SSR Institute of International Journal of Life Sciences
ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Rath *et al*., 2025
doi: 10.21276/SSR-IIJLS.2025.11.5.49

Original Article

open access

Comparison of Hemodynamic Parameters Using Point of Care Echocardiography among Sick Neonates vs Healthy Neonates in a Tertiary Care Hospital of Odisha

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Received: 25 Apr 2025/ Revised: 29 Jun 2025/ Accepted: 21 Aug 2025

ABSTRACT

Background: Hemodynamic instability in neonates arises from multifactorial causes such as sepsis, perinatal asphyxia, patent ductus arteriosus (PDA), shock, and myocardial dysfunction. Sick neonates often exhibit abnormal echocardiographic findings, including altered preload, increased afterload, and diastolic dysfunction, whereas healthy neonates maintain a stable cardiac output and balanced circulation. Comparing hemodynamic parameters between sick and healthy neonates using point-of-care ultrasonography (POCUS) aids in early detection and management of cardiac dysfunction.

Methods: A prospective, case-control study was conducted on 143 neonates admitted to the NICU and SNCU of PGIMER and Capital Hospital, Bhubaneswar, over 18 months. The study included 60 sick neonates (cases) and 83 healthy neonates (controls). Sick neonates requiring hemodynamic evaluation due to suspected sepsis, asphyxia, prematurity, respiratory distress syndrome, PPHN, or congenital heart defects were enrolled. Echocardiographic parameters—Ejection Fraction (EF), E/A ratio, Isovolumic Relaxation Time (IVRT), Cardiac Output (CO), Left Atrium/Aorta (LA/Ao) ratio, Velocity Time Integral (VTI), and IVC collapsibility—were compared between groups. Data were analyzed using SPSS version 26 with a significance level of $p<0.05$.

Results: Sick neonates had significantly lower E/A ratio ($p=0.03$), indicating diastolic dysfunction, while EF, IVRT, CO, LA/Ao ratio, VTI, and IVC collapsibility showed no significant differences ($p>0.05$). ROC analysis revealed E/A ratio (AUC=0.60, $p=0.03$) as the only significant predictor of hemodynamic instability.

Conclusion: E/A ratio was a significant marker of diastolic dysfunction in sick neonates. POCUS serves as a useful, non-invasive bedside tool for detecting early myocardial dysfunction and guiding targeted management in neonatal intensive care.

Key-words: Neonatal intensive care units (NICUs), Patent ductus arteriosus (PDA), Point-of-care ultrasonography (POCUS), Hemodynamic Parameters

INTRODUCTION

Hemodynamic instability in neonates remains a major cause of morbidity and mortality in neonatal intensive care units (NICUs) worldwide [1]. The transition from fetal to extrauterine circulation necessitates rapid and well-coordinated cardiovascular adjustments, encompassing alterations in pulmonary and systemic vascular resistance, cardiac contractility, and oxygen delivery [2]. Failure of this adaptive process due to conditions such as sepsis, perinatal asphyxia, PDA, persistent pulmonary hypertension of the newborn (PPHN), congenital heart defects, or shock can lead to circulatory compromise and multiorgan dysfunction [3]. Early identification and correction of hemodynamic disturbances are therefore essential to improve neonatal outcomes.

Traditional methods of hemodynamic assessment—such as monitoring heart rate, blood pressure, capillary refill

How to cite this article
Rath J, Das L, Panda DK, Mohapatra A. Comparison of Hemodynamic Parameters Using Point of Care Echocardiography among Sick Neonates vs Healthy Neonates in a Tertiary Care Hospital of Odisha. SSR Inst Int J Life Sci., 2025; 11(5): 8539-8546.

Access this article online
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doi: 10.21276/SSR-IIJLS.2025.11.5.49

time, and urine output—are indirect and may not accurately reflect true cardiac performance or systemic blood flow [4]. These clinical indicators can remain deceptively normal even in the presence of significant myocardial dysfunction, particularly in preterm or critically ill neonates. Hence, there is a growing need for a bedside, non-invasive, and objective technique that can accurately assess cardiovascular function in real time.

