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Original Research Article

ASSESSMENT OF CARDIAC OUTPUT AND STROKE VOLUME IN CRITICALLY ILL ADULT PATIENTS BY TRANSTHORACIC ECHOCARDIOGRAPHY AND PULSE INDEX CONTINUOUS CARDIAC OUTPUT MONITOR

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Abstract: *Accurate measurement of cardiac output (CO) and stroke volume (SV) is crucial for the management of critically ill patients. While transthoracic echocardiography (TTE) is a well-established method, pulse index continuous cardiac output (PiCCO) monitoring is gaining attention for its potential advantages in constant hemodynamic monitoring.* ***Objective:*** *To compare cardiac output and stroke volume assessments derived from transthoracic echocardiography (TTE) and pulse index continuous cardiac output monitoring (PiCCO) in critically ill adult patients.* ***Methods:*** *This prospective comparative study was conducted at Khyber Teaching Hospital from May 2022 to November 2022, following ethical approval from the institutional review board. A cohort of 25 adult patients of both genders, requiring hemodynamic monitoring as per clinical indications, was included through non-probability consecutive sampling. Both TTE and PiCCO were performed to measure cardiac output and stroke volume. Pearson correlation and Bland-Altman plots were utilized to analyze the outcomes statistically.* ***Results:*** *The comparison revealed a non-significant positive correlation between CO values obtained via TTE and PiCCO (P=0.434, r=0.164) and a significant positive correlation for cardiac index (CI) values (P=0.010, r=0.506). Conversely, a non-significant negative correlation was observed for SV values (P=0.45, r=-0.158). The mean differences for CO, CI, and SV between TTE and PiCCO were 0.214 L/min, -0.0056 L/min, and -1.292 L/min, respectively, with varying confidence intervals across the measurements.* ***Conclusion:*** *The measurements of cardiac output and stroke volume obtained from transthoracic echocardiography were comparable to those obtained via PiCCO. These findings support the reliability of echocardiography for assessing hemodynamic parameters in critically ill patients.*

Keywords: Adults, Cardiac Index, Cardiac Output, Critical Illness, Echocardiography, Stroke Volume

Introduction

Critically ill patients often develop hemodynamic instability and require a comprehensive assessment and management of cardiac function to optimize patient outcomes. Key parameters underlying cardiac performance include cardiac output and stroke volume, which must be accurately measured (1). Initially, transthoracic echocardiography (TTE) was considered the "gold standard" for evaluating cardiac function in patients, given its non-invasive nature and the ability to obtain real-time images of cardiac structures (2). However, given the recent developments in monitoring technologies, pulse index continuous cardiac output monitoring (PICCO) has become an alternative form to achieve constant and less operator-dependent hemodynamic measurements (3). Transthoracic echocardiography is an imaging technique that allows various assessments of cardiac anatomy, function, and hemodynamics without breaking through the skin (4). Cardiac biometry, left ventricle size, wall motion abnormalities, valvular function, cardiac output, and stroke volume estimation using Doppler techniques are some of the applications of TTE (5). Despite many benefits, TTE has limitations, such as personnel dependency, suboptimal imaging in some patient groups, and intervals between measurements (6). Pulse index continuous cardiac output monitoring is an alternative method that uses transpulmonary thermodilution technology for hemodynamic measurements. The apparatus records aortic pressure and manually injects a cold solution into a central venous line. The blood temperature is continuously recorded as the solution passes through the circulation. The low-dose radiography is used to validate a one-point calibration curve (3). Given the importance of precise cardiac output estimations to drive clinical decision-making and improve patient outcomes, it is necessary to evaluate and then compare TTE to non-invasive pulse index continuous cardiac output monitoring in critically ill adults (7). Although TTE remains the gold standard for cardiac imaging, PICCO monitoring may also be preferable (8). However, there is currently very little evidence to substantiate this statement. This study will bridge this gap by comparing the CO and SV assessments derived from TTE and PICCO monitoring in a cohort of critically ill adult patients. Our further evaluation of both methods' accuracy, reproducibility, validity, and clinical relevance will contribute toward understanding their unique and intertwined benefits within the broader scope of hemodynamic management in critically ill patients.

