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Research article

Effectiveness of pediatric asthma education program in the context of a general hospital in France: A retrospective real-life study

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ABSTRACT

Objective: To assess the feasibility and effectiveness of a pediatric asthma education program delivered in the context of a French suburban general hospital.
Design: Monocentric retrospective study including children with asthma in Melun, Île-de-France, from January to December 2019. Data collected concerned asthma management, symptoms, education, and knowledge.
Results: We included 262 patients with a median age of 4.5 years. Asthma education (AE) was taught to 226 (86 %) children, 36 with minimal education (ME), 155 (69 %) with an unstructured asthma education program (USEP) and 71 (31 %) a structured asthma education program (SEP). Patients with an SEP had better knowledge of the disease and its treatment as compared with those with a USEP or ME ($p < 0.05$). Lung function was evaluated for 70 % of children with ME, 90 % with a USEP ($p = 0.144$) and 77 % an SEP ($p = 0.455$). Allergy testing was assessed for 42 % of children with ME, 69 % a USEP ($p = 0.020$) and 57 % an SEP ($p = 0.185$). Almost all children with USEP (93 %) and SEP (94 %) also had a written asthma action plan as compared with 49 % of the children with ME ($p < 0.001$). Also, 76 % of children with ME did not have an asthma follow-up as compared with 37 % with a USEP and 52 % an SEP. Overall, 69 % of children with ME had at least one hospitalization within the year as compared with 32 % with a USEP ($p = 0.001$) and 59 % an SEP ($p = 0.506$).
Conclusions: An asthma education program delivered in a general hospital resulted in increased disease knowledge for children and their caregivers, together with reduced acute interventions.

- **What is already known on this topic.**

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Asthma education and self-management are key components of asthma control in children. There is growing evidence that when quality interventions are offered, self-management education results in an improvement in adherence to therapy and follow-up.

- **What this study adds:**

Here, we investigated the impact of a pediatric asthma educational program in a French regional hospital. Such a program delivered in a general hospital resulted in increased disease knowledge for children and their caregivers, together with reduced acute interventions even in the absence of a structured program.

- **How this study might affect research, practice or policy.**

This study highlights the benefits of supporting asthma education in rural hospitals even if they do not have structured education programs.

1. Introduction

Asthma is the most common chronic disease among children [1,2], and pediatric asthma, due to its high prevalence, poses a significant burden on healthcare systems [3]. In France, its prevalence is estimated at 9 %, with two thirds of patients under age 15 years hospitalized for an asthma attack [4]. Despite guidelines and expert recommendations on asthma management [5–9] as well as progress in understanding the disease and the availability of treatments, asthma control and adequate prescription remain insufficient in France [4,10].

Educational programs are now recognized as an essential component of asthma education and should systematically be considered when managing asthma in children [11,12]. Many studies suggest their efficacy on several asthma control evaluation criteria, including hospitalizations, emergency department visits and unscheduled consultations. Asthma education programs have also been found to reduce clinic visits and the need for inhaled corticosteroid, improve lung function as well as reduce school absenteeism, limitations of physical activities and night-time respiratory symptoms [13–18].

Structured education programs are more effective than information alone. They are based on teaching patients to self-manage their treatment (personal written action plan, assessment of symptoms and/or measurement of peak expiratory flow by the patient), combined with regular medical follow-up. They should be offered at an early stage to all asthma patients and their families. They can be carried out in consultation, during hospitalization or as part of a care network [11].

Components of an asthma education program should focus on three criteria: knowledge (of the disease, symptoms, triggers and role of treatments); ability, such as the correct use of the inhaler; and self-management (ability to take adequate measures during respiratory symptoms or risk situations) [17,19]. Most of the studies on such programs were performed in academic clinical situations [16,18], and the literature remains scarce in suburban and regional hospitals. Implementing an education program for children with asthma can be challenging in a non-academic, suburban hospital setting. The population cared for in these hospitals often features low living conditions, socio-economic levels and access to healthcare. Exposure to environmental tobacco smoke, suboptimal therapy, poor treatment adherence, lack of continuity between routine and acute asthma care, commonly encountered in this environment, have a negative impact on the diagnosis and management of asthma [20–22].

In this context, we aimed to share our institutional experience on the design and impact of an asthma education program on the care pathway and asthma knowledge in children presenting asthma in a French suburban general hospital in the Paris area.

