Body Mass Index and Survival After In-Hospital Cardiac Arrest

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Background—The quality and effectiveness of resuscitation processes may be influenced by the patient’s body mass index (BMI); however, the relationship between BMI and survival after in-hospital cardiac arrest has not been previously studied.

Methods and Results—We evaluated 21 237 adult patients with an in-hospital cardiac arrest within the National Registry for Cardiopulmonary Resuscitation (NRCPR). We examined the association between BMI (classified as underweight [\(<18.5 \text{ kg/m}^2\)], normal [18.5 to 24.9 \text{ kg/m}^2\]), overweight [25.0 to 29.9 \text{ kg/m}^2\], obese [30.0 to 34.9 \text{ kg/m}^2\], and very obese [\(\geq35.0 \text{ kg/m}^2\)]) and survival to hospital discharge using multivariable logistic regression, after stratifying arrests by rhythm type and adjusting for patient characteristics. Of 4499 patients with ventricular fibrillation or pulseless ventricular tachycardia as initial rhythm, 1825 (40.6\%) survived to discharge. After multivariable adjustment, compared with overweight patients, underweight (odds ratio [OR], 0.59; 95\% confidence interval [CI], 0.41 to 0.84; \(P=0.003\)), normal weight (OR, 0.75; 95\% CI, 0.63 to 0.89; \(P<0.001\)), and very obese (OR, 0.78; 95\% CI, 0.63 to 0.96; \(P=0.02\)) had lower rates of survival, whereas obese patients had similar rates of survival (OR, 0.87; 95\% CI, 0.72 to 1.06; \(P=0.17\)). In contrast, of 16 738 patients with arrests caused by asystole or pulseless electric activity, only 2501 (14.9\%) survived. After multivariable adjustment, all BMI groups had similar rates of survival except underweight patients (OR, 0.67; 95\% CI, 0.54 to 0.82; \(P<0.001\)).

Conclusions—For cardiac arrest caused by shockable rhythms, underweight, normal weight, and very obese patients had lower rates of survival to discharge. In contrast, for cardiac arrest caused by nonshockable rhythms, survival to discharge was similar across BMI groups except for underweight patients. Future studies are needed to clarify the extent to which BMI affects the quality and effectiveness of resuscitation measures. (Circ Cardiovasc Qual Outcomes. 2010;3:00-00.)

Key Words: cardiopulmonary resuscitation • obesity • heart arrest • defibrillation

Although studies have linked body mass index (BMI) to worse outcomes for a wide variety of cardiovascular and noncardiovascular conditions,1–7 the role of BMI in mediating factors related to a high or low BMI could affect the quality of chest compressions, the efficacy of vasoactive drugs, or the safety of defibrillator shocks because none of these measures are standardized to a patient’s BMI or weight. Finally, it is possible that patients at each end of the BMI spectrum are treated less aggressively during the acute resuscitation. If patients with very high or low BMI were found to have lower rates of survival after in-hospital cardiac arrests, this would prompt additional studies to determine whether this was caused by hospital, patient, or physician factors.

To explore this gap in knowledge, we examined the association between BMI and survival for patients with in-hospital cardiac arrests within the National Registry of Cardiopulmonary Resuscitation (NRCPR). We explored dif-
ferences in survival to discharge by BMI group and also examined if differences in acute resuscitation treatment (defibrillation response time, number of shocks, and resuscitation duration) varied by BMI group. The NRCPR, which is a large, multisite quality improvement registry that prospectively collects data on consecutive in-hospital cardiac arrests, provides a unique resource for exploring this question.

WHAT IS KNOWN

- In-hospital cardiac arrest is common and is associated with low rates of survival.

WHAT THE STUDY ADDS

- For in-hospital cardiac arrest, rates of survival to hospital discharge are influenced by a patient’s body mass index.
- For cardiac arrests caused by shockable rhythms (ventricular fibrillation and pulseless ventricular tachycardia), overweight patients had the highest survival, with significantly lower rates of survival in patients who were underweight, normal weight, or very obese.
- In cardiac arrest caused by nonshockable rhythms (asystole and pulseless electric activity), underweight patients had the lowest survival rate.

