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Original Article

Noninvasive haemodynamic monitoring and hypotension management with transesophageal duplex among mechanically-ventilated patients: An analytical study

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Abstract

Introduction: Central venous (CV) line is one of the most common methods of central venous pressure (CVP) measurement and hemodynamic monitoring among patients admitted to the intensive care unit (ICU). However, its complications are not rare and are life-threatening in some cases. Recently, transesophageal duplex is frequently used to monitor the cardiac output (CO) and intravascular fluid volume of patients admitted to ICU. The present study was conducted aiming to assess noninvasive hemodynamic monitoring and hypotension management with transesophageal doppler among mechanically-ventilated patients.

Methods: In this descriptive cross-sectional study, 25 patients admitted to the ICU of Imam Reza Hospital, Tabriz, Iran, were studied. CV line had been inserted into the body of the patients prior to the study for various reasons. CO was measured using esophageal duplex and also transthoracic echocardiography (TTE), and CVP was determined via esophageal duplex and CV line findings.

Results: Mean CO of the patients was 4.88 ± 0.61 and 4.86 ± 0.59 l/minute measured by esophageal duplex and TTE, respectively. Hence, the difference was not statistically significant between the two methods. The mean CVPs of the patients measured by esophageal duplex and CV line were 4.94 ± 1.15 and 4.54 ± 1.04 mmHg, respectively. In addition, the left ventricular (LV) filling pressure measured by Oesophageal Doppler Monitoring (ODM) and by TTE was 9.28 ± 2.66 and 9.28 ± 2.66 mmHg, respectively. The difference for both of the mentioned variables was statistically significant but clinically negligible.

Conclusion: Based on the results of this study, esophageal duplex as a less invasive, safe and precise method can replace the use of CV line among patients undergoing mechanical ventilation. This will help clinicians to obtain accurate haemodynamic data from critically ill patients and avoid unexpected complications imposed by CV line insertion.

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Introduction

Recent technological advances and the introduction of numerous new devices have greatly enhanced the non-invasive evaluation of patients in the internal medicine field. Despite these improvements, there are

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uncertainties about the use of some of these devices.[1,2]

The accuracy of information from non-invasive methods has always been a question to the physicians. The most crucial issue in this regard has been whether we can provide patients with better health using these new monitoring technologies. For example, when pulmonary artery catheter (PAC) was used for the first time in the 1970s in bedside to evaluate the patient's oxygenation, it was not likely that one day this information could be obtained simply by a finger probe.[3,4]

Nowadays, Oesophageal Doppler Monitoring (ODM) is widely used to measure the cardiac output (CO) and volume of intravascular fluid in the intensive care unit (ICU). This is achieved by inserting a small ultrasound probe into the oesophagus through the mouth or nose. The ultrasound probe produces low-frequency waves (4 mHz) near the aorta that returns to the probe when it hits the red blood cells (RBCs). Using Doppler principles, these waves can be used to determine the speed of circulation and then using standardised charts, volumetric data like CO can be obtained. Recently, this method has been confirmed as a non-invasive strategy to measure these variables in the ICU.[1-4] Doppler-based techniques provide an excellent beat-to-beat measurement of CO.[5] A recent study also showed that ODS could reliably track CO among patients undergoing surgery. Further CO measurements conducted by ODM could be used as a tool to guide fluid therapy.[6]

Central venous (CV) line insertion is commonly performed through the internal jugular vein because it is readily available and the incidence of adverse effects like pneumothorax is minimal. The internal jugular veins (right and left) are short, straight, and large, so it's easy to enter the CV line catheter in these veins. CV line provides easy access to the large central vein and monitors central venous pressure (CVP) among ill patients. It also allows obtaining more information about the patients' haemodynamics.[7] However, CV line insertion has some complications including incorrect insertion of CV catheter, haematoma formation, coronary artery perforation (CAP), pneumothorax, haemorrhage, sepsis, air embolism, ambulatory catheter, thrombosis, haemothorax, cardiac tamponade, cardiac arrhythmia, and hydro-pneumothorax.[8] Thus, the use of non-invasive methods like ODM is of high priority.