2. Methods and design

2.1. Data collection

This was a retrospective descriptive study including patients under age 18 years who presented asthma at the general hospital of Melun, France, from January 1 to December 31, 2019. Cases were selected from the database of pediatric pneumo-allergology visits, asthma education visits and from the register using the French common classification of diagnosis (ICD-10) for children and adolescents hospitalized for asthma. Stays included were those for which asthma was the main diagnosis: codes J45 (J45.0 predominantly allergic asthma, J45.1 non-allergic asthma, J45.8 associated asthma, J45.9 unspecified asthma) or J46 (acute severe asthma). Data collected included age; sex; personal and family medical history; starting date of respiratory symptoms; age at asthma diagnosis; treatments received; data concerning hospitalizations, urgent care visits and routine visits; medical investigations; asthma education and knowledge; as well as the use of inhaler devices. Patients were divided into three groups in terms of the education about asthma they received: 1) minimal education (ME: absence of documented information about asthma in the patients' files); 2) unstructured asthma educational program (USEP: written material alone or short unstructured verbal interaction mentioned in the patients' files); and 3) structured asthma educational program (SEP).

2.2. Structured asthma education program

Structured patient education includes a written treatment plan, assessment of symptoms and/or measurement of peak expiratory flow, and regular monitoring. The SEP was delivered to children and their parents/guardians in a hospital setting with specific

consultations adjusted to the child's age. The asthma education (AE) team consisted of two pulmonologists for children, two nurses (one dedicated to therapeutic education), one physiotherapist and one medical advisor for indoor environments. Other medical team members including general pediatricians and nurses could also provide AE in addition to the AE team. The SEP included first an evaluation by an AE team member, followed by one to five interactive AE sessions depending on the needs and motivation of the child and the family. Children were assessed on their knowledge immediately after the first educational session.

To monitor progress, the AE team developed several questionnaires. One grid was created to assess theoretical and practical skills regarding asthma. It was based on recommendations for clinical practice by the French health evaluation and accreditation agency [23, 24] and the French health authority [25]. Twelve items were evaluated: "Always has the treatment at disposal", "Recognize the symptoms of an asthma attack", "Know how to react during asthma attack", "Has knowledge of asthma mechanisms", "Know the impact of smoking on asthma", "Know the importance of medication compliance", "Know the role of treatments", "Know at least a few triggers/aggravating factors", "Know how to use a peak flowmeter", "Know emergency phone number", "Is compliant", and "Inhalation technique assessed". For each item, degrees of competence and knowledge were classified as unknown, being acquired, partially acquired, and known. To simplify the comparison, we choose to regroup the items "known" with "partially acquired" and the items "unknown with "being acquired (Table 2). Additional grids were used to evaluate the use of inhaler devices, based on educational videos from the Zephir website (https://splf.fr/videos-zephir/), guides form the French healthcare organization website (Assurance Maladie; https://www.ameli.fr/medein/exercice-liberal/memos/suivi/utilisation-dispositifs) and the French pharmacist committee website (Comité d'éducation sanitaire et sociale de la pharmacie française; https://www.cespharm.fr/content/download/38039/file/asthme-grilles-d-evaluation-des-techniques-d-inhalation.pdf?version=17). The questionnaire used to evaluate the use of the meter-dose inhaler with spacer (MDI-spacer) consisted of 12 action items, 12 for the MDI without spacer, 16 for the autohaler and 13 for the diskus (dry powder inhaler). Each action was classified as mastered or not mastered (Table 3). Participants were also asked to indicate whether they completed the questionnaires alone or with the help of family/relatives. AE information could also be traced by medical observation, hospitalization reports or medical consultation reports, especially for children who received only USEP.

2.3. Statistical analysis

Patient characteristics are described with number (percentage) for categorical variables and median (interquartile range [IQR]) for quantitative variables globally and by asthma education mode. Among children with data on AE (USEP and SEP), patients who benefitted from SEP were compared to those with USEP. Data on asthma management, follow-up, and healthcare use were analyzed according to ME, USEP and SEP groups. Categorical data were compared by chi-squared or Fisher test as appropriate according to their conditions of application. For the 2 quantitative variables, because their distribution was not normally distributed (graphically), we used the non-parametric Kruskall-Wallis test. Univariate analyses were performed, and we secondarily adjusted for age and sex using logistic regression (reporting the odd ratios (OR) and their 95 % confidence interval [95%CI]) or multinomial logistic regression (reporting the relative-risk ratios (RRR) and their 95 % confidence interval [95%CI]) models as appropriate. $P < 0.05$ was considered

