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Review Article

Implementation of High Flow Oxygen Therapy in Pediatrics

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Abstract

Lower acute respiratory infections (ARIs) are one of the main causes of consultation in ambulatory care services, and may represent up to 36% of emergency services consultations, 25% of hospital admissions and 55% of hospital requirements. mechanical ventilatory assistance (MVA), with bronchiolitis being the main clinical entity.

The mainstay of the treatment of patients with ARFI and acute respiratory failure is oxygen therapy.

According to the delivered flow, it is divided into low and high flow. It should be noted that low flow systems have some disadvantages, such as inaccuracy to deliver a constant and quantifiable FiO2, insufficient humidification and heating, inadequate

Relationship between the delivered flow and the inspiratory demand of the patient and the risk of re-inhalation of CO2 with the use of masks.

In this context, oxygen therapy arises through high-flow nasal cannulas, which are open and easy-to-use systems, on which the review of this article will be based.

Keywords: *Oxygen Therapy; High Flow; Acute Lower Respiratory Infection; Bronchiolitis*

Abbreviations

ARI: Acute Lower Respiratory Infection; AVM: Mechanical Ventilatory Assistance; ARF: Acute Respiratory Failure; PICU: Pediatric Intensive Care Unit; CABA: Autonomous City of Buenos Aires; TI: Inspiratory Time; Vt: Dead Space / Tidal Volume Ratio Vd/; min: Liters / Minute: L /; FiO2: Inspired Oxygen Fraction; RH: Relative Humidity; NIV: Non-Invasive Ventilation; CNAF: High Flow Nasal Cannula; VA5: Continuous Upper Airway; CPAP: Continuous Airway Pressure; FR: Respiratory Rate; Pes: Esophageal Pressure

Introduction

Acute lower respiratory infections (ARI) are one of the main causes of consultation in ambulatory care services, and can represent up to 36% of visits to Emergency services, 25% of hospital admissions [1] and 55% of the requirements for mechanical ventilatory assistance (MVA), with bronchiolitis being the main clinical entity [2].

In the Autonomous City of Buenos Aires (CABA) approximately 35,000 patients with ARI are assisted in the Abbreviated Hospitalization Program dependent on the public health system [3]. Of these, between 8 and 10% are hospitalized, and of them 5 to 12% may

require AVM. This represents an occupancy of 40% of the beds in the pediatric intensive care units (PICU) of the CABA between May and September [4].

The mainstay of the treatment of patients with ARFI and acute respiratory failure is oxygen therapy. According to the delivered flow, it is divided into low and high flow. High flow is considered from 2 liters / minute in children under one month, 4 L / min in infants and children, and 6 L / min in adults. It should be noted that low-flow systems have some disadvantages, such as the inaccuracy to deliver a constant and quantifiable FiO2 according to the variability of the pattern and the respiratory rate (RF) of the patient (in addition to always being less than 50%), insufficient humidification and heating, with the consequent worsening of secretions, inadequate relationship between the delivered flow and the inspiratory demand of the patient and risk of re-inhalation of CO2 with the use of masks.

In this context, and as an intermediate step between low-flow oxygen therapy and closed systems (non-invasive ventilation –NIV– and invasive mechanical ventilation –AVM–), oxygen therapy arises through high-flow nasal cannulas, which are Easy-to-use open systems that allow the supply of O2 with optimal temperature and relative humidity (RH).

Advantages and mechanism of action

Conditioning of the inspired gas to body T °, 100% RH and measurable FiO2.

The unconditioned gases given during low-flow oxygen therapy cause a series of alterations: cooling and loss of water from the airway, alter mucociliary transport, increase the osmolarity of respiratory secretions, promote bronchospasm through muscarinic receptors (both in healthy subjects and in asthmatic patients), increase the viscosity secretions and increase the resistance of the upper airway (V.A.S.). The alveolar gas must arrive in the following condition: 37 ° C and RH 100%, which is achieved at the expense of high caloric expenditure.

In contrast, oxygen therapy with high-flow nasal cannulas improves mucociliary function and facilitates the expulsion of secretions, with the consequent reduction in the formation of atelectasis, improves lung compliance and decreases AV resistance, also lowering the metabolic output of the patient.

