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Original Article

Use of vena cava inferior collapsibility index and perfusion index in volume status monitoring during intermittent fasting in the ramadan

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Abstract

Aim: This study aimed to evaluate the hemodynamic status of fasting emergency service professionals by measuring the inferior vena cava collapsibility index (IVCCI) using bedside ultrasonography and the perfusion index (PI) using a noninvasive method and examining the relationship between these two parameters.

Materials and Methods: This was a prospective cross-sectional study. The IVCCI and PI were measured in emergency service professionals at 11:00 am, 07:00 pm, and 10:00 pm between May 16 and June 4, 2018, corresponding to the 11^{th} and 20^{th} days of Ramadan. IVCCI and PI levels at different times of fasting and after feeding were compared.

Results: The IVCCI-2 value of the volunteers at the 16^{th} hour of fasting was significantly higher than the IVCCI-1 value at the 8^{th} hour of fasting ($p < 0.001$). The IVCCI-3 value at the postprandial 2^{nd} hour after eating was significantly lower than both the average IVCCI-1 at the 8^{th} hour of fasting ($p < 0.001$) and average IVCCI-2 at the 16^{th} hour of fasting ($p < 0.001$). The PI-2 value at the 16^{th} hour of fasting was significantly lower than the PI-1 value at the 8^{th} hour of fasting. The PI-3 value at the postprandial 2^{nd} hour after eating was significantly higher than both the average PI-1 at the 8^{th} hour of fasting ($p = 0.001$) and the average PI-2 at the 16^{th} hour of fasting ($p < 0.001$).

Conclusion: The collapsibility increased at the longest time of fasting, and the collapsibility ratio decreased after eating. Similarly, PI was the lowest at the longest time of fasting, whereas PI increased after eating.

Keywords: Fasting; inferior vena cava collapsibility index; perfusion index

INTRODUCTION

During the month of Ramadan, Muslims worldwide abstain from food, drinks (including water), smoking, and sexual activities from dawn until dusk. Throughout the month of Ramadan, meals are eaten during the night hours, with a large meal being taken after the sunset (iftar), and a smaller meal taken before dawn (suhoor). Thus, depending on the season and geographical location, the time during which meals can be taken is limited to 6–12 hours in a day (1, 2). Fasting is a common practice in different faiths, including Islam, Christianity, Judaism, and Hinduism. Fasting is different from hunger, which is a chronic and serious deficiency during which the caloric energy intake is below that necessary to sustain life (3). Staying hungry for a longtime is associated with positive effects on mood owing to changes in cellular physiology, such as increased levels of central endogenous neurotransmitters, endogenous opioids, and endocannabinoids (4). In contrast, fasting is reported to have negative effects on non-communicable diseases (5), sleep patterns, and cognitive function (6), in addition to other effects such as fluctuations in mood and body weight (7). Furthermore, fasting can lead to changes in some parameters such as the body mass index and hematocrit and albumin levels as well as cause dehydration (8,9). Thus, it can be presumed that hunger during the month of Ramadan may have various effects on circulation and peripheral perfusion. To our knowledge, there are no studies on this topic to date. An insufficiency in vena cava collapsibility and low perfusion index (PI) reflect a hemodynamic disorder. In a previous study, the volume of vena cava was evaluated by emergency medicine specialists by measuring the diameter of the inferior vena cava (IVC) using a bedside ultrasound (10); however, we found no study that focused on fasting.

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PI is the ratio of the pulsatile blood flow in the peripheral tissue to the non-pulsatile or static blood. PI allows noninvasive and continuous measurement of peripheral perfusion using a pulse oximeter. PI measurement involves evaluation of the pulsatile strength in a specific area (the hand, finger, or foot) and represents an indirect and noninvasive measurement of peripheral perfusion. During the initial evaluation of critical patients, PI is determined in addition to five vital parameters: arterial blood pressure, pulse, respiratory rate, temperature, and saturation (11).

The aim of this study was to evaluate the hemodynamic status of fasting emergency service professionals by measuring the inferior vena cava collapsibility index (IVCCI) using bedside ultrasonography and the PI using a noninvasive method and examining the relationship between these two parameters.

MATERIALS and METHODS

Study Design

This prospective cross-sectional study was conducted between May 16 and June 4, 2018, corresponding to the 11^{th} and 20^{th} days of the month of Ramadan. The ethical approval for the study was obtained from the local ethics committee of the Health Sciences University, Diyarbakir Gazi Yasargil Training and Research Hospital (Decision Date: 13 April 2019, No: 61).