Methods

Study Design

The design of the NRCPR has been previously described in detail. Briefly, the NRCPR is a large, multisite, prospective registry of in-hospital cardiac arrests sponsored by the American Heart Association and prospectively collects data on cardiac arrests using standardized Utstein definitions. Specially trained research coordinators at participating hospitals abstract data on consecutive patients with an in-hospital cardiac arrest, defined as unresponsiveness, apnea, and the absence of pulse. Patients with prior do-not-resuscitate orders at the time of cardiac arrest (work hours: 8AM to 5 PM; after hours: 5PM to 8 AM or weekend) as covariates, regardless of significance level. Additional candidate variables were selected from the following list after determining a significant univariate association (P<0.10) with survival: (1) clinical comorbidities or conditions present before cardiac arrest (history of myocardial infarction, congestive heart failure, diabetes mellitus; renal, respiratory, hepatic insufficiency; metastatic or hemolitic-malignancy; baseline evidence of motor, cognitive, functional deficits; stroke; sepsis; hypotension; pneumonia; major trauma; requirement for hemodialysis), (2) myocardial infarction or congestive heart failure during the index admission, (3) an admitting cardiac diagnosis, (4) use of invasive therapy (mechanical ventilation, intra-aortic balloon pump, or pulmonary artery catheter) or continuous intravenous vasoactive medications (dopamine, dobutamine, norepinephrine, and phenylephrine) at the time of cardiac arrest, and (5) use of a hospital-wide cardiopulmonary arrest alert or the presence of an organized hospital code team during the resuscitation.

In January 2006, the NRCPR began collection of patient data on height and weight; we therefore limited our analyses to the 34 588 cardiac arrest cases in adult patients ages 18 years or older occurring within NRCPR from January 1, 2006, to December 31, 2007. Of these patients, 21 237 (61.4%) had available data on both height and weight patients who presented with a shockable (VT or VF) or nonshockable (asystole and pulseless electric activity [PEA]) rhythm.

BMI Categories

BMI was determined by the standard formula of weight (in kilograms) divided by the square of the height (in meters) and was classified using the World Health Organization (WHO) classification: underweight (<18.5 kg/m²), normal (18.5 to 24.9 kg/m²), overweight (25.0 to 29.9 kg/m²), obese (30.0 to 34.9 kg/m²), and very obese (≥35.0 kg/m²). Analyses were stratified by whether the first identifiable rhythm in a patient was shockable (pulseless ventricular tachycardia [VT] and ventricular fibrillation [VF]) or nonshockable (asystole and pulseless electric activity [PEA]) rhythm.

Results

We identified 21 237 cardiac arrest cases at 328 hospitals. The mean age for the study population was 66.0±15.6 years, of which 12 409 (58.4%) were male and 13 690 (64.5%) were
Table 1. Baseline Characteristics of Study Sample by Body Mass Index Group

