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Predictors and components of inpatient asthma hospital cost: A retrospective cohort study. Analysis from a sample of 14 Belgian hospitals

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Abstract

Background: Addressing the challenges of asthma has involved various approaches, including the examination of costs associated with hospitalization. However, there is a limited number of studies that have investigated the actual expenses incurred by hospital settings in caring for asthma patients. This study aims to describe the costs, predictors, and breakdown of expenditures in different categories.

Design and methods: A retrospective cohort study was conducted, involving 314 hospital stays of patients over 12 years old who were admitted for asthma and classified under APR-DRG 141 (asthma). Univariate and multiple linear regression analyses were performed.

Results: The median cost, regardless of DRG severity, amounted to 2.314€ (1.550€−3.847€). Significant variations were observed when the sample was stratified based on the severity of DRG, revealing a cost gradient that increases with severity. The length of stay followed a similar trend. Six predictors were identified: age, admission to intensive care, asthma severity, severity level of the DRG, winter admission, and length of stay. The cost breakdown showed that 44% constituted direct costs, 25% were indirect costs, 26% were attributed to medical procedures performed outside the patient unit, and 5% were related to medication administration.

Conclusions: This study initiates a discussion on the role of reducing hospital costs in strategies aiming at controlling asthma-related costs. We argue that cost reduction cannot be achieved solely at the hospital level but must be approached from a public health perspective. This includes promoting high-quality outpatient care and addressing factors leading to poor adherence to the care plan.

Keywords

Asthma, hospital cost, health care economics, adherence, public health

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Significance for public health

Many studies on hospital expenses use data from the social security perspective as a proxy. Very few manage to display actual hospital costs. This study aims to describe the costs, predictors, and breakdown of expenditures in different categories for asthma hospitalizations. Due to ongoing reforms in Belgian hospital financing, getting actual costs become necessary as we transition toward a prospective payment system. One of our results suggests paying

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attention to the inclusion of intensive care related costs in the new financing model. This concern is shared by other European countries.

If our research is meaningful for economic matters, it also highlights the need to consider these findings in a broader public health scope. Results question asthma care management, strategies aiming at controlling asthma-related costs, frontier between inpatient and outpatient care in the health continuum and the healthcare performance. This remains crucial for asthma and probably other common chronic diseases.

Background

Context

Adherence to long-term therapy plays a crucial role in achieving control over asthma symptoms and preventing the complications associated with uncontrolled asthma.[1] Inadequate asthma control frequently leads to a diminished quality of life.[2] Recent research indicates that enhanced asthma control is a principal predictor of improved quality of life among adults in real-life settings.[3] This inadequacy in control may also precipitate hospitalizations, leading to direct and indirect costs for patients and society alike.[2,4]

In France, hospitalization expenses would account for over half of the overall costs associated with asthma,[5] while in the United States, more than 50% of direct costs are attributed to hospital stays.[6,7]

The burden of hospitalizations for asthma on the Belgian healthcare budget is known. In 2019, a total of 4.746 asthma-related hospitalizations were recorded, indicating a decreasing trend over the years. However, the average cost per stay gradually raised, reaching 3317.64 €.[8] These figures are derived from the analysis of billing data, reflecting the perspective of social security regarding hospital charges. Nevertheless, a limited number of studies have investigated the actual costs incurred by healthcare institutions in caring for these patients (hospital costs). Furthermore, limited research has been conducted to examine the distribution of these hospital costs across different expenditure items.

In France, the *Agence technique de l'information sur l'hospitalisation* (ATIH) publishes annual data on hospital costs using the national cost scale (ENC).[9] However, the French classification system for hospital stays, known as *Groupes Homogènes de Malades* (GHM), differs from Belgium's *All Patient Diagnosis Related Groups* (APR-DRG),[10] making direct comparisons challenging. Specifically, the inclusion of asthma with other bronchitis in the French classification system hinders the isolation of the costs associated solely with asthma management. Moreover, the breakdown of costs according to admission diagnosis (e.g. J45/J46xx for asthma) is not readily available.

Consequently, the hospital cost of asthma at the Belgian level remains unknown. However, the ongoing reforms in Belgian hospital financing, announced since 2016, emphasize the need to consider costs from the hospital's perspective. The intention is to transition toward a prospective payment system based on justified costs per Diagnosis Related Group (DRG) using the APR-DRG-SOI classification.[11,12] SOI means Severity of Illness and divides up each APR-DRG into four categories: minor, moderate, major and extreme. The more comorbidities or complications the patient will have, the higher the SOI is likely to be. Therefore, it is crucial for hospitals to determine the cost of their APR-DRG-SOI and understand how these costs are distributed across different expenditure items. This information will assist hospitals in assessing whether the allocated fixed price will be sufficient to cover their costs.

Theoretical framework

Predictors of asthma hospital cost. Based on a literature review and an understanding of the disease's natural history, it is evident that there is a consensus within the scientific community regarding predictors of cost from the perspective of social security.

