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Original Article

Are aortic artery diameter and inferior vena cava diameter reliable predictor indices in traumatic patients with hemorrhagic shock?

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Abstract

Introduction: Intravascular volume is the most important factor in determining patients' hemodynamic status. The present study aimed to assay the predictive value of aorta artery diameter and inferior vena cava (IVC) diameter in trauma patients with hemorrhagic shock.
Methods: This was a cross-sectional study conducted on 69 trauma patients who were referred to Imam Reza hospital in Tabriz. Inclusion criteria were all trauma patients with hemorrhagic shock. Patients with diseases such as liver disease, cardiovascular diseases, coronary heart disease and concurrent dehydration were excluded. Odds ratios (ORs) and adjusted ORs for the risk of events were obtained using cumulative logit ordinal regression model with version 15 of Stata software.
Results: There were 58 men (84.1%) and 11 women (15.9%) with an average age of 36.4±12.4 years. Findings showed that for one unit increase in the diameter of the aorta by controlling the effect of other variables, the odds of mortality decreased 2% compared with hospitalization in ward or intensive care unit (ICU). The reduction was also statistically significant ($P=0.037$). Furthermore, by modifying the effect of other variables, one unit increase in the diameter of IVC during inhale and exhale, increases the odds of hospitalization in ward or ICU.
Conclusion: This study showed that the diameter of the aorta and also the diameter of IVC during inhalation and exhalation could be used to predict the outcome of trauma patients with hemorrhagic shock and eventually to take steps for emergent and effective treatment.

Introduction

Intravascular volume, in other terms the effective circulating volume, is the key factor in determining the hemodynamic status of patients. The volume either decreases or increases could have consequences on the outcome and status of patients' recovery. The decreased intravascular volume which happens due to the bleeding and dehydration can result in hypovolemic shock and may cause death.[1,2] On the other hand, the increased intravascular fluid volume will cause pulmonary edema and decrease in intravascular fluid volume is threatening and causes morbidity and mortality.[3,4] Body fluid volume regulation is created by many factors which balance hydrostatic pressure of intravascular and extracellular fluid osmolarity.[5-7]

Awareness of intravascular volume as a determining factor in the hemodynamic status of critically ill patients is very important. The body fluid requirement can be calculated by clinical examination, pulse and blood pressure changes, and urine output. At present, the measurement of central venous pressure (CVP) is the most accurate way to estimate the body fluid. It is worth mentioning that direct measurement of CVP could be detrimental but have potential side effects.[5,6,8] The diameter of inferior vena cava (IVC) on ultrasound during inhale and exhale has been calculated 10.5±5 and 14±4 mm, respectively.[9,10] There is a direct relationship between IVC diameter and intravascular fluid volume.[11] Such a correlation has been shown in patients with chronic kidney failure who have been dialyzed.[12,13] One study has shown that the ratio of IVC diameter to aortic artery diameter has a 86% sensitivity and a 56% specificity in assessing intravascular fluid volume.[14] However, the other study did not confirm such a relationship.[15]

According to above-mentioned issues, attention to the grade of dehydration in patients suffering from hemorrhagic shock as well as using methods for estimating dehydration with noninvasive method will be preferable

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*Corresponding Author: Neda Gilani, Email: gilanin@tbzmed.ac.ir in determining the patients' prognosis.[13,14,16,17] It is also important to note that, patients with hemorrhagic shock are classified into similar prognosis group and as a result, a significant improvement in the treatment of patients with hemorrhagic shock will be made. The purpose of this study was to assay the predictive effect of aorta and IVC diameters in trauma patients with hemorrhagic shock.

