TOWARDS REDUCING ANTIMICROBIAL INJECTION PREPARATION ERRORS IN A PAEDIATRIC WARD, PENANG HOSPITAL

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Abstract

Antimicrobial injections are intended for the prevention and treatment of infections caused by microorganisms. Proper reconstitution and storage post reconstitution are crucial in maintaining the viability of multi-dose vials. Multi-dose vials are cost-effective and able to reduce medication wastage, especially in paediatrics dosage application that is according to their weight. However, incorrect reconstitution and multiple uses of single-use injections could potentially cause ineffective treatment, leading to antimicrobial resistance, thus making proper handling of these injections more essential. This study aimed to reduce antimicrobial injection preparation errors. A quality improvement project was carried out from September 2017 until May 2019 in a paediatric ward. Data on medication supply (by the pharmacy) and preparation processes (by ward) were collected. Questionnaires were distributed to assess the knowledge of persons involved in product stability. About 86.3% of all antimicrobial injection preparations contained at least one error. The contributing factors leading to the preparation errors were incomplete labelling (76.1%) as well as poor knowledge of injection stability among nurses (39.5%) and pharmacy staff (43.5%). Training and pocket guidelines were given as a reference for antimicrobial stability. Furthermore, flashcards were placed on the medication preparation trolleys to guide the reconstitution process. A reminder list on storage conditions was sticked on refrigerators in the ward. Mnemonic method and Antimicrobial Dilution Protocol (Paediatrics) were developed during the second cycle. From September 2017 to May 2019, antimicrobial injection preparation errors were successfully reduced from 86.3% (n=117) to 16.4% (n=122).

KEYWORDS: Antimicrobial injection, Preparation errors, Paediatrics

Problem

Penang Hospital (HPP) is the main public hospital in Penang, Malaysia. It also serves as a tertiary reference hospital for Northern Malaysia and consists of multidisciplinary wards, including eight paediatric wards with 156 beds. C1 is a paediatric medical ward with 40 beds, which is the highest number of beds (25.6%) among all paediatric wards, and the occupancy rate occasionally might increase up to 125%. Ward C1 has a total of 28 staff nurses who work in three shifts. There is also a clinical pharmacist in charge of the paediatric medical ward.

Paediatric dosage requirements are based on their body weight or size. Only a small dose of antimicrobial is needed for paediatric patients, therefore they tend to share the antimicrobial injection vial. The multiple-use vials are beneficial for cost management and cutting medication waste, especially for the paediatric patients. However, they are prone to preparation errors that can harm paediatric patients, as well as cause ineffective treatment and antimicrobial resistance (1).

A five-day verification study in August 2017 found out that a total of about 45% (27/60) of antimicrobial injection preparation errors occurred from all eight paediatric wards. The highest rate of preparation error of 58.1% (18/31) was detected in the paediatric medical ward (Ward C1). This showed an overwhelming amount of more than half of antimicrobial injections in Ward C1 were wrongly prepared and not complied with the recommended guidelines. These errors included multiple uses of single-use injections, inappropriate injection reconstitutions, inappropriate labelling of reconstituted injections, and inappropriate storage of reconstituted injections.

Following the verification study, a baseline (pre-remedial) study with a longer duration of one month was then carried out again in Ward C1 for a better investigation. The baseline study indicated an even higher error rate (86.3%) in the preparation of antimicrobial injection. Therefore, this project aimed to reduce the incidence of antimicrobial injection preparation errors in the paediatric medical ward (Ward C1) from 86.3 to 0% within two years.

Background

Paediatric is a vulnerable population with specific medical needs compared to adults (2). Most injections given to paediatrics are from vials with a pre-adjusted dose specifically for the adult population. Hence, paediatric medication preparation requires manual manipulation of the product to deliver the prescribed dose, which may vary from neonatal to adult dosing (3). This leads to the need for a specific weight-based drug-dose calculation and preparation such as mg/kg, mcg/kg, and mg/m^2 (per body surface area) for an individual patient (1, 2).

