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High Flow Nasal Cannula and Non Invasive Ventilation for Acute Bronchiolitis in the Paediatric Wards

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ABSTRACT

Aim: Bronchiolitis is a leading cause of respiratory distress and hospital admissions in infants. While high-flow nasal cannula is effective for patients unresponsive to standard oxygen therapy, evidence regarding continuous positive airway pressure and noninvasive ventilation in the wards remains inconclusive. This review explores the feasibility and criteria for initiation, titration, and monitoring of high-flow nasal cannula, continuous positive airway pressure, and noninvasive ventilation in infants with bronchiolitis in paediatric wards.

Methods: Narrative review of studies from PubMed and the Cochrane Library (2000–2024), focusing on high-flow nasal cannula, continuous positive airway pressure, and noninvasive ventilation in bronchiolitis, particularly in paediatric wards.

Results: High-flow nasal cannula is widely used in paediatric wards as a safe and effective option for bronchiolitis. Evidence for continuous positive airway pressure and noninvasive ventilation outside intensive care is limited but suggests potential to reduce escalation in selected cases.

Conclusion: Continuous positive airway pressure and noninvasive ventilation in paediatric wards appear to carry limited safety concerns. While not proven superior to high-flow nasal cannula or standardised in their use, when applied selectively with trained staff and close monitoring, they may serve as rescue therapies. Better understanding of current evidence may support standardisation and improve resource allocation.

1 | Aim

Acute bronchiolitis, a lower respiratory tract infection affecting infants under 12 months, presents with a wide clinical spectrum ranging from mild respiratory symptoms to severe respiratory distress [1]. Bronchiolitis constitutes a substantial health burden for infants, accounting for up to 20% of total hospitalisations in this age group, of which 5%–6% require paediatric intensive care unit (PICU) admission [2, 3]. Cornerstones of treatment are nutritional and respiratory support, the latter being administered mainly as low-flow, standard oxygen therapy (SOT) [4, 5]. High-flow nasal cannula (HFNC) has now established itself as an

Abbreviations: Bpm, beats per minute; BROSJOD, Bronchiolitis Score of Sant Joan de Déu; CBS, COMFORT Behavioural Scale; CPAP, continuous positive airway pressure; EDIN, Echelle de douleur et d'Inconfort du Nouveau né; EPAP, expiratory positive airway pressure; EU, European Union; FiO_2, fraction of inspired oxygen; H-CPAP, helmet-CPAP; HFNC, high-flow nasal cannula; HR, heart rate; IMV, invasive mechanical ventilation; IPAP, inspiratory positive airway pressure; LOS, hospital length of stay; M-WCAS, Modified Wood Clinical Asthma Score; NIV, noninvasive ventilation; NR, not reported; PCO_2, pressure of carbon dioxide; PEEP, positive end-expiratory pressure; PHDU, Paediatric High Dependency Units; PICU, paediatric intensive care unit; PIP, positive inspiratory pressure; RCTs, randomised controlled trials; ROX, Respiratory rate–OXygenation index; RR, respiratory rate; SOT, standard oxygen therapy; SpO_2, peripheral oxygen saturation; WOB, work of breathing.

Summary

- Bronchiolitis can cause severe respiratory distress, warranting evaluation of the feasibility of non-invasive respiratory support outside the paediatric intensive care unit (PICU).
- While high-flow nasal cannula (HFNC) is effectively used in the wards for bronchiolitis unresponsive to low-flow oxygen, continuous positive airway pressure (CPAP) and noninvasive ventilation (NIV) may represent feasible and appealing alternatives in the same setting.
- Expanding CPAP and NIV use to the wards may reduce PICU admissions and optimise resource allocation.

effective rescue therapy for infants unresponsive to SOT [6, 7]. Infants deteriorating despite HFNC are generally managed in PICUs, mainly with continuous positive airway pressure (CPAP) or non-invasive ventilation (NIV) [8]. Despite recent advancements, PICU admission for bronchiolitis has surged by up to 130% without corresponding changes in markers of disease severity such as hospitalisation rates, hospital length of stay (LOS), or mortality [2, 9]. This growing intensity of care has been mainly driven by a 5.8-fold rise in NIV usage, raising concerns about a potential inappropriate use of PICU resources rather than increased disease severity [9, 10]. The widespread use of NIV and CPAP for bronchiolitis in the PICUs suggests that these supports may also hold promise for treating selected patients on general paediatric wards. At present, only a handful of studies have described the use of these respiratory supports for bronchiolitis outside the PICU, suggesting the possible benefits of their early utilisation in the paediatric wards [11–14]. Provided safety is ensured, the adoption of CPAP and NIV in paediatric wards could ideally reduce nonessential PICU admissions and prevent unintended morbidity linked to intensive care settings. However, initiating such supports outside PICUs entails significant challenges, including the severity of patients' condition with greater potential for deterioration, the need for appropriate monitoring, and adequately trained and numbered staff.

This review explores the current evidence on HFNC, CPAP, and NIV for acute bronchiolitis, focusing on the Paediatric wards. We propose practical criteria for initiation, titration, and monitoring based on the available literature to optimise care and resource use.

2 | Methods

Electronic databases, namely PubMed (MEDLINE) and the Cochrane Collaboration Library, were searched on December 5th, 2024, for relevant studies. The search was conducted by combining the following search terms: “bronchiolitis” AND “HFNC” OR “high-flow nasal cannula” OR “CPAP” OR “continuous positive airway pressure” OR “BIPAP” OR “bilevel positive airway pressure” OR “NIV” OR “noninvasive ventilation” AND (“paediatric” OR “infants” OR “children”). We then performed a sub-analysis of the selected articles to specifically identify studies reporting on the use of CPAP and NIV in paediatric ward settings or analysing starting settings, monitoring and weaning strategies combining the previous research with the following: AND (“paediatric ward” OR “wards” OR “inpatient care”) AND/OR (“monitoring” OR “titration”). We considered randomised controlled trials (RCTs) and observational studies comparing different respiratory support strategies among infants admitted for acute bronchiolitis. Inclusion was restricted to English-language papers published from January 1st, 2000, to December 5th, 2024. References from included studies were screened to identify additional relevant publications not captured in the initial database search.

