

Factors influencing nurse satisfaction with Automated Medication Dispensing Cabinets

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Abstract

To improve efficiency, quality and safety of medication administration systems, hospitals have been implementing automated dispensing cabinets (ADCs) in healthcare units. The purpose of this study was to evaluate nursing staff's level of satisfaction with ADCs by analyzing several aspects and differences in perceptions between groups of users. It being a fact that nurses are the end users of the ADC system, their perceptions and opinions are crucial to the success of this technological implementation. A cross-sectional survey was conducted in units with ADCs from a Spanish hospital (n = 97, 32.12% response rate). Data were analyzed using comparisons between groups and principal component analysis (PCA). The results show that, in general terms, nursing staff have a high degree of satisfaction with ADCs, with order and organization being the most valued aspect. The type of clinical unit and personnel seniority explain some of the differences in valuation. PCA revealed the existence of two general dimensions of nurse satisfaction: efficiency and safety. From this study, conclusions can be drawn to help hospital managers achieve success in implementing ADCs in their centers.

Keywords: Inventory Management; Automated medication dispensing cabinets (ADCs); nurse satisfaction; survey; efficiency; medication safety

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Introduction

The main objective of every medication administration system is to ensure safe and effective therapy. The medication-use process is made up of many interdependent parts that work in concert and includes not only

medications, but also policies, procedures, individuals, and technologies (Fox et al., 2015). Among these technologies, automated dispensing cabinets (ADCs) have become increasingly important in hospitals and healthcare centers around the world (Monzón Moreno et al., 2016; Rochais et al., 2014). In US healthcare institutions, the use of ADCs has become widespread (Cello et al., 2022), with 70.2% using ADCs as the main method of maintenance dose distribution (Schneider et al., 2018).

ADCs are devices used for the storage and dispensing of drugs on the hospital floor. They were first introduced in the 1980s (Burton, 2019; Metsämuuronen et al., 2020) and are gradually replacing traditional cabinets in clinical units where significant consumption of drugs justifies the investment. ADCs are flexible electronic configuration structures integrated into the hospital's computer network. The numerous advantages of these systems include (Bourcier et al., 2016; Mandrack et al., 2012; Newell et al., 2011; Novek et al., 2000; Pazour & Meller, 2012; Zheng et al., 2021):

- For nursing staff: They are time-saving since they eliminate the need for stock management and provide greater availability of medicines, greater control of access, elimination of counts, etc.
- For the pharmacy: They provide better control of each patient, fewer urgent orders, greater inventory control, additional information for the development of strategies and protocols, etc.
- For management: They afford a reduction in storage space, cost reductions, better control of costs per patient, more information on inventories, etc.
- For the patient: fundamentally, greater safety and fewer medication administration errors.

There are several reviews of the literature on ADCs and other technologies that hospitals are using to improve the efficiency and safety of medication processes: Kangasniemi et al. (2019) on the use of robots and other automated instruments in nursing work; Ahtiainen et al. (2020) on automated and semi-automated drug distribution systems in hospitals for evaluating their effectiveness on medication safety, time and costs of medication care; Zheng et al. (2021) on the impact of several technologies (including ADC) for controlled drugs on work process and safety; Batson et al. (2021) on the clinical and economic value of automated hospital pharmacy services, especially in drug dispensing. All of them agree on the need for more high-quality research in the field of these technologies.

Although the previous literature generally confirmed the benefits of implementing ADCs over traditional manual methods in terms of clinical and economic outcomes (Batson et al., 2021; Ahtiainen et al., 2020), some studies show that the effectiveness of ADCs has been mixed (Cochran et al., 2016; Novek et al., 2000). Several authors warn of the limitations and risks of these technologies, especially with regard to patient safety (Burton, 2019; Rhodes & McCarthy, 2019). As a result, there are at least two guidelines for the safe use of these instruments published by institutions (Institute for Safe Medication Practices, 2019; American Society of Health-System Pharmacist (Cello et al., 2022)).

Hence, it is still necessary to improve the functionality of ADC and the commitment of suppliers, research on human factors and interdisciplinary cooperation are key factors to achieve this goal (Rhodes & McCarthy, 2019). In this regard, Burton (2019) suggests careful planning, along with well-designed and clearly communicated interaction practices with the device. Additionally, collaboration between nurses and pharmacists, expert guidance, self-assessment tools, compliance with nursing best practices, and continuing education are essential to optimize the safety and productivity of ADC use (Mandrack et al., 2012). Further, technological capabilities need to be supplemented with work processes (Zheng et al., 2021). It is well

known that any new technology implies organizational and social changes, without which its performance remains unsatisfactory. In the case of ADCs, nurses, who are their direct users, need to modify their routines and show a positive and collaborative attitude. New technologies, especially when imposed by managers, can often generate mistrust and skepticism on the part of users. Consequently, as nurses are end-users of the ADC system, their perceptions and opinions are crucial to the success of this technology (Arinal et al., 2014; Metsämuuronen et al., 2020; Zaidan et al., 2016).

