

# Protective Role of Obesity on Trauma Impact: A Retrospective Analysis of Patients with Surgical Blunt Bowel Mesenteric Injury Due to Road Traffic Accidents

Ting-Min Hsieh<sup>1</sup>, Po-Chun Chuang<sup>2</sup>, Chun-Ting Liu<sup>3</sup>, Bei-Yu Wu<sup>3</sup>, Yueh-Wei Liu<sup>4,\*</sup>, Ching-Hua Hsieh<sup>5,\*</sup>

<sup>1</sup>Division of Trauma, Department of Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan; <sup>2</sup>Department of Emergency, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan; <sup>3</sup>Department of Chinese Medicine, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan; <sup>4</sup>Division of General Surgery, Department of Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan; <sup>5</sup>Division of Plastic Surgery, Department of Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan

\*These authors contributed equally to this work

Correspondence: Yueh-Wei Liu; Ching-Hua Hsieh, Division of General Surgery, Department of Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan, Tel +886-7-7317123 ext. 8002; +886-7-7317123 ext. 8001, Email [anthony0612@adm.cgmh.org.tw](mailto:anthony0612@adm.cgmh.org.tw); [m93chinghua@gmail.com](mailto:m93chinghua@gmail.com)

**Background:** The “cushion effect” theory proposes that increased body mass index (BMI) is associated with less severe abdomen injury following blunt abdomen trauma, while the “obesity paradox” describes the protective effect of obesity against mortality. However, most previous studies used the abdominal abbreviated injury scale as the outcomes seemed to be inadequate owing to the injuries to the abdominal organs, such as the spleen and liver, which may be attributable to the force that caused the chest trauma. This study aimed to use adult trauma patients with surgical blunt bowel mesenteric injuries (BBMIs) to investigate the influence of obesity on the clinical outcomes and overall morbidities.

**Methods:** This retrospective study reviewed the data of all hospitalized trauma patients between 2009 and 2019 and included all patients with surgically proven small bowel, colon, or mesenteric injuries due to a road traffic accident. Comparison of the outcomes was performed among 123 patients with surgically proven BBMI, who were categorized by BMI into the normal-weight ( $n = 73$ ,  $BMI < 25 \text{ kg/m}^2$ ), overweight ( $n = 37$ ,  $25 \leq BMI \leq 30 \text{ kg/m}^2$ ), and obese groups ( $n = 13$ ,  $BMI > 30 \text{ kg/m}^2$ ).

**Results:** The obese group had a significantly lower incidence of isolated bowel injury (0%) compared with the normal-weight (35.6%) and overweight (16.2%) groups ( $p = 0.005$ ), but with higher incidence of isolated mesenteric injury or combined injury, although this was not significant. The obese group (92.3%) had a significantly higher percentage of overall morbidity than the normal-weight (61.6%) and overweight (70.3%) groups ( $p = 0.047$ ). No significant difference was observed in the in-hospital mortality and 24-hour mortality among the three study groups.

**Conclusion:** The study findings do not support the existence of a cushion effect and obesity paradox of obesity in blunt abdominal trauma.

**Keywords:** obesity, trauma, blunt bowel mesenteric injury, mortality

## Introduction

The adverse effect of obesity on physical health has long been extensively studied in the literature.<sup>1</sup> However, the “obesity paradox” theory regarding the protective effect of obesity against mortality had also begun to exist.<sup>2</sup> Because the obese individuals may sustain distinct injury patterns different from those of normal-weight individuals,<sup>3–5</sup> whether the obesity paradox has an effect on the trauma population still under debate. Meta-analysis reported that obese trauma

patients had different injury patterns and worse outcomes<sup>6</sup> as well as a 1.45-fold higher risk of mortality than the lean trauma patients.<sup>7</sup> In addition, increased risk of mortality was found in those obese patients with a body mass index (BMI) of  $>30 \text{ kg/m}^2$ , as a  $1 \text{ kg/m}^2$  elevation in the BMI value was significantly associated with 2.5% increased odds of death.<sup>8</sup> In a National Trauma Database study of 415,807 patients, Dvorak et al<sup>9</sup> reported that the obesity paradox has been demonstrated a U-shaped relationship between BMI and mortality, with a protective effect in the overweight population.

Another debate in the field of trauma is the “cushion effect”, which describes the association between increased BMI and less severe abdominal injury after a blunt abdominal trauma (BAT). The cushion effect was first reported by Arabi et al<sup>10</sup> based on the lower injury severity score (ISS) and abdominal abbreviated injury scale (AIS) score after a motor vehicle accident (MVA). The cushion effect suggests that increased subcutaneous fat has a protective effect against abdominal injury following a MVA.<sup>11</sup> The cushion effect had been especially reported in those overweight patients after a MVA, with a BMI of  $28 \text{ kg/m}^2$  being associated with the lowest mortality rate.<sup>12</sup> On the contrary, obesity had suggested with no protective effects on abdominal injuries and survival after a MVA as there was higher mortality rate in overweight patients (1.87 times) and obese patients (3.89 times) than in normal-weight patients.<sup>13</sup> Furthermore, in a computational study using the subcutaneous adipose tissues in the torso obtained from the magnetic resonance imaging datasets,<sup>14</sup> the results revealed that although the subcutaneous adipose tissue in the torso of overweight patients serves as a protection against abdominal injury, the momentum effect of a greater body mass in overweight patients was superior to the cushion effect, causing an increased injury to the head, thorax, and lower limbs, except in the abdomen.

