ORIGINAL ARTICLE

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IMPACT OF THE IMPLEMENTATION OF AN ALGORITHM IN THE TREATMENT OF CHILDREN HOSPITALIZED FOR ACUTE ASTHMA

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ABSTRACT

Patients hospitalized for acute asthma treated with a pre-established algorithm could decrease hospital stay and critical bed requirement (PICU). The objective of this article was to implement and evaluate the impact of a pre-established algorithm to treat children hospitalized for acute asthma. It is a cross-sectional and comparative study, with a prospective sample for convenience, of asthmatic children between 5 and 15 admitted during 2017 without response to the first line treatment in the emergency room. Patients with cardiorespiratory comorbidities and with direct admission to PICU were excluded. An algorithm was applied for 2 hours and its effectiveness was evaluated by a clinical score (PAS: Pediatric Asthma Score). 55 patients were admitted, average age 8.02 years, 41.8% female. The PAS decreased from 8 to 5 points at the end of the algorithm ($p < 0.001$). When comparing the results obtained with the group treated the previous year, without an algorithm application in 51 patients with similar demographic characteristics, a shorter hospitalization was observed (0.6 days versus 0.95 days ($p < 0.0368$)). The algorithm for acute asthma unified treatment criteria and times in its application. A rapid decrease in clinical score and a shorter hospital stay were observed.

Key words: acute asthma; algorithm; clinical effectiveness.

INTRODUCTION

Asthma affects 334 million people worldwide and is the most common chronic obstructive inflammatory airway disease in children (1). In Chile, the prevalence is high (2) and different according to age, between 9 to 16% in children aged 6 to 7, and 7 to 12% in children aged 13 to 14 (2,3), with epidemiology similar to that observed in schoolchildren in developed countries (3).

Asthma exacerbations are common in children, with a frequency close to 5% of ER consultations, reaching a maximum of 10 to 15% at certain times of the year, with approximately 15 % requiring hospitalization (4,5) . It is estimated that 10% of hospitalized asthmatic patients require admission to an intensive care unit, with a mortality of 4% in those requiring invasive mechanical ventilation (6).

The treatment of acute asthma is well established and includes first-line management with bronchodilators and systemic corticosteroids (7). In moderate and severe acute asthma the association of Short-acting Beta 2-agonists with ipratropium bromide (IB), used in the emergency room in repeated doses, has been shown to reduce hospitalization rates (8) and reduce the need to transfer to more complex units (9).

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Despite the existence of clinical scores that allow to determine the severity of acute asthma and define the therapy to be used in each case (10), there is no clear consensus regarding the recommended protocols, which combine the pharmacological pillars mentioned above with second-line therapies such as magnesium sulfate (11) and non-pharmacological therapies designed to treat acute respiratory failure such as high flow oxygen therapy (12) and non-invasive ventilation (NIV) (13).

The objective of this study was to describe and evaluate the impact of a treatment algorithm for children hospitalized for severe refractory asthma to first-line treatment in the emergency room.

PATIENTS AND METHODS

A cross-sectional and comparative study was conducted with consecutive sampling for the convenience of children aged 5 to 15, admitted for acute asthma to the Pediatric Department of the Hospital Clínico San Borja Arriaran (HCSBA), in Santiago, Chile, between December 2016 and December 2017. The group with which the results were compared was a cohort of HCSBA patients evaluated in a prospective multicenter observational study of patients hospitalized for acute asthma previously performed during 2016 (14). In this group, the algorithm for decision making was not used, and only NIV was used, since there was no systematic incorporation of HFOT. Intravenous magnesium sulfate was indicated in later stages of the evolution of the crisis, once admitted to intermediate care and with NIV. There was no mesh nebulizer for the bronchodilator therapy for the patient in NIV, so continuous NBZ was used with a Hudson jet nebulizer or repeated doses of a metered dose inhaler (MDI).

Acute asthma or asthmatic exacerbation is defined as an abrupt and progressive episode of bronchial obstruction, of varying severity, manifested by chest tightness, shortness of breath, coughing, wheezing, dyspnea, polypnea and retraction. This clinical definition is related to a decrease in expiratory flows, which in pediatrics are rarely evaluated with flowmetry, despite recommendations by GINA clinical guidelines (15). Asthmatic status is defined as an episode of severe acute asthma, refractory to treatment, in need of hospitalization and with acute respiratory failure with potential ventilatory support requirement (7,16).