<table>
<thead>
<tr>
<th>Arrest rhythm</th>
<th>BMI, kg/m²</th>
<th>Underweight (n=1437)</th>
<th>Normal (n=6935)</th>
<th>Overweight (n=5919)</th>
<th>Obese (n=3412)</th>
<th>Very Obese (n=3534)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asystole</td>
<td></td>
<td>571 (39.7)</td>
<td>2595 (37.4)</td>
<td>2059 (34.8)</td>
<td>1178 (34.5)</td>
<td>1296 (36.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PEA</td>
<td></td>
<td>645 (44.9)</td>
<td>2971 (42.8)</td>
<td>2532 (42.8)</td>
<td>1417 (41.5)</td>
<td>1474 (41.7)</td>
<td></td>
</tr>
<tr>
<td>VF</td>
<td></td>
<td>116 (8.1)</td>
<td>800 (11.5)</td>
<td>800 (13.5)</td>
<td>486 (14.2)</td>
<td>468 (13.2)</td>
<td></td>
</tr>
<tr>
<td>Pulseless VT</td>
<td></td>
<td>105 (7.3)</td>
<td>569 (8.2)</td>
<td>528 (8.9)</td>
<td>331 (9.7)</td>
<td>296 (8.4)</td>
<td></td>
</tr>
<tr>
<td>Time of day or week for cardiac arrest</td>
<td></td>
<td>64.9 ± 16.7</td>
<td>68.6 ± 16.2</td>
<td>66.9 ± 15.2</td>
<td>64.9 ± 14.4</td>
<td>60.2 ± 14.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male sex</td>
<td></td>
<td>739 (51.4)</td>
<td>4133 (59.6)</td>
<td>3729 (63.0)</td>
<td>2005 (58.8)</td>
<td>1803 (51.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>White, non-Hispanic</td>
<td></td>
<td>833 (58.0)</td>
<td>4448 (64.1)</td>
<td>3875 (65.5)</td>
<td>2298 (67.4)</td>
<td>2236 (63.3)</td>
<td></td>
</tr>
<tr>
<td>Black, non-Hispanic</td>
<td></td>
<td>393 (27.3)</td>
<td>1473 (21.2)</td>
<td>1172 (19.8)</td>
<td>672 (19.7)</td>
<td>847 (24.0)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td></td>
<td>77 (5.4)</td>
<td>408 (5.9)</td>
<td>393 (6.6)</td>
<td>193 (5.7)</td>
<td>198 (5.6)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>134 (9.3)</td>
<td>606 (8.7)</td>
<td>479 (8.1)</td>
<td>249 (7.3)</td>
<td>253 (7.2)</td>
<td></td>
</tr>
<tr>
<td>Hospital arrest location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Intensive care unit</td>
<td></td>
<td>644 (44.8)</td>
<td>3444 (49.7)</td>
<td>2992 (50.6)</td>
<td>1764 (51.7)</td>
<td>1832 (51.8)</td>
<td></td>
</tr>
<tr>
<td>Telemetry unit</td>
<td></td>
<td>252 (17.5)</td>
<td>1227 (17.7)</td>
<td>1008 (17.0)</td>
<td>548 (16.1)</td>
<td>556 (17.5)</td>
<td></td>
</tr>
<tr>
<td>Nonmonitored unit</td>
<td></td>
<td>387 (26.9)</td>
<td>1369 (19.7)</td>
<td>998 (16.9)</td>
<td>585 (17.2)</td>
<td>621 (17.6)</td>
<td></td>
</tr>
<tr>
<td>Procedure suites</td>
<td></td>
<td>63 (4.4)</td>
<td>403 (5.8)</td>
<td>438 (7.4)</td>
<td>249 (7.3)</td>
<td>227 (6.4)</td>
<td></td>
</tr>
<tr>
<td>Emergency room</td>
<td></td>
<td>70 (4.9)</td>
<td>414 (6.0)</td>
<td>399 (1.4)</td>
<td>223 (6.5)</td>
<td>240 (6.8)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>21 (1.5)</td>
<td>78 (1.1)</td>
<td>84 (1.4)</td>
<td>43 (1.3)</td>
<td>58 (1.6)</td>
<td></td>
</tr>
<tr>
<td>Arrest characteristics</td>
<td></td>
<td>1213 (84.4)</td>
<td>5615 (81.0)</td>
<td>4732 (80.0)</td>
<td>2686 (78.7)</td>
<td>2773 (78.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time of day or week for cardiac arrest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week night (5 PM to 8 AM)</td>
<td></td>
<td>914 (63.6)</td>
<td>4290 (61.9)</td>
<td>3603 (60.9)</td>
<td>2083 (61.1)</td>
<td>2156 (61.0)</td>
<td>0.32</td>
</tr>
<tr>
<td>Weekend</td>
<td></td>
<td>411 (28.6)</td>
<td>1874 (27.0)</td>
<td>1566 (26.5)</td>
<td>883 (25.9)</td>
<td>931 (26.3)</td>
<td>0.33</td>
</tr>
<tr>
<td>After hours (nights or weekends)</td>
<td></td>
<td>1058 (73.6)</td>
<td>4986 (71.9)</td>
<td>4179 (70.6)</td>
<td>2443 (71.6)</td>
<td>2517 (71.2)</td>
<td>0.18</td>
</tr>
<tr>
<td>Cardiac admitting diagnosis</td>
<td></td>
<td>1027 (71.5)</td>
<td>4317 (62.3)</td>
<td>3361 (56.8)</td>
<td>1927 (56.5)</td>
<td>2094 (59.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prearrest characteristics</td>
<td></td>
<td>209 (14.9)</td>
<td>1179 (17.0)</td>
<td>1084 (18.0)</td>
<td>577 (16.9)</td>
<td>734 (20.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CHF during admission</td>
<td></td>
<td>216 (15.0)</td>
<td>1218 (17.6)</td>
<td>5919 (18.1)</td>
<td>3412 (18.9)</td>
<td>782 (22.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prior CHF before admission</td>
<td></td>
<td>157 (10.9)</td>
<td>1031 (14.9)</td>
<td>1088 (18.4)</td>
<td>603 (17.7)</td>
<td>541 (15.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MI during admission</td>
<td></td>
<td>162 (11.3)</td>
<td>997 (14.4)</td>
<td>917 (15.5)</td>
<td>546 (16.0)</td>
<td>516 (14.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prior MI before admission</td>
<td></td>
<td>375 (26.1)</td>
<td>1809 (26.1)</td>
<td>1573 (28.2)</td>
<td>934 (27.4)</td>
<td>897 (25.4)</td>
<td>0.41</td>
</tr>
<tr>
<td>Hypotension</td>
<td></td>
<td>223 (15.5)</td>
<td>951 (13.7)</td>
<td>685 (11.6)</td>
<td>375 (11.0)</td>
<td>286 (8.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Metastatic or hematologic malignancy</td>
<td></td>
<td>606 (42.2)</td>
<td>2640 (38.1)</td>
<td>2239 (37.8)</td>
<td>1323 (38.9)</td>
<td>1502 (42.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Respiratory insufficiency</td>
<td></td>
<td>401 (27.9)</td>
<td>2089 (30.1)</td>
<td>1886 (31.9)</td>
<td>1088 (31.9)</td>
<td>1224 (34.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td></td>
<td>50 (3.5)</td>
<td>255 (3.7)</td>
<td>239 (4.0)</td>
<td>158 (4.6)</td>
<td>152 (4.3)</td>
<td>0.12</td>
</tr>
<tr>
<td>Renal failure requiring hemodialysis</td>
<td></td>
<td>89 (6.2)</td>
<td>494 (7.1)</td>
<td>400 (6.8)</td>
<td>247 (7.2)</td>
<td>256 (7.2)</td>
<td>0.59</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td></td>
<td>261 (18.2)</td>
<td>1509 (21.8)</td>
<td>1636 (26.8)</td>
<td>1181 (34.6)</td>
<td>1522 (43.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Baseline CNS depression</td>
<td></td>
<td>261 (15.0)</td>
<td>966 (13.9)</td>
<td>686 (11.6)</td>
<td>382 (11.2)</td>
<td>374 (10.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Acute stroke</td>
<td></td>
<td>53 (3.7)</td>
<td>289 (4.2)</td>
<td>244 (4.1)</td>
<td>121 (3.6)</td>
<td>98 (2.8)</td>
<td>0.005</td>
</tr>
<tr>
<td>Pneumonia</td>
<td></td>
<td>258 (18.0)</td>
<td>1001 (14.4)</td>
<td>687 (11.6)</td>
<td>367 (10.8)</td>
<td>380 (10.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sepsis</td>
<td></td>
<td>268 (18.7)</td>
<td>1162 (16.8)</td>
<td>877 (14.8)</td>
<td>555 (16.3)</td>
<td>592 (16.8)</td>
<td>0.002</td>
</tr>
<tr>
<td>Major trauma</td>
<td></td>
<td>37 (2.6)</td>
<td>207 (3.0)</td>
<td>213 (3.6)</td>
<td>104 (3.1)</td>
<td>113 (3.2)</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Values are expressed as n (%) or mean ± SD.
CHF indicates congestive heart failure; CNS, central nervous system; and MI, myocardial infarction.
non-Hispanic white. Nearly 4 in 5 patients presented with a nonshockable cardiac arrest rhythm, and half the cohort was in an ICU at the time of cardiac arrest. Most patients had either normal BMI (6935 patients; 32.7%) or were overweight (5919 patients; 27.9%); however, 1437 patients (6.8%) were classified as underweight, 3412 (16.1%) were normal weight, and 3534 (16.6%) were very obese.