The present study was carried out aiming to evaluate the haemodynamic status using ODM and compare it with the findings regarding CV line among patients with haemodynamic instability in the ICU. The use of ODM for this purpose provides a non-invasive method to measure the discussed variables among critically ill patients and may heighten the accuracy of the obtained results.

Methods

This was a descriptive-analytical study performed on 25 intubated patients with haemodynamic instability admitted to the ICU of Imam Reza Hospital, Tabriz University of Medical Sciences, Tabriz, Iran. The duration of this study was 1 year between May 2016 and 2017.

All patients who were admitted to the ICU and were under mechanical ventilation or had hypotension [systolic blood pressure (SBP) below 120 mmHg or diastolic blood pressure (DBP) below 80 mmHg], were included in the study. The included patients also had a CV line prior to the study. Moreover, patients who were not critically ill, lacked mechanical ventilation, hypotension, or CV line insertion during the study were excluded. Furthermore, in case of the lack of possibility to perform ODM on a subject, the patient would be excluded. Every patient who declined to participate in the study was excluded from this study.

25 patients with haemodynamic instability who were under mechanical ventilation and had CV line were randomly selected (using convenient sampling method) and included in the study. All of the patients were selected from the ICU of Imam Reza Hospital, Tabriz University of Medical Sciences.

Basic demographic information of the patients including age, sex, height, and weight was recorded in the checklist designed for this purpose. In addition, the information required on the haemodynamic status of the patients was obtained using CV line and echocardiography.

In the next stage, all patients were examined by a physician who was expert at ODM. The CO and the CVP of these patients were measured using ODM device, and the values were compared with the those of CV line and echocardiography (LV filling pressure).

SPSS software (version 20, IBM Corporation, Armonk, NY, USA) was applied for all statistical analyses of the study. The obtained data were expressed as mean ± standard deviation (SD), rate, and percentage. Student t-test was used to compare the quantitative variables of the study. The sample size was determined using the number of patients used in the previous studies, the test power of 80%, and the acceptable error rate (α) of 5%, which yielded the number of 25 patients. In all comparisons, $P \leq 0.050$ was considered to be statistically significant.

Results

Of the 25 patients studied, 13 (52.0%) and 12 (48.0%) were men and women, respectively. The mean age of the subjects was 42.16 ± 17.14 years (ranging between 20 and 78 years). Table 1 shows the basic vital signs of the patients.

Table 1. Basic vital signs of the subjects

Vital signs	Mean ± SD	Min	Max
Respiratory rate (/minute)	16.04 ± 1.39	14	18
Heart rate (bpm)	87.68 ± 11.77	70	110
SBP (mmHg)	103.12 ± 11.86	85	120
DBP (mmHg)	65.72 ± 9.53	50	80
Body temperature (°C)	37.26 ± 0.76	36	38.5

Bpm: Beats per minute; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; SD: Standard deviation; Min: Minimum; Max: Maximum

The results of the present study showed no statistically significant difference between the CO measured by ODM and echocardiography [P = 0.405; 95% confidence interval (CI) = -0.229 to 0.549] (Table 2) (Figure 1).

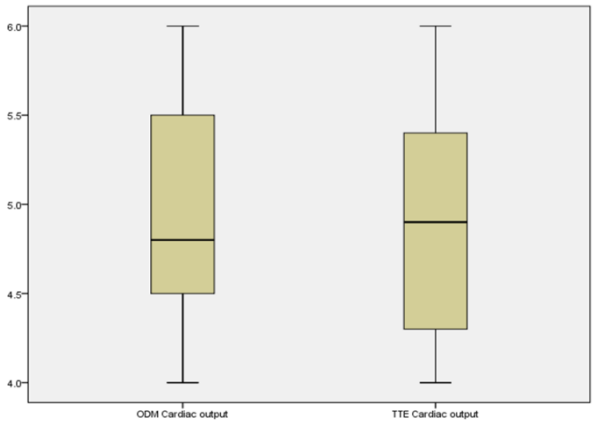

Figure 1. Comparison of cardiac outputs (COs) measured by oesophageal duplex and echocardiography

