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ORIGINAL ARTICLE

Pulse index contour continuous cardiac output (PICCO) monitoring in critically ill patients.

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ABSTRACT… Objective: To evaluate the utility of Pulse index Contour Continuous Cardiac Output (PiCCO) monitoring in critically ill patients. **Study Design:** Cross-sectional study. **Setting:** Intensive Care Unti of Sindh Institute of Urology and Transplant, Karachi, Pakistan. **Period:** October 2022 to March 2023. **Methods:** Patients presenting with various types of shock, requiring high-dose vasopressors or inotropes, and not responding to initial fluid therapy were analyzed. Demographic details, SOFA score, APACHE score, and invasive hemodynamic parameters using the PiCCO system were documented. **Results:** Out of 142 ICU admissions, 38 patients were included in the study. Most patients were males (73%) with a median age of 39 years. Significant changes were observed in the cardiac index, cardiac performance index, global ejection fraction, and systemic vascular resistance index (SVRI), all with p-values less than 0.05. The interventions included the initiation of inotropes in 22 patients (57.8%), diuretics in 4 patients (10.5%), and intravenous fluids in 19 patients (50%). Additionally, vasopressor doses were adjusted in 18 patients (47.3%). Initially, patients were presumed to have pure septic shock based on CO_2 gap, mixed venous saturation, and echocardiographic assessment. However, after applying PiCCO monitoring, the diagnosis was revised to mixed shock in 21 patients (55.2%). **Conclusion:** PiCCO monitoring appears to be a valuable tool in the ICU for managing patients with complex hemodynamic profiles, facilitating targeted interventions that lead to significant improvements in hemodynamic stability.

Key words: Diuretics, Inotrope, Intensive Care Unit, Shock, Vasopressor.

INTRODUCTION

Circulating fluid volume and hemodynamic monitoring are of pivotal importance when managing patients in intensive care units.[1] Maintaining ideal circulatory volume is a challenge when caring for these patients whereas sub-optimal circulating volume can result in tissue hypo-perfusion and reduced oxygen delivery.[2] The "Pulse index Contour Continuous Cardiac Output (PiCCO)" system, is a minimally invasive system that gives beat to beat cardiac output and volume status along with presence of pulmonary edema via trans-pulmonary thermodilution technique and pulse contour analysis. PiCCO gives full picture of patient's vascular tone, preload and cardiac function and is considered as "all-inclusive device".[3] However, only a handful of studies have investigated outcomes of patient with treatment aided by PiCCO monitoring, so the link between its use and clinical outcome is largely unknown.[4,5]

Septic shock is commonly encountered in intensive care settings and early goal-directed therapy is based on urine output, mixed venous saturation, central venous pressure or mean arterial pressure, is clinically useful in guiding therapy.[6,7] Yet there are objections to it and optimal fluid therapy is relatively unknown and awaiting clear answers. It has been observed that keeping net fluid balance negative improves survival in critical care settings.[8] It has been supported by recent studies that suggests increased extra vascular lung water is associated with poor outcome.[9] Thus, targeting to optimize extra vascular lung water in these groups could be potentially beneficial.

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Conditions like sepsis induced cardiomyopathy, or chronic kidney disease pose a different challenge concerning volume status as these patients are at elevated risk of developing volume overload and its associated complications particularly related to cardiovascular system.[10,11] In this study, we aimed to share our experience of using invasive hemodynamic monitoring in a group of patients admitted in SIUT, which is predominantly a dialysis and transplant center. The spectrum of patient in our hospital is not limited to a specific type of shock and usually a mixture of different types of shock is seen after workup. Invasive hemodynamic monitoring using PiCCO tool can help in early identification of mixed type of shock in our patients. This technology is relatively new in our country and no experience is shared in the published form to the best of our review of literature. The objective of this study was to evaluate the utility of PiCCO monitoring in critically ill patients.

METHODS

This cross-sectional study was conducted at the Ruqaiyya Jafarani intensive care untit (ICU) of Sindh Institute of Urology and Transplant (SIUT), Karachi, Pakistan from October 2022 to March 2023. Based on previous estimates, the proportion of congestive heart failure was found to be 4.4% in patients with shock[12], with a margin of error of 7% and a 95% confidence level, the sample size was calculated to be 33. Approval from "Institutional Ethical Committee" was obtained (SIUT-ERC-2022/PA-412). Patients presenting with various types of shock, requiring high-dose vasopressors or inotropes, and not responding to initial fluid therapy were analyzed. Exclusion criteria included contraindications to catheter insertion and pre-existing conditions that interfere with PiCCO measurements. Non-probability consecutive sampling technique was used.

