Trauma Surgery & Acute Care Open

# Subcutaneous and visceral fat are associated with worse outcomes in gunshot injuries but not stab injuries to the torso

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► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/tsaco-2022-001072).

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Received 8 December 2022
Accepted 28 July 2023

**To cite:** Mejias C, Hoegger M, Snyder J, *et al*. *Trauma Surg Acute Care Open* 2023;**8**:e001072.

## ABSTRACT

**Purpose** The effect of obesity in penetrating trauma outcomes is poorly understood. The purpose of this study was to determine if there is a protective effect of subcutaneous or visceral fat from stab and gunshot wounds.

**Methods** 443 patients admitted after penetrating traumatic injury of the torso were retrospectively identified from our institution's trauma registry. CT scans performed at presentation were used to determine cross-sectional area of visceral and subcutaneous fat at the level of the umbilicus via manual segmentation. Obesity-associated parameters including body mass index, visceral and subcutaneous fat were compared with injury severity score, length of hospital/intesive care unit (ICU) stay, and number of operating room (OR) visits. Parameters were compared between patients who sustained stab wounds versus gunshot injuries.

**Results** Comparing all patients with gunshot injuries with those with stab injuries, gunshots resulted in increased hospital and ICU length of stay, and injury severity score (ISS). For patients with gunshot wounds, all obesity-related parameters correlated with increased length of stay and total ICU stay; subcutaneous fat and visceral fat were correlated with increased OR visits, but there was no significant correlation between obesity-related parameters and ISS. In contrast, with stab wounds there were no statistically significant associations between obesity parameters and any of the outcome measures.

**Conclusion** For penetrating trauma in the torso, obesity is correlated with worse outcomes with gunshot injuries but not in stab injuries.

**Level of evidence** Level III, prognostic and epidemiological.

### WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ The effect of obesity in penetrating trauma is controversial.
- ⇒ It is established that in patients requiring laparotomy, obesity leads to worse outcomes, but studies differ on the effects of obesity in penetrating trauma in general.

### WHAT THIS STUDY ADDS

- ⇒ Obesity leads to worse outcomes in gunshot injuries, but not in stab injuries.

### HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ This study could help emergency and trauma physicians in the emergency setting to more accurately risk stratify victims of penetrating trauma based on their body composition.

## INTRODUCTION

The prevalence of obesity (defined as body mass index (BMI) >30) in the USA has steadily risen over time and the current prevalence in US adults is 38.9%.[1] Obesity is associated with a number of comorbidities resulting in significant medical costs.[2]

The effect of obesity in penetrating trauma is controversial with several studies finding no effect on outcomes.[3–5] However, one study found worse outcomes in patients with obesity requiring laparotomy for trauma,[6] and another found higher mortality and worse outcomes in patients with obesity sustaining gunshot wounds.[7] Another study found decreased need for operation in young patients with obesity sustaining penetrating trauma.[8] One study found decreased morbidity in gunshot victims with obesity,[9] and another found a protective effect of obesity in stab wound victims.[10] Additionally, obesity has long been established as an independent risk factor for complications after laparotomy.[11 12]

Previous studies regarding the effects of body habitus on penetrating trauma outcomes have been based on BMI,[3–5] however BMI is an imperfect measure of body adipose tissue and does not account for fat distribution.[13 14] In this study, we sought to correlate outcomes in admitted penetrating trauma patients using fat quantification based on abdominal CT scans. This has the advantage of accurately measuring adipose tissue, and also distinguishing between subcutaneous and visceral fat. A larger quantity of subcutaneous fat could potentially impede peritoneal violation by reducing depth of knife penetration or absorbing the kinetic energy of a projectile. Visceral fat has been previously shown to correlate more with metabolic syndrome and insulin resistance than BMI or subcutaneous fat.[15] Patients with metabolic syndrome have been shown to have worse outcomes in the postoperative setting.[16] We hypothesize that outcomes in penetrating trauma would be more strongly influenced by distribution of abdominal fat than BMI.

## METHODS

After receiving internal review board exemption, 648 patients admitted with penetrating trauma to the torso at our urban level 1 trauma center from November 17, 2014 to November 26, 2019 were identified from the prospectively maintained trauma registry. Patients were only included if they underwent CT of the abdomen and pelvis and sustained penetrating trauma.