POCUS, especially functional echocardiography, has emerged as a valuable tool in neonatal critical care settings [5]. It allows the clinician to directly visualize the heart and assess key hemodynamic parameters such as ejection fraction (EF), cardiac output (CO), E/A ratio, isovolumic relaxation time (IVRT), velocity time integral (VTI), and left atrium to aortic (LA/Ao) ratio [6]. These indices provide insight into both systolic and diastolic functions, preload and afterload, as well as intravascular volume status, thereby offering a more comprehensive picture of neonatal circulation than clinical evaluation alone [7].

Sick neonates often exhibit early diastolic dysfunction, which precedes overt systolic failure. A reduced E/A ratio or prolonged IVRT is commonly observed in sepsis or hypoxia-related myocardial dysfunction, even when ejection fraction remains within normal limits [8]. On the other hand, healthy neonates generally demonstrate normal myocardial relaxation, stable cardiac output, and balanced systemic and pulmonary circulation [9]. Thus, comparing echocardiographic parameters between sick and healthy neonates can help identify early deviations indicative of hemodynamic instability.

Several studies have highlighted the diagnostic and prognostic value of POCUS in neonatal cardiac assessment. El-Khuffash *et al*. [10] reported that diastolic dysfunction, reflected by a lower E/A ratio, was more prevalent in septic neonates and preceded measurable systolic impairment. Singh and Gupta [11] also found that POCUS provides a rapid, reproducible, and sensitive method for detecting myocardial dysfunction in critically ill neonates. Noori *et al.* [12] demonstrated that subtle alterations in diastolic and systolic performance during the transitional period can be identified by bedside echocardiography even when conventional clinical findings appear normal. These findings support the use of POCUS as a reliable, real-time tool for assessing cardiac function in NICU settings.

Beyond diagnosis, echocardiography-guided evaluation aids in clinical decision-making by differentiating the types of shock—hypovolemic, distributive, or cardiogenic—and guiding tailored interventions such as fluid resuscitation, inotrope titration, and ventilatory support [13]. It also enables monitoring of the therapeutic response, preventing both under- and over-resuscitation. Moreover, parameters such as the LA/Ao ratio and IVC collapsibility provide valuable information about fluid responsiveness and venous return, helping to optimize circulatory management [14].

Despite its proven advantages, there is limited comparative research in India evaluating echocardiographic parameters between healthy and sick neonates in tertiary care hospitals. Most available studies have focused on specific conditions such as PDA or sepsis, without including multiple cardiac indices in a single analytic framework [15]. Hence, the present study was undertaken to systematically compare hemodynamic parameters using point-of-care echocardiography among sick and healthy neonates. The study aims to determine which echocardiographic indices—specifically, the E/A ratio, EF, CO, IVRT, VTI, LA/Ao ratio, and IVC collapsibility—most effectively differentiate between hemodynamic stability and instability. Identifying these markers will not only enhance understanding of neonatal cardiovascular physiology but also promote the use of POCUS as a routine bedside tool for early recognition and management of cardiac dysfunction in high-risk neonates [16].

MATERIALS AND METHODS

Research Design- A prospective, case-control study was conducted to compare hemodynamic parameters among neonates using point-of-care echocardiography. A total of 143 neonates were enrolled, comprising 60 sick neonates (cases) and 83 healthy neonates (controls). The study was conducted over 18 months in the Neonatal Intensive Care Unit (NICU) and the Special Newborn Care Unit (SNCU) of PGIMER and Capital Hospital, Bhubaneswar, Odisha.

Study Population and Setting- Sick neonates admitted to NICU or SNCU requiring hemodynamic evaluation were included as cases, while healthy neonates without perinatal complications and with stable hemodynamic

doi: 10.21276/SSR-IIJLS.2025.11.5.49

parameters served as controls. Both preterm and term neonates were included in the study.

Inclusion Criteria- The case group consisted of neonates diagnosed with suspected sepsis, birth asphyxia or hypoxic-ischemic encephalopathy (HIE), prematurity with hemodynamic instability, respiratory distress syndrome (RDS), persistent pulmonary hypertension of the newborn (PPHN), congenital heart defects requiring assessment, or those needing inotropic support. The control group comprised neonates undergoing routine echocardiographic assessment for screening purposes, who were hemodynamically stable and required no respiratory or cardiovascular support.