Participants

The study volunteers comprised employees working in the emergency medicine clinic of our hospital. Each volunteer was evaluated three times on the same day, regardless of the amount of food intake in suhoor and body mass index., with the first, second, and third measurements taken at the 8^{th} and 16^{th} hour of fasting and at the postprandial second hour after eating (iftar) (11:00 am, 07:00 pm, and 10:00 pm), respectively. Vital parameters (arterial blood pressure and peripheral pulse per minute), PI, and IVCCI (using bedside ultrasound) were checked at each evaluation.

The study included healthcare workers who were fasting during the month of Ramadan, had no history of chronic diseases, did not have a history of regular medication use, aged >18 years, and who agreed to the conditions of the study and signed the informed consent form. 3 individuals who were pregnant, 2 individuals who had a history of chronic disease or regular medication use, and 5 individuals who were fasting without eating at suhoor were excluded. Finally, 58 healthcare workers included our study.

Study Parameters

Weight measurements comprised the first and second measurements recorded at 11:00 am and 07:00 pm on the 8^{th} and 16^{th} hour of fasting (measurements 1 and 2, respectively) and the third measurement recorded at the postprandial 2^{nd} hour after eating (measurement 3). In each of the three evaluations, arterial blood pressure, peripheral pulse per minute, PI, and IVCCI were measured using a bedside ultrasound. Each parameter was numbered according to the time of measurement: systolic blood pressure (SBP 1,2,3), diastolic blood pressure (DBP 1,2,3), pulse count (Pulse 1,2,3), perfusion index (PI-1,2,3), vena cava inspiration diameter (IVC insp-1,2,3), vena cava expiration diameter (IVC exp-1,2,3), and inferior vena cava collapsibility index (IVCCI-1,2,3).

Measurement of Inferior Vena Cava Index

The researchers who conducted the study had received certified basic and advanced ultrasonography (USG) training and routinely use bedside USG to assess critically ill patients in an emergency. They performed the protocols on how to apply a bedside ultrasound to patients. IVC measurements were performed using the rP19x 1–5-MHz probe of the bedside ultrasound (Sonosite EDGE 2, FUJIFILM Sonosite, Inc, Washington, USA) that is used in our emergency service. In the supine position, the junction of the IVC and right atrium was identified by imaging the regions around the liver and heart from the subxiphoid window. Measurements were made in this region from the images taken at approximately 2 cm to the distal using the M-mode of the device. In these measurements, the diameters (cm) during inspiration and expiration were recorded. IVCCI was calculated using the following formula: IVCCI = (IVC exp − IVC insp)/IVC exp.

Measurement of Perfusion Index

Concurrent with the vital signs of the participants, PI values were measured and noninvasively recorded from the fourth distal phalanx of the nondominant hand using the saturation probe of the Massimo-SET Root 7362A RDS7 pulse oximeter and by waiting for 1 min with the hand kept at the level of the heart.

Statistical Analysis

Data analysis was performed using the SPSS Windows 20 software (Chicago, USA). Online power analysis was used to determine the number of participants to be included in the study. When Type I and II margins of error were considered as 0.5 and 0.2, respectively, the minimum number of participants per group and the necessary test power to identify a significant difference of 0.10 units between the average IVCCIs measured at 07:00 pm and 10:00 pm were calculated as eight subjects and 80%, respectively. Moreover, when the same margins of error were used to identify a significant difference of 3.29 units between the average PIs measured at 07:00 pm and 10:00 pm, the minimum number of subjects per group and the necessary test power were calculated as 10 subjects and 80%, respectively. The Shapiro–Wilk test was then used to evaluate the distribution of the data. The one-way ANOVA was used because the data showed normal distribution. The post-hoc Tukey's test was used for intergroup comparisons, whereas the Pearson's correlation test was used to analyze the possible relationships between the data. A p value of <0.05 was considered statistically significant.

RESULTS

A total of 58 subjects comprising 41 men (70.6%) and 27 (29.4%) women (average age, 33 ± 7.9 years and average body mass index, 25.44 ± 3.27) were included.