However, while it is logical to assume that hospital costs would exhibit a similar pattern, this information is not adequately documented and requires further investigation. Thus, it is essential to clarify and verify the relationship between predictors and hospital costs. To facilitate this understanding, the identified predictors have been categorized into four primary clusters.

- Patient-related intrinsic factors
    - Age, gender, ethnic group, which are classical standardization factors.[5–7,13–16]
    - Level of adherence: patients with lower levels of adherence are more likely to experience uncontrolled asthma symptoms.[5]
    - Degree of respiratory distress: a factor in hospitalization, with severe cases often requiring admission to the Intensive Care Unit (ICU). The admission to ICU is acknowledged as a significant cost driver for hospital stays.[7,14,15]
    - Presence of co-morbidities: can influence the cost of hospitalization for asthma patie nts.[5–7,14,16] The assessment of co-morbidities was conducted using the Charlson score.[17]
- Factors related to disease and flare-up severity[5,6,13–16,18–20]
    - Disease severity (asthma severity, from GINA perspective, is a scale of the real seriousness of the disease. Ascending the scale signifies an increased complexity in achieving stable management of asthma. The APR-DRG-SOI characterizes a hospital stay. It's an indicator of medico-economic severity. The differences

between the four degrees of severity are the comorbidities and the complications that were present or appeared during the stay. Thus, while both constructs employ the term "severity," they pertain to fundamentally different concepts): advanced stages of asthma according to the Global Initiative for Asthma (GINA) classification, increased resistance to conventional treatment and more severe exacerbations challenge stabilization of asthma leading to prolonged and costly hospital stays.
  - APR-DRG severity (SOI): higher severity levels correspond to greater resource utilization and more intensive interventions, contributing to increased expenses.
  - Visits to the emergency room (ER): have also been consistently identified as a cost driver in various studies.[6,7,13]
  - Degree of control: represents the commonly accepted classification in the scientific community, categorizing asthma as controlled, partially controlled, or uncontrolled.[1]
- Length of stay (LOS)
  - Well-established impact on hospital cost.[5,6,13,14]
- Factors related to the environment
  - Season of admission: asthma exacerbations are more prevalent during colder months.[7,13]
  - Time of the week: According to a study conducted in the United States, hospital costs tend to increase for admissions occurring on weekends.[7]

Breakdown of asthma cost. In contrast to the information presented earlier, there is a scarcity of sources that provide a detailed breakdown of hospital costs across different expenditure items. Such information is sporadically disseminated within various articles consulted, making it challenging to obtain a comprehensive understanding of the cost distribution. To address this gap, a theoretical framework has been developed, drawing on the identification of relevant expenditure items and a more clinical approach.[1,6,13,21]

The class of drugs encompasses both conventional medications used for stabilizing asthma attacks and more potent agents reserved for intensive care in cases of severe bronchospasm. Examples include oxygen, aerosol therapy, corticosteroids, antibiotics, and catecholamines.

Medical procedures encompass interventions performed by medical professionals and paramedical staff. This category includes laboratory tests (such as blood analysis and antibiograms), medical imaging, pulmonary function testing, physiotherapy, invasive and non-invasive ventilation, and medical surveillance. Particular attention should be given to intensive care, which in essence puts a heavy strain on the overall cost of hospitalization.

Hospitalization represents the final expenditure item and can be divided into direct costs, such as consumables, nursing staff, medical fees, and equipment depreciation, as well as indirect costs, including laundry, food, and heating expenses.

Study objectives

Given the advantages of investigating costs from a hospital perspective and the limited existing literature on this topic concerning asthma, the primary aim of this study is to determine the hospital cost associated with asthma episodes in patients aged 12 years and above. Subsequently, a statistical model will be developed to identify significant predictors of this cost. Lastly, this research aims to provide a comprehensive description of how the cost of asthma is allocated across the various identified expenditure items.

Materials and methods

Patients and settings

Data for this retrospective study were collected in 2019 from a representative sample of 14 general hospitals located in Brussels and Wallonia. Asthma-related hospitalizations accounted for 13% of all admissions for this condition nationwide. The database was constructed by selecting stays categorized under APR-DRG 141, which includes most hospitalizations for asthma ($n = 612$). Stays with a primary diagnosis of asthma but not falling within APR-DRG 141 ($n = 16$) were excluded since only stays within the same APR-DRG-Severity of Illness (APR-DRG-SOI) could be compared to ensure consistency. Patients under the age of 12 ($n = 229$) were also excluded due to notable differences in treatment approaches compared to older patients.[1] Subsequently, stays with significant missing or outlier data were identified and removed from the dataset. This included cases of patients admitted to day hospital instead of conventional hospitalization ($n = 22$) and stays with unjustified absence of cost information in one of the principal components of the dependent variable under study ($n = 47$). Ultimately, a total of 314 complete stays constituted our dataset.