Given the difficulty in performing flowmetry in children with an asthma crisis, and since a good correlation with a clinical score has been demonstrated (17), it was decided that the Pediatric Asthma Score (PAS) would be used to assess the severity and response to treatment (10) (Table 1). The asthma crisis was categorized according to the score obtained, in mild (score 5-7), moderate (8-11) and severe (12-15) upon admission to hospital and at 30, 60 and 120 minutes (18).

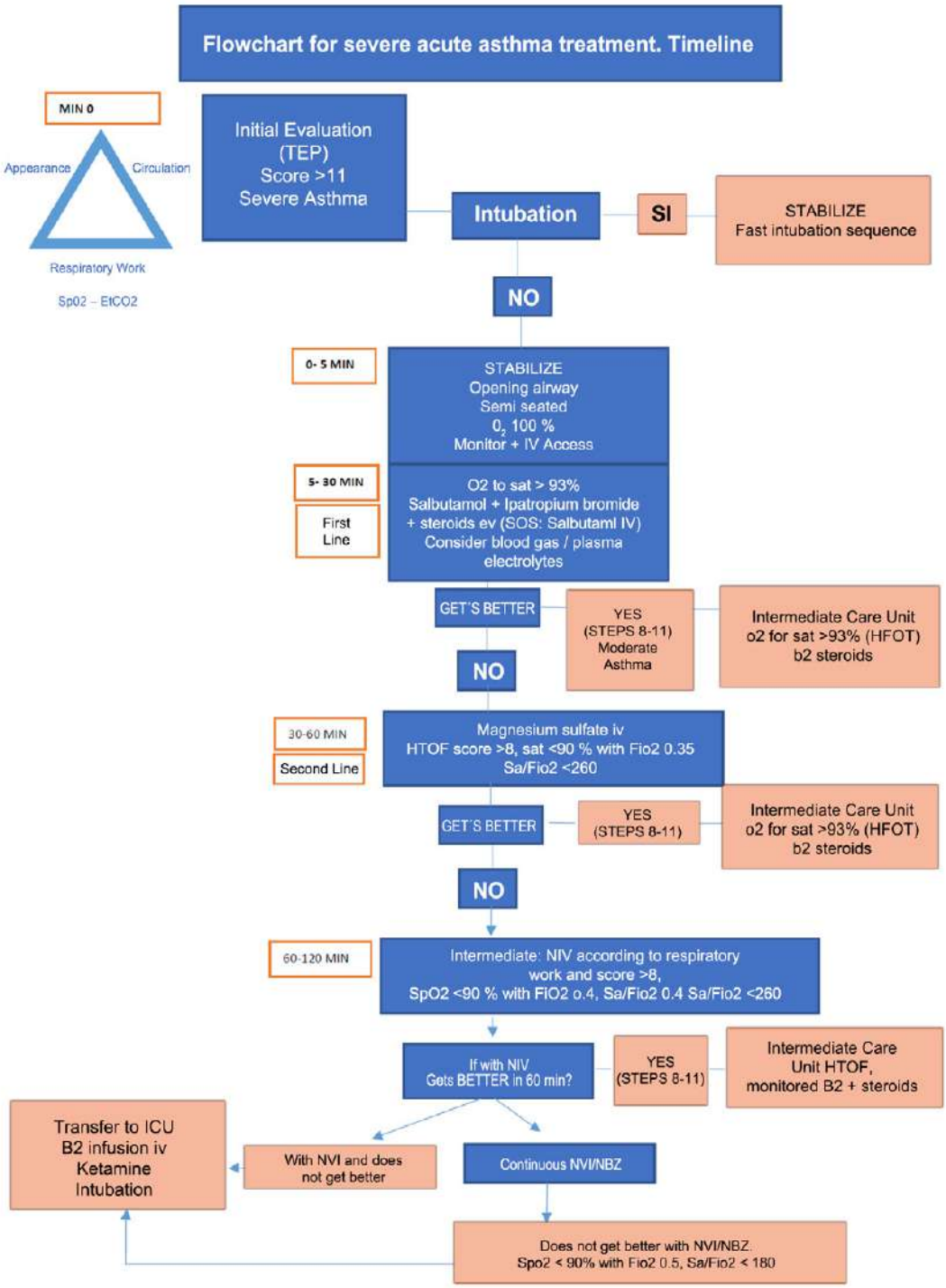
Table 1. Acute asthma severity score. Pediatric Asthma Score (PAS).

