Childhood Obesity and Survival After In-Hospital Pediatric Cardiopulmonary Resuscitation

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KEY WORDS

cardiopulmonary resuscitation, obesity, pediatrics, survival, cardiac arrest, registry

ABBREVIATIONS

CPR—cardiopulmonary resuscitation
NRCPR—National Registry of Cardiopulmonary Resuscitation
IQR—interquartile range
OR—odds ratio
CI—confidence interval

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WHAT'S KNOWN ON THIS SUBJECT: Childhood obesity is a public health crisis of epidemic proportions. CPR and advanced life support for obese children experiencing cardiopulmonary arrest may be complicated by difficulties with CPR quality and drug dosages.

WHAT THIS STUDY ADDS: Childhood obesity is associated with a lower rate of survival to hospital discharge after in-hospital, pediatric CPR.

abstract

FREE

OBJECTIVE: We hypothesized that childhood obesity would be associated with decreased likelihood of survival to hospital discharge after in-hospital, pediatric cardiopulmonary resuscitation (CPR).

METHODS: We reviewed 1477 consecutive, pediatric, CPR index events (defined as the first CPR event during a hospitalization in that facility for a patient <18 years of age) reported to the American Heart Association National Registry of Cardiopulmonary Resuscitation between January 2000 and July 2004. The primary outcome was survival to hospital discharge. A total of 1268 index subjects (86%) with complete registry data were included for analysis. Children were classified as obese (≥95th weight-for-length percentile if <2 years of age or ≥95th BMI-for-age percentile if ≥2 years of age) or underweight (<5th weight-for-length percentile if <2 years of age or <5th BMI-for-age percentile if ≥2 years of age), with adjustment for gender.

RESULTS: Obesity was noted for 213 (17%) of 1268 subjects and underweight for 571 (45%) of 1268 subjects. Obesity was more likely to be associated with male gender, noncardiac medical illness, and cancer and inversely associated with heart failure. Underweight was more likely to be associated with male gender, cardiac surgery, and prematurity and inversely associated with age and cancer. Self-reported, process-of-care, CPR quality was generally worse for obese children. With adjustment for important potential confounding factors, obesity was independently associated with worse odds of event survival (adjusted odds ratio: 0.58 [95% confidence interval: 0.35–0.76]) and survival to hospital discharge (adjusted odds ratio: 0.62 [95% confidence interval: 0.38–0.93]) after in-hospital, pediatric CPR. Underweight was not associated with worse outcomes.

CONCLUSIONS: Childhood obesity is associated with a lower rate of survival to hospital discharge after in-hospital, pediatric CPR. *Pediatrics* 2010;125:e481–e488

Childhood obesity is a public health crisis of epidemic proportions throughout the world, with an estimated prevalence of 10% to 25%.[1–3] Cardiopulmonary resuscitation (CPR) and advanced life support for obese children experiencing cardiopulmonary arrest may be complicated by difficulties with the quality of CPR and problems with drug dosages. Specifically, the obese body habitus may pose distinct difficulties with airway management and effective chest compressions. In addition, pediatric advanced life support medications typically are administered on the basis of body weight but plasma concentrations of highly water-soluble medications may be substantially higher and potentially toxic in obese children when medications are dosed according to weight. Conversely, lipid-soluble medications may not reach adequate concentrations in obese children.[4]

The relationship of childhood obesity to survival after CPR is not well known. We evaluated the association between obesity and outcomes among children after in-hospital CPR in the American Heart Association National Registry of Cardiopulmonary Resuscitation (NRCPR), a large, multicenter registry of in-hospital cardiac arrests.[5] We hypothesized that obese children would be less likely to survive to hospital discharge after in-hospital, pediatric CPR, compared with nonobese children.

METHODS

Study Design and Population

The NRCPR is a prospective, multisite, in-hospital resuscitation registry sponsored by the American Heart Association, with voluntary, fee-based membership. At each participating institution, certified research coordinators abstract information about each CPR event from hospital medical records. The resulting database contains precisely defined variables derived from the Utstein-style data-reporting guidelines for cardiac arrest.[6,7] Case-study methods are used to evaluate data abstraction, the accuracy of entries, and compliance with operational definitions. The 6 major categories of variables are facility data, patient demographic data, preevent data, event data, outcome data, and quality-improvement data. The data are submitted securely, in compliance with Healthcare Information Portability and Accountability Act regulations, to a central data repository (Digital Innovation, Forest Hill, MD). The American Heart Association oversees the entire process of data collection, analysis, and reporting, through its national center staff, scientific advisory board, and executive database steering committee. The primary purpose of the NRCPR is quality improvement through monitoring of process-of-care standards, compliance, and benchmarking against national and peer standards. This study was approved by the institutional review board at the Children's Hospital of Philadelphia.

