Original Article

THE ABILITY OF CAVAL/AORTA DIAMETER INDEX TO PREDICT POSTINDUCTION HYPOTENSION

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Abstract

Background: We aimed to assess the ability of caval/aorta diameter index in comparison to inferior vena cava (IVC) collapsibility index to predict postinduction hypotension.

Methods: This prospective observational study included adult patients undergoing elective non-cardiac surgery under general anesthesia. Before a standardized induction of anesthesia, ultrasonographic measurement of the IVC maximum and minimum diameter and aortic diameter during systole were obtained using M-mode. The IVC collapsibility index and Caval/aorta diameter index were then calculated. The primary outcome was comparison of the ability of the Caval/aorta diameter index and IVC collapsibility index in predicting postinduction hypotension (defined as systolic blood pressure <90 mmHg or >30% reduction from the baseline) using area under receiver operating characteristic curve (AUC) analysis.

Results: Ninety-six patients were analyzed from whom 54 (56%) developed postinduction hypotension. The caval/aorta diameter index were lower and the IVC collapsibility index were higher in hypotensive patients in comparison to the non-hypotensive patients. The AUC (95% confidence interval) for the ability to predict postinduction hypotension of caval/aorta diameter index was 0.95 (0.89-0.99) and was comparable to that of the IVC collapsibility index (0.93 [0.87-0.98]). The caval/aorta diameter index showed the highest positive predictive value (98%) at ratio ≤ 0.84.

Conclusion: Both caval/aorta diameter index and IVC collapsibility index can accurately predict postinduction hypotension during general anesthesia. The caval/aorta diameter index showed higher specificity than the IVC collapsibility index; at a cut-off value of ≤ 0.84 for the caval/aorta diameter index, the positive predictive value is 98%.

Keywords: hypotension; general anesthesia; ultrasound; inferior vena cava; collapsibility index; caval/aorta index

Introduction

Intraoperative hypotension is a serious condition and is associated with increased postoperative morbidity and mortality. Postinduction hypotension represent about one-third of all intraoperative hypotensive events. Postinduction hypotension's pathophysiology is complex and involve multiple risk factors such as the used anesthetic drugs and initiation of positive pressure ventilation, in addition to patients' risk factors such as age, medication, and volume status (Sessler et al. 2019; Saugel and Sessler 2021).

Early prediction of susceptible patients for postinduction hypotension is at most importance to give chance to implement appropriate preventive measures to at-risk patients. Ultrasonographic derived parameters, such as the inferior vena cava (IVC) collapsibility index, had been assessed for prediction of postinduction hypotension and showed conflicting evidence (Zhang and Critchley 2016; Szabó et al. 2019; Mohammed et al. 2021; Aissaoui et al. 2022). Caval/aorta diameter index is another ultrasonographic-derived parameter which showed promising results in predicting postspinal hypotension (Salama and Elkashlan 2019); however, data regarding its ability to predict postinduction hypotension following general anesthesia are lacking. Therefore, in this study, we aimed to assess the ability of caval/aorta diameter index in comparison to IVC collapsibility index to predict postinduction hypotension.

Methods

This prospective observational study was conducted in a University hospital from December 2020 to January 2022, after institutional Research Ethics Committee approval (Committee Chairman: Prof. M. Ibrahim, MD-245-2020). The study had been conducted in accordance with the principles set forth in the Helsinki Declaration. Written informed consent was obtained from the patient before recruitment.

We included American society of anesthesiologists-physical status I and II, adult patients (age above 18 years), scheduled for elective non-cardiac surgery under general anesthesia.

Exclusion criteria included was significant cardiac comorbidity (significant arrhythmia, severe valvular disease, unstable angina, ejection fraction <50%), uncontrolled hypertension, systolic blood pressure <90 mmHg, dyspnea, agitation, increased intra-abdominal pressure, intra-abdominal mass compressing the IVC, and pregnancy as well as poor ultrasound examination (defined as inability to properly measure the aorta and IVC)

All patients were instructed to fast 6 hours for solid food and 2 hours for clear fluid preoperatively. In the preparation room, basic monitoring was attached (electrocardiogram, non-invasive blood pressure, and pulse oximetry). Intravenous access was obtained, and 0.05 mg/kg midazolam was given if needed. None of the included patients received intravenous fluid before induction of anesthesia. Baseline systolic blood pressure and heart rate were recorded as the average of three successive readings with <10% difference.