The process of reconstitution and storage would affect the stability of post-reconstituted medication. Drug stability refers to the extent to which a drug substance retains the same properties and characteristics that it possessed at its manufacturing time and throughout its period of storage and use (4). The types of stability are generally divided into chemical, physical, microbiological, therapeutic, and toxicological. Drug stability affects the safety and efficacy of the drug product, in which degradation impurities may cause a loss of effectiveness and generate possible adverse effects. Therefore, achieving drugs' chemical and physical stability is essential to ensure their quality and safety (4).

This error-prone process and the lower dosing error tolerance of paediatrics place them at a higher risk for life-threatening medication errors. A study had shown that paediatric patients possessed a higher mortality rate (10.4%) compared to adults (4-6%) when exposed to medication errors (5). Another study showed that the paediatric inpatients' preparation and the administration error rate was between 8.0 to 62.7%. However, a higher rate was seen in medication preparation errors involving intravenous drugs, which was as high as 48.4 to 97.7% (2).

In the Ministry of Health hospital setting, eight types of antimicrobial injections such as Ampicillin and Cloxacillin injections are single-use injections. Single-use injections should be administered immediately after reconstitution and the remaining should be discarded immediately. However, based on the results from the meeting with the Head of Paediatric Department, these single-use injections tend to be misused as multiple injections due to a lack of knowledge among the staff and their reluctance to prepare multiple reconstitutions. According to National Patient Safety Agency (NPSA) Signal by the United Kingdom National Health Service (NHS), there are risks of contamination if single-use injections are used multiple times (6). In addition, according to WHO guidelines, storing an open ampoule, vial, or syringe for reuse and improper storage of these preparations are most likely lead to contamination (7).

Centers for Disease Control and Prevention (CDC) revealed that at least 19 blood-borne or bacterial infection outbreaks had been reported since 2007, which were associated with the mishandling of single-use injections (8). These examples showed that the adverse impacts of mishandling a vial were underestimated as they were typically not seen immediately due to the difficulty of tracing the exploitation (8). Some providers compromised safe infection control practices to prevent waste. However, any cost savings achieved by preventing waste could be quickly offset by one or more adverse clinical outcomes. As a result, some patients died from these infections, and many others required prolonged, sometimes life-long treatment, and follow-up care (1).

Mcdowell et al. suggested that the reconstitution step contributed to the most errors among other processes in antimicrobial preparation (9). According to Armitage et al., four main variables affecting medication errors were knowledge, attitude, behavior, and training needs (10). Another study showed that task-related conditions such as inadequate or not following standard administration protocols might cause incorrect administration and preparation (11). Taxis and Barber reported a lack of knowledge on preparation and administration procedures contributed to the cause of medication errors (12). Latif et al. agreed with both studies by stating that the leading sources of errors that caused harm were deficits in knowledge and performance (57%) and procedures not being followed (26%) (13).

Interventions such as training junior nurses to assess the basic injection preparation skills, as well as having a specific satellite pharmacy, in which central preparation of drugs is done in the pharmacy to supply paediatric medications may reduce the error rates for preparing and administering intravenous drugs (14). De Giorgi et al. did a prospective risk analysis on the safety of paediatric patients in connection with the injectable medication process. They found that the involvement of clinical pharmacists during medication screening and counterchecking, as well as the introduction of ready-to-use syringes for selected drugs were the most cost-effective tools (15).

Based on questionnaire responses from Marco et al., hospital staff believed the above-mentioned remedial measures to be effective. The questionnaire results revealed that 90.8% of them believed that protocols and informative brochures helped in reducing errors while 90.2% believed that improving their knowledge on drug preparation and administration was vital. Furthermore, 87% believed that the awareness to prevent errors from occurring among the staff must be increased (16).

Measurement

The indicator used to measure this problem in Ward C1 HPP was the percentage of antimicrobial injection vials with preparation errors. It was calculated by dividing the total number of antimicrobial injection vials with preparation errors detected over the total number of antimicrobial injection vials prepared. Any vials observed with one or more errors were considered as one vial error. Our inclusion criteria were

all antimicrobial injections prepared and stored in Ward C1, excluding those done on the weekend and during public holidays, due to a lack of manpower to perform data collection. According to the Malaysian Patient Safety Goals Guideline, the target for actual medication errors is 0% and there is no specific target set for near misses for medication errors in the guideline (17). Errors in our study included both actual and near misses for medication errors; hence our proposed standard was to achieve 0% antimicrobial injection preparation errors. The indicator and standard were chosen based on the consensus among paediatric clinical pharmacists and the Head of Paediatric Department.

