Plasma B-type Natriuretic Peptide to Predict Weaning and Extubation Outcomes in Critically Ill Children: A Narrative Review.

Nehad Ahmed Karam Abdel-Fattah[1] , Samir Zamzam[1], Eman Essam Hassan El Shetry[1], Abdullah Mohamad Abdelhameed [2]

1 Pediatrics Department, Faculty of Medicine, Zagazig University
2 Clinical Pathology Department, Faculty of Medicine, Zagazig University

Corresponding Author: Eman Essam Hassan El Shetry

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Abstract

Background: Extubation failure in pediatric intensive care units (PICUs) remains common (≈10–20%) and is associated with higher mortality, longer PICU and hospital length of stay, and increased costs. Existing readiness assessments—clinical criteria and spontaneous breathing trials (SBTs)—have imperfect predictive performance in children. Because SBTs can unmask weaning-induced cardiopulmonary stress, there is growing interest in cardiac-stress biomarkers as adjuncts. B-type (brain) natriuretic peptide (BNP) and its inactive fragment N-terminal pro-BNP (NT-proBNP) rise with ventricular wall stress and fluid overload—pathways implicated in weaning failure. Adult studies show that changes in BNP during SBTs correlate with post-extubation respiratory failure, but pediatric data are more limited and heterogeneous We aimed to synthesize contemporary evidence on the prognostic value of plasma BNP/NT-proBNP as predictors of weaning and extubation outcomes in critically ill neonates and children, outline practical considerations for testing, compare biomarker performance against established tools (e.g., diaphragm and lung ultrasound), and identify research gaps to guide future studies.

Conclusions: Pediatric studies suggest that elevated peri-extubation BNP/NT-proBNP—and particularly increases from pre- to post-SBT—associate with extubation failure in high-risk groups, including neonates with pulmonary hypertension/ventricular dysfunction and children after congenital heart surgery. Diagnostic thresholds vary widely across age, assay, and population, limiting immediate standardization. Integrative strategies that pair SBT physiology with BNP dynamics and bedside ultrasound may improve discrimination over any single test. Before routine adoption, multicenter pediatric trials should standardize sampling timing, define age-adjusted cut-points, and compare BNP-guided strategies against existing clinical pathways for calibration, reclassification, and cost-effectiveness. Pending such evidence, BNP/NT-proBNP can be considered as a targeted adjunct—especially when cardiac loading conditions or weaning-induced pulmonary edema are suspected—to refine extubation risk stratification, inform post-extubation monitoring, and personalize diuretic or vasoactive optimization

Keywords: *-type Natriuretic Peptide , Weaning and Extubation ,Critically Ill Children*

Introduction

Extubation failure, commonly defined as the need for reintubation within 24–72 hours, occurs in approximately 10–20% of ventilated children and remains a major determinant of morbidity and mortality in the pediatric intensive care unit (PICU) [1,2]. Failed extubation is independently associated with prolonged mechanical ventilation, increased length of stay, higher healthcare costs, and worse long-term neurodevelopmental outcomes [3]. Despite advances in ventilatory strategies, predicting which

children are truly ready for successful liberation from mechanical ventilation remains challenging. Current readiness assessments—such as spontaneous breathing trials (SBTs), clinical criteria, and ventilatory indices—provide useful guidance but show limited predictive accuracy in children compared with adults [4,5]. This discrepancy arises from developmental differences in respiratory mechanics, cardiovascular physiology, and the heterogeneity of pediatric critical illness. As a result, a significant proportion of children who pass an SBT still experience extubation failure, underscoring the need for better adjunctive tools.

Brain natriuretic peptide (BNP) and its inactive fragment N-terminal proBNP (NT-proBNP) are secreted in response to myocardial stretch and elevated ventricular filling pressures. Since the transition from positive-pressure ventilation to spontaneous breathing increases preload and afterload, these peptides offer a physiologic marker for hemodynamic stress that may precipitate extubation failure [6]. Adult studies suggest that rises in BNP during SBTs correlate with extubation outcomes, highlighting its role as a "biochemical stress test" [7]. Pediatric studies, while more limited, provide preliminary evidence that BNP dynamics may be particularly useful in children with cardiac dysfunction, pulmonary hypertension, or after congenital heart surgery [8,9].