Due to its significance, there is a growing interest in understanding the satisfaction level of nursing professionals with the use of ADC systems and what their perceptions are regarding various aspects related to their implementation and operation. This is reflected in the increasing publication of studies on the subject, which will be examined in the following section. Therefore, the main objective of this work is to understand the factors that affect hospital nurses' satisfaction with ADCs. In addition, this paper also has the following sub-objectives:

- Identify the aspects or benefits that are most valued by ADC users.
- Determine whether factors such as clinical unit, age or seniority of nurses may affect opinions on ADCs.
- Examine whether there are general underlying dimensions or components that explain user responses.

To achieve these objectives, this paper is structured as follows. The next section discusses the background in research on ADCs and nursing satisfaction. This is followed by an explanation of the methodology used, including case selection and methods of data collection and analysis. In the next two sections, the results obtained for each objective are presented and discussed separately. The paper ends with a section on conclusions, implications and limitations.

Literature background

In this section we focus on previous literature on the nursing view on the use of ADCs. To this end, we have conducted a systematic review of the literature in two of the main published research databases (WoS and Scopus). The aim of this review is not to conduct a detailed analysis of the state of the art in this field, but to help us to orient and contextualize our own research and to better clarify what its contribution is.

On July 2023, a search was conducted in the WoS Core Collection using the following syntax: Title (adc or "dispensing cabinet" or "automated dispensing" or "automated medication" or "automated drug" AND topic (nurs* and (survey or interview* or perception* or satisfact* or attitud* or question*)) and Document Type (article) and years (2000 to present). This search yielded 14 documents. Of these 14 documents, one was excluded for not assessing nurse satisfaction or conducting surveys, and another was excluded for not being related to ADCs. This resulted in a total of 12 articles.

Similarly, a search was conducted in Scopus using the following syntax: Article Title (adc or "dispensing cabinet" or "automated dispensing" or "automated medication" or "automated drug" AND Article Title or Abstract or Keywords (nurs* and (survey or interview* or perception* or satisfact* or attitud* or question*)) and Document Type (article or short survey) and years (2000 to present). This search yielded 18 documents. Two of these documents were removed because they were surveys targeted at pharmacists, one had no author, and another 3 were not surveys. In total, 12 articles were obtained.

Of these 12 articles, 9 were duplicates between both databases. Therefore, a total of 15 distinct articles were found that conducted surveys with nursing staff regarding ADCs. Of these 15 articles, 3 were exclusive to WoS, 3 were exclusive to Scopus, and 9 were common to both databases. Four more papers have been added, not included in these databases, obtained from other sources. However, two of the publications refer to the same study (Novek et al., 2000, and Novek, 2002), so the final sample is 19 publications, but 18 different studies.

The table in Annex 1 shows a summary of the main aspects of each of these 19 previous publications. The geographical distribution of these studies shows a predominance of studies in the Americas (7 studies, 8 publications), mostly in North America (4 in the USA and 2 in Canada), with only one in South America (Brazil). Australia and Europe (2 in France, 1 in Finland and 1 in Spain) follow with 4 studies, while Asia has 3 (in Taiwan, Qatar and Saudi Arabia). With respect to the evolution over time, there has been an increase in interest in this subject in recent years. The first studies date from the year 2000 and in that decade (at the beginning) there were only 2 studies (3 publications). In the following decade, the number increased to 10, while so far in the 2020s, 6 studies have been published.

Most of the studies focus on one or a few hospitals, so their results are not generalizable and are rather case studies. This calls for more research to accumulate evidence on the subject. The predominant research methods are surveys and interviews, although they also tend to incorporate observations and records of various data (costs, inventories, administration errors, time, etc.). Samples are often chosen for convenience, especially when interviews are used as a method of data collection, and sizes vary from 10 (Eap and Ramadan, 2022) to 312 (Elkaldy et al., 2019), sometimes mixing nursing with other groups, such as physicians (e.g. Escobar-Rodriguez et al. 2012), pharmacists (e.g. Fox et al., 2023; Craswell et al., 2021; Martin et al., 2000) or management (e.g. Lichtner et al., 2023). Very few conduct longitudinal studies (Wang et al., 2021) or pre and post implementation (Roman et al., 2016; Chapuis et al., 2010).

