

REVIEW

High-flow nasal cannula weaning protocols in children: A narrative review

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Mejora de calidad**Abstract**

High-flow nasal cannula (HFNC) therapy is a widely used non-invasive respiratory support system for pediatric acute respiratory failure (ARF), both within and outside pediatric intensive care units (PICUs). Despite its widespread adoption over the past decade, studies have highlighted its overuse in terms of indications and duration, contributing to increased hospital costs and diminished care value. One strategy to reduce HFNC overutilization is the implementation of weaning protocols tailored to specific contexts. This review examines the pediatric literature on HFNC weaning protocols published up to December 2023. It identifies nine pediatric HFNC weaning protocols applied in PICUs, with two also used in general pediatric wards. In 4/10 studies, protocols were led by physiotherapists, while in 6/10, all healthcare professionals participated. Most studies involved patients with ARF as the main cause of hospitalization. Protocol implementation was associated with reductions in HFNC exposure time, PICU stays, and overall length of stay. All protocols were considered safe, with no major complications reported. Implementation of HFNC weaning protocols, both within and outside PICUs, appears to be a safe strategy for reducing HFNC overuse in pediatric hospital settings.

**PROTOCOLOS DE RETIRO DE CÁNULA NASAL DE ALTO FLUJO EN NIÑOS:
UNA REVISIÓN NARRATIVA****Resumen**

Las cánulas nasales de alto flujo (CNAF) son un sistema de soporte respiratorio no invasivo (SRNI) muy utilizado en Pediatría para el sostén del fallo respiratorio agudo (FRA), tanto fuera como dentro de unidades de cuidados intensivos pediátricos (UCIP). Diversos estudios han mostrado evidencia de uso excesivo de CNAF (sobreuso), lo que aumenta los costos hospitalarios y disminuye la calidad de atención. Una estrategia para reducir este sobreuso es implementar protocolos de retiro de CNAF adaptados a cada contexto. La presente revisión examina la literatura pediátrica disponible sobre estos protocolos hasta diciembre de 2023. Identificamos nueve protocolos aplicados en UCIP y dos también en salas generales de pediatría. En algunos estudios, fisioterapeutas lideraron la implementación, mientras que en otros participaron todos los profesionales sanitarios participantes de la atención. La mayoría de los estudios incluyeron pacientes con FRA como causa principal de admisión. La implementación de estos protocolos se asoció a una disminución del tiempo de uso de CNAF, así como de estancia en UCIP y hospitalaria. Todos los protocolos se comprobaron como seguros y no se reportaron complicaciones graves tras su implementación. Concluimos que la implementación de protocolos de retiro de CNAF, tanto dentro como fuera de UCIP, es una estrategia segura que se asociaría a reducción de sobreuso de CNAF en ámbitos hospitalarios.

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INTRODUCTION

High-flow nasal cannula (HFNC) is a method of non-invasive respiratory support (NIRS) that delivers inspiratory gas via the nasal route, with or without added oxygen, heated and humidified and provided at supra-physiological flow rates (≥ 1 L/kg/min for patients weighing up to 10 kg or ≥ 10 L/min for those over 10 kg)⁽¹⁾. Although the precise significance of its proposed mechanisms of action—such as washing out carbon dioxide from the nasopharyngeal dead space and generating positive airway pressure—is not fully understood, HFNC has been widely adopted in hospitals worldwide as a key tool in managing acute respiratory failure (ARF), both within and outside pediatric intensive care units (PICUs)⁽²⁾. Its widespread acceptance is attributed to reported clinical benefits, including reduced work of breathing and the comfort of the technique⁽³⁻⁷⁾.

