

**Electronic Prescribing In Children (EPIC):
an evaluation of implementation at a
children's hospital.**



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The School of Pharmacy, University of London



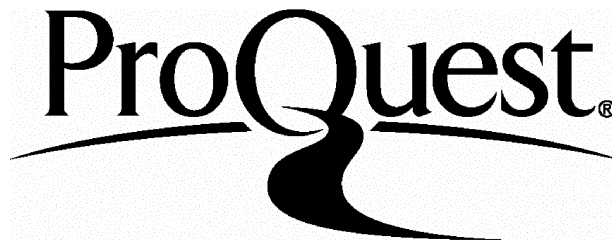
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This thesis describes research conducted in the School of Pharmacy, University of London between November 2005 and September 2008 under the supervision of Professors Nick Barber and Ian Wong. I certify that the research described is original and that any parts of the work that have been conducted by collaboration are clearly indicated. I also certify that I have written all the text herein and have clearly indicated by suitable citation any part of this dissertation that has already appeared in publication.

Signature  _____ Date 06-11-2008

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Abstract

Medication errors are common and can cause significant mortality and morbidity. Electronic prescribing (EP), with or without clinical decision support systems (CDSS), is a complex intervention that has been proposed as a solution. US studies indicate that there may be a reduction in medication errors as well as adverse events, but equally new errors may be introduced. There is a paucity of studies assessing the use and impact of EP in the UK hospital setting, especially those involving paediatric patients.

The aim of this thesis was to investigate and evaluate the implementation of an EP system at a children's hospital in the UK. The objectives were to assess the effect on prescribing errors, to explore the level of CDSS available and in use within the system, to identify any changes in practice and workflow patterns of healthcare professionals, and to determine the views of patients and users. Mixed qualitative and quantitative methods were used within an evaluation framework (the Cornford framework).

The results show an overall reduction in prescribing errors directly as a result of more complete and legible prescriptions after EP. Outpatient errors decreased from 1219/1574 (77.4%) to 33/648 (5.1%), a 72.3% reduction [95% confidence interval (CI) -74.6% to -69.3%]. The number of outpatient visits that were error free increased from 185/883 (21%) to 225/250 (90%), 95% CI of difference in proportions, 64% to 73.4%. Inpatient errors decreased from 85/1267 (6.7%) to 96/ 2079 (4.6%), 95% CI of difference in proportions, -3.4% to -0.5%. There was an increase in discharge prescription errors from 839/1098 (76.4%) to 1777/2057 (86.4%), 95% CI of difference in proportions, 7.88% to 12.94%. The dosing error rate in all types of prescriptions was lower after EP: 88/3939 (2.2%) vs. 57/4784 (1.2%), 95% CI of difference in proportions, -1.6% to -0.5%, but there was no statistically significant change in severity ratings of dosing errors. New types of errors, such as selection errors, were seen due to EP. Although principles of the medicines use process remained the same, the practical approach to tasks was altered. The system was accepted by users and patients, but there was a desire for further improvements, especially in the level of clinical decision support available to the end user.

In conclusion, the EP system was implemented successfully. The benefits in medication safety appear to be the results of effective interaction between system functionality and usability, user acceptance and organisational infrastructure.

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Abbreviations

ADE	Adverse drug event
BNF	British National Formulary
BNID	British Nursing Index Database
CDSS	Clinical decision support system
CI	Confidence interval
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CIVAS	Centralised Intravenous Additive Service
CPOE	Computerised physician/ prescriber/ provider order entry
CRN	Clinical response nurse
CSP	Clinical site practitioner
EP	Electronic prescribing
EPMA	Electronic prescribing and medicines administration
FDB(E)	First Data Bank (Europe)
GOSH	Great Ormond Street Hospital for Children
HPLC	High-performance liquid chromatography
ICT	Information and communications technology
ICU	Intensive care unit
IPA	International Pharmaceutical Abstracts
IT	Information technology
IV	Intravenous
IU	International units
κ	Kappa
LAN	Local area network
MAC	Medicines administration chart
MAP	Medication administration profile

MAS	Medication administration schedule
µg	Microgram
mL	Millilitre
mg	Milligram
NCA	Nurse controlled analgesia
NHS	National Health Service
NICU	Neonatal intensive care unit
NNT	Number needed to treat
NUU	Neonatal unit
NPfIT	National Program for Information Technology
NS	Not statistically significant
PACS	Picture archiving and communication systems
PAC	Patient administration chart
PC	Personal computer
PCA	Patient controlled analgesia
PDA	Personal digital assistant
PCCU	Paediatric critical care unit
PGD	Patient group direction
PICU	Paediatric intensive care unit
PIMS	Patient information management system
RDD	Recommended daily dose
RR	Relative risk
SHO	Senior house officer
SPSS	Statistical Package for the Social Sciences
Stat	Immediately
TPN	Total parenteral nutrition
TTA	To take away (discharge medication); used interchangeably with TTO

TTO	To take out (discharge medication); used interchangeably with TTA
u	Units
UK	United Kingdom
US	United States
VDU	Visual display unit
WHO	World Health Organisation

Glossary

Cisco card	a specialized network interface card that allows devices to connect to a wide area network.
Crystal reports	an application used to design and generate reports from data sources
Fat server	a computing client-server model in which most of the processing is implemented in the client (at user level) and the server does very little.
Hardware	the equipment and devices that make up a computer system i.e. personal computers, laptops, display screens.
Local area network	a group of computers and associated devices that share a common communications line or wireless link.
Server	a computer in a network that stores application programs and data files accessed by other computers.
Software	programs and applications that can be run on a computer system.
Thin client server	a computing client-server model in which most of the processing is implemented in the server and the client does very little. An example of this is web transactions (e.g. Amazon, eBay) in which the client (user) only runs a browser and the bulk of the transaction is processed at the server.

Preface

Patient harm due to errors in healthcare settings is now a well-recognised and publicised phenomenon. When children are involved, the matter appears to be not only emotive, but more media worthy as well, often because of the consequential tragic outcomes.

Worldwide strategies propose that information technology solutions have a role to play in improving patient safety. Electronic prescribing is one example of an information technology solution, and is anticipated to improve patient safety through improvements in the medicine use process.

The National Program for Information Technology (NPfIT) in the UK is an indication of commitment by the government to improve and modernise healthcare delivery in the National Health Service (NHS) with the use of computers. However, delays in the implementation of electronic prescribing in hospital settings, has forced organisations to consider interim solutions.

The aim of this thesis was evaluate the introduction of one such ‘interim solution’ electronic prescribing system at a children’s hospital. The thesis comprises eight chapters. The first two chapters set the background: Chapter 1 begins with a general overview of medication errors in healthcare, and focuses on the extent of the problem in children, especially in the UK. Solutions and prevention strategies that have been proposed and trialled are discussed. Chapter 2 concentrates on one possible solution, electronic prescribing. The chapter is divided into two parts: the first half is a review of the literature on the use of electronic prescribing in children; the second section emphasises the need for evaluation by exploring barriers to adoption and highlighting some unintended consequences of the technology. The aims and objectives of the thesis are stated at the end of Chapter 2. Chapter 3 provides background information about the study site, a description of the medicines use process and details of the EP system that was used. In Chapter 4, the overall methodology that was employed is presented together with the rationale for this choice. Chapters 5, 6 and 7 detail the work undertaken and report the results. The final chapter sums up the key outcomes of the evaluation, considers the strengths and limitations of the research, states the contribution of this thesis and identifies areas for future study.

Chapter 1 Introduction

“No adverse event should ever occur anywhere in the world if the knowledge exists to prevent it from happening.”

World Health Organisation (WHO) Collaborating Centre for Patient Safety Solutions

1.1 Patient safety in healthcare

In the last decade patient safety and medical errors have received considerable attention following key publications in the United Kingdom (UK) and the United States (US). These reports estimated 850,000 adverse events in UK NHS hospitals and 44,000-98,000 deaths in US hospitals each year as a result of medical errors (Department of Health 2000; Institute of Medicine 1999). A medical error is a broad term and may be defined as any error that occurs during the healthcare process. The term includes all types of clinical errors, including surgery, diagnosis, documentation and medication. When considering medication related harm three main terms, adverse drug events, adverse drug reactions and medication errors, are used in the literature (Dean et al. 2005). A definition of each of these is given below.

- Adverse drug event (ADE): any adverse event that occurs during or following medication use. This may be due to an adverse drug reaction, poisoning or an error.
- Adverse drug reaction: this has been defined by the WHO as "a response to a drug that is noxious and unintended and occurs at doses normally used in man for the prophylaxis, diagnosis or therapy of disease, or for modification of physiological function."
- Medication error (ME): any error that occurs in the medicines use process at any stage of prescribing (or ordering), dispensing, administration and monitoring. Medication errors are considered preventable and may or may not have the potential to cause harm.

Generally, adverse drug reactions are considered unpreventable ADEs, whereas medication errors are thought to be potential and/or preventable ADEs.

1.1.1 Medication errors

Medication errors are the most common type of medical error, and may occur at any stage of the medicines use process i.e. prescribing (or ordering), dispensing, administration and monitoring. The implications of medication errors are considerable, both in terms of patient harm as well as financial cost. It is estimated that at least 1.5 million preventable ADEs occur in the US each year, and there is an extra \$3.5 billion in hospital costs per year (Institute of Medicine 2007). The extent of the problem is similar in the UK. A study of drug related hospital admissions in England reported that 247,000 (6.5%) hospital admissions each year were due to harm from medicines, of

which 9% were preventable and 63% were possibly preventable (Pirmohamed et al. 2004). Reports to the National Reporting and Learning System in England and Wales for the year 2007 indicate that medication accounted for 9% (72,481/811,746) of all patient safety incidents reported (National Patient Safety Agency 2008a). The estimated cost of medication errors to the NHS in England is more than £750 million each year (National Patient Safety Agency 2007).