However, most of the previous studies<sup>10,11,13,15</sup> used abdominal AIS score as the outcome to analyze the cushion effect of BMI, which seemed to be inadequate because the impact causing injuries to the abdominal organs, such as the liver and spleen, may be partially attributable to the force of chest trauma. The use of blunt bowel mesenteric injuries (BBMIs) instead of abdominal AIS to evaluate the relationship between obesity and BAT seems to be more reasonable, and a study related to this topic has not been conducted. Furthermore, the relationship between obesity and hollow organ injury has been sparsely discussed. Following the spleen and liver, the bowel mesentery is the third most vulnerable abdominal organ and is a good candidate for evaluating the cushion effect of BMI.<sup>16</sup> In addition, the surgical BBMI is often associated with mechanisms of road traffic accidents, such as hand bar injuries in motorcycle and bicycle accidents and seat belt injuries in car accidents.<sup>17,18</sup> Therefore, this study aimed to investigate the impact of obesity on clinical outcomes and overall morbidities in adult trauma patients with surgical BBMI to examine the existence of the cushion effect and obesity paradox.

## Methods

### Ethics Statement

This study was approved by the Institutional Review Board (IRB) of Chang Gung Memorial Hospital (approval number 201902275B0) in accordance with the amended Declaration of Helsinki covering patient data confidentiality. The need for informed consent was waived according to the IRB regulations because of its retrospectively study of design.

### Study Population

This retrospective study reviewed all data added to the Trauma Registry System from January 1, 2009, to December 31, 2019, in a 2686-bed facility and Level I regional trauma center that provides care to trauma patients in southern Taiwan.<sup>19–21</sup> All data were prospectively collected from the medical records of the hospitalized trauma patients and retrospectively analyzed. In order to evaluate the victims of RTA, only the injured persons during the RTA such as motorcyclists, car occupants, pedestrians, and bicyclists were included. Other injury mechanisms, such as falls, assault, and strike against/by objects, were excluded. All patients with surgical BBMI following BAT were surgically proven to have small bowel, colon, or mesenteric injuries. Patients with stomach, duodenal, or rectal injuries were excluded. Patients who aged  $<16$  years, those who died at the emergency department (ED), those who received conservative treatment without surgical intervention, or those who underwent non-therapeutic laparotomy due to a possible BBMI were also excluded. Based on the BMI (calculated as weight in kilograms divided by height in meters squared), the studied patients were grouped into normal-weight ( $\text{BMI} < 25 \text{ kg/m}^2$ ), overweight ( $25 \leq \text{BMI} \leq 30 \text{ kg/m}^2$ ), and obese ( $\text{BMI} > 30 \text{ kg/m}^2$ ) groups.

## Study Parameters

The data collected included age; sex; weight and height; injury mechanisms; vital signs at the ED including systolic blood pressure (SBP), heart rate (HR), respiratory rate (RR), and Glasgow Coma Scale (GCS) score; trauma score including ISS; clinical presentation including the laboratory data such as hemoglobin (Hb) level upon arrival at the ED, incidence of intubation and tube thoracostomy at the ED, and presentation of shock before operation; the status of blood transfusion (BT) including the incidence of BT at the ED and massive transfusion, the amount of packed red blood cells (RBC) and fresh frozen plasma (FFP) transfused at the ED, within 24 hours, and at the operating room and ward, respectively; operative findings including the incidence of isolated small bowel injury, isolated colon injury, isolated mesentery injury, combined injury, and operative blood loss; outcomes including the incidence of morbidity, mortality, 24-hour mortality, and length of stay (LOS) in the hospital and intensive care unit (ICU); incidence of AIS scores of  $\geq 2$  and  $\geq 3$  in each body region; and presence of associated injuries. The overall morbidity included sepsis, pneumonia, septic shock, unplanned ventilator use, intra-abdominal abscess, leakage, coagulopathy, acute kidney injury, acidosis, urinary tract infection, stroke, pulmonary embolism, acute respiratory distress syndrome, pleural effusion, enterocutaneous fistula, wound infection, wound dehiscence, abdominal compartment, tracheostomy, extracorporeal membrane oxygenation, return to the operating room, and hemodialysis.

The terms of illness in this study included: shock (defined as an SBP of  $\leq 90$  mmHg prior to surgery), isolated bowel injury (defined as only small bowel injury including ischemia, rupture, serosa injury, or hematoma), isolated colon injury (defined as colon injury including ischemia, rupture, serosa injury, or hematoma), isolated mesenteric injury (defined as mesenteric injury including ischemia, rupture, serosa injury, or hematoma), and combined injury (defined as either small bowel or colon injury concomitant with mesenteric injury including ischemia, rupture, serosa injury, or hematoma). Morbidity was defined as the occurrence of postoperative complications including acidosis, sepsis, pneumonia, coagulopathy (platelet of  $< 150,000$  mg/dl or an international normalized ratio of prothrombin time or active prothrombin time of  $> 1.5$ ), septic shock, urinary tract infection, acute renal failure (increase in serum creatinine levels by  $\geq 0.3$  mg/dL within 48 hours or increase in serum creatinine levels by  $\geq 1.5$  times compared with that of the baseline level), unplanned ventilator support (incidental endotracheal tube insertion due to acute respiratory failure during hospitalization), intra-abdominal abscess (diagnosed according to the findings on computed tomography), bowel anastomotic leakage, wound infection, wound dehiscence, pleural effusion requiring drainage, stroke, adult respiratory distress syndrome, return to operating room (including unplanned or staged), renal function deterioration to hemodialysis, 24-hour mortality (in order to observe the confounding effect of immediate injury-related mortality such as death due to exsanguination or lethal traumatic brain injuries), and pelvic fracture (including simple pelvic fracture or complicated pelvic fracture).

