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Preoperative and Postoperative Assessment of Ultrasonographic Measurement of Inferior Vena Cava: a Prospective, Observational Study

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Running title: Preoperative and postoperative inferior vena cava

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Abstract

Background: Ultrasound measurement of dynamic changes in inferior vena cava (IVC) diameter and collapsibility index (CI) evaluates to estimate the fluid responsiveness and intravascular volume status. We conducted a analysis to quantify the sonographic measurement of IVC diameter changes in adult patients at preoperative and postoperative period.

Methods: Ultrasonography was performed on 72 patients scheduled for surgery with American Society of Anesthesiologists physical status I to III. Quantitative assessments of the end-expiration (D_{min}), end-inspiration (D_{max}) and CI at preoperative and postoperative period were compared in a prospective, observational study. The patients received intravenous fluid according to standard protocol regimes peroperatively. The cutt-off value of dIVC 40% was accepted as hypovolemia.

Results: Ultrasonography of IVC measurement was unsuccessful in 12.5% of patients and 63 patients remained for analyses. The mean age was 43.29 ± 17.22 (range 18 - 86) years. The average diameter of the D_{min}, D_{max} and dIVC at preoperative and postoperative were 1.99 ± 0.31 *vs*. 2.05 ± 0.29 cm, 1.72 ± 0.33 *vs.* 1.74 ± 0.32 cm, 14.0 ± 9.60 % *vs.* 15.14 ± 11.18 %, respectively ($p<0.05$). Using a threshold dIVC of 40%, one patient preoperatively and 5 postoperatively were hypovolemic ($p<0.05$). CI was also positively associated preoperatively and postoperatively (regression coefficient = 0.438, $p<0.01$).

Conclusion: The diameter of IVC did not change preoperatively and postoperatively in adult patients with standard fluid regimens. The parameters of the IVC diameter increased postoperatively according to preoperative period.

Key words: Ultrasonography, preoperative, postoperative, collabsibility index, inferior vena cava diameter

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Introduction

Perioperative fluid administration is an important issue that has been discussed for many years in anesthesiology practice.[1] The goal of the perioperative fluid management is to avoid acute renal failure, cardiac arrhythmias, inadequate tissue oxygenation, decreased blood flow to organ perfusion, hypotension due to hypovolemia and to avoid interstitial edema and cardiopulmonary complications due to excess fluid.[1,2] Therefore, the management of the fluid status of the patient in the perioperative period is important in terms of postoperative mortality and morbidity.[2]

The clinical findings, vital signs (blood pressure, heart rate) as well as hemodynamic parameters such as central venous pressure (CVP) and even pulmonary artery occlusion pressure (PAOP) have not been accurate in determining circulating blood volume during conventional perioperative fluid management.[3] Although systolic pressure and pulse pressure variations are successful methods for detecting fluid response, these do not improve patient outcome.[4] Despite improved patient outcome by esophageal Doppler-optimized fluid management, but this method is not performed commonly for financial problems and practical reasons.[5]

In recent years, ultrasonographic inferior vena cava (IVC) diameter measurement changes due to respiratory variations have become an important method to determine the fluid responsiveness.[6] Researches has also demonstrated good correlation with right atrial cardiac functions and IVC diameter measurements.[7] The caval index of the IVC and the maximum diameter at the end of the expiration in the spontaneous respiration were shown to be indicators of the fluid responsiveness in different clinical trials.[8,9]

The aim of the present study was to determine the IVC diameter measurements with respiratory variability in spontaneous breathing patients underwent surgical operations preoperatively and postoperatively with standard fluid regimens.

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Material and Methods

Patients

This prospective, observational research was performed in a single urban state hospital. The approval for the research was granted by the Institutional Ethics Committee (decision no 2017/81, Diyarbakir Training and Research Hospital Ethics Committee). Written and spoken informed consent was obtained from all patients. The inclusion criteria for the study were patients aged over 18 years with a body mass index (BMI) less than 40 kg/m^2 and patients who understood the study protocol and informed consent. Patients with abnormal anatomy of the gastrointestinal tract (previous esophageal, hepatic, gastric surgery, including hiatus hernia), pregnancy, a history of major peripheral vascular disease, increased intraabdominal pressure, difficult airway problems, coronary artery disease, myocardial infarction in the past 3 months, stroke, congestive heart failure (with an ejection fraction less than 35%), severe chronic pulmonary diseases, renal dysfunction (creatinine> 2.2 mg / dL), abnormal coagulation values, active abdominal skin infection were excluded from the study.