The clinical adoption of HFNC in pediatrics preceded robust evidence of efficacy for most indications, driven by promising results from observational studies and shifts in institutional practices⁽⁸⁾. However, several meta-analyses of controlled clinical trials indicate that while HFNC appears superior to conventional oxygen therapy, it demonstrates similar effectiveness to other traditional NIRS methods, such as CPAP, in preventing invasive mechanical ventilation (IMV) in children with moderate-to-severe acute lower respiratory infection (ALRI)⁽⁹⁻¹²⁾. Many authors have pointed out that the widespread use of HFNC may lead to increased hospitalization costs, due to the overuse of this technique in children with ALRIs. HFNC may be less cost-effective than more traditional methods, such as CPAP^(12,13). Additionally, concerns have been raised about its environmental impact, particularly the carbon emissions associated with its increased use⁽¹⁴⁾. The rise in hospital costs is associated with prolonged hospital stays and higher overall expenses, a phenomenon well-documented outside PICUs⁽¹⁵⁾.

In an effort to reduce overuse and optimize the use of this therapeutic resource in the PICU, multiple guidelines have been developed to focus on optimizing the initiation of HFNC in children with ARF outside the PICU⁽¹⁶⁻¹⁹⁾. However, the weaning of HFNC is typically left to the discretion of the clinicians who initiated it, and protocols for its weaning have been less well developed. For example, a 2020 survey of 176 pediatric intensive care physicians from 36 centers conducted by Suzanne et al. found that only 10% of pediatric centers had a written weaning protocol⁽²⁰⁾. Moreover, the literature on this topic is fragmented, and no reviews are available to consolidate the knowledge in this area. This is particularly relevant, as it could facilitate the development of new protocols for the weaning of this costly resource.

The objective of this review was to compare and contrast the available published research on the use of HFNC weaning protocols in children with ARF. To achieve this, we conducted a literature search for articles in English or Spanish, covering the entire range of bibliometric databases up to December 2023, using the following resources: PubMed/Medline, Google Scholar, CINAHL, Scopus, and SciELO. We identified relevant studies by combining terms and synonyms related to HFNC/CNAF, weaning protocols, pediatrics, and included MeSH (Medical Subject Headings) terms where available. Ad-

ditional publications were manually selected by the authors from the articles initially identified during the first review. We excluded grey literature, case reports, editorials, and studies involving populations older than 21 years.

HFNC WEANING PROTOCOLS IDENTIFIED

The search yielded a total of twelve articles of which nine met the selected search criteria and were analyzed in full. [Table 1](#) presents the main characteristics of the selected articles.

TYPES OF STUDIES AND COMPARATIVE INTERVENTIONS

The majority (8 out of 9) of the protocols reported and analyzed in the present review were quality improvement projects⁽²¹⁻²⁸⁾. Only Udurgucu et al. conducted a prospective observational study analyzing the application of two weaning protocols and comparing their outcomes⁽²⁹⁾. No controlled clinical trials were identified. In three studies, the weaning protocol was part of a broader initiative aimed at optimizing the indication, escalation, and weaning of HFNC. Wiser et al., Huang et al., and Peterson et al. described the effects of these initiatives; however, isolating the specific impact of the weaning protocol remains challenging^(22,23,26). Nevertheless, consistent benefits were reported, including a reduction in the duration of HFNC exposure.

POPULATIONS AND CLINICAL SCENARIOS STUDIED

It is noteworthy that the majority (5/9) of the protocols were studied in young children under 24 months of age with a diagnosis of ALRI, primarily acute bronchiolitis^(23,24,26-28). In three studies, the protocols were applied to the general medical-surgical pediatric population in the PICU who required HFNC^(21,22,29). Only one study specifically focused on the use of the protocol for critically asthmatic children older than two years admitted to the PICU⁽²⁵⁾. Regarding the clinical setting of the studies, we found that six protocols were implemented exclusively in PICUs^(21-25,29). Of the remaining studies, two were applied in both PICUs and general pediatric wards of medium complexity^(26,28), while the study by Charvat et al. applied the protocol only in general pediatric wards⁽²⁷⁾. Notably, all studies were conducted in middle- and high-income countries and in hospitals equipped with PICUs. These contextual infrastructure details are crucial when extrapolating the results to different clinical scenarios, such as settings lacking the capacity for prompt admission to intensive care when necessary.