The antimicrobial injection preparation errors were defined as errors in selecting, calculating, mixing, labelling, and measuring all injection forms of antibacterial, antifungal, and antiviral (18). Labelling of reconstitution injection, in particular, requires complete reconstitution information written on the vials until administration to the patient is completed. Hence, in our study, preparation errors included errors in reconstitution, labelling, and storage (Table 1).

Table 1: Types of preparation error included in the study

Type of Error	Definition
Error in reconstitution	Wrong type or volume of reconstitution solution used according to leaflet
Error in labelling	One or more of the following was not labelled on multi-use vial: • Volume of reconstitution solution • Type of reconstitution solution • Date of reconstitution • Time of reconstitution
Error in storage	• Multiple uses/storage of reconstituted single-use vial. • Wrong storage temperature of reconstituted vial. • Storage of expired reconstituted vial.

This study was carried out from May 2017 to June 2019 in the paediatric medical ward (Ward C1). Around 20 types of paediatric antimicrobial injections were studied including acyclovir, cefepime, erythromycin, vancomycin, and many other injections.

Data were collected by the team members twice a day during working days from 11 am to 12 pm and 3 pm to 4 pm. During the first session, preparation processes of antimicrobial injections were observed directly by team members, and any reconstitution and labelling errors were recorded. During the second session, antimicrobial injection vials reconstituted earlier were inspected by the team members, and any labelling and storage errors were recorded. Every vial observed or inspected was marked with a specific number using a permanent marker to avoid sample repetition. Errors from both sessions were recorded in a specific data collection form (Appendix 1). Any vials with more than one error were counted as one overall error for the indicator calculation. The data collection form was also used to record the type of errors that occurred, whether it was a reconstitution error, labelling error, or storage error. Labelling errors were further classified into no reconstitution solution, no reconstitution volume, no date, and no time labelled. Storage errors were further classified into the wrong temperature, expired vials, and multiple uses of single-use vials.

Concurrently, knowledge on injection preparation and stability among nurses and pharmacists was assessed using a

questionnaire. The questionnaire contained ten questions that focused on the 20 most commonly used antimicrobials. It was created based on common mistakes and errors found among pharmacists and nurses, which intended to assess their knowledge on antimicrobial stability and antimicrobial reconstitution process, respectively. All nurses in Ward C1 and all pharmacists involved in handling paediatric medications were assessed. The same questionnaire was used before and after training to evaluate the effectiveness of the training given. The total of correct answers given in the questionnaire was calculated to grade the knowledge of the staff involved in the process. The passing mark was set at 80% as good knowledge was vital in handling paediatric medications to avoid fatal errors.

Initial Assessment of the Problem

According to the Standard Operating Procedure (SOP) of Penang Hospital in Figure 1, every prescription (Rx) from wards is sent to Inpatient Pharmacy to be screened. Subsequently, medication is supplied to the wards accordingly. Then, the staff nurses reconstitute the injections before administering to the patients.

A total of 117 vials of antimicrobial injection were included in this study. Data was collected throughout September 2017. Out of the total, only 58 vials were observed directly during the reconstitution process, as some reconstitution processes were done by nurses outside our observation time frame of 11 am to 12 pm. The other 59 vials were inspected during the afternoon visit to the ward.

There might be more than one error in each vial of antimicrobial injection preparation. In our study, vials with more than one error were counted as one overall error. Out of these 117 vials, 101 vials (86.3%) have at least one type of preparation error. Among the 101 vials that contained at least one error, labelling error was the type of antimicrobial injection preparation error with the highest percentage (76.7%), followed by storage error (19.8%), and reconstitution error (3.5%) (Figure 2). Among all types of labeling error, the highest labelling error found was no reconstitution solution labelled on the reconstituted vials, with a percentage of 98.8%.

Under the storage error, all vials with storage errors were found to be stored under the wrong temperature. Storage under the wrong temperature meant either the staff stored fridge items at room temperature or vice versa. We also noted that 60.1% of vials with storage errors were either stored over their stability period or used multiple times when they should only be used once and discarded immediately.

