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Original Article

Body mass index interaction effects with hyperglycemia and hypocholesterolemia modify blunt traumatic brain injury outcomes: a retrospective study

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Abstract: Introduction: There is controversy regarding obesity or body mass index (BMI) effects on postinjury mortality and mechanical ventilation. The aim was to assess outcome associations with BMI and postinjury blood glucose and cholesterol. Method: Adult blunt traumatic brain injury patients admitted to a level I trauma center and requiring ≥ 3 days of intensive care were investigated. Admission blood glucose and day-4 total cholesterol were captured from the medical records. Cholesterol ratio was calculated by dividing day-4 values by published national normative levels according to sex, age, and injury date. Results: The parent cohort included 588 patients. The ventilator days ≥ 10 or died group, when compared to the ventilator days < 10 and lived group, had higher Injury Severity Score (ISS) (29.2±9.9 versus [vs.] 23.7±9.7, P < 0.0001), BMI (27.9±6.8 vs. 26.0±5.5, P = 0.0002), and admission glucose (182.6±79 vs. 155.4±59 mg/dl, P < 0.0001, n = 476) and lower emergency department Glasgow Coma Scale score (ED GCS) (6.9±4.7 vs. 10.3±5.0, P < 0.0001) and cholesterol ratio (0.64±0.2 vs. 0.70±0.2, P = 0.0018, n = 364). The ventilator days ≥ 10 or died group had independent associations with increased ISS (P = 0.0709), decreased ED GCS (P = 0.0078), and increased BMI÷cholesterol ratio (P = 0.0003). The ventilator days ≥ 10 or died group had independent associations with increased ISS (P = 0.0013), decreased ED GCS (P < 0.0001), and increased BMI × glucose (P < 0.0001). Ventilator days were increased with higher ISS (P < 0.0001), BMI (P = 0.0014) and glucose (P = 0.0031) and with lower ED GCS (P < 0.0001) and cholesterol ratio (P = 0.0004). Ventilator days had independent associations with increased ISS (P < 0.0001), decreased ED GCS (P = 0.0041), and increased BMI÷cholesterol ratio (P = 0.0010). Ventilator days had independent associations with increased ISS (P < 0.0001), decreased ED GCS (P < 0.0001), and increased BMI × glucose (P = 0.0041). Conclusion: For TBI patients, valid risk assessment measurements include ISS (anatomic injury burden), ED GCS (brain function), BMI (preinjury weight status), admission glucose (postinjury metabolism), and day-4 cholesterol ratio (postinjury inflammation).

Keywords: Blunt trauma, body mass index, obesity, traumatic brain injury

Introduction

Body mass index and adverse trauma outcomes

There is controversy regarding the impact of body mass index (BMI) or obesity on mortality and duration of mechanical ventilation following blunt trauma. Some trauma investigators have shown that increased BMI or obesity is associated with mortality [1-3], whereas others have demonstrated that there is no relationship [4-10]. Similarly, certain trauma experts have shown that increased BMI or obesity is linked to the duration of mechanical ventilation following blunt trauma [5, 7-10], yet others have failed to establish a connection [1, 4, 11].

Studies focusing on patients with traumatic brain injury (TBI) have shown varying effects regarding the association of obesity and mortality. One study found an association between mortality and obesity [12] while another investigation did not [13]. Another investigation found that obese patients had an increase in mortality; however, obesity was not an independent predictor of mortality [14]. An additional investigation noted that mortality was increased in two classes of obesity, but not in patients with intermediate obesity when compared to normal weight patients [15]. Only two of the four TBI investigations reported on the duration of mechanical ventilation with one study showing that obesity was associated with increased ventilator days [12] while the other report did not [13]. Of the 15 studies cited, only two used continuous BMI values to assess risk outcomes [5, 7], while the others used BMI to compute distinct obesity categories and then correlate these groups with adverse effects. We found no TBI publication where the impact of BMI as a continuous variable on adverse outcomes has been investigated.

