Case Series

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Paediatrics Section

Role of Norepinephrine and Vasopressin in Persistent Pulmonary Hypertension of the Newborn with Shock: A Case Series from a Tertiary Care Centre in Northern India

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ABSTRACT

Persistent Pulmonary Hypertension of the Newborn (PPHN) complicated by shock presents significant therapeutic challenges, particularly in resource-limited settings without access to inhaled Nitric Oxide (iNO) and Extracorporeal Membrane Oxygenation (ECMO). Conventional inotropic agents may worsen pulmonary pressures, making their use potentially detrimental. Norepinephrine and vasopressin, with their selective vasoconstrictive effects, may simultaneously improve systemic perfusion and pulmonary haemodynamics. This case series included five term and late-preterm neonates admitted to a tertiary Neonatal Intensive Care Unit (NICU) in North India between December 2023 and January 2025 with echocardiographically confirmed PPHN and systemic hypotension despite preserved cardiac function. All infants received intravenous sildenafil. Norepinephrine was initiated at 0.2 µg/kg/min and escalated up to 0.5 µg/kg/min as the first-line vasopressor. In cases with inadequate response, vasopressin was added, starting at 0.1 mU/kg/min and increased up to 0.2 mU/kg/min. All neonates developed hypotensive shock within the first 20–28 hours of life. Three infants showed clinical improvement in perfusion and oxygenation following norepinephrine alone while two required adjunctive vasopressin for persistent hypotension, with both demonstrating rapid stabilisation marked by improved mean arterial pressure, lactate clearance, and oxygenation indices. This dual-agent vasopressor strategy appears to be both feasible and beneficial in improving outcomes in such critical cases. However, larger prospective studies are warranted to validate these results and assess long-term safety and efficacy.

Keywords: Neonatal shock, Pulmonary circulation, Vasoconstrictor agents, Neonatal intensive care unit

INTRODUCTION

PPHN results from failure of normal circulatory transition at birth, leading to sustained elevation of pulmonary vascular resistance (PVR), reduced pulmonary blood flow, and extrapulmonary right-to-left shunting through the foramen ovale and ductus arteriosus, causing hypoxemic respiratory failure [1]. The incidence is approximately 1.9 per 1000 live births, with mortality ranging from 4–33% [2]. PPHN commonly complicates Meconium Aspiration Syndrome (MAS), sepsis, pulmonary maladaptation, and lung hypoplasia [3,4]. Persistent elevation of PVR with hypoxemia may lead to myocardial dysfunction, metabolic acidosis, and systemic hypotension [3,5]. Management aims to optimise oxygenation, reduce PVR, and maintain systemic perfusion. Standard therapies include lung-protective ventilation, sedation, pulmonary vasodilators including iNO, and ECMO in refractory cases [2]. In resource-limited settings, phosphodiesterase inhibitors such as intravenous sildenafil and vasoactive agents are frequently used alternatives [6,7]. Shock management in PPHN is complex, as dopamine and epinephrine may increase PVR due to non selective vasoconstriction [8]. Norepinephrine increases systemic vascular resistance with potentially less vasoconstrictive effect on pulmonary circulation [8]. Vasopressin, via V1 receptor activation, provides systemic vasoconstriction independent of adrenergic pathways and may improve pulmonary perfusion [5,8,9]. However, evidence regarding sequential or combined use of norepinephrine and vasopressin in neonates with PPHN and preserved ventricular function remains limited. This case series describes five neonates with PPHN and hypotensive shock managed with targeted use of norepinephrine and vasopressin.

