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ORIGINAL RESEARCH

# Obesity and Penetrating Trauma: Outcomes from a Level I Trauma Center in New York City

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**Background:** Obesity is associated with increased morbidity and mortality in trauma scenarios; however, there has been conflicting evidence on outcomes of obesity and penetrating injuries, specifically gunshot wounds and stab wounds. We hypothesized that obesity may be protective due to a "cushioning effect" attributed to increased adiposity.

**Methods:** This was a retrospective cohort study of patients presenting to a Level 1 Trauma Center with a penetrating trauma (gunshot/stab) injury during 2008–2021. Patients with a BMI ≥ 30 were compared to those with a BMI < 30. The primary outcome was Injury Severity Score (ISS). Secondary outcomes included intensive care unit (ICU) length of stay, days on ventilation, length of hospital stay, service of admission (trauma surgery, general surgery, discharged home, general medical floor), the body region of injury(s), Abbreviated Injury Scale (AIS), OR requirement, type of surgery, and discharge status. Statistical analysis was performed using $\chi^2$-test or Fisher's exact tests for categorical data, and Student's *t*-test or Mann–Whitney *U*-test for continuous variables with $p < 0.05$ as statistically significant. Subgroup analysis was performed based on the mechanism of injury.

**Results:** There were 721 patients that met inclusion criteria, of which 540 were classified in the non-obese group and 181 (25.1%) in the obese group. The primary outcome, mean ISS score, in obese patients (9.0, SD = 13.0) and non-obese patients (9.4, SD = 13.8) was similar between groups respectively. Secondary outcomes, which included rates of severe abdominal injury (AIS ≥ 3), rates of intra-abdominal organ injury, and rates of gastro-intestinal resection, were also similar between non-obese and obese patients.

**Conclusion:** This study did not demonstrate the existence of a "cushioning effect" in the setting of penetrating traumatic injury. Patients with increased BMI had similar a ISS score and patterns of injury as their non-obese counterparts.

**Keywords:** penetrating trauma, gun violence, obesity, cushioning effect

## Background

Gun violence and obesity both continue to be growing epidemics in the United States. The rate of gun violence increased 35% between 2019 and 2020.[1] Similarly, over the past two decades, the prevalence of obesity in the US increased from 30.5% to 41.9%.[2] As the rates of both continue to rise, it is important to examine the relationship of obesity and penetrating trauma injuries for triaging and prioritization of patients. Obesity is generally believed to be a risk factor for severe injury, leading to difficulties in treatment and recovery. A recent 2023 systematic review and meta-analysis that included 955,511 patients following blunt or penetrating trauma found that patients with a BMI > 40 had a significantly higher risk of in-hospital mortality, longer in-hospital LOS, and longer ICU LOS compared to normal BMI patients.[3]

However, not all mechanisms of injury have been linked to worse outcomes in obese individuals. The "cushioning effect" proposes that an increased BMI may be associated with lower incidence of injury, due to increased subcutaneous fat providing a protective effect. This has been well-demonstrated in the literature following blunt abdominal trauma.[4–7] A Trauma Quality Improvement Program (TQIP) database study of 28,475 patients with blunt traumatic injuries demonstrated a decrease in mortality in obese patients, finding that a BMI of 31.5 kg/m$^2$ had the lowest incidence of mortality.[4] In a study of trauma outcomes following a motor vehicle collision, Arbabi et al[7] found that an overweight cohort (BMI between 25 and 30) of patients saw a significant decrease in ISS score and abdominal AIS score compared



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to the lean cohort. Fu et al[6] analyzed a total of 100,459 patients with blunt abdominal trauma (BAT) from the National Trauma Data Bank (NTDB) and found lower rates of gastrointestinal tract injury and abdominal operation rates in morbidly obese patients. Conventional thinking suggests that a "cushioning effect" should apply to abdominal injuries of a penetrating nature; however, the existing data are conflicting.[8–10]

Given the paucity and conflicting nature of available data, further examination of the relationship between obesity and penetrating injury is needed. The purpose of this study is to investigate if obese patients have different patterns of injury than non-obese patients in the setting of penetrating traumas. We hypothesized that a "cushioning effect" may mitigate serious injuries in obese individuals. The primary outcome assessed was mean Injury Severity Score (ISS). Secondary outcomes include Abbreviated Injury Scale (AIS) scores, in-hospital mortality, length of stay (LOS), intensive care unit (ICU) days, rates of organ injury, and intra-operative requirements.

