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ORIGINAL RESEARCH ARTICLE

Design and implementation of an online tool for managing the availability of high-cost perishable medicines

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Abstract

Introduction Due to their impact on healthcare systems, the sustainability and optimization of high-cost drugs is an issue of concern for several countries. Different strategies have been implemented such as centralized purchasing to optimize budgetary resources. However, there is still a need for a mechanism to optimize these drugs further.

Methods We conducted this prospective multicenter intervention study in five hospitals in the Andalusian Public Health System of Cádiz (Spain) between July 2019 and September 2021. We developed an online website (Farmastock) and implemented it to determine the availability of high-cost, low-use, and near-expiry medicines in each hospital. We used a simple analysis using operational variables to assess the project intervention's savings impact on managing these high-cost drugs.

Results The implementation of Farmastock in Cádiz resulted in savings of 675,757.52 € for the Andalusian Public Health System, with 238 medicines transferred out of the 373 available. Of these medicines offered, the most considerable percentage were medicines used for pathologies with high clinical instability and accounted for nearly 80% of the medicines optimized by the tool.

Conclusions Farmastock allowed the Andalusian Public Health System to make substantial financial savings by not making new purchases of high-cost drugs available in other centers of this health network that were not being used. Therefore, this tool is a very efficient measure to contribute to the sustainability of the APHS and could be implemented in more hospitals soon.

Key Points

We are implementing an inter-hospital networking tool (Farmastock) to optimize the use of high-cost medicines.

Farmastock achieved a savings of 675,757.52 € for the APHS in 2 years in Cádiz.

Medicines used to treat pathologies with high clinical instability were the most optimized.

Introduction

Healthcare expenditure is increasing worldwide because of the growth of the aging population, technological innovations, and persistent medication errors, among others [1, 2]. This rising proportion of older people is placing upward pressure on healthcare organizations to cope with these high expenditures in healthcare by identifying and implementing cost control measures. Life expectancy in Spain is the highest in the European Union [3]. Over the last 40 years,

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the Spanish health system has evolved to the competitive levels of the best European public health systems [4]. However, today the ratio of health investment to gross domestic product (GDP) in Spain continues to be lower than in neighboring countries [5]. The improvement in the health sector has not been accompanied by an evolution in the more efficient management of available resources [6]. Therefore, increasing efficiency in managing healthcare resources and, consequently, the sustainability of the Spanish health system is considered a pivotal point to guarantee quality healthcare, with rational, universal, and equitable access and continuity for future generations [7].

In recent years, there has been an almost unstoppable increase in the prices of medicines, especially the most innovative medicines and those used to treat the most severe diseases. Therapeutic innovations such as personalized medicine, including cell, gene, or immune therapies (among others), are increasingly used, raising their success rate by allowing a better selection of patients who will benefit from them. However, their uptake in the current healthcare management model would be difficult due to their cost and complex development [8, 9]. The growth in spending on diagnostics and therapies is driven by an increase in the volume of high-cost drugs (HCDs) in different countries [6, 10–12], including Spain [13]. Optimized management of these high-impact technologies would contribute to their full implementation and cost reduction. It is one of the main challenges that European health services have to cope with [14].

Consequently, new cost-control strategies to optimize resources to the maximum are needed. These strategies should be based on indication, scientific evidence, consensual therapeutic positioning, and suitability analysis criteria in each case [15]. Therefore, medicine optimization is an urgent need in all healthcare systems. It focuses on the value of medicines, ensuring that they are clinically practical and cost effective, and reducing medicine wastage. In this regard, pharmaceutical spending on HCDs is a concern in the different national health systems [11, 12]. There is no agreed definition of high-impact medicines (HIM) or HCDs. It depends on the cultural and socioeconomic factors in each country. They are defined by the average intended use or unit cost of the medicine. In this study, we considered highly specialized HCDs, which are medicines that target a relatively small number of patients, that is, HCDs with a high price per patient-year of treatment [13, 16]. Optimizing such HCDs in healthcare centers would allow for better adaptation and access to medicines and, therefore, a more excellent state of public health and well-being for citizens [17].

