Reducing time and potential errors in CPR medications using a CPR calculator in paediatric wards

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Abstract

Background:

The aim is to present an electronic CPR calculator combined with CDSS (clinical decision support system) as a safer and faster method for CPR calculation than manual calculation.

Methods:

A group of 70 nurses were randomly selected to calculate a CPR card and then enter the patient data into the CPR calculator. The time needed to complete the calculations and the time needed to enter patient information into the CPR calculator were measured. In addition, the number of medication calculation errors were recorded.

Result: The time to finish the CPR card manually was 00:08:31 minutes and the time to generate the CPR card electronically was 00:01:15. The number of nurses who made errors in manual calculation was 23, the total number of errors was 101. There were no errors with the calculator.

Conclusion: The CPR calculator has provided an accurate (with no errors) and faster way to generate CPR cards compared to the manual method.

Keywords: Cardiopulmonary resuscitation, medication errors, paediatrics critical care; clinical decision support systems (CDSS); computerised provider order entry (CPOE).

Introduction

The aim of any hospitalisation and medication therapy is the improvement of the patient's life as well as the reduction of the patient's harm. Cardiopulmonary resuscitation (CPR) is defined as 'an emergency procedure that is conducted to save life during a heart attack, which includes breathing for the victim and applying external chest compressions, medications and/or electrical shock (cardioversion) to make the heart pump'. The CPR process is very prone to errors[1,2]. The critical patient's situation does not allow for practitioners to double check doses prior to applying prescriptions. The situation is characterised by a mixture of urgency and psychological stress. Murugan et al.[3] conducted a study that aimed to examine the accuracy of drug preparation and administration during a simulated paediatric CPR. The study demonstrated that the incidence of medication errors was more than 20% in the preparation and administration of drugs.

A medication safety incident is defined by the National Patient Safety Agency (NPSA) as 'any unintended or unexpected incident which could have or did lead to harm for one or more patients'. 'Harm' in the definition implies lack of benefit or treatment failure[4]. Adverse Drug Events (ADEs) cause many complications in the health-care system, including increasing hospital visits, lengthening hospital stays, requiring more effort and time from the healthcare team, slowed treatment processes, serious injuries and rising healthcare expenses, as well as causing death[5]. The cost of solving ADEs is estimated as double the expense of the medication used in disease management. Ernst and Grizzle reported that ADEs cost the USA about $177 billion annually[6] and it was estimated that ADEs are the fourth to sixth most frequent cause of death in United States[7].

Medication errors are one of the leading causes of patients' hospitalisation, particularly children, as they are more vulnerable to ADEs[8]. The most frequent type is prescribing errors, predominantly wrong dosing [9,10].

Larose et al.[11] concluded that generally a clinical aid providing pre-calculated medication doses did not decrease medication errors. However, it increased the confidence of residents for prescribing medications for patients. Previous studies have reported medication error in pediatric resuscitation varying between 10% and 26.5%[12–14]. An observational study showed a potential error rate of 40.8% in prescribing medications[14]. Another study showed that the use of a cognitive aid did not statistically decrease the rate of medication errors. In this study, the attendance of a clinical pharmacist significantly improved the accuracy of prescribed medications. Although the presence of a pharmacist during emergency situations should be strongly encouraged, it is impractical to expect their presence at all times and during emergency situations across all settings[1]. Standardisation and pre-printed prescriptions are a low-cost intervention that has been shown to decrease the risk of errors[13,15,16]. Fineberg and Arendts'[17] study found that a standardised weight-volume–based system was linked with a reduction in medication errors compared with traditional methods during simulated paediatric emergencies.

Using software to support the prescribing of medications is not a new idea[2]. In 2001, the Institute for Safe Medication Practices (ISMP) released guidelines for preventing medication errors in paediatrics[18] that recommended Computerised Provider Order Entry (CPOE) and other technical solutions as tools that could reduce errors that occur during the medication use process. Fortescue et al.[19] suggested a list of potential strategies for reducing medication errors in paediatric patients, and recognised CPOE combined with clinical decision support systems (CDSS) as having great impact on frequency of medication errors. Advantages of the use of CPOE include the removal of illegible or incomplete prescriptions and calculation errors, whereas CDSS assists in checking for patient attributes (allergies, renal function, age, weight) and medication issues such as dose, frequency and route. A systematic review evaluated the applications and implications of CDSS related to medication prescribing and use, and concluded that the CDSS has improved patient safety and outcomes, in addition to increasing workflow efficiency[20].

