

The pros and cons of electronic prescribing for children

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ABSTRACT

The move from paper to electronic prescribing (EP) and medicine administration systems has long been advocated. Initial studies in the adult setting showed a significant reduction in medication errors. However, there are additional challenges to overcome to tailor these systems to paediatrics. Building on the basic elements of EP with the development of customised paediatric clinical decision support seems to offer the most benefit in terms of error reduction and increasing clinical effectiveness. Continued research is required to optimise these systems and minimise any unintended consequences at all stages of the medication use process.

INTRODUCTION

Medication prescribed safely, effectively and appropriately, with regimens designed around the expressed needs of each child and individually tailored to their hopes and desires, is a recurrent theme in healthcare plans. Many have suggested that electronic prescribing (EP) will improve healthcare and reduce risk.

"He wrote in a doctor's hand – the hand which, from the beginning of time, has been so disastrous to the apothecary and so profitable to the undertaker."

Mark Twain

Was Mark Twain hypothesising that prescribing in the future must be electronic?

The Institute of Medicine recommended that handwritten orders should be replaced with automated systems by 2010.¹ However, by 2008 only 17% of US hospitals had EP.² Capital requirements and high maintenance costs were the primary barriers to implementation. The situation in Europe is no different.

Successful implementation of EP is not straightforward and requires a paradigm shift in hospital policies and processes.³ This may explain why many hospitals still use paper prescriptions. Sometime soon, however, we will experience a sea change, similar in scale to that seen when paper prescription charts were introduced 50 years ago.

The authors have many years experience of EP in a district general hospital. They combine practical insight with published reports and outline the pluses and minuses of EP for children.

WHAT IS EP?

EP is about communication and is much more than just prescribing since it also encompasses medicine supply, administration and audit. Connecting for Health usefully defined EP as,

"The utilisation of electronic systems to facilitate and enhance the communication of a prescription or medicine order, aiding the choice, administration and supply of a medicine through knowledge and decision support and providing a robust audit trail for the entire medicines use process".⁴ Much literature refers to computerised provider order entry which can include orders for items other than medicines. However, we focus on medicines in this review. Clinical decision support (CDS) is used in EP to guide clinicians to select correct orders for an individual patient.

WHAT ARE THE REQUIREMENTS FOR EP SYSTEMS FOR CHILDREN?

The suggestion that medication errors occur in 5.7% of paediatric inpatients is probably an underestimate.⁵ A more recent study across five London hospitals showed a prescribing error rate for children of 13.2%.⁶ Errors with medication administration are also a common problem in paediatric inpatients throughout the UK: the same study reported errors in 19.1% of administered doses. There are a number of factors that potentially put children at greater risk of preventable adverse drug events than adults (see box 1). An EP system will need to consider all these variables to promote better paediatric prescribing.

The American Academy of Pediatrics identified functional areas that are critical to electronic health records and therefore core requisites for EP systems for children (see table 1).

A substantial proportion of medication errors in children will not be averted if EP is focused solely on prescribing as up to one fifth of children's medicines may be incorrectly administered.⁶ Use of technology to improve prescribing must sensibly be developed in partnership with tools to support correct administration.⁷

EP systems for children must facilitate prescribing of drug doses that are practical to administer. Since many medicines are dosed per weight, calculated doses often need to be altered in light of the available preparation/concentration to something that can be physically measured. This is complicated because seemingly sensible doses of medicine may be difficult to administer (see box 2).

WHAT DOES THE EVIDENCE, AND EXPERIENCE, TELL US?