Table 1. Correlation Between VCICI, PI and other Hemodynamic Parameters

	8th hours of fasting	16th hours of fasting	2th hours of postprandial	Anova (P) *	Post-hok Tukey test		(P) ±
VCI eksp	1.93 ± 0.31	1.85 ± 0.30	2.07 ± 0.33	0 .001	VCI eksp-1	VCI eksp- 2	0.37
						VCI eksp- 3	0.51
					VCI eksp-2	VCI eksp- 1	0.37
						VCI eksp- 3	0.001
					VCI eksp-3	VCI eksp- 1	0.051
						VCI eksp- 2	0.001
VCI insp	1.44 ± 0.28	1.29 ± 0.27	1.67 ± 0.30	<0.001	VCI eksp-1	VCI eksp- 2	0.012
						VCI eksp- 3	<0.001
					VCI eksp-2	VCI eksp- 1	0.012
						VCI eksp- 3	<0.001
					VCI eksp-3	VCI eksp- 1	<0.001
						VCI eksp- 2	<0.001
VCICI					VCICI- 1	VCICI -2	<0.001
						VCICI -3	<0.001
					VCICI- 2	VCICI -1	<0.001
						VCICI -3	<0.001
					VCICI- 3	VCICI -1	<0.001
						VCICI -2	<0.001
PI	6.68 ± 2.35	5.22 ± 1.91	8.51 ± 2.67	<0.001	PI-1	PI-2	0.003
						PI-3	0.001
					PI-2	PI-1	0.003
						PI-3	<0.001
					PI-3	PI-1	<0.001
						PI-2	<0.001
SBP	118.77 ± 8.43	113.60 ± 6.77	122.86 ± 9.31	<0.001	SBP- 1	SBP -2	0.003
						SBP -3	0.023
					SBP- 2	SBP -1	0.003
						SBP -3	<0.001
					SBP- 3	SBP -1	0.023
						SBP -2	<0.001
DBP	66.75 ± 8.15	63.48 ± 7.39	68.74 ± 8.38	0.002	DBP - 1	DBP-2	0.073
						DBP-3	0.377
					DBP - 2	DBP-1	0.073
						DBP-3	<0.001
					DBP - 3	DBP-1	0.377
						DBP-2	<0.001
Pulse	70.77 ± 10.89	72.63 ± 10.18	81.62 ± 10.96	<0.001	Pulse-1	Pulse-2	0.636
						Pulse-3	<0.001
					Pulse-2	Pulse-1	0.636
						Pulse-3	<0.001
					Pulse-3	Pulse-1	<0.001
						Pulse-2	<0.001

P * Anova ve P ± Post Hok Tukey Test <0.05 significant
DBP: Diastolic Blood Pressure, PI: Perfusion Index, SBP: Systolic Blood Pressure, VCI eksp: Vena Cava Expiration Diameter, VCI insp: Vena Cava Inspiration Diameter, VCICI: Inferior Vena Cava Collapsibility Index

The average IVCCI of the participants were 0.25 ± 0.06 at 11:00 am (IVCCI-1), range 0.14–0.39 (95%CI: 0.24–0.27); 0.30 ± 0.07 at 07:00 pm (IVCCI-2), range 0.16–0.45 (95%CI: 0.29–0.32); and 0.2 ± 0.05 at 10:00 pm (IVCCI-3), range 0.11–0.30 (95%CI: 0.18–0.1; Table 1 and Figure 1). In the comparison of average IVCCI measured at different times using the post-hoc Tukey's HSD test, the IVCCI-2 value at the 16th hour of fasting was significantly higher than the IVCCI-1 value at the 8th hour of fasting ($p < 0.001$). Furthermore, the IVCCI-3 value at the postprandial 2nd hour was significantly lower than the average IVCCI-1 value at the 8th hour of fasting ($p < 0.001$) and the average IVCCI-2 at the 16th hour of fasting ($p < 0.001$).

The average PI of the participants were 6.68 ± 2.35 at 11:00 am (PI-1), range 2.3–13.0 (95%CI: 6.03–7.30); 5.22 ± 1.91 at 07:00 pm (PI-2), range 2.0–9.6 (95%CI: 4.72–5.73); and 8.51 ± 2.67 at 10:00 pm (PI-3), range 4.2–15 (95%CI: 7.81–9.21; Table 1 and Figure 2). In the comparison of PI values measured at different times using the post-hoc Tukey's HSD test, the PI-2 value at the 16th hour of fasting was significantly lower than the PI-1 value at the 8th hour of fasting (p = 0.003). Furthermore, the PI-3 value at the postprandial 2nd hour was significantly higher than the average PI-1 value at the 8th hour of fasting (p = 0.001) and the average PI-2 value at the 16th hour of fasting (p < 0.001). In the Pearson's correlation test (Table 2), a significant relationship was observed between IVCCI and PI, and an increase in collapsibility was associated with a decrease in PI (r = −0.30, p < 0.001). Moreover, PI had a moderate and positive correlation with DBP and SBP (r = 0.37, p = 0.01 and r = 0.17, p = 0.042, respectively). In the ROC analysis, the area under the curve was the lowest at 07:00 pm when the time of fasting was at its longest (PI-2; p < 0.001), and it was significantly the highest after eating (PI-3; p < 0.001; Figure 3). The other data of the participants is presented in Table 1.