Preoperative Procedure

In the preoperative care unit, the spontaneously breathing patients lying supine; gastric examination and ultrasonography were performed by an experienced practitioner (who had at least 5 months of gastric ultrasound experience and performed 50 IVC ultrasound examinations). The doctor who performed the ultrasonography did not affect anesthesia management and other processes of the patient. The procedure was performed by a 2-5 Mhz curvilinear array low frequency transducer (Sonosite® M-Turbo Bothell WA, USA) and recorded digitally. The transducer was placed along the subcostal longitudinal axis. First, the right atrium entrance of the IVC was identified as two-dimensional. Pulse wave doppler was used to separate the IVC from aorta. The IVC diameter was measured in a 2-dimensional mode with an M-mode at 2-3 cm distal from the right atrium entrance. The IVC collabsibility index was calculated as (dIVC-CI)= (dIVCmax- dIVCmin) / dIVCmax and defined as percentage (%).

Anesthesia management

The 18G or 20G intravenous catheters were inserted to all patients. The non invasive blood pressure (NIBP), standard electrocardiogram (ECG), SpO2 (peripheral oxygen

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saturation), end tidal carbon dioxide were monitored preoperatively. The anesthetic induction was applied with midazolam (0.05-0.2 mg/kg) intravenously, fentanyl (1-2 mcg/kg) intravenously, propofol (2-2.5 mg/kg) intravenously and rocuronium (0.6 mg/kg) intravenously. Anesthesia was maintained with 40-50% O2-air, MAC (minimum alveolar concentration) level inhalation gases for sevoflurane (1.45%) or desflurane (5,3%). The mechanical ventilation was adjusted as tidal volume (6-8 ml / kg), PaCO2 35-40 mmHg, I: E ratio 1.2, VCV ventilation mode (Datex Ohmeda, S/5 Avance Healthcare, Helsinki, Finland) after orotracheal intubation. Anesthetic agents were adjusted to maintain heart rate <100 bpm and mean blood pressure (MAP) within 30% baseline. MAP > 30% was treated with labetolol or gliserol trinitrate intravenously. Hypotension was treated firstly fluid administration, if not improved, then Ephedrine (5-15 mg) was applied intravenously. The bradycardia was accepted heart rate less than at 45 bpm. If required, it was treated with atropine (0.015 mg / kg) intravenously. At the end of surgery neuromuscular block was reversed with neostigmine (0.05 mg / kg) intravenously and atropine sulphate (0.015 mg/ kg) intravenously.

Spinal anesthesia was applied in midline axis between the L2-3, L3-4 and L4-5 intervertebral space with the patients in the sitting position with 10-20 mg. dosing heavy bupivacaine according to surgery type. The atraumatic pencil point needles were used for neuroaxial anesthesia. The motor and sensory block level was evaluated by Bromage scale. The operation was allowed as motor and sensory block levels reached T4-T6 dermatome levels. The hemodynamic instabilities was treated with guidelines as described above.

The supraclavicular block was applied to the patient to be treated with peripheral neuroaxial block. After antisepsis of the block to be blocked, 2 ml of 2% arythmal infiltration was performed on the subcutaneous tissue. The supraclavicular approach used 22 G, 50 mm needle (Pajunk needle, Germany) for block applications. 20 ml levobupivacaine + 0.5% 2% 10 ml lidocaine solution was used as the local anesthetic mixture.

Intraoperative fluid management

The baseline fluid requirement in perioperative period was calculated on the duration of fasting, the fluid shift toward third space and the amount of bleeding. The basal fluid requirement was calculated according to Holliday and Segar's 4-2-1 rule and for the first 10 kg wieght 4 mL / h, 2 mL/ h for the second 10 kg, and 1 mL/h for the rest. [14] Fluid deficit in pre-operative period were calculated by the fasting time of the basal fluid requirement, and ½ of this amount was administred in first hour of operation, ¼ of the second hour and ¼ of the

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third hour. For intraoperative blood and insensible loss 0-2 ml/kg fluid was infused for minimal surgical procedures (eg, inguinal hernia repair) 2-4 ml / kg for moderate surgical procedures (eg Cholecystectomy) 4-8 ml / kg for severe surgical procedures (eg bowel resection).