Based on the results of the questionnaires in the pre-remedial data collection, the knowledge of the antimicrobial injection stability among nurses in Ward C1 and pharmacists in Paediatric Pharmacy was only 39.5% (n=22) and 43.5% (n=17), respectively. The passing mark for the questionnaire was set to 80%. Thus, the results indicated that most nurses and pharmacists have poor knowledge of the antimicrobial injections stability.

Out of all antimicrobial injections supplied by Paediatric Pharmacy to the ward, 95.8% were supplied in sufficient quantity as two senior pharmacists usually performed counter-checking before the supply process. Oversupply or undersupply still happened in 4.2% of supplies due to inadequate knowledge of the pharmacists on antimicrobial injection stability. Undersupply of vials might affect the injection preparation process and thus contribute to the preparation error. It might cause a single-use injection to be used multiple times due to a shortage of supply.

Strategy

PDSA cycle 1: Our initial intervention was carried out from December 2017 until April 2018. We produced a quick reference pocket guide with the 10 most commonly used antimicrobial injections in the paediatric medical ward, which included information on reconstitution solution, injection stability post reconstitution, and a list of single-use injections. Due to space constraints in the

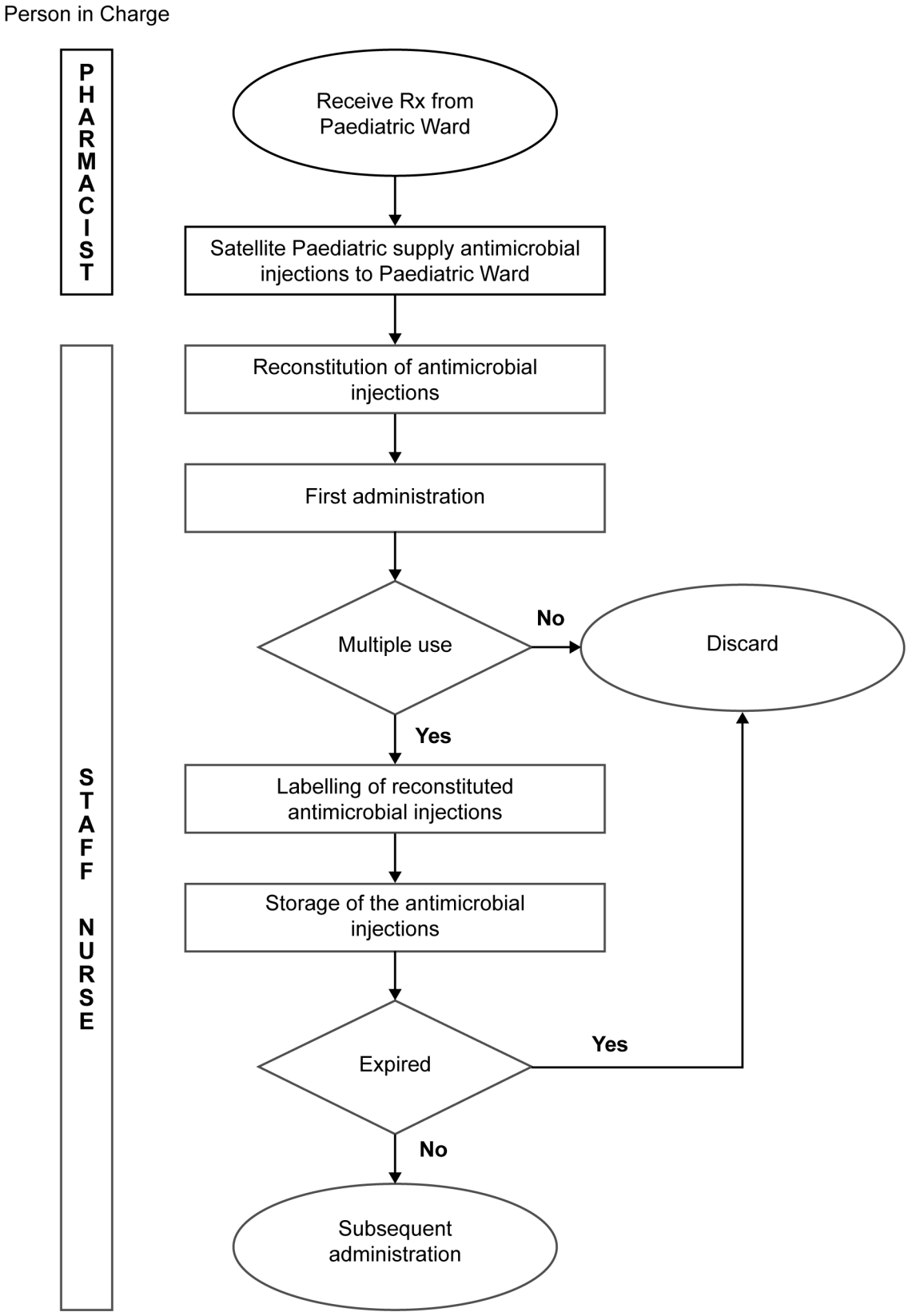

Figure 1: Standard Operating Procedure of supplying and preparation of injection medications for pediatric patients.

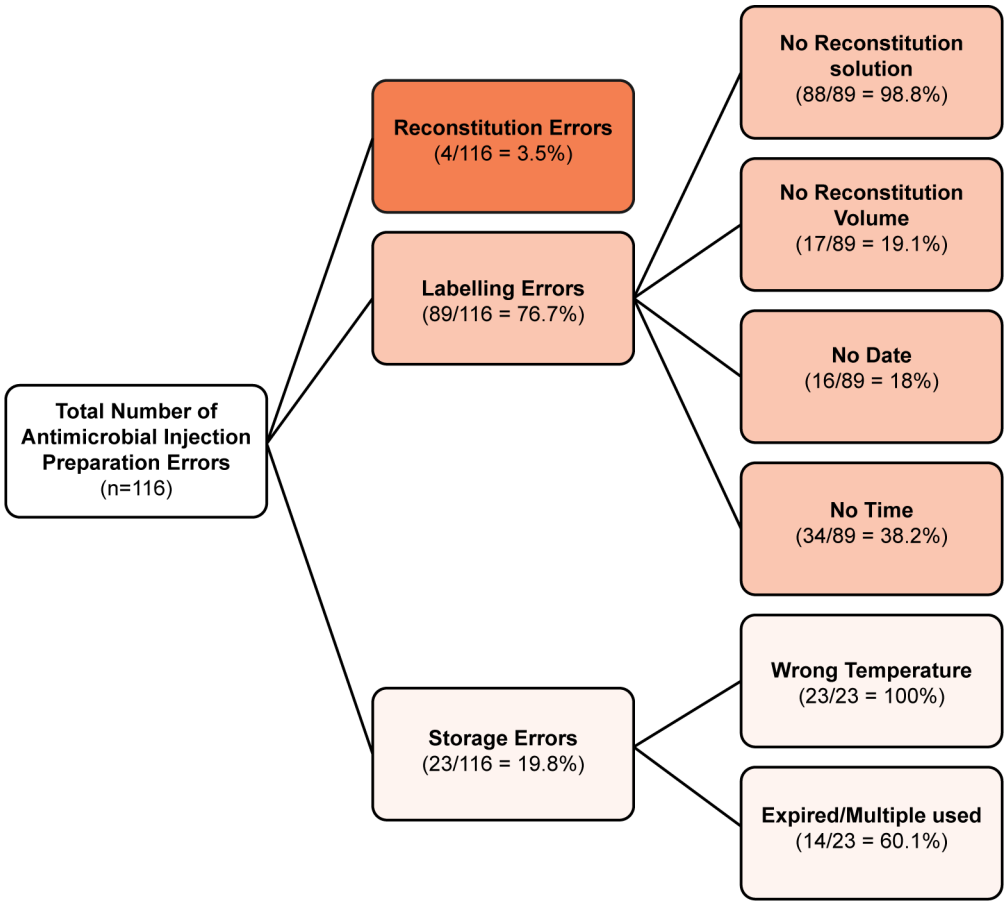

Figure 2: Number of preparation errors detected according to the types of error

pocket guide, flashcards of the antimicrobial injections commonly used in Ward C1 were then created and placed on individual product bins in the pharmacy and medication preparation trolleys in the ward for easy accessibility when supplying and preparing the medication.