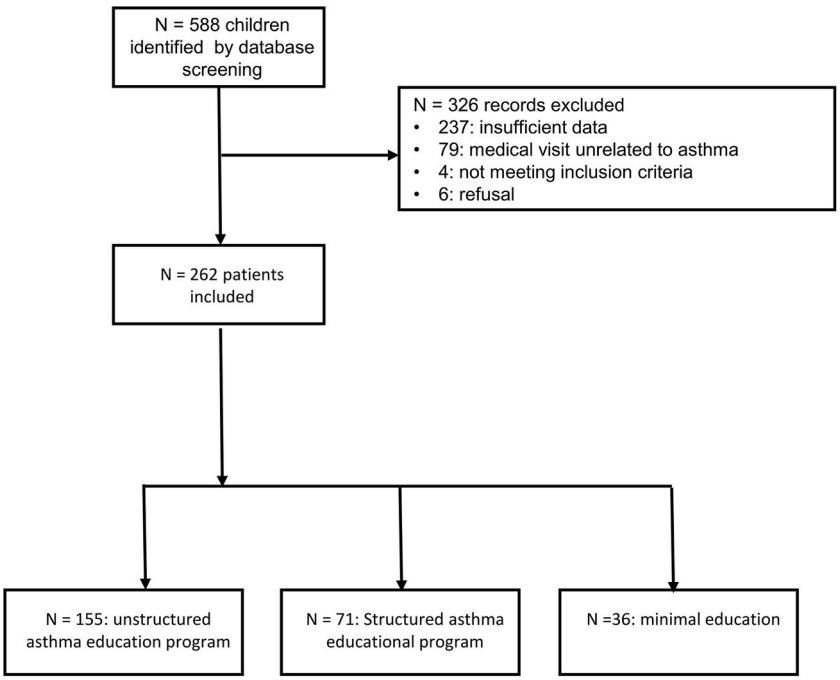

Fig. 1. Flow-chart

statistically significant and tests were two-sided. Statistical analyses were performed with STATA 17 under license (StataCorp. 2021, College Station, TX, USA).

2.4. Ethics

According to the national requirement regarding the retrospective collection of medical data, this database was declared to the *Commission Nationale de l'Informatique et des Libertés* (MR004 method, no. 0709260520) and to the register of data protection (RGPD). The study was approved by the ethics committee (*Comité Ethique et Scientifique pour les Recherches, les Etudes et les Evaluations en Santé*, CESREES no. 0709260520). informed consent was obtained from parents/guardian of the study.

3. Results

3.1. Description of the population

We included 262 patients in the analysis. The study flow chart is presented in Fig. 1 and patient characteristics are detailed in Table 1. More than half of the patients were less than 6 years old; the median age was 4.5 years. Sixty-two % were boys. The median age at diagnosis was 3 years and at the first respiratory symptoms was 1 year. The medical history was mostly family allergy (70 %) or personal allergy (food allergy for 10 %, atopic dermatitis for 19 % and allergic rhinoconjunctivitis for 31 %). In total, 34 (13 %) children were born premature and 27 (10 %) had fetal growth restriction. Nine (4 %) children had bronchopulmonary dysplasia or hyaline membrane disease, one child had sleep apnea syndrome, and one child had a history of surgery for pulmonary emphysema and another for a tracheal bronchus. In all, 22 (9 %) children had been hospitalized in an intensive care unit and 24 (9 %) received high-flow oxygen therapy, non-invasive ventilation, or mechanical ventilation.

3.2. Effect of education program on knowledge

In total, 226 (86 %) children received AE:155 (69 %) a USEP and 71 (31 %) an SEP while 36 while 36 (14 %) had ME. Results are summarized in Table 2. Concepts most addressed were asthma pathophysiology, asthma attack symptoms, how to take adequate measures during respiratory symptoms, triggers, role of treatments, the importance of medical adherence and to have the treatment at hand, and use of an inhalator device. Patients who participated in an SEP had better knowledge of the disease and its treatment as compared with those with a USEP ($p < 0.05$). Correct use of the inhaler was evaluated after an SEP for 114 children. A specific grid was used (Table 3). Most patients (85 %) used an MDI-spacer with adequate use of the device (10 of 12 actions correctly performed). The most common errors were forgetting to shake the inhaler (43 %), not breathing five respiratory cycles between each puff (26 %) and forgetting to rinse the mouth after taking inhaled corticosteroids (44 %). Thirteen children used an MDI without a spacer, three an autohaler and two a dry powder inhaler.