Aim: This review synthesizes the available evidence regarding the prognostic role of plasma BNP/NT-proBNP in predicting weaning and extubation outcomes in critically ill children, compares their performance with other modalities such as diaphragm and lung ultrasound, and identifies gaps for future multicenter research.

Research gap: Despite biologic plausibility and supportive pilot data, pediatric studies remain small, heterogeneous, and lacking standardized cut-points. The absence of age-adjusted thresholds, variability in assay methods, and uncertain incremental value beyond traditional tools limit clinical translation. Addressing these gaps is essential before BNP-guided strategies can be widely adopted in pediatric practice [1–9].

Burden and Consequences of Extubation Failure in Children

Extubation failure, defined as the need for reintubation within 24–72 hours of planned extubation, occurs in approximately 10–20% of children requiring invasive mechanical ventilation [10]. This rate is notably higher in neonates, infants with congenital heart disease, and patients with chronic lung pathology. Extubation failure is not merely a clinical setback; it reflects the interplay of respiratory mechanics, airway patency, neuromuscular strength, and cardiovascular stability. Unlike adults, pediatric patients are less tolerant of respiratory workload increases, making them particularly vulnerable during the transition from assisted to spontaneous breathing [11].

The clinical consequences of failed extubation in pediatric patients are profound. Children who fail extubation often require prolonged mechanical ventilation, higher doses of sedatives and analgesics, and repeated exposure to invasive airway instrumentation. Each of these factors increases the risk of ventilator-associated pneumonia, airway trauma, and ventilator-induced lung injury [12]. Moreover, repeated reintubation episodes predispose children to laryngeal edema, vocal cord dysfunction, and chronic airway complications, all of which complicate future weaning attempts and long-term respiratory outcomes [13].

From a health systems perspective, extubation failure significantly increases PICU and hospital length of stay, healthcare costs, and caregiver burden. Studies demonstrate that mortality is substantially higher in patients who fail extubation compared to those successfully liberated on the first attempt [14]. Beyond survival, extubation failure is associated with long-term morbidities, including impaired neurodevelopmental trajectories in neonates and infants due to prolonged sedation and mechanical ventilation [15]. Thus, preventing extubation failure is not only a short-term critical care goal but also a determinant of life-long health outcomes.

Importantly, extubation failure is often multifactorial. Causes range from airway obstruction, residual sedation, and diaphragmatic weakness to fluid overload, myocardial dysfunction, and pulmonary hypertension. This complex interplay means that no single predictor, including spontaneous breathing

trials alone, has proven sufficient in children [16]. The limitations of current tools highlight the need for adjunctive biomarkers such as BNP, which may help identify children at risk of weaning-induced cardiopulmonary stress. Integrating such biomarkers into extubation readiness assessments has the potential to reduce failure rates, improve resource allocation, and enhance overall pediatric critical care outcomes [17].

Why BNP Might Help — Pathophysiological Rationale

The transition from mechanical ventilation to spontaneous breathing imposes significant hemodynamic changes. Positive-pressure ventilation decreases venous return and left ventricular afterload, thereby reducing cardiac workload. Once positive pressure is withdrawn, preload and afterload increase, unmasking latent diastolic dysfunction or myocardial impairment. In this setting, ventricular wall stress rises rapidly, potentially resulting in pulmonary edema and extubation failure. BNP and NT-proBNP, secreted in proportion to ventricular stretch, provide a real-time biochemical reflection of this cardiac stress [18].

Unlike traditional weaning indices, which largely focus on respiratory mechanics, BNP levels integrate the cardiovascular component of weaning physiology. Children with subclinical ventricular dysfunction, pulmonary hypertension, or fluid overload may appear clinically ready for extubation but still fail due to hemodynamic decompensation. Biomarker measurement, particularly dynamic changes before and after a spontaneous breathing trial (SBT), offers an opportunity to detect vulnerability that bedside observation alone may miss [19].