The Andalusian Public Health System (APHS) provides universal healthcare to the 8.4 million inhabitants of the Andalusian community, which represents 18% of the Spanish population. The APHS encompasses an extensive network with two levels of care (1500 primary care centers and 49 hospitals) based on accessible, quality, patient-centered care in a system of universal coverage financed by taxes. The APHS operates mainly in the public sector [18]. The APHS is the standard financing body for the health resources available in the Andalusian public healthcare centers. An efficient strategy for controlling the expiry dates of medicines and the relocation of HCDs about to expire in other centers could avoid losses of perishable resources, which would lead to considerable savings for the APHS. This strategy is valuable for those therapies whose usage forecast is complex, as their continuity may depend on their efficacy in controlling the disease, patient tolerability, and even the therapy appropriateness. Thus, the incorporation of expiry monitoring of high-impact medicines in the procurement process of healthcare centers could optimize the current substantial economic losses.

This pilot study aims to develop and implement an interconnection tool that makes it possible to know the availability of high-cost medicines that are about to expire and are not expected to be used in the healthcare center of the APHS of origin. In short, a tool that optimizes the use of high-cost, low-use, and perishable medicines through exchanges of HCDs between hospitals.

Methods

Scope of the study

In the APHS, hospital or specialized care is the second level of health care and is provided for patients who require health care that cannot be resolved by primary care. Public hospitals are divided, from largest to smallest, into three categories [19]:

Regional hospitals are the highest-ranking hospitals and serve the entire population of the autonomous community. They offer all the specialties of the public health system.

Specialty hospitals serve the province in which they are located. They have more specialties than a county hospital.

County hospitals serve nearby population centers, at most 1 hour away. They provide primary hospital specialties.

Specifically, our study was a multicenter pilot study that reported a descriptive analysis. Five hospitals of the APHS in the province of Cadiz (Hospital de Jerez, Hospital de La Línea, Hospital Puerta del Mar de Cádiz, Hospital de Puerto Real, and Hospital Punta Europa de Algeciras) with different characteristics participated in this study (Table 1). The requirements to be met by the centers in order to participate in this initiative were

1. Authorization/consent of each hospital participating in the initiative.

2. Sharing of information on the availability status of HCDs.

Study design and Farmastock development

An intervention study was conducted by developing and implementing a proprietary website (Farmastock). Farmastock is an online web application developed with the Ruby language and the Ruby on Rails web framework, where the different resources needed to exchange product stock between centers were modeled. This tool manages the HCD stock of the different centers, the exchange requests, and the users' profiles with limited and controlled access. In order to speed up these exchanges, communications were made by email as soon as a request was made. Farmastock acts as a database where each medicine relocation is recorded. The fact that each relocation is recorded in the same request and transfer process streamlines the analysis process. This procedure avoids data loss, allowing a synchronous and continuous study of the functioning of the process and the analysis of its evolution. Thus, Farmastock enabled each participating hospital center to know the availability of reduced-use HIMs that, for unavoidable reasons, were not expected to be consumed before the expiry date.

Study period

The design and development phase up to the operational phase of the online website was carried out between May and June 2019. The use of the website started in July 2019 after its launch. Thus, the inclusive data collection period was between July 2019 and September 2021.

Requirements for Farmastock implementation

Briefly, the main activities for Farmastock implementation were as follows:

- Assessment and selection of those HIMs whose better management would have a high economic impact on the APHS. This evaluation avoided overloading the Farmastock repository with low-cost medicines that could have clouded and hindered the main objective of the tool. The selection criterion for medicines was merely economic, including medicines with an economic value of at least 100 € per dispensing unit.
- Incorporation and commitment of at least two professionals from each participating center. Their primary function was to be involved in the logistics management activities of these HCDs. To this end, they had to know the clinical areas with the highest consumption of HIMs in order to be able to estimate the pharmacological needs of these HIMs and facilitate the proper functioning of the tool.
- Establishment of an inter-hospital medicine transfer circuit. To this end, the connection networks between hospitals for other products, such as the transfer of plasma derivatives, and diagnostic tests, were used. These transfer systems had the necessary infrastructure to control traceability and maintain the necessary preservation conditions.
- The HIMs with a high risk of loss after a considerable period of immobilization on the Farmastock were offered to APHS hospitals outside the province of Cadiz, specifically to the Hospital Virgen Macarena and the Hospital Virgen del Rocio in the province of Seville (named as 'others' in Table 1).