Score	1	2	3
Respiratory rate			
2 to 3 years old	< 35	35-39	> 40
4 to 5 years old	< 31	31-35	> 36
6 to 12 years old	< 27	27-30	> 30
> 12 years old	< 24	24-27	> 28
SpO2	> 95%*	90-95% *	< 90%**
Costal retraction	None or only intercostal	Intercostal and subcostal	Universal
Respiratory work (Disnea)	Speaks in phrases	Broken phrases	Only words
Auscultation	Prolonged exhalation	Expiratory wheezing	Wheezing in 2 times

Five clinical characteristics are evaluated, which are assigned a score of 1 to 3 according to severity. Total score range: 5-15. Score <8 (5-7): mild; 8-11: moderate; > 11 (12-15) severe.

SpO2: Saturation of arterial oxygen pulse. FiO2: Fraction of inspired oxygen
* saturation with room air. ** saturation with room air or O2 requirement to saturate over 93%.

Figure 1. Flowchart for severe acute asthma treatment.



PET: pediatric evaluation triangle. SpO2: Oxygen saturation. ETCO2: End-tidal CO2 HFTO: high flow oxygen therapy. NIV: non-invasive ventilation. FiO2: fraction of inspired oxygen. NBZ: Nebulization. Sat: saturation. Iv: intravenous.

Table 2. Presentation and dose of drugs used.

Salbutamol MDI	Fesema (21 mcg/puff)	2-8puff c/20min x 3times
NBZ with salbutamol	Salbutamol 0,5% (1cc=5mg)	< 20kg 2,5mg/dose, > 20kg 5mg/dose
NBZ salbutamol + IB	Salbutamol 0,5% (1cc=5mg) Atrovent 0,0025% (1cc=0,25mg)	Salbutamol: < 20kg 2,5mg/dose > 20kg 5mg/dose IB: < 10kg 250mcg/dose >10kg 500mcg/dose
Continued NBZ with salbutamol	Salbutamol 0,5% (1cc=5mg) 0.25-0.5mg / kg /	h (0,05-0,1ml) maximum 10mg/h
Continued NBZ with salbutamol + IB	Salbutamol 0,5% (1cc=5mg) Atrovent 0,0025% (1cc=0,25mg)	Salbutamol: 0,25-0,5mg/kg/hr (0,05-0,1ml) IB: 0,25-0,5mg/h (1-2cc/h) Complete volume of 72cc of SF 0,9%, NBZ 18cc/h x 4hrs
Prednisone	Prednisone (20mg/5ml) o (1mg/1ml)	1-2mg/kg/day maximum 40mg/day
Hydrocortisone		10mg / kg / day load, then 5mg / kg c / 6hrs (maximum 100mg / day)
Methylprednisolone		2mg / kg load, then 0.5mg / kg c / 6hrs Maximum 60mg / dose load Maximum 120mg / day maintenance
Magnesium Sulfate	25% Magnesium Sulfate (1cc=250mg)	25-50mg / kg / dose in 30 minutes (diluted in PS) (maximum 2gr)

IB: Ipatropium bromide, PS: physiological solution. MDI: pressurized metered dose inhaler. NBZ: Nebulization

The evaluations and interventions were carried out according to a preset algorithm based on the PAS (Figure 1) by pediatric residents, and a checklist where the treatment was detailed according to the categorization of the patient attached to the clinical record of each patient in the defined times.

Hospitalization criteria were the persistence of oxygen therapy requirement despite first line treatment in the emergency room (B2, corticosteroids with or without IB). Intermediate admission criteria were NIV requirement and treatment failure to HFOT and magnesium sulfate. Criteria for admission to intensive care were acute respiratory failure that does not improve with NIV (Sa / FIO2 <180), ventilatory insufficiency with pH <7.2 PaCO2> 60 mmhg, requirement for intravenous bronchodilators, hemodynamic instability, indication of intubation for invasive mechanical ventilation or management of severe complications (pneumothorax, massive atelectasis, severe acute respiratory infection).

Patients admitted to the pediatric department with a mild clinical score were treated with beta 2 bronchodilators with a metered dose inhaler (MDI) and oral corticosteroids (prednisone), unless they had previously received intravenous corticosteroids in the emergency room.