3 | Results

3.1 | Eligibility Criteria

Studies suggest that HFNC is best suited as a rescue therapy for SOT failure rather than as a first-line alternative [6, 7]. Unfortunately, there is little consensus on how to define SOT failure, and consequently, to trigger respiratory support escalation, with significant variability in clinical signs, cardiorespiratory parameters, and severity scores used to assess bronchiolitis (Table 1) [6, 7, 20–27]. Routine use of severity scores may serve to rapidly alert medical staff about a patient's deterioration and guide a more standardised approach to respiratory support titration and weaning [28, 29].

Real-world data highlight the subjectivity of HFNC management, with only 37% of clinicians relying on protocols for HFNC inception according to a recent US survey [30, 31]. However, there is increasing evidence that supports a protocol-driven approach to HFNC [15, 32]. Treasure et al. demonstrated reduced overuse (41%–22%) and shorter hospital stays (60–45 h) when protocols for HFNC initiation were adopted [32]. Similarly, another study showed lower HFNC duration after the introduction of guidance that imposes initiating HFNC at higher flow rates and regulates weaning [15].

Despite varying approaches, standardised criteria to define SOT failure may help to precisely define eligibility for HFNC.

CPAP and NIV are widely used in PICUs for bronchiolitis, with only a small percentage of patients requiring IMV [8, 18]. However, evidence documenting the use of such supports in Paediatric wards mainly consists of small observational studies, and still no shared criteria exist to define eligibility for CPAP or NIV in bronchiolitis (Table 1), or whether these supports can be undertaken outside PICUs.

Overall, CPAP and NIV are mostly conceived as rescue respiratory support for HFNC failure. Accordingly, criteria for HFNC failure may help guide CPAP inception.

Significant variations in initiation criteria for respiratory support have been reported in the absence of dedicated protocols [17]. These and other findings suggest that the criteria to initiate CPAP or NIV in the wards vary widely between studies [11–13, 16, 19]. Although there is no clear clinical score to guide decisions for respiratory support in bronchiolitis, worsening heart

TABLE 1 | Eligibility criteria for different types of respiratory support among studies.

Author (Year)	Setting	HR	RR	SpO_2	Apneas	pCO_2	M-WCAS	BROSJOD	Other
HFNC eligibility (SOT failure)									
Kepreotes[a] 2017	Paediatric Ward	Red zone HR (age dependent) in standard paediatric observation charts	Red zone RR (age dependent) in standard paediatric observation charts	< 94% with more than 2 L per minute SOT	NR	NR	Used only for initial evaluation, not for therapy escalation	NR	NR
Franklin[a] 2018	Paediatric Ward	Unchanged or increased	Unchanged or increased	92%–94% with more than 2 L per minute SOT	NR	NR	NR	NR	Other Early Warning Scores suggestive of escalation of care
Durand[a] 2020	Paediatric Ward	NR	NR	< 94% with more than 2 L per minute SOT	> 3 apneas/h	Increased compared to baseline and/or > 60 mmHg 6 h after beginning SOT	> 5 or increased by 1 point 6 h after baseline	NR	NR
Kooiman[a] 2023	Paediatric Ward	NR	NR	NR	NR	NR	NR	NR	The treating physician chose the right moment for the escalation of treatment.
Milési[a] 2017	PICU	NR	> 10 bpm compared to baseline, with RR > 60 bpm	NR	> 2 apneas/h requiring bag and mask ventilation	NR	1 point increase compared to baseline	NR	1 point increase in EDIN scale compared to baseline, with EDIN > 4 despite mild sedation

(Continues)

TABLE 1 | (Continued)

Author (Year)	Setting	HR	RR	SpO_2	Apneas	pCO_2	M-WCAS	BROSJOD	Other
CPAP or NIV eligibility (HFNC failure)									
Kepreotes[a] 2017	Paediatric Ward	Red zone HR (age dependent) in standard paediatric observation charts	Red zone RR (age dependent) in standard paediatric observation charts	< 94% with FiO_2 0.6 and flow at 1 L/kg/min	NR	NR	Used only for initial evaluation, not for therapy escalation	NR	NR
Franklin[a] 2018	Paediatric Ward	Unchanged or increased	Unchanged or increased	92%–94% with FiO_2 more than 0.4	NR	NR	NR	NR	Other Early Warning Scores suggestive of escalation of care
Durand[a] 2020	Paediatric Ward	NR	NR	< 94% with FiO_2 0.4 and flow at 3 L/kg/min	> 3 apneas/h	Increased compared to baseline and/or > 60 mmHg 6 h after beginning HFNC	> 5 or increased by 1 point 6 h after baseline	NR	NR
Vahlkvist[a] 2020	Paediatric Ward	NR	NR	NR	NR	NR	Used for initial evaluation and once daily, not declared for therapy escalation	NR	NR
Kooiman[a] 2023	Paediatric Ward	NR	NR	NR	NR	NR	NR	NR	The treating physician chose the right moment for the escalation of treatment.
Aguera[b] 2022	Paediatric Ward	No decrease by more than 10 bpm	No decrease by more than 10 bpm	NR	Any apnea	NR	NR	Not reduced by more than 2 points	NR

(Continues)

TABLE 1 | (Continued)

Author (Year)	Setting	HR	RR	SpO_2	Apneas	pCO_2	M-WCAS	BROSJOD	Other
Oymar[b] 2014	Paediatric Ward	NR	NR	Increased oxygen supply	Recurrent apneas	Increased capillary pCO_2	NR	NR	Severe respiratory distress; retractions, severe wheezing; age < 3 months
Aricò[b] 2023	Paediatric Ward	NR	NR	NR	NR	NR	NR	NR	Clinical signs of a risk for respiratory exhaustion, and severe respiratory distress with or without Respiratory acidosis
Musolino[b] 2024	Paediatric Ward	NR	> 50 bpm and severe dyspnea	< 92% with FiO_2 0.6 at HFNC max flow	NR	NR	NR	NR	P/F < 250 despite high FiO_2 +/− mild hypercapnia (< 50 mmHg)
Milési[a] 2017	PICU	NR	> 10 bpm compared to baseline, with RR > 60 bpm	NR	> 2 apneas/h requiring bag and mask ventilation	NR	1 point increase compared to baseline	NR	1 point increase in EDIN scale compared to baseline, with EDIN > 4 despite mild sedation

(Continues)

TABLE 1 | (Continued)