Associations of adverse trauma outcomes with hyperglycemia and hypocholesterolemia

Several trauma investigations provided evidence that increased blood glucose levels at the time of admission or during the first 24 hours of admission have been associated with mortality, infection, and the duration of mechanical ventilation [3, 6, 16-18]. In a study of patients with TBI, those with severe brain injury were found to have greater hyperglycemia than those with mild brain injury [19]. Several studies demonstrated the development of hypocholesterolemia following blunt trauma [20-25]. The second author of the current manuscript demonstrated that postinjury serum hypocholesterolemia has been associated with infection, organ failure, mortality, and an increased duration of mechanical ventilation, intensive care unit (ICU) stay, and hospital length of stay [20-22].

Increased postinjury systemic inflammation

A literature review provided evidence that TBI and hyperglycemia are associated with increased systemic inflammation [26]. Substantial literature implicates systemic inflammatory up-regulation as a mechanism for fostering the development of hypocholesterolemia [27-35]. Of relevance to the current study findings are literature documentations demonstrating that 1) increased BMI is associated with increased interleukin-6 and C-reactive protein values [36], 2) traumatic injury leads to systemic inflammatory up-regulation and is associated with the Injury Severity Score (ISS) [37-39], 3) severe TBI is related to increased interleukin-6 values [40], 4) hyperglycemia is associated with interleukin-1 and tumor necrosis factor values [26], and 5) prolonged mechanical ventilation is related to increased C-reactive protein values [41].

Current study formulation

In 2009, Diaz and colleagues strongly endorsed the notion that early postinjury blood glucose should be used in all future trauma studies as a measure of severity of illness [6]. In harmony with their recommendation, we decided to investigate postinjury admission blood glucose and cholesterol as potential measures of risk for adverse outcomes.

Here, we indexed postinjury cholesterol levels according to sex- and age-associated national norms [22]. Because Diaz and colleagues showed that BMI was weakly related to age and serum glucose, we were stimulated to investigate BMI value interactions with postinjury blood glucose and cholesterol values. Our primary intent was to assess associations between adverse outcomes and preinjury BMI, postinjury admission blood glucose, and postinjury blood cholesterol. The secondary goal was to create interactive BMI values with blood glucose and cholesterol values and compare their relationships with undesirable outcomes. Based on an adverse outcomes model from our institution [42] and because of the nebulous literature findings regarding BMI or obesity associations with mortality and the duration of mechanical ventilation, we selected duration of mechanical ventilation as one adverse outcome and mortality or ≥ 10 ventilator days as the other condition. We hypothesized that BMI and postinjury blood glucose and total cholesterol would be associated with these measures of adverse outcomes.

Materials and methods

Study design and population

This was an institutional review board-approved retrospective review of all adult patients with TBI (intracranial hemorrhage or skull fracture) admitted to a regional level I trauma center. The need for informed consent was waived because of the retrospective design and the board decision that the research involves no more than minimal risk to the subjects. Study inclusion criteria were consecutive patients who were ≥ 18 years of age, had sustained blunt TBI, had an ICU length of stay ≥ 3 days, and were admitted between May 1, 2002 and December 31, 2010. Patients were excluded if height or weight was not documented (10.2% of potential candidates).

Data collection

Data obtained from the trauma registry included blunt trauma mechanism of injury, age, pre-existing medical conditions, ISS, emergency department (ED) Glasgow Coma Scale score (GCS), hospital discharge survival status, length of ICU stay (days), and duration of mechanical ventilation (days). Severe TBI was defined as ED GCS 3-8. The ventilator days ≥ 10 or died group included patients who died or required ≥ 10 days of mechanical ventilation. The 15 pre-existing medical conditions described later were each scored as 0 (absent) or 1 (present). The pre-existing medical condition score was the sum of the 15 conditions for each patient.