Data from 167 participating NRCPR hospitals that recorded cardiopulmonary arrests among patients $<$18 years of age and provided $>$6 months of data from January 1, 2000, through July 31, 2004, were analyzed. All patients $<$18 years of age who were treated with CPR at participating institutions were eligible for this study. According to NRCPR operational definitions, a CPR event was any event treated with chest compressions when a unit-wide or hospital-wide emergency response was activated, with the exclusion of events that commenced out of hospital and events involving newborn infants in the delivery suite. An index event was defined as the patient's first CPR event during the hospitalization. Only index events were eligible for inclusion in the study. Arrests among patients with "do not attempt resuscitation" orders and arrests that were resolved through implantable cardioverter-defibrillator shocks also were excluded.

The NRCPR does not collect data on the height or length of subjects. Therefore, BMI values were calculated on the basis of median height-for-age values adjusted for gender, by using World Health Organization Anthro 2.0.4 and Anthroplus 1.0.2 software (World Health Organization, Geneva, Switzerland). BMI-for-age percentiles and weight-for-length percentiles, with corresponding *z* scores, were computed as appropriate.[8,9] Weight-for-length percentiles are a well-established growth standard for children $<$2 years of age,[8] whereas BMI-for-age percentiles are considered accurate to describe growth for children $\geq$2 years of age.[9] Children were classified as obese ($\geq$95th weight-for-length percentile if $<$2 years of age or $\geq$95th BMI-for-age percentile if $\geq$2 years of age) or underweight ($<$5th weight-for-length percentile if $<$2 years of age or $<$5th BMI-for-age percentile if $\geq$2 years of age), with adjustment for gender, on the basis of reference data collected by the World Health Organization.[10]

The prospectively selected, primary outcome measure was survival to hospital discharge.[6,7] Secondary outcome measures included survival of event (defined as return of spontaneous circulation for $>$20 minutes) and survival with favorable neurologic outcome. The neurologic outcome was determined according to the Pediatric Cerebral Performance Category scale, in which category 1 represents a normal neurologic state, 2 mild disability, 3 moderate disability, 4 severe disability, 5 coma or vegetative state, and 6 death.[11,12] Neurologic status before the arrest and at discharge was determined through chart review. A favorable

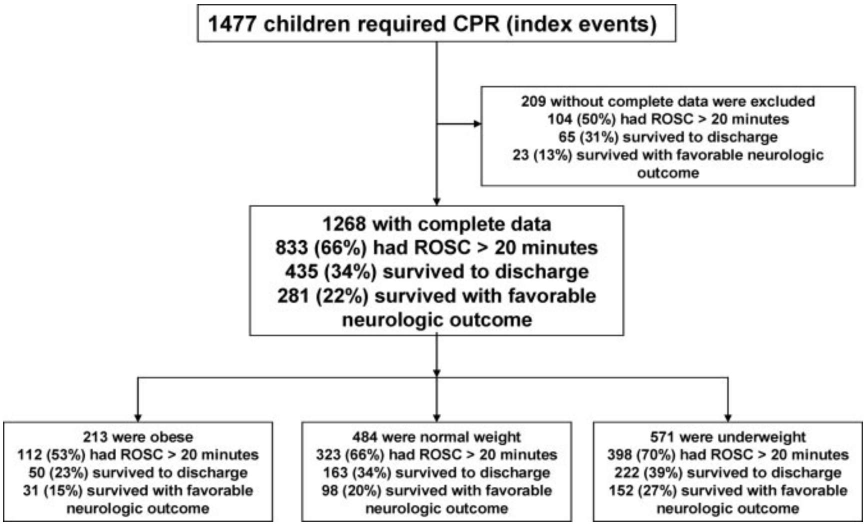

FIGURE 1
Enrollment and outcomes. Underweight indicates <5th weight-for-length percentile (for children <2 years of age) or <5th BMI-for-age percentile (for children ≥2 years of age). Obesity indicates ≥95th weight-for-length percentile (for children <2 years of age) or ≥95th BMI-for-age percentile (for children ≥2 years of age). ROSC indicates return of spontaneous circulation.

