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Chronic hypoventilation in pediatric patients at moderate altitude

Hipoventilación alveolar crónica en pacientes pediátricos a altitud moderada

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ABSTRACT. Introduction: chronic alveolar hypoventilation is defined as the clinical condition by increased $PaCO_2$ with normal pH figures; at sea level ≥ 45 mmHg and in Mexico City (2200 masl) ≥ 38 mmHg, the latter due to a decrease in the partial and alveolar pressure of oxygen due to a drop in barometric pressure. Altitude generates increased work of breathing, increased volume/minute to maintain adequate PO_2, eliminating CO_2, negatively impacting ventilatory control in patients with chronic lung diseases. **Objective:** to describe the main characteristics of pediatric patients with chronic alveolar hypoventilation at moderate altitude. **Material and methods:** observational, descriptive, cross-sectional, retrospective study, in patients from zero to 18 years of age in the period 2007 to 2020 treated at the National Institute of Pediatrics, Mexico City. **Results:** 17 patients with chronic alveolar hypoventilation were found, with a median age of 6 years, in 58.82% of cases the etiology was peripheral; the most frequent daytime symptoms were tiredness and irritability (41.2%) and among the nocturnal symptoms were snoring (41.2%) and respiratory pauses (29.4%). In 41.2% some type of non-invasive ventilation device (NIV) was used; decrease in complications and symptoms was observed after one year of follow-up in both the groups with and without NIV; although without statistical significance. **Conclusions:** it was established that the main causes are peripheral, although NIV showed benefits, its use was recorded in less than half of the cases

Keywords: chronic alveolar hypoventilation, clinical manifestations, non-invasive ventilation, evolution, complications.

RESUMEN. Introducción: la hipoventilación alveolar crónica se define como la condición clínica por aumento de la $PaCO_2$ con cifras de pH normal, a nivel del mar ≥ 45 mmHg y en Ciudad de México (2,200 msnm) ≥ 38 mmHg, esto último debido a la disminución de la presión parcial y alveolar de oxígeno por descenso de la presión barométrica. La altitud genera aumento del trabajo respiratorio, incremento del volumen/minuto para mantener una PO_2 adecuada, eliminando CO_2, lo que impacta negativamente el control ventilatorio en pacientes con enfermedades pulmonares crónicas. **Objetivo:** describir las principales características de los pacientes pediátricos con hipoventilación alveolar crónica a altitud moderada. **Material y métodos:** estudio observacional, descriptivo, transversal, retrospectivo en pacientes de cero a 18 años de edad en el período de 2007 a 2020 atendidos en el Instituto Nacional de Pediatría, Ciudad de México. **Resultados:** se encontraron 17 pacientes con hipoventilación alveolar crónica con una mediana de edad de seis años, en 58.82% de los casos la etiología fue periférica; los síntomas diurnos más frecuentes fueron cansancio e irritabilidad (41.2%) y entre los síntomas nocturnos el ronquido (41.2%) y pausas respiratorias (29.4%). En 41.2% se utilizó algún tipo de dispositivo de ventilación no invasiva (VNI); se observó disminución de complicaciones y sintomatología al año de seguimiento tanto en los grupos con y sin VNI, aunque sin significancia estadística. **Conclusiones:** se estableció que las principales causas son las periféricas; a pesar de que la VNI demostró beneficios, su utilización se registró en menos de la mitad de los casos.

Palabras clave: hipoventilación alveolar crónica, manifestaciones clínicas, ventilación no invasiva, evolución, complicaciones.

