Effect of electronic prescriptions on the safety of hospitalized pediatric patients

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ABSTRACT

Introduction. Prescription errors are the most common cause of preventable errors. Electronic prescription (EP) systems may help to reduce errors and improve the quality of care.

Objectives. To assess the effect of EP on the prevalence of prescription errors and related adverse events (AE) among hospitalized pediatric patients. To assess EP adherence, acceptability, and suitability among users.

Method. Hybrid, descriptive, and quasi-experimental, before-and-after design. Prescriptions made to hospitalized patients were included, estimating the prevalence of prescription errors and related AE in the pre- and post- EP implementation periods at a children's hospital (CH) and a general hospital (GH) used as control. Adherence was assessed based on the proportion of EP among all prescriptions registered in the post-implementation period. The acceptability and suitability of EP implementation was assessed via a user survey.

Results. The prevalence of prescription errors pre- and post-EP implementation at the CH was compared and a statistically significant reduction was observed in both hospitals: CH: 29.1 versus 19.9 prescription errors/100 prescriptions (OR: 1.65; 95% CI: 1.34-2.02; $p < 0.01$). GH: 24.9 versus 13.6 prescription errors/100 prescriptions (OR: 2.1; 95% CI: 1.5-2.8; $p < 0.01$). The rate of overall adherence to EP was 83%. The implementation of EP was adequately acceptable and suitable.

Conclusion. The prevalence of prescription errors reduced 30% after the implementation of EP. The overall adherence to EP was adequate.

Keywords: *patient safety, health plan implementation, electronic prescription, medical errors.*

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INTRODUCTION

Since the Institute of Medicine issued its report "*To err is Human*", patient safety became a priority topic. Medication errors are the most common type of medical errors, and children have a higher risk for medication-related adverse events than adult patients.[3]

Medication-related errors, especially prescription errors, are the most frequent cause of preventable errors.[4] The prevalence of prescription errors in children has been reported to be between 5% and 27%; 1% of these may involve a potential harm for the subject.[5-7] Although these errors may be frequent in specialized areas, general hospitalization wards are not exempt.[8-10]

Prescription errors may include the prescription of the wrong drug, the wrong dose, the wrong formulation or preparation, the wrong route of administration, and patient-related aspects, such as a history of allergy or a specific contraindication.[11]

EP may significantly reduce errors (between 44% and 88%).[5] Specifically in pediatrics, some prescription errors are related to the dose estimation based on patient weight,[5,6] so EP that include tools to resolve this issue are effective aids for patient safety.

Establishing an EP system in general, pediatric hospitalization areas may help to reduce errors in relation to this variable. In addition, exploring potential barriers and facilitators to adopting this tool would allow to develop effective strategies to shorten the implementation gap.

We proposed to assess the effect

of using EP on the prevalence of prescription errors and related AE in general pediatric hospitalization areas, estimate adherence, and assess EP acceptability and suitability among users.

POPULATION AND METHODS

Design. This study used a hybrid,[12] quasi-experimental, before-and-after design to measure the effect and a descriptive design to assess the implementation.

Population. Medical prescriptions made to patients hospitalized at the general ward of a tertiary care CH and at the pediatric care unit of a GH in the Autonomous City of Buenos Aires were included. The implementation of EP was assessed via a survey administered to first- and second-year residents working at the CH, who use the EP system on a regular basis.

