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Cardiac Output Monitoring by Velocity Time Integral Technique versus Smartphone-based Application "Capstesia™" in Hemodynamically Unstable Patients

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ABSTRACT

Background: Cardiac output (COP) monitoring is a cornerstone in the management of critically ill patients.
Objectives: to assess the validity of Capstesia™ app for COP monitoring compared to the traditional echo-based velocity time integral (VTI) technique in hemodynamically unstable patients. **Patients and Methods**: In prospective cohort study, 50 cases were admitted with shock state and candidates for continuous COP monitoring. Readings obtained from 50 patients were measured simultaneously by Capstesia™ app and VTI method. **Results**: The mean age of participants was 63±11 years, 29 patients were males, and 33 patients suffered from septic shock. With a p-value of 0.76, the two methods that were compared did not differ from one another in a way that is statistically significant, the level of agreement between the two methods was least in chronic kidney disease (CKD) patients.
Conclusion: Smartphone application Capstesia™ is a reliable alternative to the traditional echo-based VTI technique in continuous COP monitoring in hemodynamically unstable patients.
Keywords: Cardiac output, Velocity time integral, Capstesia™ smartphone app.

INTRODUCTION

In critically ill patients, hemodynamic instability is frequently observed as a finding. This can be traced back to hypovolemia, cardiac dysfunction, or abnormalities in vasomotor function, all of which result in organ dysfunction, worsening into multiorgan failure, and ultimately death [1].

In recent years, successful management of critically ill patients is directly related to hemodynamic goal-directed therapy (GDT) [1]. Fluids and inotropic substances both contribute to an increase in the amount of oxygen that is delivered to the tissues[2].

Monitoring the patient's hemodynamic state can be accomplished using a variety of methods, including pulmonary artery catheterization, echocardiography, thoracic electrical impedance esophageal Doppler monitoring, transpulmonary thermodilution, as well as pressure analysis. Each technique has its own advantages and disadvantages, and may range from invasive to non-invasive, calibrated or non-calibrated[3].

The non-invasive procedures that are currently accessible do not fulfil all of the requirements necessary to be termed ideal [4,5]. Given this, the smartphone Capstesia™ app (Galenic App, Vitoria Gasteiz, Spain) has emerged to explore alternatives for the measurement of advanced hemodynamic variables [5].

Advanced hemodynamic metrics like cardiac output (COP), pulse pressure variation (PPV), and maximum slope of the pressure curve (max dP/dt) are estimated using pictures of the patient monitor screen displaying invasive arterial pressure [5]. The current study aimed at comparing the level of agreement between the traditional way of COP monitoring by echocardiography and the Capstesia™ app.

PATIENTS AND METHODS

The study is a comparative prospective observational study conducted on 50 patients admitted to the Critical Care Department, Cairo University, with hemodynamic instability and shock state during the period of November 2019 to June 2020.

All fifty adult patients showed signs of hemodynamic instability (SBP < 90 mmHg or 30 mmHg fall in baseline BP or MAP< 65 mmHg, or Lactate > 2 mmol/L). Exclusion criteria were patients < 18 years, positive Allen's test in bilateral radial arteries, pacemakers or implantable cardioverter defibrillators, persistent arrhythmias, and intra-aortic balloon pump.

All patients were subjected to radial arterial line insertion. After successful placement of the cannula and noting the pulsatile blood flow which confirms proper insertion, the cannula was connected to the arterial line transducer to get the arterial line waveform on the monitor.

Echocardiographic evaluation of stroke volume using the following steps:

1- Calculation of the cross-sectional area of the left ventricular outflow tract (LVOT) from the parasternal long axis (PLAX) view by measuring the LVOT diameter during systole 0.5 cm back from the aortic valve leaflet insertion point (on the ventricular side).
2- Assessment of LVOT Velocity Time Integral (VTI): using pulsed wave Doppler in the apical five-chamber view.
3- Stroke Volume (SV) = LVOT Area × LVOT Velocity-Time Integral.