Outcome measures were collected from the database and from retrospective chart review. Injury severity score (ISS) was our primary outcome. Secondary outcomes were hospital length of stay, intensive care unit (ICU) stay, and number of OR visits.

For fat quantification, we used the free web-based analytic software CoreSlicer[17] to determine the amount of subcutaneous and visceral fat. Each CT scan was deidentified and saved as a DICOM file, then uploaded to the web-based toolkit. The trans-axial series was selected and multiplanar reconstruction was used to identify the desired slice at the level of the umbilicus (figure 1A). Visceral and subcutaneous fat were manually segmented and the cross-sectional areas saved for analysis (figure 1B). A threshold of −190 to −30 HU was used to determine which areas represented fat. This segmentation was performed by a postgraduate year 3 radiology resident under the supervision of an attending abdominal radiologist. This software was previously validated by having two non-radiologists perform segmentation on a set of 50 CT scans to measure interobserver variability. The mean error was 0.2 $cm^2$ and 1.2 $cm^2$ for visceral and subcutaneous fat, respectively and the maximum error was 8 $cm^2$. The software was also validated against existing commercial software.[17]

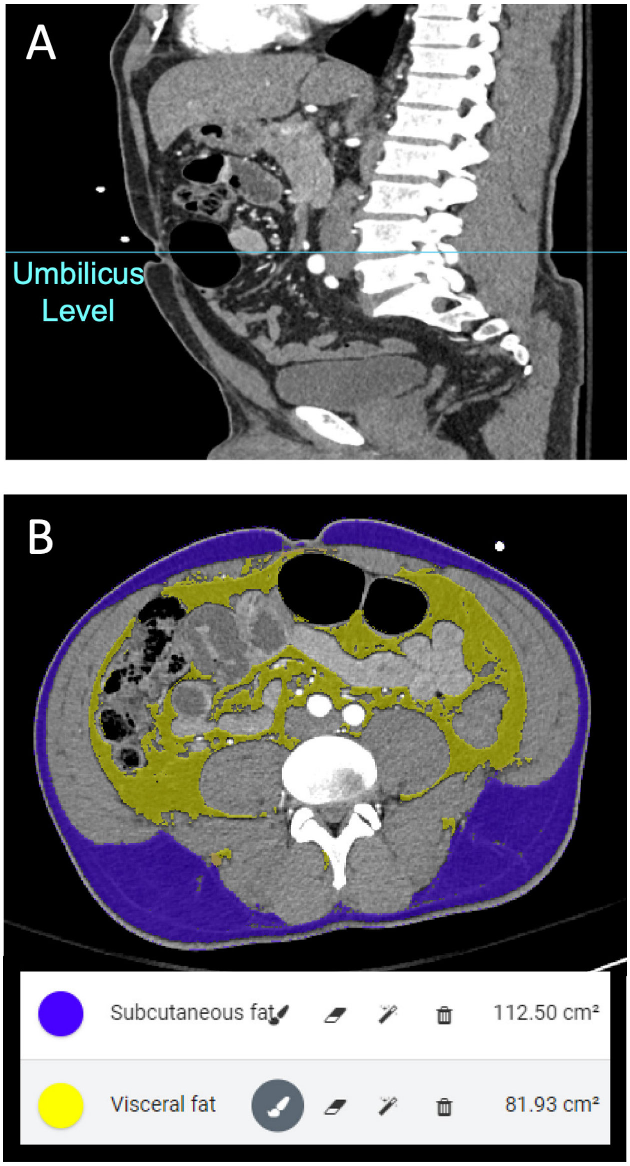

**Figure 1** Segmentation of subcutaneous and visceral fat at the level of the umbilicus. (A) Using the CoreSlicer interface, an axial slice was selected at the level of the umbilicus. (B) Subcutaneous (blue) and visceral (yellow) fat was manually segmented at the level of the umbilicus yielding an area ($cm^2$).