Methods

This cross-sectional study was performed through convenient sampling in a specific time on 69 trauma patients referred to Imam Reza hospital of Tabriz, Iran. To determine the sample size, by considering the sensitivity of the IVC diameter to a decrease in effective circulating volume of 91% and a 35% prevalence of the phenomenon and with an accuracy of 0.1 as well, the required sample size for the present study was considered at least 66 patients. Finally, 69 patients were examined. All cases of traumatic patients with hemorrhagic shock referred to the emergency department of Imam Reza hospital and volunteered to participate in this research were included in this study. Exclusion criteria were some underlying diseases such as liver disease, cardiovascular and coronary heart disease, simultaneous exposure to severe dehydration that *might* have *happened* by vomiting or gastroenteritis before or simultaneously with the trauma resulting in lack of diuresis in the patient, skin turgor, confusion, tachycardia, tachypnea, circulatory shock, and unconsciousness or delirium and, unstable hemodynamics (including symptoms of *inadequate organ perfusion*). To measure the diameter of IVC after patients admission to emergency medicine department and initial examination in terms of having inclusion criteria, curve probe 2.25-5 MHz was used once the patients were in a comfortable supine position. The prob was placed underneath the xiphoid process in the longitudinal and transverse sections. The diameter of IVC was measured underneath the intersection of the hepatic veins (2 cm below the diaphragm) where the anterior and posterior walls are parallel. It was measured during the regular breathing cycle. The aortic diameter was measured 5-10 mm above the celiac trunk near the IVC in a similar way. The used sonographic device was SocoSite M-Turbo (H-Universal Stand). It is important to say that the ethical standards were observed and all patients' data were kept confidential and the participants' consent to participate in the project was obtained. All Helsinki criteria were met as well.

The Stata software version 15 (College Station, TX: Stata Corp LLC; 2017) was used for statistical analysis. Data was presented using mean (SD) and frequency (percentage) for the numeric and qualitative variables, respectively. Odds ratios (OR) and adjusted ORs for the risk of events and 95% confidence intervals (CIs) were obtained using cumulative logit ordinal regression model. Proportional odds assumption and parallel regression assumption were accepted by an approximate likelihood-ratio test of proportionality of odds across response categories and Brant test for this regression. In general, for OR interpretation in the model we were comparing the patients who were greater than k groups versus those who were in less than or equal to k groups, where k is the level of the response variable. Model interpretation can use ORs for the cumulative probabilities and their complements. The log of this OR is the difference between the cumulative logits at those two values of independent variable. *P* value less than 0.05 was considered as significant difference.

Results

Study population

Sixty-nine trauma patients with hemorrhagic shock referred to the emergency of Imam Reza hospital were included in the study. Of all these patients, 7 (10.1%) patients were admitted to the ward, 58 (84.1%) patients were hospitalized in the intensive care unit (ICU) and unfortunately, 4 (5.8%) patients died. Available

Table 1. Descriptive statistics for qualitative demographic, injury trauma mechanism and clinical variables in patients (N=69)

Variable	Category	No. (%)	*P* value*
Sex	Male	58 (84.1)	<0.001
	Female	11 (15.9)	
Marital status	Married	22 (31.9)	.0030
	Single	47 (68.1)	
Initial complaint	accident	58 (84.1)	<.001
	Overturn	2 (2.9)	
	Falling	7 (10.1)	
	conflict	2 (2.9)	
Injury trauma mechanism	*Car crash*	9 (13.0)	<0.001
	motorcycle/car crash	4 (5.8)	
	Overturn	29 (40.6)	
	Falling	7 (10.1)	
	conflict	2.0 (2.9)	
	head-on collision.	9 (13.0)	
	Pedestrian accident	9 (13.0)	
Upper limb	Yes	12(17.4)	<0.001
	No	55 (79.7)	
Lower limb	Yes	36 (52.2)	0.718
	No	33 (47.8)	
Abdomen pelvic	Yes	52 (75.4)	<0.001
	No	17 (24.6)	
Head neck	Yes	35 (50.7)	.9040
	No	34 (49.3)	
Shock classification	I	3 (4.3)	<0.001
	II	5 (7.2)	
	III	57 (82.6)	
	IV	4 (5.8)	

* Based on chi-square test.