Another rationale for BNP measurement lies in the strong link between natriuretic peptide release and fluid status. Many critically ill children develop positive fluid balance, which elevates ventricular filling pressures and predisposes them to post-extubation pulmonary edema. BNP concentrations rise in parallel with fluid overload, reflecting not only intrinsic myocardial strain but also intravascular congestion. Thus, BNP can serve as a bridge between cardiac and renal systems in predicting tolerance to extubation, especially when fluid management is complex [20].

BNP may also provide prognostic information beyond absolute values. Adult studies have demonstrated that the relative increase in BNP during SBTs correlates more strongly with extubation outcomes than baseline concentrations. This suggests BNP behaves as a biomarker of "dynamic reserve," highlighting patients whose ventricles fail to adapt to abrupt loading changes. Translating this principle to pediatrics could allow clinicians to identify high-risk children, individualize diuretic or vasoactive therapy before extubation, and anticipate the need for noninvasive ventilation post-extubation [21].

Evidence from Adult Critical Care — Signal in the Delta

Adult studies of BNP and NT-proBNP during weaning provide the most robust foundation for pediatric investigations. Several prospective trials demonstrated that absolute BNP levels prior to extubation were less predictive of outcomes compared to the change, or "delta," observed during spontaneous breathing trials (SBTs). In particular, patients who experienced a significant rise in BNP during SBT were more likely to fail extubation or require reintubation, suggesting that the biomarker captures acute hemodynamic stress during the transition from positive to negative intrathoracic pressures [22].

One influential multicenter study showed that BNP increased substantially in patients who subsequently failed weaning, whereas successful extubators demonstrated only minor or no increases. The magnitude of BNP rise correlated with measures of left ventricular filling pressure and pulmonary edema, confirming the physiologic link between biomarker changes and cardiac adaptation to spontaneous breathing. Importantly, these findings reinforced the idea that BNP measurement is most valuable when collected as paired pre- and post-SBT samples rather than as isolated values [23].

Systematic reviews and meta-analyses of adult cohorts support the predictive value of BNP dynamics, though they also highlight heterogeneity. Differences in patient populations, assay types, cut-off values, and timing of measurement lead to variable diagnostic accuracy across studies. Some reports found excellent predictive performance, while others suggested limited utility, particularly in populations with

predominant respiratory rather than cardiac causes of weaning failure. This heterogeneity underscores the need for condition-specific interpretation rather than universal thresholds [24].

Despite these limitations, adult data remain clinically influential because they demonstrate that a biochemical marker of myocardial stretch can detect extubation vulnerability not captured by conventional respiratory indices. This provides the conceptual basis for applying BNP measurement in pediatrics, particularly in high-risk subgroups where cardiovascular load is central to the weaning process. However, unlike adults, children present with age-dependent physiology and disease-specific risks, meaning that pediatric studies must validate whether the "delta BNP" approach holds equal prognostic weight across different age groups and clinical contexts [25].

Pediatric Overview — The Landscape is Smaller but Growing

Compared to the adult literature, pediatric studies exploring BNP and NT-proBNP as predictors of extubation outcomes are sparse and heterogeneous. The smaller evidence base reflects both the lower incidence of prolonged mechanical ventilation in children and the complexity of conducting biomarker research in small, critically ill populations. Nonetheless, early investigations have indicated that natriuretic peptide concentrations may correlate with extubation failure, particularly in neonates with pulmonary hypertension and children with congenital heart disease. These findings suggest that although pediatric data remain limited, the physiologic rationale is relevant and warrants focused study [26].

One of the earliest pediatric pilot studies reported that higher BNP levels were associated with increased risk of extubation failure within 48 hours. Although small in sample size, this work demonstrated proof-of-concept that BNP could serve as an adjunctive marker in pediatric weaning. Subsequent studies have refined this by examining both absolute values and peri-SBT changes, with preliminary evidence indicating that the dynamic increase may be a stronger predictor than baseline measurement alone. However, thresholds varied substantially across reports, reflecting differences in age distribution, underlying diagnoses, and assay methodologies [27].