Once the design and development procedures were agreed upon, the list of selected HIMs was uploaded to the application, and their updated purchase price was on the provincial procurement platform. It should be noted that the price field was editable, which guaranteed continuous updating and a real-time calculation of the savings achieved.

Definitions

Several important terms are defined to aid in understanding this study's analysis. In addition, when we use the term 'medicine' in the tables and figures, it refers to the number of batches of medicines, not the number of units of medicines.

Optimized medicines are medicines that have been relocated to another center.

Pending medicines are medicines that are currently available and awaiting transfer to another center for optimization.

Table 1 APHS hospital categories

Classification of hospitals	Area of influence	Medical specialties	Center
County hospital	Population less than 1 hour away	Basic	Hospital de La Línea and Hospital Punta Europa
Specialty hospital	Provincial	Extensive	Hospital Puerta del Mar, Hospital de Jerez and Hospital Puerto Real
Regional hospital	Entire autonomous community	All	Others (Hospital Virgen del Rocío, Hospital Virgen Macarena, Sevilla)

APHS Andalusian Public Health System

Expired medicines are medicines that a center offered but could not be relocated to another center and consequently expired.

Offered medicines are medicines from one center that can be shared with another center where there are stock-outs. It is calculated as the sum of optimized, pending, and expired medicines.

Received medicines are medicines that a hospital has received from another hospital. *Participation.* This term refers to the total number of medicines offered and received by a center.

Outcome measurement

We assessed the impact and effectiveness of the Farmastock intervention on the management of HIMs by analyzing the cost-saving associated with this drug redistribution using specific indexes and operational variables defined below. We calculated how many medicines were not wasted in each of the hospitals, and we quantified how many medicines destined to expire in the purchasing hospital were received by each of the other centers.

Indexes

Reciprocity Index (RI) The reciprocity principle is a standard for behaving in an exchange. In this study, we assessed the hospitals' reciprocal medicine exchanges. We calculated this index using the ratio between the medicines received and those offered by a specific center.

Perishable Medicines Optimization Index (PMOI) We calculated this index by following the equation below:

The quotient of amount (€) of the medicines optimized by the center X × 100/amount (€) of medicines shared by the center X

Operational variables

For the evaluation of the impact and efficiency of the project's intervention in the management of HIMs, the following information will be recorded on the Farmastock website:

- Medicines: brand name, active ingredient, dose, and pharmaceutical form
- Acquisition code of the APHS Integrated Logistics Management System (SIGLO)
- SIGLO acquisition price
- Expiration date
- Batch
- Units of pharmaceutical forms
- Hospital of origin of the medicine
- Destination hospital
- Date of relocation

Results

A total of 373 batches of medicines were available for exchange between the five participating hospitals over 2 years (July 2019 to September 2021). Of these, 238 were transferred to other hospitals, where patients could benefit from their active treatment, thus making their use more efficient (Table 2).

The hospital with the highest number of batches of offered medicines (148) was the Hospital de La Línea Hospital. In fact, it was the hospital with the highest percentage of participation (32.73%) by a center (Table 2). The hospitals with the highest percentage of participation are those with the highest number of medicines received (Hospital de La Línea and Hospital Punta Europa; Table 2). The cost-saving analysis displayed that in the province of Cadiz alone, this exchange of HCDs between hospitals resulted in a total saving for the APHS of 675,757.52 € (Table 3).

Table 2 The number of offered medicines (batches per medicine) in the five participating hospitals of the APHS (Cádiz)

Center	Batches						
	Optimized	Pending	Expired	Offered	Received	Part.	% Part.
Hospital de La Línea	102	2	44	148	52	200	32.73%
Hospital Punta Europa	74	2	15	91	49	140	22.91%
Hospital Puerta del Mar	30	5	38	73	44	117	19.15%
Hospital de Jerez	14	6	4	24	14	38	6.22%
Hospital Puerto Real	10		4	14	32	46	7.53%
Others	8	14	1	23	47	70	11.46%
Total	238	29	106	373	238	611	100.00%