Medication ordering is one of the most complex aspects of medical care, requiring clinicians to simultaneously integrate a thorough understanding of available medicines, disease processes and patient-specific information in the context of

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Table 1 Critical paediatric electronic health record functional areas⁹

Requirement	Additional detail
Immunisation management	Ability to record immunisation data, link to immunisation information systems and decision support.
Growth tracking	Access results graphically and calculate percentile value against defined distribution. This should feed into decision-support functions.
Medication dosing	To include dosing by body weight with dose-range checking. Dose rounding to safe and convenient doses to express dose in volume of medicine to be administered rather than just mass of drug. Include age-based dosing decision support and dosing for the school day.
Patient identification	Newborn identification and link prenatal data to postnatal record. Accommodate name change and ambiguous sex.
Norms for paediatric data	Include both numeric and non-numeric data and complex normative relationships and gestational age.
Privacy	Adolescent privacy, children in foster or custodial care, consent by proxy, adoption, guardianship and emergency treatment.

a particular clinical circumstance.⁸ Prescribing for children is further complicated by the need to consider the patient's weight, dosing weight if different, clinical indication, organ maturity and many other factors.⁹

Providing the proper drug therapy to a hospitalised child involves several steps and multiple individuals. The prescription may require modification at a number of stages to alter formulation, concentration, volume, brand in terms of taste/palatability, availability of supply or administration times to match normal sleep-wake patterns. The prescriber will often lack detailed information concerning what product is available. Thus even with EP, pharmacy review is still required to ensure patient safety.¹⁰ Prescriptions may be written on the basis of the drug and dose required, but with an acceptable margin of variation around dose or concentration, although occasionally there is no margin for variance, for example, regarding sugar free medicine for non-ketogenic epilepsy. With EP systems consideration must be taken of what non-prescribers can amend within the prescription (see table 2). What if a nurse or parent wants to change administration times from 10:00 to 08:00 h? Does the prescription need to be changed by the prescriber or can it simply be charted as given at a different time? This opens a philosophical and legislative debate as to what variation is permitted around the prescriber's expressed instruction. What, if any, margin of variation from the written instruction is acceptable and is it product specific? (see box 3).

ADVANTAGES AND DISADVANTAGES OF EP

It is difficult to compare results from different studies that evaluated the effect of EP for children because definitions of detection and evaluation of prescription error and adverse drug event vary widely.¹¹ Most studies examine a before and after scenario, with the prescription as the end point rather than the outcome of care provided. Large randomised trials to examine the effect of EP on patient safety and clinical outcome are very difficult in practice. An alternative methodology, such as a controlled before/after study in a multicentre setting is more appropriate because EP is diverse, and many systems for CDS are customised or have local variation.¹¹

There are significant challenges in defining the advantages and disadvantages of EP. Very few studies specifically look at

Box 1 Reasons children are at greater risk of preventable adverse drug events

- ▶ More dose calculations are required. Drugs have varying doses depending on age, weight and clinical indication.
- ▶ Increased complexity of medication dosing. Universal weight-based dosing is prone to calculation errors and must also take into account adult maximum-dose limits.
- ▶ In early life age based-dosing may be influenced by chronological age in hours or days or postconceptual or gestational age.
- ▶ There is a wide range of correct doses for drugs depending upon indication. For example, the recommended dose of amoxicillin is 13, 20, 30, 40 or 60 mg/kg/dose depending on the indication.³²
- ▶ There are wide weight ranges from neonate to adolescent.
- ▶ Special domains within clinical practice create higher risk such as continuous intravenous infusions and chemotherapy with higher immediate and/or cumulative toxicity than other drug types.³³
- ▶ Medicines are more commonly used outside licence with lack of clear dosage guidance.
- ▶ Medicine formulations may not be suitable.
- ▶ Younger children have less developed communication skills limiting feedback that may prevent medicine administration errors occurring.

Box 2 Consider the following prescription

Ranitidine liquid, give 4 mg oral every 8 hours.

- ▶ The dose may be correct for a 2 kg neonate based on a 2 mg/kg/dose, but 0.33333 ml of a 75 mg in 5 ml solution is impossible to measure. It must therefore be approximated to 0.2 or 0.3 ml.