According to the above table, the results showed no significant difference between CO measured by the two modalities. In addition, LV filling pressure measured by ODM was significantly different from that of measured by echocardiography (P = 0.031; 95% CI = -0.836 to -0.043). However, the observed difference was not clinically significant. Therefore, ODM can be used as an alternative to echocardiography in the measurement of LV filling pressure among the population under study (Table 3) (Figure 2).

The results presented in the above table showed a significant difference between CO measured by the two modalities. Further analysis showed a significant difference between the CVPs measured by oesophageal duplex and CV line (P = 0.012; 95% CI = -0.161 to -0.022), however, since the observed difference was not clinically significant, ODM can be used as an alternative to CV line to measure CVP of critically ill patients (Table 4).

Table 2. Intergroup comparison of cardiac outputs (COs) measured by oesophageal duplex and echocardiography.

Variable	Modality	Mean ± SD	Min	Max	P
CO	Oesophageal duplex (l/minute)	4.88 ± 0.61	4	6	0.405
	Echocardiography (l/minute)	4.86 ± 0.59	4	6	

CO: Cardiac output; SD: Standard deviation; Min: Minimum; Max: Maximum

Table 3. Intergroup comparison of mean left ventricular (LV) filling pressure measured by oesophageal duplex and echocardiography

Variable	Modality	Mean ± SD	Min	Max	P
LV mean filling pressure	Oesophageal duplex (mmHg)	9.28 ± 2.66	4.5	13.0	0.031
	Echocardiography (mmHg)	9.32 ± 2.68	4.5	13.0	

LV: left ventricle; SD: Standard deviation; Min: Minimum; Max: Maximum

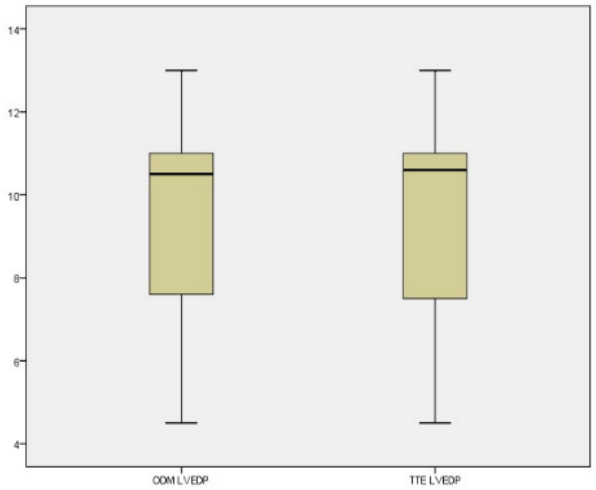

Figure 2. Comparison of left ventricular (LV) filling pressures measured by oesophageal duplex and echocardiography

According to the above table, the results indicated a significant difference between the CVPs measured by the two modalities.

Discussion

In this study, no statistically significant difference was observed between the COs measured by ODM and transthoracic echocardiography (TTE) among the subjects. Although the filling pressures of the left ventricle and CVP measured by ODM were statistically different from those evaluated by TTE and CV line, the differences were not clinically significant and thus, ODM can be used as an alternative to TTE and CV line to determine these values among the critically ill and intubated patients admitted to the ICU.