As for the aspects discussed on the use of ADCs, they are very varied and among the main ones we can mention: appropriateness, compatibility, usefulness, ease of use, location and layout, accessibility or timely access to medication, efficiency in medication administration, risk of medication errors or patient safety, impact on the user's own work, inventory control, resupply, technical assistance, training received, time for medication administration or queuing time, level of confidence in the system, or overall user satisfaction. Some analyze differences in the perceptions of different groups or units (e.g. anaesthetic staff vs all other staff in Fox et al, 2023; anaesthesia and surgical vs intensive care, in Metsämuuronen et al, 2020). A couple of studies are based on the Technology Acceptance Model (TAM) or some variant, whose main objective is to explain the degree of intention to use technology, in this case ADCs (Escobar-Rodriguez et al. 2012, Elkaldy et al., 2019).

The main results show, in general, a high level of satisfaction with ADCs (74% preference over manual systems in Fox et al., 2023; 89% in Berdot et al., 2019; 3.90 out of 5 in Wang et al., 2021). Among the benefits or advantages highlighted are improved efficiency in medication administration (Lichtner et al., 2023), facilitates the work of the nurse (Wang et al., 2021; Metsämuuronen et al., 2020), improves patient care (Wang et al., 2021) or reduces medication incidents (Rochais et al., 2014; Chapuis et al., 2010). However, some drawbacks or challenges are also recognized, such as that deviations can still happen (Lichter et al., 2023), retrieval time can be increased for certain medications (Roman et al., 2016) or new errors can be generated (Chapuis et al., 2010).

Our study adds to this current of research in search of evidence on the perception of nurses with respect to ADCs in order to achieve the successful implementation of these systems in hospitals or the improvement of their functioning. Given that the attitude of nurses may be conditioned by cultural aspects, this study contributes to knowledge on the subject by being carried out in a national context in which there are hardly any studies. As far as we know, this is the second study to be carried out in Spain. On the other hand, our study covers 11 different aspects related to the use of ADCs, including the main ones analyzed in previous studies, thus adding empirical evidence to previous research. It also includes an overall assessment of the degree of nursing satisfaction that can be compared with those of other studies in different countries and contexts. A further feature that makes this study useful is the fact that it uses sociodemographic information and distinct user groups to test whether these factors affect perceptions of ADCs. Finally, this study is the only one of which we are aware that has applied component analysis to search for latent constructs underlying perceptions of nursing.

Methods

Case selection

For this study, a single case that can be considered a typical Spanish hospital was chosen, and hence the conclusions obtained should be valid for other hospitals, with the necessary adaptations.

The institution is a third-level hospital, the highest tier in the Spanish public healthcare service. Its portfolio covers all the clinical specialties included in the service provided by the Andalusian Public Healthcare System. The basic population catered for in the hospital's reference area is 481,296 (2018). Other hospital figures at the current time are 871 Hospital Beds, 5,042 employees, 38,500 Annual Hospital Admissions, 83.57% Occupancy Rate, 32,847 Surgical Interventions, 204,686 Emergencies attended, 561 Emergency calls per day, and 759,771 Annual External Consultations.

The hospital had 14 ADCs on the date of the study. The ICU and the Emergency Room were the units with the most machines installed with 3 ADCs each. The other eight were distributed among Cardiology, Short Stay (Observation), Operating Rooms, Nephrology, Neurology, Internal Medicine, Pediatric ICU, and Recovery room, with one ADC in each clinical unit. There were 35 medical-surgical units in the hospital. More than 99% of all drug items were stored in the ADCs, which usually contain between 400 and 450 different drugs each. After a medication item is collected by the authorized nurse, it is immediately administered to the patient as all the ADCs are close to the patients' bays or rooms. Carts are not used in the system.

All the ADCs are connected to the central server, which centralizes and gathers information from each machine. The ADCs are replenished on specific days each week, except those in the emergency department, where replacement is daily, excluding weekends. Replenishment activities begin at 8 am, with various orders issued by the ADCs. During the week, stock-level and drug-expiration checks are performed on all ADCs.

Methods of data collection and analysis

A questionnaire ([Appendix 1](#)) was designed to measure the degree of nursing satisfaction with ADC. The aspects that the users were asked to evaluate were selected based on a literature review and a previous survey of satisfaction with the kanban system (Aguilar-Escobar et al., 2015). An 18-item scale developed to evaluate bar code / eMAR technology also exists, the Medication Administration System-Nurse Assessment of Satisfaction Scale (MAS-NAS) (Hurley et al., 2006, 2007), and has also been used to evaluate ADCs (Arinal et al., 2014; Douglas et al., 2017). Our 12-item questionnaire is similar but more parsimonious and focused on ADCs.