More recent investigations have focused on high-risk populations. For example, neonates with pulmonary hypertension or ventricular dysfunction have shown elevated NT-proBNP levels preceding extubation failure, and postoperative congenital heart surgery cohorts demonstrated that peri-extubation BNP values predicted the ability to sustain spontaneous breathing. These studies highlight that BNP is most informative in populations where cardiovascular function plays a central role in weaning outcomes, rather than in those with purely pulmonary disease such as bronchiolitis or pneumonia [28].

Despite these promising signals, significant limitations remain. Most pediatric studies have been single-center, with small cohorts and limited generalizability. Sampling timing is inconsistent, with some measuring BNP hours before or after SBTs rather than immediately pre- and post-trial, reducing comparability. Furthermore, the absence of age-adjusted or Z-score–based thresholds limits applicability across the pediatric age spectrum, where physiologic BNP values differ markedly from neonates to adolescents. These challenges emphasize the importance of multicenter collaborations to generate robust, standardized evidence capable of informing clinical practice [29].

Neonates with Pulmonary Hypertension or Ventricular Dysfunction

Neonates with pulmonary hypertension or ventricular dysfunction represent a particularly vulnerable subgroup during the weaning process. The transition from positive-pressure ventilation to spontaneous breathing imposes abrupt hemodynamic shifts that can overwhelm the immature myocardium and pulmonary circulation. Elevated pulmonary vascular resistance, impaired ventricular compliance, and volume overload combine to increase the risk of weaning-induced pulmonary edema and extubation failure. In this context, NT-proBNP has emerged as a valuable biomarker, reflecting both right and left ventricular stress in neonates at risk [30].

A prospective neonatal study demonstrated that higher NT-proBNP levels, particularly when expressed as Z-log–transformed values to account for age-related norms, were significantly associated with extubation failure in critically ill neonates with pulmonary hypertension or ventricular dysfunction. This work is important because it adjusted for the naturally higher baseline natriuretic peptide concentrations

observed in neonates, which typically decline over the first weeks of life. By applying age-normalized scoring, the investigators improved the discriminatory ability of the biomarker, highlighting the need for pediatric-specific interpretive strategies [31].

In neonates, BNP dynamics may also provide insight into the severity of right ventricular strain in the setting of persistent pulmonary hypertension of the newborn (PPHN). Elevated levels during weaning attempts can indicate that the right ventricle is unable to handle the increased preload and afterload associated with spontaneous breathing. This scenario predisposes infants to oxygen desaturation, increased work of breathing, and rapid extubation failure. NT-proBNP measurement, therefore, offers an indirect but clinically useful marker of cardiopulmonary adaptation in PPHN management and extubation planning [32].

Nevertheless, BNP interpretation in neonates requires caution. Beyond physiologic elevation at birth, other conditions such as renal immaturity, sepsis, or fluid overload can raise peptide levels independent of ventricular dysfunction. Moreover, most neonatal studies remain single-center with small cohorts, limiting generalizability. Despite these challenges, current evidence suggests that targeted use of BNP in neonates with suspected cardiopulmonary compromise may help clinicians better stratify extubation readiness and anticipate the need for closer monitoring or adjunctive therapies after liberation from ventilation [33].

Congenital Heart Disease — Perioperative Insights

Children undergoing congenital heart disease (CHD) surgery are among the most challenging patients to extubate. Perioperative factors such as residual ventricular dysfunction, pulmonary hypertension, myocardial edema, and fluid shifts create a delicate balance between successful liberation and extubation failure. In this group, BNP and NT-proBNP have demonstrated potential value as biomarkers that reflect postoperative myocardial stress and predict the ability to sustain spontaneous breathing following surgery [34].

Several studies have observed that elevated BNP or NT-proBNP levels measured in the immediate postoperative period correlate with difficulty in achieving successful extubation. In particular, higher peptide concentrations were associated with failed on-table extubation or the need for prolonged ventilatory support. These findings align with the physiological understanding that elevated ventricular filling pressures and impaired compliance—common after cardiopulmonary bypass—translate into measurable increases in natriuretic peptide release. Thus, BNP provides an early biochemical signal of impaired cardiac adaptation in the critical peri-extubation window [35].