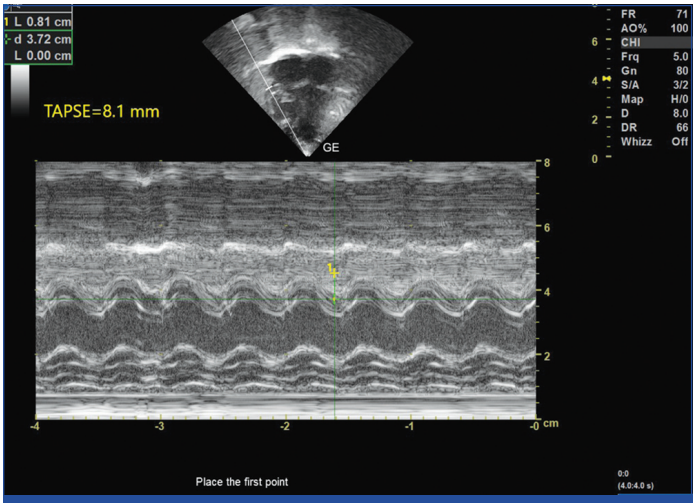
CASE SERIES

This retrospective series included five neonates with echocardiographically confirmed PPHN and haemodynamic instability. PPHN was defined as Pulmonary Artery Systolic Pressure (PASP) >35 mmHg calculated using the simplified Bernoulli equation (PASP = $4V^2$ + 5 mmHg) from Tricuspid Regurgitation (TR) velocity [10]. Additional parameters included Pulmonary Artery Acceleration Time (PAAT), PAAT: Right Ventricular Ejection Time (RVET) ratio, Tricuspid Annular Plane Systolic Excursion (TAPSE), RV output, fractional shortening, and LV output [11,12]. Shock was defined as hypotension for gestational age with prolonged capillary refill (>3 seconds), weak pulses, oliguria, and metabolic acidosis [13,14]. All infants received respiratory support and intravenous sildenafil (0.4 mg/kg loading; 1.6 mg/kg/day infusion) [6,7]. Norepinephrine and vasopressin were used for persistent hypotension [8].

Case 1

A 36-week male neonate (2.1 kg) was admitted at six hours of life with severe respiratory distress and systemic hypoperfusion. There was no significant antenatal history. On physical examination, the baby was lethargic with tachypnoea (RR 72/min), tachycardia (HR 168/min), pre-ductal SpO_2 78%, and had hypotension for gestational age (blood pressure 38/22 mmHg; mean arterial pressure 27 mmHg). Capillary refill time was four seconds, pulses were weak, and extremities were cold, suggestive of decompensated shock. Arterial blood gas analysis showed pH 7.21, PaO_2 32 mmHg, $PaCO_2$ 48 mmHg, HCO_3 18 mEq/L, and base deficit -8, consistent with hypoxemic respiratory failure with metabolic acidosis. Laboratory evaluation showed haemoglobin 14.5 g/dL, Total Leukocyte Count

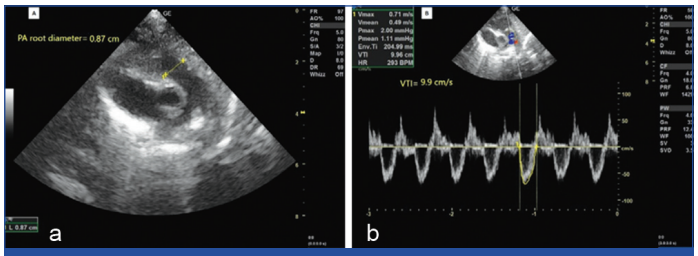
(TLC) was 18 × 10³/µL, platelet count was 199 × 10³/µL, Absolute Neutrophil Count (ANC) was 2.09 × 10³/µL, C-Reactive Protein (CRP) was 20.2 mg/L, and micro-Erythrocyte Sedimentation Rate (micro-ESR) was 11 mm in the first hour. Empirical intravenous piperacillin–tazobactam and amikacin were initiated. Blood culture subsequently grew *Klebsiella pneumoniae*, and antibiotics were escalated to meropenem according to sensitivity profile. Antibiotic therapy was continued for 14 days, with serial monitoring of CRP showing declining trend and clinical improvement. Functional echocardiography demonstrated severe PPHN with PASP of 75 mmHg, right-to-left ductal shunting, and preserved ventricular function (LVEF 65%). TAPSE was used to assess right ventricular systolic function, with value ≥8 mm considered normal [Table/Fig-1]. A diagnosis of PPHN secondary to early-onset sepsis with hypotensive shock was made. The neonate required invasive ventilation and intravenous sildenafil infusion. After fluid resuscitation, norepinephrine was started at 0.2 µg/kg/min which was gradually increased to 0.5 µg/kg/min [8]. Due to persistent hypotension with preserved cardiac function, vasopressin (0.1 mU/kg/min) [5] was added. Haemodynamic improvement was observed within 12 hours, with blood pressure stabilising to 58/34 mmHg (mean arterial pressure 42 mmHg) and improvement in pre-ductal SpO_2 to 94%. Repeat echocardiography after 48 hours showed a reduction in PASP to 45 mmHg with bidirectional ductal shunting. Vasopressin was given for 26 hours and tapered by 56 hours of life. Norepinephrine was weaned over the next 24 hours. The neonate was transitioned from invasive ventilation to conventional support on day 5 and extubated successfully on day 7. Neonate was followed-up clinically and haemodynamically until discharge from the NICU.



