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The Role of Flatness Index of Inferior Vena Cava in Early Hypovolemic Shock Concerning Blunt Torso Trauma Patients

Künt Gövde Travmalı Hastalarda İnferior Vena Cava Düzlük İndeksinin Erken Hipovolemik Şoktaki Rolü

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ABSTRACT

AIM:
Our aim is to evaluate the role of flatness index of Inferior Vena Cava (IVC) with early hypovolemic shock in blunt torso trauma patients.

MATERIAL AND METHOD:
In the computed tomography (CT) scan, patients with flatness index above 2 were considered as flat IVC patients, and those with 2 or less were considered as non-flattened IVC patients. Demographic data, comorbidities, trauma mechanism, Injury Severity Score (ISS), Glasgow Coma Score (GCS), lactate level, base deficit, shock index (SI), clinical outcomes within 24 hours, and mortality of the flat IVC patients and non-flattened IVC patients were compared.

RESULTS:
116 (30.6%) patients were found to have a flat IVC and 263 (69.4%) patients were found to have a non-flattened IVC. There was no significant difference between flat IVC patients and non-flattened IVC patients in terms of age, gender, comorbidity, and trauma mechanism (p>0.05). Flat IVC patients had a higher SI of 0.9 and above (p<0.001). ISS of flat IVC patients was higher (p<0.001). There was no difference in GCS score between patients with a flat IVC and patients with a non-flattened IVC (p>0.05). Lactate level was found to be higher in flat IVC patients (p<0.001). Base deficit in flat IVC patients was found worse to that of non-flattened IVC patients (p<0.001). Volume replacement, operation, hospitalization, and hospital mortality were higher in patients with flat IVC (p<0.001). On multivariate analysis correlation were found between the patients' flatness index of IVC and, lactate level, ISS, base deficit (r=-0.353 p<0.001; r=-0.702 p<0.001, r=0.656; p<0.001 respectively).

CONCLUSION:
In the initial CT scan of blunt torso trauma patients, the flatness of the IVC index is associated with early hypovolemic shock. The flatness of the IVC index can be used as a guide in the evaluation of intravascular volume in these patients.

Keywords:
blunt trauma, computed tomography, inferior vena cava

ÖZET

AMAÇ:
Amacımız künt gövde travmalı hastalarda İnferior Vena Kava (İVC) düzlük indeksinin erken hipovolemik şokdaki rolünü değerlendirmektir.

GEREÇ VE YÖNTEM:
Bilgisayarlı tomografi (BT) taramasında düzlük indeksi 2' nin üzerinde olan hastalar düzleşmiş IVC'lı hastalar, 2 veya altında olanlar düzleşmemiş IVC'lı hastalar olarak kabul edildi. Düzleşmiş IVC'lı hastalar ve düzleşmemiş IVC'lı hastaların demografik verileri, komorbiditeleri, travma mekanizması, Yaralanma Ciddiyet Skoru (YCS), Glasgow Koma Skoru (GKS), laktat düzeyi, baz açığı, şok indeksi (SI), 24 saat içindeki klinik sonuçları ve mortalite karşılaştırıldı.

BULGULAR:
116 (30,6%) hasta düzleşmiş IVC'lı, 263 hasta (69,4%) düzleşmemiş IVC'lı idi. Düzleşmiş IVC'lı hastalar ve düzleşmemiş IVC'lı hastalar arasında yaş, cinsiyet, komorbitite ve travma mekanizması açısından anlamlı farklılık saptanmadı (p>0.05). Düzleşmiş İVC'lı hastaların SI değeri 0,9 ve üzerindeydi (p<0,001). Düzleşmiş IVC'lı hastaların YCS'si daha yüksekti (p<0,001). Düzleşmiş IVC'lı hastalar ve düzleşmemiş IVC'lı hastalarında GKS skoru açısından fark yoktu (p>0.05). Düzleşmiş IVC'lı hastalarda laktat düzeyi daha yüksek bulundu (p<0,001). Düzleşmiş IVC'lı hastalarındaki baz açığı, düzleşmemiş IVC'lı hastalara göre daha kötü bulundu (p<0,001). Düzleşmiş IVC'lı hastalarda volüm replasmanı, operasyon, hastaneye yatış ve hastane mortalitesi daha yüksekti (p<0,001). Çok değişkenli analizde hastaların düzlük IVC indeksi ile laktat seviyesi, ISS, baz açığı arasında korelasyon bulundu (sırasıyla r=-0.353 p<0.001; r=-0.702 p<0.001, r=0.656; p<0.001).