The survey consisted of three parts with different types of questions. The first part contained sociodemographic questions. In the second part, 12 questions evaluated the various benefits of the ADC system compared to the previous cabinet system. A 10-point Likert scale was used, where 0 indicated do not agree and 10 fully agree with the statement provided. Finally, the third part of the survey included a single, optional, open-ended question, in which the worker could report problems with the use of the ADC or make a comment and/or suggestion regarding the system.

After receiving approval from the hospital pharmacy director, the questionnaires were delivered directly to the supervisors in each unit and they were informed that they were to be filled out anonymously and returned to the nursing supervisor attached to the pharmacy. Of the 302 people who made up the study population, 97 answered surveys were obtained, which equates to a response rate of 32.12% of the total population (sampling error \pm 8.4% for a 95% confidence level).

The survey data were treated with SPSS (V.22, IBM Corporation, USA). In addition to the characterization of the sample, this included a descriptive analysis of personnel satisfaction (sub-objective 1), the comparisons of means between the different groups surveyed (sub-objective 2), and a principal component analysis (PCA) (sub-objective 3).

To complement the survey data, interviews were conducted with various pharmacy officials, direct observations were made, and data were collected in the pharmacy to complete the context of the work performed and describe the case study.

Results

Characterization of the sample

Three of the 97 surveys were discarded as they presented some atypical values. When analyzing the surveys, two units in the clinical unit variable were observed to have returned the highest numbers of responses: ICU (24, 25.5%) and Emergency-Observation (34, 36.2%), with percentages similar to their weights in the population.

Regarding the professional categories, the majority of respondents were nurses (86, 91.5%). In addition, there were four nurse supervisors (who are also nurses) and four others not categorized as nurses. Analysis of the years of service of the interviewed personnel revealed that half of the respondents (47 people) had served for 20 years or more. In relation to their age, the majority (40, 42.6%) were between 40 and 49 years old.

Descriptive analysis

As can be seen in Appendix 1, the first 11 questions measure aspects where the ADC influences medicine logistics and are written as a comparison with the traditional system based on the use of conventional cabinets. Question 12 asks the users for an assessment of the level of general satisfaction.

Table 1 shows the main descriptive statistics of the 12 assessment questions into which the questionnaire is divided.

Table 1. Principal descriptive statistics for each survey question

Aspect	N°	Range	Mean	SD	Median	Mode
1) Faster	93	[0, 10]	6.81	2.795	8	8
2) More reliable	94	[0, 10]	7.32	2.428	8	9
3) Reduced consumption	88	[0, 10]	7.58	2.458	8	10
4) Fewer expirations	85	[1, 10]	7.99	2.050	9	9
5) Telephone helpline	83	[0, 10]	5.72	2.446	6	5
6) Less work	90	[0, 10]	7.94	2.295	9	9
7) More organized	91	[2, 10]	8.82	1.510	9	10
8) Less space	92	[0, 10]	7.84	2.331	9	9
9) Less quantity	84	[0, 10]	7.48	2.181	8, 9	8
10) Greater safety	91	[0, 10]	7.38	2.511	8	9
11) Fewer unjustified withdrawals	87	[0, 10]	7.25	2.324	8, 9	8
12) Overall satisfaction	92	[2, 10]	7.80	1.718	8	9

As can be observed in Table 1, the average assessment of the different aspects of ADC in dispensing medicines is favorable. The scores for the 11 aspects range from 8.82 for “more organized” to 5.72 points for “telephone helpline”. The average overall level of satisfaction of ADC consumers is 7.8. The standard deviation for each of the questions is less than half of the arithmetic mean and ranges from 1.51 to 2.79.

Comparisons between different groups

Several comparative statistical tests were carried out to determine whether the demographic variables that define users exert an influence on the answers to the assessment questions. The sample has been divided into two groups for all the demographic variables contained in the survey:

Clinical unit: group 1 = Intensive Care (ICU, Pediatric ICU, and Emergency Room-Observation), 70 nurses (74.5%); group 2 = clinical-surgical units (Cardiology, Neurology, Internal Medicine), 24 nurses (25.5%)

Years of service: group 1 = under 20 years; group 2 = 20 years or more (47 nurses, 50% each group)

Age: group 1 = up to 49 years old, 63 nurses (67%); group 2 = 50 years old or older, 31 nurses (33%)

When analyzing the mean values obtained for each of the two groups, significant differences were found in the clinical unit, years of service, age, and training variables. Statistical tests of equality of means were performed for independent samples (Student’s t-test) after checking the homogeneity of the variances

(Levene test). Table 2 shows only the results of the comparisons of the means that were statistically significant ($p < 0.05$). The last column shows a standardized measure of the difference, the unbiased Hedges–Olkin g , which allows the effect size to be evaluated.