Decreased anatomical dead space

The dead space of the V.A.S. it is twice as high in children as in adults (3 ml / kg in the newborn and 0.8 ml / kg at 6 years). The upper airway acts as a gas reservoir, thus accumulating expired CO2 and decreasing the volume of available O2. It is known that CO2 removal and oxygenation are flow dependent, therefore, the flow sent through the CNAFs to the nasopharynx washes the CO2 from the anatomical receptacle, prevents rebreathing and provides a fresh gas reservoir high in O2 for new ventilation. This effect is called a decrease in anatomic dead space due to nasopharyngeal washout. The impact of increased flow on oxygenation and ventilation occurs independently of the generation of intra-tracheal pressure. To achieve this effect, the high-flow system must be an open system, with flow delivery through a nasal cannula, where it does not totally occlude the nostrils and where the patient's mouth is not completely closed.

Provide an adequate inspiratory flow to meet the demands in I.R.A. (reduced work of breathing).

At low oxygen flow, a certain level of oxygen dilution occurs, the patient obtains ambient air to reach its peak inspiratory flow, then the FIO2 obtained is the result of mixing air with the administered oxygen. The higher the patient's peak inspiratory flow and constant delivered FiO2, the lower the inspired oxygen concentration. With the high flow, an oxygen flow is provided above the peak inspiratory flow of the patient, then the FIO2 obtained is equal to that delivered by the CNAF system (Figure 1).

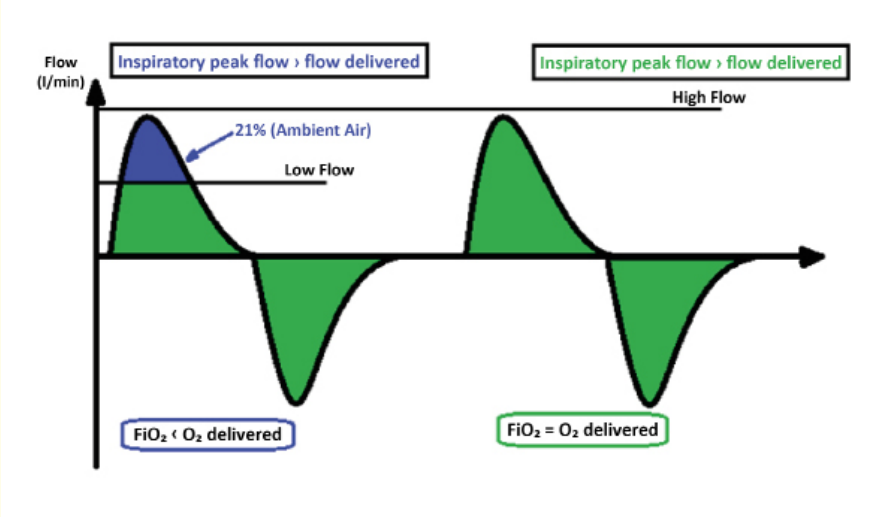

Figure 1

Figure 1. Figure on the left with low flow: the patient obtains ambient air to achieve his peak flow, the FiO2 obtained is the result of mixing the air with the administered oxygen. Figure on the right: the patient receives all the air from the high flow, the FiO2 obtained is equal to that delivered by the high flow oxygen therapy system. Peak inspiratory flow as a function of FiO2 delivered. Modified from Pilar Orive F J*., et al* [5].

Continuous positive pressure generation in the airway.

Resistance of the VAS constitutes 50% of the total resistance of the respiratory system in the child. This is generated because when the inspired gas passes through the VAS, the nasopharynx retracts, with the consequent increase in resistance. The pressurization generated with the use of CNAF counteracts this effect during inspiration. This gas flow then creates a distension force when it comes into contact with the expiratory flow of the patient and with the anatomical structures of the upper airway, reducing resistance (support effect) and generating alveolar recruitment (PEEP effect).

The pressure is variable and will depend on the inspiratory flow / administered flow ratio, anatomical dimensions and losses through the nose and mouth.