The exact magnitude of the problem remains unknown despite research dating back to the 1960s, probably because the error rate is dependent on a number of factors including the study setting, definition of medication error used, the stage of medicines use process studied and the detection method employed. For example, an early definition of a medication error was “a deviation from the physician’s medication order as written on the patient’s chart” (Allan & Barker 1990). Therefore studies using this definition would exclude errors in prescribing or monitoring. A broader definition of medication errors (“any error that occurs in the medicines use process at any stage of prescribing, dispensing, administration and monitoring”) is now used by most researchers, although the focus of the study and detailed definitions may vary depending on which stage of the medicines use process is being investigated. Likewise, the types of events included as an error may also differ. For instance, Bates et al (1995) only included errors that had the potential to harm, whereas others incorporate errors that do not result in harm or are potentially less likely to do so e.g. wrong time of administration (Tisdale 1986). Similarly, different detection methods yield different results as illustrated by a UK study in which three different methods (incident reporting, medical record review and pharmacist identification) were used to detect adverse drug events in an NHS district general hospital. The authors reported that there was little overlap in the nature of events detected by the three methods generally, but especially in the detection of medication errors, with no errors reported using incident reporting, whereas 14 medication errors were detected by record review and 30 by pharmacist identification during routine ward visits (Olsen et al. 2007).

All these factors result in a heterogeneous literature, making it difficult to consolidate or generalise the findings. Some themes have emerged from the existing literature despite the heterogeneity. Factors most likely to predispose to errors include patients with allergies, and seriously ill patients in critical and acute care settings who may be prescribed a greater number of drugs (Department of Health 2004). Medications disproportionately involved in harmful errors include anticoagulants, antiplatelet agents,

cytotoxic agents, diuretics, injectable drugs, insulin, non-steroidal anti-inflammatory drugs, opioid analgesics and drugs with a narrow therapeutic window (Howard et al. 2007; Institute for Safe Medication Practices 2005b). Quality of prescribing, particularly legibility and the use of certain abbreviations, has also been implicated (Department of Health 2004; Institute for Safe Medication Practices 2005a). Children are considered to be more at risk than adults (Department of Health 2004; Kaushal et al. 2001).

1.2 Medication errors in paediatrics

Medicine use in paediatrics is a complex process and poses specific challenges (Ghaleb et al. 2006). Dosing is usually based on body weight or body surface area, which is often changing rapidly. The age of the child (such as corrected gestational age for premature neonates) also has an impact. In chronic conditions, growth of children needs to be monitored to ensure appropriate drug dosage modifications are made. Many medicinal products are not licensed for use in children and therefore the formulations may not be appropriate for doses needed in children, resulting in the need for complex manipulation at the point of administration. Children may not be able to communicate information about any medication errors or adverse events experienced. When errors do occur, they are likely to have a greater impact on outcome than the same error in adults, as the therapeutic dose margin is considerably narrower and there may be altered, often reduced, pharmacokinetic capacity to deal with dose excesses (Department of Health 2004; Ghaleb et al. 2006).

1.2.1 Incidence, types and severity

The incidence of medication errors and preventable adverse drug events in paediatrics varies considerably in the literature. A number of recent systematic reviews of medication errors in children provide a comprehensive bibliography of the research in this field (Conroy et al. 2007; Ghaleb et al. 2006; Miller et al. 2007; Wong et al. 2004). The following sections give an overview of the incidence, types and harm/severity of paediatric medication errors in outpatient and inpatient settings based on published literature from the last 5 years (January 2003 to June 2008). For the purpose of this review, studies conducted in the ambulatory care setting, outpatient clinics and the emergency department are included in the outpatient setting as these patients are not considered hospital inpatients.

1.2.1.1 Outpatient settings

The vast majority of children are treated and cared for in the outpatient setting. Medication prescribed in this setting is usually either self-administered or given by the parents, except in the emergency department where healthcare professionals may be responsible for drug administration. Therefore, it is likely that the nature and incidence of medication errors in this setting may differ to that in the inpatient setting.

Most research on errors in the outpatient setting is from the US, and set mainly in emergency departments (Alves et al. 2007; Goldman & Scolnik 2004; Kozer et al. 2004; Losek 2004; Marcin et al. 2007; Rinke et al. 2008; Taylor, Selbst, & Shah 2005), with very few studies in outpatient clinics (Gandhi et al. 2005; Taylor et al. 2006) or in primary care (Al Khaja et al. 2007; Kaushal et al. 2007; McPhillips, Stille, & Smith 2005).

Based on these recent publications, the overall incidence of all types of medication errors ranges from 3% to 9.9% of medications prescribed (Gandhi et al. 2005; Taylor et al. 2006) and in 3% of patients (Kaushal et al. 2007), with most errors occurring at either the administration or ordering stage. In a primary care study which used prescription review, telephone survey and chart review to detect ADEs in children from 6 office practices, the authors reported preventable ADEs in 57 of the 1788 patients (3%). Of these administration errors were the most common type accounting for 70% of the errors, followed by errors in ordering (26%) (Kaushal et al. 2007). Similarly, an analysis of spontaneous reports involving chemotherapy medications showed that administration errors accounted for approximately 42% of the reports (Rinke et al. 2007). Gandhi et al (2005) used prescription review to detect errors in outpatient chemotherapy infusion units and found that most errors were at the ordering stage (47/57 errors in 2104 orders).

A higher error rate is seen in studies which focus on one stage of the medicines use process such as prescribing or administration. For example, studies of drug administration by parents show that half to three quarters of the patients received the wrong dose of antipyretics, with occurrence of underdosing as well as overdosing. In one study of 213 parents, 26 (12%) had given an overdose, and 87 (41%) an underdose of acetaminophen (Goldman & Scolnik 2004). In another study involving 200 patients, 105/117 (90%) were given an incorrect dose of dipyrrone (16 received too little, and 89 received too much) and 45/83 (54%) were given an incorrect dose of acetaminophen (38 received too little and 7 received too much) (Alves et al. 2007).

The definition used also appears to have an influence. A study involving 20 primary health care centres reported prescribing errors in 75% of medications prescribed, corresponding to over 90% of prescriptions. However, the definition used in this study included errors in prescription writing such as absence of the date of prescription, patient's personal identifiers and incomplete or illegible body of the prescription, as well as knowledge based errors in prescribing (Al Khaja et al. 2007). In contrast, a study which defined an erroneous prescription or order as one which contained an incorrect dose or was written incorrectly, but excluded illegibility and omission of details such as date of prescription and patient's personal identifiers, reported prescribing errors in a fifth of the prescription orders (Taylor, Selbst, & Shah 2005).

Information in UK outpatients is lacking; to date no research appears to have been done on paediatric medication errors in the UK outpatient setting. Table 1 summarises recent studies of outpatient medication errors.

Table 1: Studies of paediatric medication errors in outpatient settings

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
All types of errors							
Gandhi (2005)	US	Outpatient chemotherapy infusion units	Any error in the medication process, including ordering, dispensing, transcribing, administering, and monitoring, even if the error was intercepted and corrected prior to reaching the patient.	Prospective cohort study	Between March and December 2000	Prescription review	Errors = 57/ 2104 orders (3%) potential ADEs = 34/2104 orders (1.6% of all orders or 60% of ME) Ordering = 42 Dispensing = 13 Administering = 5
Kaushal (2007)	US	6 office practices	Errors in drug ordering, transcribing, dispensing, administering or monitoring.	Prospective cohort study	Consecutive 2 month block at each practice from July 2002 to April 2003	Prescription review, telephone survey and chart review	Preventable ADEs = 57/1788 patients (3%) Administering = 70% Ordering = 26% Dispensing = 3% Transmitting = 2%
Rinke (2007)	US	All settings where chemotherapy medications are used	MedMARX ('and as defined by our institution' - but not specified)	Analysis of reports to MedMARX	January 1 1999 through December 21 2004	Spontaneous reporting	310 error reports in total including inpatients; 1.6% resulted in harm. Outpatient rates: Administering = 41.9% Dispensing = 32.3% Prescribing = 22.6% Transcribing/ documenting = 3.2% Monitoring = 0 Improper dose/ quantity most reported type = 26.5%
Taylor (2006)	US	Haematology/ oncology clinic at a children's hospital	Errors were classified as occurring during the prescribing, dispensing, and/or administration phase.	Prospective case series study	Mid-April to mid-June 2005.	Chart review and parent interview	All = 17/172 medications (9.9%) Prescribing = 5 (2.9%) Administration = 12 (7%)

ADE = Adverse drug event; ME = medication error

Table 1 - continued

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
Prescribing errors							
Al Khaja (2007)	Bahrain	20 primary care health centres	Absence of prescription components such as date of prescription, any parameter of patient's personal identifiers, physician's stamp, and/or direction for use are deemed as minor errors of omission. Absence, vague, incomplete and/or illegibility of any component of body of the prescription is considered as major errors of omission. Incorrectly written component(s) of body of the prescription is considered as an error of commission. Errors of integration or knowledge-based errors in prescribing include potential drug-drug interactions or drug allergies which may reflect a failure of the prescriber to integrate information about the patient or drug history. Skill-based errors of prescribing such as illegible handwriting and/or prescriptions with non-official or unconventional abbreviations, were excluded	Retrospective study	Between 9 May and 23 May, 2004	Prescription review	Errors = 2066/ 2088 prescriptions (90.5%) and 4282/ 5745 medications (74.5%)
Rinke (2008)	US	Paediatric emergency department at an urban academic tertiary care hospital	An order or a prescription was classified as containing an error if it contained an incorrect dose or was written incorrectly. An order or a prescription was classified as containing an incorrect dose if it was contraindicated based on a patient's drug allergies or did not fall within 10% of appropriate weight-based dosing ranges as dictated by common paediatric medication guidelines. An order was classified as written incorrectly if it did not indicate a route, a weight-based target dose, and/or a prescriber's signature. A prescription was classified as written incorrectly if it did not indicate a route, a medication concentration, a frequency, and/or a prescriber's signature.	Retrospective review	17 non-consecutive days in August, September, October 2004 and April to September 2005	Chart review	47/377 (12.5%) in-house orders and 37/191 (19.4%) individual charts contained at least 1 error; 30/696 (4.3%) ambulatory prescriptions had at least one error
Taylor (2005)	US	Emergency department at an academic, tertiary care children's hospital	Not specified, but table provides clear explanations of what to include in each error type	Descriptive prospective cohort study	Between January 1 1998 and June 30 1998	Chart and prescription review	311 errors in 212 prescriptions of a total of 358 (59%) prescriptions written

