COMPUTERIZED ORDER ENTRY AND DECISION SUPPORT IN PEDIATRICS

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INTRODUCTION

Iatrogenic injuries are common among hospitalized patients and are frequently preventable.[1-3] The Institute of Medicine (IOM) reported that an estimated 44,000 to 98,000 people die each year in the United States at least in part due to medical error.[4] The accuracy of the IOM study has been questioned by some experts while supported by others, but this controversy does not detract from the fact the injuries due to medical errors are a significant problem.[5, 6] The Harvard Medical Practice Study has shown that many adverse events experienced by patients are due to complications of medication use.[7, 8] Subsequent studies have confirmed that adverse drug events (ADEs) are common, costly and often severe.[9-12]

Although medication errors are common in the inpatient setting in both adults and children, potential harm to children as a result of medication errors may be greater than it is in adults. Low weights, rapid weight changes, requirements for weight-based dosing, concentrated medication formulations, and low infusion rates for intravenous medications are among the factors that contribute to potential medication errors in pediatric patients.

Three strategies, some of which have been shown to be effective in adults, have been suggested for preventing medication errors and adverse drug events in pediatric inpatients: 1. clinical pharmacist presence during work rounds, 2. computerized provider order entry (CPOE) with clinical decision support systems

(CDSS), and 3. improved communication among physicians, nurses and pharmacists.[13-16] The primary purpose of this project is to examine the second strategy , the use of CPOE and CDSS in pediatric inpatients, especially as it pertains to reducing medication errors and the potential adverse events associated with these errors. In addition to reviewing the literature on CPOE, medication safety, and ADEs with an emphasis on pediatrics, the following items will be addressed:

1. A current state workflow analysis of medication ordering in children with a focus on normalized dosing (weight-based and body surface area-based dosing).
2. A future state workflow of medication ordering in children assuming the availability of CPOE and CDSS with automatic normalized dosing.
3. A comparison of the differences between the current state and future state weight-based medication ordering workflows.
4. A comparison of the different strategies for developing medication order sentences for children (weight-based dosing) and adults (standardized dosing).

MEDICATION ERRORS AND ADVERSE DRUG EVENTS

There will be several terms used repeatedly in this paper which should be defined. Medication errors are errors in medication ordering, transcribing, dispensing, administration, or monitoring.[17] An adverse drug event (ADE) is an injury resulting from the administration of a drug. ADEs can be classified by severity into four categories: fatal, life-threatening, serious, and significant. Preventable

ADEs are “preventable” by any means currently available while non-preventable ADEs are not.[18] A potential ADE is a medication error with significant potential for injuring a patient. Intercepted potential ADEs never affect the patient while non-intercepted potential ADEs cause no harm despite not being “caught”.[17] Figure 1 depicts the relationship among medication errors, potential ADEs and ADEs.[18]

PEDIATRICS AND MEDICATION SAFETY

Similar to adult patients, most medication errors in pediatrics occur at the stage of drug ordering.[14, 17, 19] A recent prospective, multicenter study of pediatric medication errors found medication errors occur in about 6% of medication orders, with 55 medication errors per 100 admissions and 157 medication errors per 1000 patient-days. The preventable ADE rate was similar to that found in previous adult studies, but the potential ADE rate was 3 times that seen in adults. Patients in the neonatal intensive care unit (NICU) were more susceptible to potential ADEs. Eighty percent of potential ADEs occurred at the ordering stage, and the most common error was a dosing error.[17] Another recent study evaluating strategies for reducing medication errors and ADEs in pediatric inpatients found dosing errors to be the most common type of medication error in pediatric inpatients, followed by errors in dosing frequency, route of administration order, and order transcription errors.[14]

Dosing in pediatric patients present challenges different from those in adults. Pediatric patients have a wide weight variation necessitating individualized dose calculations. Smaller doses require working with smaller numbers with potentially inherent decimal point errors. Multiple calculations requiring the choice of the correct dosing equation and entry of the correct numbers lead to the risk of 10-fold errors. Small medication doses frequently require dilution of stock medication solutions to provide smaller doses and both the calculation of the dilution and the actual dilution itself can lead to potential errors including 10-fold errors. In addition, wrong dosage equations are frequently chosen by housestaff and presumably attending staff.[20-22] Potential medication errors have been found to be higher in NICU patients, with the more critical patients being at even higher risk.[17, 23] In one study of a pediatric emergency department, 35% of the medication orders were found to have dose errors and 12% of the patients who received erroneous doses required additional treatment . Incorrect recording of the patient weights was a common cause of incorrect medication dosing.[24] In addition to the above mentioned reasons that increase the risk of medication errors occurring in pediatric inpatients, children differ from adults in their epidemiology of reasons for hospitalization, near universal hospitalization for birth, and less ability to "safety check" ones own care.

COMPUTERIZED PHYSICIAN ORDER ENTRY AND CLINICAL DECISION SUPPORT SYSTEMS

Many authors have suggested that CPOE with or without CDSS should be an approach to medication error and ADE reduction and there is now literature to which supports this approach.[2-4, 11, 14, 17, 18, 25-27] CPOE is felt to be a logical intervention to reduce medical errors since most errors occur at the ordering stage. CDSS can reduce the chance of making a medication error by presenting knowledge about drugs, providing pertinent patient information such as allergies at the time of order entry, and decrease errors of omission.

A reduction in serious medication errors and potential ADEs have been demonstrated in adult inpatients where orders were entered by CPOE compared to the traditional method. In this study, the authors found serious medication errors decreased by 55%, preventable ADEs declined 17%, and potential ADEs declined by 84%.[16] Because the traditional medication ordering process is similar in adults and pediatrics, one would expect to see similar if not greater improvement if such a system was implemented in a pediatric inpatient facility. The greater improvement could be seen because of the challenges associated with pediatric medication ordering which can be supported with CPOE, CDSS, and automated drug dosing which will be discussed later in the paper. Up to 76% of potentially harmful medication ordering errors can be prevented in pediatric inpatients by using CPOE with CDSS.[14]

Some components of CPOE with CDSS that may contribute to reducing medication errors include decreasing reliance on memory, simplifying the ordering process by providing predetermined choices and using constraints, standardizing nomenclature and syntax, utilizing protocols and checklists, improving information access, decreasing reliance on vigilance, reducing handoffs, and automating as many steps in the process as possible. Implementation of CPOE with CDSS, guided dosing algorithms, elimination of transcription of orders, standardized prescribing conventions, rules that require adequate information before allowing an order to proceed will enhance patient safety, reduce unnecessary variation, and decrease costs. Continuing to rely on memory-based medication dosing algorithms for pediatric medication dosing allow medically significant and costly errors to continue to be made.[20-23]

Some factors that make children vulnerable to medication errors also complicate the development of CDSS. Pharmacokinetics and appropriate drug doses change rapidly as renal and hepatic elimination systems mature. Dose-range checking has to be sufficiently flexible to be responsive to these changes. Weight-based dosing as well as standardized dosing needs to be implemented for most medications, increasing the complexity of CPOE systems.