See Sect. Definitions for what is meant by the following terms: optimized, pending, expired, offered, received medicines, and participation

APHS Andalusian Public Health System, *Part.* participation

Specifically, we found that the two hospitals with the highest percentage of PMOI (Hospital de la Linea, 78.51%, and Hospital Punta de Europa, 86.32%; Table 3) were the ones with the highest percentage of participation (Table 2). The Hospital Punta Europa had the highest percentage of PMOI (86.32%; Table 3), even though this center did not display the highest percentage of participation (22.91% compared with 32.73% for Hospital de La Línea; Table and Fig. 2). Particularly, this hospital managed to optimize 236,015.15 € of the 273,407.52 € offered. In contrast, the Hospital Puerta del Mar only optimized 35.05% of the medicines offered (Table 3), which is in concord with its percentage of participation (19.15%, Table 2). On the other hand, the Hospital Puerta del Mar, the Hospital Puerto Real, and the Hospital Jerez are specialty hospitals (Table 1), and their theoretical HCD needs are higher than those of a county hospital. Therefore, these hospitals could dispose of more HCDs about to expire and receive more HCDs transferred from other hospitals more frequently. However, their participation rate was lower (19.15%, 7.53%, and 6.22%, respectively, Table 2) than that of county hospitals such as the Hospital de La Línea and the Hospital Punta Europa. Thus, this could explain their lower percentage of PMOI compared with Hospital de la Linea and Hospital Punta de Europa (Table 3).

In order to incorporate these particular circumstances into our economic analysis, we proposed a novel index (RI) suitable for measuring the exchange of medicines between centers. We found the most considerable difference in RI between Hospital Jerez and Hospital Puerto Real (44.95% and 166.04% RI, respectively; Table 3 and Fig. 1). However, most hospitals did not reach an RI of 50%, indicating that most hospitals offered more medicines than they received (Table 3 and Fig. 1). We also conducted analyses considering the different ATC categories of each medicine involved in this study. Of the total number of medicines exchanged since July 2019, the highest percentage of offered medicines corresponded to antineoplastic and immunomodulators (63.54%) and those medicines derived from blood and hematopoietic organs (10.19%) (Table 4).

The analysis of the top ten groups of medicines by unit (Table 5) and by the total cost (Table 6) showed that the most frequently used medicines were the pharmacological groups with the highest economic impact. These groups (L01 and B02) belonged to antineoplastic medicines, immunomodulatory drugs, and drugs derived from blood and hematopoietic organs. Specifically, L01 comprised 53.66% of offered medicines, 62.29% of optimized medicines, and 71.68% of PMOI. Likewise, B02 comprised 14.58% of offered medicines, 16.74% of optimized medicines, and 70.91% of PMOI. These medicines treat pathologies with high clinical instability (Table 6). Both types of medicines accounted for about 80% of the medicines optimized by the tool (Tables 5, 6).

It is worth mentioning that the A16 group of medicines belonging to the category 'alimentary tract and metabolism' showed as 92.48% of PMOI despite having very low percentages of medicines offered and optimization (1.28% and

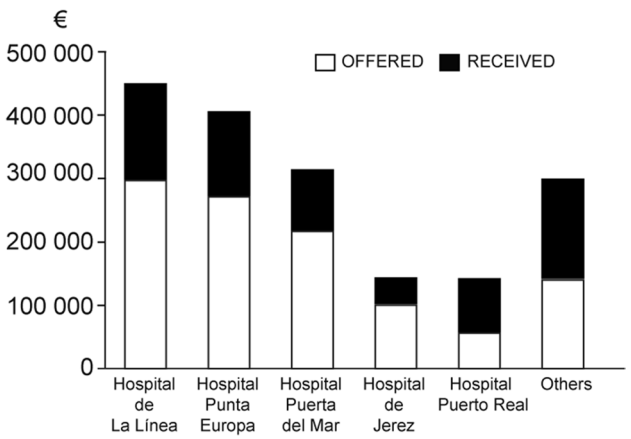

Fig. 1 Stacked evolution of the management of high-impact medicines close to expiry representing the distribution of the monetary amount of received and offered medicines per hospital (Reciprocity Index, RI)