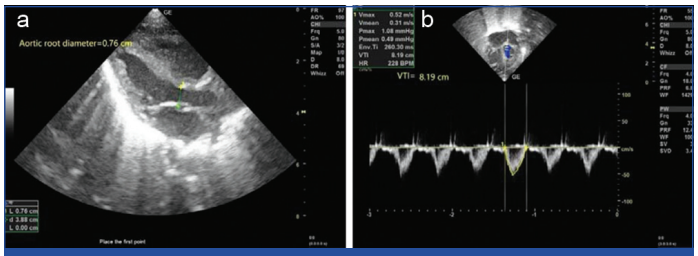
[Table/Fig-1]: M-mode measurement of Tricuspid Annular Plane Systolic Excursion (TAPSE) from the apical four-chamber view. TAPSE was used to assess right ventricular systolic function, with values ≥8 mm considered normal, Case 1.

Case 2

A term male neonate (39 weeks, 2.6 kg) presented soon after birth with excessive salivation, respiratory distress, and inability to pass an orogastric tube, suggestive of Tracheoesophageal Fistula (TEF). On examination, the neonate had tachypnoea (RR 68/min), tachycardia (HR 160/min), SpO_2 82%, prolonged capillary refill (4 seconds), feeble pulses, and cool extremities indicating hypotensive shock. Respiratory examination revealed reduced bilateral air entry; cardiovascular and abdominal examinations were otherwise normal. Arterial blood gas analysis showed pH 7.25, PaO_2 48 mmHg, $PaCO_2$ 45 mmHg, and HCO_3 19 mEq/L. Laboratory parameters included Hb 17 g/dL, TLC 19×10³/µL, platelets 204×10³/µL, ANC 1.89×10³/µL, CRP 1.5 mg/L, and micro-ESR 5 mm. In view of surgical condition (TEF) and risk of perinatal infection, empirical ampicillin and gentamicin were initiated at admission. Blood culture was sterile. Antibiotics were continued for five days perioperatively and discontinued following clinical stability and negative sepsis evaluation. Echocardiography revealed severe PPHN (PASP 85 mmHg) with right-to-left ductal shunting and preserved ventricular function (LVEF 55%). The right and left ventricular output were in normal range [Table/Fig-2,3]. The diagnosis of TEF was suspected clinically due to excessive salivation and inability to pass a nasogastric tube beyond 10 cm. A chest and abdominal radiograph demonstrated a coiled nasogastric tube in the upper oesophageal pouch with presence of distal bowel gas. The final diagnosis was TEF with severe PPHN and hypotensive shock. The neonate required mechanical ventilation and intravenous sildenafil therapy. Norepinephrine infusion (0.2-0.5 µg/kg/min) was given for hypotension and continued for 48 hours; vasopressin was not required. Haemodynamic stabilisation was achieved prior to surgical repair of TEF. The neonate underwent right posterolateral thoracotomy with ligation of the distal TEF and primary end-to-end oesophageal anastomosis. Neonate was followed-up clinically and haemodynamically until discharge from the NICU.



[Table/Fig-2]: Echocardiographic measurement of right ventricular output in the parasternal short-axis view, Case 2; a) Pulmonary artery (PA) root diameter measurement; b) Pulse-wave Doppler tracing used to derive Velocity-Time Integral (VTI) for calculating RV output. Normal RV output was defined as 150-300 mL/kg/min.