neurologic outcome was defined by a Pediatric Cerebral Performance Category score of 1, 2, or 3 or no change from baseline scores.[13]

Statistical Analyses

Summary results are presented as means ± SDs for variables that were distributed normally. Variables that were not distributed normally are presented as medians and interquartile ranges (IQRs). Differences between groups were analyzed through analysis of variance for continuous variables and the χ^2 test for dichotomous variables. Posthoc comparisons were performed with regard to the normal-weight group by using the Bonferroni method for multiple comparisons. Variables associated with obesity and underweight in univariate analyses ($P < .20$) were included in stepwise, multivariate, logistic regression analyses to characterize their association with obesity and underweight. Finally, all factors associated with primary and secondary outcomes in univariate analyses ($P < .20$) were included in stepwise, multivariate, logistic regression analyses to characterize the association of obesity and underweight with outcome measures adjusted for confounding factors. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported. All P values are 2-sided, and P values were considered significant at <.05.

RESULTS

A total of 1477 children experienced index CPR events in 167 participating centers. Of those, 1268 (86%) had complete registry data recorded and were included for further analysis (Fig 1). Obesity was noted for 213 (17%) of 1268 subjects and underweight for 571 (45%) of 1268 subjects. For children <2 years of age, the median weight-for-length percentile was 0.4 (IQR: 0.01–29.55), with a median z score of −2.67 (IQR: −4.99 to −0.54). For children ≥2 years of age, the median BMI-for-age percentile was 68.9 (IQR: 6.3–96.3), with a median z score of 0.51 (IQR: −1.53 to 1.79). Infants (age of ≤1 year) were only 22% of the obese group, compared with 34% of the normal-weight group and 72% of the underweight group ($P < .001$).

The prearrest and arrest characteristics of the patients were compared across all 3 weight categories (Tables 1 and 2). The median ages were 48 months for obese patients, 5 months for underweight patients, and 30 months for the other children ($P < .001$). Both obese and underweight patients were more likely to be male than were the other children ($P < .01$). Obese patients were more likely to have a noncardiac medical illness or trauma, whereas underweight patients were more likely to have undergone cardiac surgery ($P < .001$). Infection, cancer, trauma, and neurologic dysfunction were more-common preexisting conditions among obese patients, whereas congestive heart failure and prematurity were more common among underweight patients. In all 3 weight categories, acute respiratory insufficiency and hypotension were the most-common immediately precipitating causes of arrest. Underweight patients were more likely to have acute respiratory insufficiency as an immediate cause of arrest, compared with obese patients and other children ($P < .001$).

Of the 1268 CPR events, 725 (57%) involved initially pulseless cardiac arrests and 543 (43%) severe bradycardia with pulses. Because 245 of 543 events with initial pulses subsequently became pulseless, a total of 969 (76%) of 1268 patients experienced pulseless cardiac arrests. Obese patients more often were pulseless throughout the event (69% of obese patients, compared with 51% of underweight patients and 60% of other patients; $P < .001$). Obese patients also were more likely to have a first documented electrocardiographic rhythm of asystole (37% of obese patients, compared with 26% of underweight patients and 32% of other patients; $P < .05$). The median number of epinephrine doses during CPR was greatest in the obese group (4