## Materials and Methods

This study (Protocol number #18249) was approved by the Institutional Review Board of New York Medical College, Valhalla, New York and academic affiliate of our institution and was conducted at Richmond University Medical Center, Staten Island, New York, a Level 1 Trauma Center located in Staten Island, NY.

The objective of this study was to determine the association between BMI and hospital outcomes in the adult patients that sustained a penetrating trauma injury. Patients 18 years and older who presented to the trauma center with a penetrating stab injury or gunshot wound between 01 January 2008 and 31 December 2021 were included. Patients were excluded if they were under the age of 18, did not sustain a penetrating trauma, had non-knife related stab wounds (eg, glass, pencil, fork, needle), or presented with self-harm mechanism of injury. Additionally, patients were excluded if BMI or information necessary to calculate BMI (height and weight) was not available from the medical record. For the purposes of this study, patients were classified as those with BMI $< 30$ (non-obese) and BMI $\geq 30$ (obese). The primary outcome was Injury Severity Score (ISS). Secondary outcomes included intensive care unit (ICU) length of stay, days on ventilation, length of hospital stay, service of admission (trauma surgery, general surgery, discharged home, general medical floor), the body region of injury(s), Abbreviated Injury Scale (AIS), OR requirement, type of surgery, and discharge status. A secondary analysis was performed to account for the differences in mechanism of injury (gunshot wound vs stab wound).

Data were extracted from the electronic medical record system (EMR). Diagnoses were obtained from International Classification of Diseases (ICD) ICD-9 and ICD-10 codes. Operating room requirements were obtained via CPT (current procedural terminology) codes. Collected data points included, age, gender, BMI, mechanism of injury, height, and weight. Presence of organ injuries was identified using ICD codes and included liver laceration, kidney laceration, diaphragmatic laceration, stomach laceration, splenic laceration, small intestine perforation, large intestine perforation, bladder injury, cardiac laceration, lung contusion, and cerebral contusion. Intra-abdominal organ injuries were additionally divided between intra-abdominal solid organ (spleen, liver, kidney) injuries and intra-abdominal hollow organ (stomach, small intestine, large intestine, bladder) injuries. Intra-operative procedures performed, if applicable, were identified using CPT codes and included diagnostic laparoscopy, laparotomy, thoracotomy, craniotomy, pericardial window, tracheostomy, omental resection, small-bowel resection, large-bowel resection, colostomy, and intubation requirements.

## Statistical Analysis

Statistical analysis was carried out using IBM SPSS 28.0. Univariate analyses for continuous variables (ISS score, LOS, and ICU LOS) were compared using Student's *t*-test. The categorical variables of ISS $\geq 15$, any severe injury or area of injury (AIS $\geq 3$), laparoscopy requirement, laparotomy requirement, organ injury, intra-abdominal hollow organ injury, intra-abdominal solid organ injury, intestinal injury, and mortality were compared using $\chi^2$-test or Fisher's exact tests. A *p*-value of <0.05 was considered statistically significant. Measures of central tendency are reported as mean and standard deviation. Risks are expressed as odds ratios (OR) with 95% confidence intervals (CI). A secondary analysis was performed to investigate the association of BMI as an independent continuous variable with the clinical outcomes. Specifically, binary logistic regression models were used to test if BMI predicted adverse outcomes for categorical variables (ISS $\geq 15$, any severe injury or area of injury (AIS $\geq 3$), and operative outcomes), and linear regression models were used to test for associations with continuous outcomes (ISS score, LOS, ICU LOS).