INTRODUCTION

Chronic alveolar hypoventilation is defined as a clinical condition characterized by a decrease in ventilation/minute with elevation of arterial partial pressure of carbon dioxide ($PaCO_2$) greater than 45 mmHg above sea level and 38 mmHg in Mexico City due to the altitude (2,200 meters above sea level), this is due to the decrease in barometric pressure and therefore, the partial and alveolar pressure of oxygen triggers the adaptation process of the human organism with an increase in respiratory work due to the need to increase the volume/minute to maintain

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an adequate partial pressure of oxygen (PO_2), eliminating carbon dioxide (CO_2), that is, increasing alveolar ventilation.[1] The increase in CO_2 levels is accompanied by normal pH levels due to metabolic compensation and increased bicarbonate values.[2]

Alveolar hypoventilation disorders can be classified as central or peripheral depending on the underlying pathology;[3] in central disorders there is a low or absent sensitivity of the respiratory center to CO_2, they can derive from a variety of congenital or acquired conditions.[4-6] In peripheral hypoventilation disorders there is an alteration in the mechanics of breathing that prevents an adequate response to ventilatory needs as in neuromuscular diseases (NMDs), chest deformities,[3,7] also in underlying lung parenchymal diseases[8] and hypoventilation obesity syndrome (HOS).

The most common clinical manifestations of hypoventilation do not occur in isolation, but within the spectrum of signs and symptoms generated by the wide variety of underlying diseases, these will be more evident during sleep, although daytime symptomatology will also be present and its severity is directly related to the magnitude of nocturnal hypoventilation.[1,7,9,10]

Diagnosis is based on clinical data and different invasive and non-invasive techniques for measuring the CO_2 level, one of the most commonly used techniques being arterial or capillary blood gases; however, blood collection during the night interrupts patients' sleep, so daytime samples that reflect the ventilation status throughout the night are chosen.[11]

Management initially focuses on any causal factor, but sometimes these measures will not be sufficient, so the treatment of patients with chronic hypoventilation is support with noninvasive ventilation with bilevel positive pressure, demonstrating short and long term benefits.[12-14]

Early identification of manifestations associated with hypoventilation and complications such as infectious processes together with cardiovascular deterioration, explained by the vasoconstrictor response in the pulmonary bed, will be important. The increase in pulmonary vascular resistance results in an increase in the work of the right ventricle and hypertrophy and eventual heart failure.[9]

In adults in Mexico, hypoventilation was detected in up to 68% of patients with obesity and in 69% with NME;[15] and the prevalence in children is not underestimated, so in the absence of local data, this study was undertaken.

MATERIAL AND METHODS

The aim of this research is to describe the main characteristics of patients with chronic alveolar hypoventilation in the National Institute of Pediatrics (INP), for this purpose an observational, descriptive, cross-sectional, retrospective study was carried out in patients from zero to 18 years of age, diagnosed with chronic alveolar hypoventilation in the pulmonology and thoracic surgery service from January 1, 2007 to December 31, 2020. Patients of both genders with at least one year of follow-up and a control in the first quarter after diagnosis were included. Patients with additional diseases with dyspnea were excluded. Data were collected by searching clinical records in both physical and electronic format after filling out the database and analysis using the SPSS v.21 statistical package. The statistical evaluation was carried out descriptively through univariate analysis with frequencies and percentages for qualitative variables and measures of central tendency and dispersion for quantitative variables. Finally, the results were presented in the form of tables.

RESULTS

Forty-one outpatient records with a diagnosis of alveolar hypoventilation were reviewed; only 17 met all the criteria necessary to be included in the study. Of these, 88.24% were female, with ages between 4 months and 16 years and a median of 6 years. The lowest median age of diagnosis was in patients with MND, while the latest was in chest wall and spine deformities *(Table 1)*. The most frequent causes were peripheral with 58.82%, among them chest wall and spine deformity with 35.29% (scoliosis n = 5, bone dysplasia n = 1) followed by ENM (Duchenne dystrophy n = 1 and spinal cord atrophy n = 1) and obesity (n = 2) each with 11.7%; with respect to central causes, they were present in 35.29% of the subjects.

Among the most frequent diurnal symptoms, tiredness and irritability stand out with 41.2% each; similar pattern of presentation in central and peripheral disorders. As for nocturnal symptoms, snoring stood out with 41.2% with an average of four days/week, respiratory pauses with 29.4% with an average of seven days/week *(Table 2)*. Facial dysmorphias were observed in 52.4%, evidenced in half of the subjects with central causes.