Postperative procedure

All patients were followed at postanesthesia care unite (PACU) for at least 30 minutes. IVC ultrasonography was performed to spontaneously breathing patients lying supine after pain management with Tramadol (0,8-1 mg/kg) if required, by the same experienced physician. The doctor who performed the ultrasonography was not aware of anesthesia management and the other processes of the patient. The procedure was repeated as described above preoperatively. Patients who were suspected of increase in postoperative intraabdominal pressure were not included in the USG procedure.

Data collection

During the study period, the data of the patients were recorded prospectively. The age, gender, height, weight, body mass index (calculated according to BMI = weight / height^2 formula), types of surgery, applied anesthesia techniques (general anesthesia, spinal anesthesia, peripheral nerve blocks), preoperative and postoperative IVC values (IVC diameter at inspiration and expiration), amount of peroepratif fluid and peroperative hemodynamic values were recorded.

Statistical Analyses

In this study, to demonstrate the results a descriptive analysis of the demographic data (age, weight, height, and BMI), gender and ASA classifications were used. The data were summarized using the mean and standard deviation. The Shapiro–Wilk test was used for the assumption of normal distribution of continuous variables. If variables were normally distributed, central tendency was expressed as the mean (SD). Means were compared using independent or paired Student's t-test. Spearman correlation analysis was used to find out a correlation between non-normally distributed independent variables. Fisher exact test was used for categorical data and expressed in count, percentages. Differences were considered significant if $p<0.05$. Statistical analysis was performed using SPSS 22 (Chicago, Illinois, USA).

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Results

A seventy two patients were recruited in study. Ultrasonography of IVC measurement was unsuccessful in 12.5% of patients. A total of 9 patients were excluded; in 7 patients detailed images could not be taken effectively preoperatively and postoperatively, and 2 patient had suspicion of intraabdominal pressure insrease postoperatively due to abdominal surgery. Therefore, evaluation was made with 63 patients. (Figure 1) The patients comprised 32 males and 31 females with a mean age of 43.29 ± 17.22 years (range, 18-86 years). Average body mass index was 25.73±4.07 kg/m^2. The perioperatively mean infused fluid was 985.80±484.27 ml. The demographic data of the patients are shown in Table 1. The following surgical operations were included: general (32), orthopedic (n = 16), general (n = 12), urology(n = 6), otolaryngology (n=4), neurosurgical (n = 4). The comorbidities of patients were six patients with hypertension (n=6), diabetes mellitus (n=4), cardiovascular diseaes (n=2), respiratuary (n=2).

USG images of inferior vena cava of the patients are shown in Figure 2. The two-dimensional scan of the IVC with right atrium to the left was shown in panel above. The M-mode scan with respiratory variations in diameter was shown in panel below.

The mean, standard deviation, minimum and maximum values of the inferior vena cava diameter on inspirium, expirium and collabsibility index are shown in Table 2. The maximum diameter of inferior vena cava were 1.99±0.31 mm. preoperatively and 2.05±0.29 mm postoperatively (p>0.05). The preoperative IVC-CI was 14,0±9,60 % preoperatively and 15.14±11.18 % postoperatively. No statistically significant difference was determined between the mean inferior vena cava diameters on inspirium, expirium and collabsibility index preoperatively and postoperatively (p > 0.05). There was no significant difference between hemodynamic parameters (systolic, diastolic, mean blood pressure) of preoperatif and postoperatif periods.(p>0.05)

There was seen no significant differences between mean arterial pressure and dIVC postperatively (Figure 3A). The correlation coefficient was determined as r = 0.018 (p = 0.31). Similar results were determined in the relationship between mean arterial pressure and dIVC preoperatively (r=0.005, p>0.05) (Figure 3B). Positive and statistically significant

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correlation was found between preoperative CI and posoperative CI. (r=.438, p<0.01) (Figure 4)

Discussion

In our prospective study, we determined the changes of the inferior vena cava diameter and collapsibility index values preoperatively and postoperatively. We did not find any significant difference of the IVC measurement values between the pre and postoperative periods in accordance with hemodynamic parameters.