## Power Analysis

An a priori power analysis based on data of Bloom et al[8] that evaluated the impact of obesity on outcomes of penetrating abdominal injuries was performed. The study found that the mean ISS score decreased with increasing BMI, noting a significant difference between normal (11.3 ± 8.2) and obese patients (8.6 ± 5.3). Based on these data, we estimate a medium–large effect size (cohen's $d = 0.39$). Assuming two-tailed test with at least 80% power and alpha of 0.05, a total number of 208 patients will be enough to provide a sample of sufficient power.

# Results

## Patient Demographics and Comorbidities

During the study period, 838 patients presented to the trauma center with penetrating injury, of which 721 met inclusion and exclusion criteria. Of these 721 patients, 74.9% (540/721) patients were classified in the non-obese group and 25.1% (181/721) patients in the obese group. Demographics are presented in Table 1. The mean age was 32.4 years old (SD = 11.1), and mean body mass index was 26.4 kg/m$^2$ (SD = 5.5 kg/m$^2$). The mean Injury Severity Score (ISS) was 9.3 (SD = 13.6). The frequencies of operating room requirements, types of organ injury, and injury severity are outlined in Table 1. Of the 838 patients, 603 patients were admitted to an inpatient service and had a mean length of stay of 3.9 days (SD = 7.3). A total of 164 patients required an intensive care unit (ICU) stay, with an average length of stay of 4.8 days (SD = 9.6). The hospital outcomes are presented in Table 1.

**Table 1** Patient Demographics and Outcomes

| Population Demographic | Frequency | Percentage (%) |
|---|---|---|
| **Sex** | | |
| *Male* | 649 | 90.0% |
| *Female* | 72 | 10.0% |
| **Race** | | |
| *Caucasian* | 101 | 14.0 |
| *Black* | 452 | 62.7 |
| *Asian* | 2 | 0.3 |
| *Hispanic/Latino* | 155 | 21.5 |
| *Native American* | 1 | 0.1 |
| *Native Hawaiian* | 1 | 0.1 |
| *Unspecified* | 9 | 1.2 |
| **Mechanism of Injury** | | |
| *Stab wound* | 458 | 63.5 |
| *Gunshot wound* | 263 | 36.5 |
| **Outcome** | | |
| *Dead* | 41 | 5.7 |
| *Admitted to intensive care unit* | 158 | 21.9 |
| **Injury Severity** | | |
| *Injury Severity Score (ISS) ≥ 15* | 152 | 21.1 |
| *Any one severe injury (AIS ≥ 3)* | 264 | 36.6 |
| *Severe head/neck injury (AIS ≥ 3)* | 26 | 3.6 |
| *Severe face injury (AIS ≥ 3)* | 25 | 3.5 |
| *Severe chest injury (AIS ≥ 3)* | 130 | 18.0 |
| *Severe abdominal injury (AIS ≥ 3)* | 92 | 12.8 |
| *Severe extremity/pelvic girdle injury (AIS ≥ 3)* | 75 | 10.4 |

(*Continued*)


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**Table 1** (Continued).

| Population Demographic | Frequency | Percentage (%) |
|---|---|---|
| **Procedure** | | |
| *Diagnostic Laparoscopy* | 28 | 3.9 |
| *Laparotomy* | 103 | 14.3 |
| *Thoracotomy* | 29 | 4.0 |
| *Craniotomy* | 2 | 0.3 |
| *Thoracostomy* | 116 | 16.1 |
| *Lung resection* | 5 | 0.7 |
| *Pericardial drainage/window* | 13 | 1.8 |
| *Splenectomy* | 5 | 0.7 |
| *Nephrectomy* | 1 | 0.1 |
| *Resection of small intestine* | 26 | 3.6 |
| *Resection of large intestine* | 16 | 2.2 |
| **Injuries** | | |
| *Any organ injury* | 133 | 18.4 |
| *Cerebral contusion/laceration* | 12 | 1.7 |
| *Spinal cord transection* | 4 | 0.6 |
| *Cardiac injury* | 17 | 2.4 |
| *Lung contusion* | 26 | 3.6 |
| *Diaphragmatic injury* | 17 | 2.4 |
| *Intra-abdominal solid organ injury* | 48 | 6.7 |
| *Liver laceration* | 33 | 4.6 |
| *Pancreatic injury* | 2 | 0.3 |
| *Splenic laceration* | 13 | 1.8 |
| *Kidney injury* | 10 | 1.4 |
| *Intra-abdominal hollow organ injury* | 67 | 9.3 |
| *Stomach injury* | 19 | 2.6 |
| *Small intestine injury* | 33 | 3.9 |
| *Large intestine injury* | 21 | 2.9 |
| *Rectum injury* | 5 | 0.7 |
| *Any intestinal injury* | 54 | 7.5 |
| *Bladder injury* | 3 | 0.4 |
| *Gallbladder injury* | 2 | 0.2 |