MEDICATION ORDERING PROCESSES

Virtually all medication orders are written by physicians and initiate a series of processes. The inpatient medication ordering process involves at least three and usually 4-5 people including the physician, unit secretary, unit and central pharmacists, and a nurse. Figure 2 depicts an example workflow process for a single written medication order. There are approximately 30 process steps. The physician's part of the process, shown at the left side of the Figure 2, appears to be relatively simple because there are only two steps shown, but the figure does not illustrate the decision-making and individual steps that are involved with the writing of a medication order. For example, the ordering physician will probably need to know the patient's current medication profile, allergies, recent laboratory values, weight, height, and perhaps other information from the patient record. In an environment where the patient record is kept on paper, this information will come from disparate sources such as the current inpatient record, the bedside chart, the medication administration record (MAR), the old patient record, and the electronic information systems that might supply laboratory data. The gathering of these information sources and collating of the data is time-consuming and frequently leads to omission of important orders.[26] A detailed workflow analysis of the decisions and steps involving the physician part of the medication ordering process are presented later in the paper.

CPOE with CDSS simplifies the medication ordering process by eliminating communication steps which can lead to errors such as order transcription by a unit secretary. Orders can be transmitted directly to pharmacy and nursing, verified directly by pharmacy, and the system can provide instantaneous feedback to the ordering physician, pharmacist, and nurse. Both the status of a recently written or modified order and the MAR can provide useful information about medication administration. CDSS supports decision-making to all involved clinicians. Figure 3 illustrates the medication order process with CPOE and CDSS. With the institution of CPOE with CDSS, several processes have been eliminated or changed. The unit secretary is no longer involved in the process. The most significant changes that occur in the pharmacy and with nursing is the embedding of CDSS into the process. For example, the medication order verification is now supported by the same decision support that was in place when the physician wrote the order. Real-time information is provided to nursing regarding the status of the order from pharmacy so the nurse can see the instant the pharmacist has verified the order. Multiple efficiencies are gained.

AUTOMATIC NORMALIZED MEDICATION DOSING

Normalized dosing refers to medication dosing based on a patient's weight or body surface area (BSA), while standardized dosing refers to the ordering and administration of standard doses. Normalized doses require a series of calculations to determine the final dose while standardized dosing does not. The need to calculate a final dose makes normalized dosing more prone to error than standardized dosing. Examples of normalized and standardized dosing are shown in the Table 1.

TABLE 1: EXAMPLES OF NORMALIZED AND STANDARDIZED DOSING*

WEIGHT-BASED	BSA-BASED	STANDARD
Ampicillin 50mg/kg IV q6h = Ampicillin 600mg IV q6h	Vincristine 1mg/m^2 IV= Vincristine 0.54mg IV	Ranitidine 50mg IV q12h
Digoxin 5mcg/kg PO bid = Digoxin 60mcg PO bid	Adriamycin 60mg/m2 IV = Adriamycin 32.4mg IV	Digoxin 0.125mg PO qd
Ranitidine 2mg/kg PO bid = Ranitidine 24mg PO bid	Cytoxan 600mg/m^2 IV = Cytoxan 324mg IV	Gentamicin 80mg IV q8h

*Based on patient weight 12kg, height 86cm, BSA 0.54 m^2; doses are <u>not</u> rounded

Since most medication errors are made at the time the order is written, CPOE provides the opportunity to decrease the chance for errors during medication ordering. This is especially true in pediatrics where normalized dosing is common and automatic weight-based dosing can be accomplished with CPOE and CDSS.[14, 17]

As noted earlier, dosing in pediatric patients present challenges different from those in adults. Other than the wide weight variations seen in pediatric patients, multiple calculations are required by both the ordering physician, the pharmacist, and the nurse during the medication ordering, dispensing, and administration process.

Most of these calculations are performed manually and require the user to manually transcribe a series of numbers into an equation, assuming the correct equation has been chosen. Incorrect dosage equations are frequently chosen and deficiencies in dosage calculation are not uncommon.[20-22] Manual ordering of weight-based medications is a complicated and error prone process. Ten-fold dosing errors are a problem in pediatrics, and the complicated manual process contributes to the possibility of making these errors.[24, 28-30]

Figure 4 illustrates the details of the manual weight-based ordering process and Figure 5 illustrates the details of the automatic weight-based ordering process for an inpatient assuming the CPOE and CDSS have been implemented. Figures 4 and 5 are derived from original work performed by the author. The steps in these workflow diagrams were determined by observations of multiple resident and attending staff at multiple institutions during the medication ordering process. In addition, the author based many of the workflow steps from personal experiences as an attending pediatrician. Although the order of the steps may vary somewhat, all of the steps shown are required to determine the final dose. Figures 4 and 5 focus on the "Physician" lane illustrated on the left side of Figures 2 and 3. The remainder of the medication ordering process involving the unit secretary, pharmacist(s), and nurse were not examined in detail for this project. Figures 2 and 3 illustrate the steps in the process that involve these other personnel. Briefly, after the handwritten order is placed on the counter or chart rack, the order is subjected to transcription by a unit secretary, manual entry into a pharmacy information system by a pharmacist or pharmacy technician, dispensing the medication which may require dilution from the stock solution, and administration of the medication by a nurse which may require small volumes.

The manual dose ordering process for weight-based medication dosing relies on memory-based decision support, transcription of numbers into a manual calculator, manual calculation of a dose, a decision about whether the calculated dose needs to be further divided based on the dosing frequency, and finally writing of the calculated dose as a handwritten order. This process is described in detail below.