Musen et al.[21] defined the CDSS as "any computer program designed to help healthcare professionals to make clinical decisions. In a sense, any computer system that deals with clinical data or knowledge is intended to provide decision support. It is accordingly useful to consider three types of decision-support functions, ranging from generalized to patient specific". CDSSs are aimed to support diagnosis and dosing the medications as well as promoting use of best practices[10].

Sankar et al.[22] assessed the effect of a training as a strategy to improve performance of medical residents in prescribing to reduce the medication errors during paediatric CPR. The results showed that the rates of medication errors in paediatric CPR went down with structured training. However, the medication errors were not eliminated completely with only a single training.

The aim of this study is to verify whether a computer-based CPR calculator provides a faster and safer method for CPR calculation than manual calculation. The project was initiated to replace the existing paper-based CPR card with a CPR calculator combined with CDSS.

Materials and methods

Study setting

The study was conducted in paediatric wards in the Prince Sultan Military Medical City (PSMMC), Riyadh, which is one of the leading tertiary hospitals in Saudi Arabia. The pharmacy and nursing departments in PSMMC Riyadh started a project to develop a CPR card software to calculate the CPR medication doses. The objectives of this project are to reduce the chance of medication errors and to reduce the time needed to prepare the CPR card.

As part of admission procedure for each paediatric patient in PSMMC, CPR medications doses are calculated as illustrated in Figure 1. The card requires 25 calculated data entries. The PSMMC CPR committee, which consists of a consultant clinical pharmacist, a consultant intensivist physician and a nurse is responsible for evaluation of all the original medications on the CPR card, including medications and doses. The doses are calculated using the child's weight. The CPR medications chart consists of 14 medications, the cardioversion procedure dose and the length of endotracheal tubes (ETT). The CPR medications chart is calculated manually by one nurse and the results are checked independently by other nurses, then the card is approved by a physician. Even though the process is designed to be robust, it is still highly prone to errors. In addition, it is time-consuming. In Vardi et al. study[23], the doses were calculated by one nurse, another nurse checked the results, and a doctor would confirm the calculation independently. As a result, the errors that were detected were missed by three professionals (by two nurses and a doctor).

The PSMMC CPR card carries the names and doses/kg of the drugs in addition to the strengths of CPR medications. Many factors make paediatrics in a critical care setting more susceptible to ADEs, including the facts that the dosing is weight-based, patients can have significant weight changes, medications dilution, and limited

PAEDIATRIC CPR CARD

Name		Number		Weight	

DRUGS (IV Route)	Concentration	Dose/ kg	Dose ml/kg	Final Dose
Adrenaline 1:10,000	0.1 mg/ml	10mcg/kg	0.1ml x	= mls
Pulseless arrest after 1st dose of Adrenaline				
Adrenaline1:1,000	1mg/ml	100mcg/kg	0.1ml x	= mls Adre
Atropine	600mcg/ml	20mcg/kg	0.03 ml x	= mls Atro
Ca Cl3 10%	100mg/ml	20mg/kg	0.2 ml x	= mls CaCl3
NaHCO3 8.4%	1meq/ ml	1meq/kg	1 ml x	= mlsNaHCO3
Lignocaine 1%	10mg/ml	1mg/kg	0.1ml x	= mls Ligno
Narcan	0.4mg/ml	0.1mg/kg	0.25ml x	= mls Narcan

DRUGS (ET Route)	Concentration	Dose/kg	Dose ml/kg	Final Dose
Adrenaline 1: 1000	1mg/ml	100mcg/kg	0.1ml x	= mls Adre(ET) Dilute in 1-2 mls NaCl
Atropine	600mcg/ml	20mcg/kg	0.03ml x	= mls Atro(ET)
Lignocaine 1%	10mg/ml	1mg/kg	0.1ml x	= mls Ligno(ET) Dilute in 1-2ml NaCl
Narcan	0.4 mg/ml	0.1mg/kg	0.25 ml x	= mls Nar(ET)