Simultaneously, we used the Capstesia™ app to measure COP. The images of the screen were taken parallel to the screen, as recommended by the maker, to capture the complete monitor screen and simulate the use of the application by any clinician in a clinical situation. Trimming the signal was done to be evaluated and feeding in real-time readings of vitals like heart rate and blood pressure. Capstesia™ digitalizes the cardiac signal and then provides an output. (Figure 1).

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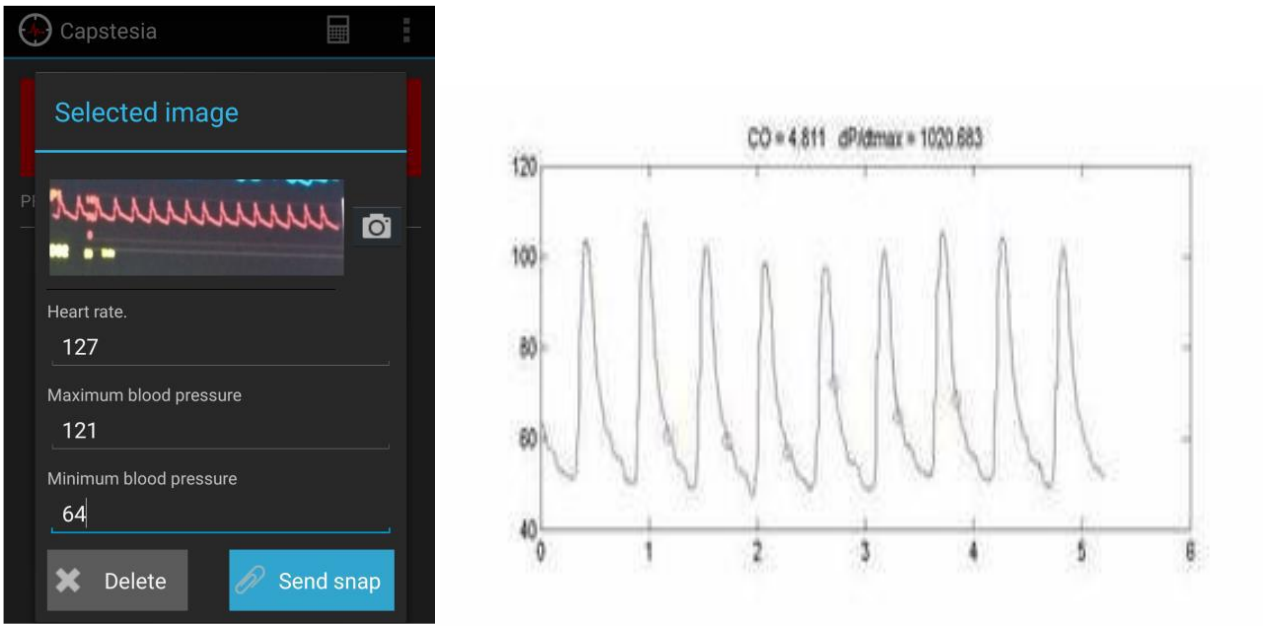

Figure (1): Analyzing blood pressure waves by Capstesia™

Ethical approval:

All patients or their legal guardians gave their agreement for participation in the study, and the study was approved by the Ethics Committee at the Faculty of Medicine, Cairo University. We adhered to the Helsinki Declaration, the ethical guideline of the World Health Organization for human trials.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 26 was used for data coding and entry (IBM Corp., Armonk, NY, USA). Quantitative data were summarised using measures of mean and standard deviation, while qualitative data were summarised using measures of frequency (count) and relative frequency (percentage). In order to find a statistically significant difference between the two strategies, we used the Student's T-test. To visualize the degree of concordance between the two quantitative measures, a Bland Altman plot was created. P value < 0.05 was considered significant.

RESULTS

Fifty people were admitted to the Cairo University Critical Care Unit; 29 males (58%) and 21 females (42%), with a mean age of 63.06±11.44 years.

The study population constituted of 28 diabetic patients (56%), 28 hypertensive patients (56%), 20 patients had coronary artery disease (40%), and 18 patients had heart failure (36%). Other co-morbidities (CKD, Liver disease, Asthma, Malignancy, and stroke) were less frequent.

Our patients were simultaneously subjected to two methods for COP monitoring: (1) Velocity time integral technique (VTI), and (2) Capstesia™ app.