At baseline, demographics, disease details, SOFA score, and APACHE score were documented. After screening and obtaining informed consent, a PiCCO line was inserted. Invasive hemodynamic data were collected using the thermodilution method, where 15 ml cold saline was injected through the central venous catheter, and the temperature difference detected by the arterial thermistor provided the cardiac index and other variables. This procedure was repeated three times for each recording, and the mean value was recorded. Continuous monitoring was recorded using trends from the monitor software, and calibration of the machine was done in each shift or after any access to the central line. Data about invasive hemodynamic parameters was also noted. Shock was defined as a mean arterial pressure below 60 mm Hg and serum lactate > than 2 mmol/liter. Respiratory failure was defined as PaO_2 to FiO_2 ratio < 300 with a positive end-expiratory pressure of more than 5 cm H_2O, onset within one week of a known clinical insult or new/worsening respiratory symptoms, chest imaging showing bilateral opacities not explained by other pathophysiology, and respiratory failure not fully explained by cardiac failure or fluid overload. Septic cardiomyopathy did not have specific diagnostic criteria but was known to have three features: left ventricular dilatation with low or normal filling pressures, depressed ejection fraction, and recovery within 7-10 days. A special proforma was designed to record all study information.

Data analysis was performed using "IBM-SPSS Statistics, version 22.0". Normally distributed continuous variables were reported as mean and standard deviation (SD) or median and inter-quartile (IQR) range if non-parametric. Categorical variables were presented as frequencies and percentages. Pre- and post- comparisons for continuous variables were done using Paired T-test or Wilcoxon signed-rank test as appropriate. Chi-square was applied for the comparison of categorical data. P-value<0.05 was considered significant.

RESULTS

During the study period, 142 patients were admitted to the ICU, and out of these, 104 were excluded as 64 did not have shock, or 40 patients had their shock improved within 24 hours. Consequently, 38 patients were included in the final analysis. The median age of the patients was 39 years (IQR= 30-58), with an age range

of 22-77 years. The majority of the patients were male (73%), with 31.6% having a history of renal transplant and 52.6% diagnosed with "chronic kidney disease (CKD)". The median APACHE II score was 22 (IQR=18-29), with the highest score recorded being 38. Table-I is showing details about the baseline characteristics of patients.

Significant changes were observed in the cardiac index, cardiac performance index, global ejection fraction, and systemic vascular resistance index (SVRI), all with p-values less than 0.05. The interventions included the initiation of inotropes in 22 patients (57.8%), diuretics in 4 patients (10.5%), and intravenous fluids in 19 patients (50%). Additionally, vasopressor doses were adjusted in 18 patients (47.3%). Table-II compares the hemodynamic measurements before and after interventions guided by PiCCO monitoring.

Initially, patients were presumed to have pure septic shock based on CO_2 gap, mixed venous saturation, and echocardiographic assessment. However, after applying PiCCO monitoring, the diagnosis was revised to mixed shock in 21 patients (55.2%). Table-III illustrates the diagnostic efficacy of PiCCO monitoring in identifying obscured shock.

Baseline Characteristics		Number (%) / Median (IQR)
Sex, n (%)	Male	28(73.7)
	Female	10(26.3)
Age, years		39.5(30-58.25)
BMI, kg/m^2		21.08(20.41-22.8)
Coexisting Disorders, n (%)	Hypertension	12(31.6)
	Diabetes mellitus	7(18.4)
	Chronic kidney injury	20(52.6)
	Renal transplant recipient	12(31.6)
	Post Surgical	10(26.3)
Lab parameters (IQR)	High sensitivity troponin I pg/ml (IQR)	377(43.88-967.6)
	Hemoglobin (g/dl)	9.4 (8.37-10.9)
	Albumin (g/dl)	2.4 (1.9-2.8)
	Total Leucocyte count (10^9/L)	10.24 (6.2021.26)
Baseline lab parameters for shock (IQR)	Central Venous Oxygen Saturation (%)	69.8(55.4-78.6)
	Lactate (mmol/L)	2.95(1.9-6.45)
	CO_2 Gap (mm Hg)	6.35 (4.05-9.97)
	pH	7.31(7.21-7.39)
Highest SOFA Score (IQR)		12(8.75-13.25)
Baseline APACHE II score (IQR)		22(18-29)
Baseline Echocardiography Results, (IQR)	LV ejection fraction (%)	50.5(30-60)
	Right heart systolic function (mm)	17(15-18)
	Inferior vena cava diameter (mm)	13(11.35-16)
Clinical diagnosis on admission n (%)	Cardiogenic shock	2 (5.3)
	Septic + Cardiogenic shock	4 (10.5)
	Septic Shock	32 (84.2)
Reason for mechanical ventilation n (%)	Respiratory Failure	10 (26.3)
	Heart failure	4 (10.5)
	Metabolic problems	9 (23.6)
	Septic shock	10 (26.3)
	Post operative complication	5 (13.1)