In recent years, bedside ultrasongraphy has gained popularity in anethesiology as being cost-effective, supplying real time images, non-invasive and practical diagnostic tool. There were many research investigated inravascular volume status by USG of IVC diameters on healty volunteers [10], peritoneal dialysis patients [11], healthy volunteers in the center of phlebotomy [12], critically ill patients in intensive care units [13,14] and was shown to be a safe and reliable method in metanalyses for fluid resuscitation.[15]

The variation of IVC diameter is related to complaince of IVC vessel, central venous pressure, intrathoracic and intraabdominal pressure. Although there were some studies using (Dmax + Dmin) / 2 formula for the calculation of the Caval index (CI) calculation [16], we calculated with (dIVCmax - dIVCmin)/dIVCmax formula which is mostly used.[17–19] Ultrasonography of IVC was measured multiple locations in different studies and it was shown that the measurement locations affects the CI values.[20] The upstream origin of suprahepatic vein [14], at level of left renal vein [20], 10 mm distal to the diaphragm [21] were different locations that IVC measured. In our study, we obtain images from the most frequently used measuring location which was within 2-3 cm from the right atrium outlet.[8,14,17] Nine patients (12,5%) were excluded from the study because IVC ultrasonography measurements were not obtained due to excessive gas, large body size and increased subcutaneous fat texture in the intestine. Our results were consistent with other studies that unsuccesful IVC visualization observed in 11% [17] and 13.5% [16] of patients in different studies.

The post-laparotomy or increased intraabdominal pressure may affect the IVC diameter, these patient groups excluded from the study did not include our study.[22] In addition, adequate analgesic supplementation may be needed for comfortable USG images due to restlessness caused by postoperative pain.

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The IVC diameter and IVC variability are an effective method for predicting fluid responsiveness both in mechanically ventilated critical ill patients and spontaneous breathing patients. Studies conducted up to now on the cut-off values of IVC parameters did not result in a common result. The cut-off value for IVC-CI fluid responsiveness in mechanically ventilated septic patients was measured varied between 12-18% [13,14]; whereas in spontaneous breathing patients, Müller et al. demonstrated a cut-off value of 40% [18] , Airapetian et al. 42%.[17][24] Muller et al. showed that cIVC above 40% are more likely to respond fluid challenge, although values below 40% can not exclude fluid responsiveness in patients with acute circulatory failure.[18] Due to the uncertainty of the cutoff values in spontaneous breathing patients, we have not used a common value that can show fluid responsiveness in our study.

To prevent the risk of pulmonary aspiration, preoperative fasting protocols are applied before planned surgeries. It is assumed that hemodynamic fluctuations intraoperatively and at anesthetic induction period that decreased blood volume may be caused by hypovolemia and dehydration due to preoperative fasting. [2,16,23] Opposite to this assumption, other studies like Müller et al. stated that there is not significant effect of preoperative fasting on hypovolemia.[22] Jacob et al. stated that healhty patients remain normovolemic after preoperative fasting and hpotension developing after anesthetic induction was not due to hypovolemia. [24] There is evidence that the IVC diameter is a reliable indicator of volume status.[25] The greater collabsibility index with small IVC diameter suggested low volume status in study of Seif et al.[26] In our study, we did not detect higher collabsibility index (14,0±9,60 %) and smaller IVC diameters preoperatively. Based on these results, we can say that preoperative fasting does not cause volume changes based on IVC diameter measurements.

Fluid balance in post-operative period can be predicted by changes in body weight, peroperative fluid input, urine output, hemodynamic parameters, CVP etc. But the results are not accurate and efficient. For example, low urine output does not mean low intravascular blood volume. Because the surgical stress increases both antidiuretic hormone and sympathetic tone that lower urine output. Moreover, large amount of total blood volume loss may maintain blood pressure in normal level.[27] Other measurement devices like pulmonary artery catheters and cardiovascular surgeons are limited due to practical limitations in elective non-cardiac surgeries. Although CI index change was higher in preoperative patients than in

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postoperative patients, no significant difference was found in or study. It was also observed that the number of patients with elevated CI increased. Possible causes of this nonspecific results include the changes in the compartments of the fluid in the body due to surgical stress, anesthetic agents and hypothermia.[23,28] So we think that ultrasonographic IVC measurements are a simple, practical, and effective method for determining volume status in the postoperative early period.

There are several limitations on this study. In order to confirm these findings, the study population should be large. In our study, because of the measurement of different surgical operations, minor and major surgical procedures cause different levels of stress activation and consequently the fluid shifts between compartments may differ and these can cause different measurement results. For this reason, it is important to perform separate studies in similar surgical procedures. In addition, since the perioperative fluid regimes differ, the work should be extended with different fluid regimes. Because the increase in intraabdominal pressure is a limiting factor for IVC measurements. Another measurement for dIVC method should be performed for this group patients.

Conclusion

In conclusion, ultrasonographic IVC measurements of postoperative patients and CI calculation were not found to be statisticaly higher than preoperative patients despite standard preioperative fluid treatments. IVC diameter measurements are an effective, practical, non-invasive method for demonstrating fluid responsiveness that can be used safely in fluid management of pre and postoperative patients.