The IVC and aortic measurements were obtained in the M-mode scan using a curvilinear (3.5 to 5 MHz) ultrasound transducer connected to Acuson x300 ultrasound (Siemens Healthcare, Seoul, Korea). All ultrasound measurements were obtained during regular spontaneous breathing, while the patient was in the supine position and were performed by an experienced operator.

The transducer was placed longitudinally in the subxiphoid region. The IVC maximum and minimum anterior-posterior diameters were obtained just distal to the IVC-hepatic vein junction at the end of expiration and inspiration of the same respirator cycle, respectively. The IVC collapsibility index was calculated as [(IVC maximum diameter – IVC minimum diameter) / IVC maximum diameter] x 100.

The abdominal aorta was identified to the left of the IVC, 10-mm above the coeliac trunk. The maximum internal anterior-posterior diameter of the aorta was obtained during systole. The caval/aorta diameter index was calculated as the ratio between IVC maximum diameter and aortic diameter.

Anesthetic management

Upon arrival to the operating room, routine monitors (electrocardiogram, pulse oximetry, and non-invasive blood pressure) were applied. Induction of general anesthesia was achieved by intravenous administration of 1.5 mg/kg propofol and 1-2 mcg/kg fentanyl. Muscle relaxation was achieved by 0.5 mg/kg atracurium. Endotracheal intubation was attempted 3-min after mask ventilation. Patients who needed more than one-intubation attempt were excluded from the analysis.

Anesthesia was maintained by 1.2% isoflurane in oxygen/air admixture, and atracurium 0.1 mg/kg increments every 20 minutes. Ringer lactate solution was infused at a rate of 2 mL/Kg/hour. Heart rate and systolic blood pressure were recorded every minute after induction of anesthesia for five min then every five min until 15-min postinduction.

Postinduction hypotension (defined as systolic blood pressure <90 mmHg or >30% reduction from baseline measurement from the time of induction of anesthesia until 15 min postinduction) was managed by 10 mg ephedrine.

The primary outcome was comparison of the accuracy of caval/aorta diameter index and IVC collapsibility index for prediction of post-induction hypotension

The secondary outcomes included the accuracy of aortic diameter, maximum and minimum IVC diameter, caval/aorta diameter index and IVC collapsibility index in prediction of post-induction hypotension. According to the occurrence of postinduction hypotension, patients were divided into two groups: hypotensive group and non-hypotensive group. Both groups were compared regarding the demographic data and baseline hemodynamic parameters.

Sample size calculation

In a previous study, the area under receiver operating characteristic cure (AUC) for the IVC collapsibility index to predict postinduction hypotension was 0.65 and the incidence of postinduction hypotension was 40% (Szabó et al. 2019). We calculated the sample size using MedCalc Statistical Software version 14.10.2 (MedCalc Software bvba, Ostend, Belgium) to detect a difference of 0.15 in *the AUC* between the caval/aorta diameter index and IVC collapsibility index. The required minimum number to have a study power of 80% and alpha error of 0.05 was 95 patients with a minimum 38 cases with postinduction hypotension. The recruitment was continued until including 115 patients to compensate for possible dropouts.

Statistical analysis

Statistical Package of Social Science Software program, version 26 (IBM SPSS Statistics for Windows Armonk, NY: IBM Corp.) and MedCalc V14 were used for statistical analysis. Continuous variables were presented as the means ±standard deviation or medians (quartiles) and were analyzed using the unpaired t-test or Mann-Whitney test as appropriate. All categorical data were analyzed by the Chi-squared test. Categorical variables were presented as frequency (percentage). A P-value less than 0.05 will be considered statistically significant. The AUC for the ability to predict postinduction hypotension and its 95% confidence interval (CI) was calculated. The optimal cut-off value was calculated using the Youden index and the corresponding positive and negative predictive values were reported. The grey zone (the range of values that provide inconclusive information) was identified as combining the values of the 95% CI of the optimal cut-off value (using the bootstrap technique) and the range of values bounded by two cut-off values, one with 90% specificity and the other with 90% sensitivity (Ray et al. 2010; Cannesson et al. 2011).

Results

One-hundred and nineteen patients were screened for eligibility, four patients were excluded for not able to visualize the IVC and/or aorta, and 115 patients were included. Nineteen patients were excluded from the analysis due to either use of different induction protocol (n=5), use of regional technique (n=4), more than one-intubation attempt (n=3) or early start of surgery before complete collection of hemodynamic data (n=7), and 96 patients were included into the final analysis.