Table 1 - continued

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
Prescribing and administration							
Kozer (2004)	Canada	Emergency department at a tertiary paediatric hospital	A medication that was ordered but not given (unless the order was cancelled), a medication that was given but not ordered, a drug given in a dose different by at least 20% from the recommended dose, administration of a drug by an incorrect route, and a drug ordered that is not indicated for the patient's condition.	Prospective observational study	September 2001 to May 2002	Observation and syringe content analysis	Errors in 7 out of 8 mock resuscitations when 125 drugs were initiated. 9 dose prescribing errors and 1 dose administration error
Marcin (2007)	US	4 rural emergency departments	Included medication given but not ordered; medication ordered but not given; wrong drug given from what was ordered; wrong dose; wrong or inappropriate drug for condition; wrong administration technique, wrong route; wrong dosage form; wrong time; and error related to patient information. Wrong dose was determined by preset criteria, with doses above or below 10% to 25% of correct dose considered errors, depending on class of medication.	Retrospective review	Between January 1 2000 and June 30 2003	Chart review	Errors = 84 in 69 patients, 62.2% of those that had any medication prescribed (135) and 47.5% of all patients (177) Administration = 58/84 Physician related = 24/84

Table 1 - continued

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
Dosing errors							
Alves (2007)	Brazil	Paediatric emergency department at a teaching hospital	Dose deviation from acetaminophen 10-15 mg/kg per dose and dipyron 15-20 mg/kg per dose	Cross sectional study	September 2004 to February 2005	Questionnaires administered to parents	150 out of 200 patients (75%) received the wrong dose
Goldman (2004)	Canada	Emergency department at children's hospital	Acetaminophen dosage based on the recommended dosage 10-15 mg/kg per dose	Cross sectional study	September 2000 to February 2001	Parent interview	113/213 (53%) gave the wrong dose
Losek (2004)	US	Emergency department at an urban children's hospital	Acetaminophen dose > 16mg/kg	Retrospective cross sectional study	February 3-9 1998	Chart review	34/156 (22%) patients had wrong dose (15, <10mg/kg and 19, >16mg/kg)
McPhillips (2005)	US	3 health maintenance organizations	A medication dispensed at a dose meeting any of the following criteria: (1) total mg/kg/d dispensed at 110% or more of the maximum RDD (potential overdose); (2) total mg/d dispensed at more than the maximum recommended adult dose (potential overdose); (3) total mg/kg/d dispensed below 90% of the minimum RDD and below the adult minimum recommended dose in total mg/d (potential underdose)	Retrospective review	Between June 1999 and June 2001	Prescription review	Error = 280/1933 (15%)

RDD = recommended daily dose

1.2.1.2 Inpatient settings

Research into paediatric medication errors is predominantly from the hospital inpatient setting with the majority of studies being conducted in the US and Canada. Recent studies report the overall medication error rate as 1% of admissions (Sangtawesin et al. 2003), 1.2% of all orders (Fahrenkopf et al. 2008), 1.8%-5.4% of spontaneous error reports (Hicks et al. 2007; Hicks et al. 2008; Hicks, Becker, & Cousins 2006) and 5.2 to 11.8 per 100 orders (Buckley et al. 2007; Wang et al. 2007). Studies which focus on one stage of the medicines use process report higher incidence rates than those which include all types of medication errors. For example, in a study of prescribing errors in surgical patients, Engum & Breckler (2008) reported 308 medication variances in 180 patients. Similarly for administration errors, Prot et al (2004) found an overall error rate of 31.3%.

Analogous to the outpatient setting, the wide variation in the medication error rates is because of differences in definitions of medication errors, the detection methods employed, the study setting and the denominators used to calculate the error rate. As a result comparisons between studies is difficult. For example, the medication error rate was reported as 11.8 per 100 medication orders in one study which used observation to identify the rate of preventable actual and potential adverse drug events in a medical and surgical intensive care unit (ICU) (Buckley et al. 2007). In contrast, another study in general paediatric units used three methods (daily chart review, voluntary reports and solicited information about errors) to detect errors and reported a lower rate of 5.2 per 100 orders (Wang et al. 2007). Aside from the difference in methods used, the study settings were different (ICU vs. general) and the definition used also varied. Wang et al (2007) included any errors in the process of medication delivery, unlike Buckley et al (2007) whose definition included only medication errors that were likely to cause adverse events. A lower error rate in the general unit despite using a wider definition of medication errors suggests that error rates may be higher in intensive care areas compared to general units, and/or that observation is a more efficient method for error detection.

Despite this disparity in incident rates, the literature indicates that errors are most likely to occur at the stages of prescribing and administration. Administration errors account for nearly half to two thirds of errors in studies which used spontaneous reporting (Hicks et al. 2007; Miller, Clark, & Lehmann 2006; Rinke et al. 2007), whereas

prescribing (including transcribing) errors were higher, ranging 40%-86% of errors, in studies which used other error detection methods (Buckley et al. 2007; Kunac & Reith 2008; Wang et al. 2007).

Dose errors are the commonest type of error across all stages of the medicines use process, ranging from 20% to 72% of errors (Buckley et al. 2007; Engum & Breckler 2008; Hicks et al. 2007; Hicks et al. 2008; Kunac & Reith 2008; Rinke et al. 2007; Sangtawesin et al. 2003). Drug administration errors involving infusions are also prone to a high error rate. In one study of infusions in a surgical ICU, 16 dosing errors were detected in 206 infusions (error rate 105.9 per 1000 patient days) (Herout & Erstad 2004). Another study which used high-performance liquid chromatography (HPLC) to compare ordered and measured concentrations of morphine infusions found there was a difference in concentrations of more than ten per cent in 65% of the samples (Parshuram et al. 2003).

There has been one UK study of medication error incidence over the past five years, which investigated prescribing errors (Keady et al. 2005). This audit focussed on analgesic prescribing on two paediatric wards and revealed 33 errors in 159 prescriptions, of which three were considered to be major. Table 2 summarises studies of inpatient medication errors.

Table 2: Studies of inpatient medication errors

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
All types of errors							
Buckley (2007)	US	Paediatric medical/ surgical ICU at a major teaching medical centre	Definitions of medication errors and ADEs, and classification of medication errors according to preventability and severity, were based on the work of Bates et al.	Prospective observational study	Four observational study periods between February and June 2004	Observation	52 errors/ 58 ADE; 42 clinically important. Prescribing = 13/42 Transcription = 5/42 Dispensing = 9/42 Administering = 15/42 Dosing = 11/42 (26.2%) most common Medication error rates: per 100 orders actual preventable ADE rate = 2 potential ADE rate = 9.8
Chuo (2007)	US	Neonatal ICU	MedMARX	Analysis of reports to MedMARX database	2000 to 2005	Spontaneous reporting	266/7329 reports (3.6%); 10/266 (3.8%) harmful Improper dose/ quantity 69.3% (192)
Fahrenkopf (2008)	US	3 free standing urban children's hospitals	Any error in the ordering, transcription, or administration of a medication, whether harmful or trivial	Prospective cohort study	mid-May through to the end of June 2003	Prescription review	125 errors in 10 277 orders Error rate 1.2% No breakdown by type or stage
Hicks (2006)	US	All (any provider in any setting)	Any preventable event that may cause, or lead to, inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer.	Analysis of reports to MedMARX	between January 1 1999 and December 31 2003	Spontaneous reporting	3.3% (19,350 of 580,761) of all records; 4.2% (816/19350) harmful No breakdown by stage Improper dose/ quantity most commonly reported (88/208)
Hicks (2007)	US	Post anaesthesia care unit	Not stated, but same database as above	Analysis of reports to MedMARX	Between September 1 1998 and August 31 2005	Spontaneous reporting	1.8% (59/3260) of all records; 20.3% harmful Prescribing = 18/78 (23.1%) Transcription = 4/78 (5.1%) Dispensing = 6/78 (7.7%) Administering = 49/78 (62.8%) Monitoring = 1/78 (1.3%) No breakdown by type

ADE = Adverse drug event; ICU = intensive care unit

Table 2 - continued

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
All types of errors							
Hicks (2008)	US	All areas using patient controlled analgesia	Not stated, but same database as above	Analysis of reports to MedMARX	July 1 2000 to June 1 2005	Spontaneous reporting	241/ 5404 (4.5%) records; 28 (12%) harmful. No breakdown by stage or type for paediatric patients. Overall improper dose or quantity reported most commonly (38% of all reports)
Holdsworth (2003)	US	A general paediatric unit and a paediatric ICU in a metropolitan medical centre	An event resulting in an injury from a medication or lack of an intended medication. A potential ADE was defined as an error that had the potential to result in a significant injury. Potential ADEs included errors detected before drug administration as well as errors that did not produce significant adverse consequences.	Prospective review	September 15 2000 to May 10 2001	Chart review and staff interviews	ADE = 6/100 admissions, 7.5/1000 patient- days; 18 (24%) life threatening; Medication errors: Preventable actual ADEs = 46/76 (61%) All potential ADEs = 8/100 admissions, 9.3/1000 patient-days Preventable ADE rates/ 1000 patient days = 1.99 (PICU); 2.1 (general unit) No breakdown of errors by stage or type
Kunac (2008)	New Zealand	Paediatric wards at a university affiliated urban general hospital	Medication related events were classified as non-preventable, preventable and potential ADEs, harmless medication errors, trivial rule violations and other events (adapted from the work of Kaushal et al 2001)	Prospective observational cohort study	18 March to 9 June 2002	Chart review, attendance at multi-disciplinary meetings, parents/ carers/children interview and voluntary/ solicited reports	368/696 medication related events were preventable and could be attributed to more than one stage: n (/100 medication orders) Prescribing = 224 (7.1) Dispensing = 34 (1.1) Administration = 164 (5.2) Monitoring = 55 (1.7) Improper dose = most common error type
Miller (2006)	US	Large academic children's institution	"an act or omission (involving medications) with potential or actual negative consequences for a patient that, based on standard of care, is considered to be an incorrect course of action"; encompassed any error along the continuum of medication administration from prescribing, dispensing, recording to administration records, and administration.	Retrospective cohort study	1 July 2001 to 31 January 2003	Spontaneous reporting	1010 error reports/ 581 reported events Prescribing = 298 (30%) Dispensing = 245 (24%) Administering = 410 (41%) Documentation = 57 (6%) After expert review = 899 errors Prescribing = 262 (29%) Dispensing = 223 (25%) Administering = 345 (38%) Documentation = 69 (8%) No breakdown by type