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Abbreviations

IVC: inferior vena cava; dIVC: inferior vena cava diameter, CI: collapsibility index, CVP: central venous pressure, PAOP: pulmonary arterial occlusion pressure, USG: ultrasonography.

Competing interests

The authors declare that they have no competing interests. Consent for publication Not applicable. Funding None

Authors contributions

Conceptualization, A.K. and E.G; Methodology, A.K.; Software, A.K.; Validation, A.K., E.G.; Formal Analysis, A.K.; Investigation, A.K.; Resources, A.K.; Data Curation, A.K, E.G.; Writing – Original Draft Preparation, A.K.; Writing – Review & Editing, A.K.; Visualization, A.K.; Supervision, E.G.; Project Administration, A.K.; Funding Acquisition, E.G

Ethics approval

This study was reviewed and approved by the institutional review board at the Diyarbakir Gazi Yasargil Training and Education hospital, ID: 81, 2017. Written informed consent was obtained from all patients.

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Table legands:

Table 1. Demographic characteristics of patients

Table 2. Characteristics of Inferior vena cava diameters and hemodynamic parameters preoperatively and postoperatively.

Figure legands:

Figure 1. Flow chart

Figure 2. Ultrasound measurements of inferior vena cava (IVC). Panel *above* shows two-dimensional scan of the IVC with right atrium to the left and panel *below* shows M-mode scan with respiratory variations in diameter. dIVCmax = maximum diameter of IVC; dIVCmin = minimum diameter of IVC.

Figure 3. Scatter plots showing the relationships of preoperative (3A) and postoperative (3B). Mean blood pressure (MBP) and collapsibility index (CI) of inferior vena cava. $p>0.05$

Figure 4. Correlation of the collapsibility index (CI) of inferior vena cava between preoperative and postoperative period. $p<0.01$

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Table 1. Demographic data of the patients

Characteristic	
Age (years)	42.88 ± 17.38 (18-86)
Gender (M/F)	32/31
Height (cm)	166.37 ± 9.18 (148 – 186)
Weight (kg)	71.36 ± 11.76 (53 – 105)
BMI (kg/m^2)	25.73±4.07 (17.72 – 37.78)
Operation duration (min.)	78.30±45.45(20 – 216)
Peroperatively infused fluid	985.80±484.27(150 – 2500)
Preoperative hemodynamic parameters	
Preop Systolic BP	136.40±22.17
Preop Diastolic BP	80.14±13.80
Preop MAP	98.88±15.25
ASA	
ASA I	35
ASA II	22
ASA III	6
Comorbidities	
Hypertension	6
Diabetes mellitus	4

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Cardiovascular	2
Respiratuar	2
Type of surgery	
General surgery	33
Orthopedia	16
Urology	6
Otolaryngology	4
Neurosurgery	4
Planned Anesthesia	
General	39
Spinal	20
Regional block	4
Surgery	
Emergency	16
Elective	47
Total	63

ASA: American Society of Anesthesiologists.; mean ± standard deviation; n : Patient number;

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Table 2. Characteristics of Inferior vena cava diameters and hemodynamic parameters preoperatively and postoperatively.

Characteristic	preop	postop	*p*
IVC max diameter (cm±SD)	1.99±0.31	2.05±0.29	0,063
IVC min diameter (cm±SD)	1.72±0.33	1.74±0.32	0,407
CI index %	14,0±9,60	15.14±11.18	0,416
SBP	136.39±22.17	135.19±24.19	0.710
DBP	80.14±13.80	78.93±17.26	0.605
MBP	98.89±15.25	97.68±18.24	0.621
Total	63		

CI = ollapsibility index; dIVCmax = maximum diameter of IVC; SBP= Systolic blood pressure; DBP= Diastolic blood pressure, MBP = mean blood pressure. IVC: Inferior vena cava