Those with a moderate clinical score or with clinical deterioration during hospitalization, received salbutamol nebulization along with IB every 20 minutes for 1 hour, intravenous corticosteroids preferably methylprednisolone in usual doses, using load, or maintenance dose if previously used in the emergency room. If another intravenous corticosteroid such as hydrocortisone was started in the emergency room, it was continued in maintenance doses. The presentation and dose of the drugs used are detailed in Table 2. These patients, who corresponded to the group with a score> 8, SpO2 <90% with FiO2 0.35; Sa / FiO2 <260, entered the medium care unit (medium complexity) where high flow oxygen therapy (HFOT) was initiated according to the criteria established in Table 3 and second-line therapy with intravenous magnesium sulfate at a dose of 50mg / kg in 30 minutes. In the case of lack of clinical response for 1 hour, manifested by a SpO2 <90% with FiO2 > 0.4, Sa / FiO2 <260, as in those who entered from the ER with a severe clinical score, we proceeded to transfer them to the intermediate care unit for non-invasive ventilation (NIV) (Table 3) according to pre-established criteria. In the absence of clinical improvement, it was decided to transfer the patient to the intensive care unit.

For the administration of high-flow oxygen therapy, a Fisher Paykel Airvo humidifier was used, which is a s a heated humidifier with integrated flow generator. It allows for the reading of FiO2 obtained by mixing oxygen from the central network through a balanced flowmeter with the selected air flow. The connection interface to the patient is an ad hoc nosepiece that admits flows up to 50 LPM, without generating resistance, the tubing or connection circuit is 15 mm in diameter and has an endomural heating system. Flows

Table 3. Criterios y parámetros de indicación de OTAF y AVNI.

	OTAF	AVNI
Criteria	Score > 8 SpO2 < 90% with FiO2 0,35 (Sa/FiO2 < 260)	Score > 8, failure 1h HFOT SpO2 < 90% with FiO2 > 0.40 (Sa / FiO2 < 260)
Parámeters	For a child older than 2 years: 1lt/kg/min; 20-50 LPM	I/E: 10/6 cmH2O hasta 20/8 Ti: 0,8-1,2 FR: 12-20 RPM

HFOT: High flow oxygen therapy with nasal cannula. NIV: non-invasive ventilation
LPM: Flow expressed in liters per minute. SpO2:, non-invasive oxygen saturation
FiO2: Fraction of inspired oxygen I: inspiratory pressure, E: expiratory pressure.
IT: inspiratory time. RR: respiratory rate

of 1 LPM per kilo of weight were used, with a maximum flow of 30 LPM and a heated humidifier temperature of 34 C °.

Non-invasive ventilation (NIV) was delivered through Philips Trilogy 202 volume-control & pressure-control ventilator, which allows for FiO2 through its integrated blender. The FiO2 used was the one necessary to maintain a Spo2 between 93 and 95%, the ventilation modalities were S / T with bilevel pressure, using the RR chosen according to the patient's age, a minimum expiratory positive airway pressure (Epap) of 6 a 8 cm of H2O and a inspiratory positive airway pressure (Ipap) of 10 to 20 cm of H2O, allowing a differential pressure of at least 4 cm, with a Epap to fast Ipap risetime of 100 ms. Ipap was adjusted by increasing to 2 cm H2O every 30 minutes, seeking a decrease in respiratory work (decrease in RR and HR, retraction and / or suprasternal circulation, absence of paradoxical respiration and improvement of SpO2).

Depending on the patient's adaptation, Philips total face masks or Philips or Fisher Paykel nasal masks were used as interfaces, with sizes according to weight and face shape that allowed the least possible airflow escape. Sedation was not used (13).

Bronchodilator therapy in patients with NIV, when using the algorithm, was performed with Aerogen mesh nebulizers attached to the dry arm of the Fisher Paykel MR810 heat humidifier base. This mesh nebulizer generates particles of 2 ug of aerodynamic average diameter and uses an electric generator or processor that allows to deliver continuous NBZ of 12 ml / hour or discontinuous bronchodilators. For bronchodilator therapy with a metered dose inhaler (MDI), salbutamol, GlaxoSmithKline's Fesema, was used with a standard non-valve 350-500 ml air chamber. HFOT was not suspended at the time of performing the inhalation maneuver. In the 2016 cohort, bronchodilator therapy in patients with NIV was performed with MDI and an adapter proximal to the ventilation circuit using 4 puffs of the MDI and continuous nebulization performed with a T-circuit and a Hudson Draft nebulizer II with a volume of 4ml and 18 ml per hour.