SONUÇ:
Künt gövde travmalı hastaların ilk BT incelemesinde IVC düzlük indeksi erken hipovolemik şok ile ilişkilidir. VCI düzlük indeksinin intravasküler volüm değerlendirilmesinde yol gösterici olabileceğini düşünmekteyiz.

Anahtar kelimeler:
künt travma, bilgisayarlı tomografi, inferior vena kava

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INTRODUCTION

Globally trauma-related injuries are among the leading causes of morbidity and mortality. Nearly half of the deaths due to trauma are due to hypovolemic shock caused by bleeding.1 Early recognition of hypovolemic shock in these patients and performing the necessary treatment are important in terms of reducing mortality.

Traditionally, trauma patients are evaluated by injury mechanism, injury severity, and initial vital signs.2 However, changes in vital parameters in the early period may not be evident due to the compensation of the body's autoregulatory mechanisms, and vital parameters such as hypotension and tachycardia may not be proportional to the state of shock in these patients.3-5 Lactate level, base deficit, and shock index (SI) are generally accepted as factors that predict hemodynamic deterioration and reliably predict the need for transfusion in hemodynamically stable patients.3,6

Approximately 70% of the total blood volume in the body is located in the venous system, and the inferior vena cava (IVC) is the major representative of this system.7 IVC size varies according to the volume in the body.8 Taylor et al. described four signs of hypoperfusion in their study with children with severe injury due to blunt trauma in the computed tomography (CT) scan and a decrease in the diameter of the inferior vena cava (IVC) was among these symptoms.9 Jeffrey and Federle stated in their study that the observation of flat VCI (flat at more than one level) in the initial CT scans of patients with blunt trauma was a strong sign of hypovolemia due to major bleeding.10

In this study, our aim is to evaluate the role of flatness index of Inferior Vena Cava (IVC) with early hypovolemic shock in blunt torso trauma patients.

MATERIAL AND METHOD

Study Design and Setting

This study was approved by the ethics committee of the hospital (Ankara, Turkey, date: 14.06.2021- clinical trial number:113 /02). Blunt torso trauma patients aged 18 years and older who were hemodynamically stable and had thoracoabdominal CT were included in the study. Patients who are intubated before CT scan., patients with alcohol intoxication, diabetic ketoacidosis, epileptic seizure, known bleeding disorder, IVC injury, retrohepatic hematoma, right ventricular failure, IVC variation, CT images that couldn't evaluate because of artifacts, and with missing records were excluded from the study.

Study Protocol and Measurements

Demographic data of patients (age, gender), comorbidities, trauma mechanism, initial admission lactate level and base deficit, SI, Injury Severity Score (ISS), Glasgow Coma Score (GCS), flatness index of IVC in initial CT scan, clinical outcome within 24 hours (need for volume replacement, operation, hospitalization) and mortality were evaluated. All vital signs used for SI were obtained at admission, all laboratory studies and CT scans were obtained within 1 hour after patient arrival. SI was calculated by the ratio of heart rate (HR) per minute to systolic blood pressure (SBP).5 The determination of ISS is done via the addition of the severity squares of the injuries in the three most severe injury received anatomical regions.

CT scan protocol and IVC measurements

The CT scans were performed with a 64-detector row CT machine (GE Optima 660 SE 64 Detector 128-slice CT, General Electric Medical Systems, Milwaukee, WI). All studies were obtained with contiguous 2.5-mm axial sections. The patients were placed in the supine position during the scanning procedure. All patients were instructed to hold their breath without deep inspiration or expiration during CT scans. A bolus injection (3 ml) of 80–100 mL (1.5 mL/kg body weight) non-ionic contrast agent was made through the cubital vein via an automatic pressure injector. Anteroposterior and transverse measurements of the IVC were made from the axial section with standard abdominal window settings, manually with an electronic length clipper over the picture archiving and communication system (Extreme PACS, Ankara, Turkey). Measurements were made by two radiologists with experience in abdominal radiology blinded from clinical and laboratory findings and each other's measurements. We measured the maximum transverse and anteroposterior diameters of the IVC, just above the renal veins in the axial section. The flatness index of IVC was calculated by dividing the transverse diameter of the IVC by the anteroposterior diameter