DEFIBRILLATION	2 Joules/ kg	2 Joules x	= Joules

INTUBATION Drugs	Concentration	Dose/kg	Dose ml/kg	Final Dose
Morphine	10mg/ ml	0.1mg/ kg	0.01 ml x	= mls MSO4
Suxamethonium	50mg/ml	1mg/kg	0.02ml x	= mls SUX
Atropine	500mcg/ml	10mcg/kg	0.02ml x	= mls Atro
Give; if 2nd dose of Suxamethonium is needed				

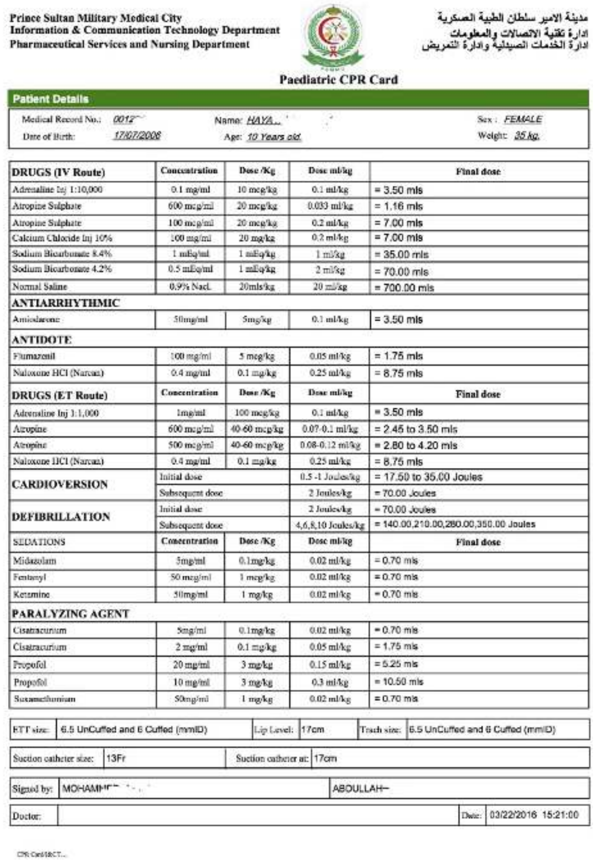
ETT size:		Cut at: cm	Trach size:	
Suction Catheter size :		At: cm		

Signed by:____________ and ____________ DATE ____________

Figure 1. Old CPR form which used to be filed manually.

ability to communicate with patients.[19,24,25]. The calculated doses of the CPR card are considered as 'orders on hold' or 'standing orders' for each patient admitted to the paediatric wards, to be implemented at the time of CPR without any further checking.
A study conducted at King Saud Medical City (KSMMC) Riyadh, Saudi Arabia found that medication errors are less likely to be reported due to fear of punishment[26,27]. Also, ninety percent of KSMMC nursing staff were non-Saudi and because of that they may not know the procedure of reporting medication errors or were fearful[28]. PSMMC adopted the blame-free culture to encourage reporting of errors; the number of reported errors is still very low. Therefore, the task group decided to develop this CPR calculator regardless of the number of reported medication errors. Also, the time needed for completing and printing the CPR card was another main factor.