Exclusion Criteria- Neonates with major congenital anomalies incompatible with life, complex structural heart defects, severe perinatal asphyxia leading to early demise, incomplete data, or lack of parental consent were excluded. Healthy neonates with any infection, abnormal clinical findings, or requiring resuscitation or oxygen support immediately after birth were also excluded.

Statistical Analysis- All collected data were analyzed using SPSS version 26. Descriptive and inferential statistical methods were applied. Categorical variables were expressed as percentages, while continuous variables were presented as median (IQR). A *p*-value of less than 0.05 was considered statistically significant for all analyses.

Ethical approval- Data collection was performed after obtaining approval from the Institutional Ethics Committee and informed written consent from the parents.

RESULTS

A total of 143 neonates were included in the present study, comprising 60 sick neonates (cases) and 83 healthy neonates (controls). The echocardiographic parameters were compared between both groups using POCUS to assess myocardial function, preload, afterload, and overall hemodynamic status.

The median ejection fraction (EF) was comparable between sick and healthy neonates [62 (IQR 4.8) vs. 63 (IQR 6.0); p=0.81], indicating preserved systolic function in both groups. In contrast, the E/A ratio was significantly lower in sick neonates [1.0 (IQR 0.4)] than in healthy neonates [1.1 (IQR 0.5)], with p=0.03, suggesting diastolic dysfunction and impaired ventricular relaxation among the sick cohort. The isovolumic relaxation time (IVRT) [76.5 (11.5) vs. 78 (13); p=0.51] and cardiac output (CO) [160 (19.5) vs. 160 (22); p=0.79] were not significantly different between the groups, confirming that cardiac contractility and output were maintained despite diastolic changes (Fig. 1 & 2).

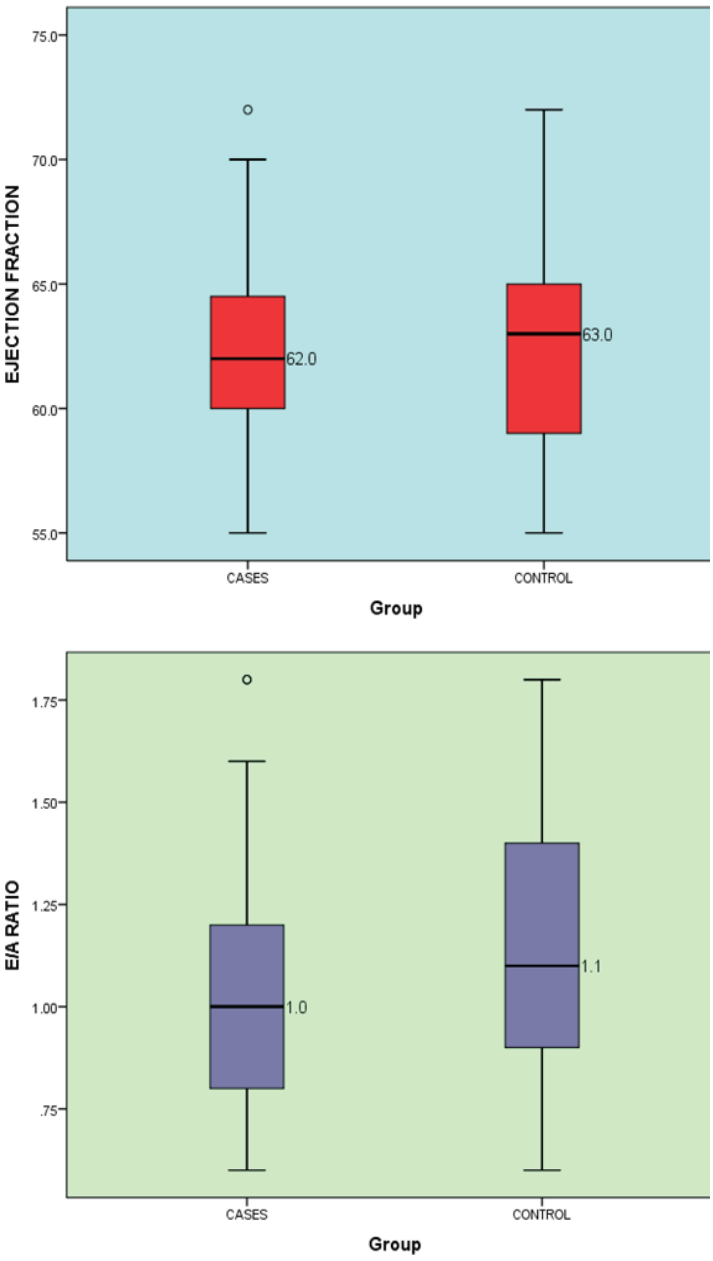

Fig. 1: Echocardiographic parameters showing Ejection Fraction (EF) and E/A ratio among sick and healthy neonates. A lower E/A ratio in sick neonates indicates diastolic dysfunction.