Electronic prescribing should guide the clinician to prescribe:

- ▶ Ranitidine (75 mg per 5 ml) liquid, give 4.5 mg oral every 8 hours.

whether EP changes patients' medical outcome.¹² While there is conflicting information about the influence of EP on patient outcomes, there is growing evidence that highlights the benefits and adverse consequences associated with EP. Unlike other healthcare interventions such as a new medicine, which is guided by regulatory approval, EP is not a single intervention. It encompasses a range of disparate systems deployed in very different settings around the world. Systems also vary substantially in their capabilities, with some acting as standalone EP systems with limited CDS while others are integrated into a clinical information system with extensive CDS. Review papers suggest that a key strategy to minimise medication errors in children is utilisation of EP with CDS.¹³

We present the advantages and disadvantages of EP in terms of increasing complexity of systems.

ADVANTAGES OF EP

Basic EP eliminates errors associated with illegible handwriting and yields a detailed audit trail that clearly identifies the prescriber or the person who administered the

Table 2 Who influences a child's prescription and how

Who	How
Paediatrician	Selects medicine and dosage form, dose, route of administration, frequency and times of administration.
Child	May change times of administration or frequency or manipulate dosage form. May request different brand because of taste, or personal preference.
Parent/carer	May change times of administration or frequency or manipulate dosage form. May request different brand because of taste, or child's preference.
Pharmacist	May advise dose change to an appropriate dose for age or weight of child, clinical indication or organ function or to a more easily measured amount. May change dosage form in terms of what is available and brand and method of administration such as via a feeding tube. May advise changing times of administration, eg, in relation to meals/feeds, sleep/wake patterns or optimal effect.
Nurse	May change times of administration or frequency or manipulate dosage form. May give different brand because of taste, or child's preference.

Box 3 Consider the following cases

- ▶ Joe is prescribed paracetamol (120 mg in 5 ml) solution, give 150 mg orally 6 hourly if required.
 - ▶ Should the nurse administer 3 ml of paracetamol (250 mg in 5 ml) solution because that preparation is available on the ward?
 - ▶ Is this practical, reasonable and common sense? Is it legal and in keeping with healthcare institute policy?
- ▶ Jim is prescribed phenobarbital sodium (50 mg in 5 ml) solution, give 20 mg orally twice daily.
 - ▶ Should the nurse administer 6.7 ml of a phenobarbital sodium (15 mg in 5 ml) elixir because that strength of solution is available on the ward?
 - ▶ Is this practical, reasonable and common sense? Is it legal and in keeping with healthcare institute policy.
 - ▶ Clearly this is a different scenario because phenobarbital sodium is a controlled drug and the 15 mg in 5 ml elixir is formulated in 38% ethanol.

medicine. The need to rewrite prescription charts, with potential transcription error, is removed. Most systems require prescription order entry in a structured fashion with basic components being mandated, namely drug name, dose, route of administration and frequency. However, although prescriptions are complete, this does not mean that they are correct. There is limited evidence that basic systems reduce some types of medication error. Kadmon *et al*¹⁴ evaluated implementation of a commercial EP system in a paediatric intensive care unit in Israel. A basic EP system produced a slight and non-significant reduction in prescription errors, with further reductions achieved following the introduction of enhanced CDS.

EP can support adherence to the hospital formulary. Basic systems may include only formulary drugs in the drug database, however this may be dangerous and lead the prescriber to select what they believe is the right drug because that is all that is listed. It may be preferable to list all drugs and distinguish between formulary and non-formulary items. With the use of CDS formulary functionality can be enhanced by guiding clinicians to appropriate choices.

CDS encompasses interventions ranging in complexity from utilisation of a standard drug dictionary to checking drug choices against documented comorbidities. The benefit of including CDS was highlighted by Bates in the landmark study at Brigham and Women's Hospital where a 'homegrown' adult EP system, with some basic decision support, such as limited drug allergy checking, reduced non-intercepted serious medication errors by 55%.¹⁵ With the addition of improved CDS, including suggested doses and frequencies for all medicines and complete allergy and drug interaction screening, non-intercepted serious error rates were reduced by 86%.¹⁶

Following the success of EP with CDS in adults, a study aimed to determine how many medication errors could be prevented following the introduction of EP in a US paediatric hospital.¹⁷ The medication error rate was 5.2%, with most errors occurring during ordering. A model CDS system that included allergy/interaction checking, with suggested doses based on patient parameters and drug dose checking based on age and weight, would improve the interception of potentially harmful prescribing errors but not administration errors.