TABLE 1 Prearrest Characteristics of Patients

Prearrest Characteristic	Obesity ($N = 213$)	Normal Weight ($N = 484$)	Underweight ($N = 571$)	P
Age, median (IQR), mo	48 (17–144)[a]	30 (8–132)	5 (1–16)[a]	<.001
Male, n (%)	124 (58)[a]	225 (46)	334 (58)[a]	<.001
BMI, median (IQR), kg/m^2	22.7 (19.7–28.2)[a]	16.2 (15–18.3)	11 (9.3–12.6)[a]	<.001
BMI-for-age percentile, median (IQR)	99.6 (98.5–99.9)[a]	47.3 (21.4–76.4)	0.01 (0.01–0.3)[a]	<.001
BMI-for-age percentile z score, median (IQR)	2.62 (2.17–3.75)[a]	−0.07 (−0.79 to 0.72)	−3.94 (−5.73 to −2.75)[a]	<.001
Race or ethnicity, n (%)				
White	120 (56)	275 (57)	302 (53)	.40
Black	44 (21)	108 (22)	141 (25)	.43
Other	31 (15)	66 (14)	74 (13)	.84
Unknown/not documented	18 (8)	35 (7)	54 (9)	.43
Facility type, n (%)				
Pediatric	85 (40)	229 (47)	312 (55)[a]	<.001
Adult	11 (5)	25 (5)	6 (1)[a]	<.001
Mixed	117 (55)	230 (48)	253 (44)	<.05
Event location, n (%)				
ICU	156 (73)	333 (69)	405 (71)	.48
Operating room	5 (2)	24 (5)	16 (3)	.10
Emergency department	23 (11)	48 (10)	41 (7)	.16
Inpatient, monitored	6 (3)	30 (6)	32 (6)	.18
Inpatient ward	14 (7)	29 (6)	48 (8)	.30
Other/unknown	9 (4)	20 (4)	29 (5)	.74
Illness category, n (%)				
Medical, cardiac	29 (14)	85 (18)	107 (19)	.24
Medical, noncardiac	130 (61)[a]	225 (46)	245 (43)	<.001
Surgical, cardiac	8 (4)[a]	69 (14)	166 (29)[a]	<.001
Surgical, noncardiac	10 (5)	44 (9)	42 (7)	.13
Trauma	33 (15)	57 (12)	7 (1)[a]	<.001
Other	3 (1)	4 (1)	4 (1)	.63
Preexisting conditions, n (%)				
Respiratory insufficiency	121 (57)	278 (57)	387 (68)[a]	<.001
Hypotension	88 (41)	191 (39)	189 (33)	<.05
Congestive heart failure	22 (10)[a]	112 (23)	195 (34)[a]	<.001
Arrhythmia	38 (18)	94 (19)	115 (20)	.77
Infection (pneumonia or sepsis)	79 (37)[a]	116 (24)	157 (27)	<.01
Renal insufficiency	29 (14)	61 (13)	66 (12)	.71
Hepatic insufficiency	16 (8)	31 (6)	36 (6)	.82
Cancer	19 (9)	35 (7)	15 (3)[a]	<.001
Major trauma	40 (19)	57 (12)	8 (1)[a]	<.001
Metabolic/electrolyte abnormality	44 (21)	99 (20)	128 (22)	.71
Toxicologic abnormality	4 (2)	6 (1)	4 (1)	.35
Central nervous system disorder	72 (34)	153 (32)	142 (25)	<.05
Prematurity	8 (4)	23 (5)	120 (21)[a]	<.001
Mode of discovery of event, n (%)				
Witnessed	193 (91)	457 (94)	543 (95)	.06
Monitored through electrocardiography	178 (84)	424 (88)	494 (87)	.36
Monitored through pulse oximetry	179 (84)	421 (87)	514 (90)	.06
Existing interventions in place, n (%)				
Vascular access	193 (91)	439 (91)	506 (89)	.49
Arterial catheter	58 (27)	161 (33)	183 (32)	.28
Mechanical ventilation	124 (58)	304 (63)	341 (60)	.43
Vasoactive infusion	79 (37)	208 (43)	219 (38)	.20
Dialysis/extracorporeal membrane oxygenation	7 (3)	20 (4)	12 (2)	.16

[a] $P < .001$, adjusted for posthoc comparisons with normal-weight group.

doses, compared with 3 doses in each of the other groups; $P < .005$), and obese patients more often received >2 doses of epinephrine (43%, compared with 29% in each of the other groups; $P < .001$). Obese patients were more likely to receive vasopressin, magnesium, lidocaine, and amiodarone, compared with the other 2 groups ($P < .05$), and were less likely to be treated with extracorporeal membrane oxygenation therapy ($P < .05$).