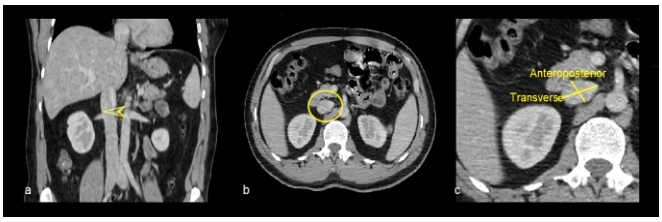

Fig. 1 a,b,c. Coronal and axial computed tomography sections show locations of the inferior vena cava just above the renal veins (a -b); method of measuring the flatness index of the inferior vena cava; calculated via dividing the transverse diameter by the anterior -posterior diameter (c).

(Figure 1). If the flatness index was above 2, it was considered as flat IVC, and if it was 2 or less, it was considered as non-flattened IVC. To test the intra-observer reliability, one of the radiologists repeated all measurements one month after the first assessment.

Statistical analysis

IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp; Armonk, New York USA) was used for all statistical analyses. Intra-observer and interobserver compatibility were examined by Intraclass Correlation Coefficient (ICC). Mean standard deviation and interquartile range (IQR) were given for descriptive statistics for continuous data, and number and percentage values were given for discrete data. Shapiro-Wilk test was used to examine the conformity of continuous data to normal distribution. The Mann-Whitney U test was used for comparisons between continuous variables of patients with a flat IVC and non-flattened IVC. Chi-square test was used for comparisons between categorical variables patients with a flat IVC and non-flattened IVC (in diagonal tables). The relationships between IVC flatness index and, initial lactate level and base deficit were analyzed with Spearman's Correlation Coefficient. P 0.05 was considered statistically significant.

RESULTS

379 patients were included in the study. Of all the patients, 299 (79.5%) were male and the mean age was 32.60±12.48 (min 18-max 69).

The causes of blunt trauma of the patients; motor vehicle accident in 161 (42.5%) patients, fall in 91 (24%) patients, pedestrain accident in 70 (18.5%) patients, motorcycle accident in 31 (8.2%) patients, and other blunt accident in 26 (6.9%) patients, respectively.

The mean IVC flatness index of the patients in the study was 2.64±0.80 (min 0.7-max 4.1). 116 (30.6%) were found to have a flat IVC and 263 patients (69.4%) were found to have a non-flattened IVC. There was no significant difference between flat IVC patients and non-flattened IVC patients in terms of age, gender, comorbidity and trauma mechanism ($p>0.05$).

The difference in SI between flat IVC patients and non-flattened IVC patients was detected ($p<0.001$). It was determined that 18 (15.5%) of flat IVC patients and 4 (1.5%) of non-flattened IVC patients had SI of 0.9 and above. Flat IVC patients had a higher SI of 0.9 and above ($p<0.001$).

ISS of flat IVC patients were higher than those of non-flattened IVC patients ($p<0.001$). It was determined that 25 (21.6%) of flat IVC patients and 10 (3.8%) of non-flattened IVC patients had an ISS of 16 and higher. The ratio of flat IVC patients having a higher ISS of 16 and above was observed ($p<0.001$).

There was no difference in GCS score between patients with a flat IVC and patients with a non-flattened IVC ($p>0.05$). However, 24 (20.7%) of flat IVC patients and 17 (6.5%) of non-flattened IVC patients were found to have GCS problem with 13 and below ($p<0.001$).

Lactate level was found to be higher in flat IVC patients than in non-flattened IVC patients ($p<0.001$). Base deficit was found to be worse in flat IVC patients ($p<0.001$, $p<0.001$).

In patients with flat IVC, volume replacement, operation need and hopitalization within 24 hours of clinical outcome were higher than patients with non-flattened IVC (p<0.001).

No patient died in ED. Hospital mortality in flat IVC patients was higher than in non-flattened IVC patients (15.5% versus 3.8%, p<0.001) (Table 1).