Methodology

After ethical approval from the institutional review board, this prospective comparative study was conducted at Khyber Teaching Hospital from May 2022 to November 2022. Through non-probability, a consecutive sampling of 25 patients above 18 years of age of both genders who required hemodynamic monitoring as per clinical indication was included in the present study. Patients with hemodynamic instability, congenital heart disease with intracardiac shunt physiology or valvular heart disease, tracheostomy tubes, or inability to tolerate the supine position of the study procedures were excluded from the present study. Continuous cardiac output monitoring of TTE and pulse index was conducted in all participants to measure cardiac output and stroke volume. Trained cardiac sonographers conducted TTE using standard echocardiographic protocols, which require two-dimensional imaging, Doppler assessment, and calculating CO and SV from flow velocities and chamber dimensions. PiCCO was performed via the insertion of a central venous catheter and an arterial catheter connected to a PiCCO computer system, which is a device that enables continuous measurement of arterial pressure and transpulmonary thermodilution curves. Cardiac output and SV measurements based on thermodilution were recorded following an initial calibration, and monitoring for the treatment course was maintained. Demographic data, clinical manifestations, and hemodynamic outcomes obtained from TTE and PiCCO monitoring were examined for each participant involved in the research. SPSS version 21 was utilized for data analysis. Categorical data was presented as frequency and percentage, while continuous data was presented as Mean± S. D. Pearson correlation and Bland-Altman plots were used to compare the outcome variables. P value ≤0.05 was considered significant.

Results

Table 1 shows the clinical and demographic parameters of the study participants. The mean age of the recruited participants was 45.56±5.76 years. The male-to-female ratio in the present study was 2:1. The mean cardiac output (CO) measured by TTECHO and PiCCO was 4.116 ± 2.0 and 3.9± 1.84 L/min. The mean cardiac index (CI) calculated by TTECHO and PiCCO was 4.68± 1.47 and 4.69 ± 1.19L/min/m^2. The mean stroke volume (SV) measured by TTECHO and PiCCO was 39.02± 2.77, 40.32± 2.79 mL/beat. Figure 1-3 shows the Pearson correlation between CO, CI, and SV values obtained through the TTECHO and PICCO. A non-significant positive correlation was observed between the CO values obtained through TTECHO and PICCO (P=0.434, r=0.164). A significant positive correlation was observed between the CI values obtained through TTECHO and PICCO (P=0.010, r=0.506). A non-significant negative correlation was observed between the SV values obtained through TTECHO and PICCO (P=0.45, r=-0.158). Figure 4-6 shows the Bland-Altman graph of mean differences of CO, CI, and SV values obtained through the TTECHO and PICCO. The mean difference of CO values obtained through TTECHO and PICCO was 0.21440 L/min with 95% CI upper 1.2431 and lower interval of -0.8143. The mean difference of CI values obtained through TTECHO and PICCO was -0.0056 L/min with 95% CI upper 0.5506 and lower intervals as -0.5618. The mean difference of SV values obtained through TTECHO and PICCO was -1.29200 L/min with 95% CI upper 0.4563 and lower intervals of -3.0403.