However, the effectiveness of CNAF is not related so much to the generation of pressure as to the possibility of equaling or exceeding the peak inspiratory flow of the patient, thus reducing the resistance to flow, which decreases the work of breathing in an equivalent way. to the application of NIV at a value of 6 cm H2O of continuous pressure (CPAP).

Milesi., *et al.* studied pharyngeal pressure and esophageal pressure generated at different flows in children under 2 years of age with bronchiolitis. Pharyngeal pressure increased from 0.2 cm H2O at 1 L / min to 4 cm H2O at 6 L / min, achieving this flow value to generate positive pharyngeal pressures both in inspiration and expiration [6].

Evidence of oxygenotherapy by C.N.A.F.

There are numerous physiological studies showing the impact of CNAF on the respiratory system.

Rubin., *et al*. measured the work of breathing in 25 patients (9 postoperative cardiovascular surgery patients and 20 measured post extubation) in which physiological variables were recorded with low-flow O2, with CNAF and in CPAP. The RF, the Pes were recorded (with an esophageal pressure monitoring catheter they measured the pleural pressure generated, which is a surrogate of the respiratory effort), which gives indices such as the Product pressure / RF (Δ Pes x RF) that the lower, the lower the work of breathing and they observed that as they increased the flow, the work of breathing decreased, the PPR being less than 8 L / m. [7] (Table 1 and 2).

Variable	Continuous Positive Airway Pressure at 4-5 cm H2O measured for intubated children (n=18) *	Standard Nasal Cannula at 2 L / min (n=20) *	High Flow Nasal Cannula (CNAF) 2 L / min(n=24) *	CNAF 5 L/ min (n=25) *	CNAF 8 L/min (n=24) *	P
Product Pressure - frequency(cm H_2O-min)	334 (159-390)	454 (249-620)	421 (233-621)	341 (232-475)	329 (195-402)	0.0003
Changes in pleural pressure (cm H_2O)	9.9 (3.6-15.0)	11.8 (7.3-20.0)	12.9 (6.3-18.0)	14.0 (6.0-18.3)	12.2 (6.4-17.3)	0.0002
Average respiratory rate (breaths / minute)	35 (25-54)	32 (26-54)	34 (27-55)	29 (25-46)	29 (22-40)	0.0004
Pleural pressure at the end of expiration(cm H_2O)	5.8 (± 4.8)	4.5 (± 4.2)	4.8 (± 4.3)	5.5 (± 5.0)	5.4 (±4.7)	0.01

Table 1

Style Name	Short Description			
	Font size (pt)	Font style	Bold (or) Normal	Alignment
Title	15	Cambria	Bold	Center
Author	10	Cambria	Bold	Justify
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Sub-sub-heading	10	Cambria	Bold	Left
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Table text	10	Cambria	Normal	Justify
Table Legend	10	Cambria	Normal	Justify
Figure Legend	10	Cambria	Normal	Justify
Bibliography	10	Cambria	Normal	Justify

Table 2

Another way to assess work of breathing is to measure the electrical activity of the diaphragm.

The diaphragm is a unique muscle in the body, since its effort is modulated by the amount of activated fibers and not by the increase in its contractility.

Phan., *et al.* measured electrical activity of the diaphragm, esophageal pressure, and lung volume by plethysmography in 14 patients with BQL and 14 with congestive heart failure. They observed

that the maximum Edi and the amplitude of the Edi were significantly higher in patients with bronchiolitis than in patients with congenital heart disease, reporting in both groups a significant decrease in these parameters during CNAF therapy, this decrease resulted of greater magnitude in patients with bronchiolitis. This occurred even when the increase in Pes was minimal [8].

In the study by Hough., *et al.* performed in 11 pediatric patients, the effect of CNAF on lung volume at the end of expiration and regional changes in ventilation was measured by electrical impedance tomography. They also measured the changes in Pes. High-flow therapy was administered at an average flow of 1.7 L / kg / min, observing a better global distribution of pulmonary air at the end of expiration and an increase in Pes at the end of expiration (6.9 ± 2.2 cmH2O). This increase in lung volumes was associated with improvement in physiological variables such as RF and SaO2 [9].

The clinical impact of the use of CNAF, measured as the decrease in the requirement of AVM and of admission to PICUs, has been reported in numerous studies, mostly observational or retrospective.