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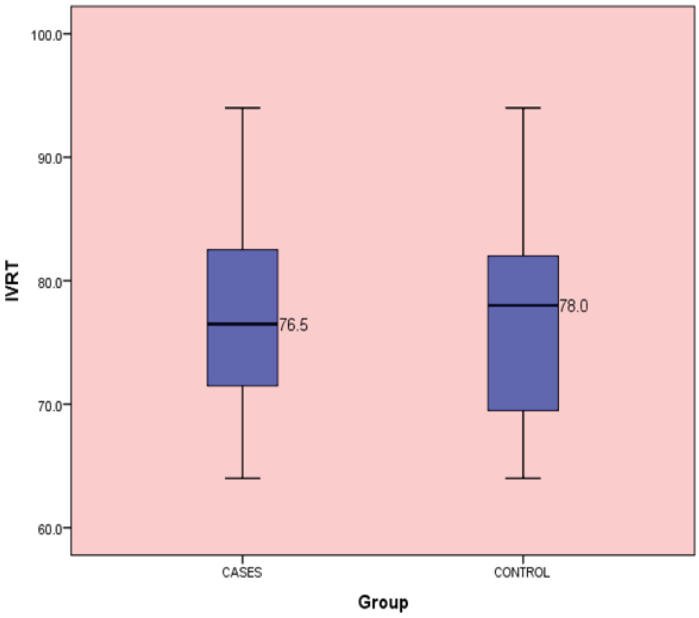


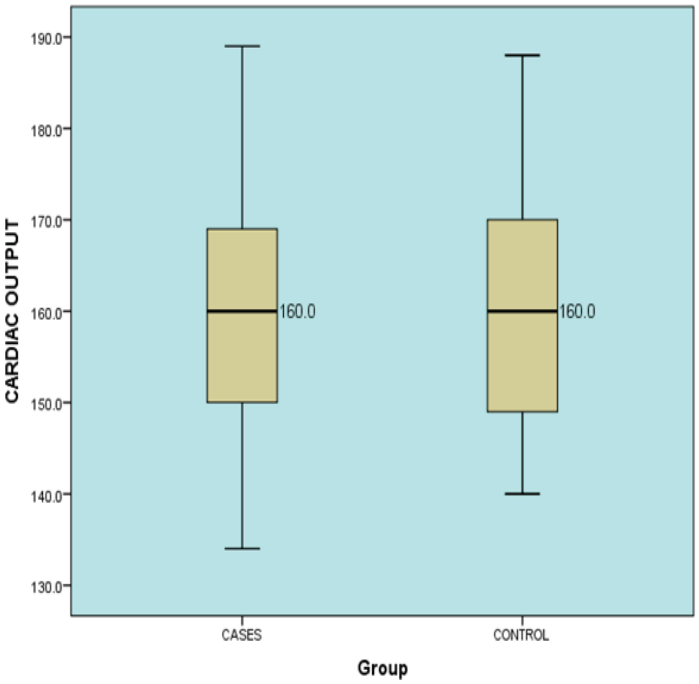


Fig. 2: Echocardiographic parameters showing Isovolumic Relaxation Time (IVRT) and Cardiac Output (CO) comparison between sick and healthy neonates.

Parameters related to volume status and chamber size also showed no significant differences. The left atrium-to-aorta (LA/Ao) ratio was marginally higher in sick neonates [1.4 (0.3)] than in healthy neonates [1.2 (0.4)], but the difference was statistically insignificant (p=0.10). Similarly, Velocity Time Integral (VTI) [19 (3) vs. 18 (1); p=0.64] and Inferior Vena Cava (IVC) collapsibility index [0.75 (0.5) vs. 0.70 (0.5); p=0.65] were comparable between the groups, indicating stable stroke volume and intravascular filling pressures (Fig. 3 & 4).