For monitoring, Mindray cardiorespiratory monitors were used in the intermediate unit and Mindray or General Electric vital signs monitors in the intermediate care units. Both have Nellcor reading technology. There was no End-tidal Co2 monitoring (ETCO2). Only Arterial blood gas (ABG) analysis were considered in those patients with severe acute respiratory failure with poor clinical response to NIV, who maintained a requirement of FiO2 over 0.5 and SpO2 <90% (Sa / FiO2 <180), with potential indication of intubation.

Discharge criteria were: severity score in mild category and saturation> or equal to 93% for 12 hours without oxygen therapy.

To assess the impact of the treatment algorithm, including HFOT, intravenous magnesium sulfate in earlier stages and the use of mesh nebulizer for bronchodilator delivery in patients in NIV, two primary variables were measured: the 2-point drop in the clinical score used at the end of the algorithm, considered as clinically significant in a recent study (19) and the decrease in hospitalization days compared to patients treated during the 2016 cohort, without algorithm. As a secondary efficacy variable, the need for transfer was evaluated: intermediate care unit or intensive care unit.

STATISTIC ANALYSIS

Statistical analysis was performed using the STATA 15 program. Quantitative variables were expressed as median and range, and qualitative variables were expressed in frequency and percentage. For the comparison of the 2 groups, the Mann Whitney test was used as a non-parametric test. For the comparison of PAS in its evolution within 120 minutes of the application of the algorithm, Wilcoxon test was used. P <0.05 was considered statistically significant.

This study was approved by the Ethics Committee of the Central Metropolitan Health Service (Resolution No. 1303) and with the informed consent of the parents and assent of those patients older than 7.

RESULTS

This study included a total of 106 patients admitted to the HCSBA Pediatric Service with acute asthma diagnosis, 55 patients during the period of application of the algorithm between December 2016 to December 2017 and 51 patients from the control group without application of the algorithm who were admitted during 2016.

Both groups were similar and comparable in terms

of age, sex, previous diagnosis of asthma, parent's smoking habits and number of exacerbations that required emergency room consultations and hospitalizations in the previous year. There was no difference statistically significant in nutritional status, more frequently overweight in the group without the algorithm, at the limit of significance. 13 (25.5%) vs 7 (12.7%) p = 0.057. There were significant differences in allergic rhinitis and use of asthma maintenance treatment in the group without algorithm, 39 (76.5%) vs 19 (34.5%) p < 0.001; 36 (70.5%) vs 25 (45.5%) p < 0.001 respectively (Table 4).

On admission to the pediatric service, 10 (18.2%) patients had a category of mild acute asthma; 40 (72.7%) moderate and 5 (9.1%) severe. The median severity score was 8 (p.50, IQR 8-10). In the control performed 30 minutes after admission, the median severity score was 6 (p.50, IQR 6-10) with a significant drop in the clinical score of 2 points (p <0.001).

At the 60-minute control, the median severity score was maintained at 6. At 120 minutes the median severity score was 5 (p.50, IQR 5-7), observing a total drop in the clinical score of 3 points after the application of the algorithm (p <0.001). (Figure 2).

30.9% of the children in whom the algorithm was applied, required HFOT, which was not used in the control group.

In both groups there were no significant differences for intermediate hospitalizations. About 20% of patients were admitted to intermediate care to receive NIV.

The duration of the oxygen therapy was similar, with an average of 3.6 days. The maximum FiO2 had no differences, with a range of 0.3 to 0.5.

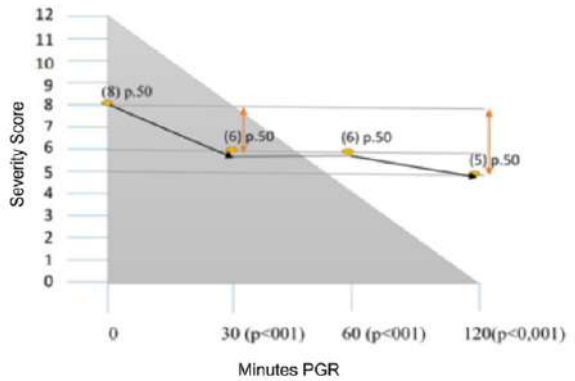
There were no differences in the frequency of use of intravenous magnesium sulfate, 4 (7.3%) and 3 (5.9%) in the group with and without algorithm, respectively.