[Table/Fig-3]: Echocardiographic assessment of left ventricular output, Case 2; a) Aortic root diameter measured in the parasternal long-axis view; b) Pulse-wave doppler tracing from the apical five-chamber view used to derive velocity-time integral (VTI) for LV output calculation. Normal LV output was defined as 150-300 mL/kg/min.

Case 3

A 38-week female neonate (2.7 kg) born through meconium-stained liquor presented with severe respiratory distress. Physical examination showed tachypnoea (RR 74/min), tachycardia (HR 170/min), SpO_2 76%, prolonged capillary refill (>4 seconds), bounding pulses, and warm extremities consistent with septic shock. Respiratory examination revealed coarse crackles with retractions. Arterial blood gas analysis showed pH 7.19, PaO_2 38 mmHg, $PaCO_2$ 62 mmHg, HCO_3 17 mEq/L, and base deficit -9. Laboratory evaluation revealed Hb 16.8 g/dL, TLC 11.7×10³/µL, platelets 180×10³/µL, ANC 2.56×10³/µL, CRP 44 mg/L, and micro-ESR 15 mm. Empirical intravenous piperacillin–tazobactam and amikacin were initiated. Blood culture subsequently grew *Klebsiella pneumoniae*, and antibiotics were escalated to meropenem according to sensitivity profile. Antibiotic therapy was continued for 14 days, with serial monitoring of CRP showing declining trend and clinical improvement. Functional echocardiography demonstrated severe PPHN (PASP 109 mmHg) with right-to-left ductal shunting and preserved ventricular function (LVEF 60%). The diagnosis was MAS with culture-proven sepsis, severe PPHN, and septic shock. The neonate required invasive ventilation, intravenous sildenafil infusion, culture-directed antibiotics, and norepinephrine support for 48 hours. Vasopressin was not required. Oxygenation and perfusion improved gradually, enabling withdrawal of vasoactive support. Neonate was followed-up clinically and haemodynamically until discharge from the NICU.

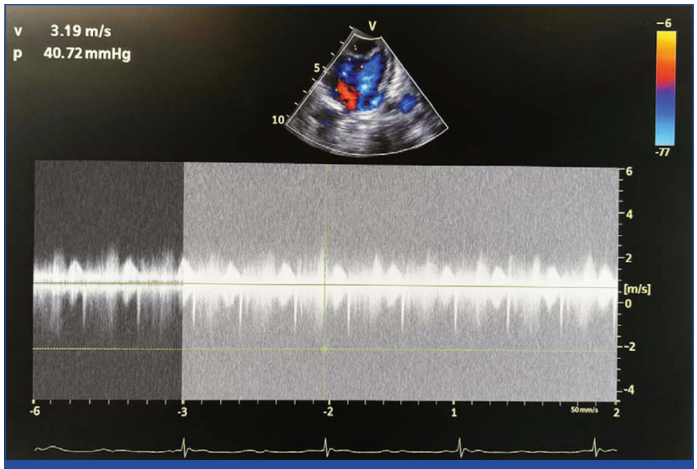
Case 4

A 37-week female neonate (3.8 kg) born through meconium-stained amniotic fluid presented with respiratory distress and hypoxemia. On examination, RR was 66/min, HR 158/min, SpO_2 80%, with prolonged capillary refill, weak pulses, and cold extremities consistent with hypotensive shock. Respiratory examination revealed coarse breath sounds with retractions; systemic examination was otherwise normal. Arterial blood gas showed pH 7.23, PaO_2 44 mmHg, $PaCO_2$ 46 mmHg, HCO_3 18 mEq/L, and base deficit -7. Laboratory findings included Hb 16 g/dL, TLC 15.4×10³/µL, platelets 350×10³/µL, ANC 1.89×10³/µL, CRP 3.6 mg/L, and micro-ESR 3 mm. Empirical ampicillin and gentamicin were initiated. Antibiotics were discontinued after five days following negative culture results and absence of clinical signs of sepsis. Functional echocardiography showed severe PPHN (PASP 90 mmHg) with preserved ventricular function (LVEF 65%). The final diagnosis was MAS-associated PPHN with hypotensive shock. Mechanical ventilation and intravenous sildenafil therapy were initiated. After fluid optimisation, norepinephrine infusion (0.2-0.4 µg/kg/min) was administered for 50 hours. Vasopressin was not required. Haemodynamic status and oxygenation improved steadily, allowing gradual weaning of support. Neonate was followed-up clinically and haemodynamically until discharge from the NICU.