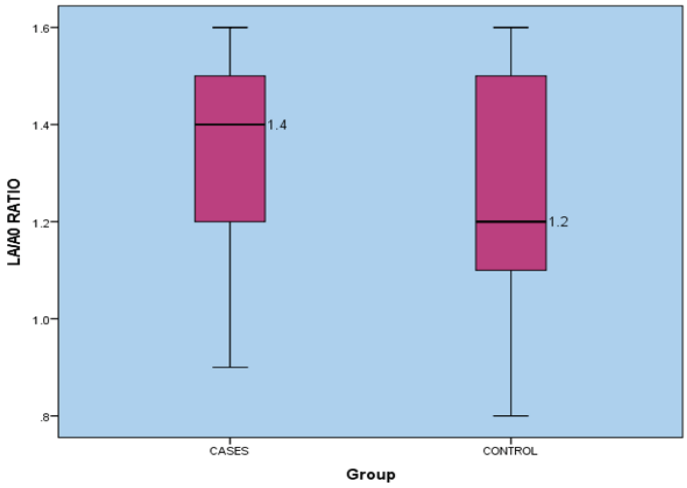
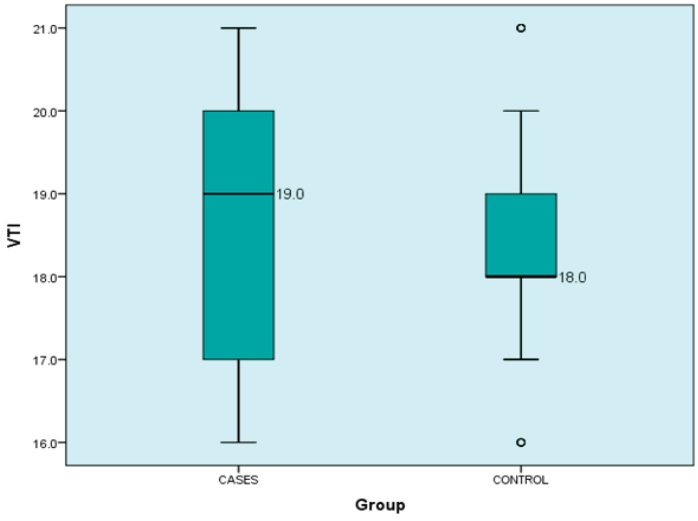


Fig. 3: Echocardiographic assessment of Left Atrium to Aortic (LA/Ao) ratio and Velocity Time Integral (VTI) among sick and healthy neonates.



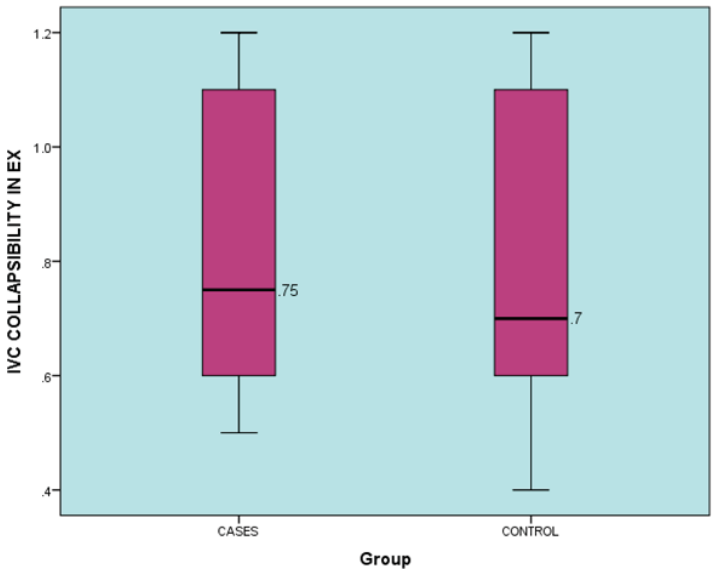


Fig. 4: Comparison of Inferior Vena Cava (IVC) collapsibility index between sick and healthy neonates, reflecting intravascular volume status.

doi: 10.21276/SSR-IIJLS.2025.11.5.49

Flow across cardiac valves was normal in most of both groups, with no significant difference in the proportion of abnormal valvular flow patterns between sick (11.7%) and healthy (18.1%) neonates (p=0.29), confirming the absence of significant valvular pathology contributing to hemodynamic instability (Fig. 5).