The demographic data of the included patients are presented in Table 1. Postinduction hypotension occurred in 54/96 (56%) of the included patients.

Table 1: Demographic data and baseline hemodynamic characteristics. Data presented as mean ±standard deviation, median (quartiles), and frequency (%)

	All (n=96)
Age (years)	41 (31, 51)
Male sex	42 (44%)
Weight (kg)	79 (75, 81)
ASA	
I	75 (78%)
II	21 (22%)
Comorbidity	
Diabetes mellites	13 (14%)
Hypertension	10 (10%)
Systolic blood pressure (mmHg)	125 (115, 138)
Heart rate (bpm)	85 ±11
Aortic diameter (cm)	1.88 (1.80, 1.98)
IVC	
Maximum diameter (cm)	1.60 (1.41, 1.79)
Minimum diameter (cm)	0.82 (0.70, 1.05)
Collapsibility index (%)	48 (42, 51)
Caval/aorta diameter index	0.84 (0.73, 0.99)

ASA-PS: American society of anesthesiologists-physical status, IVC: inferior vena cava

The demographic data and baseline systolic blood pressure and heart rate were comparable between the two groups. (Table 2) The maximum and minimum IVC diameter and caval/aorta diameter index were lower in hypotensive patients in comparison to the non-hypotensive patients. furthermore, the aortic diameter and IVC collapsibility index were higher in the hypotensive patients than that in the non-hypotensive patients. (Table 2)

Table 2: Demographic data and baseline hemodynamic characteristics in hypotensive and non-hypotensive patients. Data presented as mean ±standard deviation, median (quartiles), and frequency (%)

	Hypotensive patients (n=54)	Non-hypotensive patients (n= 42)	P-value
Age (years)	42 (36, 50)	38 (29, 51)	0.142
Male sex	21 (39%)	21 (50%)	0.305
Weight (kg)	80 (75, 82)	79 (75, 80)	0.208
ASA-PS			1.000
I	42 (78%)	33 (79%)	

II	12 (22%)	9 (21%)	
Comorbidity			
Diabetes mellites	7 (13%)	6 (14%)	1.000
Hypertension	6 (11%)	4 (10%)	1.000
Systolic blood pressure (mmHg)	123 (115,141)	126 (115,135)	0.731
Heart rate (bpm)	85 ±12	85 ±10	0.986
Aortic diameter (cm)	1.90 (1.84, 2.00)	1.80 (1.60, 1.90)	<0.001
IVC			
Maximum diameter (cm)	1.49 (1.37, 1.59)	1.79 (1.69, 1.83)	<0.001
Minimum diameter (cm)	0.70 (0.65, 0.80)	1.05 (0.99, 1.10)	<0.001
Collapsibility index (%)	51 (49, 53)	41 (40, 43)	<0.001
Caval/aorta diameter index	0.75 (0.70, 0.79)	0.99 (0.94, 1.01)	<0.001

ASA-PS: American society of anesthesiologists-physical status, IVC: inferior vena cava

The AUC (95% CI) for the ability to predict postinduction hypotension of caval/aorta diameter index was 0.95 (0.89-0.99) was comparable to that of the IVC collapsibility index (0.93 [0.87-0.98]) and it was higher than that of the aortic diameter (0.77 [0.67-0.85]) and maximum IVC diameter (0.87 [0.79-0.93]). (Table 3 and Figure 1)

The caval/aorta diameter index showed the highest positive predictive value at ratio ≤ 0.84. (Table 3)