## BMI ≥ 30 (Injury Severity, Operating Room Requirements, Hospital Course)

The mean ISS scores were comparable between the non-obese and obese group (9.4 vs 9.0, $p = 0.724$). Similarly, none of the secondary outcomes measured reached statistical significance (Table 2). Non-obese patients had similar rates of severe abdominal injury based on AIS score (13.3% vs 11.0%, $p = 0.520$) compared to obese patients. There were no statistically significant differences in rates of hollow and solid organ injuries, or need for GI resection. Both non-obese and obese groups, respectively, had a similar length of hospital stay (3.71 days vs 4.38 days, $p = 0.284$) and ICU length of stay (4.42 days vs 6.20 days, $p = 0.330$).

## Secondary Analysis

A secondary analysis was performed to control for the mechanism of injury (stab wound vs gunshot wound). There were no statistically significant differences for outcomes between non-obese and obese patients when stratified by either gunshot wound or stab wound (Tables 3 and 4).

Binary logistic regression models were used to test if BMI predicted severe injury (ISS ≥ 15), AIS ≥ 3 in each body region, and adverse clinical outcomes (Table 5). The models indicated that BMI did not significantly predict any of the

**Table 2** Obese versus Non-Obese Patients

| Measure | BMI < 30 (N = 540) | BMI ≥ 30 (N = 181) | OR | 95% CI of OR | p-value |
|---|---|---|---|---|---|
| Severe injury (ISS≥15) | 115 (21.3%) | 37 (20.4%) | 0.95 | 0.63–1.44 | 0.83 |
| Mean ISS score | 9.4 | 9.0 | – | – | 0.72 |
| *Rates of severe injury and location (AIS≥3)* | | | | | |
| Any one severe injury (AIS≥3) | 197 (36.5%) | 67 (37.0%) | 1.02 | 0.72–1.45 | 0.93 |
| Any severe head/neck injury (AIS≥3) | 17 (3.1%) | 9 (5.0%) | 1.61 | 0.71–3.68 | 0.26 |
| Any severe face injury (AIS≥3) | 16 (3.0%) | 9 (5.0%) | 1.71 | 0.74–3.95 | 0.24 |
| Any severe chest injury (AIS≥3) | 92 (17.0%) | 38 (21.0%) | 1.29 | 0.85–1.97 | 0.26 |
| Any severe abdominal injury (AIS≥3) | 72 (13.3%) | 20 (11.0%) | 0.81 | 0.48–1.37 | 0.52 |
| Any severe extremity or pelvic girdle injury (AIS ≥3) | 56 (10.4%) | 19 (10.5%) | 1.01 | 0.59–1.76 | 0.99 |
| Required operating room | 213 (39.4%) | 74 (40.9%) | 1.06 | 0.75–1.50 | 0.73 |
| *Operating room findings* | | | | | |
| Diagnostic laparoscopy | 21 (3.9%) | 7 (3.9%) | 0.99 | 0.42–2.38 | 0.99 |
| Laparotomy | 79 (14.6%) | 24 (13.3%) | 0.89 | 0.55–1.46 | 0.71 |
| Any organ injury | 104 (19.3%) | 29 (16.0%) | 0.80 | 0.51–1.26 | 0.38 |
| Intra-abdominal hollow organ injury | 52 (9.6%) | 15 (8.3%) | 0.85 | 0.47–1.55 | 0.66 |
| Intra-abdominal solid organ injury | 39 (7.2%) | 9 (5.0%) | 0.67 | 0.32–1.42 | 0.39 |
| Any intestinal injury | 41 (7.6%) | 13 (7.2%) | 0.94 | 0.49–1.80 | 0.99 |
| Length of stay (mean, days) | 3.71 | 4.38 | – | – | 0.28 |
| Required ICU stay | 122 (22.6%) | 36 (19.9%) | 0.85 | 0.56–1.29 | 0.47 |
| Length of ICU stay (mean, days) | 4.42 | 6.20 | – | – | 0.33 |
| Mortality, dead | 30 (5.6%) | 11 (6.1%) | 1.10 | 0.54–2.24 | 0.85 |