Because both obesity and underweight might have resulted in advanced life support challenges, we analyzed self-reported, process-of-care, quality issues during CPR across weight categories. Overall, the obese group

TABLE 2 Arrest Characteristics of Patients

Arrest Characteristic	Obesity (N = 213)	Normal Weight (N = 484)	Underweight (N = 571)	P
Immediate factors related to event, n (%)				
Acute respiratory insufficiency	99 (47)	242 (50)	348 (61)[a]	<.001
Hypotension	123 (58)	298 (62)	313 (55)	.09
Metabolic/electrolyte disturbance	30 (14)	48 (10)	66 (12)	.27
Acute pulmonary edema	13 (6)	16 (3)	4 (1)	<.001
Airway obstruction	11 (5)	22 (5)	30 (5)	.86
State of pulse during event, n (%)				
Pulse absent throughout event	146 (69)[a]	289 (60)	290 (51)[a]	<.001
Pulse initially present and later absent	33 (15)	88 (18)	124 (22)	.11
Pulse present throughout event	34 (16)	107 (22)	157 (27)	<.05
First documented pulseless rhythm, n (%)				
Asystole	78 (37)	155 (32)	151 (26)	<.05
Pulseless electrical activity	48 (20)	88 (18)	90 (16)	.09
VF/pulseless VT	29 (14)	64 (13)	49 (9)	<.05
Unknown/not documented	21 (10)	60 (12)	102 (18)	<.005
Pulse rhythm (when pulse present), n (%)				
Bradycardia	48 (23)[a]	150 (31)	230 (40)[a]	<.001
Sinus (including sinus tachycardia)	9 (4)	18 (4)	23 (4)	.94
Ventricular tachycardia, with pulse	1 (0)	10 (2)	3 (1)	<.05
Unknown/not documented	8 (4)	13 (3)	21 (4)	.62
Interval to initiation of CPR, median (IQR), min	0 (0–0)	0 (0–0)	0 (0–0)	.5
Duration of CPR, median (IQR), min[b]	25 (9.5–43)	21 (8.25–40)	20 (8–36)	.14
Any VF/pulseless VT, n (%)	55 (26)	121 (25)	92 (16)[a]	<.001
Interval to first defibrillation, median (IQR), min	0 (0–6)	2 (0–3)	1 (0–4)	.16
Interval to first epinephrine dose, median (IQR), min	1 (0–5)	0 (0–3)	0 (0–4)	.44
No. of epinephrine doses				
Median (IQR)	4 (2–7)[a]	3 (2–5)	3 (1–5)	<.005
0, n (%)	21 (10)	80 (17)	116 (20)	<.05
1 or 2, n (%)	41 (19)	104 (21)	130 (23)	.56
>2, n (%)	91 (43)[a]	141 (29)	168 (29)	<.001
Unknown, n (%)	60 (28)	159 (33)	157 (28)	.14
Pharmacologic interventions, n (%)				
Fluid bolus	99 (46)	192 (40)	190 (33)	.14
Dextrose with insulin	2 (1)	12 (2)	21 (4)	.10
Atropine	92 (43)	187 (39)	224 (39)	.51
Sodium bicarbonate	142 (67)	293 (61)	333 (58)	.10
Calcium	97 (46)	220 (45)	267 (47)	.90
Vasopressin	12 (6)	29 (6)	12 (2)[a]	<.005
Magnesium sulfate	20 (9)	28 (6)	27 (5)	<.05
Amiodarone	21 (10)	34 (7)	17 (3)	<.001
Lidocaine	37 (17)	73 (15)	56 (10)	<.01
Nonpharmacologic interventions, n (%)				
Extracorporeal membrane oxygenation therapy	8 (4)	27 (6)	48 (8)	<.05
Pacemaker	14 (7)	45 (9)	47 (8)	.48

VF indicates ventricular fibrillation; VT, ventricular tachycardia.

[a] $P < .001$, adjusted for posthoc comparisons with normal-weight group.

[b] Data were not available for 147 patients.

experienced more problems with resuscitation team function (eg, deviations from pediatric advanced life support protocols), compared with the other categories (10% of resuscitations for obese patients, compared with 5% for underweight patients and 7% for other patients; $P < .05$). Invasive airway problems (delays, multiple attempts, and misplacement) tended to be more common with both obese (14%) and underweight (12%) patients, compared with normal-weight patients (9%; $P = .10$). Of all patients without a preexisting invasive airway at the time of the event, obese patients tended to receive CPR for a longer time than did patients in other weight categories (median: 33.5 vs 22 minutes; $P = .08$). Vascular access problems (ie, not obtaining vascular access and/or extravasations) also tended to occur more commonly among obese (5%) and underweight (6%) patients, compared with patients of normal weight (2%; $P = .09$). Providers reported more difficulties with defibrillation (ie, delays in pad placement, problems with selection of the energy dose, and not providing defibrillation when indicated) with obese patients (5% of obese patients, compared with 1% of underweight patients and 3% of other patients; $P < .05$).