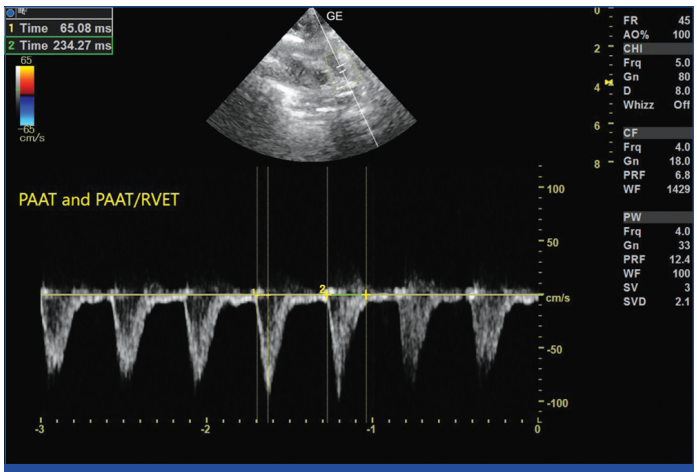
Case 5

A 38-week female neonate (2.6 kg) presented at four hours of life with severe respiratory distress and hypoxemia. Examination showed tachypnoea (RR 70/min), tachycardia (HR 172/min), SpO_2 75%, prolonged capillary refill, weak pulses, and cold extremities consistent with hypotensive shock. Respiratory examination revealed coarse breath sounds with retractions. Arterial blood gas showed pH 7.17, PaO_2 36 mmHg, $PaCO_2$ 55 mmHg, HCO_3 16 mEq/L, and base deficit -10. Laboratory findings included Hb 15.7 g/dL, TLC 25.78×10³/µL, platelets 215×10³/µL, ANC 2.57×10³/µL, CRP 60 mg/L, and micro-ESR 15 mm. Empirical piperacillin–tazobactam and amikacin were initiated. Blood culture remained sterile. Antibiotics were administered for seven days, guided by inflammatory markers and clinical response. Echocardiography demonstrated PPHN with PASP 45 mmHg [Table/Fig-4], the PAAT/RVET ratio was calculated to support assessment of pulmonary pressures and a value of 0.2-0.3s was indicative of moderate elevation [Table/Fig-5], right-to-left ductal shunting was present, and preserved ventricular function (LVEF 55%). The diagnosis was PPHN secondary to clinical sepsis with hypotensive shock. The neonate required invasive ventilation with escalation to High Frequency Oscillatory Ventilation (HFOV), intravenous sildenafil infusion, and norepinephrine support. Due to persistent hypotension, vasopressin infusion (0.2 mU/kg/min) was added, resulting in progressive improvement in perfusion and oxygenation. Following initiation of vasopressin, haemodynamic stability was achieved within 12 hours. Vasoactive agents were tapered over the next 48 hours. The neonate was then transitioned from HFOV to conventional ventilation on day 4, followed by successful extubation on day 6. Neonate was followed-up clinically and haemodynamically until discharge from the NICU.

Baseline characteristics of all the patients are presented in [Table/Fig-6] and laboratory findings in [Table/Fig-7].



[Table/Fig-4]: Continuous-wave Doppler of the Tricuspid Regurgitation (TR) jet from the apical four-chamber view used to estimate Pulmonary Artery Systolic Pressure (PASP). The peak TR velocity (V) is measured and PASP calculated using the simplified Bernoulli equation (PASP = $4V^2$ + 5 mmHg). In this example, V = 3.19 m/s yields an estimated PASP of 45 mmHg, consistent with pulmonary hypertension, Case 5.



[Table/Fig-5]: Pulse-wave Doppler assessment of Pulmonary Artery Acceleration Time (PAAT) and Right Ventricular Ejection Time (RVET) obtained from the parasternal short-axis view. The PAAT/RVET ratio was calculated to support assessment of pulmonary pressures, with values >0.3 considered normal, 0.2-0.3 indicating moderate elevation, and <0.2 suggesting significantly raised pulmonary pressures in PPHN, Case 5.