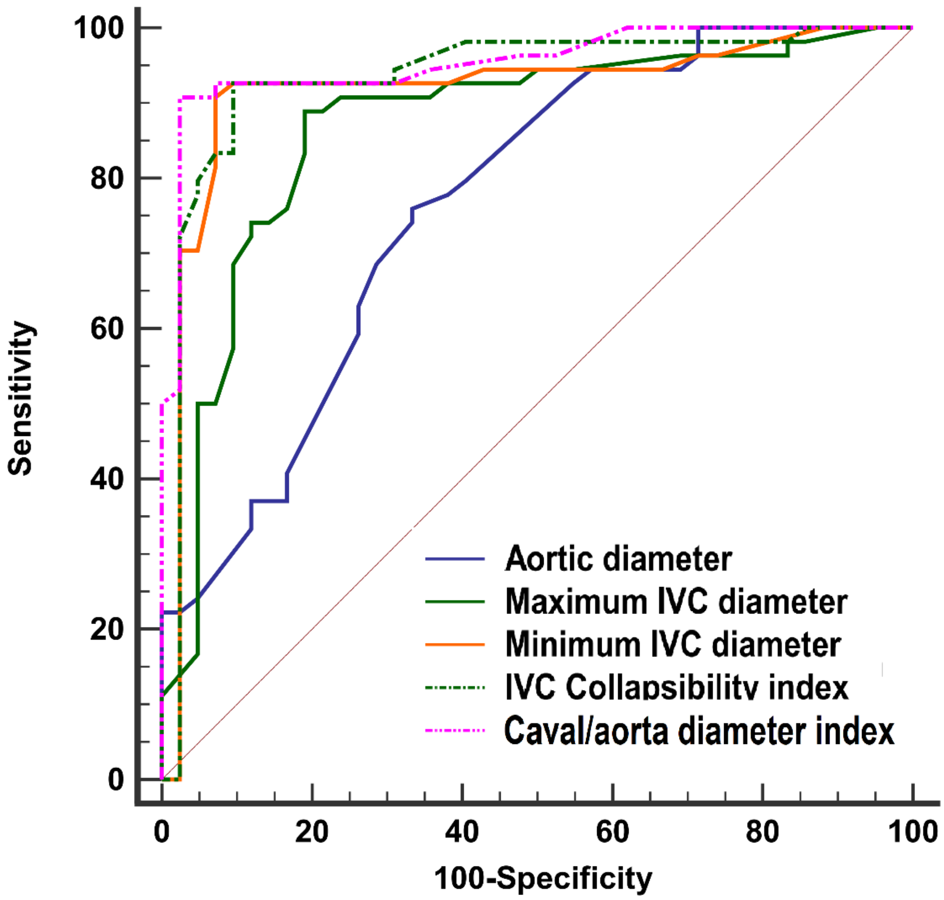
The grey zone for the caval/aorta diameter index was 0.80 to 0.89 which included 9/96 (9%) of the patients; and the grey zone for the IVC collapsibility index was 44-49% which included 16/96 (17%) of the patients.

Table 3: The AUC analysis for the ability to predict post induction hypotension

	AUC (95% CI)	Sensitivity % (95% CI)	Specificity% (95% CI)	PPV% (95% CI)	NPV% (95% CI)	Cut-off value
Aortic diameter	0.77 (0.67-0.85)	76 (62-87)	67 (51-80)	75 (61-85)	68 (52-82)	>1.83 cm
Maximum IVC diameter	0.87 (0.79-0.93) *	89 (77-96)	81 (66-91)	86 (74-94)	85 (70-94)	≤ 1.63 cm
Minimum IVC diameter	0.92 (0.84-0.96) *	91 (80-97)	93 (81-99)	94 (84-99)	89 (75-96)	≤ 0.84 cm
IVC Collapsibility index	0.93 (0.87-0.98) *	93 (82-98)	91 (77-97)	93 (82-98)	91 (77-97)	>45%
Caval/aorta diameter index	0.95 (0.89-0.99) *†	91 (80-97)	98 (87-100)	98 (89-100)	89 (76-96)	≤ 0.84

AUC: area under receiver operating characteristic curve, CI: confidence interval, IVC: inferior vena cava, NPV: negative predictive value, PPV: positive predictive value. * denotes significance in relation to the aortic diameter, † denotes significance in relation to the maximum IVC diameter.

Figure 1: The receiver operating characteristic curves for the ability to predict post induction hypotension. IVC: inferior vena cava.



Discussion

We found that the caval/aorta diameter index had excellent accuracy in predicting postinduction hypotension. Caval/aorta diameter index and IVC collapsibility index showed the highest accuracy for predicting hypotension among other ultrasound-guided parameters.

The caval/aorta index had previously shown good ability in assessing volume status (Gui et al. 2018) and predicting postspinal hypotension (Salama and Elkashlan 2019).

No data, to the best of our knowledge, are available for the use of caval/aorta diameter index in predicting hypotension after induction of general anesthesia. However, a previous study in patients who received spinal anesthesia supports our results and its results showed that the caval/aorta diameter index predicted postspinal hypotension (Salama and Elkashlan 2019). The cut-off value differed between our results and Salama and Elkashlan study (Salama and Elkashlan 2019) (0.84 versus 1.2), mostly due to the different type of anesthesia.