Table 4. Comparison of the demographic and baseline characteristics of the 2 groups studied.

Variables	Year 2016	Year 2017	P Value
	Without Algorithm (n = 51)	With Algorithm (n = 55)	
Age, median (range)	8,05 (5-14)	8,2 (5-14)	ns
Sex (%)			
Female	27 (52,9)	23 (41,8)	ns
Male	24 (47)	32 (58,1)	ns
Prior diagnosis of asthma	36 (70,5)	37 (67,27)	ns
Maintenance treatment, n (%)*	36 (70,5)	25 (45,45)	P < 0,001
Nutritional status, n (%)			
Eutrophic	14 (27,45)	34 (61,81)	ns
Overweight	13 (25,49)	7 (12,72)	p 0,057
Obese	15 (29,41)	11 (20)	ns
Malnutrition risk	3	1	
Without registration	6	2	
Smoking parents	30 (58,82)	31 (56,36)	ns
History of rhinitis, n (%)	39 (76,47)	19 (34,54)	p < 0,001
No. of prior ER consultations, median (range)	1,41 (0-6)	0,78(0-4)	ns
No. of previous hospitalizations, median (range)	0,19(0-1)	0,21(0-2)	ns

Mann Whitney test
ns (not significant), ER: Emergency Room
* Inhaled corticosteroid (budesonide 400ug / day or Fluticasone 250 to 500 ug / day) or inhaled corticosteroid + B2 long-acting (Fluticasone + Salmeterol 250/25 ug / day). None with regular treatment for allergic rhinitis.

Figure 2. Decline in clinical score and decrease in hospitalization days.



Wilcoxon Test

In the group with algorithm there was no significant difference in hospitalization days in intermediate care but significant in the total length of hospitalization days: 0.6 days and 0.95 days respectively (p <0.0368) going from 3.5 days (0-8) to 2.9 days (0-7) in intermediate hospitalization and 4.78 days (2-17) to 3.83 (1-12) in total length of hospitalization. Complications characterized by atelectasis occurred in 5 patients (9%) from the study group and 3 patients (5.88%) in the control group (non-significant difference). Pneumonia was significantly more frequent in the group not submitted to the algorithm (24 (43.6%) vs 3 (5.9%) p <0.001).

Confirmation of an infectious agent with viral immunofluorescence, and with PCR technique (Film array; for those who required NIV) was obtained in 17 (30.9%) and 11 (21.56%) patients in the study and control group respectively. Viral etiology was the most frequent. Other etiologies were Mycoplasma Pneumoniae and Chlamydia Pneumoniae.

No patient required transfer to an invasive treatment unit, intubation for mechanical ventilation, or presented other complications such as pneumothorax or other modalities of airflow escape. There was no lethality.

DISCUSSION

The objective of this study was to describe and evaluate the impact of a treatment algorithm in children hospitalized for severe refractory asthma to first-line treatment in the emergency room, applying a continuous improvement plan that incorporated clinical elements in the prioritized decision making for the treatment of acute asthma. Thus, according to the best level of available evidence, it was hypothesized that the use of a pre-established step therapy protocol at defined times, along with the use of other devices such as HFOT and mesh nebulizers and the early use of magnesium sulfate applied in patients categorized with an acute asthma clinical score, would generate an early clinical improvement, decrease in the days of critical bed use and in the total days of hospitalization compared to the usual treatment previously used.

Step therapy in pediatric acute asthma is well defined by lines and stages, with 80% of patients responding to first-line therapies. The remaining 20%, which does not respond, is cataloged as refractory asthma (9) and in them the algorithm based on a clinical score was implemented.

The use of bronchodilators in metered dose inhalers (MDIs) and systemic corticosteroids was considered as first-line therapy. There is information available that the use of IDM bronchodilators gives some advantage over the use of nebulization, even in asthma exacerbations of greater severity (10). Another first-line treatment in moderate and severe crises is the association of a beta 2 agonist with ipratropium bromide in repeated doses, demonstrating effectiveness in reducing the frequency of hospitalization, however, the benefit of this association in management has not been demonstrated on the hospitalized patient (4).

Evaluation tools to classify and prioritize patients with an acute asthma crisis are useful for their management, providing the best care in each situation. Although there are several clinical scores in order to categorize the severity of asthma, there is no consensus on which one to use. The Pulmonary Score (17) has recently been incorporated to predict the risk of hospitalization, need for intensive care unit (19), and to assess the results of the use of HFOT (12). In our study, the Pediatric Asthma Score (PAS) was used, since the SpO2 cut-off points facilitate the non-invasive assessment of the severity of respiratory failure in patients with oxygen therapy requirements.