Baseline differences in patient characteristics across the 5 categories of BMI are displayed in Table 1. In general, most factors were similar across the BMI groups. However, patients who were very obese were younger; more likely to have had congestive heart failure in the past or during the index admission, and more likely to have renal insufficiency and to be on mechanical ventilation at the time of cardiac arrest. Patients who were underweight were less likely to be of non-Hispanic white race; less likely to have had myocardial infarction in the past or during the index admission; more likely to have asystole as their first identified rhythm; more likely to have a preexisting metastatic or hematologic malignancy, pneumonia, or sepsis during the index admission; and more likely to be unmonitored at the time of cardiac arrest.

Figure 1. Relationship of BMI with survival to discharge for cardiac arrests due to ventricular fibrillation or pulseless ventricular tachycardia.

Table 2. Summary of Survival Outcomes by Body Mass Index Group, Stratified by Cardiac Arrest Rhythm

<table>
<thead>
<tr>
<th>BMI, kg/m²</th>
<th>Underweight</th>
<th>Normal 18.5 to 24.9</th>
<th>Overweight 25.0 to 29.9</th>
<th>Obese 30.0 to 34.9</th>
<th>Very Obese ≥35.0</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF and pulseless VT, n</td>
<td>221</td>
<td>1369</td>
<td>1328</td>
<td>817</td>
<td>764</td>
<td></td>
</tr>
<tr>
<td>Survived to discharge, n (%)</td>
<td>61 (27.6)</td>
<td>500 (36.5)</td>
<td>605 (45.6)</td>
<td>357 (43.7)</td>
<td>302 (39.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ROSC, n (%)</td>
<td>131 (59.3)</td>
<td>934 (68.2)</td>
<td>975 (73.4)</td>
<td>568 (69.5)</td>
<td>518 (67.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Postresuscitation survival,* %</td>
<td>46.6</td>
<td>53.5</td>
<td>62.1</td>
<td>62.9</td>
<td>58.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Asystole and PEA, n</td>
<td>1216</td>
<td>5566</td>
<td>4591</td>
<td>2595</td>
<td>2770</td>
<td></td>
</tr>
<tr>
<td>Survived to discharge, n (%)</td>
<td>125 (10.3)</td>
<td>769 (13.8)</td>
<td>700 (15.3)</td>
<td>436 (16.8)</td>
<td>471 (17.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ROSC, n (%)</td>
<td>604 (49.7)</td>
<td>2870 (51.6)</td>
<td>2348 (51.1)</td>
<td>1396 (53.8)</td>
<td>1484 (53.6)</td>
<td>0.03</td>
</tr>
<tr>
<td>Postresuscitation survival,* %</td>
<td>20.7</td>
<td>26.8</td>
<td>29.8</td>
<td>31.2</td>
<td>31.7</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Calculated as the number of patients surviving to discharge divided by the number achieving ROSC.