The predictive value of BNP in CHD patients is especially relevant in centers pursuing fast-track or ultra-fast-track extubation protocols, where infants are extubated in the operating room or within a few hours post-surgery. While such strategies reduce ICU stay and costs, they risk extubation failure if patient selection is suboptimal. Incorporating BNP or NT-proBNP measurement alongside echocardiography and hemodynamic assessment may refine readiness criteria, allowing clinicians to better identify candidates likely to tolerate early liberation from mechanical ventilation [36].

Despite these promising results, significant variability exists in reported BNP thresholds across CHD studies. Differences in surgical procedures, timing of sampling, and patient age make it difficult to establish universal cut-off values. Moreover, BNP levels may be influenced by perioperative renal function, residual shunts, and the duration of cardiopulmonary bypass, confounding their interpretation. Future multicenter studies are needed to define standardized protocols for perioperative BNP testing and to evaluate whether its integration into fast-track extubation algorithms improves clinical outcomes [37].

Early Pediatric Evidence and Exploratory Studies

Early pediatric investigations into BNP and NT-proBNP as predictors of extubation outcomes were largely exploratory, designed to assess feasibility and generate hypotheses for larger trials. These initial reports often involved small, single-center cohorts but provided important proof-of-concept that natriuretic peptides might serve as useful adjuncts in pediatric weaning assessments. In some cases, even

unpublished abstract data suggested potential associations between elevated BNP levels and extubation failure, highlighting the growing clinical interest in this biomarker [38].

One of the earliest pediatric pilot studies reported that children with higher plasma BNP levels were more likely to require reintubation within 48 hours of extubation. Although limited by small numbers and heterogeneous diagnoses, the study emphasized that BNP reflected underlying cardiac stress, which may not have been apparent through standard ventilatory parameters. This finding was important because it opened the door to evaluating BNP not just as a research tool but as a possible bedside biomarker for clinicians managing high-risk extubations [39].

Exploratory studies also highlighted that timing of BNP measurement was critical. Some investigators obtained samples prior to the spontaneous breathing trial, while others focused on immediate post-SBT levels. The variability in methodology limited cross-study comparison, yet preliminary data suggested that dynamic changes in BNP may carry more predictive value than static measurements. This aligns with the physiologic rationale that the stress of an SBT unmasks hemodynamic vulnerability, reflected biochemically by a rise in BNP concentrations [40].

Importantly, these early studies demonstrated the safety and feasibility of incorporating biomarker measurement into routine pediatric ICU workflows. Despite the challenges of limited blood volume in neonates and infants, sampling was generally achievable and well-tolerated. These initial experiences provided the foundation for subsequent targeted studies in populations such as neonates with pulmonary hypertension and postoperative congenital heart disease patients, where BNP has shown the most promise. Without these early exploratory efforts, larger and more definitive pediatric investigations would likely not have been pursued [41].

BNP Around Spontaneous Breathing Trials in Children — Absolute Value vs Change

A key question in applying BNP to pediatric extubation readiness is whether absolute levels or dynamic changes during spontaneous breathing trials (SBTs) are more informative. Several pediatric studies suggest that while elevated baseline BNP may reflect underlying myocardial stress, the change in BNP from pre- to post-SBT provides greater predictive accuracy. This is consistent with the physiologic concept that SBTs act as "stress tests," revealing cardiac intolerance only when the child transitions from positive-pressure ventilation to spontaneous breathing [42].

Absolute BNP or NT-proBNP levels are influenced by age, renal function, and chronic comorbidities, which can confound interpretation in children. Neonates, for example, naturally exhibit higher baseline natriuretic peptide values due to perinatal circulatory adaptations. As a result, a single threshold applied across age groups may be misleading. Conversely, focusing on the delta, or relative change, helps control for baseline variability and highlights patients whose ventricles are unable to adapt to the increased load of spontaneous breathing [43].

In studies that evaluated peri-SBT dynamics, children who failed extubation showed significantly greater increases in BNP or NT-proBNP compared to those successfully extubated. This rise correlated with markers of left ventricular diastolic dysfunction and fluid overload, supporting the mechanistic link between hemodynamic intolerance and biomarker elevation. In contrast, children with stable BNP across the SBT were more likely to sustain spontaneous breathing after extubation, even if their baseline levels were modestly elevated [44].