Will paediatricians comply with decision support? Using a commercial system, Killelea *et al*⁸ developed rules for 200 paediatric medications. Rules covered medication form, age and weight range and assumed the most common indication for the medication. Half of the orders had system generated suggestions: less than one third were followed exactly. Although CDS offers potential advantages, clinicians ignore them if they are not perceived as useful or relevant.

The use of structured prescribing pathways incorporating CDS was evaluated within Wirral Hospital in the UK.¹⁸ A high prescribing error rate for children was reported and some doses were impractical to administer. The trust's existing commercial EP system was modified to create new pathways that guided prescribers to select an age or weight. The system then suggested an appropriate, measurable dose scheduled at child-centred and convenient times. There was a significant reduction in prescribing errors, especially among non-paediatricians who occasionally prescribed for this age group.

The effect of EP on dose errors was measured following the introduction of a stand-alone commercial EP system in Great Ormond Street Hospital, a specialist children's hospital in London.¹⁹ Dosing errors were reduced for outpatients and discharge prescriptions but not for inpatients. Another UK study that evaluated the impact of a basic EP system in a paediatric critical care unit did not show a significant reduction in prescribing errors but there were fewer missed doses.²⁰

Due to the lack of studies that used comprehensive error surveillance methods, Walsh *et al*²¹ performed a time-series analysis after implementation of a commercial EP system in a general hospital in Boston that included both adult and paediatric patients. With this system clinicians could choose specially designed paediatric orders that were linked to weight-based dosage calculators and included allergy and interaction checking. There was a 7% reduction in the rate of non-intercepted serious medication errors, significantly less than that previously reported in adult patients. Possible reasons for this inferiority were the use of a commercial system that was not customised to the individual institution and utilisation of the same system for both adult and paediatric patients. This meant that the system was possibly better designed to prevent adult than paediatric errors. To further reduce the error rate, the system needed to be redesigned to focus on the medication needs of children.

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Table 3 Paediatric patient parameters used by the Advanced Dosing Model logic²²

Criterion	Definition
Indication	A condition that makes a particular medication dose advisable
Care area	Physical location of patient within institution which is used to infer intensity
Chronological age	Age of patient in years, months and days since date of birth
Postconceptual age	Age of patient in years, months and days since clinician estimated date of conception
Dosing weight	A user-defined weight that will be used to dose medications; this may not reflect the patient's current weight
Renal impairment	Qualitative assessment of renal impairment by the ordering provider, ie, 'impaired' or 'not impaired'

To realise the full potential of EP for children, Ferranti created an advanced dosing model that interacts with their existing EP system.²² This model supports complex paediatric dose calculation based on factors outlined in table 3. The system identified paediatric patients regardless of location because they may be cared for in adult locations or by adult surgeons within a US hospital. Additional safeguards protected children from inappropriate adult medication dosing content. Dose rounding functionality facilitated prescribing of practical doses. Using only voluntarily reported events, there was a 40% decrease in adverse drug events in both paediatrics and neonatal intensive care units.

DISADVANTAGES OF EP

The hopes that deployment of EP will solve all medication errors and facilitate evidence based practice have been somewhat misplaced. As with any healthcare intervention, adverse effects can occur. The challenge is to anticipate and identify these unintended consequences and find ways to either eliminate them or mitigate their effect.