**Table 3** Stab Wounds Only

| Measure | BMI < 30 (N = 348) | BMI ≥ 30 (N = 110) | OR | 95% CI of OR | p-value |
|---|---|---|---|---|---|
| Severe injury (ISS ≥ 15) | 38 (10.9%) | 12 (10.9%) | 1 | 0.50–1.99 | 0.99 |
| Mean ISS score | 6.6 | 6.7 | – | – | 0.95 |
| *Rates of severe injury and location (AIS≥3)* | | | | | |
| Any one severe injury (AIS≥3) | 86 (24.7%) | 30 (27.3%) | 1.14 | 0.70–1.86 | 0.62 |
| Any severe head/neck injury (AIS≥3) | 6 (1.7%) | 4 (3.6%) | 2.15 | 0.60–7.77 | 0.26 |
| Any severe face injury (AIS≥3) | 3 (0.9%) | 1 (0.9%) | 1.06 | 0.11–10.25 | 0.96 |
| Any severe chest injury (AIS≥3) | 52 (14.9%) | 20 (18.2%) | 1.27 | 0.72–2.23 | 0.45 |
| Any severe abdominal injury (AIS≥3) | 30 (8.6%) | 7 (6.4%) | 0.72 | 0.31–1.69 | 0.55 |
| Any severe extremity or pelvic girdle injury(AIS≥3) | 12 (3.4%) | 6 (5.5%) | 1.62 | 0.59–4.41 | 0.40 |
| Required operating room | 125 (35.9%) | 36 (32.7%) | 0.87 | 0.55–1.37 | 0.57 |
| *Operating room findings* | | | | | |
| Diagnostic laparoscopy | 21 (6.0%) | 6 (5.5%) | 0.90 | 0.35–2.29 | 0.82 |
| Laparotomy | 42 (12.1%) | 9 (8.2%) | 0.65 | 0.31–1.38 | 0.30 |
| Any organ injury | 53 (15.2%) | 10 (9.1%) | 0.56 | 0.27–1.14 | 0.11 |
| Intra-abdominal hollow organ injury | 21 (6.0%) | 3 (2.7%) | 0.44 | 0.13–1.49 | 0.22 |
| Intra-abdominal solid organ injury | 18 (5.2%) | 4 (3.6%) | 0.69 | 0.23–2.09 | 0.51 |
| Any intestinal injury | 15 (4.3%) | 3 (2.7%) | 0.62 | 0.18–2.19 | 0.46 |
| Length of stay (mean, days) | 2.72 | 2.15 | – | – | 0.24 |
| Required ICU stay | 68 (19.5%) | 17 (15.5%) | 0.75 | 0.42–1.35 | 0.40 |
| Length of ICU stay (mean, days) | 3.93 | 1.87 | – | – | 0.26 |
| Mortality, dead | 6 (1.7%) | 2 (1.8%) | 1.06 | 0.21–5.31 | 0.95 |

