

Right and Left Ventricular Outputs and Tricuspid Annular Plane Systolic Excursion as Key Functional Echocardiographic Markers Distinguishing Septic from Non-Septic Neonates

Ferdous Jahan^{1*}, Faria Yasmin², Mohammad Rasel³, Atikur Rahman⁴, Jinat Farjana⁵, M A Mannan⁶

ARTICLE INFO

Received: 25 June 2026
Accepted: 1 July 2026
Published Online: 3 July 2026

DOI:

Volume: 9, Number: 4, Page: 298-302

e-ISSN: 2789-5912
ISSN: 2617-0817

*Corresponding author



ABSTRACT

Background: Neonatal sepsis remains a major cause of morbidity and mortality worldwide, yet its hemodynamic consequences are often under recognized. Clinical signs alone are unreliable for assessing cardiovascular compromise. Functional echocardiography provides real-time hemodynamic data, but which specific markers best distinguish septic from non-septic neonates remains to be fully characterized. **Objective:** To compare biventricular outputs, systolic functional indices, and tricuspid annular excursion between septic and non-septic neonates and identify key echocardiographic markers distinguishing the two groups. **Methods & Materials:** This cross-sectional comparative study was conducted in the Department of Neonatology, Bangladesh Medical University, from March 2022 to September 2023. A total of 50 neonates (25 with suspected sepsis and 25 healthy controls matched for gestational age) were enrolled. Functional echocardiography was performed within 12 hours of sepsis onset. Quantitative data were compared using independent t-tests, and categorical data using chi-square tests. **Results:** Septic neonates demonstrated significantly higher mean RVO (277.4 ± 74.2 vs. 209 ± 70 ml/kg/min, $p=0.002$) and LVO (339.5 ± 43.2 vs. 276 ± 74.9 ml/kg/min, $p=0.001$) compared to non-septic controls. Mean TAPSE was significantly lower in the septic group (0.49 ± 0.13 vs. 0.74 ± 0.34 cm, $p=0.001$). No significant differences were observed in EF (72 ± 9.4 vs. $75.4 \pm 1.47\%$, $p=0.080$) or FS (37.1 ± 3.1 vs. $37.5 \pm 1.8\%$, $p=0.900$) between the two groups. **Conclusion:** Elevated right and left ventricular outputs and reduced TAPSE are key functional echocardiographic markers that distinguish septic from non-septic neonates. These parameters may aid early hemodynamic assessment and guide targeted management in neonatal sepsis.

Keywords: Cardiac output, Echocardiography, Hemodynamics, Neonatal sepsis, right ventricular dysfunction.

1. MD (Neonatology), Shaheed Suhrawardy Medical College, Dhaka, Bangladesh (ORCID: 0009-0003-7560-8934)
2. Assistant Professor (Neonatology), 250 Bedded Kishoreganj Sadar Hospital, Kishoreganj (Attachment: DNCC dedicated Covid 19 Hospital Mohakhali, Dhaka), Bangladesh
3. Assistant Professor, Department of Pediatric, Monno Medical College, Manikganj, Bangladesh
4. Assistant Registrar, Department of Cardiology, National Institute of Cardiovascular Diseases, Dhaka, Bangladesh
5. Classified Specialist in Medicine (Cardiologist), CMH, Jessore, Bangladesh
6. Professor & Chairman, Department of Neonatology, Bangladesh Medical University, Dhaka, Bangladesh

INTRODUCTION

Neonatal sepsis remains a leading cause of morbidity and mortality worldwide, accounting for nearly 3 million neonatal deaths annually, with an estimated neonatal mortality rate of 23.9 per 1000 live births globally due to sepsis [1]. In Bangladesh, sepsis contributes to approximately 19.9% of all neonatal deaths, making it one of the three primary causes of newborn mortality alongside prematurity and birth asphyxia [2]. The first 28 days of life represent the most vulnerable period for a child's survival, with the majority of sepsis-related deaths occurring during the first week of life [1,2]. The pathophysiology of neonatal sepsis is complex, involving a dysregulated host response to infection that leads to life-threatening multi-organ dysfunction [3]. Cardiovascular complications, including myocyte damage and altered cardiac blood flow induced by inflammatory mediators, are frequent consequences of neonatal sepsis [4]. Clinical signs such as poor perfusion, hypotension, tachycardia, and bradycardia have been demonstrated to be misleading in their accuracy for assessing