Data obtained from patients' hospital medical record included height, weight, admission blood glucose level, and day-4 total blood cholesterol values. An admission blood glucose value was recorded if a level was documented within the first 4 hours of ED arrival. A day-4 total blood cholesterol value was recorded if a level was documented within 96±12 hours following trauma center arrival. BMI was computed from the height and weight values of each patient. A BMI × admission glucose interaction variable was calculated by multiplying BMI and the admission glucose. A cholesterol ratio was computed for each patient by dividing the day-4 cholesterol value by national normative values published by the United States National Center for Health Statistics as they related to sex, age, and date of injury of each patient [43]. A BMI÷cholesterol ratio interaction variable was calculated by dividing the BMI by the day-4 cholesterol ratio.

Statistical analyses

The results were entered into Excel 2010 (Microsoft Corp., Redmond, WA, USA) and imported into SAS System for Windows, release 9.2 (SAS Institute Inc., Cary, NC, USA). Continuous data (e.g., BMI and glucose) and ordinal rank data (e.g., ED GCS and ISS) are presented as the mean ± standard deviation. Cohen d values were computed to assess the magnitude of intergroup mean differences. For univariate analyses with a dichotomous dependent outcome (ventilator days ≥ 10 or died; yes or no), intergroup mean differences were analyzed using independent t-test analyses for continuous data (e.g., BMI), Wilcoxon rank sum tests for ordinal rank data (e.g., ISS), and Fisher exact tests for dichotomous proportional data (e.g., mortality and pre-existing medical conditions, yes or no). In univariate analyses performed to assess correlations (R-values) with a continuous dependent variable (duration of mechanical ventilation), Pearson's correlation coefficient analysis was used for independent continuous data (e.g., glucose and BMI) and Spearman coefficient analysis was used for independent ordinal rank data (e.g., ED GCS and ISS). Multivariate linear regression analysis (procedure regression) was used to assess independent associations when the dependent variable was a continuous measure (duration of mechanical ventilation days). Multivariate logistic regression analysis (procedure logistic) was used to assess independent relationships when the dependent variable was dichotomous (ventilator days ≥ 10 or died, yes or no). Significance levels for the *P*-value were set at < 0.05 for univariate analyses and < 0.10 for multivariate analyses.

Results

For the 588 adult patients with blunt trauma TBI who met the inclusion criteria, the demographics and outcomes are described in **Table 1**. The day-4 cholesterol level was captured for 364 (61.9%) patients and admission glucose level was available for 476 (81.0%) patients. Multivariate linear regression analysis showed that the admission glucose level had independent associations with increased ISS (P = 0.0221), decreased ED GCS (P = 0.0002), pre-existing diabetes mellitus (P < 0.0001), and increased BMI (P = 0.0194). The admission glucose level was higher for those dying (196.6±82 mg/dl) when compared to those surviving (164.6±69 mg/dl; P = 0.0030; Cohen d = 0.4). Compared to the ventilator days < 10 and lived group, the ventilator days ≥ 10 or died group had significantly higher ISS, ED GCS 3-8, BMI, and admission glucose val-

Table 1. Demographics and outcomes according to ventilator days and mortality (n = 588)

	Ventilator Days < 10 and Lived	Ventilator Days ≥ 10 or Died	*P*-value	
	292 (49.7%)	296 (50.3%)		
Ventilator Days	2.7±3.2	17.6±13.9	< 0.0001	Cohen d = 1.5
Mortality	0 (0.0%)	88 (29.7%)	< 0.0001	Odds Ratio = 61.3
Intensive Care Unit Days	7.0±5.2	19.8±14.6	< 0.0001	Cohen d = 1.2
Age (years)	58.8±23.6	51.9±22.1	0.0002	Cohen d = 0.3
Injury Severity Score	23.7±9.7	29.2±9.9	< 0.0001	Cohen d = 0.6
ED GCS	10.3±5.0	6.9±4.7	< 0.0001	Cohen d = 0.7
ED GCS 3-8	99 (34.1%)	199 (67.2%)	< 0.0001	Risk Ratio = 2.0
Body Mass Index	26.0±5.5	27.9±6.8	0.0002	Cohen d = 0.3
Day-4 Cholesterol Ratio[╫]	0.70±0.2	0.64±0.2	0.0018	Cohen d = 0.3
Admission Glucose (mg/dl)[╝]	155.4±59	182.6±79	< 0.0001	Cohen d = 0.4
BMI÷Cholesterol Ratio[╫]	40.2±12	46.6±14	< 0.0001	Cohen d = 0.5
BMI × Admission Glucose[╝]	4047±1700	5253±2876	< 0.0001	Cohen d = 0.5