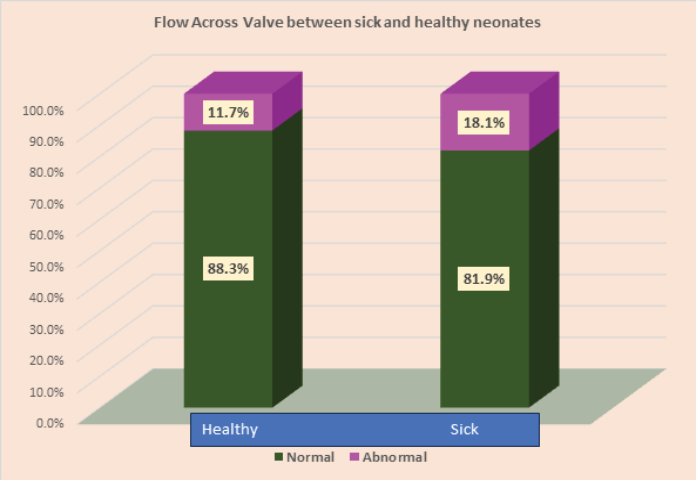


Fig. 5: Distribution of normal and abnormal flow across cardiac valves among sick and healthy neonates.

The detailed comparison of all echocardiographic parameters is shown in Table 1.

Table 1: Comparison of Echocardiographic Parameters among Sick and Healthy Neonates

Parameter	Sick Neonates Median (IQR)	Healthy Neonates Median (IQR)	p-value	Significance
Ejection Fraction (%)	62 (4.8)	63 (6.0)	0.81	Not Significant
E/A Ratio	1.0 (0.4)	1.1 (0.5)	0.03	Significant
IVRT (ms)	76.5 (11.5)	78 (13.0)	0.51	Not Significant
Cardiac Output (ml/min)	160 (19.5)	160 (22.0)	0.79	Not Significant
LA/Ao Ratio	1.4 (0.3)	1.2 (0.4)	0.10	Not Significant
VTI (cm)	19 (3.0)	18 (1.0)	0.64	Not Significant
IVC Collapsibility Index	0.75 (0.5)	0.70 (0.5)	0.65	Not Significant

Receiver Operating Characteristic (ROC) curve analysis was performed to determine the predictive value of echocardiographic parameters for identifying hemodynamic instability. Among all parameters studied, the E/A ratio demonstrated a statistically significant predictive ability (AUC=0.60; p=0.03), indicating its role as an early marker of diastolic dysfunction in sick neonates.

Other indices, including EF, CO, IVRT, LA/Ao ratio, VTI, and IVC collapsibility, did not show statistically significant predictive values (p>0.05), implying that while overall cardiac performance remained stable, subtle diastolic abnormalities were more sensitive indicators of early myocardial compromise (Fig. 6 & 7).

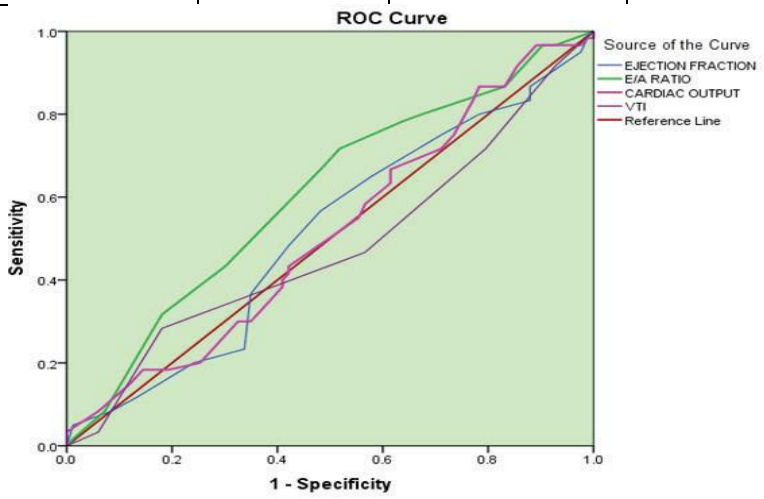


Fig. 6: Receiver Operating Characteristic (ROC) curves showing predictive value of EF, E/A ratio, CO, and VTI for hemodynamic instability.