Table I: Demographic and clinical variables of the study participants

Variables	Mean and Frequency (N=25)
Age (years)	45.56±5.76
Male to female ratio	2:1
Weight (kg)	68.54±7.8
Cardiac Variables	
CO-TTECHO (L/min)	4.116 ± 2.0
CO-PICCO (L/min)	3.9± 1.84
CI-TTECHO (L/min/m^2)	4.68± 1.47
CI-PICCO (L/min/m^2)	4.69 ± 1.19
SV-TTECHO (mL/beat)	39.02± 2.77
SV-PICCO (mL/beat)	40.32± 2.79

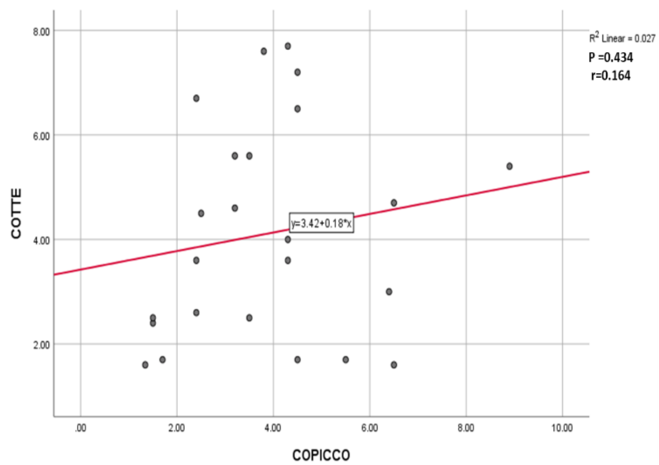

Figure 1: Pearson correlation between the values of CO obtained through the TTECHO and PICCO:

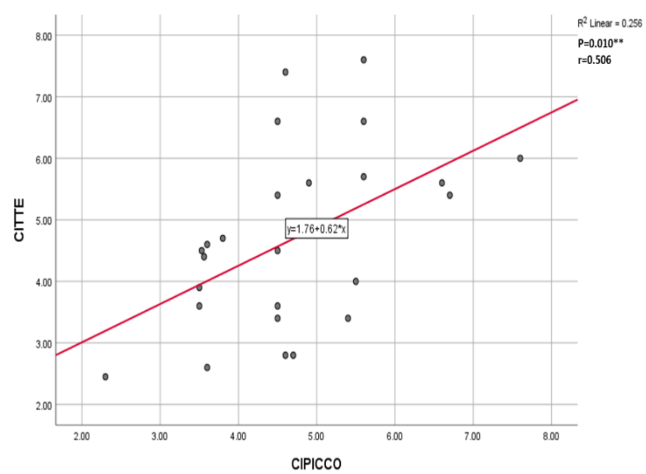

Figure 2: Pearson correlation between the values of CI obtained through the TTECHO and PICCO

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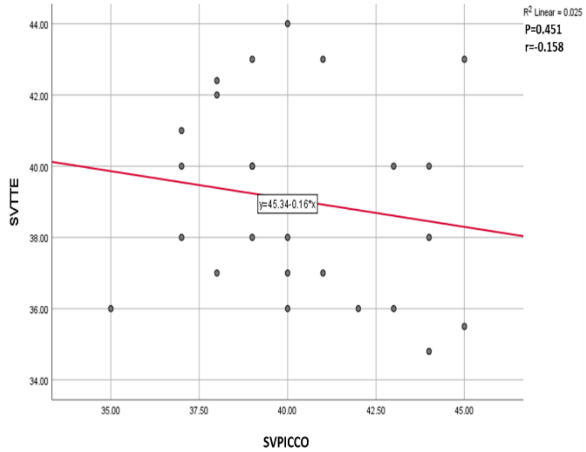

Figure 3: Pearson correlation between the values of SV obtained through the TTECHO and PICCO

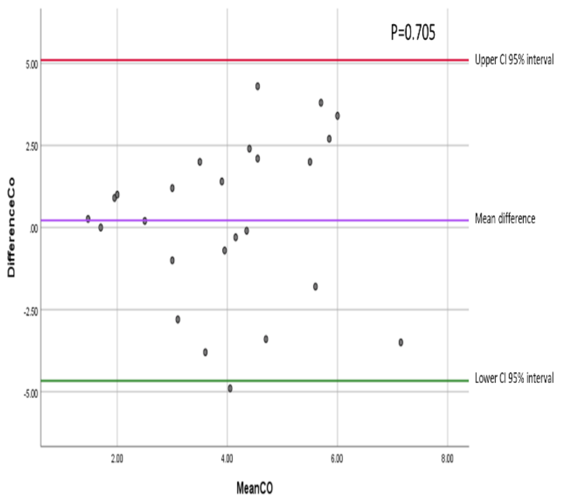

Figure 4: Bland-Altman graph of mean differences of values of CO obtained through the TTECHO and PICCO

