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

Analysis for RCOP NIS IM6

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## 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 patients with coronary artery disease (CAD).
* **Data Source**: Cross-sectional analysis of the National Inpatient Sample (NIS) from 2018 to 2020.
* **Patient Selection**: Included all hospitalized patients diagnosed 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** **(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 to 0.57) | <0.001 |
| Class II obesity (BMI 35.0-39.9kg/m²) | 0.56 (0.53 to 0.59) | <0.001 |
| Class III obesity (BMI ≥40.0kg/m²) | 0.78 (0.74 to 0.82) | <0.001 |
| Overweight (BMI 25.0-29.9kg/m²) | 0.75 (0.70 to 0.79) | <0.001 |
| Underweight (BMI ≤19.9kg/m²) | 1.38 (1.31 to 1.45) | <0.001 |
| Age, y | 1.03 (1.03 to 1.03) | <0.001 |
| Sex |  |  |
| Female | — |  |
| Male | 1.13 (1.09 to 1.16) | <0.001 |
| Race |  |  |
| White | — |  |
| Asian or Pacific Islander | 1.25 (1.13 to 1.38) | <0.001 |
| Black | 0.97 (0.92 to 1.01) | 0.15 |
| Hispanic | 1.08 (1.02 to 1.15) | 0.014 |
| Native American | 1.18 (0.96 to 1.45) | 0.12 |
| Other | 1.12 (1.02 to 1.24) | 0.017 |
| Prior CABG |  |  |
| No | — |  |
| Yes | 0.92 (0.88 to 0.95) | <0.001 |
| Prior MI |  |  |
| No | — |  |
| Yes | 0.76 (0.73 to 0.79) | <0.001 |
| Prior PCI |  |  |
| No | — |  |
| Yes | 0.79 (0.76 to 0.82) | <0.001 |
| Charlson comorbidity index | 1.16 (1.15 to 1.17) | <0.001 |
| Atrial fibrillation |  |  |
| No | — |  |
| Yes | 1.28 (1.24 to 1.32) | <0.001 |
| Cerebrovascular disease |  |  |
| No | — |  |
| Yes | 1.15 (1.10 to 1.20) | <0.001 |
| Heart failure |  |  |
| No | — |  |
| Yes | 1.38 (1.33 to 1.42) | <0.001 |
| Peripheral vascular disease |  |  |
| No | — |  |
| Yes | 0.90 (0.86 to 0.93) | <0.001 |
| Dementia |  |  |
| No | — |  |
| Yes | 1.08 (1.03 to 1.13) | <0.001 |
| Tobbacco use disorder |  |  |
| No | — |  |
| Yes | 0.91 (0.75 to 1.10) | 0.33 |
| COPD |  |  |
| No | — |  |
| Yes | 0.85 (0.83 to 0.88) | <0.001 |
| Valvular heart disease |  |  |
| No | — |  |
| Yes | 0.94 (0.91 to 0.98) | 0.002 |
| Liver disease |  |  |
| No | — |  |
| Yes | 2.39 (2.28 to 2.50) | <0.001 |
| Diabetes mellitus |  |  |
| No | — |  |
| Yes | 0.78 (0.75 to 0.81) | <0.001 |
| Hypertension |  |  |
| No | — |  |
| Yes | 0.69 (0.66 to 0.73) | <0.001 |
| Chronic kidney disease |  |  |
| No | — |  |
| Yes | 0.86 (0.83 to 0.90) | <0.001 |
| Dialysis dependence |  |  |
| No | — |  |
| Yes | 1.44 (1.36 to 1.53) | <0.001 |
| Anemia |  |  |
| No | — |  |
| Yes | 0.77 (0.73 to 0.82) | <0.001 |
| Hyperlipidemia |  |  |
| No | — |  |
| Yes | 0.69 (0.66 to 0.71) | <0.001 |
| Cancer |  |  |
| No | — |  |
| Yes | 1.02 (0.97 to 1.08) | 0.39 |
| 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 to -1.6) | <0.001 |
| Class II obesity (BMI 35.0-39.9kg/m²) | -1.8 (-1.9 to -1.7) | <0.001 |
| Class III obesity (BMI ≥40.0kg/m²) | -1.4 (-1.5 to -1.3) | <0.001 |
| Overweight (BMI 25.0-29.9kg/m²) | -0.81 (-0.89 to -0.73) | <0.001 |
| Underweight (BMI ≤19.9kg/m²) | -0.16 (-0.25 to -0.07) | <0.001 |
| Age, y | -0.01 (-0.01 to 0.00) | <0.001 |
| Sex |  |  |
| Female | — |  |
| Male | 0.10 (0.07 to 0.13) | <0.001 |
| Race |  |  |
| White | — |  |
| Asian or Pacific Islander | 0.57 (0.40 to 0.73) | <0.001 |
| Black | 0.42 (0.36 to 0.48) | <0.001 |
| Hispanic | 0.24 (0.15 to 0.32) | <0.001 |
| Native American | -0.23 (-0.44 to -0.03) | 0.027 |
| Other | 0.31 (0.16 to 0.46) | <0.001 |
| Prior CABG |  |  |
| No | — |  |
| Yes | -0.56 (-0.60 to -0.52) | <0.001 |
| Prior MI |  |  |
| No | — |  |
| Yes | -0.60 (-0.64 to -0.56) | <0.001 |
| Prior PCI |  |  |
| No | — |  |
| Yes | -0.65 (-0.68 to -0.62) | <0.001 |
| Charlson comorbidity index | 0.26 (0.24 to 0.27) | <0.001 |