On measuring COP, there was no statistically significant difference between the VTI and the Capstesia™ app. (Table 1).

Table (1): Comparison between VTI and Capstesia™ in measuring COP

	Mean	SD	p-value
Velocity time integral (VTI)	4.84	0.88	0.76
Capstesia™	4.83	0.89	

This important result can be further illustrated by the Bland-Altman plot in Figure (2).

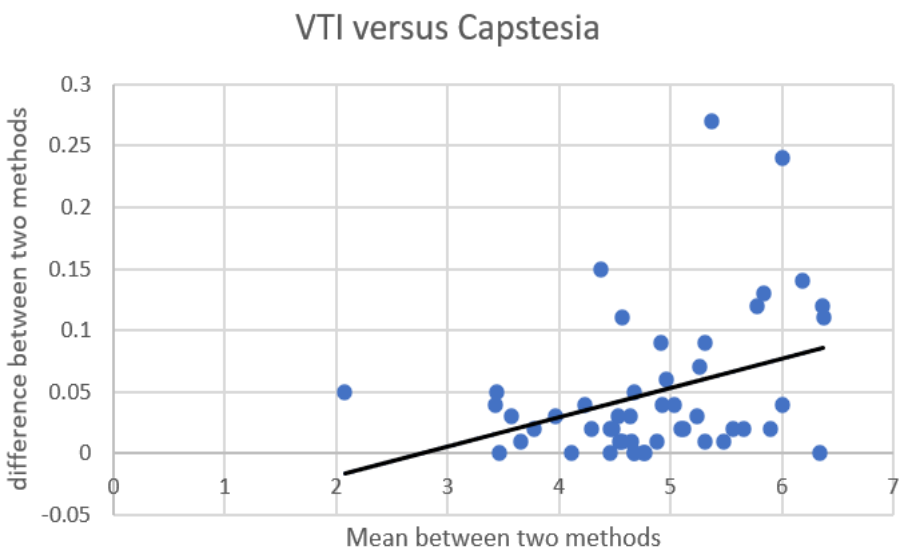

Figure (2): Bland-Altman plot in the whole study population.

From the above figure, we can observe the following:

1- The majority of values lie near the X axis, indicating small differences between the two methods.
2- The highest difference is less than 0.3 L/min.
3- The trend line is not very steep compared to the X axis.

The current study tried to go in depth to the application, so we divided the patient population into subgroups and applied the two methods for comparison.

There was an insignificant statistical difference in COP measurements between VTI and Capstesia™ when comparing different types of shock (Figure 3).

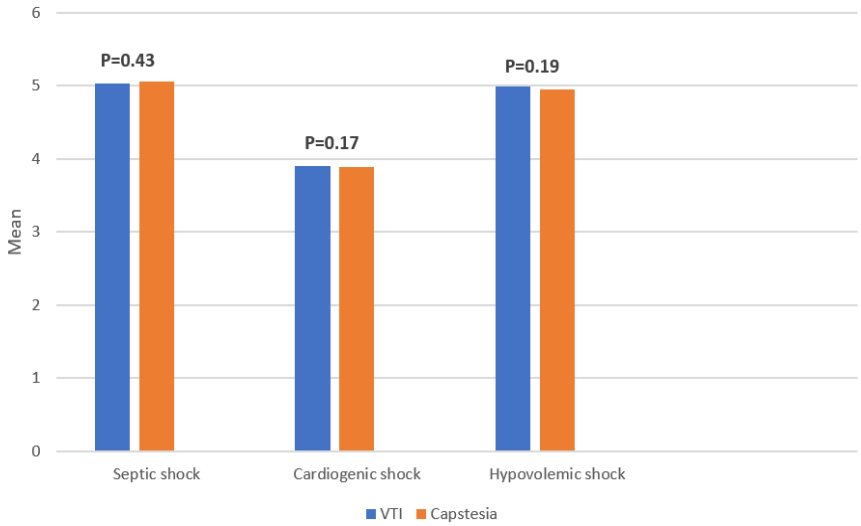

Figure (3): Comparison between different types of shock

The same was found when subdividing patients according to hypertension history (Table 2, Figure 4).