In addition to the above mentioned problems with this process, the correct dosing weight must be used to calculate the medication dose. Pediatric inpatients typically have a daily weight obtained and recorded on the medical chart. These weights are likely to vary from day-to-day with normal variations in patient weight and measurement error. The ordering physician must decide which weight to use to calculate medication doses, a process which is usually not defined, somewhat arbitrary, and is likely to be inconsistent. This problem will be most pronounced in smaller children, especially premature babies, whose weights can vary significantly based on a percent change from baseline. Defining a dosing weight is frequently based on clinical experience. In the manual medication ordering process, the dosing weight is usually determined at the time of the order writing and may change with each new ordering physician's assessment of the weights on the patient record. The arbitrary process of determining dosing weight leads to unnecessary variation and potential errors in medication ordering and dosing.

Figure 4 illustrates two manual processes involved with calculating and ordering a medication based on a patient's weight or BSA that take place in parallel but overlap during the ordering process: 1. Obtaining information from the *patient record* and, 2. Accessing *drug reference information*. Information from these two processes are combined in order to produce the medication order. The following outline describes the process steps in Figure 4 and uses the same medication order example as shown in the figure: Ampicillin, weight-based dose (200mg/kg/day), weight (4kg), and frequency (q6h).

1. Information from patient paper record – the following items are obtained from multiple sources including the current inpatient chart, the bedside or nursing chart, the medication chart with the MAR which may be separate from the other parts of the current inpatient record, and finally the past paper record covering previous encounters.
    a. Allergy profile
    b. Past medical history
    c. “Dosing” weight (an important concept in weight-based dosing discussed in detail below in the description of Figure 5)
2. Drug reference information – these items are obtained from memory and printed and/or online information sources.
    a. Choice of the “best” medication – Ampicillin (most appropriate based on the patient’s current working diagnosis and information obtained from the patient record; e.g., not a medication to which the patient is allergic)
    b. Medication dose -- 200mg/kg/day, frequency – q6h , route – IV

3. Weight and/or Height (height would be required as well as weight for BSA-based dosing; weight-based dosing is used in this example)
    a. The correct weight for dosing the medication must be determined from existing data – 4kg
    b. If no dosing weight exists, it must be determined either by weighing the patient or from the patient record.
4. Dosing equation
    a. Choice of the correct dosing equation – (weight x weight-based dose)
    b. Use of the dosing weight in the dosing equation
    c. Choice of the correct equation the mathematical skills to correctly calculate the dose have been shown to be sources of medication ordering errors[20-22]
5. Manual calculator
    a. Enter dosing equation
    b. Enter dosing weight
    c. Enter weight-based dose
    d. Calculate "dose" – 200mg/kg/day x 4kg = 800mg/day
    e. Determine frequency
    f. If calculated dose is daily:
        i. Divide by correct number – in this case the frequency is q6h so divide by "4" to calculate correct divided dose – 800mg/4 = 200mg

ii. Determining number by which to divide is memory-based

g. If calculated dose is divided:

i. No need to divide

6. Write final medication order

a. Transcribe dose from calculator or paper worksheet to order sheet

b. Include correct frequency

c. Include correct medication administration route

These steps involve the use of a manual calculator. Each step of the manual calculation weight-based medication ordering process is prone to error because all pertinent data such as patient weight and weight-based dose must be obtained from a source not connected to the calculator then manually entered by the user in to the calculator.

In a system where CPOE and CDSS have been implemented, memory-based drug reference information can be eliminated because the system provides the ordering physician with the "best" choices for medication, drug dose, frequency and route. These best choices have been determined by best evidence, common practice, published practice guidelines, and local expertise. The system now provides the dosing weight used for weight-based medication dosing and automatically calculates the correct dose, eliminating the need to transcribe the weight and weight-based dose into a manual calculator and then perform the correct mathematical operations to calculate the medication dose. The dosing weight, dosing equations, weight-based dose, and all necessary mathematical calculations on these data are performed automatically which provides a safe and consistent process for normalized medication dosing.

As noted above in the description of the manual dosing process, the correct dosing weight must be used to calculate the medication dose. In the manual medication ordering process, the dosing weight is usually determined at the time of the order writing, may vary from provider to provider, and is not determined by any systematic process. In the automatic medication ordering process, rules in a CDSS can prevent the physician from ordering a medication if the record does not have a recent dosing weight. For example, if there is no dosing weight, one must be entered before a medication can be ordered. If there is a dosing weight but it falls out of the time range for a "recent" dosing weight specified by the CDSS, a new dosing weight must be entered. For example, a dosing weight for a child less than six months of age must have been obtained no more than 14 days ago or the ordering physician will be notified and asked to update the dosing weight. Unlike in the manual dosing process, a systematic method exists with automatic weight-based dosing and a CDSS to ensure that a recent dosing weight exists before a medication can be ordered.

Figure 5 illustrates the weight-based medication ordering process in a system with CPOE and CDSS. As with the manual process shown in Figure 4, the automatic process involves the use of drug reference information in parallel with clinical information, but this information is provided automatically without the need for manual transcription or manual calculation. The following outline describes the process steps in Figure 5 and uses the same medication order example as in the figure: Ampicillin, weight-based dose (50mg/kg), weight (4kg), and frequency (q6h).

1. Patient information from electronic medical record (EMR) – the following items are obtained automatically and may include information from the current and past encounter(s). This is important because information required to make a decision may only be available in records from previous encounters and this information is immediately available for decision making in an EMR.
    a. Allergy profile
    b. Past medical history
    c. "Dosing" weight
2. Drug reference information – the following items are obtained from the CDSS.
    a. Choice of the "best" medication – Ampicillin (most appropriate based on the patient's current working diagnosis and information obtained from the patient record; e.g., not a medication to which the patient is allergic)
    b. Medication dose -- 50mg/kg, frequency – q6h , route – IV
3. Dosing weight and/or height (height would be required as well as weight for BSA-based dosing; weight-based dosing is used in this example)
    a. The correct dosing weight is available from the EMR and is automatically chosen by the CDSS for the medication order – 4kg
    b. The CDSS enforces the availability of a recent dosing weight
4. Automatic calculator

a. The correct dosing equation is *automatically* chosen by the CDSS – (weight x weight-based dose)
b. The correct dosing weight is *automatically* used in the dosing equation
c. The correct weight-based dose is *automatically* used in the dosing equation – 50mg/kg
d. The correct dose is *automatically* calculated – 50mg/kg x 4kg = 200mg
e. The correct dosing frequency is *automatically* used to complete the order
f. With CPOE and CDSS, each of the above steps (a-e) is performed without the need for user input and are performed in a single step
g. Without CPOE and CDSS, the above steps are performed individually and require manual input of data and calculation by the user