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Figure 1. Flow chart

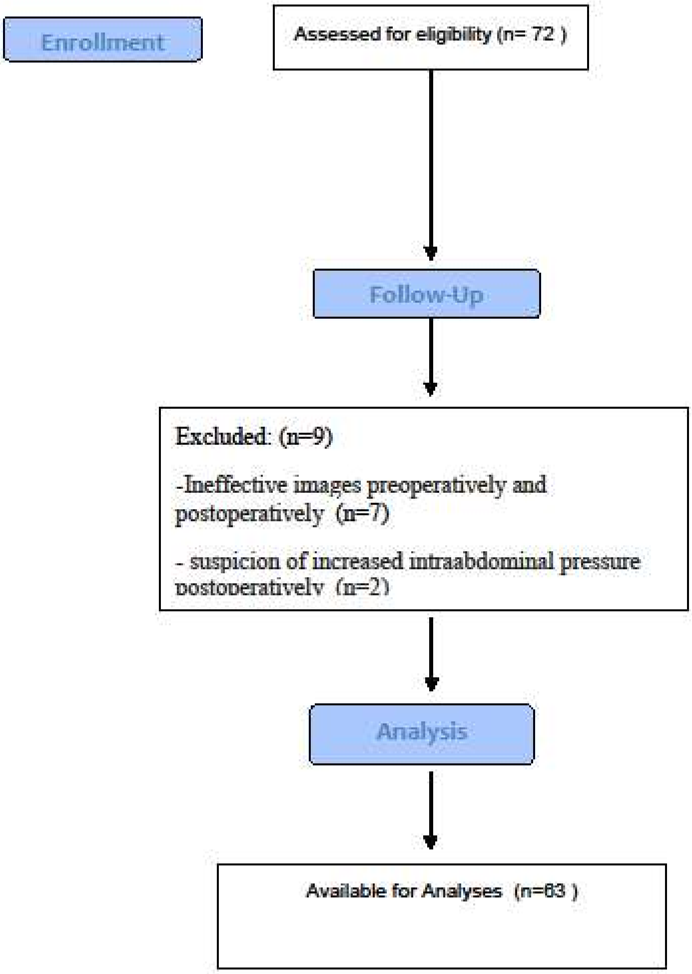

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Figure 2. Ultrasound measurements of inferior vena cava (IVC). Panel *above* shows two-dimensional scan of the IVC with right atrium to the left and panel *below* shows M-mode scan with respiratory variations in diameter. dIVCmax = maximum diameter of IVC; dIVCmin = minimum diameter of IVC.