| Atrial fibrillation |  |  |
| No | — |  |
| Yes | 0.67 (0.63 to 0.71) | <0.001 |
| Cerebrovascular disease |  |  |
| No | — |  |
| Yes | 0.80 (0.74 to 0.87) | <0.001 |
| Heart failure |  |  |
| No | — |  |
| Yes | 0.57 (0.53 to 0.60) | <0.001 |
| Peripheral vascular disease |  |  |
| No | — |  |
| Yes | -0.03 (-0.08 to 0.02) | 0.21 |
| Dementia |  |  |
| No | — |  |
| Yes | 0.52 (0.45 to 0.60) | <0.001 |
| Tobbacco use disorder |  |  |
| No | — |  |
| Yes | -0.37 (-0.51 to -0.23) | <0.001 |
| COPD |  |  |
| No | — |  |
| Yes | -0.20 (-0.23 to -0.16) | <0.001 |
| Valvular heart disease |  |  |
| No | — |  |
| Yes | 0.39 (0.34 to 0.44) | <0.001 |
| Liver disease |  |  |
| No | — |  |
| Yes | 0.62 (0.54 to 0.71) | <0.001 |
| Diabetes mellitus |  |  |
| No | — |  |
| Yes | -0.06 (-0.10 to -0.03) | <0.001 |
| Hypertension |  |  |
| No | — |  |
| Yes | -0.26 (-0.32 to -0.20) | <0.001 |
| Chronic kidney disease |  |  |
| No | — |  |
| Yes | 0.01 (-0.03 to 0.06) | 0.56 |
| Dialysis dependence |  |  |
| No | — |  |
| Yes | 0.18 (0.10 to 0.26) | <0.001 |
| Anemia |  |  |
| No | — |  |
| Yes | 0.86 (0.79 to 0.93) | <0.001 |
| Hyperlipidemia |  |  |
| No | — |  |
| Yes | -0.56 (-0.60 to -0.52) | <0.001 |
| Cancer |  |  |
| No | — |  |
| Yes | 0.48 (0.41 to 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 to 2,675) | 0.15 |
| Class II obesity (BMI 35.0-39.9kg/m²) | -2,980 (-4,514 to -1,446) | <0.001 |
| Class III obesity (BMI ≥40.0kg/m²) | -5,347 (-6,983 to -3,711) | <0.001 |
| Overweight (BMI 25.0-29.9kg/m²) | 6,135 (4,555 to 7,715) | <0.001 |
| Underweight (BMI ≤19.9kg/m²) | -1,673 (-3,228 to -118) | 0.035 |
| Age, y | -516 (-553 to -478) | <0.001 |
| Sex |  |  |
| Female | — |  |
| Male | 8,599 (8,024 to 9,174) | <0.001 |
| Race |  |  |
| White | — |  |
| Asian or Pacific Islander | 34,990 (30,054 to 39,926) | <0.001 |
| Black | -2,601 (-4,016 to -1,185) | <0.001 |
| Hispanic | 24,877 (22,319 to 27,435) | <0.001 |
| Native American | -8,959 (-13,041 to -4,877) | <0.001 |
| Other | 24,508 (19,403 to 29,613) | <0.001 |
| Prior CABG |  |  |
| No | — |  |
| Yes | -18,115 (-18,935 to -17,296) | <0.001 |
| Prior MI |  |  |
| No | — |  |
| Yes | -12,112 (-12,818 to -11,405) | <0.001 |
| Prior PCI |  |  |
| No | — |  |
| Yes | -12,635 (-13,286 to -11,984) | <0.001 |
| Charlson comorbidity index | 2,795 (2,553 to 3,036) | <0.001 |
| Atrial fibrillation |  |  |
| No | — |  |
| Yes | 8,735 (7,954 to 9,517) | <0.001 |
| Cerebrovascular disease |  |  |
| No | — |  |
| Yes | 10,430 (9,291 to 11,570) | <0.001 |
| Heart failure |  |  |
| No | — |  |
| Yes | 3,125 (2,418 to 3,833) | <0.001 |
| Peripheral vascular disease |  |  |
| No | — |  |
| Yes | 3,813 (2,869 to 4,757) | <0.001 |
| Dementia |  |  |
| No | — |  |
| Yes | -13,873 (-14,854 to -12,891) | <0.001 |
| Tobbacco use disorder |  |  |
| No | — |  |
| Yes | -3,699 (-6,647 to -752) | 0.014 |
| COPD |  |  |
| No | — |  |
| Yes | -10,484 (-11,193 to -9,776) | <0.001 |
| Valvular heart disease |  |  |
| No | — |  |
| Yes | 21,319 (20,054 to 22,583) | <0.001 |
| Liver disease |  |  |
| No | — |  |
| Yes | 8,311 (6,659 to 9,963) | <0.001 |
| Diabetes mellitus |  |  |
| No | — |  |
| Yes | -3,788 (-4,455 to -3,122) | <0.001 |
| Hypertension |  |  |
| No | — |  |
| Yes | -3,781 (-4,816 to -2,746) | <0.001 |
| Chronic kidney disease |  |  |
| No | — |  |
| Yes | -8,869 (-9,775 to -7,963) | <0.001 |
| Dialysis dependence |  |  |
| No | — |  |
| Yes | 5,623 (4,222 to 7,024) | <0.001 |
| Anemia |  |  |
| No | — |  |
| Yes | 412 (-706 to 1,531) | 0.47 |
| Hyperlipidemia |  |  |
| No | — |  |
| Yes | 791 (-4.4 to 1,586) | 0.051 |
| Cancer |  |  |
| No | — |  |
| Yes | 4,016 (2,684 to 5,349) | <0.001 |
| 1CI = Confidence Interval | | |