Table 2. Descriptive statistics and 95% confidence interval for quantitative demographic and clinical variables

Variables	Mean ± SD	Min-Max	95 % CI Mean
Age (y)	32.36±12.37	15-85	29.40-35.33
SBP (mm Hg)	78.82±12.02	50.00-100.00	75.44-82.20
DBP (mm Hg)	42.94±12.69	30.00-65.00	39.37-46.52
PR (/min)	131.78±10.98	91.00-155.00	128.69-134.87
SPO_2 (%)	89.96±5.39	75.00-100.00	88.44-91.48
GCS	13.67±1.07	9.00-15.00	13.37-13.97
HGB (gr/dL)	10.57±1.72	8.00-16.00	10.14-10.99
HCT (%)	32.22±0.57	24.40-43.90	31.07-33.39
PLT (/mL)	259.81±82.12	140.00-492.00	233.97-285.65
Cr (g/dL)	0.99±0.15	0.75-1.40	0.93-1.06
Na (meq/dL)	140.34±2.91	135.00-150.00	139.29-141.39
K (meq/dL)	4.29±0.40	3.40-5.20	4.15-4.42
INR	1.14±0.11	0.90-1.50	1.11-1.18
PR=100 (/min)	0.99±0.12	0.00-1.00	0.95-1.01
PR=120 (/min)	0.91±0.28	0.00-1.00	0.84-0.98
Aorta (mm)	172.88±50.00	90-300	160.87-184.90
IVC inhale diameter (mm)	75.59±22.01	20-172	70.31-80.88
IVC exhale diameter (mm)	95.77±21.98	30-194	90.49-101.05
I/A	0.46±0.14	0.15-0.81	0.42-0.49
E/A	0.58±0.16	0.15-0.94	0.55-0.62
Diff (I-E)/A	0.12±0.10	0.00-0.55	0.10-0.15

demographic and clinical characteristics are shown in Tables 1 and 2. The mean age of patients was 32.36 years with a maximum of 85 years and a minimum of 15 years. Fifty-eight patients were male (84.1%) and 11 patients were female (15.9%) ($P<0.001$). Twenty-two patients were married (31.9%) and 47 patients were single (68.1%) ($P=0.003$). The most prevalent initial mechanism was accident (58 patients) (84.1%) and the least prevalent mechanism was due to quarrel (2.9%) ($P<0.001$). Radiographic findings are shown in Table 1. In addition, based on the scale of shock classification, most patients were placed in grade III, and categorizing patients in different classes was statistically significant ($P<0.001$). The average diameter of the aorta and IVC during inhalation and exhalation was 172.88 ± 50.00, 75.59 ± 22.01, and 95.77 ± 21.98, respectively.

Aorta, inhalation and exhalation IVC diameters with the end outcome classifications (unadjusted analysis)

The relationship between the diameter of IVC during breathing to the diameter of aorta and the outcome of patients using the cumulative logit ordered logistic regression model are shown in Table 3. As it is demonstrated, for one-unit increase in the aorta diameter, the OR of mortality versus hospitalization in the ward or ICU is reduced by 3% which is also statistically significant ($P=0.003$). In addition, for one-unit increase in the diameter of IVC during inhalation and exhalation the odds of hospitalization in ward or ICU are increased 5% ($P=0.006$) and 6% ($P=0.001$), respectively compared with an odd of mortality.

Aorta, inhalation and exhalation IVC diameters with the end outcome classifications (adjusted analysis)

Furthermore, the correlation between the diameter of the aorta as well as the diameter of IVC during inhalation and exhalation phases, and patients outcome by controlling the effect of the other variables are shown in Table 3. In other words, by controlling the effect of other variables, one unit increase in the diameter of aorta resulted in a 2% decrease in the OR of mortality compared with hospitalization in the ward or ICU (the change was statistically significant ($P=0.037$)). Moreover, for one unit increase in the diameter of IVC during inhalation and exhalation, the odds of hospitalization in the ward or ICU increased 5% ($P=0.017$) and 6% ($P=0.003$), respectively compared with an OR of mortality.

Age, blood pressure and other covariates with the end outcome classifications (unadjusted analysis)

According to Table 3, for one year increase in age, the OR of mortality in trauma patients increased by 10% (this was statistically significant (OR=1.10, $P=0.044$)). It is worth mentioning that other variables such as systolic blood pressure (OR= 0.91, $P=0.007$), diastolic blood pressure (OR=0.92, $P=0.013$), SPO_2 (OR=0.83, $P=0.041$) and other significant effective factors were calculated for determining the final outcome. Also, an increase in the Glasgow Coma Scale (GCS) score of patients increases the OR of mortality by 26% (OR=1.26, $P=0.009$). The other variables studied in Table 3 did not show a statistically significant effect on patients' outcomes.