Patient population
All admitted paediatric patients: the average daily number of admitted paediatric patients is 65 patients, including emergency department.
Design
Experimental prospective cohort study.
Method
From 300 nurses working in PSMMC paediatric wards, a group of 70 nurses were randomly selected from all the paediatric wards, including inpatient wards and emergency department, to calculate a CPR card manually then to enter the patient data into the CPR calculator. Randomisation was carried out by using a computerised randomisation program to select 2 to 3 nurses daily on different areas and times.
The time used to complete the manual calculations of the paper-based CPR card and the time used to finish entering patient information into the CPR calculator were recorded. In addition, the number of medication calculation errors were recorded. The research received approval from the research ethics committee.
Data analysis
Paired sample t-test was used to compare the time used to prepare the CPR card and the errors in the CPR card before and after the implementation of the CPR calculator. In addition, descriptive statistics were generated using Microsoft Excel 2016.
Computer systems
The CPOE/CDSS was developed in two stages: Microsoft Excel spreadsheet and web-based computer programs using a mixture of the HTML and the .NET Framework.
The first stage in calculator development was creating a Microsoft Excel spreadsheet to be used as prototype for the dose calculations. It calculates the 14 medication doses, the cardioversion procedure doses, and the length of ETT. The implementation of the developed spreadsheet aimed to test the concept and process as well as to measure the success of the proposed solution. In addition, it was used as a temporary solution until the calculator is completed. The Excel spreadsheet was deployed in the paediatric section at the emergency department. The first version of the Excel spreadsheet was installed on a personal computer for one month and it experienced many changes based on the feedback of users. Once the nurse enters the patient's weight, doses are instantly calculated and the results presented. A paper copy can be printed out instantly, with all the drug doses as illustrated in Figure 2. As with all such calculators it is vital that the accuracy of weight entry is double-confirmed by a second professional before medication is administered.
The CPR medication doses are fixed according to the patient's weight. However, there is a potential of entering a wrong patient's weight. For that reason, a software that links an average patient's weight based on The World Health Organization (WHO)[29] child growth chart with the patient's age using soft and hard limits for weight was used to minimise potential errors. A team from pharmacy and nursing developed tables for the upper and lower limits of



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ادارة الخدمات الصيدلية وادارة التمريض

Paediatric CPR Card

Patient Details

Medical Record No.: 0012 Name: HAYA... Sex: FEMALE
Date of Birth: 17/07/2006 Age: 10 Years old Weight: 35 kg.

DRUGS (IV Route)	Concentration	Dose /Kg	Dose ml/kg	Final dose
Adrenaline Inj 1:10,000	0.1 mg/ml	10 mcg/kg	0.1 ml/kg	= 3.50 mls
Atropine Sulphate	600 mcg/ml	20 mcg/kg	0.033 ml/kg	= 1.16 mls
Atropine Sulphate	100 mcg/ml	20 mcg/kg	0.2 ml/kg	= 7.00 mls
Calcium Chloride Inj 10%	100 mg/ml	20 mg/kg	0.2 ml/kg	= 7.00 mls
Sodium Bicarbonate 8.4%	1 mEq/ml	1 mEq/kg	1 ml/kg	= 35.00 mls
Sodium Bicarbonate 4.2%	0.5 mEq/ml	1 mEq/kg	2 ml/kg	= 70.00 mls
Normal Saline	0.9% Nacl.	20mls/kg	20 ml/kg	= 700.00 mls
ANTIARRHYTHMIC				
Amiodarone	50mg/ml	5mg/kg	0.1 ml/kg	= 3.50 mls
ANTIDOTE				
Flumazenil	100 mg/ml	5 mcg/kg	0.05 ml/kg	= 1.75 mls
Naloxone HCl (Narcan)	0.4 mg/ml	0.1 mg/kg	0.25 ml/kg	= 8.75 mls
DRUGS (ET Route)	**Concentration**	**Dose /Kg**	**Dose ml/kg**	**Final dose**
Adrenaline Inj 1:1,000	1mg/ml	100 mcg/kg	0.1 ml/kg	= 3.50 mls
Atropine	600 mcg/ml	40-60 mcg/kg	0.07-0.1 ml/kg	= 2.45 to 3.50 mls
Atropine	500 mcg/ml	40-60 mcg/kg	0.08-0.12 ml/kg	= 2.80 to 4.20 mls
Naloxone HCl (Narcan)	0.4 mg/ml	0.1 mg/kg	0.25 ml/kg	= 8.75 mls
CARDIOVERSION	Initial dose		0.5 -1 Joules/kg	= 17.50 to 35.00 Joules
	Subsequent dose		2 Joules/kg	= 70.00 Joules
DEFIBRILLATION	Initial dose		2 Joules/kg	= 70.00 Joules
	Subsequent dose		4,6,8,10 Joules/kg	= 140.00,210.00,280.00,350.00 Joules
SEDATIONS	**Concentration**	**Dose /Kg**	**Dose ml/kg**	**Final dose**
Midazolam	5mg/ml	0.1mg/kg	0.02 ml/kg	= 0.70 mls
Fentanyl	50 mcg/ml	1 mcg/kg	0.02 ml/kg	= 0.70 mls
Ketamine	50mg/ml	1 mg/kg	0.02 ml/kg	= 0.70 mls
PARALYZING AGENT				
Cisatracurium	5mg/ml	0.1mg/kg	0.02 ml/kg	= 0.70 mls
Cisatracurium	2 mg/ml	0.1 mg/kg	0.05 ml/kg	= 1.75 mls
Propofol	20 mg/ml	3 mg/kg	0.15 ml/kg	= 5.25 mls
Propofol	10 mg/ml	3 mg/kg	0.3 ml/kg	= 10.50 mls
Suxamethonium	50mg/ml	1 mg/kg	0.02 ml/kg	= 0.70 mls