Table 2: Comparison of VTI and Capstesia™ according to hypertension history

	Group	Method	Mean	SD	p-value
HTN	No	VTI	4.76	0.82	0.25
		Capstesia™	4.75	0.83	
	Yes	VTI	4.89	0.93	0.92
		Capstesia™	4.89	0.94	

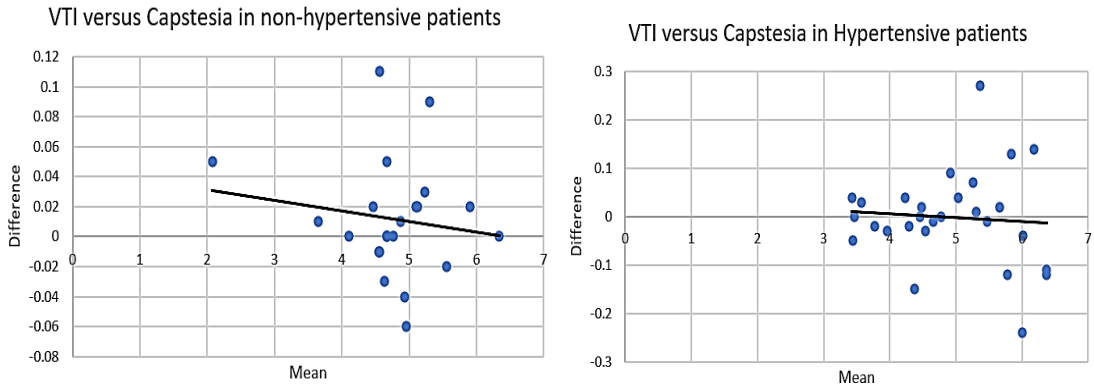

Figure (4): Bland-Altman plot in non-hypertensive and hypertensive patients

Concerning chronic kidney disease (CKD), our results reported a lower level of agreement between VTI and Capstesia™ in CKD patients (Table 3, Figure 5).

Table (3): Comparison of VTI and Capstesia™ according to CKD history

	Group	Method	Mean	SD	p-value
CKD	No	VTI	4.88	0.94	0.59
		Capstesia™	4.89	0.95	
	Yes	VTI	4.70	0.68	0.15
		Capstesia™	4.66	0.66	

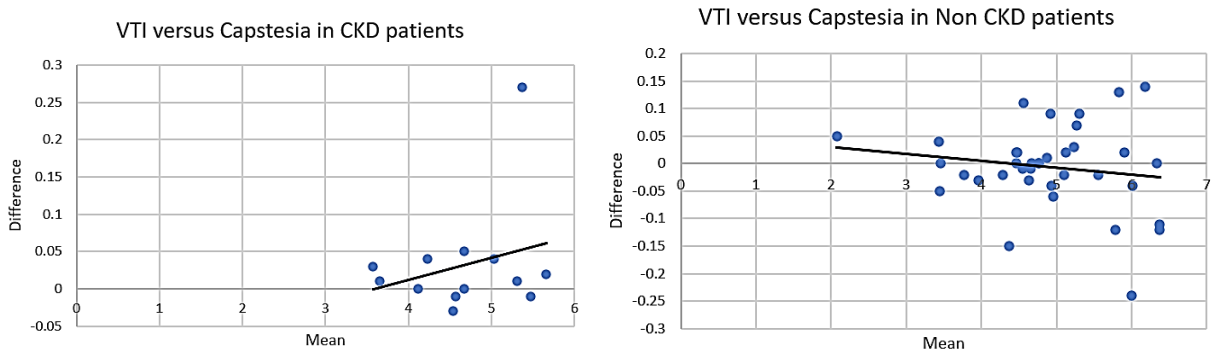

Figure (5): Bland-Altman plot according to CKD

Other co-morbidities such as DM, liver diseases, and heart failure in addition to mechanical ventilation failed to show a statistically significant differences between the two methods as shown in table 4.