The highest rate of survival to discharge in overweight patients (45.6% [605/1328]) and lower survival rates in underweight (27.6% [61/221]), normal weight (36.5% [500/1369]), obese (43.7% [357/817]), and very obese (39.5% [302/764]) patients. Although ROSC was achieved in 3126 (69.4%) patients and 1825 (58.4%) of these successfully resuscitated patients survived to discharge, a similar pattern of higher crude rates of ROSC and postresuscitation survival was seen in overweight patients (Table 2).

Despite differences in crude survival, rates of delayed defibrillation response times were similar across BMI groups (Table 3). However, among those who died during the initial resuscitation (ie, no ROSC), there were differences in the total number of defibrillations administered and the total duration of the resuscitation event by BMI group. This was especially evident among underweight patients. In contrast, among those achieving ROSC, the duration of resuscitation was similar among the BMI groups.

After adjustment for patient factors and rates of delayed defibrillation time, compared with overweight patients, underweight (adjusted odds ratio [OR], 0.59; 95% CI, 0.41 to 0.84; P=0.003), normal weight (adjusted OR, 0.75; 95% CI, 0.63 to 0.89; P<0.001), and very obese patients (adjusted OR, 0.78; 95% CI, 0.63 to 0.96; P=0.02) were less likely to survive to hospital discharge, whereas overall survival was similar for obese patients (adjusted OR, 0.87; 95% CI, 0.72 to 1.06; P=0.17). These differences in overall survival by BMI group were attributable to both differences in ROSC and postresuscitation survival (Table 4).

Nonshockable Rhythms

Of 16 738 patients with cardiac arrest caused by asystole or PEA, 2501 (14.9%) survived to hospital discharge. The relationship between BMI and survival to discharge for asystole and PEA arrests is depicted in Figure 2. Underweight patients had lower crude rates of survival to hospital discharge than the other BMI groups: underweight, 10.3% (125/1216); normal weight, 13.8% (769/5566); overweight, 15.3% (700/4591); obese, 16.8% (436/2595); and very obese, 17.0% (471/2770) (P<0.001 for differences across groups). Although ROSC was achieved in 8702 (52.0%) patients and 2501 (28.7%) of these successfully resuscitated patients survived to discharge, a similar pattern of lower crude rates of...
ROSC and postresuscitation survival was seen in underweight patients (Table 2). Finally, underweight patients were resuscitated for shorter periods, both among patients who survived with ROSC and those who died without ROSC during the initial resuscitation (Table 3).

After adjustment for patient factors, compared with overweight patients, underweight patients (adjusted OR, 0.67; 95% CI, 0.54 to 0.82; \( P < 0.001 \)) were less likely to survive to hospital discharge, whereas overall survival was similar for normal weight (adjusted OR, 0.94; 95% CI, 0.84 to 1.06; \( P = 0.30 \)), obese (adjusted OR, 1.08; 95% CI, 0.95 to 1.24; \( P = 0.24 \)), and very obese patients (adjusted OR, 0.97; 95% CI, 0.85 to 1.11; \( P = 0.68 \)). Because there were no differences in adjusted rates of ROSC across the BMI groups, lower overall survival to hospital discharge in underweight patients was due to lower postresuscitation survival (Table 5).

### Discussion

We found that survival outcomes after in-hospital cardiac arrest differed by BMI. For cardiac arrest caused by VF or VT, patients who were underweight, normal weight, and very obese had lower survival. Lower overall survival in these BMI groups was due to lower rates of both ROSC and postresuscitation survival. Although there were no differences in defibrillation response times by BMI group, underweight patients were treated for shorter durations before physician termination of resuscitation. In contrast, for cardiac arrest caused by asystole and PEA, rates of survival to discharge were similar across BMI groups, except for underweight patients. The higher mortality rate seen in underweight patients was attributable to their overall lower postresuscitation survival, as rates of acute resuscitation were similar. Collectively, these findings suggest that BMI is associated with differences in survival after in-hospital cardiac arrest, and this relationship differs by cardiac arrest rhythm.