**Table 4** Gunshot Wounds Only

| **Measure** | **BMI < 30 (N = 192)** | **BMI ≥ 30 (N = 71)** | **OR** | **95% CI of OR** | **p-value** |
|---|---|---|---|---|---|
| Severe injury (ISS ≥ 15) | 77 (40.1%) | 25 (35.2%) | 0.81 | 0.46–1.43 | 0.57 |
| Mean ISS score | 14.59 | 12.71 | – | – | 0.41 |
| *Rates of severe injury and location (AIS≥3)* | | | | | |
| Any one severe injury (AIS≥3) | 111 (57.8%) | 37 (52.1%) | 0.79 | 0.46–1.37 | 0.48 |
| Any severe head/neck injury (AIS≥3) | 11 (5.7%) | 5 (7.0%) | 1.25 | 0.42–3.72 | 0.77 |
| Any severe face injury (AIS≥3) | 13 (6.8%) | 8 (11.3%) | 1.75 | 0.69–4.42 | 0.30 |
| Any severe chest injury (AIS≥3) | 40 (20.8%) | 18 (25.4%) | 1.29 | 0.68–2.44 | 0.50 |
| Any severe abdominal injury (AIS≥3) | 42 (21.9%) | 13 (18.3%) | 0.80 | 0.40–1.60 | 0.61 |
| Any severe extremity or pelvic girdle injury (AIS≥3) | 44 (22.9%) | 13 (18.3%) | 0.75 | 0.38–1.50 | 0.50 |
| Required operating room | 88 (45.8%) | 38 (53.5%) | 1.36 | 0.79–2.35 | 0.33 |
| *Operating room findings* | | | | | |
| Diagnostic laparoscopy | 0 (0.0%) | 1 (0.3%) | – | – | 0.27 |
| Laparotomy | 37 (19.3%) | 15 (21.1%) | 1.12 | 0.57–2.20 | 0.73 |
| Any organ injury | 51 (26.6%) | 19 (26.8%) | 1.01 | 0.55–1.87 | 0.99 |
| Intra-abdominal hollow organ injury | 31 (16.1%) | 12 (16.9%) | 1.06 | 0.51–2.19 | 0.85 |
| Intra-abdominal solid organ injury | 21 (10.9%) | 5 (7.0%) | 0.62 | 0.22–1.70 | 0.49 |
| Any intestinal injury | 26 (13.5%) | 10 (14.1%) | 1.05 | 0.48–2.30 | 0.99 |
| Length of stay (mean, days) | 5.49 | 7.83 | – | – | 0.10 |
| Required ICU stay | 63 (32.8%) | 22 (31.0%) | 0.92 | 0.51–1.65 | 0.88 |
| Length of ICU stay (mean, days) | 4.98 | 9.30 | - | - | 0.16 |
| Mortality, dead | 24 (12.5%) | 9 (12.7%) | 1.02 | 0.45–2.31 | 0.99 |

**Table 5** Logistic Regression Analysis with BMI as Continuous Variable, Categorical Outcomes

| **Measure** | **OR** | **95% CI of OR** | **p-value** |
|---|---|---|---|
| Severe injury (ISS ≥ 15) | 0.99 | 0.96–1.03 | 0.78 |
| Any severe head/neck (AIS≥3) | 1.03 | 0.97–1.10 | 0.39 |
| Any severe face injury (AIS≥3) | 1.04 | 0.99–1.09 | 0.15 |
| Any severe chest injury (AIS≥3) | 1.02 | 0.99–1.06 | 0.21 |
| Any severe abdominal (AIS≥3) | 0.98 | 0.94–1.03 | 0.44 |
| Any severe extremity injury or pelvic girdle (AIS≥3) | 0.99 | 0.98–1.03 | 0.54 |
| Required operating room | 1.01 | 0.98–1.03 | 0.82 |
| Diagnostic laparoscopy | 0.99 | 0.93–1.07 | 0.90 |
| Laparotomy | 0.99 | 0.96–1.04 | 0.96 |
| Any organ injury | 0.97 | 0.93–1.00 | 0.73 |
| Intra-abdominal hollow organ injury | 0.97 | 0.92–1.02 | 0.16 |
| Intra-abdominal solid organ injury | 0.97 | 0.91–1.02 | 0.23 |
| Any intestinal injury | 0.96 | 0.91–1.02 | 0.16 |
| Required ICU stay | 0.99 | 0.96–1.03 | 0.42 |
| Mortality, dead | 1.03 | 0.97–1.08 | 0.38 |

outcomes. Linear regression models were used to test if BMI significantly predicted LOS, ICU LOS, and ISS score. The models showed the BMI poorly correlated with the three outcome variables (see Table 6), and each of the regression models generated was not statistically significant.