[╫]total = 364; [╝]total = 476; BMI, body mass index; ED GCS, emergency department Glasgow Coma Score.

Table 2. Pre-existing medical conditions according to duration of ventilation and mortality (n = 588)

Pre-existing Medical Conditions:	Ventilator Days < 10 and Lived	Ventilator Days ≥ 10 or Died	*P*-value
	292 (49.7%)	296 (50.3%)	
Anemia	21 (7.2%)	12 (4.1%)	0.1090
Cancer	11 (3.8%)	9 (3.0%)	0.6270
Antithrombotic	28 (9.6%)	31 (10.5%)	0.7213
Cardiovascular Disease	95 (32.5%)	69 (23.3%)	0.0126
Cerebrovascular Accident	22 (7.5%)	11 (3.7%)	0.0443
Dementia	16 (5.5%)	7 (2.4%)	0.0574
Diabetes Mellitus	54 (18.5%)	53 (17.9%)	0.8535
Drug/Ethanol Abuse	51 (17.5%)	55 (18.6%)	0.7250
Hypertension	121 (41.4%)	86 (29.1%)	0.0017
Movement Disorder	14 (4.8%)	10 (3.4%)	0.3855
Other	87 (29.8%)	73 (24.7%)	0.1621
Psychiatric Disorder	42 (14.4%)	24 (8.1%)	0.0159
Pulmonary Disorder	31 (10.6%)	28 (9.5%)	0.6406
Renal Disorder	25 (8.6%)	11 (3.7%)	0.0143
Smoking	51 (17.5%)	39 (13.2%)	0.1486
Pre-existing Medical Condition Score	2.3±2.0	1.8±1.7	0.0003

The 15 pre-existing medical conditions were scored as 0 (absent) or 1 (present). The pre-existing medical condition score was the sum of the 15 conditions for each patient.

ues and significantly lower age, ED GCS, and day-4 cholesterol ratio values. The ventilator days ≥ 10 or died group had significantly higher BMI÷cholesterol ratio and BMI × admission glucose values than the ventilator days < 10 and lived group. The Cohen d for BMI÷cholesterol ratio values was greater than that for the individual BMI or cholesterol ratio values. The Cohen d for BMI × admission glucose values was greater than that for the individual BMI or admission glucose values. Pre-existing medical conditions are described in **Table 2**. Of the 15 categories, none had a significantly higher proportion in the ventilator days ≥ 10 or died group. The pre-existing medical conditions score was significantly lower in the ventilator days ≥ 10 or died group than in the ventilator days < 10 and lived group (**Table 2**).

Table 3. Correlations with ventilator days (n = 588)

	R-value	*P*-value
Age	-0.27	< 0.0001
Pre-existing Medical Conditions Score	-0.20	< 0.0001
Injury Severity Score	0.36	< 0.0001
ED GCS	-0.50	< 0.0001
Body Mass Index	0.13	0.0014
Cholesterol Ratio[╫]	-0.18	0.0004
Admission Glucose Level[╝]	0.14	0.0031
BMI÷Cholesterol Ratio[╫]	0.22	< 0.0001
BMI × Admission Glucose[╝]	0.20	< 0.0001

[╫]total = 364; [╝]total = 476; BMI, body mass index; ED GCS, emergency department Glasgow Coma Scale score.