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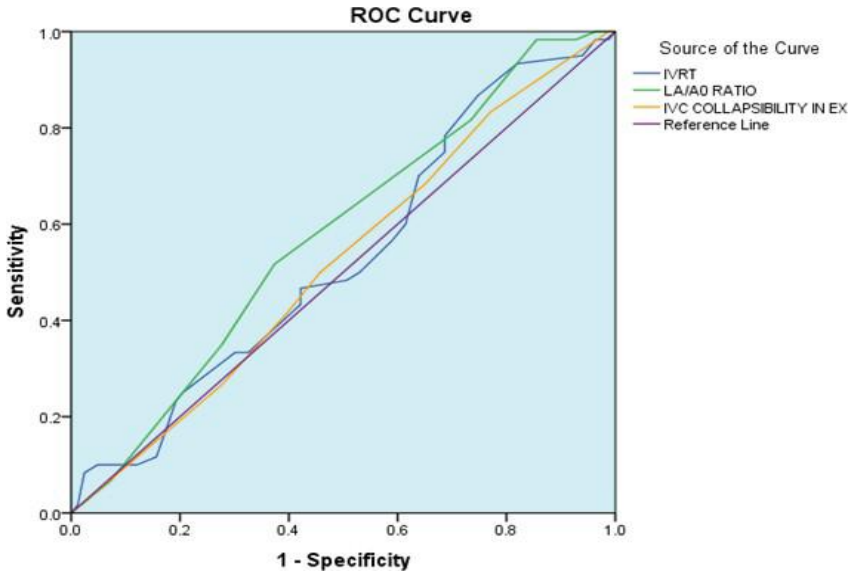

Fig. 7: ROC curves showing predictive value of IVRT, LA/Ao ratio, and IVC collapsibility index for hemodynamic instability.

The summary of ROC findings is presented in Table 2.

Table 2: ROC Analysis of Echocardiographic Parameters for Predicting Hemodynamic Instability

Parameter	AUC (95% CI)	p-value	Interpretation
Ejection Fraction	0.51 (0.41–0.60)	0.81	Not significant
E/A Ratio	0.60 (0.51–0.69)	0.03	Significant predictor
Cardiac Output	0.51 (0.41–0.60)	0.79	Not significant
VTI	0.47 (0.37–0.57)	0.64	Not significant
IVRT	0.53 (0.43–0.62)	0.51	Not significant
LA/Ao Ratio	0.57 (0.48–0.67)	0.10	Not significant
IVC Collapsibility	0.52 (0.42–0.61)	0.65	Not significant

DISCUSSION

Hemodynamic instability in neonates remains one of the major causes of morbidity and mortality in intensive care settings. Early recognition of subclinical cardiac dysfunction is crucial for timely intervention and improved outcomes. The present study aimed to compare echocardiographic parameters between sick and healthy neonates using POCUS and to identify the most sensitive indicators of hemodynamic instability.

In this study, the E/A ratio was significantly lower among sick neonates compared to healthy neonates (p=0.03), suggesting early diastolic dysfunction and impaired myocardial relaxation. Other echocardiographic indices, including Ejection Fraction (EF), Isovolumic Relaxation Time (IVRT), Cardiac Output (CO), Left Atrium to Aortic (LA/Ao) Ratio, Velocity Time Integral (VTI), and Inferior Vena Cava (IVC) collapsibility index showed no statistically significant differences (p>0.05). This indicates that while systolic function and cardiac output were preserved, the diastolic phase of ventricular filling was compromised in sick neonates. ROC analysis further confirmed the E/A ratio as the only significant predictor of hemodynamic instability (AUC=0.60; p=0.03).

These results demonstrate that diastolic dysfunction precedes measurable systolic impairment in critically ill neonates, highlighting the diagnostic value of early diastolic indices. This observation aligns with earlier studies that have shown reduced E/A ratio and prolonged IVRT as sensitive indicators of subclinical

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myocardial dysfunction in neonates with sepsis or hypoxia [4,5,10].