Table 1 . Comparison of initial lactate level and base deficit in flat IVC and non-flattened IVC patients with their demographic and clinical characteristics

	Total (n=379)	**Flat IVC (n=116)**	**Non-flattened IVC (n=263)**	**P value**
Age (years), [median (IQR)]	27 [15 (25 -40)]	27 [15 (25 -40)]	26.5 [16 (24 -40)]	0.732 [a]
Gender, n (%)				
Female	80 (21.1)	26 (22.4)	54 (20.5)	0.679 [b]
Male	299 (79.5)	90 (77.6)	209 (79.5)	
Comorbidity , n (%)				
No	320 (84.4)	102 (87.7)	218 (82.9)	0.212 [b]
Yes	59 (15.6)	14 (12.1)	45 (17.1)	
Trauma mechanism , n (%)				
Motor vehicle accident	161 (42.5)	56 (48.3)	105 (39.9)	0.270 [b]
Fall	91 (24)	22 (19)	69 (26.2)	
Pedestrian accident	70 (18.5)	19 (16.4)	51 (19.4)	
Motorcycle accident	31 (8.2)	8 (6.9)	23 (8.7)	
Other blunt accident*	26 (6.9)	11 (9.5)	15 (5.7)	
SI, [median (IQR)]	0.6 [0.1 (0.5 -0.6)]	0.6 [0.2(0.5 -0.7)]	0.6 [0.1(0.5 -0.6)]	**<0.001** [a]
ISS, [median (IQR)]	11 [5 (9 -14)]	15 [1 (14 -15)]	10 [2 (9 -11)]	**<0.001** [a]
GCS, [median (IQR)]	13 [1 (13 -14)]	14 [2 (13 -15)]	13 [1 (13 -14)]	**0.075** [a]
Lactate, (mmol/L), [median (IQR)]	1.5 [0.5(1.2 -1.7)]	1.9 [0.4(1.5 -1.9)]	1.5 [0.4(1.2 -1.6)]	**<0.001**[a]
Base deficit, (mmol/L) , [median (IQR)]	-1.6 [2 (-3.2 – 1.2)]	-4.0 [1.30 (-4.5 –-3.2)]	-1.4 [0.80 (-1.9–-1.1)]	**<0.001**[a]
Volume replacement , n (%)				
No	273 (72)	48 (41.4)	225 (85.6)	**<0.001**[b]
Yes	106 (28)	68 (58.6)	38 (14.4)	
Operation, n (%)				
No	353 (91.3)	98 (84.5)	255 (97)	**<0.001**[b]
Yes	26 (6.9)	18 (15.5)	8 (3)	
Hospitalization, n (%)				
No	263 (69.4)	47 (40.5)	216 (82.1)	**<0.001**[b]
Yes	116 (30.6)	69 (59.5)	47 (17.9)	
Hospital mortality, n (%)				
No	351 (92.6)	98 (84.5)	253 (96.2)	**<0.001**[a]
Yes	28 (7.4)	18 (15.5)	10 (3.8)	

IVC: inferior vena cava, SI: shock index, GCS: Glasgow Coma Score, ISS : Injury Severity Score, a: Mann Whitney -U test, b: Chi -Square test

Other blunt accident*: fall of heavy object, truck accident, bus accident etc.

On multivariate analysis there was no correlation between the patients' flatness index of IVC and age, GCS and SI (p>0.05). And correlation were found between the patients' flatness index of IVC and, lactate level, ISS, base deficit (r=-0.353 p<0.001; r=-0.702 p<0.001, r=0.656; p<0.001 respectively) (Table 2).

Table 2. Correlation between patients' IVC flatness index and shock index, Glasgow Coma Score, Injury Severity Score, lactate level and base deficit

	The Flatness Index of IVC r; p value [a]
Age	0.038; 0.485
Shock index	-0.141; 0.006
Injury Severity Score	**-0.702; <0.001**
Glasgow Coma Score	-0.004; 0.944
Lactate	**-0.353; <0.001**
Base deficit	**0.656; <0.001**

a: Spearman's Correlation Coefficient

The flatness index of IVC intraobserver and interobserver correlation was found significant (p<0.001). Intra and interobserver intraclass correlation coefficients for all quantitative measurements were 0.96 and 0.94, respectively.