5. The final medication order is automatically written – Ampicillin 200mg IV q6h

In this process, drug dosing information is standardized so that the "best" choices as determined by best evidence, common practice, and local expertise for dose, dose unit, route, and frequency are presented to the ordering physician. In the example from Figure 5, "Ampicillin, 50mg/kg, IV, q6h" is chosen and the automatic dosing calculation function is invoked without user input other than the choice of a weight-based dose. With CPOE and CDSS, information that guides the user to the best choice or choices can be provided in the design of the electronic order and order sentences such as "Moderately severe infection" or "Suggested IV loading dose".

Examples of how order sentences can be best designed will be provided in the next section on *Medication Order Sentence Design*. When an order sentence is chosen, the automatic dosing calculation function is invoked and the patient's weight, medication name, dose, and dose unit are automatically used. The dose is calculated and the correct order is placed in the CPOE system. Since most medication errors are made at the ordering stage, the automated method presented in Figure 5 can potentially reduce a significant number of incorrect medication orders.

The need for an automatic dose calculation function is less important when ordering standardized doses because choosing the correct dosing equations, entering order sentence details, and calculating a dose are not necessary. Nevertheless, with correct order sentence design and well designed CDSS, CPOE can provide standardized doses for the best medications as determined by evidence, practice guidelines, common practice, and local expertise. Such a system decreases medication errors.[15, 16, 26, 27] As discussed previously, the manual and automatic medication ordering process workflows shown in Figures 4 and 5 and discussed in detail above are the original work of the author and are used as the basis for the comparison between the manual and CPOE/CDSS supported weight-based medication ordering.

MEDICATION ORDER SENTENCE DESIGN

In CPOE systems, there are different designs of medication orderables, order sentences and order details. Orderables, order sentences, and order details may overlap, but with correct design the user can be quickly provided with their order of choice.

Orderables are the highest level of items from which a CPOE user can choose. All items in a system's order catalog are available in the orderables list which might contain thousands of items. Examples of orderables are "CBC", "CT Head", "Ampicillin", "Post Myocardial Infarction Orderset", to name a few.

Order sentences contain more details about the orderable and may allow the user to choose one from several choices. From the examples given above, order sentences associated with "CT Head" could be "CT Head w/contrast", "CT Head w/o contrast", and "CT Head r/o Head Injury". For ampicillin, order sentences could be "Ampicillin 25mg/kg, IV, q6h", "Ampicillin 50mg/kg. IV, q6h", and "Ampicillin 500mg, IV, q6h".

Order details further define each order with details such as Priority: Routine or Stat, comments, and further details that may be required such as Reason for Exam.

TABLE 2: ORDERABLES, ORDER SENTENCES, AND ORDER DETAILS

ORDERABLE	ORDER SENTENCES	ORDER DETAILS
Ampicillin	1. 25mg/kg, IV, q6h 2. 50mg/kg, IV, q6h 3. 75mg/kg, IV, q6h 4. 250mg, IV, q8h 5. 500mg, IV, q8h 6. 1,000mg, IV, q8h	*Priority*: STAT or Routine *Comment*: First dose now *Route**: IV, PO, IM *Frequency**: q4h, q6h, q8h, BID, TID, QID *These details allow the user to modify the original order
Digoxin	1. 5mcg/kg, PO, q12h, oral maintenance dose 2. 30mcg/kg, PO, q12h, oral loading dose 3. 20mcg/kg, IV, q12h, IV loading dose	

During the design phase of CPOE, the orderables, associated order sentences and associated order details for each sentence are determined and built into the system. For pediatric drug dosing, designing the order sentences to provide all of the important information for the user to make a correct decision about the medication and dose is critical to the success of the system. Table 2 provides examples of medication orderables with associated order sentences and order details.

The concept of orderables, order sentences, and order details are common in CPOE systems. The exact separation of information into this hierarchy is determined both by the CPOE system and design preferences of the CPOE site, so there is no standard or correct method for designing orders in a CPOE system. Figure 6 provides an example of how orderables, order sentences and order details are presented to the ordering physician in a CPOE system using the same example (Ampicillin 50mg/kg IV q6h in a patient who weighs 4kg) that was presented in the manual and automatic weight-based medication ordering workflows (Figures 4 and 5).

- Step 1: the orderable "Ampicillin" is chosen from the order medication catalog in the CPOE system.
- Step 2: after choosing ampicillin, the ordering physician is presented with a series of order sentences. In this example, the ampicillin order sentences include both weight-based dosing sentences (e.g., 50mg/kg, IV, q6h) and standardized order sentences (e.g., 500mg, IV, q6h). In addition to the basic information provided in the order sentence (medication, dose, route, and frequency), more information can be provided that helps guide the decision as to which order sentence to choose. Information provided here can include

indications, recommendations, and age or weight ranges. In this example, the ordering physician chooses 50mg/kg, IV, q6h and additional information is provided to guide the choice, "Recommended dose for > 30 days old".

- Step 3: the dosing calculation function is invoked automatically when a weight-based dosing sentence is chosen and then calculates the dose based on the order sentence information and the patient weight. Assuming the dose from the calculator is accepted, the ordering physician is then presented with further order details.
- Step 4: further order details for the dosing frequency is shown and the ordering physician can change the frequency if desired. In many cases, the required order details are already complete and no further input is required other than to accept and sign the order.
- Step 5: the completed order is presented for final review and signature.