Parameter	Case 1	Case 2	Case 3	Case 4	Case 5
Gestation (weeks)	36	39	38	37	38
Sex	Male	Male	Female	Female	Female
Birth Weight (Kg)	2.1	2.6	2.7	3.8	2.6
Diagnosis	PPHN / EONS	TEF with PPHN	MAS / PPHN / Sepsis (Klebsiella)	PPHN with MAS	PPHN with Sepsis
Respiratory Support (Highest)	Invasive ventilation	Invasive ventilation	Invasive ventilation	Invasive ventilation	Invasive ventilation + HFO
Sildenafil					
Loading Dose (mg/kg)	0.4	0.4	0.4	0.4	0.4
Maintenance Dose (mg/kg/day)	1.6	1.6	1.6	1.6	1.6
Age at Initiation (hrs)	6	8	10	4	4
Duration (days)	7	5	5	7	7
Noradrenaline					
Initiation (hrs)	24	20	28	24	24
Initial Dose (mcg/kg/min)	0.2	0.2	0.2	0.2	0.2
Maximum Dose (mcg/kg/min)	0.5	0.5	0.2	0.4	0.5
Duration (hrs)	40	48	48	50	52

DISCUSSION

This case series highlights the potential role of norepinephrine and vasopressin in the management of PPHN with shock, particularly in settings where iNO is unavailable. All five neonates demonstrated haemodynamic stabilisation and improved oxygenation following targeted vasopressor therapy. Vasopressor selection was guided

Vasopressin					
Initiation (hrs)	30	-	-	-	30
Duration (hrs)	26	-	30	-	-
Maximum Dose (mUnits/kg/min)	0.1	-	-	-	0.2

[Table/Fig-6]: Patient details and intervention.
PPHN: Persistent Pulmonary Hypertension of the Newborn, EONS: Early Onset Neonatal Sepsis, TEF: Tracheoesophageal Fistula, MAS: Meconium Aspiration Syndrome, HFO: High-Frequency Oscillation Ventilation

Parameter	Case 1	Case 2	Case 3	Case 4	Case 5
Hb (g/dL)	14.5	17	16.8	16	15.7
TLC (×10³/µL)	18.0	19	11.7	15.4	25.78
Platelets (×10³/µL)	199	204	180	350	215
ANC (×10³/µL)	2.09	1.89	2.56	1.89	2.57
CRP (mg/L)	20.2	1.5	44	3.6	60
Micro-ESR (mm)	11	5	15	3	15
Blood culture	*Klebsiella pneumoniae*	Sterile	*Klebsiella pneumoniae*	Sterile	Sterile
Serum sodium	Within normal limits	Within normal limits	Within normal limits	Within normal limits	Within normal limits
Serum creatinine	Within normal limits	Within normal limits	Within normal limits	Within normal limits	Within normal limits
Urine output	Adequate	Adequate	Adequate	Adequate	Adequate
Blood glucose	Normal	Normal	Normal	Normal	Normal
Arrhythmias	None observed	None observed	None observed	None observed	None observed
Feeding intolerance/ NEC	None	None	None	None	None
Peak PASP (mmHg)	75	85	109	90	45
Right-to-left/ bi-directional shunt	Present	Present	Present	Present	Present
Ejection fraction (%)	65	55	60	65	55
Biventricular dysfunction	No	No	No	No	No

[Table/Fig-7]: Summary of case investigations, echocardiographic findings, and safety monitoring.
Abbreviations: Hb: Haemoglobin; TLC: Total leukocyte count; ANC: Absolute neutrophil count; CRP: C-reactive protein; ESR: Erythrocyte sedimentation rate; PASP: Pulmonary artery systolic pressure; NEC: Necrotising Enterocolitis

by the haemodynamic phenotype–based approach described by More K et al., which recommends norepinephrine or vasopressin in hypotension with preserved myocardial function [15]. This phenotype- characterised by low systemic vascular resistance and relatively intact ventricular contractility- benefits from systemic vasoconstriction to restore perfusion pressure and reduce right-to-left shunting.