true hemodynamic status, often providing limited insight into the adequacy of systemic blood flow and organ perfusion [5]. Given these limitations, there has been a significant increase in the use of bedside echocardiography in neonatal intensive care units [6]. Functional echocardiography, also known as neonatologist-performed echocardiography or targeted neonatal echocardiography, has emerged as a key tool for hemodynamic assessment in the intensive care setting [7]. This non-invasive, portable technology provides real-time physiological information that, when integrated with clinical assessment, can guide targeted therapeutic interventions [7,8]. Several functional echocardiographic markers have been investigated in neonatal sepsis. Left ventricular output (LVO) and right ventricular output (RVO) reflect systemic blood flow and venous return, respectively, with normal values ranging from 150 to 300 mL/kg/min [9]. Ejection fraction (EF) and fractional shortening (FS) are traditional measures of left ventricular systolic function, with normal neonatal EF values ranging from 56% to 78% [10].

However, these parameters are influenced by preload and afterload conditions, limiting their sensitivity in isolation [10]. The tricuspid annular plane systolic excursion (TAPSE) has emerged as a reliable, reproducible measure of right ventricular systolic function, particularly valuable given the complex geometry of the right ventricle [11]. Values lower than 4 mm in newborns have been associated with increased need for extracorporeal membrane oxygenation and death [9]. Recent studies have demonstrated that TAPSE, along with other echocardiographic markers, shows significant alterations in septic neonates compared to healthy controls [12,13]. Despite growing evidence supporting the utility of functional echocardiography in neonatal sepsis, data from low- and middle-income countries remain limited. This study aimed to compare key functional echocardiographic markers between septic and non-septic neonates to identify parameters that reliably distinguish these populations and may guide early hemodynamic management.

METHODS & MATERIALS

This cross-sectional comparative study was conducted in the Department of Neonatology, Bangladesh Medical University, Dhaka, Bangladesh, from March 2022 to September 2023. Neonates (term and preterm >34 weeks) with suspected early or late-onset sepsis were enrolled as cases, while healthy neonates from the postnatal ward matched for gestational age were enrolled as controls.

Inclusion criteria: Neonates with the presence of at least one clinical feature of sepsis (respiratory distress, lethargy, poor feeding, temperature instability, tachycardia, or seizure) along with two or more risk factors for sepsis and positive septic screening were included in the septic group.

Exclusion criteria: Neonates with major congenital anomalies (including congenital diaphragmatic hernia and tracheoesophageal fistula), perinatal

asphyxia, or antenatally or postnatally diagnosed congenital heart disease were excluded from the study. In neonates with multiple episodes of late-onset sepsis, only the first episode was included.

Study procedure: Written informed consent was obtained from parents. Functional echocardiography was performed by an experienced neonatologist using a My Lab Gamma ultrasound machine with a neonatal probe (4-8 MHz transducer) within 12 hours of sepsis onset. Right ventricular output, left ventricular output, ejection fraction, fractional shortening, and tricuspid annular plane systolic excursion were measured following standard protocols.

Data analysis: Data were analyzed using SPSS version 25. Quantitative variables were expressed as mean ± standard deviation and compared using an independent t-test. Categorical variables were presented as frequency and

percentage and compared using the chi-square test. A p-value <0.05 was considered statistically significant.

RESULT

A total of 50 neonates were enrolled, comprising 25 septic neonates and 25 non-septic healthy controls matched for gestational age. Baseline maternal characteristics showed no significant differences between the two groups. Most mothers in both groups had four or more antenatal visits (64% in the septic group vs. 72% in the non-septic group). Lower uterine cesarean section was the predominant mode of delivery in both groups (80% vs. 72%). Maternal risk factors, including premature rupture of membranes (28% vs. 20%), fever (16% vs. 8%), urinary tract infection (12% vs. 4%), and oligohydramnios (40% vs. 24%), were comparable between septic and non-septic groups. Maternal antibiotic use was also similar (32% vs. 16%, p=0.85) (Table I).