The design of orderables and order sentences will differ for standardized and weight-based dosing. In the example shown in Figure 6, both standardized and weight-based dosing choices are presented to the ordering physician under a single orderable, "Ampicillin". An alternative design would be to separate the order sentences at the orderable level so the user can choose the orderable that has only standardized doses or weight-based doses, but not both. This separation is important from a patient safety standpoint because there is less confusion if the ordering physician is presented with a consistent set of order sentences from which to choose. But a potential problem with this design approach is that there will be a larger number of orderables from which to choose. The design approach taken will depend on the type of inpatients cared for, and physician, pharmacy and nursing considerations such as formulary and medication administration processes. Table 3 provides an example of this second approach to designing orderables and order sentences for where the system separates the standardized and weight-based order sentences are under different orderables.

TABLE 3: SEPARATING STANDARDIZED AND WEIGHT-BASED ORDERING SENTENCES	
ORDERABLE	**ORDER SENTENCES**
Ampicillin, Standard	1. 500mg, IV, q6h 2. 750mg, IV, q6h 3. 1,000mg, IV, q6h 4. 1.5gm, IV, q6h 5. 2.0gm, IV, q6h
Ampicillin, Pediatric	1. 25mg/kg, IV, q6h (Mild infection) 2. 50mg/kg, IV, q6h (Moderate infection) 3. 75mg/kg, IV, q6h (Severe infection)

SUMMARY AND CONCLUSIONS

Medication errors and associated ADEs have been associated with increased costs and injury to patients.[9, 12] The use of CPOE has been advocated as a method to decrease medical errors and ADEs.[4, 14] Pediatric inpatients are particular susceptible to medication errors because of a wide range of weights, frequent weight changes, small weights which require small doses, dilution of stock medication solutions, and administration of small volumes. Calculation of the correct weight-based dose is prone to errors and requires the correct choice of a dosing equation and manual calculation of the correct dose. Automating the process with CPOE, CDSS, and providing an automated weight-based dosing function standardizes and simplifies the process making it less error-prone since most medication errors are made at the time a medication is ordered.

Reduction of medical errors has become a priority among government and regulatory agencies, and healthcare payers and providers.[4] The manual paper medication order process without CPOE or CDSS requires input from multiple people including a physician, unit clerk, pharmacist, and nurse. One of the goals of this project was to describe and compare, in detail, the manual and automatic weight-based medication ordering process workflows of the physician. Step-by-step workflow diagrams (Figures 4 and 5) were developed as original work and detailed descriptions of the physician workflows were provided in this paper. The workflows focus on processes that are more common in pediatric than adult medicine, namely weight-based medication ordering. Nevertheless, these workflow analyses provide useful information as current state and future state workflows allowing an institution who is considering CPOE to understand their current medication ordering processes and how these processes will change with CPOE and CDSS. Instead of attempting to take current medication ordering processes and use them in CPOE system, the opportunity to examine current state processes in detail and improve on those areas that have been problematic now exists.

In addition to automating the weight-based medication ordering process by providing an automated dose calculation function, there are special design considerations for orderables and order sentences for a CPOE system used in pediatrics. The system should lead the ordering physician to an appropriate choice or set of choices which provide the correct weight-based dose, route, frequency, and other information so the user can make an informed decision. Although there are no standards for designing CPOE medication orderables for pediatrics, two design approaches that would support safe weight-based medication ordering were discussed. It is important to realize that CPOE design approaches that work well in one institution may not work well in another. The design must be individualized and based on current workflow processes, the physician population (e.g., housestaff, attending staff, hospitalists), the patient population (e.g., mixed pediatric and adult population, pediatrics only, adults only), pharmacy procedures, formulary, and numerous other considerations.

One of the primary goals of all institutions involved in the care of patients is patient safety. Since most medication errors are made at the time of the medication order and pediatric patients are more susceptible to potential errors, addressing the problems associated with weight-based medication ordering process is critical to addressing the safety of pediatric patients.[14,17-18] The problems associated with weight-based medication dosing were examined and discussed in detail. Providing an automated method of calculating a weight-based dose and providing the ordering physician with appropriate medication orders from which to choose are two critical areas that can be supported by CPOE with CDSS. Any institution considering CPOE with CDSS where children are cared for can improve the process of weight-based medication ordering and support their patient safety initiatives with proper design and implementation of the system with appropriate planning and design.

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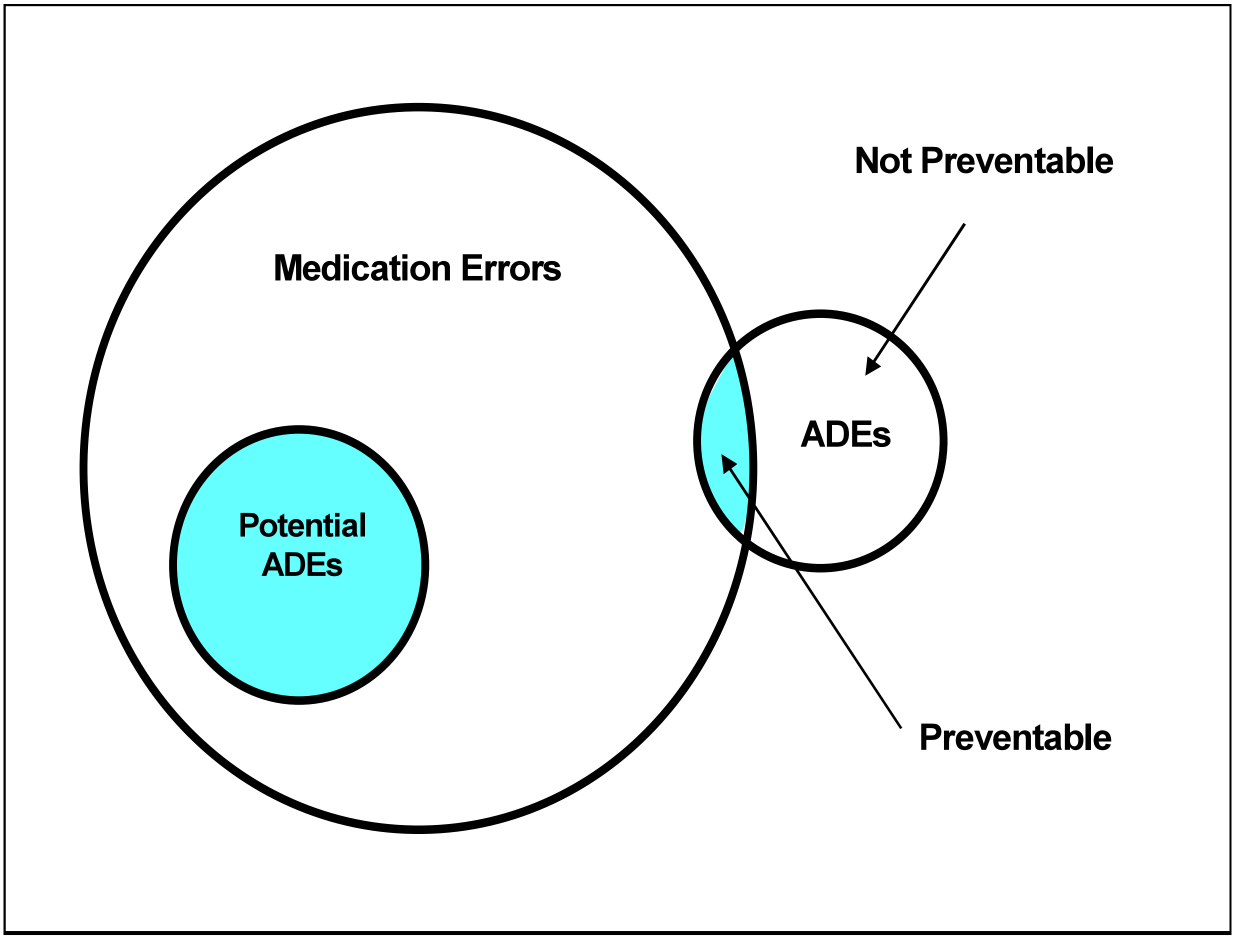