Although an inverse U- or J-shaped relationship between BMI and survival has been described in other disease states,4–6,18–21 the relationship between BMI and survival outcomes for in-hospital cardiac arrests has not previously been explored. Although 2 small studies have evaluated the relationship between BMI and out-of-hospital cardiac arrests, these studies had limited power (combined sample size of fewer than 300 patients), were retrospective, involved single centers, and may not be generalizable to in-hospital cardiac arrests.22,23 In the NRCPR registry, we found that BMI was independently

### Table 3. Defibrillation Performance and Duration of Resuscitation by Body Mass Index Group

<table>
<thead>
<tr>
<th>BMI, kg/m²</th>
<th>Underweight</th>
<th>Normal</th>
<th>Overweight</th>
<th>Obese</th>
<th>Very Obese</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF and pulseless VT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defibrillation time &gt;2 min, n (%)</td>
<td>36 (16.3)</td>
<td>206 (15.1)</td>
<td>182 (13.7)</td>
<td>107 (13.1)</td>
<td>7 (15.5)</td>
<td>0.41</td>
</tr>
<tr>
<td>Shock No., median (IQR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROSC</td>
<td>1 (1 to 3)</td>
<td>1 (1 to 3)</td>
<td>2 (1 to 3)</td>
<td>2 (1 to 3)</td>
<td>2 (1 to 3)</td>
<td>0.10</td>
</tr>
<tr>
<td>No ROSC</td>
<td>3 (2 to 5)</td>
<td>4 (2 to 6)</td>
<td>4 (2 to 6)</td>
<td>4 (2 to 7)</td>
<td>4 (2 to 6)</td>
<td>0.03</td>
</tr>
<tr>
<td>Code duration, median (IQR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROSC</td>
<td>7 (4 to 15)</td>
<td>8 (3 to 16)</td>
<td>7 (3 to 17)</td>
<td>8 (3 to 19)</td>
<td>8 (3 to 19)</td>
<td>0.84</td>
</tr>
<tr>
<td>No ROSC</td>
<td>19 (12 to 30)</td>
<td>23 (15 to 33)</td>
<td>25 (16 to 34)</td>
<td>23 (16 to 35)</td>
<td>27 (18 to 38)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Asystole and PEA, median (IQR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROSC</td>
<td>10 (6 to 18)</td>
<td>10 (5 to 18)</td>
<td>10 (5 to 20)</td>
<td>10 (5 to 20)</td>
<td>11 (6 to 21)</td>
<td>0.01</td>
</tr>
<tr>
<td>No ROSC</td>
<td>18 (11 to 26)</td>
<td>20 (13 to 30)</td>
<td>22 (14 to 32)</td>
<td>23 (15 to 33)</td>
<td>24 (15 to 34)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

IQR indicates interquartile range.

### Table 4. Adjusted Estimates of the Association of Body Mass Index With Survival Outcomes in Patients With VF or VT Arrest

<table>
<thead>
<tr>
<th>BMI, kg/m²</th>
<th>Survival to Discharge</th>
<th>ROSC</th>
<th>Postarrest Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>(&lt;18.5)</td>
<td>0.58 (0.41, 0.83)</td>
<td>0.003</td>
<td>0.65 (0.48, 0.87)</td>
</tr>
<tr>
<td>18.5 to 24.9</td>
<td>0.75 (0.63, 0.89)</td>
<td>&lt;0.001</td>
<td>0.84 (0.70, 1.00)</td>
</tr>
<tr>
<td>25.0 to 29.9</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>30.0 to 34.9</td>
<td>0.87 (0.72, 1.06)</td>
<td>0.17</td>
<td>0.80 (0.65, 0.98)</td>
</tr>
<tr>
<td>(\geq 35.0)</td>
<td>0.78 (0.63, 0.96)</td>
<td>0.02</td>
<td>0.80 (0.65, 0.99)</td>
</tr>
</tbody>
</table>

Models include demographic characteristics, initial cardiac arrest rhythm (VF versus VT or PEA versus asystole), cardiac arrest location, and time of cardiac arrest, regardless of significance level. In addition, other variables with a univariate association (\( P < 0.10 \)) with each survival outcome are included in final models. These include prearrest characteristics (ie, clinical comorbidities), arrest characteristics, and interventions in place before cardiac arrest, as outlined in Table 1.
associated with survival despite adjustment for a number of important patient factors. Given the large sample size and detailed data collection in this multisite registry, we were able to (1) examine the relationship of BMI separately for cardiac arrests that were shockable and nonshockable, (2) determine whether observed differences in overall survival were attributable to differences in ROSC or postresuscitation survival, and (3) evaluate whether observed differences were associated with several key predictors of survival, such as delays in defibrillation time and duration of resuscitation.