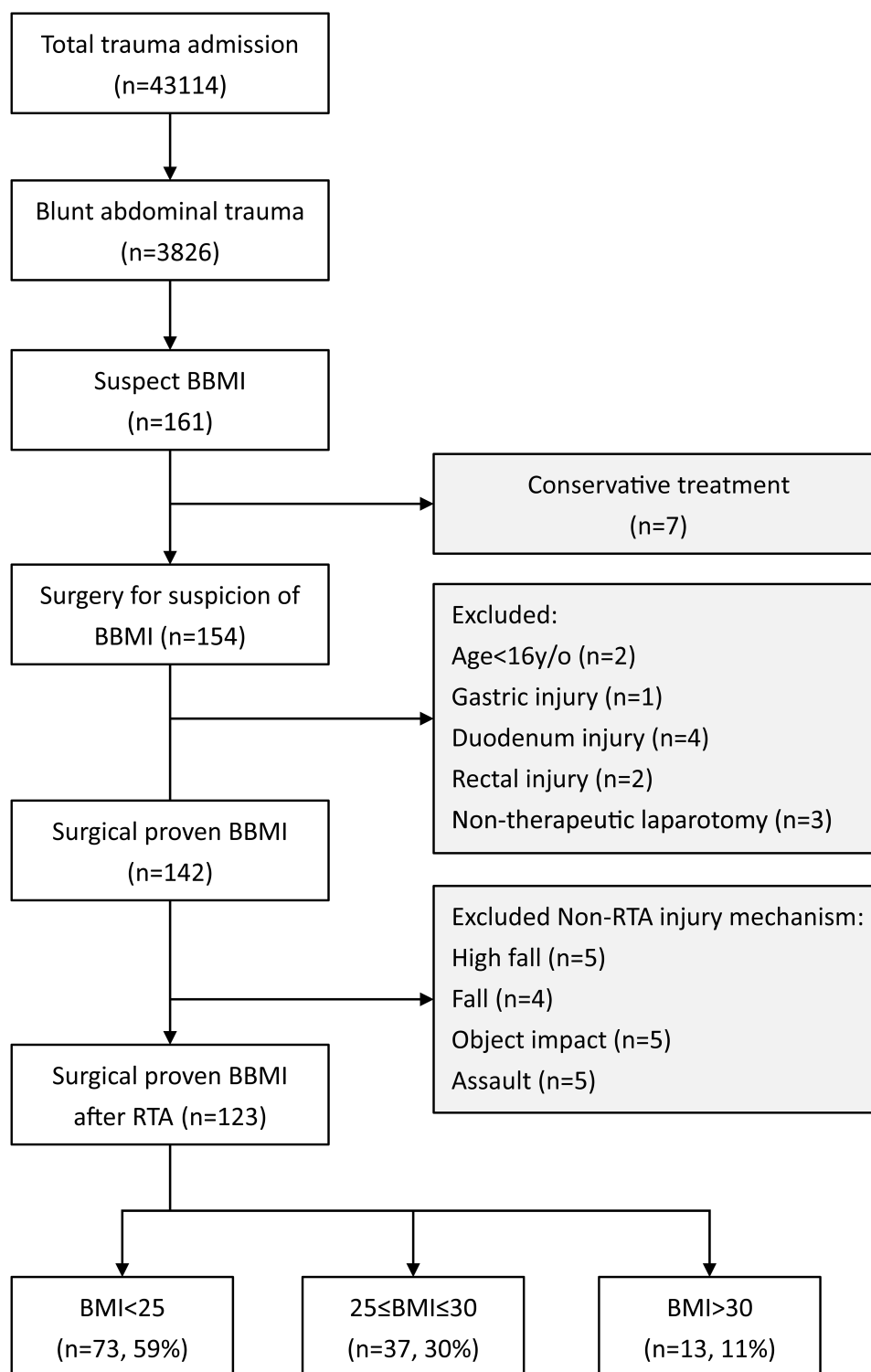
## Statistical Analysis

The Kolmogorov–Smirnov test was used to analyze the normalization of the distributed data for continuous variables. The non-normally distributed data were analyzed using the Mann–Whitney *U*-test and expressed as medians and interquartile ranges (IQRs). The categorical data was expressed as frequencies and percentages. The statistical significance of trends across categories was determined using least squares and maximum likelihood for continuous and categorical variables, respectively. A *p* value of  $< 0.05$  was considered significant. The odds ratios (OR) of developing complications according to the BMI category were determined using logarithmic binomial regression models, which were expressed based on the values of the normal-weight group, and the 95% confidence interval (CI) was also obtained. Kaplan–Meier analysis was used to identify whether the higher BMI groups had a higher risk of morbidity. The Log rank test was used to assess the differences in the morbidity curves between the patient groups.