Patients were stratified according to injury mechanism—either gunshot wounds or stab wounds. Unpaired Student's t-test was performed for mean comparison between gunshot and knife injury groups. Linear regression was performed with ISS, hospital length of stay, ICU length of stay and number of OR visits as dependent variables and BMI, visceral and subcutaneous fat as independent variables. The results were reported as $R^2$ (1.0=perfect fit, −1.0=negative association, and 0=no association). For secondary outcomes, multiple linear regression was performed controlling for ISS. Statistical significance was met at $p<0.05$ and the Holm-Bonferroni method was used to correct for multiple comparisons.[18] Unless otherwise indicated, data are presented as median with IQR. Data analysis was performed using GraphPad Prism V.9.0.2 (La Jolla, California, USA) and R Studio V.2022.12.0+353.

## RESULTS

Six hundred forty-eight patients were initially identified from the prospectively maintained trauma registry. Patients who underwent laparotomy prior to their initial CT were excluded as postsurgical changes could interfere with the fat quantification software. One hundred thirty-two patients were therefore excluded due to laparotomy occurring before a CT was obtained (123 gunshot wounds, 9 stab wounds). Twenty-eight cases were excluded due to no CT being performed or available, nine cases were excluded because the penetrating injury did not involve the torso, nine cases were excluded due to being misclassified in the original database, and one patient was excluded due to being pregnant (which made quantification of the visceral fat unreliable). A total of 469 patients were included in the analysis. Three hundred ninety-two patients with gunshot wounds met inclusion criteria and 77 patients with stab wounds met criteria. This is summarized via a Consolidated Standards of Reporting Trials diagram in figure 2. Demographic information and outcome measures are summarized in table 1.

There was no difference between the gunshot and knife injury groups when BMI, subcutaneous fat, or visceral fat were compared. However, there were significantly worse outcomes in the gunshot cohort compared with the stab wound cohort including increased number of OR visits, increased hospital total length of stay, increased ICU stay, and increased ISS.

To ensure that body habitus parameters demonstrated internal correlation, we performed a Pearson's correlation test between BMI, subcutaneous fat, and visceral fat. All demonstrated a strong correlation and specific values are summarized in table 2.

The correlation values for body habitus measures and outcome measures were calculated and are summarized in table 3. For patients with gunshot wounds, higher BMI, higher subcutaneous fat, and higher visceral fat were all weakly, but significantly associated with increased length of stay, and total ICU stay. Subcutaneous fat and visceral fat were associated with increased number of OR visits. There was no significant association of body habitus with ISS.

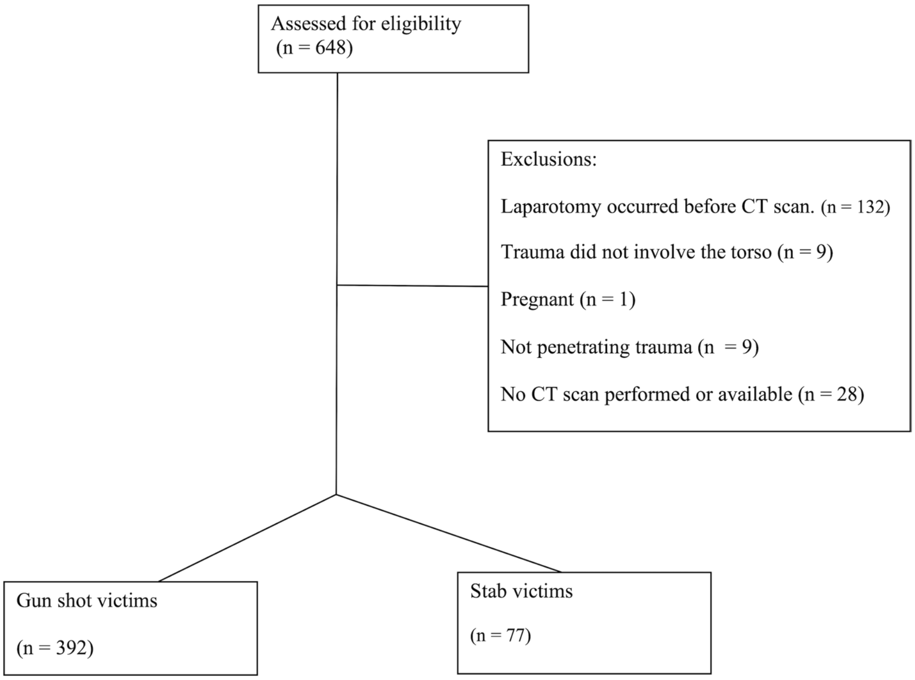

**Figure 2** Consolidated Standards of Reporting Trials diagram for patient selection.

For patients with stab wounds, there was no significant association between visceral fat, subcutaneous fat, or BMI with ISS, total length of stay, ICU length of stay, or number of OR visits.