Norepinephrine was initiated in all infants and was sufficient in three cases. It is well established as a first-line vasopressor in septic shock in adult and paediatric populations [16], with emerging neonatal evidence supporting its role in PPHN-associated circulatory failure. Through predominant $\alpha 1$-adrenergic stimulation, norepinephrine increases systemic vascular resistance and coronary perfusion, with comparatively limited pulmonary vasoconstrictive effects. Experimental and clinical observations suggest that it may favourably reduce the pulmonary-to-systemic vascular resistance ratio, possibly through $\alpha 2$-mediated nitric oxide release in the pulmonary endothelium [8]. Tourneux P et al., demonstrated improvement in systemic blood pressure, left ventricular output and oxygenation in neonates with PPHN receiving norepinephrine despite iNO therapy [17]. Similar improvements in mean arterial pressure, perfusion, and oxygenation were observed in the present series.

Traditional inotropes such as dopamine and epinephrine may increase pulmonary artery pressure or myocardial oxygen demand at higher doses. Dopamine's pulmonary vascular effects are dose-dependent and unpredictable, while epinephrine is associated with tachyarrhythmias and metabolic disturbances without demonstrated superiority in neonatal trials [8]. These considerations support norepinephrine as a targeted systemic vasopressor in PPHN with preserved ventricular function.

Vasopressin was used in two infants with catecholamine-resistant hypotension. Acting through V1 receptor–mediated vasoconstriction, vasopressin increases systemic vascular tone independently of adrenergic pathways and may be advantageous in prolonged shock states with receptor desensitisation [5]. Low-dose vasopressin has also been associated with improved pulmonary haemodynamics, possibly via nitric oxide–mediated mechanisms [8]. Mohamed A et al., reported improved oxygenation index and blood pressure in neonates with refractory PPHN treated with vasopressin [18], and similar findings have been described in preterm infants [19]. Shah S et al., demonstrated significant improvement in mean arterial pressure, oxygenation index, and vasoactive-inotrope score in term neonates with severe PPHN receiving vasopressin [20]. In index series, vasopressin facilitated blood pressure stabilisation and successful tapering of norepinephrine.

The combination of norepinephrine and vasopressin provides complementary haemodynamic support through distinct receptor pathways [21], reinforcing the principle of balancing pulmonary and systemic circulations in PPHN management. All infants also received early sildenafil therapy, contributing to pulmonary vasodilation. In the absence of iNO, combining pulmonary vasodilators with systemic vasopressors represents a rational "pull–push" strategy [5,8]. Milrinone was avoided due to preserved myocardial function and concern for worsening hypotension.

As a case series, the findings demonstrate clinical association rather than definitive therapeutic efficacy. Multiple concurrent interventions including ventilation optimisation, antibiotic therapy and supportive care may have contributed to the observed improvement, and the absence of a comparison group managed without norepinephrine or vasopressin precludes assessment of the independent effect of these vasopressors. The lack of access to iNO limits comparison with standard therapy, although it reflects real-world constraints in resource-limited settings. Aetiological heterogeneity, including early-onset sepsis, MAS, and TEF, may influence disease trajectory and treatment response despite a shared final physiological pathway of PPHN with shock. Also, only short-term outcomes, haemodynamic stabilisation and survival to discharge were evaluated while long-term neurodevelopmental outcomes were not assessed.

CONCLUSION(S)

Targeted systemic vasopressor therapy using norepinephrine, with vasopressin as rescue in catecholamine-resistant hypotension, may support haemodynamic stabilisation and improve oxygenation in neonates with PPHN and shock, particularly in resource-limited settings. Larger prospective studies are required to define optimal timing, safety, and standardised phenotype-based haemodynamic protocols.

REFERENCES

[1] Abman SH. Recent advances in the pathogenesis and treatment of persistent pulmonary hypertension of the newborn. Neonatology. 2007;91(4):283-90.
[2] Mathew B, Lakshminrusimha S. Persistent pulmonary hypertension in the newborn. Children (Basel). 2017;4(8):63.
[3] Singh Y, Lakshminrusimha S. Pathophysiology and management of persistent pulmonary hypertension of the newborn. Clin Perinatol. 2021;48(3):595-618.
[4] Sankaran D, Lakshminrusimha S. Pulmonary hypertension in the newborn—Etiology and pathogenesis. Semin Fetal Neonatal Med. 2022;27(4):101381.
[5] Chawla D. Vasopressin in persistent pulmonary hypertension of newborn. Indian J Pediatr. 2021;88(5):431-32.