Table (4): Comparison of VTI and Capstesia™ according to different co-morbidities

	Group	Method	Mean	SD	p-value
DM	No	VTI	4.73	0.98	0.57
		Capstesia™	4.72	0.99	
	Yes	VTI	4.92	0.80	0.78
		Capstesia™	4.92	0.80	
Liver disease	No	VTI	4.80	0.89	0.42
		Capstesia™	4.80	0.89	
	Yes	VTI	5.00	0.85	0.41
		Capstesia™	5.03	0.90	
Heart failure	No	VTI	5.04	0.65	0.76
		Capstesia™	5.03	0.66	
	Yes	VTI	4.48	1.11	0.93
		Capstesia™	4.48	1.12	
Mech. ventilation	No	VTI	4.77	0.75	0.69
		Capstesia™	4.78	0.77	
	Yes	VTI	4.91	1.02	0.44
		Capstesia™	4.89	1.02	

DISCUSSION

Continuous COP monitoring in critically ill patients is a cornerstone in guiding hemodynamic GDT. The traditional echo-based VTI technique measures COP with accepted accuracy. However, smartphone applications are useful in providing clinical data in a simpler and more accessible way.

It is clearly understood that none of the non-invasive or minimally invasive methods for cardiac output monitoring has shown sufficient accuracy in measuring the absolute value of COP [6].

Our study included a total of 50 patients presenting with hemodynamic instability and shock state and candidates for continuous cardiac output monitoring. The two methods were applied simultaneously with no significant differences regarding demographic or baseline clinical characteristics.We pointed out the high level of agreement between Capstesia™ app and the traditional VTI method in COP measurement with the mean values of VTI and Capstesia™ app are 4.84±0.88 L/min and 4.83±0.89 L/min, respectively. The concordance correlation coefficient was 0.996 and percentage of error below 10%. In agreement with our findings, **Santiago-López *et al.*** [7] used the Capstesia™ app and the Vigileo™ monitor to measure COP in real-time from 30 patients. Results from the Vigileo™ and Capstesia™ monitors showed a COP of 4.43±1.37 L/min and 4.45±1.38 L/min, respectively, with a concordance correlation coefficient of 0.966.

Confirming the above results, **Shah *et al.*** [8] compared the COP retrieved from Capstesia™ to the COP obtained from the conventional cardiac output monitor Vigileo™ in 53 patients during intraoperative monitoring; the results demonstrated a positive connection between the two and the strength of the correlation was 0.757; concluding that Capstesia™ is a reliable and feasible alternative to Vigileo™ for intraoperative COP monitoring. **Barrachina *et al.*** [9] showed how well the patient monitor's signal analysis and the Capstesia™ app agreed on COP readings. The COP correlation value was 0.96 with an error of 13.8%, indicating that Capstesia™ app screenshots agree well with signal analysis of the original patient monitor data.

On contrary, **Huber *et al.*** [10] conducted a study comparing COP measurements and cardiac index by Capstesia™ app versus PiCCO. Thirty-nine simultaneous measurements were performed in 11 ICU patients and the results showed that CI_ Capstesia™ and CI_PiCCO were not significantly different (3.2±1.3 versus 3.7±1.7 L/min/m^2). However, the p value was 0.049, indicating just moderate accuracy between the two methods. Moreover, **Hoppe *et al.*** [11] in a prospective study on patients undergoing major abdominal surgery, PPV and COP were simultaneously measured using Capstesia™ and using invasive internally calibrated pulse wave analysis (ProAQT; Pulsion Medical Systems). The PPV diagnostic agreement was calculated to be 64.7% overall. There was an average discordance of 0.6 percentage points between COPs, with a 48.7 percent margin of error and a 45.1% rate of agreement. They concluded that further development of the app's technical infrastructure is required before it can be recommended for hemodynamic monitoring. Poor imaging quality (2 megapixels) and a small sample size cast doubt on the study's findings [11].

CONCLUSION

Smartphone application Capstesia™ is a reliable alternative to the traditional echo-based VTI technique in continuous COP monitoring in hemodynamically unstable patients.

STUDY LIMITATIONS

- Capstesia™ app is only compatible with Android system.
- The study tested COP only and no other hemodynamic indices.
- The study is a single center trial with a limited number of patients.

Sponsoring financially: Nil.

Competing interests: Nil.

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