We report that the IVC collapsibility index had good accuracy in predicting postinduction hypotension at a cut-off value of >45%. The use of IVC-derived measurements in hemodynamic monitoring had been extensively used in the last decade. The IVC diameters and collapsibility index are well-known indices of fluid responsiveness in circulatory shock as well as the preoperative evaluation of volume status (Hasanin and Mostafa 2020b). However, the use of the IVC indices is usually limited in non-paralyzed patients for being less accurate in this population (Hasanin and Mostafa 2020a) and its accuracy for prediction of postinduction hypotension varied among previous studies (Zhang and Critchley 2016; Szabó et al. 2019; Mohammed et al. 2021; Aissaoui et al. 2022). The cut-off value for the IVC collapsibility index in the current study is close to previous studies (45% in this study versus 42-43% in previous reports (Zhang and Critchley 2016; Aissaoui et al. 2022)). The grey zone for IVC collapsibility in this study was 44-49% and included 17% of the patients, this range is higher than the that reported by Zhang and Critchley (Zhang and Critchley 2016) (38-43% and included 12% of the patients) and narrower than that reported by Aissaoui et al (Aissaoui et al. 2022) (17-47% and included 45% of the patients). This difference in the range of the grey zone might be related to different type of induction agent (etomidate in Zhang and Critchley) or different population characteristics (older population in Aissaoui et al) (Zhang and Critchley 2016; Aissaoui et al. 2022). The IVC collapsibility index had been reported to be influenced by the age which might affect its value in older patients (Gui et al. 2018). The IVC collapsibility is also affected by diaphragmatic activity and respiratory drive (Gignon et al. 2016).

Hypotension is undesirable adverse event of anesthesia and is associated with increased postoperative morbidity and mortality (Sessler et al. 2019; Saugel and Sessler 2021). Anticipating patients at high risk of postinduction hypotension is important to the anesthetist to provide preventive measures to high-risk patients. Our study has several advantages in that we are the first to evaluate the caval/aorta diameter index in predicting postinduction hypotension and to report its grey zone in addition to the best cut-off value. The grey zone approach had been introduced to include values that would produce inconclusive results instead of dichotomizing population based on a single cut-off value from the AUC analysis which is more useful in clinical practice (Ray et al. 2010). When the value occurs within the grey zone, clinician could seek additional diagnostic test to confirm the diagnosis (Ray et al. 2010). Also, reporting the number of patients occurring within the grey zone gives an idea about the usefulness of the test in clinical practice, the fewer the number of patients in the grey zone the higher the usefulness of the test in real practice (Zhang and Critchley 2016).

Our findings suggest that low caval/aorta diameter index and high IVC collapsibility index can accurately predict postinduction hypotension. The caval/aorta diameter index might have advantages over the IVC collapsibility index in that it has higher specificity and positive predictive value and that the number of patients in the grey zone were fewer than the that in for the IVC collapsibility index. This would make the caval/aorta diameter index more conclusive than the IVC collapsibility index for prediction of postinduction hypotension. Furthermore, the measurement of the caval/aorta diameter index might be more convenient than IVC collapsibility index as it is less dependent on the respiratory cycle and depth of breathing which affect the IVC collapsibility index accuracy (Gignon et al. 2016).

Our study has some limitations. 1- It was conducted in a single centre. 2- All ultrasound examination were conducted by a single operator; however, previous studies showed that the interrater agreement is good for caval/aorta diameter index and IVC collapsibility index (Salama and Elkashlan 2019). 3- We included patients with American society of anesthesiologists-physical status <III undergoing elective non-cardiac procedure; therefore, future studies are needed to confirm our findings in other population.

Conclusion

Both caval/aorta diameter index and IVC collapsibility index can accurately predict postinduction hypotension during general anesthesia. The caval/aorta diameter index showed higher specificity than the IVC collapsibility index; at a cut-off value of ≤ 0.84 for the caval/aorta diameter index, the positive predictive value is 98%.

Declaration of interests:

The authors declare that they have no conflict of interest with this work.