**Table 6** Linear Regression Analysis with BMI as a Continuous Variable, Continuous Outcomes

| | Regression Equation | R Square | F Statistic | Beta Coefficient | p-value |
|---|---|---|---|---|---|
| LOS | y = 0.004x + 2.96 | 0.001 | F(1718) = 0.49 | 0.03 | 0.481 |
| ICU LOS | y = 0.13x + 1.48 | 0.007 | F(1156) = 1.09 | 0.08 | 0.297 |
| ISS Score | y = - 0.04x + 10.36 | 0.001 | F(1718) = 0.19 | −0.02 | 0.666 |

## Discussion

In our study of 721 patients presenting with stab or gunshot penetrating traumas, 25.1% of our penetrating trauma patients have obesity, which is below both the current New York State rate of 29.1% and the current national rate of 33.9%.[10] Injuries from all body regions were included, not just the abdomen, as in several other studies.[7–9,11] Many previous studies looked at the cushioning effect in the context of abdominal traumas. However, we elected to use ISS as the primary outcome because body fat distribution is complex in obese patients. Depending on gender and/or genetic factors, adiposity can be primarily upper or lower body. ISS allowed us to assess for a total body "cushioning effect". AIS scores as secondary measures provided additional analysis if certain areas were more protective than others. We found that obesity was not protective for our primary outcome of mean ISS score. Secondary outcomes measured, including AIS scores for each body region, mortality, laparotomy requirement, length of stay, and ICU length of stay, also yielded similar, non-statistically significant results between obese and non-obese populations.

We originally hypothesized that the cushioning effect may apply to the obese population because of the improved mortality seen in blunt abdominal trauma (BAT)[4–7] and smaller studies of penetrating injuries that looked at one body region (abdomen or thorax) or one mechanism of injury (stab or gunshot wound).[7–9,11] The cushioning effect has been well-demonstrated with obesity and trauma, particularly with motor vehicle collisions (MVC) and BAT.[4–7] In addition, the following smaller and more focused studies demonstrated improved injury patterns in obese populations with penetrating traumas, supporting our original hypothesis. Bloom et al[8] stratified 249 abdominal stab wound patients into four BMI groups, and demonstrated decreased rates of visceral injury and therapeutic operation with increasing BMI. Similarly, Patel et al[9] stratified 40 abdominal gunshot wound patients from an urban Level Two Trauma Center into four BMI groups, and found that obese patients were significantly less likely to have abdominal fascial penetration and fewer mean visceral injuries compared to overweight and normal-weight cohorts. These studies support the existence of a cushioning effect, demonstrating a correlation between obesity and improved injury outcomes in blunt abdominal trauma and certain penetrating injuries.

Despite the above data supporting a "cushioning effect" in certain mechanisms of traumatic injury, our study did not demonstrate its existence in the context of penetrating injuries. In line with our findings, Hsiao et al[10] found that with 100 abdominal stab wound patients there were no statistically significant differences between the types of intra-abdominal organ injuries or GI resection requirement between obese and non-obese patients. Similarly, a TQIP database study (2013–2017) of 2616 adult patients aged $\geq$ 16 presenting with an isolated abdominal gunshot injury found similar AIS scores, ISS score, and intra-abdominal organ injury for obese versus non-obese patients.[12] Interestingly, this study also found that the obese patients had a significantly higher mortality rate, longer hospital length of stay, more ventilator days, and higher incidence of hospital-acquired pneumonia. This was different from our findings, as we observed no difference in mortality, LOS, or ICU LOS between our obese and non-obese patients. Another large national database study of adolescent patients found similar rates of severe injury, operative intervention, and mortality following abdominal penetrating trauma, regardless of obesity status. Interestingly, the authors noted that adolescents with obesity following an isolated thoracic gunshot wound had a lower rate of severe injury.[13]