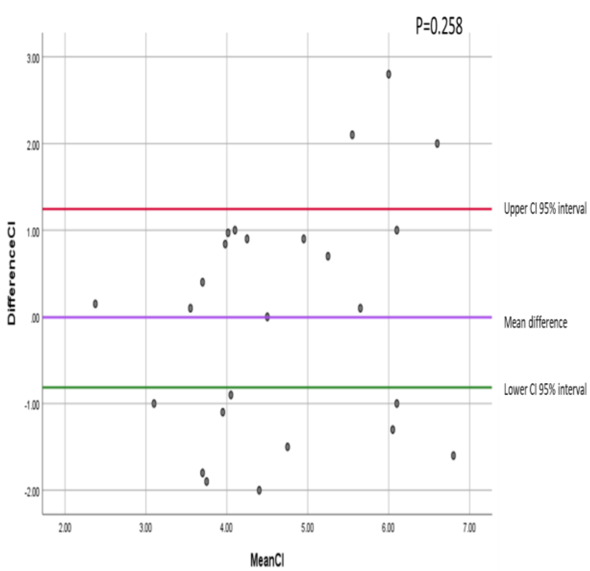

Figure 5: Bland-Altman graph of mean differences of values of CI obtained through the TTECHO and PICCO

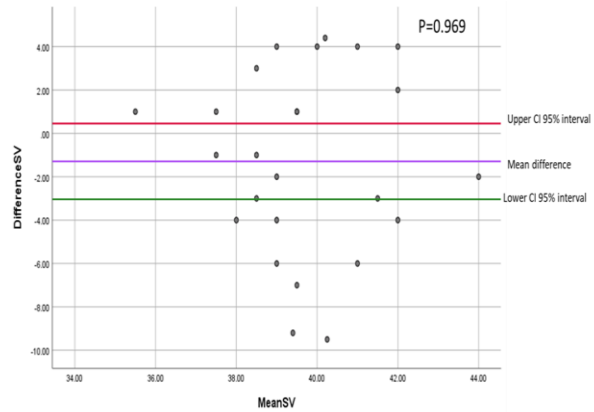

Figure 6: Bland-Altman graph of mean differences of values of SV obtained through the TTECHO and PICCO

Discussion

Planning the optimal fluid and inotrope-vasopressor-indicator management in critically ill adult patients is essential. Cardiac output measurement is vital in guiding fluid and inotrope treatment in adults with shock of any etiology. CO can be determined in intensive care units using echocardiography, pulmonary artery catheterization, and transpulmonary thermodilution (9). Pulmonary artery catheter "offers to monitor CO, CI, CVP, systemic vascular resistance Index, and pulmonary capillary wedge pressure. Since this method is invasive for patients due to the insertion of a catheter into the right heart, the procedure is related to several cardiopulmonary complications. Transpulmonary thermodilution technology allows continuous CO, preload, afterload, and pulmonary permeability measurement by adding a pulse contour technology to the transpulmonary thermodilution (10). This method was determined to correlate well with pulmonary artery catheter measurements. The monitoring of CO can also be carried out using transthoracic Doppler echocardiography, and the results showed its efficiency in estimating cardiac output in critically ill patients (11).

