15, 1.17 | <0.001 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 1.28 | 1.24, 1.32 | <0.001 |
| Cerebrovascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.15 | 1.10, 1.20 | <0.001 |
| Heart failure |  |  |  |
| No | — | — |  |
| Yes | 1.38 | 1.33, 1.42 | <0.001 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 0.90 | 0.86, 0.93 | <0.001 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 1.08 | 1.03, 1.13 | <0.001 |
| Tobbacco use disorder |  |  |  |
| No | — | — |  |
| Yes | 0.91 | 0.75, 1.10 | 0.3 |
| COPD |  |  |  |
| No | — | — |  |
| Yes | 0.85 | 0.83, 0.88 | <0.001 |
| Valvular heart disease |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.91, 0.98 | 0.002 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 2.39 | 2.28, 2.50 | <0.001 |
| Diabetes mellitus |  |  |  |
| No | — | — |  |
| Yes | 0.78 | 0.75, 0.81 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 0.69 | 0.66, 0.73 | <0.001 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 0.86 | 0.83, 0.90 | <0.001 |
| Dialysis dependence |  |  |  |
| No | — | — |  |
| Yes | 1.44 | 1.36, 1.53 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 0.77 | 0.73, 0.82 | <0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 0.69 | 0.66, 0.71 | <0.001 |
| Cancer |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.97, 1.08 | 0.4 |
| 1OR = Odds Ratio, CI = Confidence Interval | | | |

## Multivariable Linear Regression:

### Length of Stay:

| **Characteristic** | **Beta** | **95% CI**1 | **p-value** |
| --- | --- | --- | --- |
| Body mass index (BMI) |  |  |  |
| Normal weight (BMI 20.0-24.9kg/m²) | — | — |  |
| Class I obesity (BMI 30.0-34.9kg/m²) | -1.7 | -1.8, -1.6 | <0.001 |
| Class II obesity (BMI 35.0-39.9kg/m²) | -1.8 | -1.9, -1.7 | <0.001 |
| Class III obesity (BMI ≥40.0kg/m²) | -1.4 | -1.5, -1.3 | <0.001 |
| Overweight (BMI 25.0-29.9kg/m²) | -0.81 | -0.89, -0.73 | <0.001 |
| Underweight (BMI ≤19.9kg/m²) | -0.16 | -0.25, -0.07 | <0.001 |
| Age, y | -0.01 | -0.01, 0.00 | <0.001 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 0.10 | 0.07, 0.13 | <0.001 |
| Race |  |  |  |
| White | — | — |  |
| Asian or Pacific Islander | 0.57 | 0.40, 0.73 | <0.001 |
| Black | 0.42 | 0.36, 0.48 | <0.001 |
| Hispanic | 0.24 | 0.15, 0.32 | <0.001 |
| Native American | -0.23 | -0.44, -0.03 | 0.027 |
| Other | 0.31 | 0.16, 0.46 | <0.001 |
| Prior CABG |  |  |  |
| No | — | — |  |
| Yes | -0.56 | -0.60, -0.52 | <0.001 |
| Prior MI |  |  |  |
| No | — | — |  |
| Yes | -0.60 | -0.64, -0.56 | <0.001 |
| Prior PCI |  |  |  |
| No | — | — |  |
| Yes | -0.65 | -0.68, -0.62 | <0.001 |
| Charlson comorbidity index | 0.26 | 0.24, 0.27 | <0.001 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 0.67 | 0.63, 0.71 | <0.001 |
| Cerebrovascular disease |  |  |  |
| No | — | — |  |
| Yes | 0.80 | 0.74, 0.87 | <0.001 |
| Heart failure |  |  |  |
| No | — | — |  |
| Yes | 0.57 | 0.53, 0.60 | <0.001 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | -0.03 | -0.08, 0.02 | 0.2 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 0.52 | 0.45, 0.60 | <0.001 |
| Tobbacco use disorder |  |  |  |
| No | — | — |  |
| Yes | -0.37 | -0.51, -0.23 | <0.001 |
| COPD |  |  |  |
| No | — | — |  |
| Yes | -0.20 | -0.23, -0.16 | <0.001 |
| Valvular heart disease |  |  |  |
| No | — | — |  |
| Yes | 0.39 | 0.34, 0.44 | <0.001 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 0.62 | 0.54, 0.71 | <0.001 |
| Diabetes mellitus |  |  |  |
| No | — | — |  |
| Yes | -0.06 | -0.10, -0.03 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | -0.26 | -0.32, -0.20 | <0.001 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 0.01 | -0.03, 0.06 | 0.6 |
| Dialysis dependence |  |  |  |
| No | — | — |  |
| Yes | 0.18 | 0.10, 0.26 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 0.86 | 0.79, 0.93 | <0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | -0.56 | -0.60, -0.52 | <0.001 |
| Cancer |  |  |  |
| No | — | — |  |
| Yes | 0.48 | 0.41, 0.56 | <0.001 |
| 1CI = Confidence Interval | | | |