Koppel described 22 types of medication error risk in a study of a commercial EP system in the USA.²³ Two main groups of errors were identified. First, information errors generated by data fragmentation and integration failures and second, human-machine interface flaws. The information errors included prescribers completely relying on the system to guide dosing, failure to chart or a delay in charting immediate orders, gaps in antibiotic therapy due to failure to renew treatment and incorrect diluents being chosen for intravenous drug administration. The human-machine interface flaws included errors with selecting the correct patient, loss of data and time when the system was non-functional. Some of these errors are similar to those reported at our institution which uses the same EP system although Wirral's has undergone extensive customisation over the last two decades. For example, it only presents appropriate diluents for each injectable product to prevent mis-selection. Errors with selecting the wrong patient can be very serious, especially in the paediatric context since multiple siblings, sometimes without names, may be treated in neonatal intensive care units.

A subsequent study looking at five different hospitals with a mixture of home-grown and commercial EP systems in the USA identified nine types of adverse unintended consequences.²⁴ These included increased work for clinicians that slowed the speed of documentation and ordering, changes in communication patterns and practices leading to immediate orders not being administered, selection errors from drop-down

lists caused by problematic electronic data presentation and clinicians over-relying on technology by assuming that if something is in the computer then it must be correct. CDS was associated with a disproportionately large number of adverse consequences with the indiscriminant, excessive use of alerts. Other studies have highlighted the problem of alert proliferation. Nightingale *et al*²⁵ showed that 92% of their low level warnings within University Hospital Birmingham were overridden, suggesting very low specificity.

None of the studies outlined above looked solely at paediatric prescribing, but it is reasonable to assume that similar issues will occur. A study in a subgroup of patients referred and admitted to a regional, academic, tertiary care level children's hospital in the USA demonstrated that after implementing a commercial EP system, the mortality increased significantly from 2.8% to 6.6%.²⁶ This finding was alarming, but there were several significant changes to workflow and processes that could have accounted for the increased mortality. The inability to preregister patients before emergency admission, and pharmacy services changing to a centralised model may have delayed treatment. The lack of paediatric specific order sets would also delay documenting orders. Utilisation of an adult based application in a children's hospital may possibly have been suboptimal.

The same commercial system was implemented in another paediatric hospital in the USA but with the addition of over 230 disease and/or departmental order sets and the use of code set filtering to make relevant orders more accessible to clinicians.²⁷ Following the introduction of the new system, an improvement in mortality was not demonstrated. However, it was shown that a more carefully planned implementation did not actually worsen mortality. We would question whether mortality is too crude and suggest it should not be used as the sole outcome measure to assess the success of EP for children.

There is also little evidence in either adult or paediatric settings to suggest that medication administration errors can be reduced by EP. A UK study comparing administration error rates in adult wards with and without EP in two separate hospitals found no significant difference in error rates.²⁸

THE FUTURE

EP systems are still at an early stage in their evolution, but they will undoubtedly make significant contributions to future healthcare. When carefully implemented and customised to the particular setting, EP can improve efficiency and patient safety, but the truism remains, "If an error can be made, it will be made". The challenge to EP system designers and implementers is to integrate the concept of inherent safety into system configurations by using design decisions that absolutely prevent the possibility of certain hazards or errors.²⁹ For example, it should be impossible to prescribe intrathecal vincristine to a child.

CDS potentially optimises patient safety but if poorly delivered will alienate clinicians and endanger patients as users ignore most alerts. CDS approaches that anticipate and facilitate appropriate next steps rather than interrupting users with poorly constructed alerts are needed.³⁰ This concept of passive decision support should help eliminate known errors and increase user efficiency and satisfaction.

Any improvements or modifications to EP systems must ensure the basic requirements of users are met. In particular, the primary determinant of user satisfaction is system speed

and any changes must not compromise this.³¹ EP is not the solution to all medication errors and therefore work must continue to explore other systems that can help, particularly with administration errors.

CONCLUSION

Continued research is required to optimise EP systems for children with customised paediatric CDS.

The evolution of EP mirrors child development. After a long and protracted birth EP arrived, and initially thrived. During infancy it suffered some minor setbacks and a serious scare. It has now come through these tribulations intact if a little chastened. As EP now leaves the toddler years behind it faces a challenging world knowing that with the right support and guidance it can look forward to childhood with optimism.

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