Age, blood pressure and other covariates with the end outcome classifications (adjusted analysis)

The last two columns of Table 3 show the results of the multivariate regression analysis. Based on these results, if the age of trauma patients increases for one year, by controlling the effect of other variables, the OR of mortality will increase by 8% (OR=1.08, $P=0.041$). On the other hand, by eliminating the effect of other variables in the model, systolic blood pressure (OR=0.87, $P=0.009$), diastolic blood pressure (OR=0.84, $P=0.019$) and SPO_2 (OR=0.79, $P=0.095$) were specified as the significant effective factors in the final outcome. By modifying the effect of other variables, one unit increase in GCS score of patients increased the odds of mortality by 28% (OR=1.28, $P=0.008$). The other variables in Table 3 were not statistically significant on patients' outcomes.

Bivariate association between aorta, inhale and exhale diameters

Pearson correlation results between aorta diameter and

Table 3. The association of variables in the model with the outcome of patients by cumulative logit ordinal regression model (N= 69)

Variables	Ward Patients	ICU Patients	Died Patients	Unadjusted OR (95% CI)	*P* value	Adjusted OR* (95% CI)	*P* value
	Mean (SD)	Mean (SD)	Mean ± SD				
Total, No. (%)	7 (10.1)	58 (84.1)	4 (5.8)				
Age (y)	31.14 (6.67)	31.29 (11.00)	50.00 (25.26	1.10 (1.05,1.15)	0.044	1.08(1.02-2.14)	0.041
SBP (mm Hg)	82.86(9.06)	77.57 (11.43))	60.00 (14.14)	0.91(0.86-0.97)	0.007	0.87(0.81-0.92)	0.009
DBP (mm Hg)	50.71 (10.96)	42.10 (12.17)	42.10 (12.17)	0.92(0.86-0.98)	0.013	0.84(0.84-0.91)	0.019
PR (/min)	126.14 (19.14)	132.57 (8.75)	128.75 (13.15)	1.03(0.97-1.09)	0.387	0.93(0.80-1.09)	0.407
SPO2 (%)	94.67 (.97)	89.36 (5.42)	90.00 (2.21)	0.83(0.75-0.97)	0.041	0.79(0.65-0.87)	0.045
GCS	12.43 (3.36)	13.49 (1.78)	14.50 (0.58)	1.26(1.12-1.66)	0.009	1.28(1.13-1.71)	0.008
HGB (g/dL)	12.18 (1.20)	10.23 (1.44)	12.60 (3.26)	0.92(0.60-1.42)	0.708	1.12(0.73-1.72)	0.600
HCT (%)	36.34 (2.19)	31.69 (4.04)	35.40 (11.60)	0.88(0.72-1.06)	0.175	1.02(0.73-1.44)	0.886
PLT (/qL)	250.75 (22.54)	261.36 (89.24)	250.0 (32.53)	1.00(0.99-1.01)	0.930	0.99(0.98-1.01)	0.726
Cr (g/dL)	1.01 (0.02)	0.97 (0.147)	1.23 (0.25)	5.28(0.07-10.24)	0.225	1.47(0.05-5.02)	0.916
Na (meq/dL)	139.75 (2.06)	140.48 (3.21)	140.0 (1.56)	1.03(0.78-1.35)	0.859	1.10(0.77-1.59)	0.587
K (meq/dL)	4.25 (0.47)	4.31 (0.41)	4.10 (0.26)	0.67(0.09-5.21)	0.705	0.55(-.05-6.46)	0.634
INR	1.25 (0.10)	1.12 (0.10)	01.27 (0.21)	0.41 (0.21-7.02)	0.814	0.54 (0.01-7.43)	0.884
Aorta (mm)	215.71 (49.62)	171.02 (46.82)	125.0 (51.96)	0.97 (0.95-0.99)	0.005	0.98 (0.96-0.99)	0.037
Inhale (mm)	93.14 (37.54)	75 (18.27)	49.50 (13.67)	0.95 (0.92-0.99)	0.006	0.95 (0.92-0.99)	0.017
Exhale (Mm)	120.57(34.09)	94.55 (16.96)	70.0 (28.56)	0.94 (0.90-0.97)	0.001	0.94 (0.90-0.97)	0.003
I/A	0.45 (0.18)	0.46 (0.14)	0.47 (0.23)	1.59 (0.02-4.21)	0.840	1.00 (0.96-1.05)	0.711
E/A	0.58 (0.17)	0.58 (0.14)	0.67 (0.35)	1.97 (0.06-2.12)	0.443	1.52 (0.01-1.97)	0.858
Diff (I-E)/A	0.13 (0.03)	0.12 (0.10)	0.12 (0.10)	1.31 (0.02-2.33)	0.420	1.04 (0.99-1.10)	0.098