In patients with peripheral causes, the group with scoliosis presented a Cobb angle measurement classified as moderate and severe, of this group, four cases underwent respiratory function tests (RFT), specifically spirometry, all of them showed a reduction in both forced expiratory volume in the first second (FEV1) with a mean of 34.5% of the predicted value (PV) and in forced vital capacity (FVC) values with a result of 39.8% of the PV. It should be noted that only two patients underwent respiratory function tests prior to the diagnosis of alveolar hypoventilation.

The nutritional status of the patients was eutrophic in 35.3%, mainly in the group of peripheral causes (66.6%) and malnutrition in 29.4%, especially in patients with central causes and ENM. As for the gasometric data, at the time

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Table 1: Distribution of patients according to etiology, sex and age at diagnosis in patients with chronic alveolar hypoventilation at the National Pediatric Institute. 2007-2020.

Characteristics	Total (N = 17)	Centrals (N = 6)	Peripherals (N = 10)			
			Deformity of the thoracic cage and spine (N = 6)	Neuromuscular diseases (N = 2)	Obesity (N = 2)	Mixed (N = 1)
Age (median) years	6	4.5	13.5	3	6.5	6
Interquartile range	11.5	9	8.2	–	–	–
Maximum-minimum value	4 meses-16 años	–	–	–	–	–
Sex, n (%)						
Female	15 (88.24)	6 (100)	6 (100)	2 (100)	1 (50)	–
Male	2 (11.76)	–	–	–	1 (50)	1 (100)

Table 2: Daytime and nocturnal symptomatology at diagnosis.

Characteristics	Total (N = 17) n (%)	Centrals (N = 6) n (%)	Peripherals (N = 10)			
			Deformity of the thoracic cage and spine (N = 6) n (%)	Neuromuscular diseases (N = 2) n (%)	Obesity (N = 2) n (%)	Mixed (N = 1) n (%)
Daytime symptomatology						
Excessive daytime sleepiness	6 (35.3)	4 (66.7)	2 (33.3)	–	–	–
Morning headache	3 (17.6)	1 (16.7)	2 (33.3)	–	–	–
Exercise intolerance	4 (23.5)	1 (16.7)	3 (50)	–	–	–
Dyspnea	6 (35.3)	1 (16.7)	3 (50)	–	2 (100)	–
Fatigue	7 (41.2)	2 (33.3)	3 (50)	–	1 (50)	1 (100)
Irritability	7 (41.2)	4 (66.7)	2 (33.3)	–	–	1 (100)
Morning sickness	2 (11.8)	1 (16.7)	1 (16.7)	–	–	–
Supine thoracoabdominal dissociation	2 (11.8)	1 (16.7)	–	–	1 (50)	–
Use of accessory muscles of respiration	1 (5.9)	–	–	–	1 (50)	–
Learning and memory problems	3 (17.6)	1 (16.7)	2 (33.3)	–	–	–
Nocturnal symptomatology						
Restless sleep	3 (17.6)	3 (50)	–	–	–	–
Nocturnal awakenings	2 (11.8)	2 (33.3)	–	–	–	–
Parasomnias	–	–	–	–	–	–
Snoring	7 (41.2)	4 (66.7)	2 (33.3)	–	1 (50)	–
Mean (range) days/week	4 (1-7)	–	–	–	–	–
Breathing pauses	5 (29.4)	2 (33.3)	–	–	2 (100)	1 (100)
Mean days/week	7	–	–	–	–	–
Choking sensation at night	3 (17.6)	1 (16.7)	–	–	2 (100)	–
Mouth breathing	3 (17.6)	3 (50)	–	–	–	–
Thoracoabdominal dissociation during sleep	2 (11.8)	1 (16.7)	–	–	1 (50)	–

of diagnosis, hypoxemia was reported in 64.7%, being frequent in central causes with 83.3% and in all patients with ENM and obese *(Table 3)*.

Regarding complications, they were present in all groups, with a lower occurrence in patients with mixed disorder; the most frequent were pneumonias, which were present in 47% with a mean of 1.6 events/year, and were common in the subgroups of peripheral causes; followed by pulmonary artery hypertension (PAH) in 41.2% and respiratory failure with 35.3%, both described in all obese and ENM patients.