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References:

1. Aissaoui, Younes, Mathieu Jozwiak, Mohammed Bahi, Ayoub Belhadj, Hassan Alaoui, Youssef Qamous, Issam Serghini, and Rachid Seddiki. 2022. Prediction of post-induction hypotension by point-of-care echocardiography: A prospective observational study. *Anaesthesia, critical care & pain medicine* 41: 101090. https://doi.org/10.1016/j.accpm.2022.101090.
2. Cannesson, Maxime, Yannick Le Manach, Christoph K Hofer, Jean Pierre Goarin, Jean-jacques Lehot, Benoît Vallet, and Benoît Tavernier. 2011. Assessing the diagnostic accuracy of pulse pressure variations for the prediction of fluid responsiveness: a “gray zone” approach. *Anesthesiology* 115: 231–41. https://doi.org/10.1097/ALN.0b013e318225b80a.
3. Gignon, Lucile, M Sc, Claire Roger, M Sc, Sophie Bastide, Sandrine Alonso, Laurent Zieleskiewicz, et al. 2016. Influence of Diaphragmatic Motion on Inferior Vena Cava Diameter Respiratory Variations in Healthy Volunteers. *Anesthesiology* 124: 1–9. https://doi.org/10.1097/ALN.0000000000001096.
4. Gui, Jianjun, Zhengfei Yang, Bing Ou, Anding Xu, Fan Yang, Qiaozhu Chen, Longyuan Jiang, and Wanchun Tang. 2018. Is the Collapsibility Index of the Inferior Vena Cava an Accurate Predictor for the Early Detection of Intravascular Volume Change? *Shock* 49: 29–32. https://doi.org/10.1097/SHK.0000000000000932.
5. Hasanin, Ahmed, and Maha Mostafa. 2020a. Evaluation of fluid responsiveness during COVID-19 pandemic: what are the remaining choices? *Journal of anesthesia* 34. Springer Japan: 758–764. https://doi.org/10.1007/s00540-020-02801-y.
6. Hasanin, Ahmed, and Maha Mostafa. 2020b. Evaluation of fluid responsiveness during COVID-19 pandemic: what are the remaining choices? *Journal of anesthesia* 34. Springer Singapore: 758–764. https://doi.org/10.1007/s00540-020-02801-y.
7. Mohammed, Sadik, Rashmi Syal, Pradeep Bhatia, Swati Chhabra, RavindraS Chouhan, and Manoj Kamal. 2021. Prediction of post-induction hypotension in young adults using ultrasound-derived inferior vena cava parameters: An observational study. *Indian Journal of Anaesthesia* 65: 731. https://doi.org/10.4103/ija.IJA_1514_20.
8. Ray, Patrick, Yannick Le Manach, Bruno Riou, and Tim T. Houle. 2010. Statistical evaluation of a biomarker. *Anesthesiology* 112: 1023–1040. https://doi.org/10.1097/ALN.0b013e3181d47604.
9. Salama, Eman Ramadan, and Mohamed Elkashlan. 2019. Pre-operative ultrasonographic evaluation of inferior vena cava collapsibility index and caval aorta index as new predictors for hypotension after induction of spinal anaesthesia: A prospective observational study. *European Journal of Anaesthesiology* 36: 297–302. https://doi.org/10.1097/EJA.0000000000000956.
10. Saugel, Bernd, and Daniel I. Sessler. 2021. Perioperative Blood Pressure Management. *Anesthesiology*: 250–261. https://doi.org/10.1097/ALN.0000000000003610.
11. Sessler, Daniel I., Joshua A. Bloomstone, Solomon Aronson, Colin Berry, Tong J. Gan, John A. Kellum, James Plumb, et al. 2019. Perioperative Quality Initiative consensus statement on intraoperative blood pressure, risk and outcomes for elective surgery. *British Journal of Anaesthesia* 122: 563–574. https://doi.org/10.1016/j.bja.2019.01.013.
12. Szabó, Marcell, Anna Bozó, Katalin Darvas, Alexandra Horváth, and Zsolt Dániel Iványi. 2019. Role of inferior vena cava collapsibility index in the prediction of hypotension associated with general anesthesia: An observational study. *BMC Anesthesiology* 19. BMC Anesthesiology: 1–8. https://doi.org/10.1186/s12871-019-0809-4.
13. Zhang, Jie, and Lester Augustus Hall Critchley. 2016. Inferior vena cava ultrasonography before general anesthesia can predict hypotension after induction. *Anesthesiology* 124: 580–589. https://doi.org/10.1097/ALN.0000000000001002.