ETT size: 6.5 UnCuffed and 6 Cuffed (mmID) Lip Level: 17cm Trach size: 6.5 UnCuffed and 6 Cuffed (mmID)

Suction catheter size: 13Fr Suction catheter at: 17cm

Signed by: MOHAMM... ABDULLAH

Doctor: Date: 03/22/2016 15:21:00

Figure 2. The generated CPR form using the CPR medications software

weight based on the patient's sex; an example of these tables shown in Figure 3. The soft limit will alert the user that he/she exceeds the usual weight for this patient based on the tables and give the user the chance to override the alert. The hard limit will stop and prevent the user from continuing the process once he/she exceeds the hard limit as shown in Figure 4. These improvements were implemented in the second stage.

In the second stage, the CPR calculator was developed on web-based computer programs using a mixture of HTML and .NET. The calculator was uploaded to the hospital intranet and was initially used in one ward before being rolled out to the rest of the hospital. The CPR calculator is designed to present a simple user-friendly web-based interface. The CPR calculator is integrated with the hospital information systems. After entering the patient medical record number, the CPR calculator will retrieve the patient age and gender. These information are used to validate the patient's weight using the aforementioned tables.

Review process

The task group examined the accuracy of calculations and formulas before and after implementation.

Results and Discussion

The study result showed that, using manual calculation, the average time for nurses to complete the calculations was 06:01. The longest time was 11:41 minutes and shortest time was 02:55 minutes. The average time needed to check the CPR calculation was 02:31 minutes. The maximum time was 10:55 minutes and minimum was 00:45 minute. The average total time to calculate and check the CPR card was 08:31 minutes. The longest time was 18:01 minutes and shortest time was 05:02 minutes. With the CPR calculator, the time needed to enter patient's medical number and patient's weight was 01:15 minute whereas the shortest time was 00:35 minute and longest time was 04:58 minutes. Table 1 summarises the study result. The decrease in the time needed for the preparation of the CPR card was significantly reduced compared with manual reports[2,23,30]. Vardi et al.[23] found the time to complete the CPR card dropped from 14:42 minutes to 2:14 minutes. Another study showed a significant time reduction, from 16:47 (range 09:40 to 25:30, standard deviation 04:43) with the manual method and the mean time for the computer model was 05:12 (range 03:40 to 08:45, standard deviation 01:43)[2]. The difference between time needed to complete CPR card manually and time needed to generate the CPR card electronically is statistically significant ($p < 0.05$).

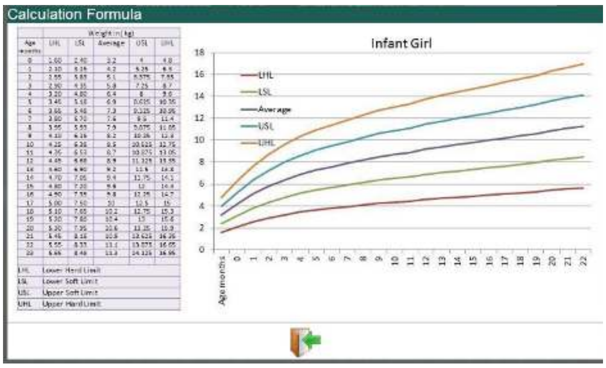

Figure 3. Table of weight and weight validation female less than 24 Month

Table 1. Summary of results

	Calculation	Check	Total Time	Profiling	Manual errors
Total	07:00:36	02:55:43	09:56:19	01:27:48	101
Mean	00:06:01	00:02:31	00:08:31	00:01:15	1.44
Max	00:11:41	00:10:55	00:18:01	00:04:58	17.00
Min	00:02:55	00:00:45	00:05:02	00:00:35	0.00