Table I

Baseline maternal characteristics of the study population.

Parameter	Septic group	Non-septic group	p-value
	(n=25) n(%)	(n=25) n(%)	
Antenatal visit ≥4	16 (64)	18 (72)	0.540
Multiple gestation	0 (0)	1 (4)	0.312
LUCS mode of delivery	20 (80)	18 (72)	0.508
PROM (>18 hours)	7 (28)	5 (20)	0.508
Maternal fever	4 (16)	2 (8)	0.380
Urinary tract infection	3 (12)	1 (4)	0.308
Oligohydramnios	10 (40)	6 (24)	0.225
Maternal antibiotic use	8 (32)	4 (16)	0.850

Statistical test: Chi-square test.

Neonatal baseline characteristics were well-matched between groups. Mean gestational age was 35.64±2.018 weeks in the septic group and 35.76±0.970 weeks in the non-septic group (p=0.790). Mean birth

weight was 2310±26.5 grams in septic neonates and 2399±113.3 grams in non-septic neonates (p=0.204). Male predominance was observed in both groups (64% vs. 56%). The majority of neonates

in both groups were appropriate for gestational age (96% vs. 100%) (Table II).

Table II

Baseline neonatal characteristics of the study population.

Parameter	Septic group	Non-septic group	p-value
Gestational age (weeks), Mean ± SD	35.64 ± 2.018	35.76 ± 0.970	0.79
Birth weight (grams), Mean ± SD	2310 ± 26.5	2399 ± 113.3	0.204
Male sex, n(%)	16 (64)	14 (56)	0.564
AGA at birth, n(%)	24 (96)	25 (100)	0.312

Statistical test: Independent t-test for quantitative variables; Chi-square test for categorical variables

Among septic neonates, the most common clinical presentation was respiratory distress (96%), followed by lethargy

(76%), tachycardia (52%), and seizure (36%). Hypothermia and bradycardia were

less frequently observed (8% and 4%, respectively) (Table III).

Table III
Clinical characteristics of septic neonates (n=25).

Clinical feature	n	%
Respiratory distress	24	96
Lethargy	19	76
Tachycardia	13	52
Seizure	9	36
Hypothermia	2	8
Bradycardia	1	4

Comparison of functional echocardiographic parameters between septic and non-septic neonates revealed statistically significant differences for right ventricular output, left ventricular output, and tricuspid annular plane systolic excursion. Septic neonates demonstrated higher mean right ventricular output (277.4±74.2 vs. 209±70 ml/kg/min, p=0.002) and left ventricular output (339.5±43.2 vs. 276±74.9 ml/kg/min, p=0.001) compared to controls. Mean tricuspid annular plane systolic excursion was significantly lower in the septic group (0.49±0.13 vs. 0.74±0.34 cm, p=0.001). Ejection fraction and fractional shortening showed no significant differences between groups (p=0.080 and p=0.900, respectively) *Table IV*.

Table IV
Comparison of functional echocardiographic parameters between septic and non-septic neonates.

Parameter	Septic group	Non-septic group	p-value
	Mean ± SD		
Right ventricular output (ml/kg/min)	277.4 ± 74.2	209 ± 70	0.002
Left ventricular output (ml/kg/min)	339.5 ± 43.2	276 ± 74.9	0.001
Ejection fraction (%)	72 ± 9.4	75.4 ± 1.47	0.080
Fractional shortening (%)	37.1 ± 3.1	37.5 ± 1.8	0.900
TAPSE (cm)	0.49 ± 0.13	0.74 ± 0.34	0.001

Statistical test: Independent t-test.