ADE = Adverse drug event; ICU = intensive care unit; PICU = paediatric intensive care unit

Table 2 - continued

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
All types of errors							
Rinke (2007)	US	All settings where chemotherapy medications are used	MedMARX ('and as defined by our institution' - but not specified)	Analysis of reports to MedMARX	January 1 1999 through December 21 2004	Spontaneous reporting	310 error reports including outpatients; 1.6% resulted in harm. Inpatient rates: Administering = 50.3% Dispensing = 23.4% Prescribing = 11.7% Transcribing/ documenting = 7.6% Monitoring = 0.6% Improper dose/ quantity most reported type = 18.9%
Sangtawesin (2003)	Thailand	Paediatric hospital	Not specified	Retrospective review	September 2001 to November 2002	Spontaneous reporting	322/32105 admissions (1%); 2 harmful (0.62%) Prescribing = 114 (35.4%) Dispensing = 112 (34.78%) Administration = 49 (15.22%) Dosing = 83 (25.78%)
Takata (2008)	US	12 freestanding children's hospitals	An injury, large or small, cause by the use (including non-use) of a drug	Cross-sectional study	Between March 18 2002 and May 28 2002	Chart review and application of trigger tool	MEs = 22% of 107 ADEs. No further breakdown of MEs. ADE rate = 11.1 per 100 patients, 15.7 per 1000 patient days and 1.23 per 1000 medication doses.
Wang (2007)	US	Paediatric units of a large academic community hospital.	An error in the process of medication delivery, including those occurring during prescribing, transcribing, dispensing, administering, or subsequent monitoring	Prospective review	February through April 2002	Daily review of documentation, voluntary reporting, and solicitation	865 errors (5.2 /100 medication orders) near-miss rate = 0.96% and preventable ADE rate = 0.09% Ordering = 464 (54%) Transcribing = 278 (32%) Dispensing = 2 (0.2%) Administration = 101 (12%) Monitoring = 11 (1.3%) No breakdown by type

ADE = adverse drug event; ME = medication error

Table 2 - continued

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
Prescribing errors							
Engum (2008)	US	Free-standing tertiary referral centre including paediatric ICU and neonatal ICU	Any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient or consumer	Analysis of spontaneous reports via a computerized online database	January 2004 to June 2006	Spontaneous reporting	1340 medication variances in 757 patients, of which 308 were in 180 patients treated by a surgical subspecialty team. 5% resulted in temporary harm, but 71% had potential to cause harm. Wrong dose = 30/180 instances
Keady (2005)	UK	2 paediatric wards	Minor errors were classed as an inappropriate formulation was prescribed, a minor change of dose was required to aid administration, or cautionary information was missing. Major errors were drug doses that would have had a major impact on mortality or morbidity.	Prospective audit	3 weeks	Prescription review	33 errors in 159 prescriptions for analgesia 3 major errors No breakdown of type
Administration errors							
Parshuram (2003)	Canada	University-affiliated tertiary paediatric centre.	Difference of >10% between ordered and measured concentrations of morphine infusions.	Prospective observational study	Random samples during 7 months	HPLC	150/232 samples (65%) >10% difference; two-fold or greater errors = 13/232 (6%)
Parshuram (2006)	Canada	University-affiliated tertiary paediatric centre	Errors in the measured methotrexate concentration of each bag of 10% or more	Prospective observational study	8 months	HPLC	23% of all infusions; 24/78 bags (31%)
Prot (2004)	France	4 clinical units in a paediatric teaching hospital	Any discrepancy between printed or handwritten physicians' orders and drug delivery to patient, in keeping with the classification developed by the American Society of Hospital Pharmacy.	Prospective study	April 2002 to March 2003	Direct-observation	467 drugs with at least one error /1719 opportunities for error (27.2%); 538 errors overall (31.3%); 302 (17.6%) excluding timing. Timing errors most frequent, followed by route (19%) then dosage (15%)

ICU = intensive care unit; HPLC = high-performance liquid chromatography

Table 2 - continued

First author/ year	Country	Setting	Medication error definition	Study design	Time frame	Method used	Results
Dosing errors							
Herout (2004)	US	Surgical ICU at a tertiary care teaching institution	For non weight-based infusions, any difference in dose recorded or prescribed vs. the dose infusing; for weight-based infusions, a 5% difference between dose infusing and the dose prescribed or recorded. Charting inconsistency = any variation (including omissions) between the recorded information on the flow sheet and what was actually infusing into the patient.	Observational study	January 2 to February 1 2001	Observation and document review	16 dosing errors in 206 infusions; Overall rate 105.9 per 1,000 patient days
Kozer (2006a)	Canada	Tertiary paediatric hospital	Tenfold errors were defined as a dose that was ten times higher or lower than the recommended dose.		between 1 April and 1 November 2000; 12 randomly selected days in summer 2000	Spontaneous reporting; chart review and observation	Spontaneous = 20 reports (1/22500 doses) Chart review = 2/1678 orders (0.12%) Observation = 4/125 orders (3.2%)

ICU = intensive care unit

1.2.1.3 Harm due to errors

Medication errors provide a measure of the quality and accuracy of the medicines use process, but not necessarily the actual outcomes in terms of patient harm. In fact not all medication errors result in adverse events, but as some errors do cause harm or have the potential to do so if they are not intercepted, they are considered a useful proxy measure of outcome (Dean et al. 2005).

Studies in children which assessed preventable ADEs show that the rate of harmful or potentially harmful medication errors is 1.6%-2% of orders, 3%-11.1% of patients or 4.1 to 15.7 per 1000 patient days (Buckley et al. 2007; Gandhi et al. 2005; Holdsworth et al. 2003; Kaushal et al. 2007; Kunac & Reith 2008; Takata et al. 2008; Wang et al. 2007). Spontaneous reports to local and national databases indicate that up to 20% of medication errors may have resulted in actual patient harm (Chuo, Lambert, & Hicks 2007; Hicks et al. 2007; Hicks et al. 2008; Hicks, Becker, & Cousins 2006; Rinke et al. 2008).

The findings of these paediatric studies should be interpreted with caution and take into account some of the methodological limitations. Medication errors are often intercepted and rectified once detected and so a large proportion do not result in actual harm. In addition, studies of medication errors are not designed to examine the resultant effects and often end before any outcomes become apparent. Thus an assessment of potential harm has to be used to consider the effects on patient outcome. In contrast, ADE studies are designed to capture any medication related harm. An assessment of preventability is then made to identify those that are secondary to medication errors.

Assessments of both potential harm due to errors as well as preventability of ADEs are subjective and reliant on the reviewers' knowledge and expertise. The reliability of reviewers' assessments is therefore an important factor when interpreting studies reporting medication error related harm. Most studies use the kappa (κ) statistic to assess the reliability of judgements. The κ statistic provides an indication of the level of agreement between two judges, taking into account agreement by chance. It is calculated by the equation $(O - E)/(1 - E)$, where O=observed agreement and E=expected agreement by chance; a value of 0 indicates poor agreement and 1 indicates total agreement.

Although studies in adults which have used κ suggest good reliability of trained reviewers classifying medication errors and ADE according to preventability,

ameliorability, disability and severity (Morimoto et al. 2004), assessments of preventability and seriousness may be more difficult in children (Kunac et al. 2006). In a study investigating the reliability of reviewer judgements for classification of paediatric inpatient medication related events, the authors reported substantial agreement ($\kappa = 0.73$, 95% CI 0.69 to 0.77) for the presence of an ADE, but only slight agreement for potential ADEs ($\kappa = 0.20$, 95% CI 0.00 to 0.40). Of note, agreement for seriousness classifications as serious versus not serious was moderate ($\kappa = 0.50$, 95% CI 0.46 to 0.54), and for preventability decision was fair ($\kappa = 0.37$, 95% CI 0.33 to 0.41) (Kunac et al. 2006). Other paediatric studies in which κ has been used to assess reliability of reviewers' judgements imply that determining seriousness may be more difficult than preventability. For example, Buckley et al (2007) reported a κ value of 0.14 for error seriousness, which denotes slight agreement, but the κ value for error preventability was 0.93, which is considered to be almost perfect agreement. Similarly, Walsh et al (2006, 2008) reported a κ of 0.4 for seriousness, but 0.8 for preventability, indicating moderate and substantial agreement between reviewers respectively.

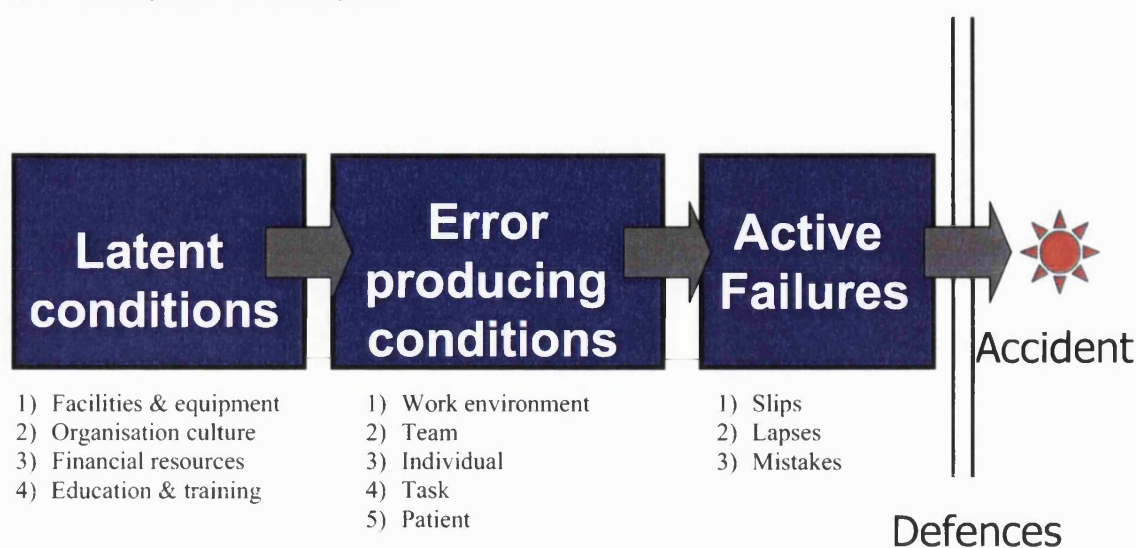
Despite the limitations in reliability of reviewers' judgements, these studies, all from the US, do provide an estimate of the detrimental effects of medication errors on patient safety.