Table 3 Perishable Medicines Optimization Index (PMOI) and Reciprocity Index (RI)

Center	Expenditure (€)						
	Optimized	Pending	Expired	Offered	Received	% PMOI	% RI
Hospital de La Línea	242,333.25	8551.80	57,764.55	308,649.60	146,439.56	78.51	47.45
Hospital Punta Europa	236,015.15	8023.51	29,368.86	273,407.52	134,512.85	86.32	49.20
Hospital Puerta del Mar	76,296.55	15,974.57	125,410.52	217,681.64	99,600.71	35.05	45.76
Hospital de Jerez	57,908.52	28,676.10	13,017.21	99,601.83	44,773.07	58.14	44.95
Hospital Puerto Real	33,916.82		19,631.54	53,548.36	88,912.04	63.34	166.04
Others	29,287.23	111,582.56	433.00	141,302.79	161,519.29	20.73	114.31
Total	675,757.52	172,808.54	245,625.68	1,094,191.74	675,757.52	61.76	61.76

See Sect. Definitions for what is meant by the following terms: optimized, pending, expired, offered, received medicines, and participation

Table 4 The number of offered medicines (batches per medicine) is classified by the type of medicine category in the five participating hospitals of the APHS (Cádiz)

Category of medicines	ATC code	Batches				
		Optimized	Pending	Expired	Offered	% Offered
Alimentary tract and metabolism	A	1		1	2	0.54
Blood and hematopoietic organs	B	22	3	13	38	10.19
Cardiovascular system	C	3		3	6	1.61
Dermatological	D	1		1	2	0.54
Genitourinary system and sex hormones	G	1			1	0.27
Systemic hormonal preparations, excluding sex hormones and insulins	H	8	1	5	14	3.75
Anti-infectives for systemic use	J	17	3	15	35	9.38
Antineoplastic and immunomodulators	L	168	16	53	237	63.54
Nervous system	N	7		6	13	3.49
Antiparasitic, insecticides and repellents	P	3	1	1	5	1.34
Respiratory system	R	2	3	1	6	1.61
Various	V	5	2	7	14	3.75
Total		238	29	106	373	100.00

See Sect. Definitions for what is meant by the following terms: optimized, pending, expired, offered, and received medicines

APHS Andalusian Public Health System, *ATC* International classification of medicines based on anatomical and therapeutic criteria

Table 5 Ranking of top ten groups of medicines by total units

ATC code	Batches				
	Optimized	Pending	Expired	Offered	% Offered
L01	144	15	39	198	53.08
B02	20	3	7	30	8.04
L04	20	1	7	28	7.51
J05	11		11	22	5.90
H01	7	1	5	13	3.49
V03	5	1	3	9	2.41
L03	4		3	7	1.88
B01	2		4	6	1.61
N05	3		3	6	1.61
R03	2	3		5	1.34
J02	4		1	5	1.34
N07	3		2	5	1.34

See Sect. Definitions for what is meant by the following terms: optimized, pending, expired, offered, and received medicines

ATC International classification of medicines based on anatomical and therapeutic criteria

1.91%, respectively). Although high, this is because the cost of these drugs is lower than that of L01 and B01. Therefore, their savings are lower, so their relevance in total savings is also low. Similarly, the H01 drugs belonging to the systemic hormonal preparations group are less relevant in total savings (Table 6).

We also analyzed the temporal evolution of Farmastock use. The results are shown in Fig. 2. We detected a decrease in the use of Farmastock during 2020.

Discussion

In this study, we have developed and implemented an interconnection tool (Farmastock) that optimizes the use of high-cost, low-use and perishable medicines through exchanges of HCDs between healthcare centers of the APHS.

Hospital care accounts for 30% of total healthcare expenditure, which will continue to increase due to the aging population and costly technological improvements. It is, therefore, crucial to contain costs to ensure high access and quality of services [20, 21]. In this regard, health systems cannot allow any necessary supplies or products, including medicines, to go to waste [22]. In this study, we have shown that Farmastock could contribute to better managing hospital healthcare expenditure.