Table 1
Characteristics of the population with minimal education (ME), unstructured educational program (USEP) and structured educational program (SEP).

Characteristics, n (%)	Total	ME	USEP	SEP	Global p-value
Girls	100 (38.2)	11 (30.6)	56 (36.1)	33 (46.5)	0.198*
Age, years					0.684***
0-6	155 (59.2)	25 (69.4)	87 (56.1)	43 (60.6)	
6-12	72 (27.5)	7 (19.4)	45 (29.0)	20 (28.2)	
12-18	35 (13.4)	4 (11.1)	23 (14.8)	8 (11.3)	
Age at the beginning of first respiratory symptoms, years, median (IQR)	1 [0.5–2.5]	0.8 [0.4–2.5]	1 [0.5–2.5]	1 [0.5–2.3]	0.370**
Age at asthma diagnosis, years, median (IQR)	3 [1.5–5]	2 [1–3.5]	3 [2–6]	3 [1.5–5.5]	0.170**
History					
Prematurity (n = 257/36/154/67)	34 (13.2)	3 (8.3)	24 (15.6)	7 (10.5)	0.486***
Fetal growth restriction (n = 257/36/154/67)	27 (10.5)	1 (2.8)	20 (13.0)	6 (9.0)	0.211***
Bronchopulmonary dysplasia (n = 257/36/154/67)	9 (3.5)	1 (2.8)	5 (3.3)	3 (4.5)	0.886***
Other pulmonary disease (n = 257/36/154/67)	3 (1.2)	0 (0.0)	2 (1.3)	1 (1.5)	>0.999***
Hospitalization in ICU (n = 257/36/154/67)	22 (8.6)	3 (8.3)	13 (8.4)	6 (9.0)	>0.999***
History of HFOT, NIV or MV (n = 257/36/154/67)	24 (9.3)	4 (11.1)	12 (7.8)	8 (11.9)	0.481***
Bronchomalacia (n = 257/36/154/67)	6 (2.3)	0 (0.0)	6 (3.9)	0 (0.0)	0.217***
Gastro-esophagial reflux (n = 258/36/155/67)	16 (6.2)	1 (2.8)	11 (7.1)	4 (6.0)	0.761***
Food allergy (n = 258/36/155/67)	25 (9.7)	4 (11.1)	16 (10.3)	5 (7.5)	0.829***
Atopic dermatitis (n = 258/36/155/67)	48 (18.6)	2 (5.6)	32 (20.7)	14 (20.9)	0.095*
Allergic rhinoconjunctivitis (n = 259/36/155/68)	79 (30.5)	4 (11.1)	53 (34.2)	22 (32.4)	**0.024***
Passive or actual smoking (n = 127/10/63/54)	60 (47.2)	4 (40.0)	29 (46.0)	27 (50.0)	0.828***

Data are n (%) unless otherwise indicated. AE: asthma education; HFOT: high-flow oxygen therapy; ICU: intensive care unit; IQR: interquartile range; MV: mechanical ventilation; NIV: non-invasive ventilation. * chi-squared test. ** Kruskal-Wallis test. *** Fisher test. The numbers between brackets for each variable correspond to the numbers on which the analyses were carried out.

Table 2
Comparison of USEP and SEP in content of asthma education.