## DISCUSSION

Previous research has focused on the effect of BMI on outcomes in trauma patients with some studies finding no significant effect,[3–5] but at least one study finding worse outcomes with patients with obesity requiring laparotomy after trauma,[6] another study finding worse outcomes in patients with obesity sustaining gunshot wounds,[7] and three finding a protective effect of obesity in penetrating trauma.[8–10] In addition to using BMI, we sought to use CT-based fat quantification to more accurately assess body adipose tissue. Additionally, we sought to separate the effects of subcutaneous fat and visceral fat in patients with stab wounds and gunshot wounds.

Various mechanisms have been proposed for the effect of obesity on penetrating trauma. It has been suggested that subcutaneous fat could act as a cushion and a barrier—increasing the distance needed to travel before damaging internal organs and also dissipating the force,[3] however, we were not able to demonstrate a protective effect of subcutaneous fat in gunshot or stab injuries. This could be in part because our registry data only included admitted patients. We are therefore unable to make conclusions about people who sustained penetrating injuries that were not severe enough to require hospitalization. It is possible that high levels of subcutaneous fat reduce the chances of being hospitalized after a stab wound. However, a different study design would be needed to answer this question as our data only included admitted patients.

**Table 1** Demographic characteristics of the 443 patients included in the study sample

|  | All patients (n=469) | Gunshot injury (n=392) | Stab injury (n=77) | Compare gunshot and knife with Holm-Bonferroni corrected p value |
|---|---|---|---|---|
| Age (years) | 28 (23–37) | 28 (23–37) | 30 (24–41) | 0.006** |
| Gender | Male: 413<br>Female: 56 | Male: 353<br>Female: 39 | Male: 60<br>Female: 17 |  |
| BMI (kg/m$^2$) | 2 5 (22–29) | 25 (22–29) | 25 (22–31) | 0.144<br>N.S. |
| Subcutaneous fat (cm$^2$) | 135 (52–321) | 133 (48–303) | 174 (66–383) | N.S. |
| Visceral fat (cm$^2$) | 31 (11–84) | 29 (10–76) | 63 (18–106) | N.S. |
| Total length of stay (days) | 5 (2–9) | 5 (2–10) | 2 (1–3) | <0.001*** |
| Total ICU stay (days) | 0 (0–3) | 0 (0–3) | 0 (0–0) | <0.001*** |
| Injury severity score | 11 (5–20) | 13 (9–24) | 5 (1–10) | <0.001*** |
| Number of OR visits | 1 (0–1) | 1 (0–2) | 1 (0–1) | <0.001*** |

Mean comparison of gunshot and knife injury is with Student's t-test.
** <0.01
*** <0.001
BMI, body mass index; ICU, intensive care unit; N.S., statistical significance not reached.

**Table 2** Correlation between BMI, subcutaneous fat, and visceral fat

| | R correlation |
|---|---|
| BMI versus subcutaneous fat | 0.79 (p<0.00001) |
| BMI versus visceral fat | 0.72 (p<0.00001) |
| Subcutaneous fat versus visceral fat | 0.68 (p<0.00001) |

BMI, body mass index.

For gunshot wounds, a bullet is able to pierce the subcutaneous fat with less resistance. Furthermore, obesity is known to lead to poorer outcomes in open surgery,[19] as well as being associated with a number of comorbidities. In our data, higher amounts of subcutaneous and visceral fat as well as BMI were associated with poorer outcomes for gunshot wounds.

At least one previous study that analyzed the effect of obesity in penetrating trauma demonstrated no overall effect on morbidity,[20] however this study did not separate cases by mechanism of injury or quantify body fat. In our analysis, increased body fat had different effects in patients with gunshot wounds and stab wounds. Although stab wounds and gunshot wounds are often grouped together under the broad heading of penetrating trauma, our findings show that gunshot wounds are more severe and that body habitus has different implications, depending on trauma mechanism. The relationship between body habitus and trauma is complex and not simply related to potential effects of adipose distribution. However, in a resource-limited situation such as a mass casualty event, having additional data to help stratify acuity may prove helpful.