Accessibility to medicines is another significant public health concern. Health systems must meet the demand for medicines quickly and adequately. In many cases, it is difficult to determine the level of medicine stocks correctly. This problem is intensified by the limited product life cycle [23]. Medicines are perishable, meaning they become useless after a specific expiry date [3]. Farmastock could also help to solve this problem once it has been implemented in more locations.

Table 6 Ranking of the top 10 groups of medicines by total cost

ATC code	Expenditure (€)						
	Optimized	Pending	Expired	Offered	% Offered	% Optimized	% PMOI
L01	420,905.35	57,376.10	108,907.98	587,189.43	53.66	62.29	71.68
B02	113,095.46	6755.22	39,641.42	159,492.10	14.58	16.74	70.91
R03	5634.60	80,527.92		86,162.52	7.87	0.83	6.54
L04	41,313.72	2461.48	22,382.30	66,157.50	6.05	6.11	62.45
J05	19,964.18		24,418.65	44,382.83	4.06	2.95	44.98
H01	22,202.20	3022.50	5907.44	31,132.14	2.85	3.29	71.32
V03	8110.38	4988.70	9457.56	22,556.64	2.06	1.20	35.96
B01	5629.88		11,705.36	17,335.24	1.58	0.83	32.48
J01	2003.40	12,115.15		14,118.55	1.29	0.30	14.19
A16	12,917.63		1050.30	13,967.93	1.28	1.91	92.48

See Sect. Definitions for what is meant by the following terms: optimized, pending, expired, offered, and received medicines

ATC International classification of medicines based on anatomical and therapeutic criteria, *PMOI* Perishable Medicines Optimization Index

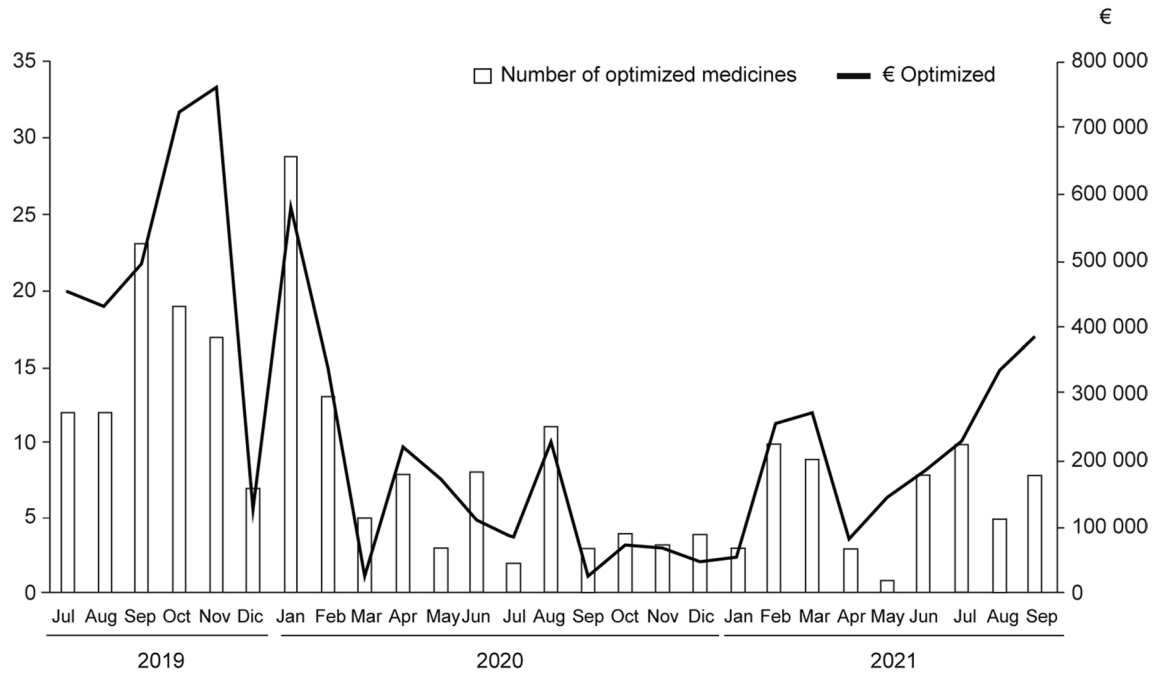

Fig. 2 Temporal evolution of the use of Farmastock representing several medicine relocations to other centers (blue) and the amount of money optimized concerning these high-cost medicines about to expire (red)