Content of asthma education (n = USPE; SEP) - Partially acquired/known (%)	USEP	SEP	OR [95%CI] p-value*	OR [95%CI] p-value**
Always has the treatment at disposal (n=63; 61)	22 [35]	32 (52)	2.06 [1.00; 4.23] **p=0.050**	2.67 [1.21; 5.88] **p=0.015**
Know how to react during asthma attack (n=64; 61)	15 [23]	38 (62)	5.40 [2.48; 11.73] **p < 0.001**	6.94 [2.97; 16.24] **p < 0.001**
Has knowledge of asthma mechanisms (n=62; 59)	15 [24]	30 (51)	3.24 [1.50; 7.03] p = 0.003	3.27 [1.48; 7.20] p = 0.003
Know the impact of smoking on asthma (n=24; 38)	12 (50)	30 (79)	3.75 [1.23; 11.46] **p=0.020**	3.59 [1.16; 11.09] **p=0.026**
Know the importance of medication compliance (n=63; 58)	26 [41]	35 (60)	2.17 [1.05; 4.48] **p=0.037**	2.34 [1.11; 4.97] **p=0.026**
Know the role of treatments (n=63; 60)	19 [30]	27 [45]	1.89 [0.90; 3.97] **p=0.091**	2.22 [1.02; 4.83] **p=0.044**
Recognize the symptoms of an asthma attack (n=63; 61)	28 [44]	36 (59)	1.8 [0.88; 3.67] p = 0.106	2.28 [1.05; 4.93] **p=0.037**
Know at least a few triggers/aggravating factors (n=60; 61)	15 [25]	28 (46)	2.55 [1.18; 5.51] **p=0.018**	2.89 [1.29; 6.48] **p=0.010**
Know how to use a peak flow flowmeter (n=7; 19)	1 [14]	4 [21]	1.6 [0.15; 17.41] p = 0.700	2.95 [0.20; 44.13] p = 0.433
Know emergency phone number (n=41; 51)	32 (78)	41 (80)	1.15 [0.42; 3.17] p = 0.783	1.18 [0.42; 3.29] p = 0.752
Is compliant (n=43; 52)	20 (46)	34 (65)	2.17 [0.95; 4.97] p = 0.066	2.34 [0.99; 5.53] p = 0.053
Inhalation technique assessed (n=60; 61)	26 [43]	35 (57)	1.76 [0.86; 3.62] p = 0.124	1.95 [0.93; 4.11] **p=0.078**

USEP: unstructured asthma educational; SEP: structured asthma educational program; OR: odd ratio; 95%CI: 95 % confidence interval. * Logistic regression; ** Logistic regression, adjusted on age and sex. Reference modality for content of asthma education variables was "Unknown/being acquired". The numbers between brackets for each variable correspond to the numbers on which the analyses were carried.

3.3. Effect of education program on asthma management, follow-up, and healthcare use

Table 4 summarizes the asthma management, follow-up, and healthcare use by type of AE program with comparisons adjusted for age and sex. Lung function was evaluated for 70 % of children with ME, 90 % with a USEP (p = 0.144) and 77 % with an SEP (p = 0.455). Allergy testing was performed in 42 % of children with ME, in 69 % with USEP (p = 0.020) and in 57 % with SEP (p = 0.185). Chest radiography was prescribed for most of the children regardless of type of AE (94 % of children with ME, 98 % with USEP, and 98 % with SEP). Inhaled corticosteroids were prescribed for 95 % of the patients, for half (53 %) during a visit to the hospital and regardless of type of asthma education.

Almost all children with USEP (93 %) and SEP (94 %) also had a Written Asthma Action Plan (WAAP) as compared with 49 % of the children with ME (p < 0.001). A WAAP for school (WAAP-S) was provided for 15 % of children with ME as compared with 36 % of children with a USEP (p = 0.041) and 59 % of the children with an SEP (p < 0.001).

For more than half the children (54 %), their asthma follow-up was provided by a primary care physician, general practitioner (32 %) or pulmonology pediatrician (59 %). Also, 76 % of children with ME did not have asthma follow-up as compared with 37 % with a USEP and only 52 % with an SEP (p = 0.003 and p = 0.098 respectively). A total of 170 (65 %) children had at least one visit to the emergency department within the year of presentation, and almost half (45 %) were hospitalized. Overall, 69 % of children with ME had at least one hospitalization within the year as compared with 32 % with a USEP (p = 0.001) and 59 % an SEP (p = 0.506) (Table 4).

4. Discussion

In this study, we reviewed a population of 262 children with asthma in a general hospital in a suburban area of Paris. We show that 86 % of patients received AE, including a USEP for 69 % and an SEP for 31 % while 36 (14 %) had only ME. The benefits of asthma education have been demonstrated, but most of the studies were performed in an academic hospital with a dedicated asthma education center [15,16], whereas asthma is a common chronic condition requiring management in a nearby hospital. Hence, real-life data from regional non-academic hospitals are scarce and focus mainly on rural populations [13,26,27]. In the present study, only half of our patients who presented asthma at our hospital had an asthma follow-up, although many had visited the emergency department or had to be hospitalized for asthma within the year after the presentation. Our findings suggest that at least half of the children had asthma assessment and management during a visit to the hospital (routine visits, urgent care, or hospitalizations) but without any follow-up. These results could be explained by an insufficient number of asthma management-trained physicians and lack of adherence to follow-up by families (misunderstanding the need for follow-up, economic difficulties).