*Adjusted odds ratio (95% CI) for all other variables

Table 4. Results of Pearson correlation for Aorta, Inhale and Exhale variables

Variable	1. Aorta		2. Inhale		3. Exhale	
	r	*P*	*r*	*P*	*r*	*P*
1. Aorta	1	-				
2. Inhale	0.45	<0.001	1	-		
3. Exhale	0.51	<0.001	0.78	<0.001	1	-

r: Pearson correlation coefficient.

IVC diameter during breathing are shown in Table 4. The table shows that there is a significant direct binary relationship between these variables. For instance, if the IVC diameter during inhalation increases, the IVC diameter during exhalation increases as well and vice versa significantly (r=78, $P<0.001$). The predictive percentage of the IVC diameter during exhalation via IVC diameter during inhaling is r^2 = 061 (61%).

Discussion

The main goal of this study was to investigate the predictive value of IVC diameter as well as the diameter of aorta in trauma patients with hemorrhagic shock. Radiographic findings showed that in terms of damaged part, the percentage of injury in upper limbs, lower limbs, abdomen and pelvis, and also head and neck were 17.4%, 52.2%, 75.4%, and 50.7%, respectively. In addition, based on the scale of shock classification, most patients were placed in grade III, and categorizing patients in different classes was statistically significant. Results from Baumann's study showed a significant relation between diameter of the aorta as well as the diameter of IVC during inhaling and exhaling phases.[18] Mechanical insufflation-induced collapse of the superior vena cava has been shown to be correlated with the respiratory variation in blood pressure. It has been reported that in patients whose lungs are being mechanically ventilated, a collapse of the superior vena cava may also occur, which is significantly reduced by volume loading.[19,20] IVC diameter was found to be unrelated to age. In this study, the increase in the diameter of aorta resulted in decrease in the OR of mortality compared with hospitalization in the ward or ICU. In this regard Airapetian et al demonstrated that neither the IVC diameter nor IVC variability could accurately predict fluid responsiveness in spontaneously breathing patients hospitalized in the ICU.[21] It has been also reported that respiratory variation in IVC diameter has limited ability to predict fluid responsiveness, particularly in spontaneously ventilating patients. A negative test cannot be used to rule out fluid responsiveness. With an increase in the diameter of IVC during inhale and exhale, the OR of hospitalization in the ward or ICU increased compared with an OR of mortality. Clinical context should be taken into account when using IVC ultrasound to help make treatment decisions. Also, the study of Mandelbaum & Ritz and Gutierrez et al showed a clear correlation

Study Highlights

What is current knowledge?

- Ultrasound is noninvasive method for diagnosisof early stages of hypivolemic shock in emergency department

What is new here?

- Aort diameter is a good index and parameter fordiagnosis of hypivolemic shock

between systolic blood pressure, diastolic blood pressure and IVC risk during exhalation which is consistent with our results.[22,23] Actual increase in downstream pressure induced by mechanical insufflation may not result in an increase in IVC size when the vessel is already fully distended. According to the other studies and this study, for one year increase in age, the OR of mortality in trauma patients increased by 10%.[24,25]

Conclusion

This study showed that the diameter of IVC during inhalation and exhalation and also the diameter of the aorta can be used to predict the outcome of trauma patients with hemorrhagic shock and eventually to take steps for urgent and effective treatment.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

The study was approved by the ethics committee of Tabriz University of Medical Sciences (Code: IR.TBZMED.REC.1395/3-6/7).

Author's Contribution

All authors have reviewed, approved, and consented to the submission, and they are accountable for all aspects of its accuracy and integrity.

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