The association of very low BMI and survival for shockable and nonshockable cardiac arrests may reflect residual confounding. Although we were able to adjust for whether patients had a significant malignancy (hematologic or metastatic) and hepatic insufficiency, we did not have sufficiently detailed information on these 2 variables to adjust for specific types of malignancies, the extent of their metastases, malnutrition, and end-stage liver disease—all of which may be more prevalent in underweight patients and are linked to lower in-hospital survival. However, we did find that among patients who did not survive the initial resuscitation (ie, no ROSC), underweight patients were treated for 4 to 5 minutes shorter in both types of cardiac arrests. Moreover, underweight patients received fewer defibrillation shocks than patients in other BMI groups. Yet, it is unclear whether longer periods of resuscitation beyond the median of 19 minutes or additional defibrillation attempts beyond the median of 3 shocks in underweight patients would have meaningfully improved survival. Notably, among patients surviving the initial resuscitation, the period of time without spontaneous circulation was similar across BMI groups for patients with VF or VT arrests and shorter for underweight patients with asystole or PEA arrests. This suggests that longer times without spontaneous circulation before achieving ROSC were not responsible for the lower rates of postresuscitation survival in underweight patients for both types of cardiac arrests.

Nonetheless, the association of underweight patients and poor survival after in-hospital cardiac arrest may have important clinical implications. Malnutrition or poor functional status may explain lower survival from cardiac arrest in underweight patients. Moreover, the overall frailty of patients with low BMI, compared with other BMI categories, may account for their lower survival after cardiac arrest. These unmeasured aspects of patient health status in our study may explain a physician’s propensity to conduct a shorter resuscitation or administer fewer defibrillations in underweight patients. Alternatively, our findings may reflect a pattern of undertreatment of underweight patients with cardiac arrest. This association deserves further study in cardiac arrest registries that are able to capture clinical information particular to patients with low BMI.

In contrast, there was an association between very high BMI and lower survival for VT and VF arrest but not for asystole and PEA arrest. Because a key difference in the treatment of VT and VF arrests is the use of defibrillation, this survival finding raises several important implications. First, it suggests that the current use of fixed-dose defibrillation therapy (200 J, 300 J, or 360 J) in adult patients with VT or VF arrest may be inadequate in patients with very high BMI. In a prior study, higher thoracic impedance was associated with decreased defibrillation success, and BMI has previously been shown to correlate with thoracic impedance.

Although these studies are preliminary, they raise questions about whether defibrillation therapy in Advanced Cardiac Life Support protocols should be standardized to a patient’s BMI. Indeed, we found in this study a trend for a higher number of required defibrillations to achieve ROSC among overweight, obese, and very obese patients with a VF or VT arrest. Given that defibrillation energy protocols for children within Pediatric Acute Life Support (PALS) are weight-
based, additional animal and human studies on the optimal defibrillation energy by BMI may be warranted.

There may be other reasons why a very high BMI may be associated with worse survival outcomes after cardiac arrest. Longer times to intubation and delays in the administration of vasoactive medications in morbidly obese patients may affect the quality of resuscitation measures. Compression depth may also vary by patient BMI, which would affect the delivery of effective cardiopulmonary support during resuscitation. Preliminary studies of compression depth and the duration of interrupted cardiopulmonary resuscitation, however, do not seem to suggest that these are of lower quality in very obese patients. Moreover, these logistical and resuscitation issues, while plausible, would not account for the differential association of very high BMI and survival for shockable and nonshockable cardiac arrests.

Limitations

Our findings should be interpreted in the context of the following limitations. First, data on height and weight were not collected within the NRCPR until 2006, so our study includes cardiac arrests from 2006. Moreover, 38% of patients did not have assessments of height and weight and were excluded. However, patients with missing data on height and weight were not found to be meaningfully different in patient characteristics than patients included in this cohort. Second, although the NRCPR registry is the largest prospective registry of in-hospital cardiac arrests with detailed information on many patient factors, we did not have complete information on several resuscitation factors to more fully account for the relationship between BMI and survival, such as cardiopulmonary compression quality (depth and frequency of compressions, proportion of interrupted resuscitation time), defibrillation and medication doses, and times to repeat defibrillation, vasoactive medications, and intubation. Similarly, we did not have assessments of patients’ nutritional and functional status or the severity of preexisting comorbidities to further account for the relationship between low BMI and survival. Third, our sample was drawn from a minority of US hospitals (~15% of large US hospitals) that participated in a quality improvement resuscitation registry. However, we have no reason to believe that hospital participation within NRCPR would affect the relationship of BMI and survival. Although we observed a relationship between BMI and survival, this relationship should not be interpreted as causal.

Conclusion

In this large national registry of in-hospital cardiac arrests, we found that survival to discharge varied substantially by BMI. For cardiac arrest caused by VT or VF, underweight, normal weight, and very obese patients had lower overall survival despite adjustment for a number of patient factors and defibrillation response time. For asystole and PEA arrests, underweight patients had lower overall survival. Future studies are needed to determine whether the relationship between low BMI and survival is due to unmeasured differences in patient severity of illness and comorbidity and the impact of very high BMI on defibrillation effectiveness and resuscitation quality.

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Disclosures

None.

References


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Supplemental Material

Appendix. Comparison of Patient Characteristics Between Patients With and Without Data on Body Mass Index.