ODM is a simple procedure with excellent safety, a high degree of credibility, and no particular need for calibration. It has been shown that CO changes can be monitored during the onset of critical illness in the ICU using ODM. However, the probe used can cause discomfort among the individuals; therefore, patients monitored in this way often need sedation or were intubated.[9]

In this regard, Singer and Bennett conducted a study to assess ODM applicability among intubated patients admitted to the ICU or subjects to whom a PAC had been inserted. The results of this study showed that ODM could be applied for fast and non-invasive measurement of LV filling pressure among these patients.[10]

In another study by Feldman et al., the applicability of ODM was assessed to determine CVP among patients undergoing laparoscopic donor nephrectomy (LDN) and compare the values with those measured by a CV line catheter. It was found in this study that CV line catheter was not an accurate method to determine CVP among these patients and ODM can be safely applied to noninvasively control preload changes during LDN.[11]

In addition, Noblett et al. conducted a study to evaluate the usefulness of ODM in the management of fluid therapy after elective colorectal surgery among 108 patients. The results of this study showed that the intervention group (among whom the haemodynamic status was controlled using ODM) had less hospital stay than the control group (7 days versus 9 days with P = 0.005). Postoperative complications were less among the intervention group compared to the control group (2 versus 15%, P = 0.043).

Table 4. Intergroup comparison of mean central venous pressure (CVP) measured by oesophageal duplex and central venous (CV) line

Variable	Modality	Mean	Min	Max	P
CVP	Oesophageal duplex (mmHg)	4.94 ± 1.15	3.0	7.0	0.012
	Echocardiography (mmHg)	5.04 ± 1.08	3.1	6.9	

CVP: central venous pressure; SD: Standard deviation; Min: Minimum; Max: Maximum

Moreover, the intervention group received the oral feeding earlier than the control group (2 versus 4 days, P = 0.029). According to this study, it was concluded that ODM could be used as an alternative to other methods of fluid load control among the critically ill patients.[12]

Similarly, Walsh et al. conducted a study to investigate the use of ODM in fluid therapy on 393 patients undergoing abdominal surgery. The results of this study indicated that ODM application was associated with lower postoperative complications and mean hospital stay.[13]

Furthermore, Mowatt et al. conducted a review study on the efficacy and cost-effectiveness of ODM among high-risk patients. Based on this review study, 5 of the reviewed studies indicated that the mortality, significant complications, and duration of hospitalisation were lower among the ODM group compared to those of CV line group. 3 other studies showed no difference in the mortality between the two groups, however, the duration of hospitalization was lower among the ODM group. 2 other studies showed a significant difference in the mortality, the severity of complications and hospital stay between the two groups. In general, this review proved the clinical value and cost-effectiveness of ODM among the critically ill and high-risk patients undergoing surgical operation.[14]

Conclusion

In conclusion, ODM is a suitable method for non-invasive evaluation of haemodynamic variables including CO, LV filling pressure, and CVP among critically ill patients admitted to the ICU. This method is both accurate and safe in determining the mentioned variables. Although CVP and LV filling pressure measured by ODM were found to be different from those measured by CV line or TTE, the difference was clinically negligible. Some differences observed in this regard are due to differences in sample selection and also the study methods, and other variables studied. Further studies in this field are necessary for better decision making.

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Authors' Contribution

Study concept and design: Mohammad Reza Ghaffari, Seyyed Ali Asadi-Tahaa

Acquisition of data: Seyyed Ali Asadi-Tahaa

Analysis and interpretation of data: Behnaz Ghamari, Sepideh Karkon-Shayan, Roya Feizollahi, Farid Karkon-Shayan

Drafting of the manuscript: Farid Karkon-Shayan

Critical revision of the manuscript for important intellectual content: Mohammad Reza Ghaffari, Seyyed Ali Asadi-Tahaa

Statistical analysis: Behnaz Ghamari, Farid Karkon-Shayan

Administrative, technical, and material support: Mohammad Reza Ghaffari, Seyyed Ali Asadi-Tahaa Study supervision: Mohammad Reza Ghaffari.

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Conflict of Interest

Authors have no conflict of interest.

Ethical Approval

This study was approved by the Medical Ethics Committee of Tabriz University of Medical Sciences.

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