In addition, training on injection stability was carried out for staff nurses to emphasise labelling adherence and improve their knowledge on antimicrobial injection reconstitution and stability. All attendees were given a small pocket guide. Some negative feedbacks was received regarding the pocket guide and flashcards, in which they did not include all antimicrobial injections and it was difficult for the staff nurses to memorise all the single-use antimicrobial injections.

A list of "NO ENTRY ITEMS" with images was placed on the fridge in Ward C1 to provide a reminder for nurses before storing the single-use injections or non-fridge injections into the refrigerator. Another training was also given to the pharmacists to increase their awareness on injection stability, which would directly affect the quantity of injections supplied by the pharmacy, especially a sufficient amount of single-use injections. Also, this training would equip pharmacists when they receive drug stability calls from nurses.

PDSA cycle 2: Our second intervention was implemented from December 2018 until April 2019. Antimicrobial Dilution Protocol (Paediatrics) 2019 was formulated to cover all the antimicrobial injections, including all the antimicrobial injections available in HPP, their stability data provided by the drug companies, and the dilution protocols permitted for paediatric used based on several references. In addition, a mnemonic method was introduced to empower the nurses' memory with the list of single-use antimicrobial injections. For example, ReLa4K stands for Reconstitution, Label 4 items and Keep, and MAU FACE stands for metronidazole,

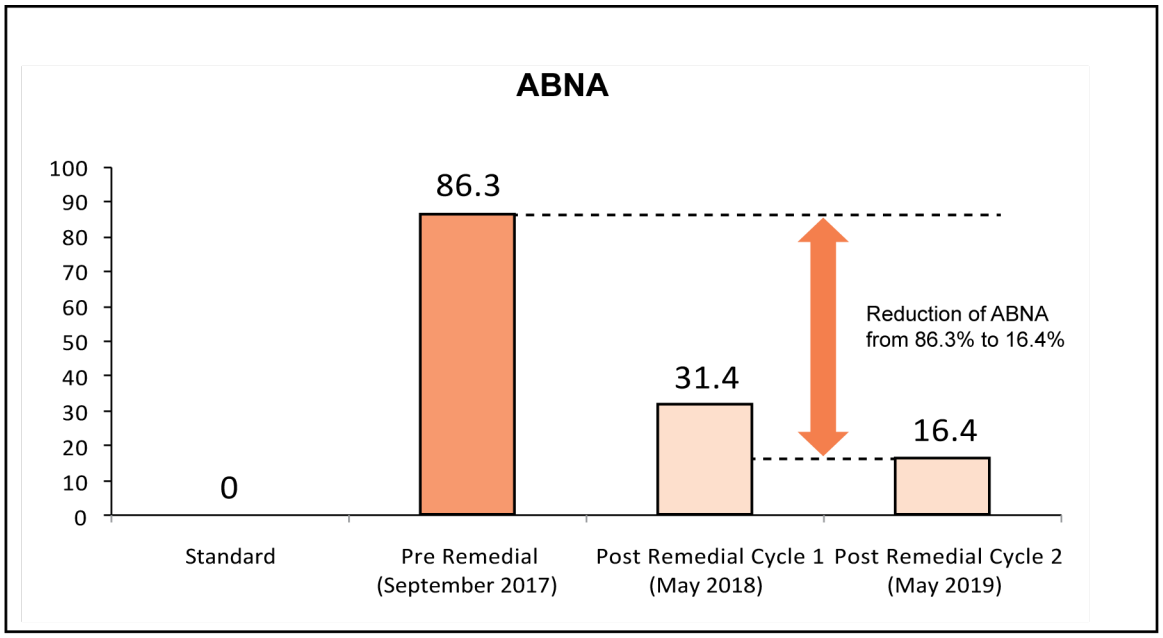

Figure 3: ABNA comparison pre-remedial and post remedial

Augmentin, Unasyn, fluconazole, ampicillin, cloxacillin, erythromycin, which are all single-use injections. After implementing our remedial measures for two cycles, a satisfaction survey on pocket guides, flashcards, and training was conducted among the nurses.