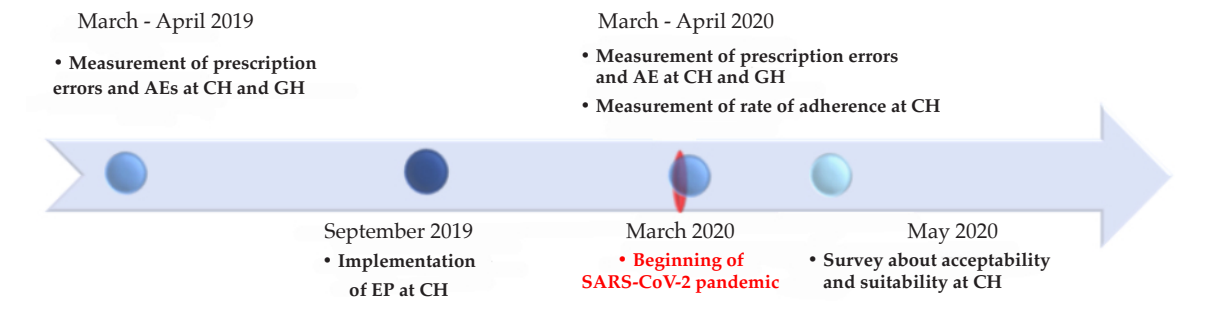
Procedure. The effect of EP implementation was established by measuring prescription errors before and after its implementation in the CH. Considering that EP has been used since September 2019 across all units of the CH (upon training) and that it was gradually implemented, the baseline prevalence of prescription errors was that measured 6 months before said implementation. The second measurement was done 6 months later. These measurements took place both in the CH units and the pediatric unit of the GH, where EP was not used (*Figure 1*). In addition, selected medical records were reviewed to look for AE related to prescription errors using a tool based on drug related AE triggers.[13] If an AE was detected; each medical record was assessed by a second reviewer to establish causality and severity.

A prescription error was defined as any medical indication that unintentionally causes a reduction in the potential effectiveness of a treatment or increases the probability of harm compared to the adequate indication.[8] The following types of error were considered: inadequate patient identification, omission of weight, missed diagnosis, missed reporting of history of allergy or isolation, erroneous medication, missed medication, wrong dose, wrong dosing intervals, wrong route of administration, omission of the route of administration, wrong pharmaceutical form, omission of prescription time and/or modification time, illegibility. The adequate dose, route of administration, and formulation were reviewed based on a broadly known and widespread used pharmacopeia.[14] The adequacy of treatment to diagnosis was verified using the CH's diagnosis and treatment guidelines,[15] the Argentine Society of Pediatrics' consensuses,[16-20] and other clinical practice guidelines.[21-23]

Prescription errors were classified based on severity according to the National Coordinating Council for Medication Error Reporting and Prevention taxonomy, adapted by Otero et al.[24] (*Table 1*).

The implementation of EP was assessed by establishing its acceptability and suitability[25] using an anonymous survey with a 5-point Likert-like scale that had been previously validated in a population with similar characteristics[26] (see *Annex*). Acceptability was considered adequate when less than 75% of items 1, 2, 3, and 4 obtained a score ≥ 3, whereas suitability was considered adequate when less than 75% of items 5, 6, 7, and 8 obtained a score ≥ 3. The proportion of EP over the total number of prescriptions was estimated to assess adherence to EP use.

Figure 1. *Timeline of study procedures*



AE: adverse events; CH: children's hospital; GH: general hospital; EP: electronic prescriptions.

Sample size and selection. Considering that there are approximately 800 hospitalizations per month at the CH, that each patient receives an average of 3 prescriptions per day, and a 5% prevalence of prescription error,[5] the sample size was estimated at 963 prescriptions (321 medical records), with a 95% confidence interval (CI). The same number of prescriptions was reviewed after the implementation of EP, considering that EP implementation may reduce the prevalence of error to a half (2.5%), with a 95% CI and an 80% power (EpiInfo Statcalc 7.2.6.6®, CDC, 2018). Sampling was carried out through simple random selection among the prescriptions corresponding to the months pre- and post-implementation (March-April 2019 and 2020) among the hospitalization units of the CH. If a medical record was incomplete, the immediately subsequent one was selected. The first prescription available in the medical record was reviewed. In addition, considering that there are approximately 40 pediatric hospitalizations in the GH per month, all medical records corresponding to the study period were selected and all prescriptions were reviewed. If the same prescription error was observed on successive days, it was registered only once to avoid overestimating the prevalence of errors at the GH.

Statistical analysis. The prevalence of prescription errors before and after the implementation of EP in both hospitals was estimated. The prevalence of prescription errors was compared between both periods and both hospitals using a χ^2 test. Categorical variables were described as absolute values or percentages with their corresponding 95% CI ($p \leq 0.05$).

Ethical considerations. The study was approved by the Research and Ethics Committee of both hospitals.