Figure 1. The Relationship Among Medication Errors, Potential ADEs and ADEs[18]

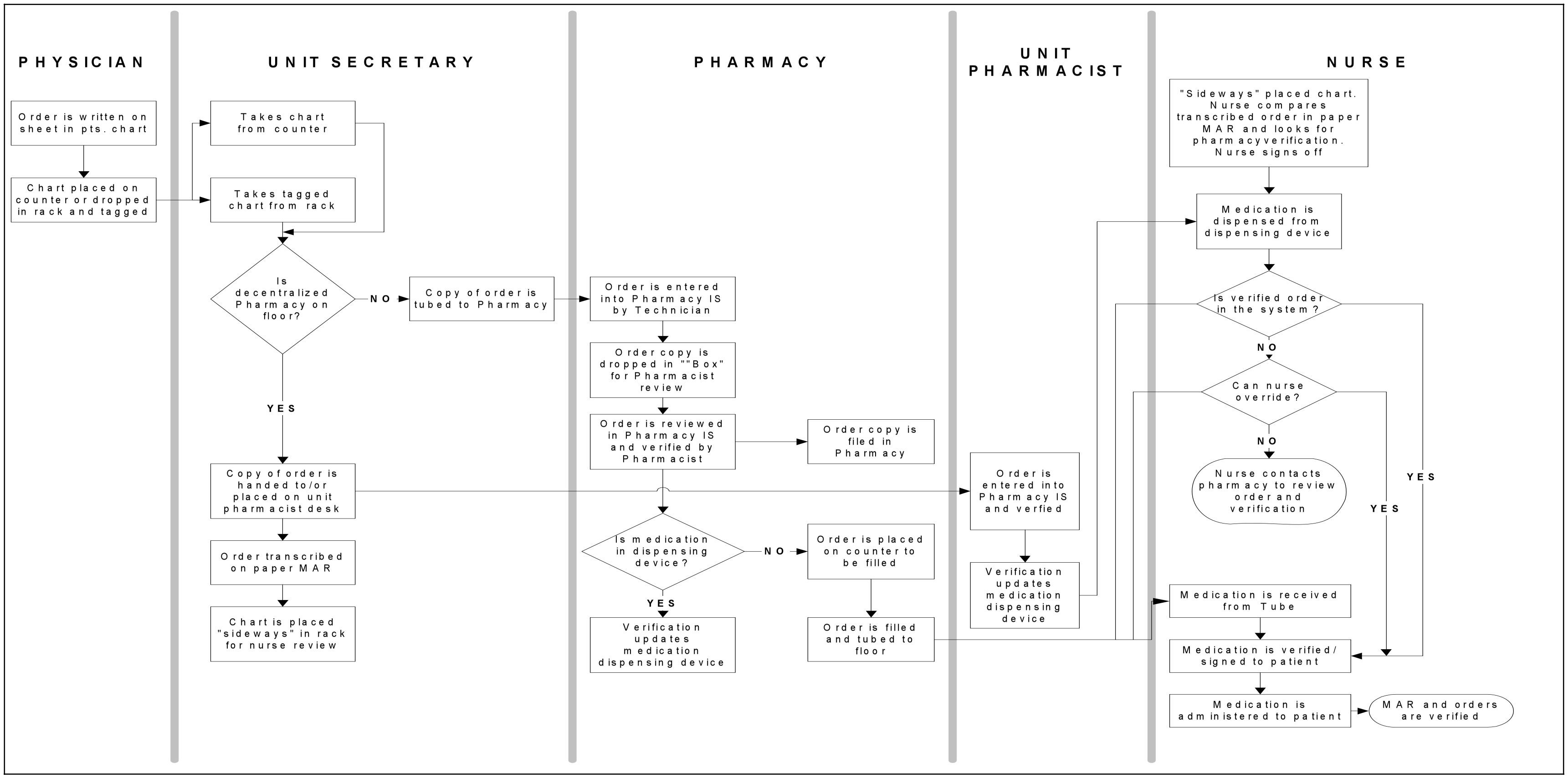

Figure 2. Workflow for Paper-based Medication Ordering
(Adapted from Medication Ordering Process Evaluation, Cerner Corporation)