Results

Our main outcome measure on antimicrobial injection vials with preparation error was successfully reduced from 86.3% (September 2017) to 31.4% (first cycle, May 2018) and 16.4% (second cycle, May 2019). The achievable benefit not achieved (ABNA) result is shown in Figure 3.

Besides, the pharmacists' knowledge on the stability of antimicrobial injection improved from 43.5 to 92.9% and 89.3% in the first and second cycles, respectively. The slight drop in knowledge percentage in the second cycle might be due to a high staff turnover rate, which could be improved with continuous training. An improvement in the nurses' knowledge was observed from an average score of 39.5 to 81.4% in the first cycle and 90.9% in the second cycle.

The number of preparation errors detected during the post-remedial showed a reduction in reconstitution errors from 6.9% in the first cycle to 0% in the second cycle. All labelling errors were also reduced from 76.1 to 17.7% (first cycle) and 16.4% (second cycle). However, expired or multiple uses of single-use injections increased from 12% to 14.5% in the first cycle. This might be due to the unawareness of some nurses on the single-use injections. After the mnemonic method was introduced, the second cycle showed multiple uses of single-use injection errors reduced to 1.6% and overall storage errors were reduced from 19.7 to 16.9% (first cycle) to 4.1% (second cycle). Moreover, the average satisfaction score among nurses towards remedial measures implemented was found to be good with 76%.

Lessons and Limitations

The key learning point of this study was to get readily available and accessible information, which could be the success factor in reducing the antimicrobial injection preparation error at a marginal cost of innovation apart from the continuous training.

During the pre-remedial data collection period, 98.8% of labelling errors were due to the reconstitution solution type not being labelled. Without the label, it was hard to check if a correct reconstitution solution was used for each antimicrobial injection. There is a possibility that this might cause the

reconstitution errors to be underestimated.

We acknowledged the limitations of this study. We did not manage to capture all antibiotic reconstitutions conducted in the ward due to the inconsistent drug preparation schedule. The two observers were not available in the wards at all times and could not observe two preparations simultaneously. Therefore, some preparations were missed. The wards were also observed during periods when most medications were prepared and the highest workload for the nurses, which could increase the error rate (14).

One disadvantage of the observation technique was the influence of observer presence on the nurses' behavior (Hawthorne effect) (14). The error rate could increase as an observer's presence would likely cause extra pressure and anxiety among the nurses. The error rate might also decrease in the observer's presence due to the nurses being more cautious during the observation.

Other than that, remedial measures were also done in a short duration and thus, continuous monitoring on the implementation of these remedial measures is necessary to ensure their sustainability. It was also challenging to measure the clinical impact of these interventions on paediatric patients, as it was not seen immediately. A high turnover of staff in both ward and pharmacy departments requires the training on product stability to be done frequently.

Conclusion and the Next Steps

In conclusion, this study had successfully reduced the percentage of antimicrobial injection vials with preparation errors in the Paediatric Ward C1 from 86.3% to 16.4% through remedial actions. This study had also found out that factors such as incomplete labelling and lack of knowledge among staff had led to this error. The implementation of remedial measures such as training, pocket guide, flashcard, NO ENTRY ITEMS on the fridge, mnemonic method, and Antimicrobial Dilution Protocol (Paediatrics) enabled the preparation errors to be reduced. However, continuous work is required to achieve our standard of 0% antimicrobial injection preparation errors. Continuous training on antimicrobial injection preparation and product stability updates will be done frequently for staff nurses, especially for the new staff. Pocket guide, flashcard, and "NO ENTRY" items will be updated periodically and distributed to other paediatric wards as well. An audit will be carried out periodically to ensure that the reconstituted vials are labelled appropriately.

Expanding our study on to other types of injectables could also be done in the future. Another viable strategy of reducing preparation errors is supplying ready-to-use syringes to the ward, which could be included in the future study.

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Conflict of Interest

None.

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Appendix 1

Data Collection Form for Direct Observation and Inspection

No.	Antibiotic Name	Reconstitution		Labelling				Storage	
		Solution & volume		Solution	Volume	Date	Time	Temperature	Expired/ multiple used
1									
2									
3									
4									
5									
6									