DISCUSSION

Trauma-related injuries, which are among the most common causes of admission to ED, are important causes of morbidity and mortality. 30% of patients with multiple injuries die from hypovolemic shock within 2-3 hours after receiving injury.11 Early recognition of hypovolemic shock is important in terms of reducing the effects of tissue hypoxia, anaerobic metabolism, and metabolic acidosis and preventing mortality.1

CT scan is a frequently used radiological method in the evaluation of patients exposed to trauma in ED. The IVC is an important but often overlooked vascular structure in abdominal examinations.12 In our study, we evaluate the role of flatness index of IVC with early hypovolemic shock in blunt torso trauma patients. In studies on the relationship of IVC diameter or IVC ratio with hypovolemia in trauma patients, there are various differences between anatomical localizations and measurements in which IVC is measured. For example, some studies evaluated the anteroposterior diameter measurements at levels above and/or below the renal vein level of the IVC.4,13, while other studies evaluated the flatness index by measuring the ratio of the transverse diameter to the anteroposterior diameter.6,11,15,16 In our study, we evaluated the IVC flatness index from above the renal veins.

Mechanical ventilation increases intrathoracic pressure and changes the appearance of the IVC compared to spontaneously breathing patients.17 In these patients, the IVC diameter reaches a maximum with inspiration and a minimum IVC diameter with expiration.18 Therefore, we did not include mechanically ventilated patients before CT scanning in our study.

There is no agreement about the cut-off value for the IVC flatness index in trauma patients. Li et al in their study with 63 patients with multiple injuries with ISS equal to or larger than 16 stated the flatness index cut-off as 3.02 and they found that the incidence of hypovolemic shock was higher in those with a flatness index above this value.11 Johnson et al. reported a cut-off of 1.9 for the IVC flatness index to predict mortality in their study (sensitivity 52%, specificity of 88%), and suggested a rate of 2 to define flat IVC in clinical use.8 In our study, we considered those with a flatness index above 2 as flat IVC, and those with a flatness index of 2 and less as non-flattened IVC.

In this study, similar to other studies conducted with trauma patients, we did not find a significant relationship between the IVC flatness index and age and gender.8,11,19 Motor vehicle accident, fall, and pedestrian accident were the most common trauma mechanisms, respectively. And similar to other studies.8,17,19, we did not find a significant relationship between the IVC flatness index and trauma mechanisms in the present study.

The SI, which is the ratio of HR to SBP, is more sensitive in estimating shock in the early period.20 Even if the heart rate and systolic blood pressure are within normal limits, the increase in the shock index shows the relationship with the circulating volume.5 Elevation in SI has been correlated with circulatory volume, even when HR and SBP are within normal limits. In our study, SI was higher in flat IVC patients than in non-flattened IVC patients. Nguyen et al. found that SI was higher in flat IVC patients, and flat IVC was an independent risk factor for occult shock.17

Trauma scoring systems are widely used to determine the severity of the patient's condition in the early period and to predict the prognosis.21 ISS is the scoring system used to evaluate the severity of injury in trauma patients with multiple injuries, and GCS is the scoring system used to evaluate the neurological status. ISS is observed to be higher in patients with flat IVC.8,17,22 It has been reported that there is a negative correlation between the GCS score and the flatness index of IVC.19 While we found a negative correlation between the flatness index of IVC and ISS in our study, we did not observe a correlation between the GCS score and the flatness index of IVC.

Initial admission lactate level and base deficit are shock markers that show physiological irregularity in the evaluation of trauma patients.23 Furthermore, it reliably predicts the need and outcome of transfusion in hemodynamically stable patients.3

In our study, first admission lactate level was higher in flat IVC patients compared to non-flat IVC patients. The study of Li et al. observed that the lactate level of the patients in the shock group was higher, by comparing the patients in the shock group and the stable group.11 Nguyen et al. found flattened IVC patients have higher lactate level than non-flattened IVC patients.17 Miraflor et al. found no significant difference between IVC-ratio and lactate level in their study, in which they divided the patients into two groups as normal and high (>2 mmol/L) lactate levels.15 However, in this study, patients who had CT scans within 2 hours were included and approximately 13% of the patients had on positive pressure ventilation in the CT scan.15 Davis et al. in their study with trauma patients, stated that base deficit ≥-6 is indicator of moderately to severely injured trauma patients.23 In our study, first admission base deficit was found to be worse in flat IVC patients than non-flat IVC patients.