<table>
<thead>
<tr>
<th>PATIENT CHARACTERISTICS</th>
<th>Included Patients (n=21,237)</th>
<th>Excluded Patients (n=13,351)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARREST RHYTHM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asystole</td>
<td>36.3%</td>
<td>35.9%</td>
</tr>
<tr>
<td>Pulseless Electrical Activity</td>
<td>42.6%</td>
<td>43.8%</td>
</tr>
<tr>
<td>Ventricular fibrillation</td>
<td>12.6%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Pulseless Ventricular Tachycardia</td>
<td>8.6%</td>
<td>8.2%</td>
</tr>
<tr>
<td>Age, years ± SD</td>
<td>66.0 ± 15.6</td>
<td>65.8 ± 16.3</td>
</tr>
<tr>
<td>Male sex</td>
<td>58.4%</td>
<td>57.8%</td>
</tr>
<tr>
<td>Nonwhite Race</td>
<td>35.5%</td>
<td>36.6%</td>
</tr>
<tr>
<td>HOSPITAL ARREST LOCATION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensive care unit</td>
<td>50.3%</td>
<td>45.8%</td>
</tr>
<tr>
<td>Telemetry unit</td>
<td>16.9%</td>
<td>15.2%</td>
</tr>
<tr>
<td>Nonmonitored unit</td>
<td>18.7%</td>
<td>18.4%</td>
</tr>
<tr>
<td>Procedure Suites</td>
<td>6.5%</td>
<td>6.9%</td>
</tr>
<tr>
<td>Emergency Room</td>
<td>6.3%</td>
<td>10.5%</td>
</tr>
<tr>
<td>Other</td>
<td>1.3%</td>
<td>1.2%</td>
</tr>
<tr>
<td>ARREST CHARACTERISTICS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital-wide code blue</td>
<td>80.1%</td>
<td>78.7%</td>
</tr>
<tr>
<td>Time of day or week for cardiac arrest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weeknight (5pm to 8am)</td>
<td>61.4%</td>
<td>62.3%</td>
</tr>
<tr>
<td>Weekend</td>
<td>26.7%</td>
<td>27.4%</td>
</tr>
<tr>
<td>Afterhours (Nights or Weekends)</td>
<td>71.5%</td>
<td>72.5%</td>
</tr>
<tr>
<td>Cardiac Admitting Diagnosis</td>
<td>40.1%</td>
<td>39.6%</td>
</tr>
<tr>
<td>PRE-ARREST CHARACTERISTICS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHF during admission</td>
<td>17.7%</td>
<td>16.8%</td>
</tr>
<tr>
<td>Prior CHF before admission</td>
<td>18.5%</td>
<td>17.6%</td>
</tr>
<tr>
<td>MI during admission</td>
<td>16.1%</td>
<td>15.4%</td>
</tr>
<tr>
<td>Prior MI before admission</td>
<td>14.8%</td>
<td>13.2%</td>
</tr>
<tr>
<td>Hypotension</td>
<td>26.3%</td>
<td>24.4%</td>
</tr>
<tr>
<td>Metastatic or Hematologic Malignancy</td>
<td>11.9%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Respiratory insufficiency</td>
<td>39.1%</td>
<td>37.7%</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>31.5%</td>
<td>28.8%</td>
</tr>
<tr>
<td>Renal failure requiring hemodialysis</td>
<td>4.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Hepatic insufficiency</td>
<td>7.0%</td>
<td>6.2%</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>28.8%</td>
<td>26.2%</td>
</tr>
<tr>
<td>Baseline CNS depression</td>
<td>12.4%</td>
<td>11.3%</td>
</tr>
<tr>
<td>Acute stroke</td>
<td>3.8%</td>
<td>3.4%</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>12.7%</td>
<td>10.8%</td>
</tr>
<tr>
<td>Sepsis</td>
<td>16.3%</td>
<td>17.4%</td>
</tr>
<tr>
<td>Major trauma</td>
<td>3.2%</td>
<td>4.3%</td>
</tr>
<tr>
<td>INTERVENTIONS AT TIME OF ARREST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical ventilation</td>
<td>33.2%</td>
<td>34.8%</td>
</tr>
<tr>
<td>Intra-aortic balloon pump</td>
<td>1.7%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Pulmonary artery catheter</td>
<td>3.7%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Intravenous Dopamine</td>
<td>12.3%</td>
<td>12.7%</td>
</tr>
<tr>
<td>Intravenous Dobutamine</td>
<td>3.6%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Intravenous Norepinephrine</td>
<td>13.5%</td>
<td>12.6%</td>
</tr>
<tr>
<td>Intravenous Phenylephrine</td>
<td>5.2%</td>
<td>4.9%</td>
</tr>
</tbody>
</table>