Table 2. Comparisons of means between groups

Variable	Item	Mean Difference		Effect size ^c
		M ₁ - M ₂ [95%CI]	t-Student (df), p-value ^a	
Clinical unit 1: ICU 2: Others	6) Less work	1.69 [0.43. 2.94]	$t(31.453)=2.746, p=.010^b$	0.76
	8) Less space	1.81 [0.77. 2.85]	$t(90)=3.459, p=.001$	0.82
	9) Less quantity	1.26 [0.21. 2.31]	$t(82)=2.395, p=.019$	0.59
	10) Greater safety	1.71 [0.57. 2.85]	$t(89)=2.987, p=.004$	0.70
	12) Overall satisfaction	1.48 [0.55. 2.42]	$t(30.393)=3.227, p=.003^b$	0.92
Years of service 1: fewer than 20 2: 20 or more	9) Less quantity	-1.78 [0.88. 2.68]	$t(67.337)=-3.952, p=.000^b$	0.88
	10) Greater safety	-1.61 [0.62. 2.61]	$t(75.040)=-3.235, p=.002^b$	0.69
	11) Fewer unjustified withdrawals	-0.99 [0.01. 1.96]	$t(85)=-2.009, p=.048$	0.43
Age (years) 1: under 50 2: 50 or over	1) Faster	-1.07 [0.01. 2.12]	$t(84.653)=-2.009, p=.048^b$	0.38
	10) Greater safety	-1.17 [0.23. 2.11]	$t(83.685)=-2.470, p=.016^b$	0.47

^a Two-tailed test

^b Contrast of means not assuming equality of variances according to the Levene test

^c Unbiased Hedges–Olkin g

According to these results, there are differences in the clinical unit in terms of perceived improvement averages in the ICUs compared to those in the clinical-surgical units in five questions. In relation to years of service, we observed significant differences with higher means for those who have worked for more than 20 years compared to staff who have worked for fewer years in three questions. Third, in age, there are also significant differences in two questions, with the highest scores in the older age group.

The values of the effect size g (between 0.38 and 0.92) in Table 2 show that the differences are small (between 0.20 and 0.50) in age, mainly medians in the clinical unit (between 0.50 and 0.80) and vary in size in years of service.

Principal component analysis (PCA)

To address the last objective of this study, a PCA was performed. PCA can help to discover which variables in the set form coherent subsets that are relatively independent of one another. The sample size for this analysis was 72, once missing values were eliminated. In the Kaiser–Meyer–Olkin test for sampling adequacy, a value of 0.817 was obtained, which is higher than the recommended 0.6 (Tabachnick & Fidell, 2007). Furthermore, Bartlett’s sphericity test was statistically significant ($\chi^2(55) = 364.62, p < 0.001$), so we could conclude that the sample was adequate to perform a PCA.

The PCA determined the existence of two components by considering eigenvalues greater than 1 and by observation of the scree plot. Table 3 shows the matrix of rotated components, which includes the value of the two components for each of the variables. Cronbach's alpha coefficients for the two components were higher than 0.7 (0.77 and 0.75, respectively); therefore, the components can be considered reliable scales.

Table 3. Matrix of rotated components of the principal component analysis (two components)^a

Aspect of the ADC system	Component		Communality
	1	2	
9) Less quantity	0.839	-0.035	0.706
7) More organized	0.813	0.305	0.755
3) Reduced consumption	0.748	0.324	0.665
11) Fewer unjustified withdrawals	0.681	0.237	0.520
8) Less space	0.480	0.389	0.381
2) More reliable	0.237	0.799	0.694
10) Greater safety	0.335	0.701	0.603
5) Telephone helpline	0.013	0.670	0.449
4) Fewer expirations	0.175	0.665	0.473
6) Less work	0.535	0.604	0.651
1) Faster	0.408	0.524	0.441
Sum of squares (eigenvalue)	3.271	3.065	6.336
Percentage of variance	29.74	27.87	57.61

^a Method of extraction: principal component analysis. Method of rotation: Varimax with Kaiser normalization. Variables are sorted in terms of highest loading.

As can be observed, component 1 consists of 5 items, while component 2 has 4 items. The remaining two items — 'faster', and 'less work' — were not assigned to any component, as they did not have clearly defined loads.

Discussion

The general objective of this study was to determine what factors affect the satisfaction of nursing staff with ADCs. In this sense, the overall score obtained of 7.8 out of 10 and the fact that 94.6% of users gave a global assessment of ADCs of more than 5 reflect a high degree of satisfaction. Previous studies showed similar results: 84% of satisfaction with ADCs (Metsämuuronen et al., 2020), 91% of overall satisfaction rate for two hospitals (Zaidan et al., 2016), or 96,7% of professionals recommending the use of electronic dispensing (Menezes et al., 2018). However, a total of 17 workers (18.08% of respondents) reported problems with ADC use or made comments and/or suggestions. Among these comments, certain complaints should be highlighted, including slowness of the system, inventory inaccuracy problems, failures in fingerprint recognition, unregistered patients, breakdowns, missing medications, and delayed responses to urgent requests to the pharmacy.