Twenty years ago, the AIRE study [28] highlighted a gap between the reality and objectives in asthma management in Europe. A survey of Spanish primary care physicians also showed that pediatric asthma management remained insufficient. Propositions were to improve record-keeping, facilitate resources required for diagnosis and prioritize education [29]. Despite these difficulties, most of the patients in our regional hospital had asthma explorations as required, received inhaled corticosteroids and had been given a WAAP. Many children received AE mostly as a USEP. Of note, despite being a suburban regional hospital, Melun hospital offers a center dedicated to education intervention (mostly asthma and chronic obstructive pulmonary disease) with a culture of educational practices, which may explain the fairly good results.

The content of asthma education is related to inhaler technique assessment, WAAP, and asthma management [15,16]. We showed that children who received an SEP had better knowledge of asthma especially regarding the management of an asthma attack. Patients who received AE had fewer visits to the emergency department and fewer hospitalizations. They also more frequently had an asthma follow-up as well as written documents on asthma management.

Table 3
Inhalation technique assessed in structured asthma educational program (n = 114 children).

Criteria	n (%)
MDI-spacer (n = 96)	
Number of items mastered (/12), median (IQR)	10 [9–11]
Remove the cap	95 (99)
Hold the device vertically	96 (100)
Shake the inhaler	55 (57)
Place inhaler on the spacer adequately	93 (97)
Place spacer mask on the face adequately	90 (94)
Deliver the dose adequately	94 (98)
Take 1 puff at a time	81 (84)
Count 5 breathing cycles between each puff	71 (74)
Close the device	91 (95)
Clean the spacer regularly	40 [41]
Rinse the mouth after taking ICS	54 (56)
Know when the device is empty	85 (89)
MDI (n=13)	
Number of items mastered (/12), median (IQR)	9 [8–10]
Shake the inhaler	7 (54)
Remove the cap	13 (100)
Hold the device vertically	13 (100)
Exhale deeply before taking a puff	10 (77)
Place the lips around the inhaler adequately	13 (100)
Deliver the dose adequately	13 (100)
Take a deep breath	9 (69)
Take 1 puff at a time	10 (77)
Have good coordination	7 (54)
Hold their breath for 5–10 s	4 [31]
Rinse the mouth after taking ICS	12 (92)
Know when the device is empty	8 (62)
Autohaler (n=3)	
Number of items mastered (/16), median (IQR)	14 [12–14]
Remove the cap	3
Shake the inhaler	2
Activate the device if it has not been used for many days	2
Hold the device vertically	3
Lift the lever and then activate the device	3
Exhale deeply before taking a puff	3
Place the lips around the inhaler adequately	3
Take a deep breath	2
Take 1 puff at a time	3
Wait for the click sound meaning the dose has been delivered	2
Hold their breath for 5–10 s	1
Lower the lever	2
Repeat the steps for next dose	3
Close the device	3
Rinse the mouth after taking ICS	3
Know when the device is empty	2

ICS: inhaled corticosteroids; IQR, interquartile range; MDI: meter-dose inhaler.
Categorical variables are presented as number (percentage) for variables and quantitative variables as median (interquartile range [IQR]).

Use of an inhaler device was assessed in 114 patients from the SEP group. In line with our findings, Kamps et al. showed that many asthmatic children used their inhaler devices too poorly even after instruction [30]. A study demonstrated the essential role of regularly evaluating the patient and caregivers to ensure correct inhaler application. The authors suggested that factors related to the correct performance included duration of use for more than 1 year, instruction in the inhaler technique by trained technicians and level of education of caregivers [31]. Agertoft et al. showed that after individual instruction associated with training at home, children knew better how to use their device [32]. In a phone call survey of American families, the most-taught concepts were being taught how to use an inhaler, what to do during an asthma episode and how to recognize early symptoms of an asthma episode [33].

Our study confirms the quality and relevance of our AE program content in comparison to French recommendations [24] and what is described in real life in the literature [26,27]. Indeed, children frequently had asthma follow-up and asthma management plans if they had AE. In two large American cohorts (ACBS [33], NHIS [34]), 14 %–16 % of children had taken a class on asthma management, but only 40 %–43 % had an asthma management plan. Another study focusing on pediatric asthma management by European ambulatory pediatricians (ECPC [35]) estimated that 80 % of patients had a WAAP.