RESULTS

A total of 3420 prescriptions were analyzed: 2059 from the CH and 1361 from the GH (*Table 2*).

Effect of electronic prescriptions (EP) on error.

The prevalence of prescription errors reduced significantly after the implementation of EP at the CH (29.1 versus 19.9 prescription errors/100 prescriptions; OR: 1.65; 95% CI: 1.34-2.02; $p < 0.01$). Prescription errors also reduced at the GH, without the implementation of EP (24.9 versus 13.6 prescription errors/100 prescriptions; OR: 2.1; 95% CI: 1.5-2.8; $p < 0.01$) (*Table 2*).

Characteristics of errors and adverse events.

The most common prescription error in the CH was "not specifying the route of administration". With EP, it reduced significantly (30.1% versus 16.3%; OR: 2.6; 95% CI: 1.7-4; $p < 0.01$). A similar observation corresponded to "wrong dose" (*Table 3*).

TABLE 1. *Categories of prescription error severity*

Category	Definition
Potential error	
A	Circumstances or events that have the capacity to cause error.
Error, no harm	
B	An error occurred, but the error did not reach the patient.
C	An error occurred that reached the patient, but did not cause patient harm.
D	An error occurred that reached the patient and required monitoring and/or intervention to preclude harm.
Error, harm	
E	An error occurred that may have contributed to or resulted in temporary harm to the patient and required intervention.
F	An error occurred that may have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization.
G	An error occurred that may have contributed to or resulted in permanent patient harm.
H	An error occurred that required intervention necessary to sustain life.
Error, death	
I	An error occurred that may have contributed to or resulted in the patient's death.

(Based on the National Coordinating Council for Medication Error Reporting and Prevention taxonomy of medication errors, adapted by Otero et al.[24])

At the CH, the most common prescription error was "wrong dosing intervals" (30.6%), but the reduction was not significant. However, "not specifying the route of administration" showed a significant reduction (*Table 3*).

In relation to error severity, 80.7% corresponded to category B and 10.5%, to category A in the pre-implementation period at the CH.

After the implementation of EP, 95.2% corresponded to category B. At the GH, 71.3% corresponded to category B and 23.9%, to category A. During the second measurement, 81.7% corresponded to category B.

At the CH, the implementation of a tool based on triggers helped to identify 5 AE related to prescription errors: 3 corresponding to category D and 2, category E. After the implementation of EP, 3 AE related to prescription errors were observed: all corresponding to category E. At the GH, no AE was related to prescription errors. No prescription error or AE observed in both hospitals resulted in permanent harm or death.

Assessment of EP implementation

The rate of overall adherence to EP was 83%. EP acceptability and suitability among users was estimated using a survey administered to health care providers working at the CH who currently use the system.

The survey reliability was acceptable (Cronbach's alpha = 0.8). The implementation of EP was adequately acceptable and suitable. EP users were invited to complete the survey. Out of a total of 70 health care providers, 58 (82.8%) completed the survey. In relation to acceptability items, a score ≥ 3 was obtained in all questions according to 57/58 respondents. In relation to suitability items, a score ≥ 3 was obtained in all questions according to 55/58 respondents

TABLE 2. *Prevalence of prescription errors and adverse events*

	Children's hospital				General hospital			
	Pre-	**Post-**	**OR (95% CI)**	***p***	**Pre-**	**Post-**	**OR (95% CI)**	***p***
Total reviewed prescriptions	1016	1043			839	522		
Total prescription errors	296	208			209	71		
Prescription errors per 100 prescriptions	29.1	19.9	1.6 (1.34-2.02)	< 0.01	24.9	13.6	2.1 (1.5-2.8)	< 0.01

Pre-: pre-implementation; Post-: post-implementation; OR: odds ratio; CI: confidence interval.