Belgium context

In Belgium, hospital stays are coded using the APR-DRG-SOI system, which employs an algorithm developed by 3M and utilizes various data sources.[11] The aim is to create medico-economic groups that exhibit homogeneity, ensuring that patients within the same APR-DRG-SOI category possess similar disease profiles and require comparable resource utilization. The SOI was derived from the DRG complications hierarchy, which is determined by the extent of organ system loss of function or physiologic decompensation. The allocation of a patient to one of these subgroups takes into account the specific secondary diagnoses and the interaction between secondary diagnoses, age, principal diagnosis, and procedures.[22] Establishing the SOI is disease specific and high severity of illness is primarily determined by the interactions of multiple conditions.[23] This standardized coding system enables meaningful comparisons between hospitals and is a part of the financing in the healthcare sector.

Data collection

The cost per hospital stay was determined using a comprehensive full-costing methodology.[24] It is important to highlight that prior to analysis, all data were anonymized to ensure that neither the participating hospitals nor the patients could be identified by the research team. In this study, only one dependent variable was examined, namely the total cost per stay from the hospital perspective. It is noteworthy that the distribution of this variable exhibited a pronounced skewness.

Independent variables – Predictors of cost

- Age: presented either as a continuous quantitative variable or categorized into quartiles, depending on the specific analysis conducted.
- Gender: female/male.
- Ethnic group: initially, there was no specific variable for ethnic group. Instead, patient nationality was utilized to categorize individuals into Belgian, European (excluding Belgian), or non-European groups.
- Degree of adherence: not obtainable from the medico-administrative data.
- Degree of respiratory distress: assessed through the variable "ICU admission," categorized as either YES or NO.
- Charlson score: constructed through a series of SQL queries in Microsoft Access® to associate each stay with an overall score, adhering to established weighting rules.[17] Recoded into three categories: 0, 1–3, and 4 or higher.
- Asthma severity: derived from the admission diagnosis coded according to the ICD-10 system. Recategorization was performed to align with the different GINA stages: mild intermittent, mild persistent, severe persistent, unspecified, and status asthmaticus.
- Severity of DRG: classified into four stages: minor, moderate, major, extreme.
- Emergency room visit: categorized as either YES or NO.
- Degree of asthma control: not directly extrapolated from the medico-administrative data. However, it can be cautiously inferred that an admission for asthma indicates a loss of control, potentially related to an exacerbation caused by viral infection/allergy or poor adherence.[1,14]
- Length of stay: expressed in days or quartiles.
- Time of the week: differentiated between weekday and weekend.
- Season: categorized into winter, spring, summer, and fall.

Variables comprising the cost of asthma. Variables comprising the cost of asthma were extracted from the dataset. All variables are continuous quantitative measures and expressed in euros (€). It is important to exercise caution when interpreting the breakdown of the "medical procedures" component as this item solely includes procedures performed by professionals who are not part of the care unit in which the patient was admitted. Examples of such professionals may include hospital physical therapists, radiologists, or clinical biologists. Consequently, the cost associated with healthcare professionals affiliated with the patient's care unit will be included in the "direct costs" category, while fees for services provided by external professionals will be reflected in the "medical procedures" item.

Types of analysis and statistical methods used

To conduct this study, Excel®, Access®, and STATA® (version 17.0) software were utilized. The significance level was set at 5%.

Initially, the hospital stays were analyzed as a whole, resorting to univariate analysis. Subsequently, they were stratified based on the degree of severity to compare the four groups. As a reminder, the stays are assumed to be medically and economically homogeneous within each APR-DRG-SOI, allowing for meaningful comparisons. Quantitative variables were presented using their median (P25–P75) due to their skewed distribution. Categorical variables were described using proportions. Following stratification by severity degree, statistical tests were conducted to assess potential significance of the observed differences. The Kruskal-Wallis test with Bonferroni correction was employed to identify categories that significantly differed at a significance level of $\alpha = 5\%$. The Cuzick test was privileged when a linear trend was observed. Categorical variables were subjected to Pearson's Chi² test, or Fisher's exact test if the assumptions for Pearson's Chi² test were not met.

To determine predictors of asthma hospital cost, a multiple linear regression model was constructed using variables identified in a preliminary univariate analysis. In the univariate analysis, the logarithm of the dependent variable was utilized to ensure normality of the residuals. Simple linear regression was employed to assess the association between each independent variable and the logarithm of the total cost. Only variables demonstrating a significant association ($p < 0.05$) with the logarithm of total cost were included in the multivariate model. However, a multivariate model incorporating all predictors was developed and confirmed the lack of significance for variables rejected after the simple linear regression analysis. Given the logarithmic transformation of the dependent variable, the geometric mean

(CI95%) was used to express the variation in cost based on the selected independent variables. The regression coefficients were described using the Geometric Mean Ratio (GMR (CI95%)), following a similar approach performed in another study.[25] This allows for the interpretation of results in a manner akin to measures of association in epidemiology. As heteroscedasticity was detected in several variables within our multivariate models, robust standard errors were employed. This method preserves the regression coefficients while adjusting their confidence intervals. Additionally, a Wald test was conducted in the multivariate analysis for each independent variable with more than two categories to obtain a global *p*-value. Multicollinearity was assessed by ensuring that the variance inflation factors were all below 10, which was confirmed.