Our patients could receive AE in an SEP. Education on asthma knowledge is the hallmark of asthma education and quality of life, and knowledge of asthma is positively related [36]. Liu et al. showed that any method of education increased parental asthma knowledge and decreased children's anxiety as well as child asthma morbidity scores; asthma severity was reduced when knowledge

Table 4
Effect of asthma education on asthma management, follow-up, and healthcare use.

	Total	ME	USEP	SEP	RRR [IC95 %] p-value ǂ USEP *vs.* ME	RRR [IC95 %] p-value ǂ SEP *vs.* ME
Asthma management						
Chest radiography (n = 241/35/143/63)	234 (97)	33 (94)	140 (98)	61 (97)	2.69 [0.42; 17.12] p = 0.294	1.93 [0.25; 14.65] p = 0.526
LFT (n = 95/10/63/22)	81 (85)	7 (70)	57 (90)	17 (77)	3.76 [0.64; 22.21] p = 0.144	2.06 [0.31; 13.78] p = 0.455
Allergology testing (n = 251/36/150/65)	156 (62)	15 [42]	104 (69)	37 (57)	2.69 [1.17; 6.19] p = 0.020	1.87 [0.74; 4.70] p = 0.185
Asthma treatment prescribed (n = 258/36/155/67)	247 (95)	32 (89)	150 (97)	65 (97)	4.08 [0.97; 17.13] p = 0.055	3.42 [0.57; 20.53] p = 0.178
WAAP (n = 252/33/151/68)	221 (88)	16 (49)	141 (93)	64 (94)	13.88 [5.15; 37.42] p < 0.001	19.17 [5.31; 69.11] p < 0.001
WAAP-S (n = 241/33/143/65)	94 [39]	5 [15]	51 [36]	38 (59)	2.91 [1.04; 8.14] p = 0.041	8.77 [2.93; 26.25] p < 0.001
Follow-up						
Follow-up visits (n = 256/34/153/69)					0.003	0.098
No follow-up	118 (46)	26 (76)	56 [37]	36 (52)	1	1
Once a year	41 [16]	2 [6]	34 [22]	5 [7]	6.88 [1.40; 33.77] p = 0.019	1.59 [0.26; 9.80] p = 0.615
Every 3 months or every 3–6 months	97 [38]	6 [18]	63 [41]	28 [41]	4.56 [1.69; 12.31] p = 0.003	3.21 [1.11; 9.28] p = 0.031
LFT – at least once a year (n = 95/10/63/22)	81 (85)	7 (70)	57 (91)	17 (77)	3.76 [0.64; 22.21] p = 0.144	2.06 [0.31; 13.78] p = 0.455
Healthcare use						
At least 1 ED visit/year	170 (65)	29 (81)	86 (56)	55 (78)	0.38 [0.14; 1.03] p = 0.057	1.12 [0.37; 3.39] p = 0.846
At least 1 hospitalization/year	117 [45]	25 (69)	50 [32]	42 (59)	0.24 [0.11; 0.56] p = 0.001	0.73 [0.29; 1.85] p = 0.506

Data are n (%). AE: asthma education; ED: emergency department; LFT: lung function testing; ME: minimal education; USEP: unstructured asthma educational program; SEP: structured asthma educational program; WAAP: written asthma action plan; WAAP-S: written asthma action plan for school; ED: emergency department; RRR: relative-risk ratios; 95%CI: 95 % confidence interval ǂ Multinomial logistic regression adjusted for age and sex. The numbers between brackets for each variable correspond to the numbers on which the analyses were carried out.