In preterm neonates (34 to <37 weeks), right ventricular output remained higher in septic cases (263.1 ± 73.2 and 208.1 ± 79.8; p=0.039) with elevated left ventricular output (337.4 ± 44.1 and 273.8 ± 74.3; p=0.004). TAPSE was significantly lower (0.49 ± 0.136 and 0.76 ± 0.39; p<0.001), while ejection fraction and fractional shortening showed no significant difference (*Table V*).

Table V
Comparison of functional echocardiographic parameters in preterm neonates (34 to <37 weeks).

Parameter	Septic group	Non-septic group	p-value
	Mean ± SD		
Right ventricular output (ml/kg/min)	263.1 ± 73.2	208.1 ± 79.8	0.039
Left ventricular output (ml/kg/min)	337.4 ± 44.1	273.8 ± 74.3	0.004
Ejection fraction (%)	74.3 ± 7.1	75.7 ± 1.5	0.45
Fractional shortening (%)	37.8 ± 3.0	37.4 ± 1.7	0.59
TAPSE (cm)	0.49 ± 0.136	0.76 ± 0.39	<0.001

Statistical test: Independent t-test.

Table VI shows that right ventricular output (312.8 ± 68.9 and 211.4 ± 41.9; p=0.006), left ventricular output (359.3 ± 13.36 and 281.4 ± 82.4; p=0.030), and TAPSE (0.51 ± 0.13 and 0.71 ± 0.15; p=0.025) differed significantly between groups, whereas ejection fraction (66.0 ± 12.2 and 74.5 ± 1.73; p=0.119) and fractional shortening (34.8 ± 4.7 and 36.5 ± 1.9; p=0.443) remained statistically comparable.

Table IV
Comparison of functional echocardiographic parameters in term neonates (37 to 40 weeks).

Parameter	Septic group	Non-septic group	p-value
	(n=7)	(n=7)	
	Mean ± SD		
Right ventricular output (ml/kg/min)	312.8 ± 68.9	211.4 ± 41.9	0.006
Left ventricular output (ml/kg/min)	359.3 ± 13.36	281.4 ± 82.4	0.030
Ejection fraction (%)	66.0 ± 12.2	74.5 ± 1.73	0.119
Fractional shortening (%)	34.8 ± 4.7	36.5 ± 1.9	0.443
TAPSE (cm)	0.51 ± 0.13	0.71 ± 0.15	0.025

Statistical test: Independent t-test.

DISCUSSION

This cross-sectional comparative study of 50 neonates demonstrated that right ventricular output, left ventricular output, and tricuspid annular plane systolic excursion are key functional echocardiographic markers that significantly distinguish septic from non-septic neonates. In contrast, ejection fraction and fractional shortening showed no significant differences between the two groups. These findings underscore the value of functional echocardiography in detecting sepsis-related hemodynamic alterations that remain occult to clinical examination alone [1,5]. The significantly elevated right and left ventricular outputs observed in septic neonates reflect the hyperdynamic circulatory response characteristic of sepsis [3,14]. The mean left ventricular output in the septic group (339.5±43.2 ml/kg/min) exceeded the established normal range of 150-300 ml/kg/min reported in healthy newborns [9], indicating a state of high cardiac output with reduced systemic vascular resistance. Similar findings have been reported in neonatal sepsis, where increased cardiac output represents a compensatory mechanism to maintain oxygen delivery despite peripheral vasodilation and relative hypovolemia [15,16]. A prospective cohort study documented that late-onset neonatal sepsis significantly affects cardiac output, and a decrease of more than 50% in right or left ventricular output from initial measurement is associated with mortality [14]. The finding of significantly reduced tricuspid annular plane systolic excursion in septic neonates (0.49±0.13 cm vs. 0.74±0.34 cm, p=0.001) provides evidence of right ventricular systolic dysfunction in neonatal sepsis [17]. The right ventricle is particularly susceptible to sepsis-induced dysfunction due to its thinner wall, greater compliance, and higher sensitivity to afterload changes compared to the left ventricle [11,18]. Several studies have established that tricuspid annular plane systolic excursion is a reproducible and load-independent measure of right ventricular longitudinal function, with normal neonatal values ranging from 7 to 11 mm in term infants and 4 to 6 mm in preterm very low birth weight infants [11,19]. Values below 4 mm have been associated with increased need for extracorporeal membrane oxygenation and death [19]. The present study adds to this evidence by demonstrating that even moderate reductions in tricuspid annular plane systolic excursion can identify septic neonates before overt clinical deterioration [12,20]. Notably, ejection fraction and fractional shortening did not differ significantly between septic and non-septic neonates. This observation aligns with previous work demonstrating that