As part of the treatment, NIV was used in 41.2%, of which one patient used a continuous positive airway pressure device (CPAP), a patient corresponding to the obese group; in the other groups, bilevel pressure devices in ST mode were used; it was not possible to determine the parameters used due to incomplete information in the

records. The mean daily use was 14.4 hours, highlighting that patients with central causes and ENM required day/night ventilation, while the rest used nocturnal ventilation. Meanwhile, the device titration method was performed in sleep laboratories and hospital with similar frequency (42.86%); it should be clarified that titration in the hospital was in patients who were referred to the pulmonology service because of difficulty in weaning from oxygen or withdrawal of mechanical ventilation, even without an established diagnosis of alveolar hypoventilation. With respect to the interface, the most commonly used was nasal (57.14%) and only one case of complications related to skin lesions due to its use was reported *(Table 4)*.

Regarding the evolution of the patients who used NIV, in the short term the symptomatology was very similar to that manifested at the time of diagnosis; however, in the long term it was completely reduced, except for the snoring that was maintained in one of the patients, who belonged to the mixed disease group, with poor adherence to NIV treatment. In all the variables studied, the p-value was not significant, probably due to the small sample size *(Table 5)*.

In addition, at one year follow-up, a decrease in the frequency of complications was observed in the groups with and without NIV. Both patients with Cor pulmonale and the vast majority of PAH cases evolved favorably, except for one patient (5.9%) with restrictive thorax secondary to severe scoliosis who did not use NIV, and no new respiratory failure events were recorded. Specifically in patients with NIV device use, long-term improvement was demonstrated with the exception of two cases that required hospitalization: central cause (n = 1) and thoracic deformity (n = 1); in the latter, an event of pneumonia was also reported; although complications were reduced compared to baseline findings, there was no significant difference in general and with each of the groups *(Table 6)*.

DISCUSSION

The increase in $PaCO_2$ can be secondary to a variety of pathologic processes,[16] the most frequent being peripheral disorders, similar to the study by Castro et al. in 622 children with alveolar hypoventilation who used NIV, who found 83% peripheral causes, among the most frequent: obesity and Down syndrome; and only 17% reported a central cause. These authors also report a median age at diagnosis of 7.8 years,[17] something similar to that observed in the present investigation. The ages were younger in patients with MND; in contrast, Katz and Fauroux report later ages (mean 11.7 years);[18,19] while the latter authors mention that diagnosis in the group with rib cage and spine deformities was more common in the school year 18 versus what was found in this study, which was in adolescence.

In the spectrum of symptomatology, the present study showed a greater frequency of daytime symptoms such as tiredness and irritability followed by excessive daytime sleepiness and dyspnea; in the work of Casas

Table 3: Nutritional status and gasometric data.

Characteristics	Total (N = 17) n (%)	Centrals (N = 6) n (%)	Peripherals (N = 10)			Mixed (N = 1) n (%)
			Deformity of the thoracic cage and spine (N = 6) n (%)	Neuromuscular diseases (N = 2) n (%)	Obesity (N = 2) n (%)	
Nutritional status						
Malnutrition	5 (29.4)	3 (50)	1 (16.7)	1 (50)	–	–
Eutrophic	6 (35.3)	1 (16.7)	4 (66.6)	1 (50)	–	–
Overweight	2 (11.8)	1 (16.7)	–	–	–	1 (100)
Obesity	4 (23.5)	1 (16.7)	1 (16.7)	–	2 (100)	–
Gasometric data						
Hypoxemia	11 (64.7)	5 (83.3)	2 (33.3)	2 (100)	2 (100)	–
$PaCO_2$ mmHg X	52.7 (45-72)*	48.4	54.9	54.1	56.7	54.7
HCO_3 mmol/L X	28.0 (22-44)*	25.5	28.8	31.5	25.5	36.3
Complications						
Pneumonias‡	8 (47.0)	2 (33.3)	3 (50.0)	2 (100)	1 (50)	–
Respiratory failure	6 (35.3)	1 (16.7)	1 (16.7)	2 (100)	2 (100)	–
Pulmonary arterial hypertension	7 (41.2)	1 (16.7)	2 (33.3)	1 (50)	2 (100)	1 (100)
Cor pulmonale	4 (23.5)	1 (16.7)	2 (33.3)	1 (50)	–	–

* Range. ‡ Medium pneumonias: 1.6 events (1-3).