Author (Year)	Setting	HR	RR	SpO_2	Apneas	pCO_2	M-WCAS	BROSJOD	Other
Sarker[a] 2018	PICU	Unchanged or increased	Unchanged or increased	< 92% with FiO_2 0.6	NR	NR	NR	NR	Clinical sign of exhaustion (RDAI score); need to protect airways and/or copious tracheal secretion; persistent air leak; patient intolerance (CBS or nasal injury); hemodynamic impairment; adverse patient event
Cesar[a] 2020	PICU	NR	NR	NR	NR	NR	NR	NR	Need to escalate support
Borgi[a] 2021	PICU	NR	Increased	≤ 90% with FiO_2 0.6	NR	NR	NR	NR	NR
MV eligibility (CPAP or NIV failure)									
Vahlkvist[a] 2020	Paediatric Ward	NR	NR	NR	NR	NR	Used for initial evaluation and once daily, not declared for therapy escalation	NR	NR

(Continues)

TABLE 1 | (Continued)

Author (Year)	Setting	HR	RR	SpO_2	Apneas	pCO_2	M-WCAS	BROSJOD	Other
Oymar[b] 2014	Paediatric Ward	NR	NR	NR	Severe apneas	High or increasing capillary CO_2	NR	NR	Severe respiratory distress severe retractions, tachypnea > 70/min; poor general condition or discomfort; unstable circulation
Aricò[b] 2023	Paediatric Ward	Not reduced	Not reduced	FiO_2 of up to 0.6 with CPAP of 7.5–8 mBar	Any	NR	NR	NR	Not improved respiratory dynamics
Sarker[a] 2018	PICU	Unchanged or increased	Unchanged or increased	< 92% with FiO_2 0.6	NR	NR	NR	NR	Clinical sign of exhaustion (RDAI score); need to protect airways and/or copious tracheal secretion; persistent air leak; patient intolerance (COMFORT scale or nasal injury); hemodynamic impairment; adverse patient event

(Continues)

TABLE 1 | (Continued)

Author (Year)	Setting	HR	RR	SpO_2	Apneas	pCO_2	M-WCAS	BROSJOD	Other
Cesar[a] 2020	PICU	NR	NR	NR	NR	NR	NR	NR	Need to escalate support
Borgi[a] 2021	PICU	NR	Increased	≤90% with FiO_2 0.6	NR	NR	NR	NR	NR

Abbreviations: bpm, beats per minute (when referred to HR) or breaths per minute (when referred to RR); BROSJOD score, Bronchiolitis Score of Sant Joan de Déu [15]; CBS, COMFORT Behavioural Scale [16]; CPAP, continuous positive airway pressure; EDIN, Échelle de doleur et d'Inconfort du Nouveau né [17]; FiO_2, fraction of inspired oxygen; HFNC, high-flow nasal cannula; HR, heart rate; MV, mechanical ventilation; M-WCAS, Modified Wood Clinical Asthma Score [18]; NIV, non-invasive ventilation; NR, not reported; pCO_2, carbon dioxide partial pressure; PICU, paediatric intensive care unit; RDAI, Respiratory Distress Assessment Instrument [19]; RR, respiratory rate; SOT, standard oxygen therapy; SpO_2, peripheral oxygen saturation.

[a]Randomised Controlled Trial.

[b]Observational study.

rate (HR), respiratory rate (RR), fraction of inspired oxygen (FiO_2) requirements, or work of breathing (WOB), together with blood gas analysis or transcutaneous partial pressure of carbon dioxide (pCO_2) should inform treatment step-up [28, 33]. Recently, emerging approaches based on SpO_2/FiO_2 as a proxy for PaO_2/FiO_2 as ROX (Respiratory rate–OXygenation) index [$(SpO_2/FiO_2)/RR$] have been proposed to monitor respiratory support in bronchiolitis, but current data on the heuristic value of this formula are conflicting [34, 35].

3.2 | Patient Outcomes and Safety

Several RCTs have examined the use of HFNC for bronchiolitis in Paediatric wards, suggesting that this support should be used as a rescue therapy where SOT fails. Conversely, HFNC holds no significant advantages over SOT when used as first-line support [6, 7, 20, 36].

A recent meta-analysis shows that CPAP and NIV were superior to HFNC in avoiding IMV for bronchiolitis even if conclusive evidence is still lacking [37, 38].

Most RCTs examining CPAP for bronchiolitis have been conducted in PICUs with only one RCT comparing the two methods in a paediatric ward [16, 24, 39–42]. Although some of these trials suggest that CPAP may be superior to HFNC, the evidence is not conclusive [16, 24, 38–40]. Only a handful of studies have examined the effectiveness, tolerability, and safety of CPAP and NIV when implemented in general paediatric wards (Table 2), with promising results. For example, in the study from Oymar et al. 7.9% of the infants required CPAP, with an extremely low IMV rate (0.4%), and 62% were successfully treated with CPAP in the ward without PICU referral [12]. Similarly, Aguera et al. reported that 56% of infants treated with CPAP did not require PICU transfer [11]. Patients responding favourably to CPAP displayed lower HR and RR at the beginning of CPAP and, remarkably, lower HR, RR, Bronchiolitis Score of Sant Joan de Déu (BROSJOD) score, and FiO_2 60 min from initiation compared to non-responders [11, 23]. Moreover, a pre/post comparison showed reduced PICU admissions after the introduction of CPAP without changes in IMV rates [11]. Along the same lines, Musolino et al. safely implemented CPAP in moderate-to-severe bronchiolitis, avoiding PICU admission in 85% of cases with relevant cost reduction [19]. Interestingly, data on CPAP and NIV from resource-limited countries (RLCs) align with findings from the European Union (EU). However, the use of CPAP in RLCs appears to be strictly context-dependent, requiring dedicated areas and adequate staff resources [43–45].

Overall, the implementation of CPAP in paediatric wards appears to be associated with favourable outcomes, provided adequate staffing is available and close monitoring is ensured [11, 12]. Conversely, the risk of procrastinating on the use of IMV in severe cases remains a relevant issue. When using CPAP in the ward, the availability of a prompt referral to the PICU should be mandatory.

Much less is known about using NIV for bronchiolitis outside PICUs. While NIV equipment may be readily available,

TABLE 2 | Efficacy and safety end-points among studies.