## Results

### Patient Characteristics, Clinical Presentation, and Outcome

As shown in [Figure 1](#), during the 12-year period, 43,114 trauma patients were admitted to our Level I Trauma Center, of whom 154 underwent emergent laparotomy due to a possible BBMI. Finally, 123 patients with surgically proven BBMI met the inclusion criteria and were divided into groups according to the BMI category: normal-weight ( $n = 73$ ), overweight ( $n = 37$ ), and obese groups ( $n = 13$ ); no differences were observed in patients' age, sex, injury severity, and initial vital signs at the ED



**Figure 1** Flowchart of the enrollment process of patients who experienced surgical blunt mesentery bowel injury (BBMI) after a road traffic accident (RTA).

among the groups (Table 1). MVAs occurred significantly less frequently in overweight patients (40.5%) than in obese (76.9%) and normal-weight (64.4%) patients ( $p = 0.020$ ). No difference was found among the study groups in terms of physiological presentation and management at the ED; however, significant difference was observed in the proportion of patients requiring BT at the ED, the amount of packed RBC and FFP transfused at the ED, and the amount of packed RBC

**Table 1** Clinical and Injury Characteristics of Patients with BBMI According to the Body Mass Index Category

|                                  | <b>Normal Weight<br/>n = 73</b> | <b>Overweight<br/>n = 37</b> | <b>Obese<br/>n = 13</b> | <b>P value</b> |
|----------------------------------|---------------------------------|------------------------------|-------------------------|----------------|
| Age, years                       | 42 (23–57)                      | 51 (38–56)                   | 44 (28–52)              | 0.273          |
| Male, n (%)                      | 59 (80.8%)                      | 31 (83.8%)                   | 11 (84.6%)              | 0.940          |
| Trauma mechanisms, n (%)         |                                 |                              |                         |                |
| Car accident                     | 19 (26%)                        | 17 (45.9%)                   | 3 (23.1%)               | 0.087          |
| Motorcycle accident              | 47 (64.4%)                      | 15 (40.5%)                   | 10 (76.9%)              | 0.020          |
| Pedestrian accident              | 3 (4.1%)                        | 3 (8.1%)                     | 0 (0%)                  | 0.449          |
| Bicycle accident                 | 4 (5.5%)                        | 2 (5.4%)                     | 0 (0%)                  | 1.000          |
| ISS                              | 17 (9–24)                       | 16 (9–21)                    | 21 (16–27)              | 0.251          |
| ISS ≥ 16                         | 41 (56.2%)                      | 22 (59.5%)                   | 10 (76.9%)              | 0.373          |
| ISS ≥ 25                         | 18 (24.7%)                      | 8 (21.6%)                    | 6 (46.2%)               | 0.204          |
| ED physiological presentation    |                                 |                              |                         |                |
| SBP (mm/Hg)                      | 116 (94–135)                    | 118 (87–137)                 | 113 (80–124)            | 0.746          |
| HR (/min)                        | 98 (80–112)                     | 95 (84–114)                  | 112 (83–126)            | 0.304          |
| RR (/min)                        | 20 (18–20)                      | 20 (19–20)                   | 19 (16–20)              | 0.162          |
| GCS                              | 15 (15–15)                      | 15 (15–15)                   | 15 (11–15)              | 0.468          |
| ED presentation and management   |                                 |                              |                         |                |
| Hb (g/dL)                        | 12.1 (10.2–14.3)                | 12.7 (11.5–14)               | 12.1 (10.5–12.6)        | 0.422          |
| Shock, n (%)                     | 30 (41.1%)                      | 18 (48.6%)                   | 9 (69.2%)               | 0.163          |
| Intubation, n (%)                | 12 (16.4%)                      | 9 (24.3%)                    | 5 (38.5%)               | 0.173          |
| Chest tube insertion, n (%)      | 17 (23.3%)                      | 4 (10.8%)                    | 4 (30.8%)               | 0.168          |
| Blood transfusion, n (%)         | 34 (46.6%)                      | 24 (64.9%)                   | 11 (84.6%)              | 0.017          |
| ED Pack RBC (U)                  | 0 (0–4)                         | 2 (0–4)                      | 4 (2–6)                 | 0.006          |
| ED FFP (U)                       | 0 (0–2)                         | 0 (0–4)                      | 2 (0–6)                 | 0.036          |
| 24-hour Pack RBC (U)             | 4 (0–10)                        | 6 (2–14)                     | 10 (4–12)               | 0.019          |
| 24-hour FFP (U)                  | 2 (0–6)                         | 4 (0–8)                      | 6 (4–12)                | 0.077          |
| OR Pack RBC (U)                  | 0 (0–8)                         | 4 (0–8)                      | 6 (4–6)                 | 0.064          |
| OR FFP (U)                       | 0 (0–4)                         | 0 (0–4)                      | 4 (2–6)                 | 0.138          |
| Ward pack RBC (U)                | 0 (0–2)                         | 0 (0–4)                      | 2 (0–6)                 | 0.305          |
| Ward FFP (U)                     | 0 (0–4)                         | 0 (0–6)                      | 2 (0–6)                 | 0.560          |
| Massive transfusion, n (%)       | 21 (28.8%)                      | 12 (32.4%)                   | 7 (53.8%)               | 0.217          |
| Operative findings               |                                 |                              |                         |                |
| Isolated bowel injury, n (%)     | 26 (35.6%)                      | 6 (16.2%)                    | 0 (0%)                  | 0.005          |
| Isolated colon injury, n (%)     | 11 (15.1%)                      | 1 (2.7%)                     | 1 (7.7%)                | 0.094          |
| Isolated mesentery injury, n (%) | 17 (23.3%)                      | 14 (37.8%)                   | 6 (46.2%)               | 0.103          |
| Combined injury, n (%)           | 20 (27.4%)                      | 16 (43.2%)                   | 6 (46.2%)               | 0.159          |
| Operative blood loss (mL)        | 250 (50–1300)                   | 1000 (300–3000)              | 1700 (600–2000)         | 0.007          |
| Outcomes                         |                                 |                              |                         |                |
| Morbidity, n (%)                 | 45 (61.6%)                      | 26 (70.3%)                   | 12 (92.3%)              | 0.047          |
| In-hospital mortality, n (%)     | 9 (12.3%)                       | 6 (16.2%)                    | 2 (15.4%)               | 0.737          |
| 24 hours mortality, n (%)        | 2 (2.7%)                        | 3 (8.1%)                     | 0 (0%)                  | 0.378          |
| ICU LOS (days)                   | 2 (1–6)                         | 3 (2–8)                      | 6 (3–23)                | 0.079          |
| Hospitalization LOS (days)       | 19 (10–31)                      | 16 (11–33)                   | 27 (12–38)              | 0.531          |