Multivariate logistic regression analysis of the 364 (61.9%) trauma patients with day-4 cholesterol data demonstrated that those in the ventilator days ≥ 10 or died group had independent associations with increased ISS (P = 0.0709), decreased ED GCS (P = 0.0078), and increased BMI÷cholesterol ratio (P = 0.0003). When BMI and the cholesterol ratio were added to the model, the stepwise procedure selected the interaction variable, BMI÷cholesterol ratio, but excluded BMI (P > 0.05) and the cholesterol ratio (P > 0.05). BMI and the cholesterol values had a weak positive association (R = 0.14; P = 0.0083). Multivariate logistic regression analysis of the 476 (81.0%) trauma patients with admission glucose data showed that those in the ventilator days ≥ 10 or died group had independent associations with increased ISS (P = 0.0013), decreased ED GCS (P < 0.0001), and increased BMI × admission glucose (P < 0.0001). When BMI and the admission glucose level were added to the model, the stepwise procedure selected the interaction variable, BMI × admission glucose, but excluded BMI (P > 0.05) and the admission glucose level (P > 0.05). BMI and the admission glucose values had a weak positive association (R = 0.15; P = 0.0012).

Correlation analyses showed that a greater duration of mechanical ventilation was associated with a lower age, pre-existing medical conditions score, ED GCS, and day-4 cholesterol ratio and higher ISS, BMI, and admission glucose level (**Table 3**). Ventilator days were increased with ED GCS3-8 (severe TBI) (14.2±13.5; median = 11) when compared to ED GCS 9-15 (6.2±10.1; median = 1; P < 0.0001; Cohen d = 0.7). Analyses also demonstrated that an increase in the number of mechanical ventilation days was associated with higher BMI÷cholesterol ratio and BMI × admission glucose values (**Table 3**). The R-value was higher and the *P*-value was lower for the BMI÷cholesterol ratio when compared to those for the individual BMI or cholesterol ratio values. The R-value was higher and the *P*-value was lower for BMI × admission glucose when compared to the individual BMI or admission glucose values.

Multivariate linear regression analysis of the 364 trauma patients with day-4 cholesterol data demonstrated that the days of mechanical ventilation had independent associations with increased ISS (P < 0.0001), decreased ED GCS (P = 0.0041), and increased BMI÷cholesterol ratio (P = 0.0010). When BMI and the cholesterol ratio were added to the model, the stepwise procedure selected the interaction variable, BMI÷cholesterol ratio, but excluded BMI (P > 0.05) and the cholesterol ratio (P > 0.05). Multivariate linear regression analysis of the 476 trauma patients with admission glucose data showed that the days of mechanical ventilation had independent associations with increased ISS (P < 0.0001), decreased ED GCS (P < 0.0001), and increased BMI × admission glucose (P = 0.0041). When BMI and the admission glucose level were added to the model, the stepwise procedure selected the interaction variable, BMI × admission glucose, but excluded BMI (P > 0.05) and the admission glucose level (P > 0.05). The correlation between the continuous ED GCS and the dichotomous severe TBI (ED GCS 3-8, no or yes) was inverse and strong (R = -0.95; P < 0.0001). The ED GCS was lower for GCS 3-8 (3.8±1.6) than for GCS 9-15 (13.6±1.6; P < 0.0001; Cohen d = 6.1). When the dichotomous ED GCS 3-8 was substituted for the continuous ED GCS, the *P*-values for all relationships were virtually identical.

Discussion

Important findings from the current study indicate that increased ISS, decreased ED GCS (severe TBI), preinjury increased BMI, and postinjury metabolic perturbations, hyperglycemia and hypocholesterolemia, had significant associations with adverse blunt TBI outcomes. Because patients with an ICU stay < 3 days were eliminated, we believe that the exclusion of patients with minor injuries and those with devastating trauma fostered the inclusion of patients that were at risk for adverse outcomes, yet enhanced relative patient homogeneity. Combining mortality and duration of mechanical ventilation into a dichotomous outcome is not a common methodological approach; however, precedence for such a paradigm has been found to have merit [42]. Because the investigation included only patients with a minimum ICU stay of 3 days, even the ventilator days < 10 and lived group had a mean ISS over 20 and required a week of intensive care with 40% needing 3-9 mechanical ventilation days. In comparison, the ventilator days ≥ 10 or died group had a mortality of nearly 30% and required longer durations of ICU stay and mechanical ventilation. In this group, ISS was significantly higher and ED GCS was substantially lower, which lends support to the validity of this model because these variables are considered standards for assessing injury severity. Most would agree that managing this cohort of patients would substantially tax nurse and physician clinical skills, create family emotional turbulences, and impose burdens on hospital fiscal and operational resources.