Author (Year)	Setting (nurse: patient ratio)	Type of respiratory support	Patients [*n*]	Treatment failure [*n* (%)]	Crossover	PICU transfer [*n* (%)]	IMV [*n*]	Length of respiratory support [hours]	Length of hospital stay [days]	Air leak [*n*]	Other adverse events [*n*]	Mortality [*n*]
Kepreotes[d] 2017	Paediatric Ward (NR)	SOT	101	33 (32.7)	32 (to HFNC)	13 (12.9)	NR	1 (0.8–1.2)[b]	2 (1–3)[b]	0	2 (circuit disconnection)	0
		HFNC	101	14 (13.8)	0	13 (12.9)	NR	0.8 (0.8–1.3)[b]	2 (1–3)[b]	0	2 (circuit disconnection, condensed inhalation)	0
Franklin[d] 2018	Paediatric Ward (NR)	SOT	733	167 (22.8)	167 (to HFNC)	65 (8.9)	4	1.9 (2.1)[a]	2.94 (2.7)[a]	1	3 (apneas)	0
		HFNC	739	87 (11.8)	0	87 (11.8)	8	1.8 (2.2)[a]	3.12 (2.4)[a]	1	3 (apneas)	0
Durand[d] 2020	Paediatric Ward (NR)	SOT	135	27 (20)	NR	26 (19.3)	0	2.5 (2)[a]	3.8 (2.7)[a]	0	0	0
		HFNC	133	19 (14.3)	NR	21 (15.7) (9 patients underwent HFNC in the PICU)	0	1.7 (1.7)[a]	4.4 (2.4)[a]	3	0	0
Kooiman[d] 2023	Paediatric Ward (NR)	SOT	52	NR	2 (to HFNC)	6 (11.5)	6	2.9 (2–5.2)[b]	4.8 (2.9–7.9)[b]	0	0	0
		HFNC	55	NR	0	8 (14.5)	8	3.3 (2.3–4.9)[b]	4.2 (3.7–6.4)[b]	0	0	0
Vahlkvist[d] 2020	Paediatric Ward (NR)	HFNC	22	2 (9.1)	2 (to CPAP)	0	NR	NR	NR	NR	NR	NR
		CPAP	28	4 (14.3)	2 (to HFNC)	2 (7.1)	NR	NR	NR	NR	NR	NR

(Continues)

TABLE 2 | (Continued)

Author (Year)	Setting (nurse: patient ratio)	Type of respiratory support	Patients [*n*]	Treatment failure [*n* (%)]	Crossover	PICU transfer [*n* (%)]	IMV [*n*]	Length of respiratory support [hours]	Length of hospital stay [days]	Air leak [*n*]	Other adverse events [*n*]	Mortality [*n*]
Milési[d] 2017	PICU (NR)	HFNC	71	36 (50.7)	36 (to HFNC, among these 7 needed further NIV, and 1 HFNC with increased flow)	N/A	2	4.1 (4.2)[a]	6.2 (6)[a]	0	2 (skin lesions)	0
		CPAP	71	22 (31)	22 (to HFNC; among these 3 needed further NIV and 1increased flow of HFNC)	N/A	0	3 (1.9) [#]	7.5 (13)[a]	0	6 (skin lesions)	0
Sarkar[d] 2018	PICU (NR)	HFNC	15	1 (6.7)	No	N/A	1	3.6 (0.36)[a]	5 (1.6)[a]	0	4 skin lesions	0
		CPAP	16	1 (6.3)	No	N/A	1	3.8 (0.8)[a]	5 (1.8)[a]	0	12 skin lesions	0
Cesar[d] 2020	PICU (NR)	HFNC	35	13 (37.1)	No	N/A	7	2.8 (0.6–3.4)[b]	9 (7–12)[b]	0	0	0
		CPAP	28	10 (35.7)	No	N/A	3	2.3 (1–3)[b]	8 (7–12)[b]	0	0	0
Borgi[d] 2021	PICU (NR)	HFNC	130	64 (49.2)	64 (to CPAP/NIV)	N/A	29 (22.3)	NR	5.9 (4.1)[a]	0	3 abdominal distension	0
		CPAP/NIV	125	37 (29.6)	0	N/A	37 (29.6)	NR	6.7 (5.6)[a]	2	10 abdominal distension	1
Oymar[c] 2014[d]	Paediatric Ward (1:2)	CPAP	46	13 (28.3)	N/A	13 (28.3)	2	1 (0.3–1.8)[b]	7 (5–8)[b]	NR	NR	NR
Aguera[c] 2022	Paediatric Ward (1:6)	CPAP	57	25 (43.9)	N/A	25 (43.9)	12	2.2 (0.5–4)[b]	9 (7–13)[b]	0	0	0

(Continues)

TABLE 2 | (Continued)

Author (Year)	Setting (nurse: patient ratio)	Type of respiratory support	Patients [*n*]	Treatment failure [*n* (%)]	Crossover	PICU transfer [*n* (%)]	IMV [*n*]	Length of respiratory support [hours]	Length of hospital stay [days]	Air leak [*n*]	Other adverse events [*n*]	Mortality [*n*]
Aricò[c] 2023	Paediatric Ward (1:6)	CPAP	16	3 (18.8)	N/A	3 (18.8)	1	4 (2.3)[a]	6.4 (2.7)	NR	NR	1
Musolino[c] 2024	Paediatric Ward (NR)	H-CPAP	26	4 (15)	N/A	4 (15)	4	72 (CPAP)[b]	NR	0	2. Bradycardia due to sedation	0

Abbreviations: CPAP, continuous positive airway pressure; H-CPAP, Helmet CPAP; HFNC, high-flow nasal cannula; IMV, invasive mechanical ventilation; N/A, not applicable; NIV, non-invasive ventilation; NR, not reported; PICU, paediatric intensive care unit; SOT, standard oxygen therapy.

[a]Mean (standard deviation).

[b]Median (range).

[c]Observational study.

[d]Randomised Controlled Trial.

challenges may include selecting the appropriate ventilator and interface, together with managing leaks. However, NIV represents a further escalation of care in the event of CPAP failure, particularly in patients with high pCO_2. In these instances, strict observation of the patient should be mandatory if exacerbated symptoms require prompt admission to the PICU.

3.3 | Resource Utilisation

CPAP and NIV are increasingly used in PICUs for infants with bronchiolitis, with only a small percentage of patients requiring IMV [8, 18]. Notably, a remarkable increase in CPAP and NIV use for bronchiolitis in US PICUs between 2010 and 2019 (1.2%–9.5%) has been documented, with similar trends noted in Europe [8, 18]. These respiratory supports are traditionally believed to be best resolved in the PICU, mostly due to staff expertise, higher personnel-to-patient ratio, and availability of IMV. However, CPAP and NIV use is expanding beyond PICUs. A recent European survey reported a use of NIV in Paediatric wards, emergency departments, and intra-hospital transport of 15.5%, 20%, and 36.4%, respectively [8]. Studies suggest that CPAP and NIV may be effectively used for treating bronchiolitis in these settings, given proper training is ensured [11–14]. In the UK, 57% of the Paediatric wards surveyed stated they were capable of providing CPAP support [46].