In Spain, hospital pharmaceutical expenditure has progressively increased in recent years [24], with a 53% increase between 2014 and 2020 [25]. This increase is due to high drug prices and the growing number of patients with chronic and specialized diseases who increasingly need treatment with HCDs. The high budget impact of drugs approved in Spain during the COVID-19 pandemic between 2020 and October 2021 has contributed to this increase [25]. Several countries are concerned about sustainability and optimizing the use of these HCDs. Different strategies have been implemented, such as voluntary collaboration projects to obtain better access to information on these HCDs and centralized purchasing to optimize budgetary resources and increase access to the public health system [11, 12, 26]. However, our study is the first to quantitatively evaluate the effectiveness of online web tools in reducing waste and costs of perishable HCDs in five hospitals in the AHPS. Our results align with the systematic need to identify, prioritize, and implement

medication cost containment using international initiatives [7, 21].

Furthermore, we found that drugs used for oncological treatments and immunotherapies were the most optimized. As expected, these results align with previous studies [25]. This is because these specific HCDs are innovative, advanced, high-specificity drugs to treat pathologies with high clinical instability. They have the most important economic impact with an increasingly personalized approach to their use in patients. The second most optimized group we detected was the coagulation factors. These drugs are used in health emergencies when bleeding occurs due to trauma, making consumption forecast difficult [27]. Therefore, these HCDs are used on demand in necessary treatments. On the other hand, they are obligatory treatments, so it is difficult to avoid their expiration if they are not consumed.

The state of health alert due to the COVID-19 pandemic, which impacted the entire healthcare system, led to a decrease in the use of Farmastock (Fig. 2). However, it should be noted that despite the COVID-19 pandemic, the data obtained on HCD cost reduction from this study (collected over <2 years) suggest that the Farmastock tool is a very effective measure for the sustainability of the APHS. Furthermore, it suggests that Farmastock could contribute to short-term cost containment goals without negatively affecting the volume and quality of care.

Other initiatives focusing on finding an innovative solution to drug accessibility have already pointed out the need for proper communication about drug storage and the existence of a cooperative network hub for drug reallocation and exchange among hospitals [28]. A specific mobile application has already been developed to detect the medicine expiry date for users [29]. Despite these alternative solutions, we have shown for the first time the validation of a tool that allows the exchange and sharing of high-cost drugs that are about to expire. There is another similar Spanish initiative called Farmatrueque. The data obtained with this platform have not yet been published in any scientific journal. It is a platform for exchanging medicines between the Pharmacy services of 15 public hospitals in Castilla-La Mancha. This platform is also a system for sharing information on the availability of high-impact drugs that are about to expire without anticipation of use in the corresponding Pharmacy Service, and which, in this way, could be used in other hospitals with patients undergoing active treatments [30]. This drug exchange system saved the Castilla-La Mancha Health Service (SESCAM) more than 352.00 €. The savings obtained with Farmastock (675,757.52€) are more substantial than with Farmatrueque. Moreover, the existence of the Farmatrueque implementation project corroborates the need for intervention to minimize losses of hospital HIMs due to expiry.

The Farmastock implementation is in line with the development and implementation of health inventory management in national health systems. In healthcare, inventory management is essential because it directly impacts the availability of medicines and the efficiency of the system [5, 31]. Moreover, future implementation of our tool should be carried out with guidelines that integrate these procurement and inventory management activities, and medicines use management. The specialized HCDs are frequently used in a limited number of patients; therefore, the suspension of these treatments implies that the hospital has an immobilized stock without the possibility of use. Our tool allows a considerable economic saving to the health service by not making new purchases of medicines that are available in other centers of the same health network and that are not being used. Hence, combining the use of our tool with medication use management strategies, such as clinical practice guidelines and therapeutic exchange [7], could lead to further optimization of the use of HCDs. In addition to the cost reduction achieved with this medicine exchange tool, medicine relocation could indirectly contribute to reducing medicine waste, protecting the environment, and improving public health.