In a retrospective study by Schibler., *et al.* [10], where 298 children were included, reported a decrease in the percentage of patients who required intubation between the years 2005 and 2009, from 37% to 7%, during which the use of CNAF was gradually incorporated in patients with bronchiolitis who were admitted to the PICU. Similar results were found by Wing., *et al.* [11] in a retrospective study that compared 3 cohorts: the first when they still did not have CNAF in 2006; the second, when CNAF was available only in the PICU (2007 - 2008) and the third in 2009, when CNAF was already available in the emergency service and in the pediatric ward. 848 patients were included (190, 289 and 369 in each of the cohorts, respectively). A doubling in the proportion of CNAF use was reported, placing 42% of admitted patients, reducing the proportion of endotracheal intubation (IOT) by half: from 16% to 8%. It is speculated that early onset could be beneficial, since patients in whom CNAF was started in the emergency service had an intubation rate of 7.1%, while in those with later onset, it was 18%. The use of CNAF was shown to be more effective in preventing OTI in patients with bronchiolitis than in patients with pneumonia.

Franklin., *et al.* [12] in a multicenter, randomized and controlled trial that included 1,472 patients with bronchiolitis younger than 12 months compared the use of standard therapy (system of low-flow oxygen delivery) vs CNAF therapy. The treatment failure rate was lower in the CNAF group than in the standard therapy group. However, these two groups do not showed significant differences with respect to the length of hospital stay and the duration oxygen treatment.

Predictors of failure

RF as a predictor of failure was also analyzed in a retrospective observational study performed in a general pediatric hospital ward in which minor patients were included 18 months with moderate to severe bronchiolitis. These patients were prescribed oxygen therapy by CNAF if they presented a Wood Downes score [13] greater than or equal to 8 or a FR greater than or equal to 70 cycles / minute in children under 1 month and RR greater than or equal to 60 cycles / minute in the elderly. The utilization rate was 7% (25 out of 350 admissions), significant decreases in RF, heart rate (HR) and disappearance of suprasternal tracing were observed in those patients who did not require AVM. The authors also reported a 4% decrease in PICU admissions, which meant one bed less occupied by patients with bronchiolitis every day, throughout the SARI epidemic season [14]. Regarding the failure of this therapy reported in the literature, the highest

percentage occurred among patients with pneumonia and the risk factors for OTI found were: RF greater than the 90th percentile for age, a higher arterial partial pressure of CO2 at 50 mmHg and a pH lower than 7.30. The history of prematurity did not affect the results [15].

Adverse effects

In the literature, certain complications secondary to the use of oxygen therapy have been described High Flow, mainly due to a possible increase in pressure, such as pneumothorax and injuries to the nostrils. The possibility of producing atelectasis when 100% O2 is used for a prolonged period, due to alveolar collapse due to nitrogen flushing, has also been described.

Implementation of high-flow oxygen therapy.

Starting in 2017, the R. Gutiérrez Children's Hospital (HNRG) incorporated this therapeutic strategy applying it in pediatric inpatient units 7 and 8. According to the experience of the authors of the present article, the Airvo 2 humidified high-flow system from Fisher and Pykel Healthcare was used®, with Optiflow infant cannula (up to 20 L / m). There are also other devices of different manufacturers and, in addition, it can be administered through mechanical ventilation equipment that acts as a mixer between compressed air and oxygen (Figure 2).