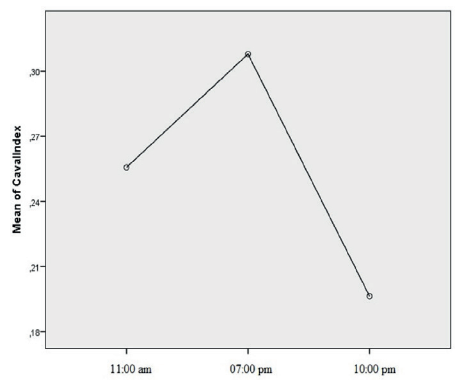

Figure 1. The mean inferior vena cava collapsibility index (IVCCI) of the participants with the first, second, and third measurements

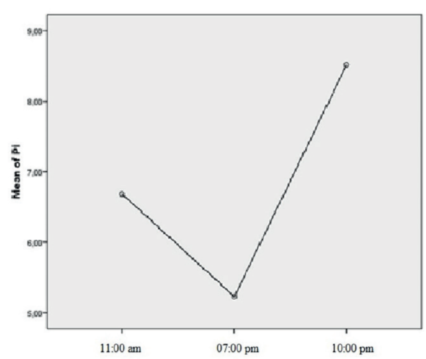

Figure 2. The mean Perfusion Index (PI) of the participants with the first, second, and third measurements

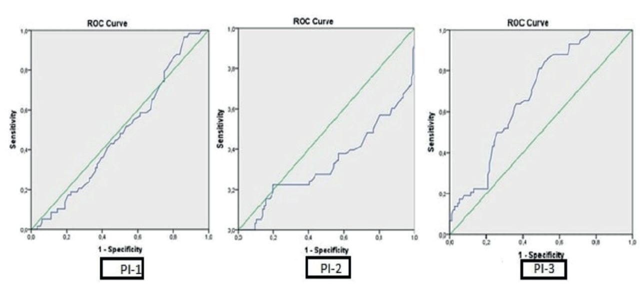

Figure 3. In the ROC analysis for perfusion index (PI), the area under the curve was the lowest at 07:00 pm when the time of fasting was at its longest (PI-2; P<.001), and it was significantly the highest after eating (PI-3; P<0.001)

Table 2. The relationship of PI with VCICI and other hemodynamic parameterss according to Pearson's correlation test

PI	VCICI	VCI insp	VCI eksp	DBP	SBP	Pulse
r*=	- 0.30	0.42	0.37	0.17	0.06	-0.007
P*=	< 0.001	< 0.001	< 0.001	0.02	0.42	0.92

r * : Pearson's Correlation Coefficient,
P * : Correlation is significant at level <0.05
DBP: Diastolic Blood Pressure, PI: Perfusion Index, SBP: Systolic Blood Pressure, VCI eksp: Vena Cava Expiration Diameter, VCI insp: Vena Cava Inspiration Diameter, VCICI: Inferior Vena Cava Collapsibility Index

DISCUSSION

Our results showed that the IVCCI-2 value at the 16th hour of fasting was significantly higher than the value at the 8th hour of fasting (IVCCI-1), and the IVCCI-3 at the postprandial 2nd hour was significantly lower than the average IVCCI-1 at the 8th hour of fasting and the average IVCCI-2 at the 16th hour of fasting. Moreover, the PI-2 value at the 16th hour of fasting was significantly lower than the PI-1 value at the 8th hour of fasting, whereas the PI-3 value at the postprandial 2nd hour was significantly higher than the average PI-1 value at the 8th hour of fasting and the average PI-2 value at the 16th hour of fasting.

Fasting results in ketogenesis as well as strong changes in metabolic pathways and cellular processes. There are various fasting types depending on the length of time and the quantities of food and liquids allowed.