Table-I. Baseline patients characteristics

Hemodynamic Parameters	Pre-Intervention (95% CI)	Post-Intervention (95% CI)	P-Value
Mean arterial pressure (mm Hg)	80.9 (72.5-89.2)	80.0 (69-95)	0.91
Heart rate (beats / min)	108 (87-126)	108 (90-129)	0.94
Cardiac index (L/min/m^2)	2.67 (2.08-3.3)	3.18 (2.38-4.0)	0.01
Cardiac power index (W/m^2)	0.50 (0.36-0.66)	0.59 (0.42-0.73)	0.03
Systemic vascular resistance index (dynes.sec.cm-^{5})	2132 (1641-2600)	2059 (1460-2419)	0.04
Pulse pressure variation (mm Hg)	12 (6-20)	9 (7-17)	0.61
Stroke volume variation (ml)	16 (7.5-27)	14 (10-22)	0.65
Global end-diastolic volume index (ml/m^2)	567 (464-693)	615 (474-681)	0.11
Extravascular lung water index (ml/kg)	10 (8.7-13)	10 (7-13)	0.43
Pulmonary vascular permeability index	2.7 (2.0-3.5)	2.2 (1.7-3.6)	0.69
Central venous pressure (cmH_2O)	9 (5-15)	8 (6-12)	0.93

Table-II. Comparison of hemodynamic parameters before and after intervention guided by pulse index contour continuous cardiac output

		Types of shock on Pulse index Contour Continuous Cardiac Output				P-Value
		Cardiogenic + Hypovolemic (n=2)	Cardiogenic shock (n=4)	Septic + Cardiogenic shock (n=21)	Septic shock (n=11)	
Clinical impression	Cardiogenic shock	-	2 (50.0%)	-	-	<0.001
	Septic + Cardiogenic shock	1 (50.0%)	2 (50.0%)	1 (4.8%)	-	
	Septic shock	1 (50.0%)	-	20 (95.2%)	11(100%)	

Table-III. Type of shock: Clinical impression versusPulse index Contour Continuous Cardiac Output diagnosis

DISCUSSION

Our study investigated the utility of PiCCO monitoring in a cohort of 38 critically ill patients admitted to the ICU. The key findings included a high rate of discordance between clinical and PiCCO-based diagnoses of shock (63.2%), significant hemodynamic improvements with PiCCO-guided therapy, and a concerningly high mortality rate (71.1%). The observed discrepancy between clinical and PiCCO diagnoses of shock (63.2%) aligns with findings from previous international studies. A study done by Duan et al reported a similar discordance rate between clinical assessment and PiCCO results between 46% to 65.4%.[13] Studies have proven the limitation of clinical prediction to assess advanced hemodynamic parameters like cardiac output, extra lung water index and global end diastolic volume index.[14-16] This suggests that PiCCO may unveil hemodynamic derangements not readily apparent through traditional clinical evaluation. Early identification and targeted therapy for these hidden hemodynamic abnormalities could potentially improve patient outcomes.

The decision of adding or modifying therapy depends on the correct measurement of hemodynamic parameters.[17] In our study we have to modify the treatment in 57% of patients which is close to what has been studied. Our study demonstrated significant improvements in several hemodynamic parameters with PiCCO-guided therapy. Pre-treatment cardiac index (CI), cardiac power index (CPI), and gastric emptying fraction (GEF) all showed statistically significant improvement following PiCCO-guided interventions. It has been observed in previous studies that invasive hemodynamic monitoring has reduced the length of stay and post-surgical complications. The observed improvement in systemic vascular resistance index (SVRI) after intervention was modest. Further research is needed to explore the complex interplay between cardiac function, vascular tone, and specific patient characteristics in this critically ill population. The high mortality rate (71.1%) observed in our study population is concerning but reflects the severity of illness in critically ill patients admitted to ICU. Global data regarding mortality rates indicate a

rise in mortality corresponding to the deterioration of APACHE II scores.[18] High mean Apache II score on admission indicated a high risk of death, and a significant portion of patients had chronic health conditions like CKD and a history of renal transplant, and these findings are consistent with the published literature.[19,20] Elevated lactate and troponin levels suggested tissue hypoxia and potential myocardial injury, further contributing to the high mortality rate. The mortality corrected with severity of disease is comparable or better in our population as compared to other studies.[21,22]

Our study had some limitations. The relatively small sample size restricts generalizability of the findings. The study design did not control specific therapeutic interventions based on PiCCO data. Future research with larger, multicenter cohorts and a prospective design could further elucidate the impact of PiCCO-guided therapy on mortality rates in critically ill patients.

CONCLUSION

Our study suggested that PiCCO monitoring may be a valuable tool in managing critically ill patients, particularly those with complex hemodynamic profiles. The high rate of discordance between clinical and PiCCO diagnoses highlights the potential for PiCCO to identify hidden hemodynamic abnormalities.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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1	Hafiz Syed Wahaj Azim Fatmi	Conceptualized the study, Involved in data collection, Initial manuscript writing.	
2	Fakhir Raza Haidri	Designed the study protocol, Critically revised the initial manuscript draft.	
3	Nazia Arain	Data collection, Initial manuscript writing.	
4	Bushra Zafar	Performed data analysis and involved in result writing.	
5	Syeda Maheen Fahim	Performed data analysis and involved in result writing.	
6	Mirza Usman Baig	Performed data analysis and involved in result writing.