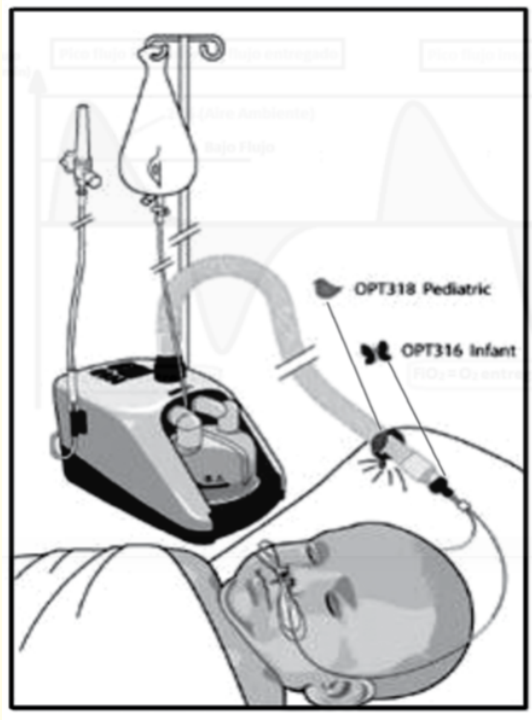

Figure 2

The Airvo 2 is a humidifier with an integrated flow generator that allows the patient to be administered High-flow oxygen therapy at optimal temperature and humidity, at programmed flow and FiO2.

The integrated flow generator allows to deliver flows between 2 and 60 L / m. Oxygen is taken from wall supply, and a built-in ultrasonic oxygen analyzer ensures delivery of the desired FiO2. The breathing tube has heating cables and a built-in managed gas temperature sensor.

The tubes used are individual, disposable and have a single size. The Nasal cannulas have different presentations and are used according to the age and weight of the patient.

In the HNRG, Infant cannulas are used for infants that provide a flow of up to 20 liters / minute, remembering that it must occupy 50% of the nostrils. The device is easy to put on. The cannula itself consists of two self-adhesive fabrics that are fixed to the patient's cheeks, in case it needs to be rearranged, it can be removed by means of a velcro that it has between the self-adhesive sheet and the device. In a quick and easy maneuver, it can be adjusted to each patient.

There is no universal criterion and regulation that indicates in whom this mode of oxygen therapy should be applied. It is implemented according to what is established in each institution, but its misión is to act as an intermediate step between a low-flow mode and system ventilation closed.

At the HNRG this technology is applied to patients between 1 and 18 months of age with a diagnosis of IRAB, and that they fail treatment with low-flow oxygen therapy.

According to the protocol of the Maternal-Infant Department of the CABA (16), it is considered failure of the treatment to:

- The impossibility of saturating 94% with low-flow oxygen therapy (maximum 3 L / min).
- Lack of decreased work of breathing after three hours of starting low-flow oxygen therapy and appropriate medical treatment.

Evaluate HR and FR by age ranges:

- Patients ≤ 6 months: HR ≥ 140 / min and RR ≥ 55 / min.
- Patients> 6 months: HR ≥ 140 / min and RR ≥ 45 / min.

Increased work of breathing during evolution according to age criteria.

Contraindications

- Signs of acute respiratory claudication, apneas.
- Signs of hemodynamic instability (sepsis, shock, hypotension).
- Seizures or acute deterioration of the level of consciousness.
- Patients that the treating physician considers should be consulted with Intensive Care.

The flow is programmed at 2 L / kg / min, and remains fixed throughout the treatment. FiO2 Initially it can be programmed in 0.9, but it must be adjusted, after stabilizing the patient, to fractions equal to or less than 0.6, with a target SaO2 of 94% over a period of time no longer than three hours. FiO2 drops to 0.05 points, keeping the flow constant in 2 L / kg / min. If, when FIO2 decreases during treatment, the patient presents a drop in SaO2 due to below 94% or increased work of breathing, support will restart at the last value used, adjusting the FiO2 for a target SaO2 ≥ 94%.

The unlinking of the CNAF will be performed by removing the CNAF when the patient has achieved stay 4 hours with FiO2 0.21.

Support failure with CNAF will be considered, and consultation with a specialist doctor will be requested in pediatric intensive care, to evaluate escalation in treatment before any of the the following clinical situations: [16].

- The impossibility of achieving a SaO2 ≥ 94%
- Lack of decrease in work of breathing after three hours of starting support with CNAF and appropriate medical treatment. HR and FR will be specially evaluated according to criteria by age.

Conclusion

CNAF is a new practice and a different therapeutic option that brings benefits in patients with pictures of I.R.A. The early introduction of the C.N.A.F. In different series, it has been shown to reduce the intubation rate in patients with bronchiolitis and with AKI in general.

Therefore, it represents, within oxygen therapy, a step of intermediate therapy before achieve a closed ventilation system (both invasive and non-invasive).

Conflict of Interest

I declare that I have no conflicts of interest.

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