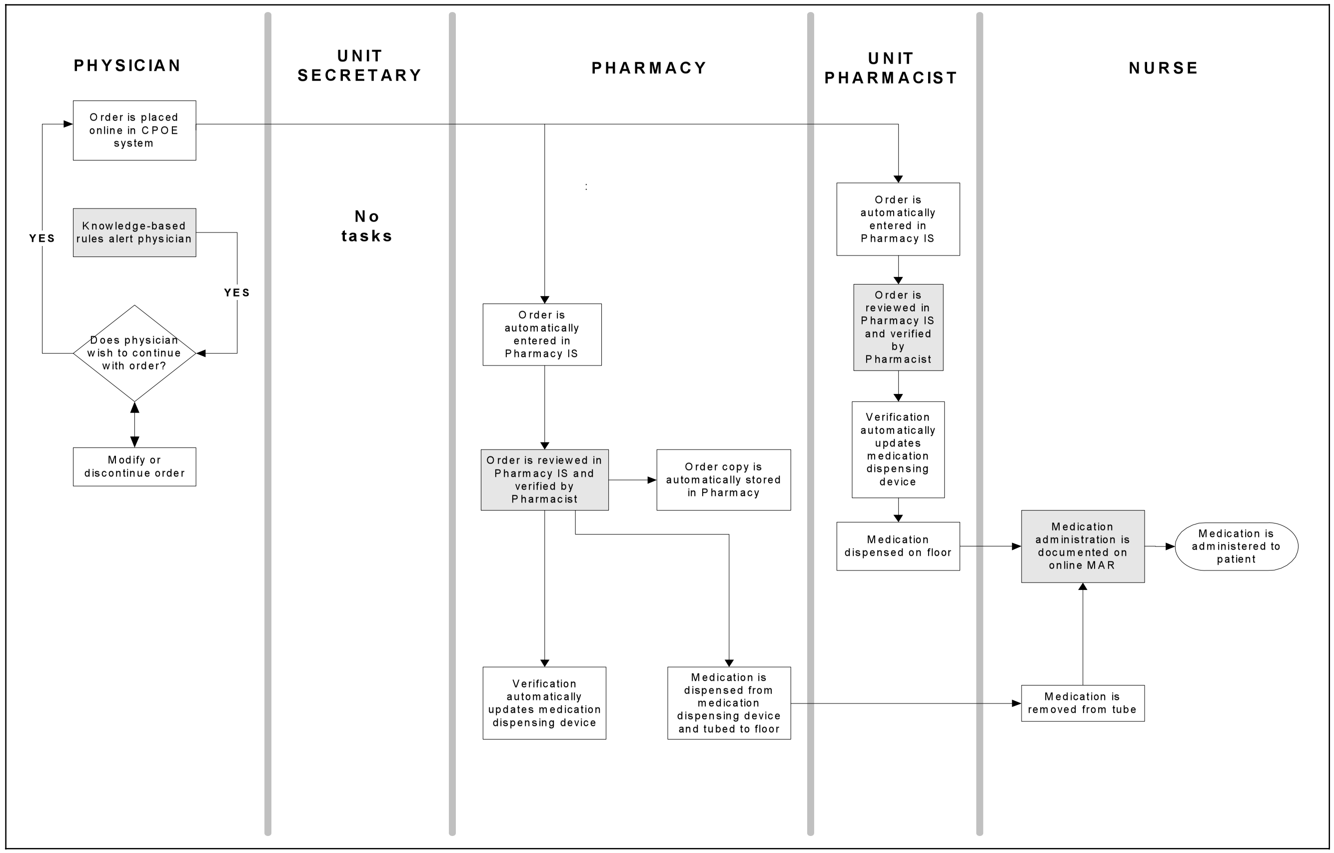

Figure 3. Simplified workflow with CPOE
(gray boxes indicate steps where CDSS can be instituted)
(Adapted from Medication Ordering Process Evaluation, Cerner Corporation)