1.2.2 Why do errors occur?

James Reason describes two main models of error theory: the individual model and the system model (Reason 1990). In the first, the individual is considered responsible for the error, and is isolated from any other external factors. The system model considers the individual to be part of a system, the whole of which contributes to the successful conclusion of an action. This model comprises four components: latent conditions, error producing conditions, active failures and defences designed to prevent or mitigate consequences of failure. Accidents or errors happen when the first three factors are aligned and if defences fail; figure 1 provides a schematic of the model. This is now accepted as the main model for errors in the healthcare setting. Inherent in this model is the acceptance that humans will err, and therefore the system must be robust enough to prevent or minimise this.

Figure 1: Human error theory – accident causation model

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1.2.2.1 Causes and contributory factors

Research into adverse drug events shows that lack of information about the patient and/or drug is often the most common causative factor (Leape et al. 1995). In terms of medication errors, lack of information may manifest in the form of omission errors or incomplete information.

Recent studies in adults (Coombes et al. 2008; Dean et al. 2002b) indicate that the common causes of medication errors are active failures (slips in attention, failure to apply rules), error producing conditions (workload, busy ward, communication, lack of supervision and lack of knowledge), and organisational factors (perception of prescribing as a low importance and repetitive low risk chore).

In the past five years, studies of medication errors in children have begun to consider causes and contributory factors, and these appear to be similar to those found in adults. Buckley et al. (2007) found that over 40% (17/42) of the errors were due to active failures (slips and memory lapses 23.8% and rule violations 16.7%), followed by lack of drug knowledge (8/42, 19%), an error producing condition in which the individual's skill and knowledge affects performance. Others have reported errors as a result of performance deficit in 26.8%-51% of cases (Chuo, Lambert, & Hicks 2007; Payne et al. 2007; Rinke et al. 2008). Performance deficit has been defined as an error in which the health care practitioner has the required skills and knowledge to execute a task but errs

nonetheless, and is therefore analogous to skill based slips and memory lapses (active failures) in Reason's model.

Contributory factors comprise the drug itself, route of administration and prescriber characteristics. The medications most often involved in paediatric errors include analgesics, antimicrobials, sedative agents and cardiovascular drugs (Hicks, Becker, & Cousins 2006; Kunac & Reith 2008; Miller et al. 2007; Prot et al. 2005; Takata et al. 2008; Wang et al. 2007); non oral routes, especially the intravenous (IV) route, are more likely to be implicated in errors than the oral route (Kunac & Reith 2008; Losek 2004; Prot et al. 2005). Prescriber characteristics, such as training and seniority of prescribers have also been shown to influence prescribing error rates, with higher rates in non-paediatricians and junior doctors (Kirk et al. 2005; Taylor, Selbst, & Shah 2005). Fahrenkopf et al (2007) reported that depressed residents made 6.2 times as many errors as residents who were not depressed.

1.2.3 Error prevention strategies

One of the key steps in prevention of errors is identifying the cause and then removing or minimising it. This has been done in a couple of ways for paediatric medication errors. Some have used formal prospective hazard analysis techniques, such as failure modes and effects analysis, and identified ordering and administration as failure modes of high severity within the medicines use process (Apkon et al. 2004; Kunac & Reith 2005; Robinson, Heigham, & Clark 2006). This is borne out by the high incidence of medication errors seen for both these types as discussed in the previous section. Others have assessed the possible effects of common sense prevention strategies and suggest that a large proportion of adverse drug events may be averted with the advent of clinical pharmacists (28% outpatient errors; over 80% inpatient errors), computerised physician order entry (74% outpatient errors; 72.7% inpatient errors) and changes in communication between healthcare professionals and/or parent (72% outpatient errors; 75.5% inpatient errors) (Fortescue et al. 2003; Gandhi et al. 2005; Kaushal et al. 2007).

1.2.4 Interventions used to reduce medication errors

Information technology (IT) based solutions such as 'smart' infusion pumps and computerised physician order entry (CPOE), are increasingly being used in an attempt to reduce medication errors in children (table 3). Other interventions include ward based clinical pharmacists, guidelines, educational interventions and non-IT solutions,

such as pre-printed order sheets or the Broselow tape (a colour-coded paper system to aid with medication dosage and equipment sizing for paediatric emergencies). On the whole, the choice of interventions has been using common sense rather than an evidence based approach. A majority of the interventions, such as CPOE, pre-printed order sheets, educational interventions and guidelines have been targeted to reduce prescribing errors. With the exception of guidelines, most have been successful to some degree. In a UK study, a junior doctor tutorial resulted in a statistically significant reduction in prescribing errors on the ward from 1 in 3.3 orders to 1 in 6.1 orders (Davey, Britland, & Naylor 2008). However, the same study reported no change in error rate following guideline implementation. Interventions aimed at reducing administration errors include 'smart' syringe pumps, standardised drug concentrations, unit dose dispensing system and colour coded dosing methods and devices.

Most interventions are often used in combination, thus making it difficult to ascertain which intervention is the most effective. For example, Larsen et al (2005) reported an overall error reduction in administration errors from 3.1/1000 doses to 0.8/1000 doses ($p < 0.001$) and in 10 fold dosing errors from 0.41/1000 doses to 0.08/1000 doses following a three pronged approach using standard drug concentrations, 'smart' syringe pumps and human-engineered medication labels. There was only one comparative study of two different interventions: the Broselow tape and a standardised volume/weight based dose reformulation of resuscitation and critical care medications (reformulated to 0.1mL/kg) (Fineberg & Arendts 2008). In this randomised crossover trial involving 16 volunteers using 3 simulated patients, the proportion of dosing errors with the Broselow tape was higher than the standardised volume/weight based dose reformulation (8 errors vs. 1 error, not statistically significant).

On the whole, CPOE appears to be the most effective for reducing all types of medication errors, with certain errors being eliminated altogether. Reduction in prescribing errors ranges 37.5% to 77.3% (Fontan et al. 2003; Potts et al. 2004); administration errors 6.8% to 8.2% (Fontan et al. 2003; Taylor et al. 2008) and dosing errors 15.6%-100% (Cordero et al. 2004; Farrar et al. 2003; Kirk et al. 2005). Improvements in documentation (Kim et al. 2006) and monitoring (Abboud et al. 2006) have also been demonstrated. Conversely, two studies of computer related errors showed that prescribing errors continued to occur but were different in nature compared to non computer errors. Examples of computer related errors are selection errors from drop-down menus or keypad entry errors (Chuo & Hicks 2008; Walsh et al. 2006).

Table 3: Studies of interventions used to reduce medication errors

First author/ year	Country	Setting	Intervention	Study design	Error type	Method used	Time frame	Results
Information technology based solutions								
Abboud (2006)	US	Tertiary care children's hospital	Corollary order screen within CPOE	Before and after	Monitoring	Electronic query of the CPOE system	September 2003 to November 2003 and January 2004 to March 2004	Appropriate monitoring Pre = 128/159 courses (80.5%) Post = 146/177 (82.5%) Therapeutic levels Pre = 94/111 (84.7%) Post = 100/125 (80%) p = 0.44 Toxic levels Pre = 9 (8.1%) Post = 15 (12%) p = 0.44 Sub therapeutic Pre = 8 (7.2%) Post = 7 (5.6%) p = 0.81 Both Pre = 0 Post = 3 (2.4%) p = 0.29
Brown (2007)	US	NICU in women's and children's hospital	Interactive computerised parenteral nutrition worksheet	Retrospective cross-sectional study	Prescribing	Prescription review	2 weeks in July 2003 and 3 weeks in January 2004	Errors Pre = 44/303 (14.5%) Post = 12/177 (6.8%) Post errors due to data entry or transcription
Chuo (2008)	US	NICU	Computer entry and CPOE	Retrospective review	All errors	Electronic query of MedMARX database	since 1991	Computer entry = 298 errors; CPOE = 45 errors. 71% CPOE errors at prescribing stage.
Cordero (2004)	US	NICU in a university medical centre	CPOE	Retrospective review	Dose prescribing	Pre-CPOE from medical records; post-CPOE data from the computerized lifetime patient record	Not specified	On admission Pre = 14/105 (13%) Post = 0/89 Late onset Pre = 2/31 (6%) Post = 0/28

CPOE = computerised physician order entry; NICU = neonatal intensive care unit

Table 3 - continued

First author/ year	Country	Setting	Intervention	Study design	Error type	Method used	Time frame	Results
Information technology based solutions								
Farrar (2003)	UK	District general hospital	Structured paediatric prescribing screens within electronic prescribing	Before and after audit	Dose prescribing	Prescription review	Not specified	Non-paediatricians – errors (%) Main system = 29/38 (76%) Revised system = 4/33 (12%) Paediatricians – errors (%) Main system = 17/65 (26%) Revised system = 3/80 (4%)
Fontan (2003)	France	Nephrology unit at a paediatric and maternity hospital	Handwritten prescriptions plus ward stock distribution system compared to computerised prescribing plus unit dose drug dispensing system	Cross sectional study	Prescribing and administration	Prescription and chart review	1 February to 31 March 1999	Prescription error rates Computerised prescribing = 419/3943 - 10.6% (2.9% clinically significant) Handwritten = 87.9% 518/589 (4.8% clinically significant) Administration errors Computerised = 22.5% (888/3943) Handwritten = 29.3% (189/646)
Holdsworth (2007)	US	PICU and general paediatric unit at a children's medical center	CPOE with substantial decision support	Prospective review	All types	Chart review	September 2000 to May 2001 (previous study) and between April 1 2004, and October 5 2004	Total ADEs (preventable) per 100 admissions Pre = 6.3 (3.8) Post = 3.1 (2.2) per 1000 patient days Pre = 7.5 (4.5) Post = 4.8 (3.5) Potential ADEs per 100 admissions Pre = 7.9 Post = 2.9 per 1000 patient days Pre = 9.3 Post = 2.4

ADE = adverse drug event; CPOE = computerised physician order entry; PICU = paediatric intensive care unit