Nguyen et al. and Liao et al. found in their studies that resuscitation of flattened IVC patients required significantly higher amounts of crystalloids and blood products compared to non-flattened IVC patients.17,22 Matsumoto et al. in their study with blunt torso trauma patients that flat IVC is an indication of hemodynamic deterioration and requires early blood transfusion in trauma patients.6 On the other hand, Radomski et al., in their study with blunt trauma patients, stated that IVC size in trauma patients was not associated with emergency transfusion.4 In our study, a volume replacement was observed to be higher within 24 hours of clinical outcome in patients with flat IVC. It is thought that these differences may be due to the varying severity of traumas in the patients included in the studies. Radomski et al. stated in their study with blunt trauma patients that IVC size in CT scan could not be used to predict mortality.4 However, patients who were intubated before CT scan were also included in this study. In addition, before the CT scan, the amount of intravenous volume given to the patients and lactate level measurements were not available.

Arslan et al. found no difference in mortality in flattened and non-flattened IVC patients in their study, and they stated that this was due to concomitant head traumas.16 In the study of Nguyen et al., patients with flat IVC had a higher mortality rate than patients with fat IVC (5.2% vs. 5.8%, $P = 0.867$); however, statistically, no significant difference was observed.17 In the study of Johnson et al., it was stated that flattening in the IVC could be used as a mortality determinant in trauma patients.8 In the study of Matsumoto et al., the mortality rate was 52% versus 2% ($p < 0.05$) in the presence and absence of flat IVC, respectively, while it was 31% versus 2% ($p < 0.05$) in the Liao et al. study. 6,22In this study, hospital mortality was higher in flat IVC patients than non-flattened IVC patients. This is thought to be resulting from patients with flat IVC having severer injuries which had higher ISS need for surgery within 24 hours of clinical outcome, and hospitalization compared to non-flattened IVC patients.

The current study features the limitations that all retrospective studies encounter. In addition, it is a single institute study. Although all laboratory studies and CT scans were obtained within 1 hour after patient arrival, it may differ from patient to patient in terms of timing of laboratory studies and CT scans. The study group consisted of patients with blunt injuries; the results may not be valid for penetrating trauma patients.

CONCLUSION

IVC is an important vascular structure in the initial CT scan of trauma patients. And in the initial CT scan of blunt torso trauma patients, the flatness of IVC index is associated with early hypovolemic shock. It is thought that the flatness of IVC index can be a guide in the evaluation of intravascular volume in these patients.