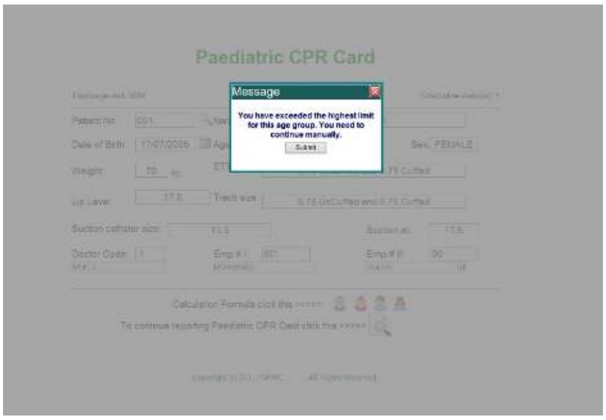

Figure 4. Hard upper limit message

One study showed that all except one subject (20) encountered at least one calculation error[2]. The Vardi et al.[23] study used the reported incidents to measure the incidence of errors. There were three incident reports of errors among 13,124 CPR medication prescriptions in the year prior to the implementation of the system, and no error reports after the implementation of system. Siebert et al. conducted a study to examine the impact of a mobile device app on incidence of medication errors, time to prepare drugs, and time to drug delivery during paediatric CPR, compared to manual preparation methods. Their results showed the medication errors were decreased from 70% to 0% by using mobile device app[31]. Moreover, the time was reduced by 55% when compared with conventional preparation methods[32].

In this study, using the manual CPR card, 23 nurses made errors out of the 70 nurses. A total of 101 errors were recorded from these 23 nurses. The nurse with the maximum number of errors made 17 errors on her form. She used mental calculation without any other aids. With the CPR calculator system, no errors are recorded. In this study, the errors can be classified into overdose and underdose. The causes of these errors are wrong calculations, illegible handwriting, and decimal errors (where the calculations were almost correct except the location of decimal was misplaced), as shown in Table 2. There was no incident of errors that could be linked to the use of the CPR calculator in the PSMMC paediatric wards.
A study demonstrating the use of CPOE during resuscitation in the PICU found no medication errors in the two years post-implementation[11].

Table 2. Calcifications and causes of errors

Cause	Overdose errors	Underdose errors	Total
Wrong calculation	53	40	93
Decimal	2	3	5
Illegible handwriting	2	1	3
Total	57	44	101

Garg et al.[33] performed a systematic literature review of 100 researches to examine the influence of CDSS on practitioner performance. They concluded that CDSS enhanced healthcare quality in 64% of the studies and enhanced patient outcomes in 13% of the studies. A systematic literature review by Kawamoto et al.[34] of 70 studies concluded that CDSS significantly enhances clinical practice in 68% of trials. CDSS minimises practice variation and enhances patient care. In addition, it makes calculations more accurate and faster[2]. Many studies have shown that CDSS can improve physician compliance with hospital policies and reduce cost, and provide better patient care[9,10,35–38].
Advantages of the implementation of CPOE in healthcare settings include elimination of incomplete orders or illegible handwriting, while CDSS helps in removing prescribing errors – e.g. calculation errors, in checking for patient factors (renal function, weight, age, allergies) and medications aspects (frequency, dose, route). CPOE has been recommended as a tool that may eliminate prescribing errors by the Institute of Medicine (IOM), the American Academy of Paediatrics (APP) , Leapfrog Group, ISMP, American Medical Association (AMA), and others[19,38,39].
The CPR calculator has been recommended as a tool that could eliminate errors that happen during the dose calculation, and its use was proposed as a hospital safety measure that results in enhanced performance of care and decrease healthcare costs.

Conclusions

In conclusion, the implementation of the CPR medications calculator offers many advantages which include eliminating medication errors, improving service and response times, enhancing interaction between healthcare professionals, improving patient contact time and increasing productivity as well as efficiency.

Competing interests

None.

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