It should be taken into consideration that this paper describes a pilot study of the implementation of the Farmastock tool. The main limitations of our study were internal organizational barriers. These were essentially the lack of time for staff responsible for medicines management to enter and query medicines in an external management tool and to incorporate the use of the tool into the hospital's medicines procurement procedure. Consequently, we obtained our results through a manual and voluntary process. Therefore, there was some risk that high-cost drugs (HCDs) continue to expire. Despite this, our results have shown a very high yield in savings. We expect to overcome this limitation in the project's next phase, which is already underway. We are working on improving the strategy's performance with automation and expiration prediction based on artificial intelligence methodology. This second phase will automate the availability of medicines with instant alerts in the application through its implementation in the APHS internal network.

In this second phase, we will consider adopting several critical recommendations from ASHP for the full implementation of Farmastock. These involve the amount of time pressure (the time available until the cost reductions occur), key stakeholder (e.g., nurse, physician) sensitivity and willingness to collaborate, the extent of leadership support for the initiative, resources required, and existing level of expertise within the organization for the specific cost-management opportunity [7]. All these recommendations are expected to increase the participation of hospitals and thus the access to medicines on offer. Therefore, we expect greatly improved optimization of HCDs and a substantial reduction in HCDs

that expire before they can be used. In this regard, we expect the RI to improve when Farmastock is implemented in other APHS hospitals (Table 3 and Fig. 1).

Another limitation of our study was the number of pending HCDs detected (Tables 2, 3). Pending HCDs are drugs that have not yet expired but have not yet been optimized. At the time of results analysis, pending HCDs were still in the allocation phase to a hospital other than the one they came from. The application we are developing for Farmastock optimization will also include a query in the hospital's purchasing proposal process. This automation process could require utilization of medicines immobilized in another hospital before new HCDs are acquired from a supplier.

Nevertheless, further studies are necessary to endorse the use of Farmastock in the rest of APHS hospitals in the future. We want to point out that the savings achieved are high considering that only five hospitals participated. We expect that when Farmastock is fully implemented in the rest of the AHPS hospitals, much higher levels of savings will be achieved. Although we are still at an early stage of implementing this tool, the success of our initiative and others similar to it has identified the potential of this as a promising HCD relocation tool to be rolled out globally throughout the rest of the Spanish national health system.

Conclusion

In this multicenter study, the Farmastock tool made it possible to reallocate high-cost medicines that were about to expire, sharing them with other hospitals and successfully dispensing them to their patients. Farmastock saved 675,757.52 € for the APHS in two years in Cádiz. The medicines used to treat pathologies with high clinical instability were the most optimized. The results from this pilot study suggest that incorporating this tool in the rest of APHS hospitals in the future could help ensure that short shelf-life and high-cost medicines are distributed to other hospitals and do not expire. Therefore, this tool appears to be an effective measure to contribute to the sustainability of the APHS, although further studies are required.

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Declarations

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Conflict of interest The authors declare that they have no known competing financial conflicts of interest or personal relationships.

Ethics approval Not applicable since the data analysis came from the drug databases of the pharmacy services of the different hospitals participating in the study and therefore did not include the names or data of the patients.

Data availability statement Data processed in an Excel file are available on reasonable request. The availability of Farmastock data is subject to the restrictions of the Spanish Data Protection Act.

Consent to participate Not applicable since individual patient consent was not required. Only an internal authorization/consent was obtained from each hospital participating in the initiative.

Consent for publication Not applicable since this study did not involve study participants.

Code availability Farmastock is an online web application developed with the Ruby language and the Ruby on Rails web framework.

Author contributions All co-authors have reviewed and approved the manuscript's contents, and the authorship requirements have been met. This manuscript is not under review at any other journal and does not overlap with previous work. MGG: conceptualization, methodology, implementation of the tool and collecting data, data analysis, drafting, editing and reviewing manuscript, implementation of the tool and collecting data. JRP, MJMB, RSE, AGA, MdCJdJ, MDC, JCRM, JCR, and JRÁÁ: implementation of the tool and collecting data. JDN: conceptualization and methodology. JGG: web design and development. AVR: editing the manuscript. ASG: data analysis. CNO: data analysis and editing the manuscript.

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