In relation to the first sub-objective, ascertaining which aspects of the ADCs are most valued by the users, the 11 analyzed aspects received scores above 5 (the scale mean) and eight received an assessment of over 7. In general, the aspects of quality and patient care, as well as those related to better stock management and cost reduction, received high scores. The worst-valued aspect was the telephone helpline, which may indicate dissatisfaction with the telephone service provided by the pharmacy. Similarly, other studies also found concerns about operational support to nurses from pharmacy staff (Craswell et al., 2021; Novel et al., 2000).

The second sub-objective was to verify whether any differences existed in the levels of satisfaction between different user groups. Significantly, the users who most appreciate the benefits of ADCs are those in intensive care units (ICUs and Emergency Room), which is in line with the findings of Metsämuuronen et al. (2020). This may be due to these units having the highest concentrations of outpatients, where slower systems, such as single doses and cabinets, evidently offer lower performance. Older respondents and those with longer service records gave higher ratings, although they are probably less accustomed to sophisticated technologies such as ADCs. An initial explanation may be that they can appreciate the benefits of safety, space reduction, etc., which these instruments provide compared to conventional systems.

The third objective of the study was to determine whether the assessment variables used in this study could be reduced to a smaller number of latent components or variables. The results of the PCA indicate that nine of the variables were influenced by two underlying components: component 1, which can be defined as efficiency, and component 2, which can be referred to as safety. This confirms the idea that security and productivity are essential for optimizing the use of ADCs (Mandrack et al., 2012) and is also consistent with the MAS-NAS scale, which includes efficacy, safety, and a third dimension, access (Hurley et al., 2006, 2007).

Conclusions, implications and limitations

This study performed an in-depth analysis of the opinion of nursing staff on ADCs, and the results show that nurses fundamentally value two factors in ADCs: safety and efficiency. What professionals are ultimately seeking is to minimize non-value activities and increase safety. This conclusion is in line with other works (Newell et al., 2011). A significant conclusion of this study is that nurses value two aspects at the same time, efficiency and safety, which can be understood as contradictory, but for this group they are not. For the end users of the ADCs, it is important that the administration of drugs is carried out with the maximum guarantees of safety, but at the same time, they are committed to the efficiency and sustainability of the health system, which is a fundamental aspect, even more so when it is a hospital supported exclusively by public funds.

Implications can be drawn from this study that help hospital managers achieve an orderly, incremental, and more efficient implementation of ADCs in their centers and greater nurse satisfaction. Managers must emphasize the aspects that increase efficiency and safety, as these are the factors that nurses really value and can result in a safer and higher quality patient service. The results of our study show some aspects on which the management of the hospital analyzed needs to intervene. Specifically, the telephone assistance provided by the pharmacy service and the speed of access to medication were the issues most poorly rated by nurses. These aspects could vary in other contexts, which highlights the importance of conducting this type of nursing survey to improve the use and functioning of ADCs. On the other hand, the differences detected in

nursing perceptions highlight the need to adapt nursing actions and training according to the clinical unit in which the ADCs are installed and the age and seniority of the nursing staff.

As is known, there is a link between nurse and patient satisfaction in healthcare (Rosati et al., 2009). In this line, Craswell et al. (2021) suggest taking a sociotechnical approach to the decision making and implementation strategy, and point out that it is vital that nurses are involved in all stages of implementation of systems that are integral to their work. The last is also remarked by Elkady et al. (2019), who emphasize the need to consider perceived usefulness and perceived risks associated with the use of ADCs, as the most influential factors that promote and prevent (respectively) nurse acceptance of this technology.

As for the limitation, it is necessary to start by saying that the response rate is not completely satisfactory. Another limitation is that there may be other variables in the workplace that have not been considered in this study and could affect the responses of the nursing staff, including the number of nurses per ADC and the frequency of ADC replenishment, among other things. Our findings about the factors underlying the perception of nursing would need to be refereed by additional studies. Finally, in view of the already large number of empirical studies on the subject, and given that they all collect evidence on one or two hospitals in a single country, a rigorous literature review or even a meta-analysis might be appropriate. It should be noted that the topic is important because it deals with the use of technological tools for inventory management of products with special characteristics, such as medicines (which are essential for the health of patients, have a shelf life, etc.), and in an environment that is also special, such as the hospital environment, where errors and inefficiencies can have very serious consequences for the patients.

Conflict of interests

The authors declare no conflicts of interest.