TABLE 3. *Types of prescription errors*

	Children's hospital				General hospital			
Prescription errors	**PRE- n = 296**	**POST- n = 208**	**OR (95% CI)**	***p***	**PRE- n = 209**	**POST- n = 71**	**OR (95% CI)**	***p***
Type of error	%	%			%	%		
Route of administration not specified	30.1	16.3	**2.6 (1.7-4)**	**< 0.01**	13.4	4.2	**5.9 (1.8-19.7)**	**< 0.01**
Modification time missing	21.3	34.6	0.89 (0.6-1.2)	0.5	14.8	4.2	**6.6 (2-21)**	**< 0.01**
Missing dose or medication	13.9	13.5	1.5 (0.9-2.4)	0.1	7.2	4.2	3.1 (0.9-10.9)	0.09
Wrong dosing intervals	11.1	10.6	1.5 (0.9-2.6)	0.14	30.6	64.8	0.8 (0.5-1.2)	0.4
Wrong dose	6.4	2.9	**3.2 (1.3-8.2)**	**0.01**	7.2	9.9	1.3 (0.5-3.3)	0.6
Isolation reporting	4.7	3.8	1.8 (0.7-4.3)	0.25	1	7	0.2 (0-1.2)	0.13
Illegibility	3.7	6.7	0.8 (0.3-1.7)	0.73	12.9	0	**17.3 (2.3-127)**	**< 0.01**
Allergy reporting	2.4	2.9	1.2 (0.4-3.5)	0.74	0	0		
Erroneous medication	2	1	3.1 (0.6-15)	0.27	1.4	4.2	0.6 (0.1-2.9)	0.82
Diagnosis in indication	1.7	0.5	5.1 (0.6-44.1)	0.20	1	0		
Patient identification	1.4	0			10	1.4	**13 (1.7-99.7)**	**< 0.01**
Patient weight	1	0			0	0		
Wrong route of administration	0.3	1.9	0.2 (0-2.2)	0.38	0	0		
Date in indication	0	3.4			0.5	0		
Wrong pharmaceutical form	0	1.9			0	0		

PRE-: pre-implementation; POST-: post-implementation; OR: odds ratio; CI: confidence interval.

(*Table 4*). A lack of materials necessary for EP was identified as the most common difficulty at the time of implementation (71%).

DISCUSSION

In this study, the prevalence of prescription errors before the implementation of EP was in the range of what had been reported in studies conducted at a local and international level, which was between 14-41%[6,11,27] and 4-58%,[28] respectively.

After the implementation of EP, the reduction in prescription errors was similar to that observed in studies with a design similar to ours, with reduction close to 36%, which evidences the positive impact of these actions.[29,30]

Strikingly, a reduction was observed in prescription errors at the GH, although EP was not implemented there. This is probably related to several factors. On the one side, the GH started using a pre-designed prescription form to be completed manually. This procedure, not established in the original protocol, was implemented in the setting of the measures to fight the COVID-19 pandemic, and may have facilitated the prevention of prescription errors. On the other side, a substantial portion of the population hospitalized at the GH (41%) during the post-implementation period were patients with suspected or confirmed mild COVID-19 from vulnerable neighborhoods who lacked the conditions required for outpatient isolation[31,32] and who required prescriptions of low complexity (pain and fever drugs), which contributed to a lower prevalence of errors. This was not the case of the CH, where only 1 of the 5 studied hospitalization wards received patients with COVID-19. In any case, the results of our study may suggest that standardizing the prescription process, regardless of the tool, may help to reduce the prevalence of prescription errors.

Table 4. *Results of the implementation survey*

Item	Median	IQR
Adequate use	4	4-5
Meets needs	4	3-4
Friendly EP system	4	4-5
Willingness to use EP system	5	4-5
Considers EP use complicated*	2	1-2
EP adapted to workplace	4	3-4
Appropriate for use	4	4-4
Adequate implementation	4	4-5

IQR: interquartile range; EP: electronic prescription.
*The inverse scores to those obtained were exposed because it was a question written in negative.