The breakdown of total stay costs across various expenditure items was initially examined in a general manner. Median costs and proportions for each category were calculated. Subsequently, this breakdown, stratified by severity degree, underwent descriptive analysis and statistical comparison. Differences between each severity degree were assessed using the Cuzick test.

Results

Among 314 asthma-related stays, the median hospital cost was 2.314 (1.550–3.847) €.

The analysis reveals a higher proportion of women among the hospitalized patients. Six percent of the stays required admission to the Intensive Care Unit (ICU). Furthermore, more than 80% of the stays lacked a precise classification according to the ICD-10 coding system (Table 1).

It is observed that as the severity of asthma APR-DRG increases, there is a corresponding rise in the total cost of hospital stays. This trend is also evident in the length of stay, which increases with greater severity (Table 2).

The results of the univariate analysis enabled the development of a multivariate model that excluded variables that demonstrated no association with the logarithm of asthma cost. Nationality, emergency room visit, time of the week, and death rate were not included in the final model. Table 3 presents the results of the optimized model, wherein the dependent variable was restored to its original form without the logarithmic transformation.

We initially identified 13 potential predictors that could influence the cost of asthma hospitalization from the hospital perspective, based on the constructed theoretical framework. Following various stages of analysis, we have determined that, after mutual adjustment using multiple linear regression, six of these variables were found to be significant predictors. The profile of the most expensive stay includes patients who:

- ✓ Are under 30 or over 69 years old
- ✓ Are admitted to intensive care unit
- ✓ Have a diagnosis of severe persistent asthma
- ✓ Fall under the extreme category in terms of APR-DRG-SOI
- ✓ Are admitted during the winter season
- ✓ Have an extended length of hospital stay

It should be noted that in our model, certain age categories serve as significant protective factors.

Table 1. Descriptive statistics of the global sample.

Variables	*n*	%	Median (P25–P75)
Hospital cost (€)	314		2.314 (1.550–3.847)
Age	313		50 (30–69)
<30 years		25.88	
30–50 years		24.28	
50–69 years		24.92	
>69 years		24.92	
Gender	313		
Female		59.11	
Male		40.89	
Nationality	310		
Belgian		90.00	
European (except Belgian)		5.16	
Non-European		4.84	
ICU admission	314		
No		93.95	
Yes		6.05	
Charlson score	313		
0		37.38	
1–3		36.74	
4+		25.88	
Asthma severity	313		
Mild intermittent asthma		0.96	
Mild persistent asthma		0.64	
Unspecified asthma		86.58	
Severe persistent asthma		7.67	
Status asthmaticus		4.15	
Severity of DRG	314		
Minor		30.89	
Moderate		40.13	
Major		25.48	
Extreme		3.50	
Emergency room (ER) visit	314		
No		14.65	
Yes		85.35	
LOS (days)	314		4.64 (2.83–7.14)
Time of the week	314		
Weekday		77.07	
Weekend		22.93	
Season	314		
Fall		22.61	
Winter		28.03	
Spring		22.29	
Summer		27.07	
Death	313		
No		99.36	
Yes		0.64	

Table 2. Description of the sample stratified by severity degree.

Variables	Minor (n = 97)	Moderate (n = 126)	Major (n = 80)	Extreme (n = 11)	Test	p-value
Hospital cost (€)	1766 (1293–2499)	2298 (1604–3313)	3559 (2202–6155)	6189 (5464–9858)	$z = 8.00$	<0.001**
Age (years)	33 (19–48)*	54.5 (40–71)	66 (42–79)	65 (50–90)	$\chi^2 = 56.79$	<0.001
Gender						
Female	44.33%	60.32%	74.68%	63.64%	$\chi^2 = 16.86$	0.001
Male	55.67%	39.68%	25.32%	36.36%		
Nationality						
Belgian	87.63%	90.40%	90.91%	100.00%	$\chi^2 = 6.38$	0.452
European (except Belgian)	5.15%	7.20%	2.60%	0.00%		
Non-European	7.22%	2.40%	6.49%	0.00%		
ICU admission						
No	97.94%	98.41%	86.25%	63.64%	$\chi^2 = 33.25$	<0.001
Yes	2.06%	1.59%	13.75%	36.36%		
Charlson score						
0	68.04%	24.60%	22.78%	18.18%	$\chi^2 = 83.66$	<0.001
1–3	27.84%	50.00%	27.85%	27.27%		
4+	4.12%	25.40%	49.37%	54.55%		
Asthma severity						
Mild intermittent asthma	2.06%	0.79%	0.00%	0.00%	$\chi^2 = 23.60$	0.005
Mild persistent asthma	0.00%	0.00%	2.53%	0.00%		
Unspecified asthma	87.63%	91.27%	79.75%	72.73%		
Severe persistent asthma	6.19%	7.94%	7.59%	18.18%		
Status asthmaticus	4.12%	0.00%	10.13%	9.09%		
Emergency room visit						
No	7.22%	24.60%	10.00%	0.00%	$\chi^2 = 17.54$	0.001
Yes	92.78%	75.40%	90.00%	100.00%		
LOS (days)	3.06 (2.07–4.81)	4.56 (2.92–6.58)	6.46 (4.62–9.13)	9.10 (6.98–11.98)	$z = 7.97$	<0.001**
Time of the week						
Weekday	72.16%	80.16%	80.00%	63.64%	$\chi^2 = 3.51$	0.319
Weekend	27.84%	19.84%	20.00%	36.36%		
Season[a]						
Fall–winter	51.55%	42.86%	63.75%	36.36%	$\chi^2 = 9.48$	0.024
Spring-summer	48.45%	57.14%	36.25%	63.64%		
Death						
No	100.00%	100.00%	98.73%	90.91%	$\chi^2 = 14.30$	0.019
Yes	0.00%	0.00%	1.27%	9.09%		