traditional left ventricular systolic function indices often remain normal in early sepsis due to their dependence on loading conditions [10,21]. Ejection fraction and fractional shortening are preload-dependent and afterload-sensitive measures that may be preserved or even supranormal when systemic vascular resistance is reduced, as occurs in distributive shock from sepsis [16,22]. This finding reinforces the limitation of relying solely on conventional systolic function parameters for hemodynamic assessment in septic neonates and supports the inclusion of tricuspid annular plane systolic excursion and cardiac output measurements in routine functional echocardiography protocols [7,23]. Subgroup analyses by gestational age revealed consistent patterns in both preterm (34 to <37 weeks) and term (37 to 40 weeks) neonates. Preterm septic neonates exhibited significantly higher right and left ventricular outputs and lower tricuspid annular plane systolic excursion compared to their non-septic counterparts. Similar trends were observed in term neonates. These findings are clinically relevant given that preterm infants have a seven-fold higher incidence of sepsis compared to term infants and are more vulnerable to its cardiovascular consequences [24,25]. The consistency of findings across gestational age groups suggests that the hemodynamic response to sepsis follows a similar pattern regardless of maturity, though absolute values differ. The clinical implications of this study are substantial. Functional echocardiography provides real-time, non-invasive hemodynamic data that can guide targeted therapy, including fluid resuscitation, inotrope selection, and vasopressor support [6,7]. Given that clinical parameters such as capillary refill time, blood pressure, and heart rate are unreliable indicators of true hemodynamic status in neonates [5,23], incorporating right ventricular output, left ventricular output, and tricuspid annular plane systolic excursion into routine sepsis assessment may improve early recognition of cardiovascular compromise and facilitate goal-directed management.

LIMITATIONS

This study has a modest sample size and a single-center design, limiting generalizability. The cross-sectional nature precludes assessment of temporal changes in echocardiographic parameters following sepsis resolution. Sepsis severity and etiological organisms were not stratified.

CONCLUSION

Functional echocardiographic markers, including right ventricular output, left ventricular output, and tricuspid annular plane systolic excursion, significantly distinguish septic from non-septic neonates.

Elevated cardiac outputs and reduced TAPSE indicate a hyperdynamic circulation with right ventricular systolic dysfunction. These parameters may serve as reliable adjuncts to clinical assessment, guiding early hemodynamic management in neonatal sepsis.

RECOMMENDATION

Future multicenter longitudinal studies with larger sample sizes should validate these findings. Serial echocardiographic assessments following sepsis resolution and correlation with clinical outcomes, including mortality and need for inotropic support, are recommended.