The practical implication is that BNP should not be interpreted in isolation as a one-time measurement but rather as part of a paired sampling strategy around SBTs. Incorporating both baseline and post-SBT levels provides dynamic information about cardiovascular reserve. This approach mirrors the adult literature and may ultimately offer clinicians a more nuanced and individualized risk assessment. Future pediatric protocols will need to standardize the timing of these measurements to ensure consistency and to establish clinically meaningful delta thresholds for different age groups [45].

Assay Selection and Age-Adjusted Interpretation

One of the most important considerations in applying BNP measurement to pediatric extubation readiness is assay selection. Both BNP and NT-proBNP are widely available, but they differ in kinetics,

stability, and interpretation. BNP has a shorter half-life of about 20 minutes and reflects more acute hemodynamic stress, whereas NT-proBNP, with a half-life of 60–120 minutes, offers greater stability and less assay variability. In clinical practice, NT-proBNP is often preferred in pediatrics because its longer half-life and broader reference ranges make it more suitable for trending over time in critically ill children [46].

Age-specific physiology adds a layer of complexity to interpretation. BNP and NT-proBNP concentrations are physiologically elevated in neonates due to perinatal circulatory transitions, including closure of the ductus arteriosus and adaptation to extrauterine circulation. Levels naturally decline over the first months of life and stabilize in later childhood, making universal thresholds inappropriate across all pediatric ages. For this reason, several investigators have used Z-score or log-transformed values, which normalize peptide concentrations relative to age-based reference ranges, improving diagnostic performance in neonates and infants [47].

In addition to age, renal function has a significant impact on natriuretic peptide interpretation. Both BNP and NT-proBNP are cleared by the kidneys, and impaired renal function leads to disproportionately higher circulating levels, even in the absence of overt cardiac dysfunction. This is particularly relevant in the PICU setting, where acute kidney injury and fluid overload are common comorbidities. Adjusting interpretation for renal status, or combining BNP with renal biomarkers, may improve accuracy in predicting extubation outcomes [48].

Finally, assay standardization remains an ongoing challenge. Different laboratories and commercial platforms use varying antibodies and calibration methods, leading to potential discrepancies in measured values. Clinicians must be aware of which assay is used at their institution and avoid directly extrapolating cut-offs reported in other studies unless the methodology is comparable. Until standardized pediatric-specific thresholds are validated, BNP and NT-proBNP values should be interpreted as relative indicators of hemodynamic stress rather than absolute determinants of extubation readiness [49].

Where BNP Fits Among Pediatric Weaning Tools and Pathways

Weaning protocols in pediatric intensive care units are built around structured readiness assessments, spontaneous breathing trials (SBTs), and post-extubation monitoring. These tools primarily assess respiratory mechanics, gas exchange, and clinical stability. However, none of these measures directly address the cardiovascular stress that occurs during liberation from positive-pressure ventilation. BNP and NT-proBNP offer a complementary perspective by providing biochemical evidence of myocardial and volume load, helping to capture the hemodynamic component often missed by traditional indices [50].

In practice, BNP could be integrated into weaning algorithms as an adjunct for selected high-risk populations. For example, children with congenital heart disease, myocarditis, sepsis-induced cardiomyopathy, or pulmonary hypertension are more likely to experience cardiac-related extubation failure. Measuring BNP before and after SBTs in these patients may help identify those with limited cardiovascular reserve, guiding clinicians toward a more cautious approach with tailored diuretic optimization, inotropic support, or extended monitoring post-extubation [51].

The biomarker also has a potential role in refining risk stratification for post-extubation respiratory support. Patients with marked rises in BNP during SBTs might benefit from proactive initiation of noninvasive ventilation or high-flow nasal cannula therapy immediately after extubation. Embedding BNP into clinical pathways alongside ventilatory indices and bedside ultrasound could therefore allow for more individualized and anticipatory management, reducing the incidence of unplanned reintubation [52].