We observed that in the period in which the algorithm was incorporated there was a rapid decrease in the clinical severity score at 120 minutes and a significant decrease in the total days of hospitalization in regards to the control group. This effect can be attributed not only to the application of the algorithm, but also to the early use of magnesium sulfate, the use of HFOT and mesh nebulizers.

It has been shown that intravenous magnesium sulfate decreases the progression of an asthmatic exacerbation to severe respiratory failure (20,21,22).

As a third-line therapy we used both HFOT and NIV. High-flow oxygen therapy (HFOT) could be used today, within the step-up, step-down therapies for acute asthma, as a complementary therapy and better tolerated than NIV, as has been reported in observational studies done in adults with acute respiratory failure (23) . The increasing availability of devices in pediatric intensive care units, and more recently in the pediatric ward, as well as their ease of use and tolerance, has led to their incorporation in the management of children with respiratory failure (24). In a retrospective / observational study of children between 4 to 15 with a diagnosis of acute crisis of moderate to severe asthma, those treated with conventional oxygen therapy v/s HFOT were compared, finding that the use of the latter modality produced a reduction in heart rate , respiratory rate and clinical asthma score in the first 3 to 6 hours of treatment. It was shown that those patients who started HFOT with a flow> 15lt / min entered the PICU less than those who started with a flow <15lt / min (13% v / s 47%, P = 0.05) (25).

Table 5. Comparison of the results of the treatment of asthma crisis in both groups studied.

Variables	Year 2016	Year 2017	P Value
	Without Algorithm (n = 51)	With Algorithm (n = 55)	
Admission to intermediate n(%)	9(17,6)	10(18,2)	ns
Admission to PICU n(%)	0	0	
Mortality n(%)	0	0	
Pneumothorax n(%)	0	0	
Atelectasis n(%)	3(5,88)	5(9)	ns
Pneumonia n(%)	3(5,9)	24(43,6)	< 0.001
Total days of O2, mean (range)	3,6(1-13)	3,6(1-10)	ns
Total Days of Hospitalization	4,78(2-17)	3,83(1-12)	< 0.05
Total days in Intermediate Unit	3,5(0-8)	2,9(0-7)	ns
FiO2 Maximum, average (rango)	0,4(0,3-0,5)	0,37(0,3-0,5)	ns
HFOT n(%)	0	17(30,9)	na
NIV n(%)	9(17,6)	10(18,2)	ns
Magnesium n(%)	3(5.9)	4(7,3)	ns
Infectious Comorbidity n(%)			
RSV *1	4(7,84)	4(7,27)	ns
Other viruses (IAV,MPV,PI) *1	5(9,80)	4(7,27)	ns
Rhinovirus *2	na	6(12,72)	na
Mycoplasma *3	2(3,92)	2(3,6)	na
Other Agente (Clamydia Pneumoniae) *4	0	1(1,81)	ns
Total Etiology (+)	11(21,56)	17(30,9)	ns
Mild score (PAS)	na	10(18,2)	na
Moderate score (PAS)	na	40(72,7)	na
Severe score (PAS)	na	5(9,1)	na

Test de Mann Whitney
ns: no significativo, **na:** no aplica.
*1 VIF (Viral Immunofluorescence) or Film Array (2017) / * 2 Film Array (multiple PCR) / * 3 PCR (Specific polymerase chain reaction) / * 4 IgM (Specific Antibody). FiO2: inspired oxygen fraction. HFOT: high flow oxygen therapy. NVI: non-invasive ventilation. RSV: respiratory syncytial virus. IAV: influenza A virus. MPV: metapneumovirus, PI: parainfluenza virus. PAS: Pediatric Asthma Score.

Although there are few studies that support the efficacy and usefulness of HFOT in acute asthma crisis in children, there has been improvement in intermediate parameters and in clinical scores that express the decrease in respiratory distress and improvement in SpO2. This is attributed to better heat humidification, greater mucociliary clearance, nasopharyngeal dead space washing and more stable oxygen delivery, producing positive airway pressure at the end of variable expiration, which has been shown to be more useful in patients with bronchiolitis (26).