Staying hungry for prolonged duration can cause serious problems in patients suffering kidney or other diseases. Dehydration and a drop in blood pressure can lead to acute kidney damage, hyperviscosity, thrombosis, or other complications. Because of the lack of large-scale studies, there are no specific guidelines on venous collapsibility and PI in healthy people who are fasting. Certain studies analyzing the effect of hunger on patients with kidney disease have shown contradicting results. In a study including patients with kidney damages at different stages in Turkey, it was reported that there is no deterioration in kidney functions during fasting (12). A prospective cohort study showed that there was an increase in the urea and BNP levels in fasting individuals during the day (13). Liquid homeostasis during fasting in the month of Ramadan has been studied in several studies (2,3,14). The water cycle quickly increases during the month of Ramadan, with an increase in the indicators of body hydration, including levels of hematocrit, serum urea, and creatinine and urine osmolality (14). It is almost certain that these changes would have a harmful impact on people with chronic illnesses; however, there are not sufficient clinical studies to predict the effects that these changes might cause in healthy individuals. In general, studies on fasting during the month of Ramadan should be interpreted by considering certain factors such as the time of previous meal, methodological differences, and the state of hydration. Fasting during Ramadan and its physiological effects tend to become mostly apparent in countries geographically located at high altitudes and in places with the most hours of daylight (14). The present study was conducted in Diyarbakır located in the southeast of Turkey and a bridge between Asia and Europe, where summers are dry and hot. The fasting measurements were taken between May 16 and June 4, 2018, which is a relatively hot period; this might have impacted our results. The USG measurements comprised expiration and inspiration measurements obtained from images taken in the M-mode of the device, at approximately 2 cm distal of the subxiphoid window with individuals in the supine position.

The method of taking IVC diameter measurements using USG has become important to show the changes associated with respiratory changes as well as to determine the liquid response (15). Various clinical studies have reported that the caval index of IVC and the maximum diameter at the end of expiration period during spontaneous respiration are indicators of liquid response (16). Previously, USG IVC diameter was used as a parameter for liquid resuscitation in healthy volunteers (17) in different patient groups (18,19) and meta-analyses (20). In a meta-analysis study, it was reported that the measurement of IVC diameter during the differentiation of normovolemic and hypovolemic conditions represents a mild level of evidence, and further studies are necessary to completely determine the role of IVC diameter measurement (20). In the present study, IVCCI measurements were taken from emergency service professionals at the 8th hour, 16th hour of a period of fasting and thirst that can normally extend to 16 hours, and 2 hours after eating and drinking. In these measurements, we observed that IVCCI was the highest at the 16th hour of fasting, when hunger and thirst reached their peak. IVC diameter is a reliable indicator of volume status (21). However, preoperative fasting has a significant effect on hypovolemia (22,23). Seif et al. previously suggested IVC diameter measurement, good collapsibility index, and low decrease in liquid volume (24).

Changes in caval collapsibility can affect central circulation and peripheral perfusion. PI can be used as an additional parameter to evaluate the hemodynamic response to intubation, and it has been reported to have a negative correlation with average arterial pressure (25). To detect the peripheral PI changes during central hypovolemia, stroke volume, heart rate, average blood pressure, and PI were previously examined using a pulse oximeter in 25 healthy volunteer adults. Central hypovolemia and PI shock were detected very early and before cardiovascular deterioration (26). A study conducted in a healthy population determined that PI distribution was >1.4, and the PI value in critical patients after 8 hours of resuscitation significantly correlated with 30-day mortality (27). Another study concluded that PI can be used to monitor peripheral perfusion in critical patients (28). The most striking characteristic of the present study is that in the 07:00-pm measurements, when fasting was the longest, PI was significantly lower than the measurements obtained at 2 hours after the start of eating and drinking. The present study was not performed in any disease group.

The participants comprised middle-aged healthy individuals who periodically fasted during the month of Ramadan; this made our study different from others in this regard. Moreover, in the Pearson's correlation test, it was observed that an increase in collapsibility was accompanied with a decrease in PI. Moreover, PI had a moderate and positive correlation with DBP and SBP.

LIMITATIONS

There were some limitations of our study. Firstly, the number of participants was not sufficient to analyze the personal variables between the participants. Moreover, we lacked a non-fasting control group, which we believe is an important limitation. Another limitation was that only noninvasive USG and PI measurements of the volunteers were obtained. More beneficial results could have been obtained if the electrolyte and kidney functions of the participants were also examined. Also the researchers who conducted the study had received certified basic and advanced ultrasonography (USG) training and routinely use bedside USG to assess critically ill patients in an emergency. Similar studies can be done with the radiologist to check and compare USG measurements of emergency physicians.

CONCLUSION

The collapsibility increased at the longest time of fasting, whereas the collapsibility ratio decreased after eating. Similarly, PI was the lowest during the longest time of fasting, whereas PI increased after eating. However, there is a need for further comprehensive prospective studies to support these results regarding vena cava collapsibility and peripheral circulation obtained from fasting participants.

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Competing interests: The authors declare that they have no competing interest.

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Ethical approval: The ethical approval for the study was obtained from the local ethics committee of the Health Sciences University, Diyarbakir Gazi Yasargil Training and Research Hospital (Decision Date: 13 April 2018, No: 61).

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