Authors Contributions

Víctor G. Aguilar-Escobar and Pedro Garrido-Vega have collaborated in a similar way throughout the process of drafting this article: Conceptualization, Methodology, Formal Analysis, Investigation, Writing - Original Draft, Writing - Review & Editing. Patricia Vázquez Rivas: Investigation, Formal analysis. Antonio Monzón-Moreno: Conceptualization, Investigation.

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Annex I. Main results of the Systematic Literature Review

Reference	Study Setting	Aspects Covered	Research Methods	Respondents, Sample size and Response rate	Main Findings
Fox et al. (2023)	783-bed metropolitan hospital in Western Australia	Evaluation of anaesthesia-specific automated medication dispensing systems (A-stations)	Survey	Anaesthetic medical staff, nurses, anaesthetic technicians, and pharmacy staff. 26.8% (118 of 440)	Satisfaction with A-stations varied between anaesthetic medical staff and other staff. The study assessed various aspects of A-station functionality. 74% of all the responders preferred the A-stations to manual anaesthetic medication trolleys
Lichtner et al. (2023)	Children's hospital ICU in Sidney, Australia	Controlled Drugs (CD) governance: Safekeeping, Transactions, Monitoring, Reporting	Mixed-methods study with structured observations, data extracted from ADC, interviews, and audits	19 nurses, 1 management, and 3 pharmacy staff. Purposive sampling	Nurses and pharmacists perceived CD governance as more efficient with the ADC. The ADC changed the quality and distribution of tasks. It eliminated frustrating CD governance inefficiencies. Diversion can still occur with ADCs in place.
Wang et al. (2021)	National Taiwan University Hospital, Taipei, Taiwan	Time discrepancy in drug preparation, delivery, ADEs (adverse drug events), and questionnaire results	Longitudinal study using surveys and clinical observations	Nurses in various units. 100% (76)	Nurses were generally satisfied with the ADC technology (3.90 score on a scale of 1 to 5). It facilitated their work and improved patient care.
Craswell et al. (2021)	450-bed university hospital in the Sunshine Coast, Australia	Aspects involved in implementation of a distributed AMD system and impact on patient safety	Qualitative descriptive study involving interviews	Nursing and pharmacy assistant staff in medical and surgical wards, the ICU, and the emergency department. 26 interviews	Nurses supported initiatives that benefited patients despite workflow difficulties. The study focused on structural and process elements related to medication administration.
Metsämuuronen et al. (2020)	Kuopio University Hospital, Finland	Nurses' perceptions of ADCs and their impact on work	Observation and survey	Nurses (staff and head) in Anaesthesia and Surgical Unit and Intensive Care Unit. 23% (81 of 346)	Most nurses found ADCs easy to use and believed they made their work easier. The study addressed efficiency, patient safety, and work impact.

Reference	Study Setting	Aspects Covered	Research Methods	Respondents, Sample size and Response rate	Main Findings
Berdot et al. (2019)	Two teaching hospitals (814 and 643 beds) in Paris, France	Comparison of cost and benefits of ADCs vs traditional storage (TSSS)	Data registers and survey	Nurses. 60.9% in ADCs hospital (14 of 23) and 66.7% (14 of 21) in TFSS hospital	Nurses reported greater satisfaction with ADCs (89%) over traditional storage. The study assessed compatibility, usefulness, ease of use, and user satisfaction.
Douglas et al. (2017)	Large acute care teaching hospital, USA	Impact of a new ADC on medication administration. MAS-NAS Scale, 18 items on efficacy, safety and access.	Retrospective/prospective study using a survey	120 nurses. Response rate not specified	The study found statistically significant improvements with the new ADC in efficiency, safety, and access. However, overall global satisfaction was not assessed.
Roman et al. (2016)	Adult referral hospital in Melbourne, Australia	Impact of automated dispensing cabinets (ADCs) on practice	Time and motion study and qualitative survey	Emergency staff members. 78 in the pre-implementation period and 58 in the post-implementation period. Response rate not specified	Implementation of ADCs improved medication retrieval time for certain medications but increased the time needed for others. Staff reported positive impacts on practice.
Zaidan et al. (2016)	Two centers in Qatar	Nurses' sociodemographic characteristics, 21 questions on perceptions, one question on overall satisfaction, and one the system's ease of use	Survey	Nurses. 80.1% (403 of 503)	Nurses were largely satisfied with ADCs and believed they facilitated safer patient care. They found the system user-friendly and efficient.
Rochais et al. (2014)	Mother and child hospital in Montreal, Canada	Impact of ADCs on the safe delivery of healthcare. 33 items on 8 topics.	Quantitative and qualitative study	Nurses, nursing assistants, and assistant head nurses. 46% (172 of 375)	Nursing staff considered the introduction of ADC made their work easier, helped safely provide patients with care, and reduced medication incidents.