Non-invasive ventilation is effective as a third-line treatment in patients with a severe asthmatic crisis. The mechanism of action seems to be based on a direct bronchodilator effect, on the improvement of alveolar recruitment and on an increase in the response to bronchodilators (27,28). However, 2019 GINA clinical guidelines do not consider the use of NIV as part of conventional asthma interventions, since the level of evidence of its use in crisis is low. The latest GINA guidelines recommend that the use of NIV should be in monitored patients and should not be attempted in agitated patients, nor should these be sedated for use (15).

Given the benefit observed of these new treatments and respiratory therapies, it was decided to apply the algorithm that incorporates decision making according to the severity and response in step stages, adding to the conventional treatment, of the previous period, the use of early intravenous magnesium sulfate, HFOT and NIV without pediatric sedation and intermediate care unit. These measures allowed a decrease in hospitalization days. This allowed greater rotation of beds, which is of great importance in periods of high epidemiological demand.

LIMITATIONS

The main limitation of the study was not having a control group to compare the algorithm with a non-intervened group, in which the treatment was guided according to the standard of the previous period. This fact weakens the ability to establish conclusions of effectiveness and efficiency. On the other hand, the decrease in hospitalization compared to patients not subjected to the algorithm, may be due to multiple factors and not necessarily to the interventions performed the first 120 minutes. However, since there was a similar frequency of NIV and the use of intravenous magnesium sulfate, it is possible that the incorporation of HFOT in 1/3 of the patients admitted to the algorithm, could explain these results.

It was not possible to have a control group parallel to the group in which the algorithm was used, since the application of the latter was a policy of continuous improvement and good practices, in which it was estimated that there was justifying evidence for all of the patients with acute asthma to be included in the algorithm group.

For this reason, we include other effectiveness variables, such as the length of hospitalization and use of critical bed resources that allowed for comparisons with a demographically similar group that would not have used an algorithm in the period prior to its implementation. We could not compare the benefits of using HFOT in acute asthma, since this therapeutic modality was incorporated into our hospital as of 2017.

Failure to perform validation tests of the clinical score used is a limitation, but prior training was carried out for all residents, and also for nursing residence, being the responsibility of the former to evaluate the clinical score for decision making. Although both groups of patients had a similar frequency of previous diagnosis of asthma, only 25% of the patients incorporated into the algorithm were receiving control treatment, coinciding with that reported in the multicenter study of Herrera et al, in which only the 20% of children hospitalized for asthma crisis had control treatment (14).

For the comparison of hospitalization days, the demographic and baseline characteristics of the 2 groups appeared to be balanced, but patients without an algorithm could have a more severe phenotype related to overweight and allergic rhinitis.

However, as already mentioned, the group not subjected to the algorithm had a significantly higher frequency of asthma control treatment and significantly lower pneumonia. No significant differences in the confirmation of the etiological cause. Although this could impact on asthma control and the presence of triggers linked to an asthma exacerbation of greater severity such as viruses (29), both groups had no differences in episodes of major exacerbations such as ER and previous hospitalizations, suggesting a similar level of asthma control.

Both groups agreed to the same control medication, which is available at our hospital's specialty pharmacy, linked to inhaled corticosteroids or inhaled corticosteroids associated with long-acting B2 and occasionally montelukast.

Another important limitation was not to implement the algorithm from the moment of admission to the children's emergency room, at least for the incorporation of a second line of magnesium sulfate treatment. The recent experience, in which there was a decrease in hospitalizations, total costs and duration of hospitalization in patients treated with high-dose intravenous infusion and magnesium sulfate, makes it a very interesting strategy (21). But since this second-line treatment and other advanced management of acute respiratory failure such as high-flow oxygen therapy and non-invasive ventilation are not actions that are routinely implemented in the emergency room of our hospital, we found it prudent in an initial stage, to continue the management of children with acute refractory asthma to first line treatment in the pediatric plant.

CONCLUSION

The use of an algorithm allowed us to unify criteria, to implement a treatment flowchart, that guarantees performing time-dependent actions, with good evidence support. It was observed that the algorithm and the application of HFOT and early magnesium sulfate had a rapid decrease in the clinical score used and that the duration of hospitalization stay was shorter compared to the previous period without these measures. Our results could suggest that the application of an algorithm based on clinical score, along with the incorporation of HFOT and early magnesium sulfate, could improve the effectiveness and efficiency of acute asthma treatment. However, validations are required through controlled studies.

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