However, hospitals may have either Paediatric High Dependency Units (PHDUs) or PHDU beds in standard units dedicated to children requiring enhanced monitoring and interventions [47]. According to Turnham et al. CPAP was more likely to be administered in PHDU or PICU as compared to the paediatric ward in tertiary-care centres (16%), while it was more frequently used in the wards of general hospitals (56.9%) [17].

Given the widespread use of HFNC in the wards and studies showing comparable safety for HFNC and CPAP, using CPAP and maybe even NIV outside PICUs could be worth consideration [24, 41]. Portable ventilators may enable the use of CPAP and NIV in the wards, offering enhanced respiratory support compatible with ward resources. Moreover, this approach could already be standard of care in some centres, as reported by recent UK data where HFNC and CPAP usage in the wards for bronchiolitis ranged between 0%–40% and 0%–24%, respectively [46]. A parallel survey reported the use of HFNC and CPAP in general wards as high as 91% and 58%, respectively, out of 76 hospitals involved, whereas PHDUs' capability for HFNC and CPAP was 100% and 89%, respectively [46].

Observational studies confirm the feasibility of ward-based CPAP. Aguera et al. introduced CPAP as a rescue therapy for HFNC failure in a paediatric ward with a nurse–patient ratio of 1:6, with results similar to those from Oymar et al. where the ratio was 1:2 [11, 12]. In both cases, CPAP was used in the ward of tertiary centres where PICU transfer was readily available, as in the sample described by Musolino et al. [19] Conversely, Arico et al. safely deployed CPAP in a secondary level paediatric ward relying on specific training and periodic refresher sessions with nurse–patient ratios adjusted flexibly

(1:6 to 1:4) based on patient needs [13]. Furthermore, the doctor–patient ratio may also play a role in defining the feasibility of safely using CPAP in paediatric wards. However, this aspect was specified only in the paper from Oymar et al. where the ratio was 3:11 during days and 2:11 during nights and weekends [12].

Effective CPAP and NIV implementation in the wards calls for formal staff training. Rosala-Hallas et al. stressed the importance of regular in-house training coupled with ad hoc training sessions and high-dependency courses [46]. Similarly, most of the abovementioned studies provided specific training for staff members involved, providing clear criteria for both CPAP inception and PICU referral [12, 19].

While some pre-existing skills in managing CPAP/NIV devices may serve as a foundation, they cannot replace a formal training programme, provided that adequate staffing resources and dedicated areas with enhanced monitoring are ensured.

3.4 | Cost Analysis

Over the past two decades, hospitalisations for bronchiolitis in the US have decreased substantially [2, 3]. However, this decline is matched by a 5.8-fold rise in use of NIV, traditionally deployed in PICUs and translating into higher costs [9, 48, 49].

For instance, in the US, the median cost of a single bronchiolitis hospitalisation rose from $5636 in 2010 to $6973 in 2019, mainly attributed to increased PICU admission (12.4%–26.9%) [48]. Despite lower admission rates, total costs for bronchiolitis hospitalizations in the US surged from $ 449 to $ 734 million between 2003 and 2016 [3]. PICU care is significantly more expensive than ward-based treatment for bronchiolitis, with estimated costs up to 4 times higher [50]. HFNC, on the other hand, if used as rescue for SOT failure, is a cost-effective respiratory support to be safely carried out in the ward, reducing PICU admissions [51]. Conversely, an "HFNC for all" initial approach to respiratory failure in bronchiolitis is unlikely to be cost-saving when compared to a "rescue" approach [6, 52]. On the other hand, data about the direct impact on hospital costs of a ward-based adoption of CPAP and NIV for bronchiolitis are lacking.

Currently, initiating these latter supports mostly coincides with the admission to the PICU, which calls for higher costs [48, 49]. The existing studies describing the use of CPAP and NIV outside PICUs often lack cost analyses or are not sufficiently powered to document any relevant differences in the hospital LOS after CPAP or NIV introduction [11–14, 16]. However, the only available data are rather encouraging, showing a median reduction in the costs per patient of EUR 6687 after the deployment of CPAP in the ward [19].

Well-equipped and adequately staffed areas in the wards may offset some PICU admissions, but could introduce costs exceeding those for the average ward beds. However, reducing PICU admissions may help reserve PICU beds for only the most severe cases, and providing a gradual step-up approach to respiratory support could optimise resource allocation and impact the cost of consumables.

4 | Starting Settings, Monitoring, and Weaning

Clear initial settings for HFNC in bronchiolitis remain undefined despite limited variations among the existing studies (Table 3). Still, several papers suggest that specific criteria for HFNC management are highly subjective and that a protocol-based approach to this support could result in shorter LOS [30, 31].

The current literature supports starting HFNC with an initial maximal flow of 2 L/kg/min, titrating FiO_2 up to 50% to obtain SpO_2 between 92%–97%. Gas temperature should be set between 34°C and 37°C to guarantee proper humidification [53]. Figure 1 summarises the HFNC settings and compares these to those for CPAP and NIV. Response to HFNC should be ascertained clinically within 60–90 min of initiation, including improvement in respiratory distress, FiO_2, HR, and RR. Weaning should be gradual, prioritising FiO_2 reduction to room air followed by abrupt suspension of airflow [53].

Guidelines for CPAP and NIV starting settings, monitoring, and weaning in bronchiolitis are also lacking (Table 3) with these supports mostly conceived as rescue for patients unresponsive to HFNC. Thus, criteria for HFNC failure as persistent respiratory distress and unsatisfactory SpO2, may guide CPAP inception, as noted previously (Table 1). Interestingly, Rosala-Hallas et al. pointed out that there is limited variability among paediatric hospitalists in criteria for initiation and weaning of CPAP and NIV for bronchiolitis, even in the absence of stated guidelines [46]. Similarly, starting settings appear to be relatively consistent throughout both scientific literature and clinical practice (Table 3).

Starting CPAP at 7 cmH_2O is widely accepted in patients with bronchiolitis with respiratory failure, regardless of weight and age [54]. This pressure results in the greatest relief of the respiratory muscles and improvement of WOB, while higher pressures (up to 10 cmH_2O) appear to be less effective, probably because of the greater effort to overcome the gastric distension [54]. NIV is most appropriate for patients with type 2 respiratory failure (hypercapnic) with initial inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP) of 8–10 cmH_2O and 5–7 cmH_2O, respectively [55]. These can be increased up to IPAP of 12–15 cmH_2O and EPAP of 8–10 cmH_2O, as tolerated and needed [55]. Figures 1 and 2 depict illustrations of what may be reasonable guidelines for the safe use of HFNC, CPAP, and NIV in a paediatric ward.