Table 4: Characteristics of use of noninvasive ventilation with bilevel positive pressure.

Characteristics	Total (N = 17)	Centrals (N = 6)	Deformity of the thoracic cage and spine (N = 6)	Neuromuscular diseases (N = 2)	Obesity (N = 2)	Mixed (N = 1)
Use of non-invasive ventilation, n (%)	7 (41.2)	1 (16.7)	2 (33.3)	2 (100)	1 (50)	1 (100)
Hours of use of ventilation, average (range)	14.4 (8-24)	19	11	22	8	8
Time from diagnosis to onset of ventilation (months) mean (range) 7 (3-24)						
	n (%)					
Interface types	N = 7					
Nasal	4 (57.14)					
Buconasal	1 (14.29)					
Tracheostomy ventilation	2 (28.57)					
Device titration method						
Sleep laboratory (polysomnography)	3 (42.86)					
Hospital	3 (42.86)					
Home	1 (14.29)					
Origin of the devices						
Own	1 (14.29)					
Institutional	1 (14.29)					
Donation	4 (57.14)					
Rented	1 (14.29)					
Presence of complications from the use of devices						
Yes	1 (14.3)					
No	6 (85.7)					
Need for tracheostomy						
Yes	2 (28.6)					
No	5 (71.4)					
Time elapsed between diagnosis and tracheostomy (months), mean	18					

they were mostly dyspnea and asthenia followed by daytime hypersomnolence 77%;[9] in relation to dyspnea was a cardinal symptom in OHS, similarly, Espínola et al. made a comparison with obese patients with obstructive sleep apnea/hypopnea syndrome (OSAHS) without hypoventilation, demonstrating a greater degree of dyspnea ($p = 0.04$) in the OHS group;[20] this event was reproduced in our population and in the patient with mixed disease. Regarding nocturnal symptomatology, snoring and respiratory pauses were mainly detected, results similar to other studies.[21,22]

Adenotonsillar hypertrophy produces upper airway narrowing, and when superimposed with other factors results in clinically significant dynamic airway obstruction during sleep, resulting in hypoventilation.[23,24] Rosen et al. found adenotonsillar hypertrophy in 2/3 of the children studied,[22] while in the present work it was recorded in 1/3 of the cases. Another variant is facial dysmorphia, closely related to genetic variants such as the expansion mutation in PHOX2B;[25] those found in this work were related to central etiology and half of them were syndromic, and in the rest, despite genetic evaluation, they were not integrated into a definitive diagnosis; in none of the cases was it congenital.

Part of the study of patients with hypoventilation includes RFT, FVC and FEV1 values lower than 50% of PV, which usually announce the onset of ventilatory failure by increasing $PaCO_2$. Despite its importance, not all patients manage to perform them for different reasons,[26] Fauroux records the performance of RFT in 56% of his sample[27] compared to the current work in which it was documented in only 23.6%.

Another point to discuss is the nutritional status, Rosen reports that obesity was present in more than a quarter of the study population and the rest were eutrophic,[22] in the current study 1/3 of children were eutrophic, although it would be expected that most patients would be eutrophic except for patients with obesity hypoventilation syndrome; the presence of malnutrition was noteworthy with a not insignificant percentage and constituting half of the cases with central etiologies and neuromuscular diseases.

In the diagnosis of alveolar hypoventilation, the mean $PaCO_2$ was higher in children with obesity (56.7 mmHg) and lower in central causes (48.4 mmHg); meanwhile Poh Tan pointed out high figures in patients with pulmonary parenchymal disease (58 mmHg) followed by OHSS (56 mmHg); in addition the author indicated hypoxemia in 32% of the cases, especially in parenchymal disease.[21] In this study, hypoxemia was observed in 64% of cases, mainly in central causes, and it is emphasized that half of these patients also presented clinical symptoms and images suggestive of aspiration pneumopathy, leading to lung parenchymal damage and increased hypoxemia.