**Note:** Data are presented as number (percentage) or median (interquartile range) (25–75%).

**Abbreviations:** BBMI, blunt bowel mesentery injury; ED, emergency department; FFP, fresh frozen plasma; GCS, Glasgow Coma Scale; Hb, hemoglobin; HR, heart rate; ICU, intensive care unit; ISS, Injury Severity Scale; LOS, length of stay; OR, operating room; RBC, red blood cell; RR, respiratory rate; SBP, systolic blood pressure.

transfused within 24 hours among the three patient groups. The obese group received transfusion significantly more frequently and with a greater amount compared with the normal-weight and overweight groups. In this study, the obese group had a significantly lower incidence of isolated bowel injury (0%) compared with the normal-weight (35.6%) and overweight (16.2%) groups ( $p=0.005$ ); however, the obese group had higher incidence of isolated mesenteric injury or combined injury,

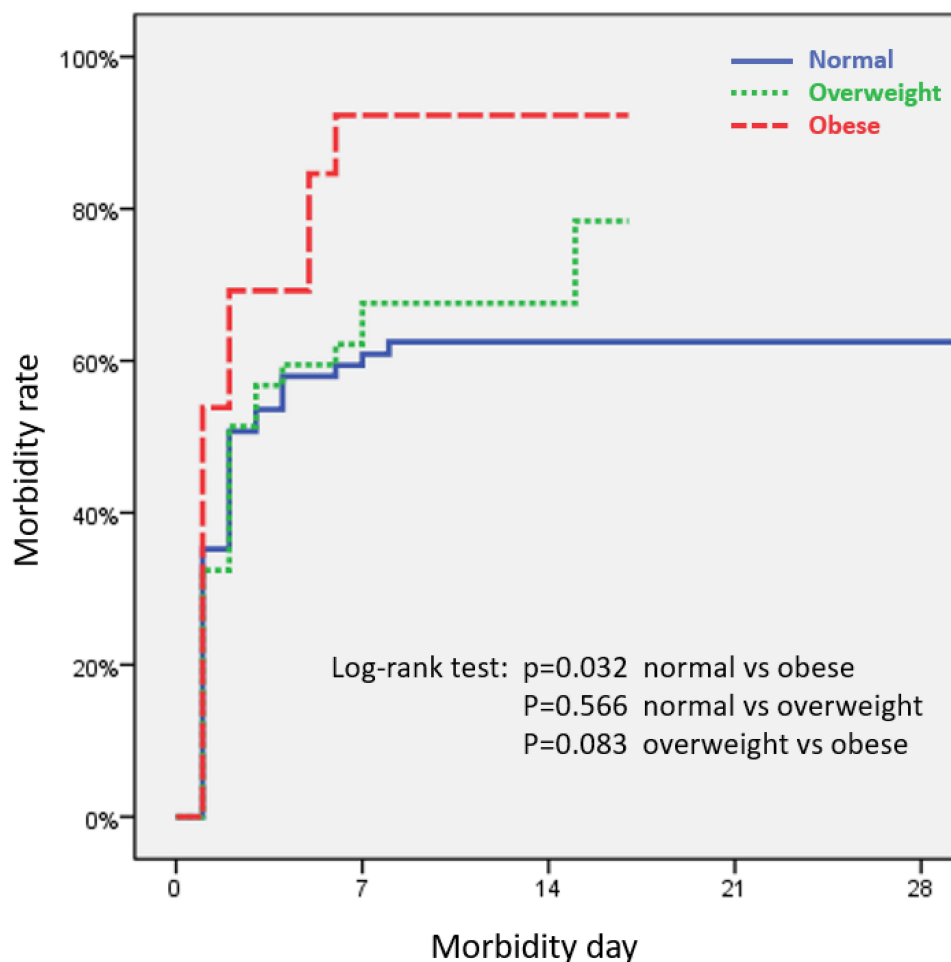
although this finding was not significant. The obese group had significantly higher volume of operative blood loss (median, Q1–Q3; 1700 mL, 600–2000 mL) than the normal-weight (250 mL, 50–1300 mL) and overweight groups (1000 mL, 300–3000 mL) ( $p=0.007$ ). The obese group (92.3%) had a significantly higher incidence of overall morbidity than the normal-weight (61.6%) and overweight (70.3%) groups ( $p=0.047$ ). According to the Kaplan-Meier analyses results, obese patients sustained complications at a significantly higher rate and earlier than normal-weight patients ( $p=0.032$ ) (Figure 2). No significant difference was observed in the in-hospital mortality and 24-hour mortality rates among the three patient groups.