PiCCO is a minimally invasive device continuously monitoring carbon dioxide levels and hemodynamics. It utilizes pulmonary artery catheterization and is fitted with a femoral artery catheter and central venous catheter (12). The technology is founded on the operational concept of pulse contour technology and transpulmonary thermodilution. The device utilizes pulse contour analysis to continuously measure cardiac output (CO) and cardiac index (CI), with transpulmonary thermodilution employed to calibrate the system. Cardiac output (CO) is determined by quantifying the integral of the waveform during the calibration period. The initial procedure involves utilizing the conventional thermodilution approach to facilitate the measurement of continuous cardiac output through pulse contour analysis on the arterial waveform (13). PiCCO technology is appropriate for patients experiencing hemodynamic instability and uncertain regarding their volume status. The PiCCO device was the initial pulse contour instrument employed for the clinical assessment of cardiac output (CO). It provides intensive care specialists with information and guidance for planning the most suitable fluid and inotrope treatment. This is achieved by providing information on the patient's preload (blood volume in the heart) and systemic vascular resistance (resistance to blood flow in the body). According to specific experts, PiCCO is considered the most reliable method for evaluating the fluid status of patients (14). In the current study, we compared the CO and CI values performed by non-invasive critical care echocardiography and PiCCO in critically ill adult patients who were admitted to the PICU and necessitated hemodynamic monitoring

To the best of our knowledge, it is one of the few studies in the literature examining and comparing CO measurements in the adult age group using transthoracic echocardiography and PiCCO. Wurzer et al. also compared the effect of transthoracic echocardiography on PiCCO in critically burned patients. They conducted a retrospective study and presented that PiCCO monitoring is a better and more reliable way to evaluate critically ill patients' cardiovascular and hyperdynamic states (14). Our investigation reveals a robust and affirmative association between the cardiac index (CI) levels assessed using critical care echocardiography and the PiCCO monitor.

Gergely et al. (15) compared three different methods: transpulmonary thermodilution, transthoracic echocardiography, and the use of conventional hemodynamic monitoring in patients who underwent open heart surgery to evaluate the volumetric preload parameters. They also reported that the time course of thermodilution-derived parameters of CO measurements may serve clinical relevance in critical care practice. Vignon et al. compared the CO measured by the TTE performed by the PCCO thermodilution in mechanically ventilated adults with septic shock and reported a moderate concordance. Another study compared the CO obtained by the TTE and the PCCO method in patients with post-cardiac arrest who were treated with therapeutic hypothermia. They found a significant difference between the hypothermia and normothermic groups (16). Since the echocardiography was not affected by the body temperature difference, it was caused by the thermal sensitivity of the PiCCO system. A study comparing the CI monitoring occasions using the PiCCO to the echocardiography measures noted consistency between the values and suggested that it might be the optimal monitor in adult cardiothoracic surgical patients (17).

Certain constraints exist in this study. The size of our sample is limited and comprises exclusively patients from a single medical center. The study had a limited patient population because PiCCO, an invasive monitoring technology, can only be used on a certain group of patients. We believe that conducting more research with larger cohorts of patients will make a valuable contribution to the existing body of literature.

Conclusion

The echocardiographic measurements of CO and SV were comparable to the measurements by PiCCO. Echocardiography is a reliable instrument for measuring hemodynamic parameters in critically ill patients.

Declarations

Data Availability statement

All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department Concerned.

Consent for publication

Approved

Funding

Not applicable

Conflict of interest

The authors declared absence of conflict of interest.

Author Contribution

MOHAMMAD HAROON (Assistant Professor)
Conception of Study, Development of Research Methodology Design, Study Design,, Review of manuscript, final approval of manuscript.
SULAIMAN (Assistant Anaesthetist)
Coordination of collaborative efforts.
MUHAMMAD JAVED KHAN (Assistant professor)
Study Design, Review of Literature.
IMRAN UL HAQ (Assistant professor)
Manuscript revisions, critical input.
SAJJAD AHMAD (TMO Pulmonology)
Conception of Study, Final approval of manuscript.
KHAYYAM FARID (Registrar Anaesthesiology)
Coordination of collaborative efforts.
MALIK NAVEED IQBAL (Fellow of Orthopaedic surgery)
Data entry and Data analysis, drafting article.

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