[a]Recoded to meet Pearson's chi² test requirements.
*Significant after Bonferroni correction.
**p-value of the linear trend.

The analysis of cost breakdown reveals that the direct and indirect costs associated with asthma hospitalization account for approximately 70% of the total costs. Within the direct costs, nursing staff remuneration contributes to 67%, while fees for independent staff, including the medical profession in Belgium, are categorized under "services and other goods." The presented medians provide insights into the monetary value of each expenditure item in our sample (Table 4). Additionally, it is worth noting that nearly 60% of medical procedures and prescribed drugs are related to items specifically indicated in the management of asthma attacks.

We should note that ICU and ER visits contribute to a median percentage of 57 and 14, respectively, of the total cost of hospitalization for asthma.

Furthermore, to compare the stays, we stratified the analysis by the degree of severity once again (Table 5).

The findings align with the description of the "total cost" variable presented in Table 2. The breakdown of expenditure items within total cost follows a linear trend as severity increases.

Table 3. Predictors of total asthma cost from the hospital perspective using univariate and multivariate linear regression.

Factors	Univariate linear regression[a]		Multivariate linear regression[b]	
	Total hospital cost (€)	Not adjusted	Adjusted	
	Geometric mean (95% CI)	GMR (95%CI)[c,d]	GMR (95%CI)[c,d]	*p*-value
Age				
<30 years	2113.6 (1834.6–2435.0)	Ref	Ref	Ref
30–50 years	1956.6 (1710.4–2238.1)	0.93 (0.76–1.13)	0.80 (0.70–0.90)**	0.004
50–69 years	2655.4 (2262.5–3116.5)	1.26 (1.03–1.54)*	0.79 (0.66–0.94)*	
>69 years	3649.6 (3170.7–4200.9)	1.73 (1.41–2.11)**	0.85 (0.69–1.04)	
Gender				
Female	2802.1 (2542.3–3088.6)	Ref	Ref	Ref
Male	2153.1 (1913.6–2422.6)	0.77 (0.66–0.89)*	0.94 (0.87–1.02)	0.166
ICU admission				
No	2363.9 (2196.4–2544.3)	Ref	Ref	Ref
Yes	6948.7 (5399.4–8942.5)	2.94 (2.19–3.95)**	1.95 (1.63–2.34)**	<0.001
Charlson score				
0	1911.5 (1718.2–2126.5)	Ref	Ref	Ref
1–3	2448.5 (2163.5–2771.0)	1.28 (1.09–1.51)*	1.03 (0.89–1.19)	0.392
4+	3888.7 (3387.7–4463.8)	2.03 (1.70–2.43)**	1.14 (0.92–1.41)	
Asthma severity				
Unspecified asthma	2365.1 (2183.6–2561.7)	Ref	Ref	Ref
Mild intermittent asthma	2428.3 (1241.4–4750.1)	1.03 (0.48–2.20)	1.23 (0.85–1.79)	0.103
Mild persistent asthma	5762.0 (NA)	2.44 (0.96–6.18)	1.44 (0.56–3.72)	
Severe persistent asthma	4127.8 (3255.6–5233.5)	1.75 (1.32–2.31)**	1.18 (1.03–1.36)*	
Status asthmaticus	3248.5 (2025.5–5209.9)	1.37 (0.95–1.99)	1.10 (0.84–1.43)	
Severity of illness (SOI)				
Minor	1809.4 (1607.8–2036.1)	Ref	Ref	Ref
Moderate	2374.0 (2151.4–2619.6)	1.31 (1.12–1.54)*	1.07 (0.97–1.19)	0.019
Major	3615.4 (3094.2–4224.3)	2.00 (1.67–2.39)**	1.04 (0.90–1.19)	
Extreme	6970.5 (4759.1–10,209.5)	3.85 (2.64–5.63)**	1.40 (1.12–1.74)*	
Season				
Summer	1953.0 (1717.6–2220.7)	Ref	Ref	Ref
Fall	3010.9 (2563.0–3537.1)	1.54 (1.25–1.90)**	1.09 (0.98–1.21)	0.171
Winter	2814.7 (2427.6–3263.5)	1.44 (1.18–1.76)**	1.11 (1.01–1.23)*	
Spring	2509.5 (2126.8–2961.0)	1.28 (1.04–1.59)*	1.04 (0.93–1.15)	
LOS (quartiles)				
Q1	1219.3 (1121.8–1325.3)	Ref	Ref	Ref
Q2	2003.2 (1850.3–2168.7)	1.64 (1.45–1.86)**	1.54 (1.39–1.71)**	<0.001
Q3	2998.3 (2741.3–3279.4)	2.46 (2.17–2.79)**	2.22 (1.96–2.51)**	
Q4	5575.3 (5022.1–6189.5)	4.57 (4.03–5.18)**	3.81 (3.29–4.41)**	