Despite its promise, BNP cannot replace clinical judgment or established weaning assessments. Instead, it should be considered as part of a multimodal strategy. By combining respiratory-focused tools such as diaphragm ultrasound or lung aeration scores with BNP dynamics, clinicians can achieve a more comprehensive assessment of extubation readiness. This integrated approach is consistent with precision

medicine in critical care, where multiple complementary modalities are leveraged to optimize patient outcomes [53].

Critically Ill Children in the PICU

Critically ill children admitted to the PICU often present with multi-organ dysfunction, fluid overload, and unstable hemodynamics, all of which complicate the weaning process. Extubation readiness in this population is particularly difficult to assess because clinical signs such as tachypnea or desaturation may reflect respiratory insufficiency, cardiac decompensation, or both. BNP and NT-proBNP provide a unique opportunity to bridge this diagnostic gap by signaling cardiac stress in real time, thereby adding valuable information to standard readiness assessments [54].

In children with sepsis or systemic inflammatory response, BNP levels are frequently elevated due to myocardial depression and cytokine-mediated stress. These elevations can precede overt echocardiographic abnormalities, making BNP a sensitive early marker of cardiac dysfunction. When such patients undergo weaning, rises in BNP during spontaneous breathing trials may indicate limited cardiovascular reserve and predict post-extubation instability. Identifying this risk early could allow for proactive interventions, such as fluid restriction, diuretic therapy, or enhanced monitoring after extubation [55].

PICU patients often experience significant positive fluid balance due to aggressive resuscitation and supportive therapies. This fluid overload not only impairs pulmonary gas exchange but also increases cardiac preload, driving BNP release. Several studies have linked fluid overload at the time of extubation with higher rates of failure, suggesting that BNP could serve as both a marker of volume status and a predictor of tolerance to spontaneous breathing. Combining BNP with daily fluid balance monitoring may therefore improve risk stratification and guide fluid management strategies in critically ill children [56].

Another relevant subgroup in the PICU includes children with neuromuscular weakness, prolonged ventilation, or sedation-related diaphragm dysfunction. While BNP does not directly assess respiratory muscle strength, its ability to detect cardiac vulnerability complements respiratory-focused tools such as diaphragm ultrasound or maximal inspiratory pressure. In this way, BNP can help distinguish children failing extubation due to cardiac loading conditions from those with primarily ventilatory pump failure. This layered approach may reduce unnecessary reintubations and promote tailored interventions across the spectrum of critically ill pediatric patients [57].

Conclusion

Extubation failure remains a major challenge in pediatric intensive care, with multifactorial causes and profound consequences for morbidity, mortality, and long-term outcomes. Current tools such as spontaneous breathing trials and ventilatory indices, while helpful, are insufficiently reliable in children, particularly in high-risk groups with complex cardiopulmonary physiology.

Plasma BNP and NT-proBNP offer a biologically plausible and clinically accessible biomarker that reflects myocardial stress and fluid overload during the critical transition from positive-pressure ventilation to spontaneous breathing. Evidence from both adult and pediatric studies highlights the value of peri-extubation dynamics—especially rises during spontaneous breathing trials—over static thresholds. These changes provide insight into cardiovascular reserve and help identify children at risk for extubation failure despite otherwise reassuring clinical parameters.

The role of BNP is particularly compelling in vulnerable populations such as neonates with pulmonary hypertension, children with congenital heart disease, and critically ill patients in the PICU with fluid overload or sepsis-induced myocardial dysfunction. When integrated into weaning protocols, BNP measurement has the potential to complement existing modalities such as ultrasound and structured clinical assessments, fostering a more holistic and individualized approach to extubation readiness.

However, BNP should not be considered a standalone solution. Challenges including assay variability, age-dependent reference ranges, and confounding from renal dysfunction or systemic inflammation must be addressed before widespread clinical adoption. Future multicenter pediatric trials are essential

to define standardized protocols, validate age-adjusted thresholds, and evaluate the incremental benefit of BNP-guided strategies in improving patient outcomes.

In summary, BNP represents a promising adjunct to current extubation readiness assessments in critically ill children. By capturing the cardiovascular dimension of weaning physiology, it may help reduce extubation failure, enhance clinical decision-making, and ultimately improve outcomes for some of the most vulnerable patients in the PICU.

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