Regarding complications, they are frequently related to infectious processes together with cardiovascular deterioration.[28] In the study, the main complications described were pneumonia and in 1/3 the presence of respiratory failure. Marik found pneumonia in 20% and respiratory failure in 63%, and also found heart failure in up to 39% of cases[29] versus 23.5% determined in this study. Other complications such as PAH, according to Held's study, were observed in 10% of cases.[30]

NIV with bilevel positive pressure has demonstrated benefits in chronic alveolar hypoventilation,[12] usually used initially during sleep by means of a nasal interface or mask, and in cases in which continuous ventilation is required, tracheostomy is the preferred option.[31] The use of NIV stands out in this study in only 41.2% of the cases, in contrast to what occurs in other centers in developed countries, where there is greater accessibility to the devices, exceeding 90% of the cases[21] and as previously mentioned, most of the NIV devices were donations due to the difficulty in acquiring the equipment in our environment, especially life support equipment due to its high cost, and often the start-up times for ventilation are prolonged until the equipment is obtained, with lapses of up to 24 months.

In relation to the use of ventilation, the literature shows a slightly greater survival advantage with use of more than four hours/day, exposing the clinical benefit of NIV over other forms of treatment. As for pediatric populations, it depends on age and in general terms it is recommended that at least 50% of hours should be used during sleep.[32]

In relation to the evolution of patients in the short and long term, although the objective of this study was not

Table 5: Evolution of daytime/nighttime symptomatology at diagnosis, three months and one year with and without use of noninvasive bilevel positive pressure ventilation.

Characteristics (N = 7)	With NIV, n (%)			Without NIV, n (%)		
	Basal	3 months	1 year	Basal	3 months	1 year
Daytime symptomatology						
Excessive daytime sleepiness	1 (14.3)	1 (14.3)	0 (0.0)	5 (50)	3 (30)	5 (50)
Morning headache	2 (28.6)	2 (28.6)	0 (0.0)	1 (10)	3 (30)	1 (10)
Exercise intolerance	3 (42.9)	4 (57.1)	0 (0.0)	2 (20)	2 (20)	3 (30)
Dyspnea	3 (42.9)	2 (28.6)	0 (0.0)	4 (40)	3 (30)	3 (30)
Fatigue	3 (42.9)	2 (28.6)	0 (0.0)	3 (30)	4 (40)	3 (30)
Irritability	1 (14.3)	0 (0.0)	0 (0.0)	5 (50)	3 (30)	2 (20)
Morning sickness	1 (14.3)	1 (14.3)	0 (0.0)	1 (10)	0 (0)	0 (0)
Supine thoracoabdominal dissociation	0 (0.0)	0 (0.0)	0 (0.0)	2 (20)	1 (10)	0 (0)
Use of accessory muscles of respiration	0 (0.0)	1 (14.3)	0 (0.0)	1 (10)	0 (0)	0 (0)
Learning and memory problems	1 (14.3)	0 (0.0)	0 (0.0)	2 (20)	2 (20)	2 (20)
Nocturnal symptomatology						
Restless sleep	0 (0.0)	0 (0.0)	0 (0.0)	3 (30)	2 (20)	3 (30)
Nocturnal awakenings	0 (0.0)	0 (0.0)	0 (0.0)	2 (20)	2 (20)	2 (20)
Parasomnias	0 (0.0)	0 (0.0)	0 (0.0)	0 (0)	0 (0)	0 (0)
Snoring	2 (28.6)	2 (28.6)	1 (14.3)	6 (60)	4 (40)	5 (50)
Breathing pauses	1 (14.3)	0 (0.0)	0 (0.0)	3 (30)	1 (10)	4 (40)
Nocturnal choking sensation	1 (14.3)	0 (0.0)	0 (0.0)	2 (20)	3 (30)	1 (10)
Mouth breathing	1 (14.3)	1 (14.3)	0 (0.0)	3 (30)	5 (50)	3 (30)
Thoracoabdominal dissociation during sleep	0 (0.0)	0 (0.0)	0 (0.0)	2 (20)	1 (10)	0 (0)

NIV = noninvasive ventilation.