Monitoring in the initial hours from inception is pivotal for CPAP and NIV success. Clinical evaluation is critical, while pCO_2 measures (either with arterial and capillary blood gases or through noninvasive transcutaneous pCO_2) may play a role. A pH $< 7.25–7.30$ and a $pCO_2 > 55–60$ mmHg seem to represent valuable predictors for an escalation of care [55].

Weaning practices have been poorly investigated except for newborns [56]. A recent PICU-based multicentre study found sudden

TABLE 3 | Starting settings and weaning protocols among studies.

Author (Year)	Setting	Device	Starting		Weaning	
			FiO_2	Flow or pressure	FiO_2	Flow or pressure
HFNC						
Kepreotes[b] 2017	Paediatric Ward	MR850 humidifier with Optiflow Junior nasal cannula	0.6	1 l/kg/min (max 20 L/min)	3 h after stabilisation, start reducing the flow by a quarter of the initial value, continue hourly if the patient remains stable	Constant flow until FiO_2 achieved room air, then stopped without progressive weaning
Franklin[b] 2018	Paediatric Ward	Optiflow system with age-appropriate Optiflow Junior cannula and the Airvo 2 high-flow system	Adjusted to obtain SpO_2 92%–98%	2 l/kg/min	Weaning of FiO_2 to room air (0.21) was permitted at any time to provide the lowest FiO_2 for SpO_2 of at least 92%	Stopped after 4 h of FiO_2 0.21 with SpO_2 above 92%
Durand[b] 2020	Paediatric Ward	Airvo 2 turbine through Optiflow junior infant size cannula	Adjusted to obtain $SpO_2 \geq 94\%$	3 l/kg/min (max 20 l/min)	NR	Reducing the flow rate by 2 L/min increments every 8 h starting at hour 12 and When FiO_2 could be reduced to ≤ 25%
Vahlkvist[b] 2020	Paediatric Ward	Optiflow system with Age-appropriate Optiflow Junior cannula	Adjusted to obtain $SpO_2 \geq 92\%$	2 l/kg/min (max 15 L/min)	NR	NR
Kooiman[b] 2023	Paediatric Ward	Optiflow system or Airvo 2 high-flow system	Started at 1 and reduced to 0.4–0.6 within 2 h, maintaining $SpO_2 \geq 94\%$	≤ 10 kg: 2 l/kg/min > 10 kg: 20 l/min +0.5 L/min for each kg above	NR	NR
Milési[b] 2017	PICU	Optiflow	Titrated to obtain SpO_2 94%–97%	2 l/kg/min (pressure release valve set at 45 cmH_2O)	NR	NR
Sarkar[b] 2018	PICU	Airvo 2 high-flow system with large-bore nasal prongs	Adjusted to obtain $SpO_2 \geq 94\%$	≤ 10 kg: 2 l/kg/min > 10 kg: 20 l/min +0.5 l/min for each kg above	NR	NR

(Continues)

TABLE 3 | (Continued)

Author (Year)	Setting	Device	Starting		Weaning	
			FiO_2	Flow or pressure	FiO_2	Flow or pressure
Cesar[b] 2020	PICU	Precision Flow Vapotherm with a nasal cannula sized to occlude no more than 50% cross-sectional area of the nostrils	Adjusted to obtain $SpO_2 \geq 94\%$	Titrated up to 1.5 l/kg/min	NR	NR
Borgi[b] 2021	PICU	Optiflow system with Cannula fitting the child's nares without occlusion	The lowest to maintain SpO_2 of 94%	Maximum flow rate for the size of the cannula (6–7 L/min)	Adjusted to maintain SpO2 of 94%	When $FiO_2 < 30\%$, decrease flow by 1 l/min every 2 h if there is no increase of WOB
CPAP						
Vahlkvist[b] 2020	Paediatric Ward	Binasal prong with a Benveniste valve connected to a humidifier	Adjusted to obtain $SpO_2 \geq 92\%$	12–14 L/min (max 15 l/min)	NR	NR
Aguera[a] 2022	Paediatric Ward	Bubble CPAP Fisher Paykel with a nasal mask	Adjusted to maintain SpO_2 93%–97%	Initially set at 5 cmH_2O and progressively increased to a minimum of 7 cmH_2O	NR	NR
Oymar[a] 2014	Paediatric Ward	CPAP GoodKnight 420E with two different nasal masks with leaks (ProfileLite Small Child or Infant Bubble Mask)	100% oxygen into the circuit as needed to keep the SpO_2 within the accepted limit	5 cm H_2O	NR	NR
Musolino[a] 2024	Paediatric Ward	Starmed Castar (Intersurgical Wokingham, UK) Helmet–CPAP	Adjusted to obtain SpO_2 93%–97%	Initially set at 5 cmH_2O and progressively increased to 7.5 cmH_2O	NR	NR
Aricò[a] 2023	Paediatric Ward	Fabian Therapy evolution SW 4.0 nasal CPAP device with a nasal interface and an Infant Flow SiPAP device	Initially 0.3, then titrated to maintain SpO2 92%–97%	5 mbar, which was increased up to 6.5–7 mbar	NR	NR
Milési[b] 2017	PICU	Infant Flow Ventilator or FlexiTrunk infant interface connected to the ventilator	Titrated to maintain SpO_2 94%–97%	7 cmH_2O	NR	NR
Sarkar[b] 2018	PICU	SERVO-i with nasal prongs or mask fitted for minimum leak and maximum comfort	Adjusted to obtain $SpO_2 \geq 94\%$	4 cmH_2O (max 8 cmH_2O)	NR	NR

(Continues)

TABLE 3 | (Continued)

Author (Year)	Setting	Device	Starting		Weaning	
			FiO_2	Flow or pressure	FiO_2	Flow or pressure
Cesar[b] 2020	PICU	Drager Evita 4 ventilator with soft anatomically curved nasal prongs	Adjusted to obtain $SpO_2 \geq 94\%$	6 cmH_2O		
Borgi[b] 2021	PICU	Babylog 2000	The lowest to maintain SpO_2 of 94%	6 cmH_2O (max 8 cmH_2O)	Adjusted to maintain SpO_2 of 94%	Started if PEEP < 6 cmH_2O and $FiO_2 < 0.3$ for at least 6 h and decreased by 1 cmH_20 every 6 h
NIV						
Borgi[b] 2021	PICU	Babylog 2000	The lowest to maintain SpO_2 of 94%	PIP 20 cmH_2O (max 30 cmH_2O) PEEP 8 cmH_2O Freq 35 cycles/min Insp time 0.7 s	Adjusted to maintain SpO_2 of 94%	Started if no increased WOB and $FiO_2 < 0.3$ for at least 6 h and decreased PIP by 5 cmH_2O every 2 h to reach 20 cmH_2O, then PEEP decreased by 1 cmH_2O/h to reach 5 cmH_2O, then passed to CPAP weaning criteria.