Table 3 - continued

First author/ year	Country	Setting	Intervention	Study design	Error type	Method used	Time frame	Results
Information technology based solutions								
Kim (2006)	US	Paediatric oncology in an academic medical centre	Implementation of a CPOE system guided by multi-disciplinary failure modes and effects analysis	Before and after study	Prescribing and dosing	Prescription and chart review	July 31-August 1 2001 and August 14 2001 - August 22 2002; February 3 2003 - February 12 2004	Correct order format (treatment plan) Pre = 50/1255 (4.0) Post = 28/1063 (2.6) RR = 0.66 Correct order format (order) Pre = 26/1153 (2.3) Post = 6/1028 (0.06) RR = 0.26 Order and treatment plan match Pre = 14/1253 (1.1) Post = 67/1112 (6.0) RR = 5.4 Cumulative dose on treatment plan Pre = 5/28 (18) Post = 29/512 (5.7) RR = 0.32 Correct calculation Pre = 3/52 (5.8) Post = 6/1102 (0.54) RR = 0.09 Nursing checklist present Pre = 59/1237 (4.8) Post = 27/1101 (2.5) RR = 0.51
King (2003)	Canada	Tertiary care paediatric teaching hospital	CPOE	Retrospective cohort study using a control group	All types	Spontaneous reporting	April 1 1993 to March 31 1996 and January 1 1997 to December 31 1999	804 MEs 18 ADEs; ME rate per 1000 patient days Overall = 4.49 Control group: Pre = 4.80 Post = 5.19 Intervention group: Pre = 4.48 Post = 3.13
Kirk (2005)	Singapore	Paediatric unit in a university teaching hospital	Computer calculated dosing within CPOE	Prospective cohort study	Dose prescribing	Prescription review using computer database query	Between March 2003 and August 2003	Overall = 19.5% (833/4274) Computer calculated = 12.6% (299/2381) Handwritten = 28.2% (534/1893)

ADE = adverse drug event; CPOE = computerised physician order entry; ME = medication error; RR = relative risk

Table 3 - continued

First author/ year	Country	Setting	Intervention	Study design	Error type	Method used	Time frame	Results
Information technology based solutions								
Larsen (2005)	US	University affiliated tertiary paediatric hospital	Standard drug concentrations, "smart" syringe pumps, and human- engineered medication labels.	Before and after	Administration	Spontaneous reporting	2002-2003	Overall per 1000 doses Pre = 3.1 Post = 0.8 Pharmacy preparation errors Pre = 0.66 Post 0.16 Tenfold dose errors Pre = 0.41 Post = 0.08
Lehmann (2004)	US	NICU at a university hospital	Online TPN calculator (initial and revised versions)	Before and after	Prescribing	Prescription review	October 2 2000 to November 14 2000; November 15 2000 to December 31 2000 and August 27 2002 to October 13 2002	Control = 60 (10.8/100 orders) Phase 1 = 20 (4.2/100 orders) Phase 2 = 8 (1.2/ 100 orders)
Lehmann (2006)	US	Children's hospital at an academic medical centre	Web-based calculator and decision support system for paediatric infusions	Before and after	Prescribing	Prescription review	February to March 2003 and February to April 2004	Orders with at least one error All handwritten orders = 55% (27% before and 70% after) Calculator orders = 6% Error rate per 100 orders Handwritten = 45 before; 120 after Calculator orders = 6
Potts (2004)	US	Multi- disciplinary PCCU at an academic institution	CPOE	Prospective before and after cohort study	Prescribing	Prescription review	October 4 2001 to December 4 2001 and January 4 2002 to March 4 2002	Overall errors per 100 orders Pre = 2662/6803 (39.1) Post = 110/7025 (1.6) potential ADEs per 100 orders Pre = 2.2; Post = 1.3 Medication prescribing errors Pre = 30.1; Post = 0.2/ 100 orders Rule violations per 100 orders Pre = 6.8; Post = 0.1

ADE = adverse drug event; CPOE = computerised physician order entry; NICU = neonatal intensive care unit; PCCU = paediatric critical care unit; TPN = total parental nutrition

Table 3 - continued

First author/ year	Country	Setting	Intervention	Study design	Error type	Method used	Time frame	Results
Information technology based solutions								
Taylor (2008)	US	NICU in an army medical centre	CPOE	Prospective before/ after observational study	Administration	Direct observation	Between August 2004 and June 2005, and August 2005 to April 2006	Variance rate Pre = 19.8% Post = 11.6% (rate ratio 0.53)
Upperman (2005)	US	Tertiary care paediatric hospital	CPOE	Retrospective review	All types	Spontaneous reporting	January 2002 to October 2002 and from November 2003 for 9 months	All ADEs per 1000 doses Pre = 0.3 ± 0.04 Post = 0.37 ± 0.05 Harmful ADEs Pre = 0.05 ± 0.017 Post = 0.03 ± 0.003
Vardi (2007)	Israel	Paediatric critical care department at a children's hospital.	CPOE	Prospective cohort study	All types	Spontaneous reports and chart review	2002 to 2003 and 2003 to 2005	Before = 3/131214 orders After = 0/46970 statistical significance not assessed due to small numbers
Walsh (2006)	US	Paediatric wards in an urban general hospital	CPOE with CDSS	Retrospective review	All types; computer related errors	Chart and prescription review and spontaneous reporting	September 2002 to May 2003	Overall = 104 (53.9 per 1000 patient days; 29.5 per 100 admission; 15 per 1000 medication orders) CREs = 20 (10 per 1000 patient days)
Walsh (2008)	US	NICU, PICU and inpatient paediatric wards at an urban hospital	CPOE with CDSS	Interrupted time-series regression analysis	All types	Chart and prescription review and spontaneous reporting	Between September 2001 and March 2002, and September 2002 and March 2003	Rate/ 1000 patient days Errors Pre = 44.7 Post = 50.9 Serious medication errors Pre = 31.7 Post = 33 Non-intercepted serious ME Pre = 23.1 Post = 20.6 Preventable ADE Pre = 7.9 Post = 6.5

ADE = adverse drug event; CDSS = clinical decision support system; CPOE = computerised physician order entry; ME = medication error; NICU = neonatal intensive care unit; PICU = paediatric intensive care unit

Table 3 - continued

First author/ year	Country	Setting	Intervention	Study design	Error type	Method used	Time frame	Results
Non information technology based solutions								
Fineberg (2008)	Australia	Emergency department at an urban teaching hospital	Broselow paediatric tape and a standardised volume/ weight based dose reformulation of resuscitation and critical care medications to yield 0.1mL/kg	Randomised crossover trial	Dosage error	Simulation	November 20 and December 10 2006	Broselow tape: 8 errors (8%, 0%, 8%) vs. 1 error (0%, 0% and 2%) with comparator (not statistically significant)
Frush (2004)	US	Paediatric emergency centre at a tertiary care medical centre	Colour coded dosing method using colour coded measuring device	Randomized controlled clinical trial.	Dosing administration	Questionnaire	December 15 2002, and March 1 2003	Average (median) deviation Dose determination - Standard = 25.8% (1%) Colour coded = 1.7% (0) Dose measuring - Standard = 29% (17.2%) Colour coded = 0.5% (0)
Kaji (2006)	US	Large, urban emergency medical service	Mandated use of the Broselow tape and pre-calculated drug dosing charts to determine patient's weight according to colour zone	Observational before/after evaluation of a natural experiment	Dosing administration	Chart review	1994 to 1997 and 2003 to 2004	Number of subjects Incorrect dose Pre = 29/ 104 Post = 21/ 37 Dose within 20% of correct dose Pre = 46/ 104 Post = 24/ 37
Kozer (2005)	Canada	Emergency department at a tertiary care paediatric hospital	Pre-printed structured order sheet	Randomized, controlled study	Prescribing	Chart review	18 days during July 2001	Number of orders (%) Overall = 105/787 (13.3%) Control = 68/411 (16.6%) Intervention = 37/ 376 (9.8%) odds ratio: 0.55

Table 3 - continued

First author/ year	Country	Setting	Intervention	Study design	Error type	Method used	Time frame	Results
Multiple interventions including education and guidelines based solutions								
Cimino (2004)	US	PICUs in nine freestanding, collaborating tertiary care children's hospitals	Dosing assists, communication/ educational and floor stock	Pre-test, post-test without a control group.	Prescribing	Pharmacy order entry, PICU nurse order transcription and team based overview	2 weeks before and 2 weeks after (3 months interventions in between)	Overall baseline error rate Pre = 11.1% Post = 7.6% Prescribing errors Pre = 0.22 per order Post = 0.17 per order
Costello (2007)	US	Paediatric critical care centre at a children's hospital	Paediatrics medication safety team; new medication error reporting form and education.	Before and after	All types	Analysis of medication-error reports	Between September and December 2004, February and May 2005, and June and September 2005	Medication-error rate: twofold, threefold, and six fold increase between phases 1 and 2, phases 2 and 3, and phases 1 and 3. Error severity (category D or E) Phase 1 = 46%, 2 = 8%, 3 = 0% Near-miss errors: Phase 1 = 9%, 2 = 38%, 3 = 51%
Davey (2008)	UK	Children's unit of a district general hospital	Junior doctor prescribing tutorial and bedside prescribing guideline	Before and after	Prescribing errors	Prescription chart review	Before = historical control; after = 1 week after introduction of intervention (February 2004 and June 2004)	Tutorial Pre = 76/249 (30.5%) Post = 44/266 (16.5%) Guideline Pre = 59/320 (18.4%) Post = 56/330 (17%)
Frush (2006)	US	Paediatric emergency providers from three study sites	Web-based education program on proper use of the Broselow Paediatric Resuscitation Tape	Randomized controlled clinical trial	Dosing errors	Simulation	Not specified	Use of tape (correct use) Pre = 40.9% (19.2%) Post = 97.7% (97.6%) Average dosing deviation Pre = 24.9%, post = 12.6%
Kozer (2006b)	Canada	Emergency department at a tertiary care paediatric hospital	Short educational intervention (30 minute tutorial)	Prospective cohort study	Prescribing errors	Chart review	18 days during July 2001	Overall = 112/899 orders Control = 46/363 (12.7%) Intervention = 66/533 (12.4%) adjusted odds ratio: 1.07