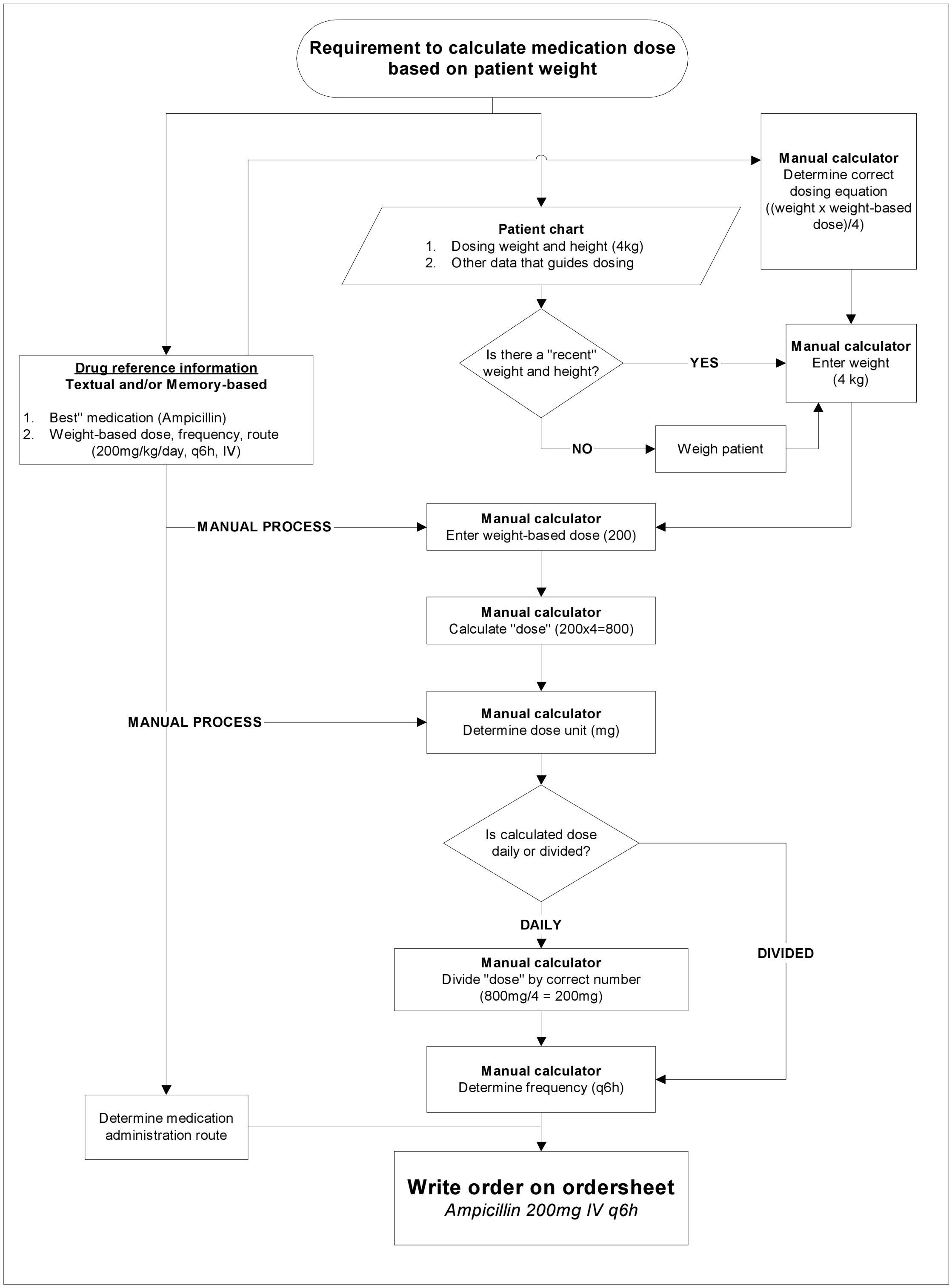

Figure 4. Detailed Order Process for Manual Weight-Based Dosing

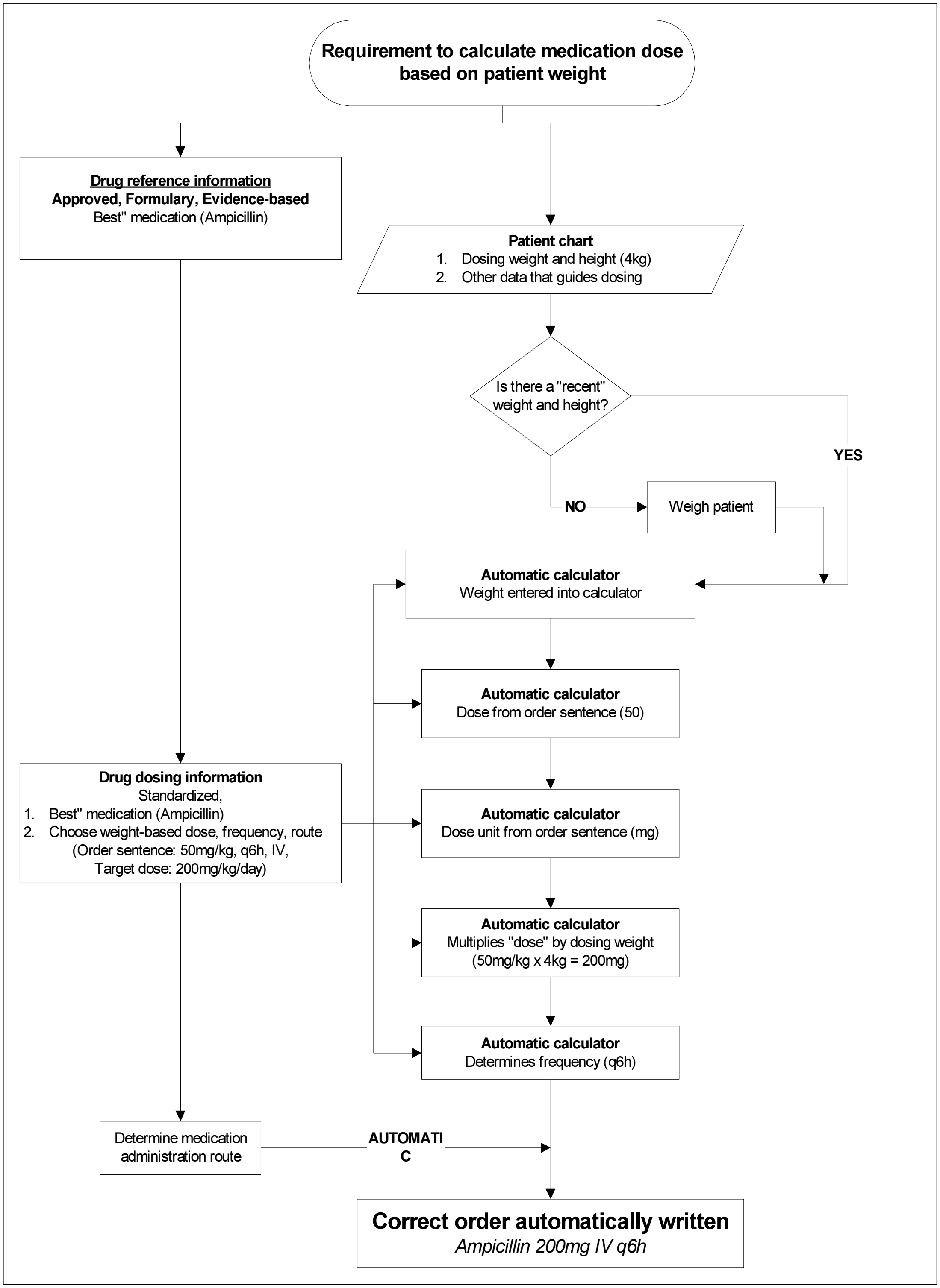

Figure 5. Detailed Order Process for Automatic Weight-Based Dosing

Step 1: Ampicillin is chosen from order catalog	
ORDERABLE	Ampicillin

Step 2: Order sentences for ampicillin
25mg/kg, IV, q12h, Recommended dose for: < 7 days old
25mg/kg, IV, q8h, Recommended dose for: 7-30 days old
50mg/kg, IV, q6h, Recommended dose for: > 30 days old
75mg/kg, IV, q6h, Severe infection
250mg, IV, q6h
500mg, IV, q6h
500mg, IV, q12h
1,000mg, IV, q6h
2,000mg, IV, q8h
2,000mg, IV, q6h

Step 3: Automatic dose calculator calculates dose
50mg/kg x 4kg = 200mg

Step 4: Order details for ampicillin 200mg IV q6h	
Order Details	Detail Values (Frequency)
Dose (200)	q2h
Dose Unit (mg)	q4h
Route of administration (IV)	*q6h*
Frequency (q6h)	q8h
First dose (05/14/2003,1100am)	q12h

Step 5: Final order presented for review and signature
Ampicillin 200mg IV q6h, First dose: 04/14/2003 1100am

FIGURE 6. Presentation of Orderables, Order Sentences, and Order Details
(Items highlighted in Turquoise are chosen by the ordering physician)