[a]All variables were statistically significantly associated with lower/higher total hospital cost in the univariate analysis.
[b]Multivariate model includes as dependent variable: total hospital cost and as independent variables: age, gender, ICU admission, Charlson score, asthma severity, SOI, season of admission, LOS in quartiles. $R^2 = 0.765$, $n = 313$.
[c]*p*-value: *<0.05, **<0.001.
[d]GMR (exponential of coefficient b): Geometric Mean Ratio is the ratio of expected geometric mean in the specific category to expected geometric mean in the reference category.

Discussion

Predictors of total inpatient asthma management cost

Our study identified 13 potential predictors for the total cost of inpatient asthma management. Among these predictors, 5 showed no significant association, 2 were unable to be measured, and 6 (age, admission to intensive care, asthma severity, severity level of the DRG, winter admission, and length of stay) were found to be significantly associated with variations in asthma costs from the hospital perspective. While some of these findings are consistent with previous literature, others are contradictory. It is important to note that the literature primarily focuses on costs from the perspective of social security or presents

Table 4. General description of the percentage and median costs of items comprising total hospitalization cost.

Variables	n	Median (P25–P75)	%
$\%_{me}$ of ICU part in the cost	19	57.3 (30.0–76.6)	-
$\%_{me}$ of emergency visit part in the cost	268	14.3 (9.3–21.5)	-
Direct costs (€)			43.75
TOTAL	314	932.9 (589.5–1633.7)	
Goods, materials, and consumables	314	55.8 (34.8–104.4)	6.33
Services and other goods	312	176.6 (59.9–336.4)	18.28
Remuneration, social security, and pensions	312	651.7 (397.5–1144.9)	67.12
Depreciation, amounts written down and provisions for liabilities	314	35.6 (15.5–65.6)	5.64
Others	314	15.7 (4.5–43.3)	2.64
Indirect costs (€)			25.01
TOTAL[a]	314	606.4 (385.3–1047.1)	
Medical procedures (€)			26.32
TOTAL	314	683.1 (462.2–1039.6)	
Medical biology	287	164.4 (89.1–298.6)	25.93
Internal medicine (including pneumology)	201	162.6 (118.4–214.0)	14.28
Radiology	205	99.1 (47.1–195.8)	10.96
Physical therapy	186	97.7 (58.0–158.1)	9.39
Others	314	266.1 (186.6–396.9)	39.43
Pharmaceutical products (€)			4.74
TOTAL	314	70.4 (39.3–142.9)	
H02A_Corticosteroids for systemic use, plain	260	9.9 (4.2–18.4)	8.40
J01_Antibacterials for systemic use	138	13.5 (5.0–41.9)	16.23
R03A_Adrenergics, inhalants	286	20.9 (5.1–41.1)	16.17
R03B_Other drugs for obstructive airway diseases, inhalants	170	5.2 (1.7–15.1)	3.95
R03C_Adrenergics for systemic use	2	5.7 (3.6–7.8)	0.02
R03D_Other systemic drugs for obstructive airway diseases	92	2.6 (1.6–3.9)	12.46
Others	314	23.1 (8.0–54.8)	42.76

[a]Consists of costs related to heating, maintenance, laundry, food. . ..

Table 5. Breakdown of expenditure items within total cost (€), stratified by severity level.

Variables	Minor (n = 97)	Moderate (n = 126)	Major (n = 80)	Extreme (n = 11)	Test	p-value
Direct costs (total)	704.0 (436.1–1140.5)	895.7 (598.4–1477.5)	1435.4 (828.8–2709.2)	2928.0 (1978.2–5346.2)	z = 7.1	<0.001*
Indirect costs (total)[a]	424.1 (296.6–658.6)	552.0 (419.6–864.3)	964.0 (617.1–1427.6)	1587.7 (1183.3–1982.6)	z = 8.2	<0.001*
Medical procedures (total)	580.3 (414.0–788.9)	672.2 (478.2–979.1)	976.8 (534.1–1518.0)	1469.1 (980.0–2423.3)	z = 6.5	<0.001*
Pharmaceutical products (total)	50.9 (24.4–77.8)	70.4 (39.9–129.6)	124.1 (63.4–250.2)	438.5 (152.5–608.5)	z = 7.6	<0.001*

[a]Consists of costs related to heating, maintenance, laundry, food. . .
*p-value of the linear trend.

only univariate data, highlighting the need for caution when interpreting our results.