REFERENCES

1. Wynn, James L., et al. "Time for a neonatal-specific consensus definition for sepsis." *Pediatric Critical Care Medicine* 15.6 (2014): 523-528.
2. Billah, Sk Masum, et al. "Quality of care during childbirth at public health facilities in Bangladesh: a cross-sectional study using WHO/UNICEF 'Every Mother Every Newborn (EMEN)' standards." *BMJ Open Quality* 8.3 (2019): e000596.
3. Fleischmann, Carolin, et al. "Global incidence and mortality of neonatal sepsis: a systematic review and meta-analysis." *Archives of disease in childhood* 106.8 (2021): 745-752.
4. ABTAHI, SAEED, et al. "COMPARISON OF SERUM VITAMIN A LEVELS BETWEEN NEONATES WITH CONGENITAL HEART DISEASE AND CONTROLS." *Asian J Pharm Clin Res* 11.10 (2018): 130-132.
5. Simonsen, Kari A., et al. "Early-onset neonatal sepsis." *Clinical microbiology reviews* 27.1 (2014): 21-47.
6. Singh, Anchala. "Targeted Neonatal Echocardiography." *Journal of Neonatology* 30.4 (2016): 6-15.
7. More, Kiran, Roopali Soni, and Samir Gupta. "The role of bedside functional echocardiography in the assessment and management of pulmonary hypertension." *Seminars in Fetal and Neonatal Medicine*. Vol. 27. No. 4. WB Saunders, 2022.
8. de Waal, Koert, et al. "The association between patterns of early respiratory disease and diastolic dysfunction in preterm infants." *Journal of Perinatology* 43.10 (2023): 1268-1273.
9. Ashrafi, Amir H., Gabriel Altit, and Patrick J. McNamara. "Echocardiographic Assessment of the Transitional Circulation." *Echocardiography in Pediatric and Congenital Heart Disease: From Fetus to Adult* (2021): 964-991.
10. Tissot, Cécile, Yogen Singh, and Nicole Sekarski. "Echocardiographic evaluation of ventricular function—for the neonatologist and pediatric intensivist." *Frontiers in pediatrics* 6 (2018): 79.
11. Koestenberger, Martin, et al. "Transthoracic echocardiography in the evaluation of pediatric pulmonary hypertension and ventricular dysfunction." *Pulmonary circulation* 6.1 (2016): 15-29.

12. Alzahrani, Ali K. "Cardiac function affection in infants with neonatal sepsis." *J Clin Trials* 7.1 (2017): 2167-0870.
13. Shokr, Ahmed Abd-Elaziz Salem, et al. "Echocardiography-directed management of hemodynamically unstable neonates in tertiary care hospitals." *Egyptian Pediatric Association Gazette* 71.1 (2023): 10.
14. Deshpande, Sujata, et al. "Cardiac Output in Late Onset Neonatal Sepsis." *Journal of Clinical & Diagnostic Research* 11.11 (2017).
15. Ranjit, Suchitra, et al. "Hemodynamic support for paediatric septic shock: a global perspective." *The Lancet Child & Adolescent Health* 7.8 (2023): 588-598.
16. Vincent, Jean Louis. "Update on surgical sepsis syndrome." *Journal of British Surgery* 104.2 (2017): e34-e40.
17. Breatnach, Colm R., et al. "Novel echocardiography methods in the functional assessment of the newborn heart." *Neonatology* 110.4 (2016): 248-260.
18. Evans, Nicholas J. "Functional Echocardiography in." *Hemodynamics and Cardiology: Neonatology questions and controversies* (2008): 83.
19. Jain, Amish. *Comprehensive Echocardiographic Evaluation of Cardiac Function and Pulmonary Hemodynamics in the Newly Born during Health and Disease*. University of Toronto (Canada), 2017.
20. Sehgal, Arvind, et al. "Hemodynamic consequences of respiratory interventions in preterm infants." *Journal of Perinatology* 42.9 (2022): 1153-1160.
21. Patel, Meghna D., et al. "Cardiac dysfunction identified by strain echocardiography is associated with illness severity in pediatric sepsis." *Pediatric Critical Care Medicine* 21.4 (2020): e192-e199.
22. Weiss, Scott L., et al. "Identification of pediatric sepsis for epidemiologic surveillance using electronic clinical data." *Pediatric Critical Care Medicine* 21.2 (2020): 113-121.
23. de Waal, Koert, and Martin Kluckow. "Prolonged rupture of membranes and pulmonary hypoplasia in very preterm infants: pathophysiology and guided treatment." *The Journal of pediatrics* 166.5 (2015): 1113-1120.
24. Gomella, Tricia Lacy, and M. Douglas Cunningham. *Gomella's neonatology*. McGraw Hill Professional, 2020.
25. Dey, Sanjoy Kumar, et al. "Is Superbug imminent? Findings of a retrospective study in Bangladesh." *Journal of Clinical Neonatology* 9.1 (2020): 38-45.