PICU = paediatric intensive care unit

Table 3 - continued

First author/ year	Country	Setting	Intervention	Study design	Error type	Method used	Time frame	Results
Multiple interventions including education and guidelines based solutions								
Leonard (2006)	US	Paediatric tertiary care academic facility	educational web site with competency examination (A), PDA-based standardized dosing reference (B), a zero-tolerance policy for incomplete or incorrect medication orders (C), prescriber performance feedback (D), and presentation of outcome data at citywide grand rounds (E)	Retrospective study: Baseline and post each intervention	Prescribing	Prescription review using computer program	1 week June 2003 and July 2003, 2 weeks October, November/December 2003 and February 2004, 1 week April 2004 and June 2004	Potential ADE rate (change) per 100 orders Baseline = 78.3 A1 = 80.5 (+2.2) B = 73.4 (-7.1) C = 35.7 (-37.7) D = 36.8 (+1.1) E = 35.3 (-1.5) A2 = 40.2 (+4.9)
Pallas (2008)	Spain	NNU in an urban teaching hospital	3 informative talks about good prescribing practice and the implementation of a pocket personal computer based automatic calculation system	Before and after evaluation study	Prescribing	Prescription review	July 2003 to March 2004 and May to September 2005	Pre = 2498/6320 prescriptions (39.5%) Post = 171/1435 prescriptions (11.9%) Adjusted prevalence ratio = 0.29 (95% CI 0.25-0.34)
Robinson (2006)	US	Haemato-oncology unit at an urban university hospital	Multiple changes including annual educational program and use of pre-printed order sheets	Failure mode and effect analysis based before and after study	All types	Chart review and spontaneous reporting	2001 and 2003	Prescribing errors Pre = 1 Post = 0 Administration errors Pre = 4 Post = 3 Dispensing errors Pre = 3 Post = 1 Potential prescribing errors Pre = 23% Post 14%
Simpson (2004)	UK	Tertiary referral NICU at a maternity hospital	Pharmacist led educational program and dose calculation assessment	Prospective review	All types	Spontaneous reporting	January 2002 to January 2003 (interventions end April 02)	Per 1000 neonatal activity days Baseline = 24.1 Post intervention = 5.1 New doctors = 12.2

ADE = adverse drug event; CI = confidence interval; NICU = neonatal intensive care unit; NNU = neonatal unit; PDA = personal digital assistant

1.2.5 Limitations of the current literature

Whilst research in the field of paediatric medication errors continues to emerge and expand, there are some limitations which prevent data consolidation and generalisation. Firstly, there is no standardised definition of what constitutes a medication error; studies reporting medication errors may include one or all of prescribing, transcribing, administration and dispensing errors. This results in different types of errors being included in the overall error rates reported and contributes to the variation seen.

Several methods have been used to detect medication errors, including prescription chart review, medical notes review, pharmacist identification, trigger tools, direct observation, computer surveillance, voluntary/ spontaneous reports and simulation studies. The detection methods used vary depending on the type of medication error being studied. Some methods are more valid for particular types of errors, and may not identify other types. Prescription chart review and pharmacist identification show a high detection of intercepted prescribing errors (Kaushal 2002), whereas use of trigger tools and medication notes review are better for detecting errors that reached the patient (Ferranti et al. 2008; Takata et al. 2008). Similarly, direct observation is considered the optimal method to detect administration errors, whilst voluntary spontaneous reporting is most likely to underestimate the incidence of all types of errors (Kozler et al. 2006a; Taylor et al. 2004). Another problem with spontaneous reports is the reliability. Reporting may be influenced by various factors, such as reporter beliefs and attitudes, and the reports may not be accurately classified. In one study, ten per cent of spontaneous error reports did not in fact involve a medication error (Miller, Clark, & Lehmann 2006) and in another, reporting rate was increased following the introduction of a paediatrics medication safety team, a new medication error reporting form and education (Costello, Torowicz, & Yeh 2007). Simulation studies, though useful, may overlook the effect of error producing conditions such as environmental and team factors that exist in a real life clinical setting.

The effect of detection methods on medication error rates is illustrated by Kozler et al. (2006a), who compared the incidence of tenfold dose errors between studies using different error detection approaches. They reported that incidence of tenfold errors was highest (3.2% of orders) in a study of mock resuscitations which involved observation and syringe content analysis, followed by a study using chart auditing (0.12% of orders) and the lowest in the analysis of voluntary incident reports (1 in 22,500 doses).

Finally, results from studies conducted in specialist areas may not be generalisable due to differences in the nature and complexity of patients' clinical condition and the drugs used. Similarly findings from single sites or settings in a particular country, may not be transferable to others because of dissimilarities in work processes, training and delivery of healthcare.

1.3 Overview of paediatric medication errors in the UK

Most paediatric medication errors studies have been conducted in the US and Canada, where healthcare delivery is different from the UK. Stages and personnel involved in the medicine use process also vary (Brock & Franklin 2007) and therefore outcomes from these countries cannot be generalised to UK settings.

However, UK studies of medication error incidence in children are lacking, with only eight publications at the time of writing this thesis (table 4). In one study which used disguised observation on two paediatric wards (Nixon & Dhillon 1996), the prescribing error rate was 5.3% and administration error rates were 5.6% and 4.5% for a medical and surgical ward respectively. Higher rates ranging 20% to 76% were reported in three studies which used prescription review to detect prescribing errors in general paediatric inpatients (Davey, Britland, & Naylor 2008; Farrar et al. 2003; Keady et al. 2005). Prescribing errors were most frequently reported, accounting for approximately 70% of reports, in two of the four studies that used spontaneous reports to examine all types of errors (Simpson et al. 2004; Wilson et al. 1998). This differs from other literature where spontaneous reports of administration errors are more frequent. The difference may be because the UK studies involved specialist and intensive care units, where complex prescribing occurs and therefore more errors may happen and/ or be reported at the prescribing stage. Indeed, a higher error reporting rate was seen in the paediatric and neonatal ICUs (0.7% and 0.98% of admissions respectively vs. 0.15% overall reporting rate) in another hospital-wide study of spontaneous reports (Ross, Wallace, & Paton 2000). In the final study of spontaneous reports at a paediatric hospital, administration errors were the commonest and accounted for over 75% of the error reports (Paton & Wallace 1997).

Unfortunately, due to the small numbers of studies and methodological limitations, the findings cannot be generalised. Half of the studies used spontaneous reports, which is considered one of the weakest methods for detecting errors (Flynn et al. 2002; Jha et al. 1998); of those only two reported error rates, one using admissions and the other

activity days as denominators (Ross, Wallace, & Paton 2000; Simpson et al. 2004). Two of the three prescribing error studies focused on a limited number of drugs: one involved 16 drugs, but these were not detailed (Farrar et al. 2003) and another involved analgesics (Keady et al. 2005). As some drugs are more likely to be involved in medication errors than others, error rates from studies which focus on a limited number of medications may not be representative of the overall prescribing error rate. All studies involved paediatric inpatients; there appears to be no data on the incidence of paediatric medication errors in the outpatient setting.

The most comprehensive research to date into UK paediatric medication errors is from a recent multicentre study of prescribing and administration errors on 11 wards (including ICUs) across five different hospitals (Ghaleb 2006). This study used prescription chart review by pharmacists to detect prescribing errors and found 297 errors in 2955 medication orders during a 22 week study period, providing an error rate of 10.1 per 100 medication orders. Incomplete prescriptions accounted for over half of the errors, and dosing errors were the second most common type, occurring in nearly 15% of the prescribing errors. The incidence of administration errors, which included preparation errors but excluded wrong time errors, was investigated using undisguised observations of 161 nurses over a 20 week period. The error rate was 15.5% in 1554 preparations and administrations, with preparation errors and wrong rates of infusion equally accounting for over half of all the administration errors. One limitation of the study is that it did not assess actual or potential harm due to these errors.

The best estimate of medication related harm in UK children comes from the National Reporting and Learning System. Recent figures show that 19% of all incidents reported by hospitals in England and Wales for patients aged 0-17 years involved medication (National Patient Safety Agency 2007). However, as with any data involving spontaneous reports, these figures are likely to underestimate the actual problem due to the level of underreporting. Furthermore, the figures incorporate all incidents that are medication related, even those not involving errors, such as adverse drug reactions. Therefore it is very difficult to assess the extent of harm attributable to medication errors.

Table 4: Published studies of paediatric medication errors in the UK

First author (year)	Setting (ICU = intensive care unit)	Medication error definition	Study type & design	Error type and Method used	Duration of study	Errors/ error rate (only pre-intervention results are stated)
Davey (2008)	Children's unit of a district general hospital	Any preventable event, which may lead to inappropriate medication use or patient harm, while the medication is in the control of the healthcare professional or patient. Criteria identified as good prescribing practice was used to identify prescribing errors	Intervention; Before and after study	Prescribing; prescription chart review	9 days	76 prescribing errors in 249 orders (30.5%)
Farrar (2003)	District general hospital	Not stated	Intervention; Before and after audit	Prescribing; prescription chart review	Not specified	29/38 incorrect prescriptions by non-paediatricians (76%) 17/65 incorrect prescriptions by paediatricians (26%)
Keady (2005)	Two paediatric wards	Minor errors: an inappropriate formulation was prescribed, a minor change of dose was required to aid administration, or cautionary information was missing. Major errors: drug doses that would have had a major impact on mortality or morbidity.	Incidence; Prospective audit	Prescribing; prescription chart review	3 weeks	33 errors in 159 prescriptions for analgesia
Nixon (1996)	Two paediatric wards at a district general hospital	Not stated	Incidence; Observational study	Administration & prescribing; disguised observation	2 weeks	Administration errors = 5.6% and 4.5% for respective wards Prescribing errors = 5.3%
Paton (1997)	Paediatric hospital	Not stated	Incidence; Retrospective review	All types; spontaneous reporting	2 years	92 error reports Administration = 70; Dispensing = 20; Prescribing = 2
Ross (2000)	Paediatric hospital and neonatal ICU at a maternity hospital	Any preventable event that may cause or lead to an inappropriate medication use or patient harm while the medication is in the control of the healthcare professional, patient or consumer	Incidence; Retrospective review	All types; spontaneous reporting	5 years	195 error reports (overall 0.15% of admissions; neonatal ICU 0.98% and paediatric ICU 0.7%)
Simpson (2004)	Tertiary referral neonatal ICU at a maternity hospital	Not stated	Intervention; Prospective review	All types; spontaneous reporting	1 year	105 error reports (24.1 per 1000 neonatal activity days) Prescribing = 71% Administration = 29%
Wilson (1998)	Paediatric cardiac ward and paediatric ICU	A mistake made at any stage in the provision of a pharmaceutical product to a patient	Incidence; Prospective cohort study	All types; spontaneous reporting	2 years	441 error reports. Prescribing = 68% Administration = 25%; Supply = 7%

1.4 Summary

Paediatric medication errors are a global problem. The extent of the problem in the UK has not been fully elucidated as there are very few studies of paediatric medication errors in hospital inpatients and none in the outpatient setting.