### Inflation Adjusted Total Charge:

| **Characteristic** | **Beta** | **95% CI**1 | **p-value** |
| --- | --- | --- | --- |
| Body mass index (BMI) |  |  |  |
| Normal weight (BMI 20.0-24.9kg/m²) | — | — |  |
| Class I obesity (BMI 30.0-34.9kg/m²) | 1,137 | -401, 2,675 | 0.15 |
| Class II obesity (BMI 35.0-39.9kg/m²) | -2,980 | -4,514, -1,446 | <0.001 |
| Class III obesity (BMI ≥40.0kg/m²) | -5,347 | -6,983, -3,711 | <0.001 |
| Overweight (BMI 25.0-29.9kg/m²) | 6,135 | 4,555, 7,715 | <0.001 |
| Underweight (BMI ≤19.9kg/m²) | -1,673 | -3,228, -118 | 0.035 |
| Age, y | -516 | -553, -478 | <0.001 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 8,599 | 8,024, 9,174 | <0.001 |
| Race |  |  |  |
| White | — | — |  |
| Asian or Pacific Islander | 34,990 | 30,054, 39,926 | <0.001 |
| Black | -2,601 | -4,016, -1,185 | <0.001 |
| Hispanic | 24,877 | 22,319, 27,435 | <0.001 |
| Native American | -8,959 | -13,041, -4,877 | <0.001 |
| Other | 24,508 | 19,403, 29,613 | <0.001 |
| Prior CABG |  |  |  |
| No | — | — |  |
| Yes | -18,115 | -18,935, -17,296 | <0.001 |
| Prior MI |  |  |  |
| No | — | — |  |
| Yes | -12,112 | -12,818, -11,405 | <0.001 |
| Prior PCI |  |  |  |
| No | — | — |  |
| Yes | -12,635 | -13,286, -11,984 | <0.001 |
| Charlson comorbidity index | 2,795 | 2,553, 3,036 | <0.001 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 8,735 | 7,954, 9,517 | <0.001 |
| Cerebrovascular disease |  |  |  |
| No | — | — |  |
| Yes | 10,430 | 9,291, 11,570 | <0.001 |
| Heart failure |  |  |  |
| No | — | — |  |
| Yes | 3,125 | 2,418, 3,833 | <0.001 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 3,813 | 2,869, 4,757 | <0.001 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | -13,873 | -14,854, -12,891 | <0.001 |
| Tobbacco use disorder |  |  |  |
| No | — | — |  |
| Yes | -3,699 | -6,647, -752 | 0.014 |
| COPD |  |  |  |
| No | — | — |  |
| Yes | -10,484 | -11,193, -9,776 | <0.001 |
| Valvular heart disease |  |  |  |
| No | — | — |  |
| Yes | 21,319 | 20,054, 22,583 | <0.001 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 8,311 | 6,659, 9,963 | <0.001 |
| Diabetes mellitus |  |  |  |
| No | — | — |  |
| Yes | -3,788 | -4,455, -3,122 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | -3,781 | -4,816, -2,746 | <0.001 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | -8,869 | -9,775, -7,963 | <0.001 |
| Dialysis dependence |  |  |  |
| No | — | — |  |
| Yes | 5,623 | 4,222, 7,024 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 412 | -706, 1,531 | 0.5 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 791 | -4.4, 1,586 | 0.051 |
| Cancer |  |  |  |
| No | — | — |  |
| Yes | 4,016 | 2,684, 5,349 | <0.001 |
| 1CI = Confidence Interval | | | |