El-Khuffash *et al*. [4] reported that neonates with sepsis or septic shock exhibited significant reductions in E/A ratio and prolonged IVRT while maintaining preserved ejection fraction, suggesting that diastolic abnormalities manifest earlier than systolic dysfunction. Similarly, in the present study, sick neonates demonstrated a lower E/A ratio without significant changes in EF or CO, supporting this physiological pattern. Singh and Gupta [9] also observed that point-of-care echocardiography could reliably detect early myocardial dysfunction, with E/A ratio being one of the most sensitive markers.

Noori *et al*. [2] documented that subtle diastolic changes can occur during neonatal sepsis and hypoxia even when cardiac output remains normal, which corresponds with our findings of preserved systolic indices despite diastolic impairment. Groves *et al*. [12] emphasized that diastolic function is a key determinant of systemic perfusion in critically ill neonates. Their study noted that IVC collapsibility and VTI were less reliable predictors of perfusion compromise—consistent with our observation that these indices were not significantly different between groups ($p>0.05$).

Furthermore, El-Khuffash and McNamara [1] highlighted the need for a paradigm shift toward functional hemodynamic assessment using bedside ultrasound, as traditional clinical parameters like heart rate and blood pressure may remain normal despite cardiac dysfunction. The present findings reinforce this approach, demonstrating the value of POCUS as a non-invasive, real-time tool for evaluating both systolic and diastolic performance in high-risk neonates.

Miller *et al*. [8] also supported the role of functional echocardiography in guiding individualized therapy, emphasizing its utility in differentiating between hypovolemic, distributive, and cardiogenic shock. In our study, the absence of significant valvular pathology ($p=0.29$) indicates that functional myocardial impairment, rather than structural abnormality, was the predominant contributor to hemodynamic instability.

The pathophysiological basis of these findings lies in myocardial immaturity, hypoxia-induced metabolic derangements, and inflammation-associated myocardial edema seen in neonatal sepsis and asphyxia. These processes impair ventricular compliance and prolong relaxation time, leading to a reduced E/A ratio while ejection fraction remains preserved. This sequence underscores the importance of early detection of diastolic abnormalities to prevent progression to overt heart failure or multiorgan dysfunction [5,6,13].

Clinically, the findings suggest that routine POCUS evaluation in NICU and SNCU settings can enable early identification of neonates with subtle diastolic dysfunction. Incorporating diastolic parameters such as E/A ratio into standard hemodynamic assessment protocols may improve the precision of bedside management decisions, including fluid therapy, inotrope use, and ventilatory adjustments.

Overall, the present study demonstrates that E/A ratio serves as an early, sensitive marker of myocardial dysfunction, while conventional parameters like EF, CO, and IVRT alone may underestimate early cardiac impairment in sick neonates. The results advocate for integrating functional echocardiography into neonatal intensive care practices for comprehensive cardiovascular evaluation.

CONCLUSIONS

In conclusion, sick neonates demonstrated significant hemodynamic and perfusion alterations, including higher heart and respiratory rates, prolonged capillary refill time, and lower diastolic blood pressure. Echocardiographic assessment revealed that diastolic dysfunction, reflected by a lower E/A ratio, was the most prominent cardiac abnormality, suggesting early impairment of ventricular relaxation rather than contractility. ROC analysis identified the E/A ratio as a moderate predictor of hemodynamic instability, highlighting its potential utility for early detection of cardiac compromise using point-of-care ultrasound (POCUS). While other echocardiographic parameters, such as VTI and IVC collapsibility, showed limited predictive value, POCUS remains a valuable, non-invasive bedside tool for guiding hemodynamic assessment, early referral, and targeted intervention. Despite its utility, conventional evaluation of vital parameters continues to be essential in NICU and SNCU settings. Larger studies with longitudinal follow-up are warranted to validate echocardiographic parameters as reliable indicators for early identification and management of critical illness in neonates.

doi: 10.21276/SSR-IIJLS.2025.11.5.49

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Data analysis and interpretation– Jyotiprakash Rath
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Manuscript preparation– Jyotiprakash Rath, Deshish Kumar Panda
Critical review– Leena Das, Deshish Kumar Panda
Final approval– Jyotiprakash Rath, Leena Das, Deshish Kumar Panda, Ashaprakash Mohapatra

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