## Injury Severity and Injury Pattern

The distribution of AIS injuries in each body region of the different BMI groups is shown in Table 2. No significant difference was observed among the groups in terms of AIS scores and incidence of an AIS score of  $\geq 2$  or  $\geq 3$  in all body regions. Based on the incidence of associated injury (Table 3), no significant difference was found among the groups; however, facial bone fractures occurred more frequently in the obese group (30.8% vs 10.8% in the overweight group and 6.8% in the normal-weight group;  $p=0.045$ ), while upper limb fractures were more prevalent in the obese group (53.8% vs 8.1% in the overweight group and 17.8% in the normal-weight group;  $p=0.003$ ).

## Overall Morbidities

The incidence of morbidities is shown in Table 4. No difference was found in the overall morbidities among the groups except for pneumonia and return to the operating room, which was significantly more prevalent in the obese group



**Figure 2** Morbidity rate curve of patients who experienced surgical blunt bowel mesentery injury in different body mass index (BMI) groups.

**Table 2** Severity of Injury in Body Regions of Patients with BBMI According to the Body Mass Index Category

|                                 | Normal Weight<br>n = 73 | Overweight<br>n = 37 | Obese<br>n = 13 | P value |
|---------------------------------|-------------------------|----------------------|-----------------|---------|
| AIS head/neck                   | 0 (0–0)                 | 0 (0–0)              | 0 (0–1)         | 0.254   |
| AIS face                        | 0 (0–0)                 | 0 (0–0)              | 0 (0–1)         | 0.121   |
| AIS chest                       | 0 (0–0)                 | 0 (0–0)              | 0 (0–3)         | 0.361   |
| AIS abdomen                     | 3 (3–4)                 | 3 (3–4)              | 3 (3–4)         | 0.695   |
| AIS extremities                 | 0 (0–2)                 | 0 (0–2)              | 2 (0–3)         | 0.172   |
| AIS head/neck $\geq$ 2, n (%)   | 11 (15.5%)              | 4 (10.8%)            | 3 (23.1%)       | 0.479   |
| AIS head/neck $\geq$ 3, n (%)   | 7 (9.9%)                | 3 (8.1%)             | 3 (23.1%)       | 0.279   |
| AIS face $\geq$ 2, n (%)        | 4 (5.6%)                | 2 (5.4%)             | 3 (23.1%)       | 0.115   |
| AIS face $\geq$ 3, n (%)        | 0 (0%)                  | 0 (0%)               | 0 (0%)          | –       |
| AIS chest $\geq$ 2, n (%)       | 17 (23.9%)              | 8 (21.6%)            | 4 (30.8%)       | 0.819   |
| AIS chest $\geq$ 3, n (%)       | 16 (22.5%)              | 8 (21.6%)            | 4 (30.8%)       | 0.736   |
| AIS abdomen $\geq$ 2, n (%)     | 71 (100%)               | 37 (100%)            | 13 (100%)       | –       |
| AIS abdomen $\geq$ 3, n (%)     | 65 (91.5%)              | 36 (97.3%)           | 11 (84.6%)      | 0.241   |
| AIS extremities $\geq$ 2, n (%) | 28 (39.4%)              | 11 (29.7%)           | 8 (61.5%)       | 0.133   |
| AIS extremities $\geq$ 3, n (%) | 16 (22.5%)              | 7 (18.9%)            | 4 (30.8%)       | 0.620   |