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REFERENCES

1.Cortés-Samacá CA, Meléndez-Flórez HJ, Robles SA, et al. Base deficit, lactate clearance, and shock index as predictors of morbidity and mortality in multiple-trauma patients. Rev Colomb Anestesiol. 2018; 46: 208–215
2.Chien CY, Yan JL, Han ST, et al. Inferior Vena Cava Volume Is an Independent Predictor of Massive Transfusion in Patients With Trauma. J Intensive Care Med. 2021;36(4):428-435. doi:10.1177/0885066619894556
3.Elst J, Ghijselings IE, Zuidema WP, Berger FH. Signs of post-traumatic hypovolemia on abdominal CT and their clinical importance: A systematic review. Eur J Radiol. 2020;124:108800. doi:10.1016/j.ejrad.2019.108800
4.Radomski M, Agnihothri R, Knapp S, et al. Inferior vena cava size is not associated with shock following injury. J Trauma Acute Care Surg. 2014;77(1):34-39. doi:10.1097/TA.0000000000000248
5.Koch E, Lovett S, Nghiem T, Riggs RA, Rech MA. Shock index in the emergency department: utility and limitations. Open Access Emerg Med. 2019;11:179-199. Published 2019 Aug 14. doi:10.2147/OAEM.S178358
6.Matsumoto S, Sekine K, Yamazaki M, et al. Predictive value of a flat inferior vena cava on initial computed tomography for hemodynamic deterioration in patients with blunt torso trauma. J Trauma. 2010;69(6):1398-1402. doi:10.1097/TA.0b013e3181fc406f
7.Bilgin S, Topal FE, Yamanoğlu A, et al. Effect of Changes in Intravascular Volume on Inferior Vena Cava and Aorta Diameters and the Caval/Aorta Index in Healthy Volunteers. J Ultrasound Med. 2020;39(2):231-238. doi:10.1002/jum.15093
8.Johnson JJ, Garwe T, Albrecht RM, et al. Initial inferior vena cava diameter on computed tomographic scan independently predicts mortality in severely injured trauma patients. J Trauma Acute Care Surg. 2013;74(3):741-746. doi:10.1097/TA.0b013e3182827270
9.Taylor GA, Fallat ME, Eichelberger MR. Hypovolemic shock in children: abdominal CT manifestations. Radiology. 1987;164(2):479-481. doi:10.1148/radiology.164.2.3602389
10.Jeffrey RB Jr, Federle MP. The collapsed inferior vena cava: CT evidence of hypovolemia. AJR Am J Roentgenol. 1988;150(2):431-432. doi:10.2214/ajr.150.2.431
11.Li Y, Zhang LY, Wang Y, Zhang WG. The flatness index of inferior vena cava is useful in predicting hypovolemic shock in severe multiple-injury patients. J Emerg Med. 2013;45(6):872-878. doi:10.1016/j.jemermed.2013.04.036
12.Smillie RP, Shetty M, Boyer AC, Madrazo B, Jafri SZ. Imaging evaluation of the inferior vena cava. Radiographics. 2015;35(2):578-592. doi:10.1148/rg.352140136
13.Mirvis SE, Shanmuganathan K, Erb R. Diffuse small-bowel ischemia in hypotensive adults after blunt trauma (shock bowel): CT findings and clinical significance. AJR Am J Roentgenol. 1994;163(6):1375-1379. doi:10.2214/ajr.163.6.7992732
14.Smithson L, Morrell J, Kowalik U, Flynn W, Guo WA. Correlation of computed tomographic signs of hypoperfusion and clinical hypoperfusion in adult blunt trauma patients. J Trauma Acute Care Surg. 2015;78(6):1162-1167. doi:10.1097/TA.0000000000000623
15.Miraflor E, Yeung L, Strumwasser A, Sadjadi J, Victorino GP. Correlation between IVC dimensions and volume status on CT scan. J Surg Res. 2011;170(2):291-296. doi:10.1016/j.jss.2011.03.057
16.Arslan CE, Yesilaras M, Atilla OD. Does flattened IVC on CT can show hypovolemia in trauma patients?. Anatolian J Emerg Med. 2020; 3(1); 1-5.
17.Nguyen A, Plurad DS, Bricker S, et al. Flat or fat? Inferior vena cava ratio is a marker for occult shock in trauma patients. J Surg Res. 2014;192(2):263-267. doi:10.1016/j.jss.2014.06.052
18.Kohli-Seth R, Neuman T, Sinha R, Bassily-Marcus A. Use of echocardiography and modalities of patient monitoring of trauma patients. Curr Opin Anaesthesiol. 2010;23(2):239-245. doi:10.1097/ACO.0b013e328335f007
19.Yazlamaz NO, Ozakin E, Bastug BT, et al. The Flatness Index of Inferior Vena Cava can be an Accurate Predictor for Hypovolemia in Multi-Trauma Patients. Prehosp Disaster Med. 2021;36(4):414-420. doi:10.1017/S1049023X21000418
20.Salottolo KM, Mains CW, Offner PJ, Bourg PW, Bar-Or D. A retrospective analysis of geriatric trauma patients: venous lactate is a better predictor of mortality than traditional vital signs. Scand J Trauma Resusc Emerg Med. 2013;21:7. Published 2013 Feb 14. doi:10.1186/1757-7241-21-7
21.Ahun E, Köksal Ö, Sığırlı D, Torun G, Dönmez SS, Armağan E. Value of the Glasgow coma scale, age, and arterial blood pressure score for predicting the mortality of major trauma patients presenting to the emergency department. Ulus Travma Acil Cerrahi Derg. 2014;20(4):241-247. doi:10.5505/tjtes.2014.76399
22.Liao YY, Lin HJ, Lu YH, Foo NP, Guo HR, Chen KT. Does CT evidence of a flat inferior vena cava indicate hypovolemia in blunt trauma patients with solid organ injuries?. J Trauma. 2011;70(6):1358-1361. doi:10.1097/TA.0b013e3181f31e37
23.Davis JW, Sue LP, Dirks RC, et al. Admission base deficit is superior to lactate in identifying shock and resuscitative needs in trauma patients. Am J Surg. 2020;220(6):1480-1484. doi:10.1016/j.amjsurg.2020.10.005