The factors significantly associated with obesity and underweight during in-hospital, pediatric CPR, with controlling for duration of CPR, in stepwise, multivariate, logistic regression analyses are shown in Table 3. Obesity was more likely to be associated with male gender, noncardiac medical illness, and cancer and was less likely to be associated with congestive heart failure. Underweight was more likely to be associated with younger age, male gender, cardiac surgery, and prematurity and was less likely to be associated with cancer.

With controlling for confounding factors (age, gender, facility type, event

TABLE 3 Variables Significantly Associated With Obesity and Underweight

Weight Category	Variable	OR (95% CI)
Obesity	Male gender	1.76 (1.23–2.53)
	Illness category	
	Medical (noncardiac)	2.21 (1.13–3.87)
	Preexisting illness	
	Heart failure	0.33 (0.19–0.59)
	Cancer	2.25 (1.12–3.93)
Underweight	Age	0.98 (0.97–0.99)
	Male gender	1.59 (1.20–2.13)
	Illness category	
	Cardiac surgery	1.97 (1.28–3.02)
	Preexisting illness	
	Cancer	0.44 (0.21–0.89)
	Prematurity	3.39 (2.04–5.63)

The variables included in the multivariate logistic regression model were age, gender, facility type, event location, illness category, preexisting conditions, interventions in place at the time of the event, immediate precipitating causes, monitored/witnessed event, arrest rhythm, advanced cardiac life support medications, extracorporeal membrane oxygenation therapy, and duration of CPR. Data for 147 patients were excluded in this analysis because the exact duration of CPR was not documented.

TABLE 4 Weight and Outcomes of CPR

Outcomes	Obesity vs Normal Weight	Underweight vs Normal Weight
Primary outcome, survival to hospital discharge		
Rate, %	23 vs 34	39 vs 34
Adjusted OR (95% CI)	0.62 (0.38–0.93)	1.16 (0.79–1.67)
Secondary outcomes		
Survival of event (return of spontaneous circulation for >20 min)		
Rate, %	53 vs 66	70 vs 66
Adjusted OR (95% CI)	0.58 (0.35–0.76)	1.23 (0.94–1.62)
Survival with favorable neurologic outcome		
Rate, %	15 vs 20	27 vs 20
Adjusted OR (95% CI)	0.69 (0.33–1.24)	1.44 (0.93–2.06)

The ORs were adjusted for factors associated with each outcome measure in multivariate logistic regression analyses. The variables included in the model were age, gender, facility type, event location, illness category, preexisting conditions, interventions in place at the time of the event, immediate precipitating causes, monitored/witnessed event, arrest rhythm, advanced cardiac life support medications, extracorporeal membrane oxygenation therapy, and duration of CPR. Data for 147 patients were excluded in this analysis because the duration of CPR was not documented.

location, illness category, preexisting conditions, interventions in place at the time of the event, immediate precipitating causes, monitored/witnessed event, arrest rhythm, concurrent advanced cardiac life support medications, extracorporeal membrane oxygenation therapy, and duration of CPR), obesity was independently associated with worse rates of event survival and survival to discharge (Table 4). In contrast, underweight was not associated with worse rates of event survival or survival to discharge.

DISCUSSION

The data from this large, multicenter registry of in-hospital, pediatric cardiopulmonary arrests established that obese children had worse survival rates after in-hospital, pediatric CPR. They were less likely to survive the CPR event and less likely to survive to hospital discharge. Surprisingly, the outcomes of children who were underweight were at least as good as those of children with normal weights. Although other studies demonstrated that childhood obesity is generally associated with increased morbidity and mortality rates,[14–16] this is the first study that demonstrates an association between childhood obesity and outcomes after CPR.