Increased BMI

Increased BMI had significant associations with the ventilator days ≥ 10 or died group and with increased duration of mechanical ventilation. The relationships between increased BMI and adverse outcomes are supported by other researchers who have investigated the effects of BMI on mortality [1-3, 12] and duration of mechanical ventilation [5, 7-10, 12]. It is interesting and elucidating that one TBI study failed to show a mortality association when using four progressive BMI categories [13]. However, when BMI was unbundled from the progressive categories, the linear expression of BMI was then found to be an independent predictor of mortality. Of the 15 pre-existing medical conditions, no proportion was significantly higher in the ventilator days ≥ 10 or died group. The pre-existing medical condition score was significantly lower in the ventilator days ≥ 10 or died group than in the ventilator days < 10 and lived group and had an inverse association with the duration of mechanical ventilation. Age was also significantly lower in the ventilator days ≥ 10 or died group than in the ventilator days < 10 and lived group and had an inverse association with the number of ventilator days. These findings suggest that BMI is the only apparent pre-existing medical condition that is associated with adverse TBI patient outcomes.

Hyperglycemia

Higher admission glucose values were associated with the ventilator days ≥ 10 or died group and with increased duration of mechanical ventilation. Numerous investigators showed that postinjury hyperglycemia is associated with an increase in mortality [3, 6, 16-18]. Some of these studies also showed a relationship between postinjury hyperglycemia and risk for infection [16] or duration of mechanical ventilation [3]. Researchers provided evidence from their investigations or literature reviews that postinjury hyperglycemia is related to the postinjury sympathoadrenal stress response, preinjury diabetes mellitus, preinjury increased BMI, or postinjury inflammation [3, 6, 16, 18, 26]. These findings indicate that postinjury hyperglycemia is a risk condition for adverse TBI outcomes.

Hypocholesterolemia

Lower postinjury cholesterol values were associated with the ventilator days ≥ 10 or died group and with increased duration of mechanical ventilation. Several studies demonstrated the development of hypocholesterolemia following blunt trauma [20-25], surgical trauma [27, 29, 44-46], and thermal trauma [30]. Numerous investigations also demonstrated the occurrence of hypocholesterolemia in critically ill patients and infected patients [20, 21, 28, 47-50]. Multiple publications indicated that the degree of hypocholesterolemia is associated with mortality in ICU patients [46], trauma patients [25], general surgical patients [44, 45], and cardiothoracic surgical patients [29]. Literature evidence supports the notion that hypocholesterolemia would likely reflect the severity of host injury and magnitude of inflammatory responses.