Reference	Study Setting	Aspects Covered	Research Methods	Respondents, Sample size and Response rate	Main Findings
Escobar-Rodriguez et al. (2012)	Hospital with over 320 beds in Huelva, Spain	Intention of healthcare personnel to use e-prescriptions and automated medication management systems (EPAMMS)	Regression analysis of latent variables with a questionnaire based on the Technology Acceptance Model (TAM)	Hospital physicians and nurses. 209, of which 91 were physicians and 118 nurses. Rate not specified	The study found that healthcare personnel's intention to use EPAMMS was influenced by several constructs, including perceived usefulness and ease of use.
Chapuis et al. (2010)	University hospital, Grenoble, France	Impact of an automated dispensing system on medication errors	Preintervention and postintervention study with questionnaires	Nurses in two medical intensive care units. 64 responses in 3 phases (18, 14 and 32) from 68 nurses. Response rates ranged from 31% to 57%	The implementation of the automated system improved the safety of medication administration by reducing errors. However, any changes may generate new error risks, justifying continuous quality monitoring.
Novek (2002)	River City Hospital, a 388-bed long-term care facility located in Winnipeg, a midsize city, Canada	Relationship between technological change and the occupational identities and practices of nurses, pharmacists, and patient care managers.	Case study with questionnaire, interviews and other sources of information	Nurses. 64.5% (102 of 158)	Nurses strongly rejected that AMDS was either more accurate or more efficient than the manual system it replaced. Frequently cited complaints were long delays and lineups waiting for the terminal, machine dispensing errors, and the imposition of standard administration times.
Novek et al. (2000)	River City Hospital, a 388-bed long-term care facility located in Winnipeg, a midsize city, Canada	Reactions of nursing to the implementation of the automated medication dispensing system (AMDS)	Survey and interviews	Nurses. 64.5% (102 of 158)	Nurses reported a low level of confidence that automation decreased the risk of medication errors. missed doses, wrong doses, wrong time errors, and the danger of overdependence on technology were frequently cited as negative risk factors associated with AMDS.
Martin et al. (2000)	2 acute care hospitals (865 and 340 beds) in the United States	Evaluation of a hospital-wide automated dispensing system	Cross-sectional survey and chart review	Pharmacists and nursing staff. Size and response rate not specified	Most nurses (91%) in the wards preferred the automated system and 54% of nurses in the intensive care areas thought the system should be adopted.

Reference	Study Setting	Aspects Covered	Research Methods	Respondents, Sample size and Response rate	Main Findings
Eap and Ramadan (2022)*	Manor Care Rehab Center-Marietta, Manor Care Rehab Center -Decatur, and Anderson Mill Health and Rehab Center, Georgia, USA	Omnicell Usability. System Usability Scale (SUS, 10 items) and the Usability Metric for User Experience-Litle (UMUX-Litle, 2 items). 4 demographic items, and 3 open-ended questions	Survey, observations and inventory records	10 nurses. Convenience sample.	90% of the surveyed nurses were satisfied with the usability of Omnicell. Nearly 80% of the nurses had a positive perception of using it, and 80% found it convenient and easy to use to perform their tasks. There were no significant suggestions for improving the technology, but nurses mentioned they needed more training.
Elkady et al. (2019)*	King Faisal Specialist Hospital and Research Centre, Jeddah, Saudi Arabia	Technology Acceptance Model (TAM) modified, 7 aspects of technology acceptance	Survey (online). Simple linear regression analysis	Nurses. 29,4% (312 de 1,062)	Perceived usefulness, perceived ease of use, perceived usefulness to enhance control systems and training have positive effects on improving nurses' attitudes and increasing acceptance of using ADCs. Perceived risks had negative effects.
Menezes et al. (2018)*	University Hospital, Brasil	Technology in the use of electronic dispensaries, care time, patient safety	Focus group	27 nurses	In general, the nursing staff showed satisfaction with the use of the equipment, but reported a need for adjustments and improvements in the work process associated with the dispensing system. Professionals reported that automated dispensing systems contribute to patient safety.
Arinal et al. (2014)*	A 133-bed academic hospital opened in Miami, Florida, USA	MAS-NAS Scale with 3 additional questions (21 in total) plus 7 questions comparing perceptions before and after installation.	Survey. T-tests for comparisons	25 of 39 (64%) nurses before the installation and 20 of 36 (56%) nurses after	Medication cabinets installed in each patient room increased nurses' satisfaction concerning medication availability, allowed nurses to spend more time with their patients and thus increased patient safety, but did not impact medication charge accuracy or medication errors

* Studies not included in WoS and Scopus database