We speculate that the disappearance of the cushioning effect in penetrating traumas can be attributed to a few different factors. One possibility is that the devastating nature of these injuries negates any protection that increased body habitus or "cushioning" may offer. In blunt traumas, the adiposity may act as a true "cushion" by absorbing the energy transferred on impact. However, even in blunt traumas, the protective element is not demonstrated with consistency. A study showed that the ideal "cushioning" effect was demonstrated in the category of BMI in the range 25–30.[14] With more obese patients, it is possible that an increase in body mass and resulting momentum overrides any protective element. Whereas in injuries of a penetrating nature, the prevention of severe injuries lies not in the absorption of energy, but more in the ability to stop energy or the projectile. We posit that projectiles (bullets and stab injuries) ruin the integrity of the cushion upon impact and thus any ability to provide additional protection. Another possibility is that BMI is not the best measure of adiposity in patients as it does not characterize the distribution and location of body fat. Future studies investigating waist circumference and outcomes in penetrating trauma patients may portray the "cushioning effect" more definitively. Finally, the previous studies that have examined the effect of penetrating traumas on body habitus are either small, drawn from large national databases, or examine limited outcomes, thus limiting their generalizability.[4,6–8,10–12]

Based on our data, there was no difference in outcomes between obese and non-obese patients suffering from penetrating traumas of a stab or gunshot wound nature. We recommend that obese and non-obese patients should be evaluated similarly, and serial abdominal examinations for all patients that do not require immediate laparotomy. Future studies involving multi-center sample sizes, and use of more accurate measures of body habitus and fat distribution may better delineate the existence of a "cushioning effect" in penetrating traumas.

## Strengths and Limitations

Strengths of our study include a high volume of ethnically diverse trauma patients presenting with penetrating injuries at an urban Level 1 Trauma Center in New York City. According to the New York State Trauma Registry that reported data between the dates of 01/01/2014 and 12/31/2015, our service area, Richmond County, has the 3rd highest annual cut/pierce trauma incidence and the 6th highest annual firearm trauma incidence in the State (of 62 New York counties).[15] In addition, our study is well powered and larger than previous single-center studies examining similar outcomes in penetrating trauma. Although other large national database studies have examined similar outcomes,[12,13] limitations of large registry studies apply, including high variability of data collection, limited follow-up, and different strategies across databases for patient sampling. Our study has its own limitations inherent to a single-institution retrospective study. Due to the large quantity of data being gathered from electronic medical records, information bias due to inadequate charting or follow-up at other institutions could have skewed our analyses.

## Conclusions

This study did not demonstrate the existence of a "cushioning effect" in the setting of penetrating traumatic injury. Patients with increased BMI had similar ISS scores and patterns of injury as their non-obese counterparts. Future studies should focus on better assessments of measured adiposity, such as waist circumference.

## Abbreviations

AIS, Abbreviated Injury Score; BMI, body mass index; CPT, current procedure terminology; EMR, electronic medical record; ICD, International Disease Classification; ICU, intensive care unit; ISS, Injury Severity Score; LOS, length of stay; MVC, motor vehicle collision; NTDB, National Trauma Data Base; OR, odds ratio; TQIP, Trauma Quality Improvement Program.

## Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Ethics Approval

Institutional Review Board approval (Protocol number #18249) was obtained from New York Medical College, Valhalla, New York, United States. All methods were performed in accordance with the ethical standards as laid down in the Declaration of Helsinki and its later amendments or comparable ethical standards.

## Consent to Participate

IRB granted waiver of informed consent as study protocol met the criteria for waiving consent or altering the elements of consent in minimal risk studies. All data were de-identified and kept in a secure location that was only accessible to study personnel.

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## Disclosure

The authors report no competing interests in this work.

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