METHODS IMPLEMENTED DURING WEANING PROTOCOLIZATION

In four of the studies, the protocol was led by PICU physiotherapists or respiratory therapists^(21,23-25). In the remaining

TABLE 1. Characteristics of the studies on HFNC weaning protocols reviewed.

Study (year)	Type of study	Scale used	Setting	Professional guiding the protocol	Weaning strategy and Comparison Group	Population and number of patients (N)	Clinical impact LOS*/LOT*	
Besters KA et al. ⁽²¹⁾ (2017)	Quality improvement Project	RAS*	PICU*	PT*	Holiday protocol vs. No protocol	All patients admitted to the PICU requiring HFNC* N: 133	5/21 days	2,5/2,1 days
Wiser RK et al. ⁽²²⁾ 2021	Quality improvement Project	Score BQ*	PICU	Personal médico no médico	Gradual reduction of flow and FiO ₂ * vs No protocol	Patients under 21 years of age who were admitted to the PICU and required HFNC 2 groups BR no BR N: 584	6.8/5.9 days	3.8/2.04 days
Peterson RJ et al. ⁽²³⁾ 2021	Quality improvement Project	Riley score	PICU	FST	Gradual reduction vs No protocol	Patients under 24 months of age with BR requiring HFNC N: 590	2.6/2.1 days	2.5/1.8 days
Maue DK et al. ⁽²⁴⁾ 2023	Quality improvement Project	Riley score	PICU	FST	Protocol of gradual reduction ⁽²³⁾ vs Incorporation of Holiday approach	Patients under 24 months of age with BR requiring HFNC N: 720	2.1/1.5 days	1.8/1.3 days
Maue DK et al. ⁽²⁵⁾ 2023	Quality improvement Project	Asthma score	PICU	FST	Progressive weaning albuterol and HFNC followed by Holiday approach vs No protocol	Patients aged 2 to 18 years with BOC* requiring HFNC and continuous albuterol N: 410	41/31.8 h	26.8/18.1 h
Huang JX et al. ⁽²⁶⁾ 2023	Quality improvement Project	RAC*	PICU and ward	Equipo de destete	Gradual reduction of flow and FiO ₂ vs No protocol	Patients under 24 months of age with BR requiring HFNC N: 223	4/2.8 days	44/36 h
Charvat C et al. ⁽²⁷⁾ 2021	Quality improvement Project	CRS*	Ward	Equipo de destete	Holiday protocol followed by discontinuing or reducing flow to 50% according to CRS vs No protocol	Patients under 18 months of age with BR requiring HFNC N: 283	84/60 h	48/31 h
Hoefert JA et al. ⁽²⁸⁾ 2022	Quality improvement Project	Own BR score	PICU and ward	Equipo de destete	Holiday protocol vs No protocol	Patients under 2 years of age with BR admitted to the hospital requiring HFNC N: 442	56/38 h	52/28 h
Udurgucu M et al. ⁽²⁹⁾ 2022	Prospective observational study	RAS*	PICU	Personal médico no médico	Gradual reduction vs Holiday	Patients between 1 month and 17 years of age admitted to the PICU requiring HFNC N: 113	9.5/6.1 days	60/36 h

PT: physiotherapist; BR: bronchiolitis; RAS: respiratory assessment score; PICU: pediatric intensive care unit; HFNC: high-flow nasal cannula; FiO₂: fraction of inspired oxygen; LOS: length of stay; LOT: length of treatment; BOC: broncho-obstructive crisis; RAC: respiratory assessment classification; CRS clinical respiratory score; h: hours.

five studies, two different implementation approaches were identified. The first involved creating a dedicated interdisciplinary wean team consisting of physicians, respiratory therapists, and nurses⁽²⁶⁻²⁸⁾. The second approach involved all PICU professionals, including both medical and non-medical staff^(22,29).