Why was obesity associated with worse outcomes after in-hospital, pediatric CPR in our study? First, it is possible that providers have more difficulty attaining adequate force and depth of compressions with obese children, compared with thinner children. The effectiveness of chest compression force and depth with respect to blood flow during CPR may be attenuated because of anatomic and physiologic effects of obesity. For example, obesity is associated independently with increased abdominal pressure, low lung volumes with atelectasis, low lung compliance, and low chest wall compliance,[17,18] all of which may attenuate blood flow during CPR. Second, the dosing of pediatric advanced life support medications on the basis of actual weight is potentially hazardous for obese children. Although there is a paucity of data regarding optimal dosing of resuscitation medications for children of any weight, plasma concentrations of highly water-soluble medications with small volumes of distribution, such as epinephrine, may be substantially higher in obese children and therefore potentially toxic.[19] Conversely, highly lipid-soluble medications, such as amiodarone, have larger volumes of distribution in obese patients,[20] and much higher doses may be needed to attain comparable effects in obese patients. Third, because defibrillation doses for children also are weight-based (ie, 2 J/kg), much higher doses may be provided to obese children, compared with other children the same length or age. It is possible that higher doses result in greater postresuscitation myocardial dysfunction.[21] Alternatively, it is plausible that obese subjects require greater defibrillation energies than the weight-based doses for successful resuscitation. Fourth, the processes of care and resuscitation team dynamics during CPR tended to be more difficult for obese children, which might have been a significant determinant of poor outcomes.

The lack of an association between underweight and worse survival outcomes is somewhat surprising. Studies with critically ill adults observed associations of low BMI values with higher mortality rates and worse functional status at hospital discharge.[22–24] In the present study, underweight children were generally younger, more likely to receive care in pediatric facilities, and more likely to be in the hospital for cardiac surgery, each of which might have favorably influenced outcomes.[25,26] Low BMI values often were associated with a malignancy in the adult studies, whereas the underweight children in our study were less likely to have a malignancy than were either the obese children or the normal-weight children.

As hypothesized, factors associated with CPR and advanced life support for obese children had adverse effects on survival outcomes. The present study examined all index CPR events, including those with no loss of pulses during the event. When we analyzed outcomes exclusively for patients who experienced pulseless cardiac arrest (n = 725), obesity continued to be associated with worse odds of event survival (adjusted OR: 0.53 [95% CI: 0.31–0.96]) and survival to hospital discharge (adjusted OR: 0.57 [95% CI: 0.27–0.98]). The underweight group of patients who received CPR because of a pulseless arrest did not differ from the normal-weight group.

There are several limitations to this study. Because the NRCPR database does not include height data, we estimated BMI values on the basis of median height-for-age values (or length-for-age values for children <2 years of age). It is possible that some of the underweight-for-age children also were short for age, and their weight-for-length percentiles (or BMI-for-age percentiles) might have been normal. Similarly, some of the heavier children might have been taller, and their BMI values might have been normal. However, both the underweight group and the obesity group differed from the normal-weight group with respect to many factors that seem consistent with their presumed phenotypes. For example, obesity was less likely among children with congestive heart failure or prematurity, whereas underweight was more likely among children with either condition.

The usual limitations of registry data regarding the integrity and validity of the data and sampling bias were addressed through the use of uniform operational definitions, uniform data collection, rigorous prospective abstractor training and competency-based certification, detailed periodic reabstraction, and large sample size. Sampling bias was minimized through the use of strict inclusion and exclusion criteria, comprehensive methods to verify data completeness, large sample size, and multicenter design. However, it is possible that the existing NRCPR data elements fail to capture unmeasured confounders of outcomes.

Although this is the largest registry of in-hospital, pediatric cardiac arrests, the number of events may lack power for some important comparisons. For example, the underweight group had an adjusted OR of 1.16 for survival to hospital discharge, compared with the normal-weight group, but the 95% CI was 0.79 to 1.67. Perhaps these differences would be statistically significant with larger numbers. Similarly, the obese group tended to have worse rates of survival with favorable neurologic outcomes but this did not achieve statistical significance, despite trends for this important secondary outcome that paralleled our primary outcome (survival to hospital discharge).

The implications of these findings are important in the context of the growing epidemic of childhood obesity. Providers need to recognize obese children and the associated comorbidities that predispose such children to worse outcomes after cardiac arrest. Further investigation is necessary to determine the effectiveness of weight-based medication and defibrillation dosing for obese children and to determine the effectiveness of standard chest compression techniques for such children. Perhaps CPR and advanced life support should be somewhat different for obese children. In addition, CPR and advanced life support training programs may need modification to address the special needs of obese children.

CONCLUSIONS

Childhood obesity is associated with a lower rate of survival to hospital discharge after in-hospital, pediatric CPR. Future pediatric CPR investigations and guidelines may need to address potential differences in CPR and advanced life support for obese children.

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