A limitation of our study was the exclusion of patients who underwent exploratory laparotomies prior to receiving a CT scan. Postsurgical changes including the presence of open wounds, packing material, and postsurgical edema make accurate fat quantification challenging. BMI data are unaffected by surgery, so previous studies based on BMI were able to include these cases. In a retrospective review of 10 987 trauma patients receiving laparotomies, BMI was associated with increased mortality, ICU, and hospitalization length of stay.[5] That review included both blunt and penetrating trauma, however, subgroup analysis for penetrating trauma was not performed. Our study is therefore unable to make conclusions about injuries severe enough to require immediate laparotomy.

In this study, we analyzed the effects of BMI, subcutaneous fat, and visceral fat in a linear fashion. Some prior studies have analyzed BMI in a stratified fashion, for instance, distinguishing between normal weight patients, overweight patients, and patients with obesity.[7] Stratification has the advantage of being able to detect non-linear effects, for instance, a moderate amount of fat may be protective, but too much could be detrimental. Some preliminary attempts at creating cut-off values for adiposity based on fat quantification have been made, however, they have not yet been fully validated or widely used.[21] Additionally, due to our relatively small sample size, creating multiple subgroups would reduce statistical power.

For our fat quantification method, we used the area of subcutaneous fat at the umbilicus based on CT, however, subcutaneous fat can be asymmetrically distributed around the abdomen. We considered a more targeted measurement, assessing adiposity at the site of injury, however, it is sometimes challenging to localize the exact site of injury, especially when there are multiple injuries. Additionally, measuring depth of subcutaneous fat creates subjectivity in measurement depending on the exact location chosen and the angle of measurement. Thus, our research did not provide this level of granularity, however, this could be a topic for future research. Area of subcutaneous fat has been previously validated as a reliable and reproducible measurement in prior work.[22 23]

## CONCLUSION

In patients admitted to our trauma center, higher BMI, subcutaneous fat, and visceral fat were associated with worse outcomes in patients sustaining gunshot wounds but not in patients sustaining stab wounds.

**Table 3** Correlation between visceral fat, subcutaneous fat, and BMI with outcome measures

| | ISS | Holm-Bonferroni corrected p value | Total LOS | Holm-Bonferroni corrected p value | Total ICU stay | Holm-Bonferroni corrected p value | Number OR visits | Holm-Bonferroni corrected p value |
|---|---|---|---|---|---|---|---|---|
| GSW visceral fat | −0.02036 | N.S. | **0.240** | <0.001*** | **0.3013** | <0.001*** | **0.1533** | 0.0058* |
| GSW subcutaneous fat | −0.01913 | N.S. | **0.201** | <0.001*** | **0.2569** | <0.001*** | **0.1499** | 0.0075* |
| GSW BMI | 0.00319 | N.S. | **0.212** | <0.001*** | **0.267** | <0.001*** | 0.122 | N.S. |
| Stab visceral fat | −0.239 | N.S. | −0.1155 | N.S. | −0.1441 | N.S. | −0.1021 | N.S. |
| Stab subcutaneous fat | −0.2729 | N.S. | −0.3322 | N.S. | −0.1846 | N.S. | −0.1755 | N.S. |
| Stab BMI | −0.259 | N.S. | −0.1073 | N.S. | −0.1337 | N.S. | −0.06063 | N.S. |

*P<0.05.
**P<0.01.
***P<0.001.
Statistically significant results are in bold (positive correlation).
BMI, body mass index; GSW, gunshot wound; ISS, injury severity score; LOS, length of stay; N.S., statistical significance not reached.

**Contributors** VM conceived of the study design, obtained the data, contributed to the writing and revision process and is the guarantor. CM cleaned the data, performed segmentation of abdominal CTs to obtain subcutaneous and visceral fat area, contributed to the statistical methods, and contributed to the writing and revision process. MH performed the statistical analyses, contributed to the methodology, and contributed to the writing and revision process. JS contributed to the methodology and the writing and revision process. CR contributed to the writing and revision process.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent for publication** Not applicable.

**Ethics approval** This study involves human participants and was approved by the Barnes Jewish Hospital Institutional Review Board (ID#201912102). This was a retrospective study using anonymized data.

**Provenance and peer review** Not commissioned; internally peer reviewed.

**Data availability statement** Data are available on reasonable request.

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