One notable finding pertains to the variable "age." Existing studies suggest either a weak relationship[5] or a positive association between age and costs.[6,7,13–16] In our study, the univariate analysis aligns with the latter, but the multivariate analysis reveals the opposite effect. We hypothesized that this paradox may be attributed to an interaction with the Charlson score, as age is a component of this score. To explore this further, we conducted additional models using different forms of age (continuous or categorical), excluding age from the equation, or testing the interaction. However, these models either exhibited increased collinearity between variables or a substantial decrease in the model coefficient of determination (R^2). Therefore, while acknowledging the potential interaction and the need for caution, the model presented in the results section best fits the data.

Contrary to some US studies,[7,16] no significant relationship was found between the variable "ethnic group/

nationality" and asthma costs. We attribute this result to two factors: the absence of a practice of stratifying patients by ethnic group in Belgium and the use of nationality as a proxy for ethnic group. Given that 90% of our sample consisted of individuals with Belgian nationality, it becomes less likely to observe a significant association.

Both the degree of respiratory distress, as indicated by ICU admission, and the length of stay (LOS) demonstrated significant associations with asthma costs in both univariate and multivariate analyses. After adjustment, ICU admission was associated with a 95% increase in hospitalization costs. Furthermore, there was a linear trend between LOS and cost, with higher LOS corresponding to increased costs. These findings are consistent with previous literature, where ICU admission and prolonged hospital stay have been identified as factors contributing to higher total hospital costs.[14]

Asthma severity, as defined in clinical guidelines, is recognized as a factor contributing to inpatient cost escalation. Chouaid et al. assert that asthma severity plays a pivotal role in determining inpatient costs.[5] This finding is supported by Gadenne et al., who cite several studies that have established a similar relationship.[19] Additionally, Com-Ruelle et al. conducted a study demonstrating the association between increased social security costs and asthma severity.[20] The conclusions reached by Sailly et al. align with these findings.[13] However, our analysis yielded less definitive results. This may be attributed to limitations in the available data. The univariate analysis using simple linear regression did demonstrate a significant overall association between asthma severity and costs, but this association was only significant for severe persistent asthma. In the multivariate analysis, the overall p-value became non-significant, with severe persistent asthma being the only significant influence on asthma costs. This discrepancy is likely due to incomplete coding of hospital episodes, with 85% of stays assigned an unspecified asthma diagnosis, making conclusive comparisons challenging. We believe that asthma severity remains a factor influencing costs, but unfortunately, our study could not provide conclusive evidence, except for the association between severe persistent asthma and costs when compared to unspecified asthma.

In the univariate analysis, the presence of comorbidities, as indicated by the Charlson score, demonstrates a significant association with the variation in asthma cost. However, after adjusting for other variables, the Charlson score no longer exhibits any influence on the cost. These findings contradict those reported in the literature. For instance, Zeiger et al. stated that a Charlson score higher than 2 leads to increased costs.[16] Similarly, Stanford et al. examined the impact of asthma APR-DRG-SOI on cost and found a clear correlation between increasing SOI and higher costs.[6] Our univariate analysis yields similar results, but when adjusting for other factors, the significance remains only for severity level 4. The lack of significance in the Charlson score can likely be connected to the severity of the DRG, which encompasses all secondary diagnoses (including comorbidities and complications) in the 3M algorithm. Since only extreme severity remains significant and pertains to a small subset of 11 patients, it is not surprising to observe that the Charlson score does not influence the cost of asthma.

While the resources utilized in the emergency department have an impact on the overall cost of hospitalization,[6,13] it remains unclear whether visiting the emergency ward serves as a predictor of asthma hospital costs. Our study did not find evidence supporting this relationship. Regarding the period of admission (weekend vs weekday), our findings differ from those of the study conducted by Kaur et al., which suggested an additional cost during the weekend period.[7] However, these discrepancies are difficult to interpret due to the distinct contexts of our respective studies. Lastly, we concur with the conclusions drawn by the authors, indicating that season appears to play a role in the cost of asthma management.[7,13] Both the univariate and multivariate analyses indicate that costs tend to be higher during the winter months compared to summer.