Abbreviations: CPAP, continuous positive airway pressure; FiO_2, fraction of inspired oxygen; HFNC, high-flow nasal cannula; NIV, non-invasive ventilation; NR, not reported; PEEP, positive end-expiratory pressure; PICU, paediatric intensive care unit; PIP, positive inspiratory pressure; SpO_2, peripheral oxygen saturation; WOB, work of breathing.
[a]Observational study.
[b]Randomised Controlled Trial.

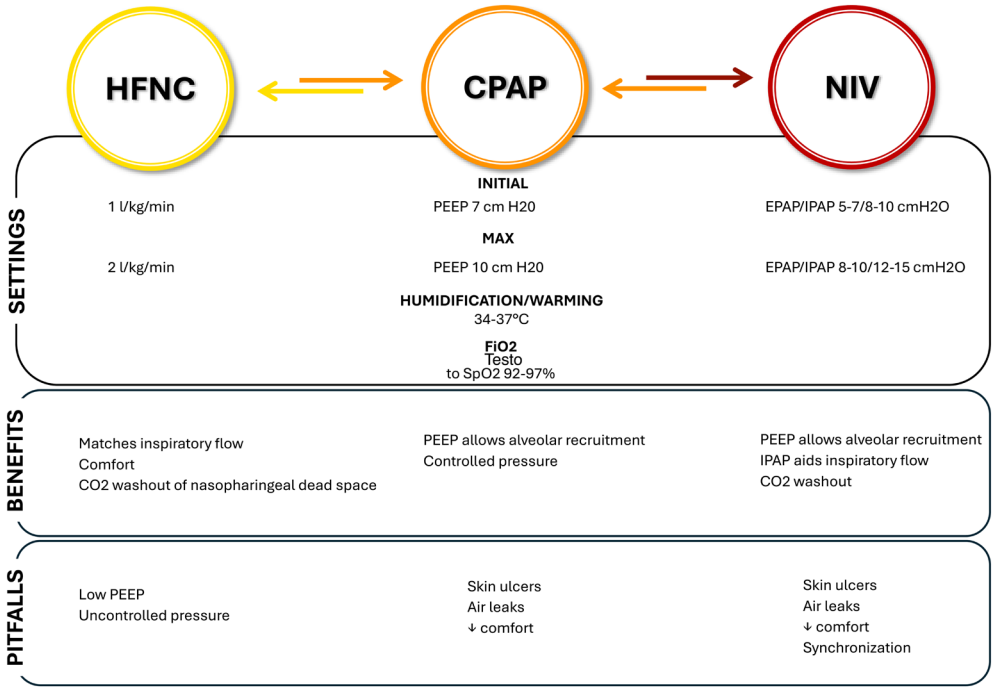

FIGURE 1 | Initial settings for respiratory support in the paediatric wards. CPAP, Continuous positive airway pressure; EPAP, Expiratory positive airway pressure; FiO_2, Fraction of inspired oxygen; HFNC, High-flow nasal cannula; IPAP, Inspiratory positive airway pressure; NIV, Non-invasive ventilation; PEEP, Positive end-expiratory pressure; SpO_2, Peripheral oxygen saturation.

weaning as the preferred approach, regardless of the type of respiratory support used [57]. This approach might significantly reduce the hospital LOS, but only if this does not lead to an increased weaning failure rate. Weaning was mostly guided by clinical parameters as respiratory distress and FiO_2, with only a low proportion of survey respondents (10%) using severity scores [57]. Further, an international consensus emphasised the importance of tailored and clinically guided weaning protocols. Key factors to be taken into consideration include improved RR, respiratory distress, and FiO_2 requirements [58]. Protocolised weaning may enhance outcomes by reducing variability among providers [58].

Despite the lack of methodologically rigorous, well-powered studies, the overall approach to starting and weaning NIV in the PICU shows broad consistency, highlighting the need for standardised protocols [42, 46, 57]. Trials should focus on unifying the existing approaches to CPAP and NIV initiation and weaning, fostering more evidence-based care.

Assessment of interface tolerance is particularly critical during the initial hours of non-invasive support. Most of the studies included in our review address agitation using non-pharmacological strategies (such as pacifier use or sucrose administration) with generally positive outcomes. In selected cases, pharmacological sedation (e.g., single-dose levomepromazine or a 10-min bolus of dexmedetomidine at 0.25 mcg/kg) may be considered [11, 19, 59]. Sedation strategies have been more extensively studied in PICU settings; however, a detailed analysis of sedation protocols lies beyond the scope of this review.

4.1 | Future Directions

While the use of CPAP or NIV in Paediatric wards seems to be feasible, more needs to be done to better define its role in bronchiolitis. Shared protocols to standardise HFNC use may help to better define guidelines for NIV initiation, titration, and monitoring. Moreover, the choice of clinically relevant outcomes, as those specific for bronchiolitis described by Rosala-Hallas et al. should not be overlooked as it can provide a foundation for conducting future trials [60]. Future research should prioritise reducing PICU admissions, IMV need, and hospital LOS, since these benchmarks may better represent the effectiveness of respiratory interventions and favourably impact healthcare costs. Once the effectiveness of NIV in infants with bronchiolitis is better clarified, additional data are needed to support the wide use of such respiratory devices in paediatric general units. Table 4 briefly summarises the issues that need to be addressed for the field of respiratory support in infants with bronchiolitis to advance.