BMI and metabolic interaction effects

Multivariate analyses demonstrated that increased ISS, decreased ED GCS (severe TBI), and preinjury BMI × postinjury admission glucose were independent predictors for the two indicators of adverse outcomes, 1) ventilator days ≥ 10 or death and 2) increased duration of mechanical ventilation. Stepwise analyses indicated that the BMI-metabolic interaction effects, BMI × admission glucose, had superior statistical associations with adverse outcomes, when compared to preinjury BMI or postinjury hyperglycemia separately. Since adverse outcomes have been demonstrated separately with increased BMI [3, 10, 12] and hyperglycemia [3, 6, 16-18], it is clinically feasible that an interaction effect between BMI and admission glucose values (BMI × admission glucose) may have an altering influence on adverse outcomes. Because evidence exists that inflammatory mediators are increased with traumatic injury [37-39], decreased ED GCS (severe TBI) [40], increased preinjury BMI [36], and postinjury hyperglycemia [26], it seems plausible that systemic inflammation is a pervasive theme for statistical findings in the current study. Although increased ISS, decreased ED GCS (severe TBI), and preinjury BMI may all increase systemic inflammation, they also create distinct clinical problems that can tax health care personnel and institutional resources. The aforementioned ideas are potential explanations for the finding that increased ISS, decreased ED GCS (severe TBI), and BMI × admission glucose had independent associations with adverse outcomes. Although the mechanisms for the interaction effects of BMI and admission glucose are uncertain, preinjury and postinjury moderations are intriguing and may lead to more clarifying investigations. The statistical observations imply that adverse outcomes are associated with anatomic injury burden (ISS), brain dysfunction (ED GCS), weight status (BMI), and metabolic stress (admission glucose).

In a similar manner, multivariate analyses showed that increased ISS, decreased ED GCS (severe TBI), and preinjury BMI÷postinjury cholesterol ratio were independent predictors for the two indicators of adverse outcomes, 1) ventilator days ≥ 10 or death and 2) increased duration of mechanical ventilation. Stepwise analyses also demonstrated that the BMI-metabolic interaction effects of BMI÷cholesterol ratio had better statistical associations with adverse outcomes, when compared to preinjury BMI or postinjury cholesterol ratio separately. Because adversity has been found separately for increased BMI [3, 10, 12] and hypocholesterolemia [20, 25], it is clinically plausible that an interactive effect between BMI and day-4 cholesterol (BMI÷cholesterol ratio) values could create a moderating influence on undesirable outcomes. In addition to the evidence for increased systemic inflammation with traumatic injury, decreased ED GCS (severe TBI), and increased BMI, hypocholesterolemia is likely to reflect inflammatory upregulation [27-35]. We reiterate that although increased ISS, decreased ED GCS (severe TBI), and preinjury BMI likely increase systemic inflammation, they also lead to unique clinical complexities that are vexing to patient care providers and hospital resources. We believe that these conjectures offer insight into the observation that increased ISS, decreased ED GCS (severe TBI), and BMI÷day 4 cholesterol ratio were independently associated with detrimental outcomes. Although the precise causes for the moderating effects of BMI and the day-4 cholesterol ratio are unclear, preinjury and postinjury interactions are stimulating and will likely foster future research. The objective analyses indicate that undesirable outcomes are associated with anatomic injury burden (ISS), brain dysfunction (ED GCS), weight status (BMI), and inflammation (day-4 cholesterol ratio). It is important to consider that blood total cholesterol testing is ubiquitously available and relatively inexpensive.

Limitations

It is important to describe some of the limitations of the current study to the reader. Because of the retrospective nature of the study, some of the potential candidates eligible for study inclusion had missing height or weight values, although this was a relatively small percent. Several patients had missing admission glucose and day-4 cholesterol values. However, the BMI interaction effects were contextualized in multivariate analyses by ISS and ED GCS in cohorts of substantial size. The pre-existing medical conditions were simplified dichotomous measures and might have shown a different result if a more standardized methodology, e.g., the Charlson Comorbidity Index, had been used.

Conclusions

In conclusion, the investigation indicates that preinjury BMI has an interaction effect with postinjury hyperglycemia and postinjury hypocholesterolemia to alter adverse outcomes in adult patients with blunt traumatic brain injury. The study implies that undesirable TBI outcomes are associated with ISS (anatomic injury burden), ED GCS (brain function), BMI (preinjury weight status), admission glucose (postinjury metabolism), and day-4 cholesterol ratio (postinjury inflammation). It is our hope that this work will encourage other investigators to include BMI, admission glucose, and postinjury cholesterol data for the purpose of risk stratification and to advance knowledge regarding the underlying pathologic mechanisms of TBI clinical perturbations.

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Disclosure of conflict of interest

None.

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