[6] Ball MK, Seabrook RB, Bonachea EM, Chen B, Fathi O, Nankervis CA, et al. Evidence-based guidelines for acute stabilization and management of neonates with persistent pulmonary hypertension of the newborn. Am J Perinatol. 2023;40(14):1495-508.
[7] Nair J, Lakshminrusimha S. Update on PPHN: Mechanisms and treatment. Semin Perinatol. 2014;38(2):78-91.
[8] Siefkes HM, Lakshminrusimha S. Management of systemic hypotension in term infants with persistent pulmonary hypertension of the newborn: An illustrated review. Arch Dis Child Fetal Neonatal Ed. 2021;106(4):446-55.
[9] Siehr SL, Feinstein JA, Yang W, Peng LF, Ogawa MT, Ramamoorthy C. Hemodynamic effects of phenylephrine, vasopressin, and epinephrine in children with pulmonary hypertension: A pilot study. Pediatr Crit Care Med. 2016;17(5):428-37.
[10] Singh P, Deshpande S, Nagpal R, Garegrat R, Gupta S, Suryawanshi P. Management of neonatal pulmonary hypertension—A survey of neonatal intensive care units in India. BMC Pediatr. 2023;23(1):149.
[11] McNamara PJ, Jain A, El-Khuffash A, Giesinger R, Weisz D, Freud L, et al. Guidelines and recommendations for targeted neonatal echocardiography and cardiac point-of-care ultrasound in the neonatal intensive care unit: An update from the American Society of Echocardiography. J Am Soc Echocardiogr. 2024;37(2):171-215.
[12] Singh Y. Echocardiographic evaluation of hemodynamics in neonates and children. Front Pediatr. 2017;5:201.
[13] Sharma SS, Kumar NC, Shanmugasundaram C, Kumar VH, Kumar G. Correlation of serum lactate levels, perfusion index and plethysmography variability index with invasive blood pressure in late preterm and term infants with shock. Indian Pediatr. 2023;60(5):364-68.
[14] Saini SS, Kumar P, Kumar RM. Hemodynamic changes in preterm neonates with septic shock: A prospective observational study. Pediatr Crit Care Med. 2014;15(5):443-50.
[15] More K, Soni R, Gupta S. The role of bedside functional echocardiography in the assessment and management of pulmonary hypertension. Semin Fetal Neonatal Med. 2022;27(4):101366.
[16] Li Y, Li H, Zhang D. Timing of norepinephrine initiation in patients with septic shock: A systematic review and meta-analysis. Crit Care. 2020;24(1):488.
[17] Tourneux P, Rakza T, Bouissou A, Krim G, Storme L. Pulmonary circulatory effects of norepinephrine in newborn infants with persistent pulmonary hypertension. J Pediatr. 2008;153(3):345-49.
[18] Mohamed A, Nasef N, Shah V, McNamara PJ. Vasopressin as a rescue therapy for refractory pulmonary hypertension in neonates: Case series. Pediatr Crit Care Med. 2014;15(2):148-54.
[19] Mohamed AA, Louis D, Surak A, Weisz DE, McNamara PJ, Jain A. Vasopressin for refractory persistent pulmonary hypertension of the newborn in preterm neonates–A case series. J Matern Fetal Neonatal Med. 2022;35(8):1475-83.
[20] Shah S, Dhalait S, Fursule A, Khandare J, Kaul A. Use of vasopressin as rescue therapy in refractory hypoxia and refractory systemic hypotension in term neonates with severe persistent pulmonary hypertension- A prospective observational study. Am J Perinatol. 2024;41(Suppl 1):e886-e892.
[21] Kumar Krishnegowda V, Prasath A, Vadakkencherry Ramaswamy V, Trevisanuto D. Neonatal shock: Current dilemmas and future research avenues. Children (Basel). 2025;12(2):128.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jan 08, 2026
- Manual Googling: Mar 08, 2026
- iThenticate Software: Mar 10, 2026 (1%)

ETYMOLOGY: Author Origin

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