**Note:** Data are presented as number (percentage) and median (interquartile range) (25–75%).

**Abbreviations:** AIS, abbreviated injury score; BBMI, blunt bowel mesentery injury.

**Table 3** Associated Injuries of the Patients with BBMI According to the Body Mass Index Category

|                                | Normal Weight<br>n = 73 | Overweight<br>n = 37 | Obese<br>n = 13 | P value |
|--------------------------------|-------------------------|----------------------|-----------------|---------|
| Intracranial hemorrhage, n (%) | 10 (13.7%)              | 5 (13.5%)            | 2 (15.4%)       | 1.000   |
| Skull fracture, n (%)          | 2 (2.7%)                | 1 (2.7%)             | 0 (0%)          | 1.000   |
| Facial bone fracture, n (%)    | 5 (6.8%)                | 4 (10.8%)            | 4 (30.8%)       | 0.045   |
| Cervical spine fracture, n (%) | 2 (2.7%)                | 0 (0%)               | 1 (7.7%)        | 0.196   |
| Clavicle fracture, n (%)       | 2 (2.7%)                | 0 (0%)               | 0 (0%)          | 0.640   |
| Scapula fracture, n (%)        | 13 (17.8%)              | 5 (13.5%)            | 3 (23.1%)       | 0.685   |
| Rib fracture, n (%)            | 11 (15.1%)              | 7 (18.9%)            | 5 (38.5%)       | 0.150   |
| Lung contusion, n (%)          | 9 (12.3%)               | 3 (8.1%)             | 4 (30.8%)       | 0.128   |
| Hemopneumothorax, n (%)        | 1 (1.4%)                | 0 (0%)               | 0 (0%)          | 1.000   |
| Diaphragm injury, n (%)        | 1 (1.4%)                | 2 (5.4%)             | 1 (7.7%)        | 0.206   |
| Great vessel injury, n (%)     | 5 (6.8%)                | 8 (21.6%)            | 3 (23.1%)       | 0.033   |
| Spleen injury, n (%)           | 7 (9.6%)                | 0 (0%)               | 1 (7.7%)        | 0.124   |
| Liver injury, n (%)            | 16 (21.9%)              | 3 (8.1%)             | 2 (15.4%)       | 0.181   |
| Pancreas injury, n (%)         | 5 (6.8%)                | 2 (5.4%)             | 0 (0%)          | 1.000   |
| Urinary bladder injury, n (%)  | 1 (1.4%)                | 1 (2.7%)             | 0 (0%)          | 1.000   |
| Kidney injury, n (%)           | 5 (6.8%)                | 1 (2.7%)             | 0 (0%)          | 0.829   |
| Thoracic spine fracture, n (%) | 3 (4.1%)                | 3 (8.1%)             | 0 (0%)          | 0.449   |
| Lumbar spine fracture, n (%)   | 4 (5.5%)                | 1 (2.7%)             | 2 (15.4%)       | 0.225   |
| Pelvic fracture, n (%)         | 11 (15.1%)              | 4 (10.8%)            | 3 (23.1%)       | 0.514   |
| Upper limb fracture, n (%)     | 13 (17.8%)              | 3 (8.1%)             | 7 (53.8%)       | 0.003   |
| Lower limb fracture, n (%)     | 14 (19.2%)              | 9 (24.3%)            | 3 (23.1%)       | 0.758   |

**Note:** Data are presented as number (percentage).

**Abbreviation:** BBMI, blunt bowel mesentery injury.

**Table 4** Incidence Rates of Postoperative Complications Among Patients with BBMI According to the Body Mass Index Category

|                            | <b>Normal Weight<br/>n = 73</b> | <b>Overweight<br/>n = 37</b> | <b>Obese<br/>n = 13</b> | <b>P value</b> |
|----------------------------|---------------------------------|------------------------------|-------------------------|----------------|
| Stroke                     | 1 (1.4%)                        | 1 (2.7%)                     | 1 (7.7%)                | 0.313          |
| Sepsis                     | 13 (17.8%)                      | 7 (18.9%)                    | 3 (23.1%)               | 0.837          |
| Pneumonia*                 | 9 (12.3%)                       | 6 (16.2%)                    | 5 (38.5%)               | 0.017          |
| Septic shock               | 8 (11%)                         | 1 (2.7%)                     | 1 (7.7%)                | 0.323          |
| Intra-abdomen abscess      | 11 (15.1%)                      | 1 (2.7%)                     | 2 (15.4%)               | 0.113          |
| Urinary tract infection    | 14 (19.2%)                      | 4 (10.8%)                    | 3 (23.1%)               | 0.455          |
| Pulmonary embolism         | 1 (1.4%)                        | 0 (0%)                       | 0 (0%)                  | 1.000          |
| ARDS                       | 1 (1.4%)                        | 0 (0%)                       | 1 (7.7%)                | 0.290          |
| Pleural effusion           | 13 (17.8%)                      | 4 (10.8%)                    | 3 (23.1%)               | 0.438          |
| Unplanned ventilator use   | 15 (20.5%)                      | 12 (32.4%)                   | 4 (30.8%)               | 0.341          |
| Tracheostomy               | 2 (2.7%)                        | 1 (2.7%)                     | 0 (0%)                  | 1.000          |
| Use of ECMO                | 1 (1.4%)                        | 0 (0%)                       | 1 (7.7%)                | 0.290          |
| Leakage                    | 7 (9.6%)                        | 0 (0%)                       | 1 (7.7%)                | 0.124          |
| Enterocutaneous fistula    | 2 (2.7%)                        | 0 (0%)                       | 0 (0%)                  | 0.640          |
| Wound infection            | 14 (19.2%)                      | 10 (27%)                     | 3 (23.1%)               | 0.619          |
| Wound dehiscence           | 3 (4.1%)                        | 4 (10.8%)                    | 0 (0%)                  | 0.329          |
| Abdomen compartment        | 3 (4.1%)                        | 3 (8.1%)                     | 0 (0%)                  | 0.449          |
| Coagulopathy               | 29 (39.7%)                      | 15 (40.5%)                   | 7 (53.8%)               | 0.630          |
| Acute renal failure        | 22 (30.1%)                      | 14 (37.8%)                   | 7 (53.8%)               | 0.232          |
| Acidosis                   | 23 (31.5%)                      | 6 (16.2%)                    | 6 (46.2%)               | 0.076          |
| Hemodialysis               | 2 (2.7%)                        | 0 (0%)                       | 0 (0%)                  | 0.640          |
| Return to operative room** | 6 (8.2%)                        | 8 (21.6%)                    | 5 (38.5%)               | 0.008          |

**Notes:** Data are presented as numbers (percentage). Odds ratio (OR) and 95% confidence interval (CI) by univariate analysis with normal weight as reference: \*Normal weight vs overweight vs obese: 1.0 (ref) vs 1.38 (0.45–4.21) vs 4.44 (1.19–16.59); \*\*Normal weight vs overweight vs obese: 1.0 (ref) vs 3.08 (0.98–9.68) vs 6.98 (1.73–28.16).