In our review, we identified two main strategies for HFNC weaning. One approach used protocols where flow and the inspired oxygen fraction (FiO₂) were gradually decreased^(22,23,26,29). These studies utilized various methods to assess patient eligibility for weaning, employing different severity scales. Nevertheless, three of the protocols^(22,23,26) shared a common method: once a patient was considered eligible, the flow was reduced progressively by 2 liters every 2 hours, accompanied by a decrease in FiO₂ to maintain oxygen saturation between 90% and 95%. The protocol by

Udurgucu et al. implemented a 25% reduction in oxygen flow every 12 hours.

The other weaning protocol design incorporated a “window” or “holiday” period, during which patients were assessed using various respiratory severity scales or based on their FiO₂ requirements, ensuring these did not exceed specific cut-off values (which varied across scales and studies) to determine suitability for the holiday period^(24,25,27,29). For these patients, high-flow oxygen was abruptly discontinued, and they were transitioned to conventional oxygen therapy^(21,23-25). Alternatively, in some cases, oxygen therapy was withdrawn entirely, allowing the patient to breathe spontaneously in room air^(27,28). During the holiday period, patients were monitored for a short duration (typically 15-30 minutes). If no clinical deterioration was observed—assessed using the previously applied severity scales—HFNC

was permanently discontinued. The holiday technique was first described and evaluated by Betters et al.⁽²¹⁾ and was subsequently adopted by five more recent protocols^(24,25,27-29), with slight variations in the severity scales used and the FiO₂ reduction. This window period was consistently considered safe, with no adverse events reported in any of the studies that implemented it^(21,24,25,27-29).

The study by Udurgucu M et al., which compared two weaning protocols (holiday versus gradual reduction), found that the holiday approach was associated with a greater decrease in both the duration of HFNC use and hospital length of stay, without an increased risk of adverse effects. However, the observational nature of the study limits the ability to draw definitive conclusions or accurately determine the effect size of this association.

KEY FINDINGS, CLINICAL IMPACT, AND CHALLENGES DURING IMPLEMENTATION OF PROTOCOLS

All the protocols reviewed consistently demonstrated significant improvements in clinically relevant outcomes. Following implementation, all studies reported reductions in both the duration of HFNC exposure and hospital length of stay. Notably, most (8/9) of the studies analyzed were part of quality improvement initiatives that involved multiple and changing cycles of learning and revision of the intervention, aimed to adapt the protocols to the specific clinical contexts in which they were applied. This contextual adaptation should be carefully considered when interpreting the effects of these protocols and extrapolating them to other settings. An example is the systematic work conducted by researchers at Riley Hospital in Indianapolis, United States⁽²³⁻²⁵⁾. Over the years, their series of implementation and quality improvement efforts demonstrated the progressive refinement of the protocols. Initially, these protocols used a gradual reduction approach, but they were later adapted to incorporate the holiday technique after quantifying its superior outcomes while maintaining safety^(23,24). Teams aiming to implement protocols should consider continuous training and revision cycles to ensure adherence and achieve the desired clinical impact.

CONCLUSIONS

- Our review of the available literature revealed that most studies on protocolized weaning from HFNC were part of quality improvement projects conducted mainly in PICUs and focused on children with primary respiratory conditions.
- The implementation of HFNC weaning protocols was associated with a reduction in HFNC exposure and length of hospital stay, and they were found to be safe without increasing the rate of complications.
- The consistent reduction in exposure times to HFNC may indicate the overuse of this therapeutic intervention in hospital settings for children with ARF and ALRI. Therefore, reviewing and adjusting both the indication for and duration of HFNC use is a crucial area for future research.

- Given the context in which the analyzed protocols were implemented (using quality improvement methods and implementation science, and conducted in high-resource settings), clinicians applying them should consider their own contexts when extrapolating the findings of this review.

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