was imparted in an interactive, face-to-face setting [37]. Many studies in emergency departments demonstrated insufficient asthma knowledge of caregivers of children with an asthma attack and that if parents were given a WAAP, they were more confident of their ability to provide care for their child during an exacerbation [38]. During an SEP, the member of the AE team can assess the patient's specific needs (the time the patient and family are able to dedicate to therapeutic education, their literacy skills, and their prior knowledge of asthma), dedicate the amount of time necessary to the patient and define personalized objectives. In our study, this type of AE, tailored to the patient needs, seems to offer better results on asthma knowledge and clinical outcomes. It confirms what has been described in previous studies: that involving the patient and taking into account their needs and preferences plays a role in asthma clinical outcomes. In a randomized study of adults with poorly controlled asthma, shared decision-making (consisting of an asthma treatment regimen based on patient goals and preferences) was more efficient that non-tailored decision-making treatment on clinical outcomes such as quality of life, healthcare use, rescue medication use, asthma control, and lung function as well as medication adherence [39]. Shared decision-making also improved asthma quality of life and asthma control for low-income children with asthma [40]. In addition, customizing the AE training of caregivers could play a role in clinical outcomes of patients with asthma. Ludden et al. randomized different medical practices to receive a full AE training program (multiple sessions led by a trained facilitator), a 1-hr AE training session with a simple presentation, or no AE intervention. Although the authors were not able to demonstrate an effect on health outcomes, when AE was performed by a team who received specific AE training, patients were more involved in their asthma management. The authors encouraged the use of tailored AE training in care practices [41].

Our study has strengths but also limitations. The originality of this work was that it involved an exhaustive analysis of the care pathway for asthmatic children in a non-academic suburban general hospital, as part of an approach to evaluating and improving practices. The suburban hospital setting, the focus on non-academic hospitals, and the culture of educational practices at Melun hospital contribute to the study's uniqueness.

To our knowledge, few studies have evaluated the effectiveness of AE programs in regional hospitals. This study suggested beneficial effects of AE on knowledge and medical outcomes. However, neighborhood hospitals also play a major role in promoting healthcare initiatives with the help of local authorities and education professionals. Asthma education interventions can be implemented in schools. A meta-analysis showed that school-based group education, including education for classmates without asthma, improved knowledge, self-efficacy and self-management behaviors [42]. The Boston Children's Hospital in Massachusetts has developed an even wider program to improve asthma management for children from low-income neighborhoods in Boston. After observing disproportionately high rates of asthma hospitalization and emergency department visits and health disparities among African American and Latino children, the hospital developed a program called CAI (Boston Children's Hospital Community Asthma Initiative). The program provides home visits, AE, environmental assessment, and workshops for school and childcare staff. The

program has helped decrease the incidence of costly hospitalizations and emergency department visits due to asthma, with economic viability [43–45]. Even more AE programs could be developed among other local hospitals, for exchanges with asthma teams on practice and experiences, and for conducting more studies gathering more data confirming the benefits of AE programs in local hospitals. From our study's results, support for AE programs should be increased in regional hospitals and these programs eventually integrated in multidisciplinary, coordinated management programs for better results.

This study is potentially limited by its retrospective design with absence of criteria to define which children received AE, which implies risk of information bias. However, baseline characteristics was similar between the three groups, which reduces possible confounding factors associated with indications of receiving AE. The study's monocentric characteristic is also a weakness of the analysis, associated with selection bias. Nevertheless, this characteristic allows for better comparison of data knowing that the content of educational programs may vary among medical centers [15].

In conclusion, this study supports the beneficial impact on children with asthma of an SEP provided in a center dedicated to education intervention included in a non-academic regional hospital. Such programs result in increased disease knowledge for children and their caregivers, allowing them to take adequate measures during respiratory symptoms and thus reducing acute interventions. Together with previous studies, these findings demonstrate the importance of supporting access to asthma education in regional hospitals to improve asthma management.

Principal Investigator statement

The authors confirm that the PI for this paper is Caroline Thach that the PI had direct clinical responsibility for patients.

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CRediT authorship contribution statement

Caroline Thach: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Charlotte Lafont:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology. **Ralph Epaud:** Writing – review & editing, Writing – original draft, Validation, Supervision, Formal analysis, Conceptualization. **Kenza Tahiri:** Visualization, Validation, Resources, Investigation, Formal analysis. **Floriane Sauvage:** Validation, Resources, Investigation, Formal analysis. **Virginie Sagorin:** Validation, Methodology, Investigation, Conceptualization. **Virginie Sérabian:** Validation, Project administration, Methodology, Investigation, Conceptualization. **Céline Delestrain:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Epaud reports a relationship with AstraZeneca Pharmaceuticals LP that includes: board membership, speaking and lecture fees, and travel reimbursement. Epaud reports a relationship with Sanofi that includes: board membership and speaking and lecture fees. Epaud reports a relationship with GSK that includes: board membership, speaking and lecture fees, and travel reimbursement. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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