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Table 6: Need for hospitalization, complications and death one year after diagnosis in patients with chronic alveolar hypoventilation with/without use of noninvasive ventilation.

	Basal, n (%)			1 year, n (%)					
Characteristics	Total (N = 17)	Ventilation (N = 7)	No ventilation (N = 10)	Total (N = 17)	p	Ventilation (N = 7)	p	No ventilation (N = 10)	p
Hospitalizations	7 (41.2)	4 (57.1)	3 (30)	3 (17.64)	0.13	2 (28.6)	1.00	1 (10)	0.24
Pneumonias*	8 (47.0)	4 (57.1)	4 (40)	2 (11.76)	1.00	1 (14.3)	0.24	1 (10)	0.24
Respiratory insufficiency	6 (35.3)	3 (42.9)	3 (30)	–	–	–	–	–	–
Pulmonary hypertension	7 (41.2)	4 (57.1)	3 (30)	1 (5.9)	–	–	–	1 (10)	0.47
Cor pulmonale	4 (23.6)	2 (28.6)	4 (40)	–	–	–	–	–	–
Deceased	–	–	–	0	–	–	–	–	–

* Mean number of pneumonia events: 1.

specifically to establish cause-effect of the use of NIV, nevertheless with the data described, a marked reduction in both daytime and nocturnal symptomatology was observed in ventilation users, especially in the long term versus those who did not use it, although the statistical probability was not significant due to the small size of the sample.

Authors such as Annane in a systematic review of studies with nocturnal NIV in chronic hypoventilation in patients with ENM and chest wall concluded that the short-term evolution (one to three months) of the patients improved symptomatology with a significant difference, as well as diurnal hypercapnia and nocturnal oxygen saturation (13). Casas evaluated the evolution of patients after one year of NIV use in patients with motor neuron disorders, showing a decrease in dyspnea and disappearance of asthenia, hypersomnolence, headache, lower limb edema and memory loss; there was also an improvement in gas exchange: PaO_2/FiO_2 and $PaCO_2$.[9] Young also demonstrated significant reduction in daytime somnolence and headache after the use of NIV in children with MND[33] analogous to this article.

On the basis of the above considerations, it is expected that pneumonia, respiratory failure and cardiovascular repercussions[30] will improve in patients using bilevel positive pressure NIV compared to those who do not. On the contrary, in this study a reduction in complications was observed in both groups, although without statistical significance; surely this is due to the establishment of other therapeutic alternatives such as amygdalectomy, improvement of nutritional status, optimization of respiratory physiotherapy, orthopedic correction of spinal deformities, etc. Although gasometric controls are ideal after the establishment of therapeutic measures for patient monitoring, not all patients had control gasometry, and this limited the long-term assessment of hypoxemia and CO_2 levels.

CONCLUSIONS

The present work is one of the first investigations of chronic alveolar hypoventilation in pediatric population at moderate altitude, knowing that higher altitude has a negative impact on ventilatory control in patients with chronic diseases that are associated with an inherent impairment in alveolar ventilation. Altitude implies an increase in volume/minute proportional to the decrease in partial pressure of oxygen and therefore an increase in work of breathing that may incur disproportionate increases in these patients.

It should be noted that most patients at the time of diagnosis presented both daytime and nocturnal symptoms, the main causes of hypoventilation were of peripheral origin; and despite the benefit of NIV as an effective measure in reducing symptoms and complications, it was not widely used as would be expected due to the high cost of equipment acquisition.

Finally, the main limitations of this work were the small size of the population studied and limited information in the records. In addition, the patients who met the criteria to be part of this study did not correspond to the exact number of alveolar hypoventilation cases in the pulmonology service due to underreporting in the hospital's computer system. As a recommendation for future research, we emphasize the need for further studies with a greater number of patients with complete information recorded in their records, as well as close follow-up of patients with NIV use.

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