In relation to the type of prescription errors, "wrong dose" and "not specifying the route of administration" reduced significantly at the CH with the implementation of EP. Ghaleb et al., observed that an error in antibiotic and sedative dosing was the most frequent one.[33] Most likely, this is related to the need to estimate the dose based on children's weight. The reduction in this type of error is noteworthy due to its high frequency and the implications in patient safety. The EP tool implemented at the CH may have contributed to better estimate the dose because once the prescription is entered, the dose is automatically indicated in mg/kg/day, thus facilitating the control of the estimated dose. The improvement in results related to specifying the route of administration may also be attributed to the implemented tool because this information cannot be omitted. At the GH, the introduction of a pre-designed prescription form probably helped to reduce error related to patient identification, route of administration, and modification time because the form included all these items. The evidence related to the type of variation in prescription errors after the implementation is highly variable. Taffarel et al.,[10] used an EP system that was very similar to ours and found that the best improvement occurred in "modification time missing"; however, "dose errors" increased after the implementation of EP. Otero et al.,[34] implemented a bundle of measures that included promoting a patient safety culture and a checklist after each prescription and found that the main reductions occurred in relation to "errors in dosing intervals," followed by "modification time missing", whereas "omission" and "illegibility" increased after the implementation. Such dissimilar results are probably explained by the bundle of measures adopted and the baseline frequency of prescription errors at each facility.

The frequency of AE related to prescription errors reduced to almost a half at the CH during the post-implementation period. Most likely, the introduction of the EP system is also responsible for such outcome.

The rate of adherence to EP was 83%. Its implementation showed an adequate acceptability and suitability among users, similar to what was observed by Bulut,[35] who reported a 78% adequacy level among users of the EP program. However, other authors have described certain level of resistance to change among health

care providers, which lessens as they become familiar with the system, and observed that the EP implementation involves a learning curve.[10,36,37] Sicotte reported that the experience with information technology, learning style, and the average number of prescriptions made per day are predictors of early adherence to EP systems.[36]

Although our results support EP use to reduce prescription errors, it is worth taking into account that new unintentional errors that derive from the use of this technology have been recently reported.[38] This phenomenon should be monitored to take the necessary actions.

Lastly, our study described the problems faced during the investigation in relation to the COVID-19 pandemic and how it may have had an indirect effect on study outcomes.[39]

CONCLUSION

The standardization of the prescription process, regardless of the strategy implemented, showed a positive effect on the safety of hospitalized patients. The prevalence of prescription errors reduced by 30% after the implementation of EP. The overall adherence to the tool was adequate. ■

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ANNEX
Survey administered to users in relation to the implementation of electronic prescription

Dear Colleague, the safety of hospitalized patients has become a priority in the health care system. The use of electronic prescriptions is part of a bundle of measures aimed at reducing medical errors in relation to health.

Hereby, you are invited to complete a questionnaire regarding the implementation of electronic prescription. It will take you less than 15 minutes. The information provided here is confidential and will help us to improve the implementation of the EP system.

Your participation is voluntary. Completing the survey will presume you give your consent. Thank you.

All questions are related to electronic prescription (EP). Answers correspond to a scale from 1 to 5, where 1 means "not at all" and 5, "completely."

Mark with an "X" the answer that you believe adequate.

To what extent did you find EP use adequate?
1-Not at all 2-Slightly 3-Moderately 4-Very 5-Completely

To what extent does EP meet all your needs?
1-Not at all 2-Slightly 3-Moderately 4-Very 5-Completely

To what extent do you find the EP system friendly?
1-Not at all 2-Slightly 3-Moderately 4-Very 5-Completely

To what extent are you willing to use the new EP system?
1-Not at all 2-Slightly 3-Moderately 4-Very 5-Completely

To what extent do you find EP use complicated?
1-Not at all 2-Slightly 3-Moderately 4-Very 5-Completely

To what extent does EP adapt to your workplace?
1-Not at all 2-Slightly 3-Moderately 4-Very 5-Completely

To what extent do you find EP appropriate for use?
1-Not at all 2-Slightly 3-Moderately 4-Very 5-Completely

To what extent do you think the selected EP system is a good implementation?
1-Not at all 2-Slightly 3-Moderately 4-Very 5-Completely

In your opinion, which of the following are potential barriers or difficulties at the time of implementing EP (mark the options you believe adequate):

- EP takes more time.
- I do not have the necessary materials to use EP (e.g., sheets of paper, printer, ink/toner).
- I believe EP is more practical; however, it reduces the possibility for learning.
- EP cannot be adapted to the needs of certain patients.
- Sometimes I have to write down notes in my prescriptions.