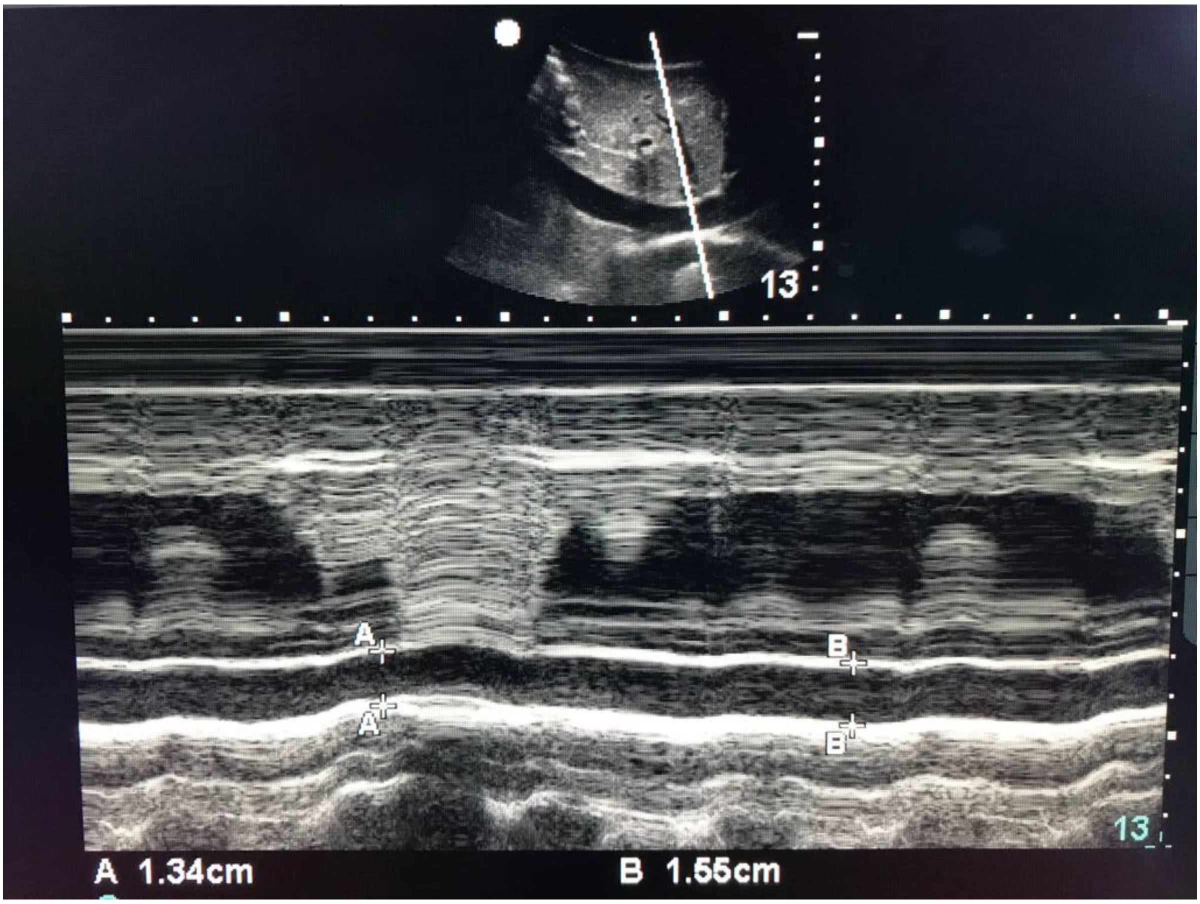

Figure 3. Scatter plots showing the relationships of preoperative (3A) and postoperative (3B). Mean blood pressure (MBP) and collapsibility index (CI) of inferior vena cava. $p>0.05$

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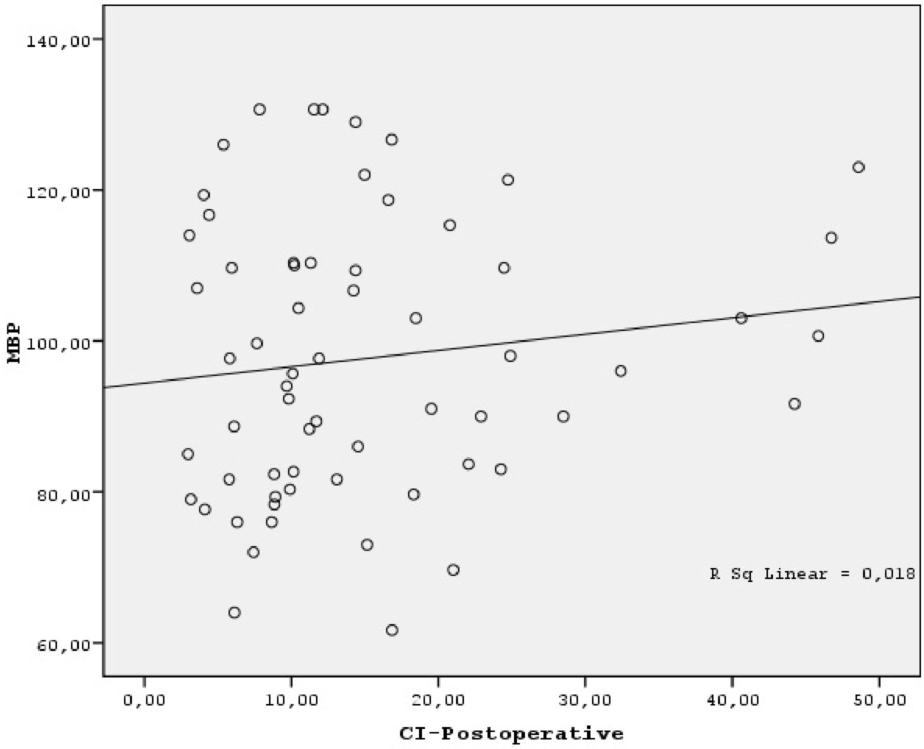