**Abbreviations:** ARDS, acute respiratory distress syndrome; BBMI, blunt bowel mesentery injury; ECMO, extracorporeal membrane oxygenation.

(pneumonia: 38.5% vs 16.2% in the overweight group and 12.3% in the normal-weight group,  $p=0.017$ ; return to the operating room: 38.5% vs 21.6% in the overweight group and 8.2% in the normal-weight group,  $p=0.008$ ).

## Discussion

In this study, we only examined the patients with surgical BBMI, in which the impact force primarily caused middle abdominal contusion rather than lower chest or upper abdominal trauma, to attenuate the confounding effect in the assessment. Results revealed that in the group with surgical BBMI, obese patients have significantly higher morbidity rate than the non-obese patients, but with similar mortality rate. The results did not represent the surgical benefit of obesity, also known as the obesity paradox, and worse mortality was not linked to the impact of obesity. Our results are similar to those of a prospective study conducted by Ciesla et al,<sup>22</sup> who reviewed 716 severely injured patients who had an ISS of >15 and found that obesity is a risk factor for postinjury multiple organ failure, but not for mortality. These results were also in agreement with that of a study conducted by Drury et al<sup>23</sup> which showed no significant differences in the BMI groups in terms of mortality, even after adjusting for injury severity, mechanism, and velocities.

In this study, the cushion effect of obesity was not observed. Although the results revealed that the obese group had a significantly lower incidence of isolated bowel injury, they showed increasing trends of isolated mesenteric injury or combined injury. The injury mechanism of BBMI usually involves compression or rapid acceleration and deceleration forces, which lead to a spectrum of injuries, including direct bowel blowout, shearing of the mesentery, or tearing of the bowel wall.<sup>17</sup> Significantly lower incidence of isolated bowel injury in the obese group could reflect the protective effect



of increased abdominal depth against direct compression leading to bowel blowout, whereas increased trends of isolated mesentery injury and combined injury in the obese group may reflect the injury caused by an acceleration force and a deceleration force, which is associated with greater momentum effect by increased body mass.

Bowel injury would lead to peritonitis with concomitant subtle bleeding, whereas mesenteric injury would lead to devastating hemorrhage, which could explain why significantly higher volume of operative blood loss was noted among the higher BMI groups. However, the significantly higher volume of operative blood loss may be related to the operative time and bleeding associated with obesity.<sup>24</sup> In addition, the significantly higher rates and amounts of blood transfusion at the ED and first 24 hours may be attributed to the fact that obese patients had a larger body mass, thus requiring a greater amount of blood to maintain the hemodynamic status.<sup>25</sup>

The negative effects of obesity on hospitalization-related complications, such as pneumonia, nosocomial infection, return to the operating room, or multiple organ failure, have been widely studied.<sup>22,26–28</sup> The increased risk of morbidity following trauma may be due to the inherent underlying comorbidity, chronic illness, altered inflammatory response, and proinflammatory status,<sup>2,29</sup> which indicate the significantly higher rates of overall morbidity, pneumonia, and return to the operative room in obese patients compared with that in normal-weight patients. However, the current study did not determine the definite effect of obesity on morbidity because of the relatively small number of patients. Hence, future studies focusing on the interplay between obesity and postinjury host responses may help illustrate the relationship between obesity and increased morbidity.

Our study has some limitations. First, it had a retrospective design with inherent selection bias. Second, although it focused on patients with RTAs, the injury patterns from motorcycles or cars, and even pedestrians, may still vary.<sup>30</sup> Third, the lack of data regarding the circumstances of the injury, such as motorcycle riders or pillions, car drivers, or occupants; crush factors, such as impact direction, velocity, and protective device used (restraints or helmet); and anthropometric data, such as subcutaneous adipose, waist-to-hip ratio, and waist circumference, would limit the interpretation of the analyzed data. However, the impact force required should be achieved in order to result in surgical BBMI. Therefore, the other confounders that may influence abdominal contusion seemed to be less important, given that the cohort only included patients with surgical BBMI. Fourth, we did not exclude patients with morbid obesity in our series, which would have led to some bias. Patients with an extreme BMI may have the highest risk of postoperative morbidity and mortality.<sup>2</sup> Finally, often times trauma patients would combine with multiple region injuries, such as traumatic brain injuries, which may lead to higher chances of mortality. As such, our results of this study were less generalized and would only apply to patients with BBMI. Despite these limitations, our study provides new information on the relationship between obesity and abdominal trauma.

## Conclusions

In a study of trauma patients with surgical BBMI following RTAs, obese patients who sustained a surgical BBMI had a higher overall morbidity rate and required blood transfusion and a greater volume of blood for transfusion. However, the study findings do not support the existence of a cushion effect and obesity paradox of obesity in blunt abdominal trauma.

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## Disclosure

The authors declare no conflicts of interest.

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