Total cost of asthma hospital management and public health

Asthma cost through the prism of public health. Examining asthma cost from a public health perspective, the findings of this study demonstrate that 44% of the total cost is allocated to direct costs, with 4/5 of this attributed to employed and independent personnel. Indirect costs account for 25%, medical procedures performed outside the unit contribute to 26%, and the remaining portion is divided between the cost of pharmaceutical products and other elements. Thus, it is evident that the hospitalization of asthma patients entails a substantial proportion of costs that are not easily reducible, particularly wage-related expenses. Consequently, aligning with the conclusions of various studies on asthma costs, we affirm that solely improving the quality of hospital care is not the most cost-effective solution from a public health standpoint.[5,6,26]

It should be noted that patients requiring hospitalization due to asthma decompensation often have poorly controlled asthma that necessitated specialized care.[27] However, this subset represents only a fraction of the larger asthma population, as the majority receive treatment in outpatient settings.[7] Outpatient management (our study focused solely on the direct costs from the hospital's perspective, while indirect costs such as lost workdays and disruptions in family dynamics were not taken into account. These indirect costs are more aligned with a social security-oriented perspective on the overall cost analysis) also imposes a significant burden on the community,[4] albeit lesser than that of hospitalizations.[5,7,13] A study by Sailly et al. effectively demonstrates that “uncontrolled” patients, despite having lower annual outpatient costs, incur hospitalization expenses that could finance 6 years’ worth of the excess costs of the “controlled” group’s outpatient care.[13]

Therefore, while improving the processes of inpatient asthma management is beneficial, it is crucial to maintain focus on reducing the burden of asthma on healthcare budgets. This requires enhancing primary and secondary prevention measures for asthma attacks,[5,6,14] offering adequate accompaniment for chronic asthma patients,[2,13,26] developing care plans collaboratively with patients based on their needs and expectations,[28] and adhering to guidelines recommended by scientific bodies such as GINA.[1,5]

When considering the worrying prevalence of inadequately controlled asthma patients,[19,29] or observing that the factors that could potentially prevent hospitalizations (such as improved adherence and medication use) are for the most part modifiable in primary care,[13] it becomes crucial to rethinking the care pathway for individuals with chronic asthma.[6,30] We believe that this thought should take place at the political level, aiming to integrate these various strategies into a coherent continuum of care that makes sense for healthcare professionals, and other stakeholders.

Furthermore, the inclusion of the indicator “number of asthma hospitalizations avoided” in the KCE-led report on Belgian healthcare performance strengthens the position we advocate. These hospitalizations not only entail significant costs but also reflect the effectiveness of primary care. Based on data from 2014, the KCE demonstrated that, among individuals aged 15 and above, a strong primary care system could have prevented 30 hospitalizations per 100,000 population.[31] In 2019, this figure decreased to 27.9, indicating a downward trend in hospitalizations.[32] Belgium is in line with the European average in this regard, although international comparisons may be less meaningful due to variations in healthcare systems.[31,32]

Outlook on hospital stays financing. The cost data from the hospital’s perspective provide valuable insights into the discussion surrounding Belgian hospital financing. The current reform plans aim to implement a prospective payment system.[12] In our view, this system should be based on accurate hospital costs rather than historical hospital charges, as is currently the case in Belgium where lump sums are allocated to “low variability clusters.”[11] The costs from the social security standpoint are derived from billing data, which in turn are based on the rates reimbursed by social security. To ensure accurate financing of stays within each APR-DRG-SOI, it is essential to have a comprehensive understanding of the actual costs incurred by hospitals.

Furthermore, ICU admission significantly increases costs even after adjusting for the length of stay. In our study, intensive care nearly doubles the cost compared to non-admitted patients. Therefore, from a lump sum financing perspective, it becomes necessary to determine whether the costs associated with ICU management should be included in the lump sum or not. This decision currently varies among European countries.[33,34]

Limitations

Three limitations should be acknowledged. Firstly, our study was conducted with a relatively small sample size. Although we had 314 hospital stays in total, the statistical analysis conducted by severity level reduced the relative size of the sample. Consequently, it is possible that our results may not be entirely generalizable to the entire population of Belgium. However, this limitation is mitigated by the fact that our hospital stays were derived from a database that includes 15% of the country’s stays.[24]

Secondly, it is important to note that the analyzed data primarily originate from third party-collected medico-administrative data, over which we have no control. This is also the case in other studies on the cost of diseases.[7,35] Nevertheless, as this type of data is utilized in the context of Belgian hospital financing,[8] it provides a degree of reliability.

Finally, the inability to find corresponding variables for two of the potential predictors of asthma hospital costs weakens our multivariate analysis, even though an R^2 of 76.5% indicates that the proposed model adequately explains the variability of the reported results.

Conclusion

This study initiates a debate regarding the role of hospital cost reduction in strategies aiming at controlling asthma-related costs. We contend that reducing the costs of asthma hospitalization cannot be solely achieved at the hospital level but must be approached from a public health perspective by promoting high-quality outpatient care and addressing factors that contribute to poor adherence to the care plan.

List of abbreviations

APR-DRG – All Patient Diagnosis Related Groups
ATIH – Agence technique de l’information sur l’hospitalisation
CI – Confidence Interval
ENC – Échelle Nationale des coûts - national cost scale
ER – Emergency Room
GINA – Global Initiative for Asthma
GMH – Groupes Homogènes de Malades
GMR – Geometric Mean Ratio
ICU – Intensive Care Units
LOS – Length of stay
SOI – Severity of Illness

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Authors' contributions

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