5 | Conclusions

The use of CPAP and NIV in Paediatric wards for infants with bronchiolitis seems to carry limited safety concerns according to the scarce existing literature. However, there is still no definitive evidence favouring CPAP over HFNC, nor is there conclusive guidance on the initiation, titration, monitoring, and weaning of respiratory support, regardless of the care setting. Therefore, methodologically rigorous multicentre RCTs are needed to further clarify the role of CPAP and NIV in bronchiolitis. Such studies can contribute to establishing unified

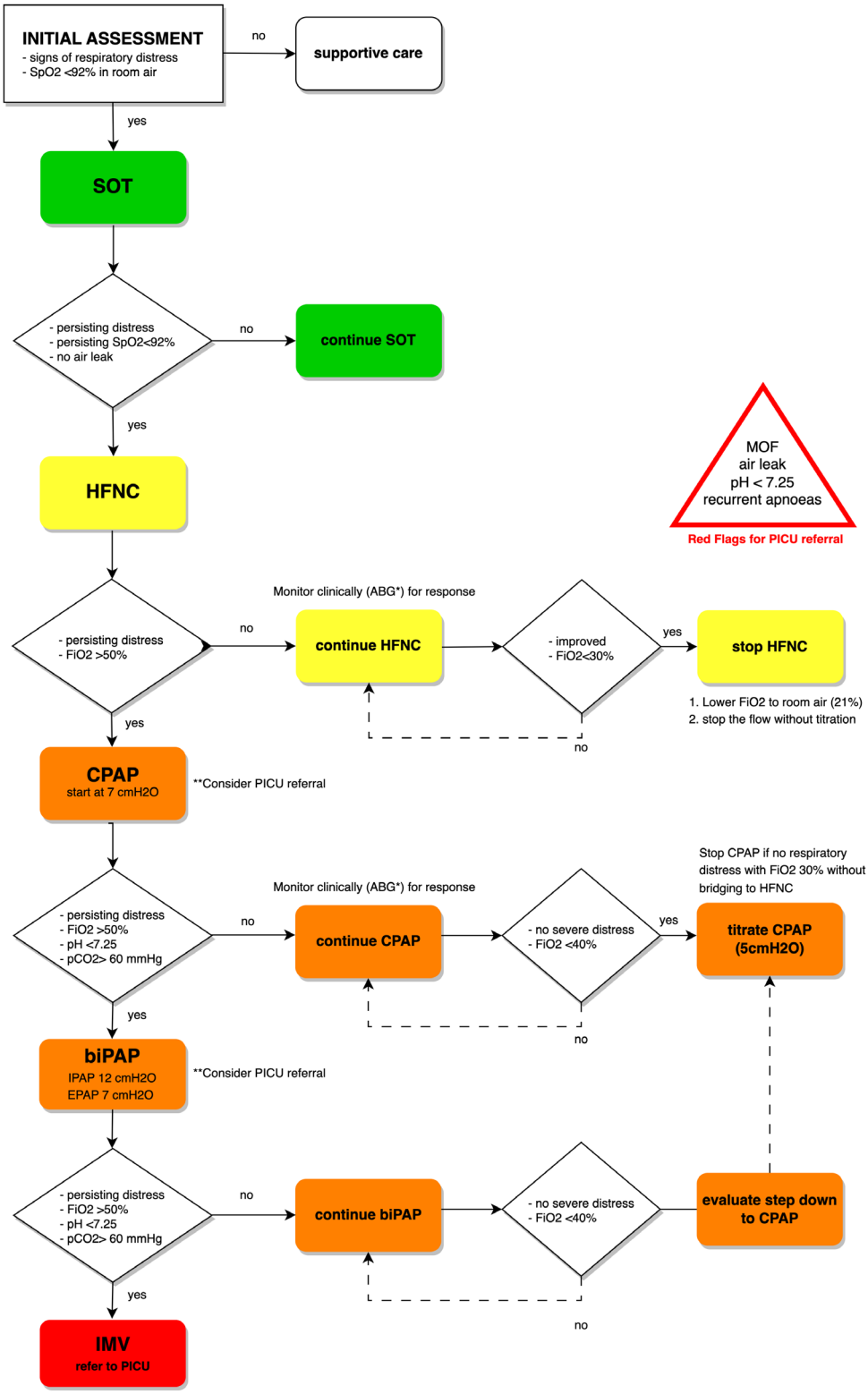

FIGURE 2 | Flow chart proposal for the safe use of HFNC, CPAP, and NIV in a paediatric ward. CPAP, Continuous positive airway pressure; FiO_2, Fraction of inspired oxygen; HFNC, High-flow nasal cannula; MOF, Multi-organ failure; NIV, Non-invasive ventilation; SOT, Standard oxygen therapy; SpO_2, Peripheral oxygen saturation. Solid arrows indicate the forward progression of the flowchart, while dashed arrows represent a return to previous steps in the absence of clinical improvement.

protocols for respiratory support in infants across diverse paediatric settings. In the meantime, the studies reviewed suggest that CPAP and NIV can be considered as respiratory rescue supports for patients who do not respond to HFNC, potentially reducing respiratory distress. Adequately skilled and trained personnel together with highly monitored areas and

TABLE 4 | Key points that need to be addressed to improve knowledge about respiratory CPAP and NIV implementation in the general paediatric ward for respiratory support in bronchiolitis.

- Eligibility criteria:
  - Standardise criteria for defining therapeutic failure
  - Identify the clinical score that adequately correlates with therapeutic failure
  - Identify a score that correlates with the appropriate mode of respiratory support
  - Identify a score that correlates with the appropriate setting of care
- Patient outcomes and safety
  - Standardise outcomes among studies
  - Standardise the adverse events of respiratory support
  - Implement psychometrically reliable and valid instruments
  - Evaluate CPAP and NIV outcomes, comparing different settings of administration
- Resource utilisation
  - Investigate the types of respiratory support used in the wards
  - Investigate the training needs of the wards' clinical staff
- Cost analysis
  - Evaluate the costs of consumables
  - Comparing indirect costs between PICU and paediatric wards
- Starting settings, monitoring, and weaning
  - Develop guidelines for starting setting, titration, monitoring, and weaning
  - RCT comparing different starting settings, titration, monitoring, and weaning protocols

the possibility of quick PICU referral should be mandatory requirements to fully endorse a medically sound use of NIV for bronchiolitis in general Paediatric wards.

Author Contributions

Conceptualisation, M.L., L.P., and G.S.; methodology, L.P., A.D., and G.S.; resources, M.L., C.B.; writing – original draft preparation, G.S. and L.P.; writing – review and editing, G.S., L.P., A.D., C.B., L.M.S., and M.L.; supervision, M.L. All authors have read and approved the final version of the manuscript.

Ethics Statement

The authors have nothing to report.

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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