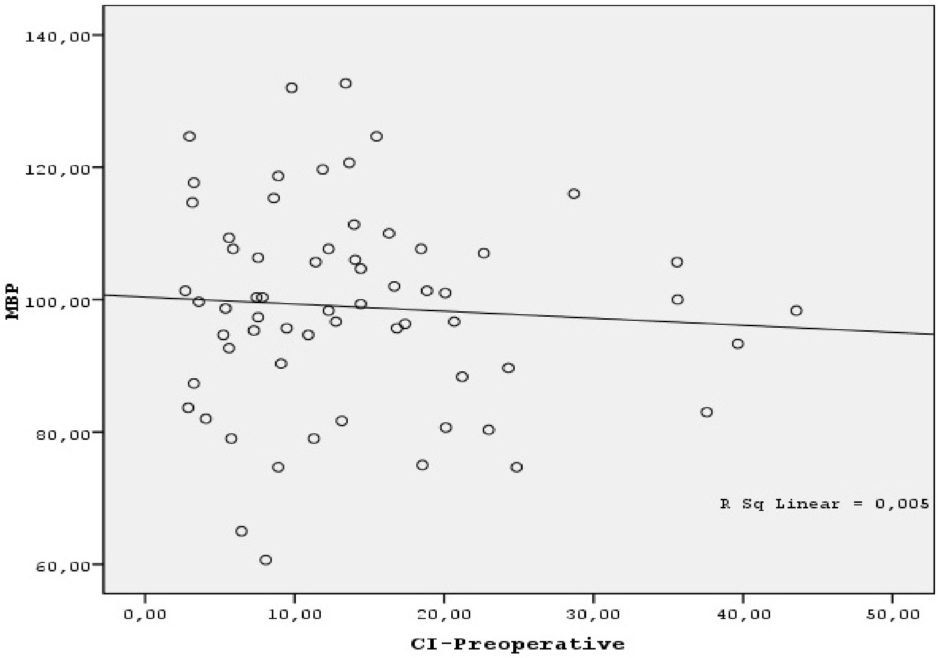

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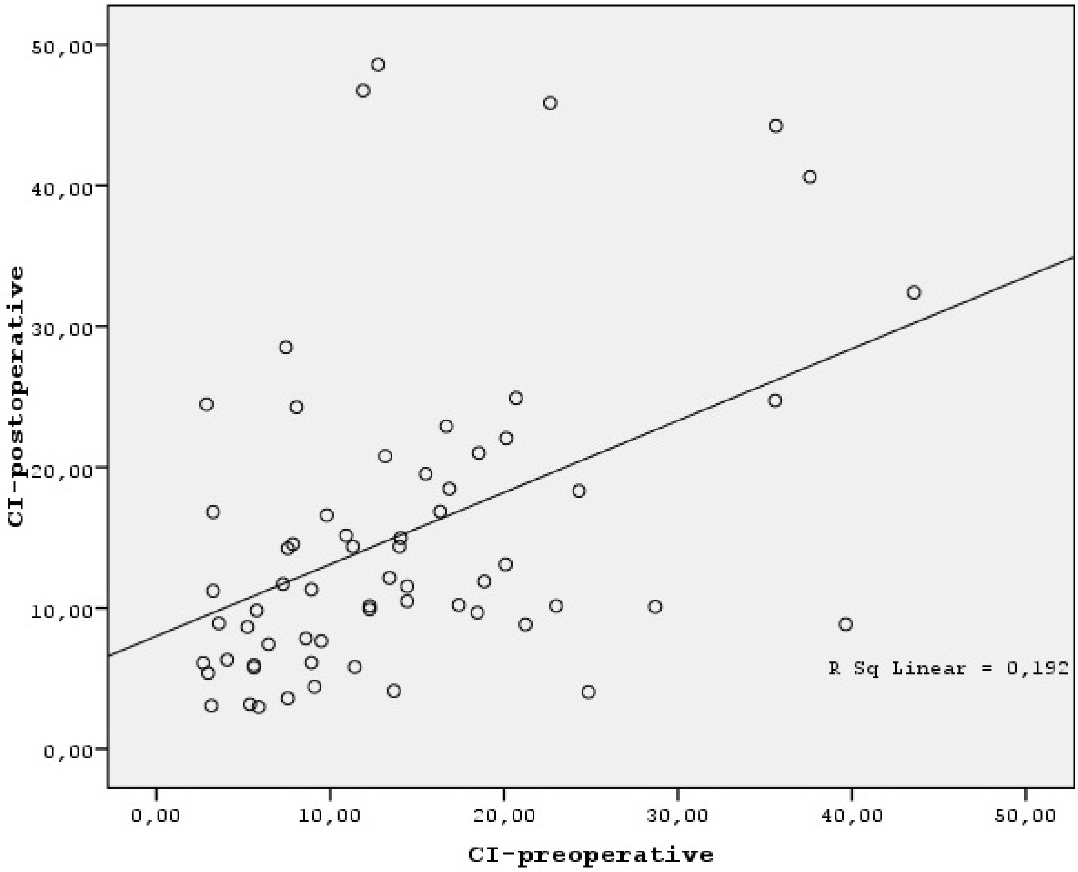
Figure 4. Correlation of the collapsibility index (CI) of inferior vena cava between preoperative and postoperative period. $p<0.01$



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