Various error prevention strategies have been utilised worldwide, of which information technology, in particular CPOE or electronic prescribing, shows the most promise. This will be explored further in the next chapter which investigates the evidence base for the use of electronic prescribing in children.

Chapter 2 Electronic Prescribing

"I think there is a world market for maybe five computers."

Attributed to Thomas Watson, chairman of IBM, 1943.

(http://en.wikipedia.org/wiki/Thomas_J._Watson)

2.1 Introduction

We have come a long way in the past 60 years since the basic technology used in digital computers, as we know them, came into being. Information technology (IT) has since become a part of everyday life, both in the home and in the workplace. However, the uptake in healthcare settings has been more gradual, beginning with limited use for administrative purposes and by individual departments, such as pharmacy and pathology. It is only in the last decade, that we have seen global promotion of electronic patient records and other technological solutions in healthcare to improve patient and medication safety. National policy in the UK and incentives in the US are key drivers for this. In June 2002, the Department of Health (UK) published “Delivering 21st century IT, Support for the NHS” outlining the 10 year plan for the national IT programme (Department of Health 2002). At the time, the program involved contracts of over £6 billion for modernisation of NHS computer systems in England and was deliverable by the agency now known as Connecting for Health. One of the four main aims was to improve the patient experience with the use of computers and included electronic prescribing (EP) and electronic transfer of prescriptions. Similarly in the US, since the publication of the Institute of Medicine report in 1999, computerised physician order entry (CPOE) systems are being promoted as one of the main approaches to minimising harm due to medicines (The Leapfrog Group 2008); a recent Medicare bill provides financial incentives to doctors who use EP systems (GovTrack.us.H.R.6331--110th Congress 2008).

The focus of this chapter is the adoption, use and impact of EP systems in acute healthcare settings. The chapter begins with a definition of electronic prescribing, and its role in patient and medication safety. This is followed by a review of the evidence base for using EP in paediatric patients. Finally, the literature on barriers to adoption and unintended consequences of EP is described.

2.2 Electronic prescribing systems

Electronic prescribing has been defined 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” (Connecting for Health 2007). The term is often used interchangeably with CPOE,

which involves the use of clinical applications by clinicians (e.g., physicians, nurses, therapists, pharmacists) to enter orders (for tests, medications, services, or other clinical processes) for further processing (storage in a database for record-keeping, routing/communicating to someone or a system performing the test or procedure, for further service delivery) (Agency for Healthcare Research and Quality). Although EP is a broader term encompassing the entire medicines use process as defined above, the terms are often used interchangeably. In this thesis EP will be used, except when referring to literature which focuses on CPOE, when CPOE will be used.

EP systems are complex innovations comprising three main components:

- 1) The technology itself i.e. the hardware and software
- 2) The users i.e. the healthcare professionals that use it, the IT staff that maintain it and the patients that 'experience' it.
- 3) The environment i.e. the organisation within which the system is used.

The key role of EP is the potential to improve medication safety by reducing prescribing errors and facilitating safe administration of medicines with the use of electronic medication administration records in all patient groups (Department of Health 2004; eHealth Initiative 2004). In UK, the National Service Framework for children recommends the use of information technology, including electronic prescribing and decision support systems suitable for paediatrics, to promote evidence based practice and to deliver and support clinical audit and decision-making (Department of Health 2003).

2.2.1 Potential benefits of EP in children

Several studies have assessed the potential preventability of medication errors in children using CPOE and report theoretical reductions ranging 73-93% (Fortescue et al. 2003; Gandhi et al. 2005; Kaushal et al. 2001; Wang et al. 2007). In a study of medication errors in paediatric inpatients, Kaushal et al. (2001) reviewed possible prevention strategies for 616 medication errors out of 10778 medication orders. The authors concluded that CPOE with integrated clinical decision support systems (CDSS) and ward-based clinical pharmacists were two of the most effective prevention strategies, with the potential to reduce potential adverse drug events (ADEs) by 93% and 94% respectively. There were 26 actual ADEs in the study, of which five were considered preventable; four of these were judged as being preventable by CPOE (Kaushal et al. 2001). In 2003, the group analysed the data further by considering ten

prevention strategies for their potential efficiency in reducing overall and potentially harmful error rates (Fortescue et al. 2003). They concluded that basic CPOE can reduce certain types of errors by ensuring completeness and legibility, whilst the addition of CDSS would mean physicians were less likely to make errors with further direction and information. Of the ten strategies considered, computerised medication administration records could also have prevented 27% of all errors reviewed. In another study, Gandhi et al studied adverse drug events in paediatric patients in an ambulatory chemotherapy setting and reported the possibility of preventing 74% of potential adverse drug events using CPOE (Gandhi et al. 2005). More recently, Wang et al. (2007) assessed the preventability of 178 potentially harmful medication errors intercepted by paediatric pharmacists, and judged that CPOE could potentially increase the rate of interception of near misses and preventable ADEs from 54% to 73% ($p < 0.001$).

These studies support the notion that EP has great potential in reducing medication errors in children, but is it actually realised?

2.2.2 EP in paediatrics – current evidence

A literature review was carried out to identify and appraise studies that assessed the impact of using an electronic prescribing system with or without clinical decision support in paediatrics using the following databases: Medline (1950 to June 2008), British Nursing Index (BNID, 1994 to June 2008), Cumulative Index to Nursing and Allied Health Literature (CINAHL, 1982 to June 2008), Embase (1974 to June 2008) and International Pharmaceutical Abstracts (IPA, 1970 to June 2008).

2.2.2.1 Search strategy

The keywords used in the search were:

Electronic prescribing OR computerised prescribing OR computerised order entry OR computerised order entry system OR computer order entry system OR CPOE OR computerised physician order entry OR computerised provider order entry OR computerised prescriber order entry OR electronic medication record OR computerised medication record OR electronic medication administration record OR computerised medication administration record OR computerised medical record system OR hospital medication system OR computerised medication system OR pharmacy information system combined with paediatric OR pediatric OR child OR children OR infant OR neonate OR neonatal OR baby OR babies OR newborn.

The search term 'hospital information system' was initially included, but a review of the first 200 citations yielded no relevant papers and therefore it was excluded. Reviews, commentaries, letters and narrative articles; studies that used electronic prescribing or an electronic medical record to identify other parameters being studied e.g. prescribing patterns for asthma medication; studies of clinical decision support in the absence of electronic prescribing; studies that evaluated utilisation rather than impact of electronic prescribing and studies reporting the use of computers or computer programs for ordering parenteral nutrition were also excluded. Original research papers in the English language, which reported the actual impact of an electronic prescribing system with or without clinical decision support in paediatrics were included.

Retrieved citations were screened by title and abstract for relevance, and bibliographies of review articles were also checked for additional articles. Twenty eight papers met the inclusion criteria and are discussed below according to the study setting, EP system used, study design and outcomes measured.

2.2.2.2 Country and setting

Healthcare delivery and practices are likely to vary by country as well as the care setting; research on the use of EP needs to be interpreted in context.

Majority of the studies were conducted in inpatient settings in the US, with two studies from Canada (King et al. 2003; King et al. 2007), and one each in the UK (Farrar et al. 2003), France (Fontan et al. 2003) and Singapore (Kirk et al. 2005); only five studies involved outpatient, discharge, emergency or ambulatory care settings (Bizovi et al. 2002; Christakis et al. 2001; Davis et al. 2007; Kirk et al. 2005; McPhillips, Stille, & Smith 2005), none of which were from the UK.

Ten studies were set in specialist areas: seven in critical/ intensive care units (Cordero et al. 2004; Del Beccaro et al. 2006; Han et al. 2005; Keene et al. 2007; Potts et al. 2004; Taylor et al. 2008; Vardi et al. 2007), one in nephrology (Fontan et al. 2003), one in oncology (Kim et al. 2006) and one in the emergency department (Bizovi et al. 2002). Thirteen studies were hospital wide, with three involving all drugs (Kaplan et al. 2006; Killelea et al. 2007; Upperman et al. 2005) and ten only a limited number of drugs (Abboud et al. 2006; Bogucki, Jacobs, & Hingle 2004; Chisolm et al. 2006; Christakis et al. 2001; Farrar et al. 2003; King et al. 2007; Kirk et al. 2005; Lehmann et al. 2006; McPhillips, Stille, & Smith 2005; Wrona et al. 2007). The remaining studies involved more than one area: four studies included a mixture of intensive care and general wards

(Holdsworth et al. 2007; King et al. 2003; Walsh et al. 2008; Walsh et al. 2006) whereas the study by Davis et al. 2007 involved three outpatient settings, an outpatient teaching clinic, a clinical practice site and a primary care paediatric clinic.

The diversity in country, settings and medications studied limit the generalisability of the findings.

2.2.2.3 EP systems and level of CDSS

The current EP systems can broadly be divided into two: 1) commercial systems, usually as part of a hospital wide information system, and 2) 'home grown' systems developed at a specific site to provide EP. Inherent differences in the structure, functionality and usability of different systems may influence the outcomes seen.

Most of the studies involved commercial systems, with six commercially available prescribing systems accounting for 17 of the studies (Abboud et al. 2006; Bizovi et al. 2002; Bogucki, Jacobs, & Hingle 2004; Chisolm et al. 2006; Cordero et al. 2004; Del Beccaro et al. 2006; Han et al. 2005; Holdsworth et al. 2007; Kaplan et al. 2006; Keene et al. 2007; King et al. 2003; King et al. 2007; Taylor et al. 2008; Upperman et al. 2005; Walsh et al. 2008; Walsh et al. 2006; Wrona et al. 2007). Eight citations involved systems that were 'homegrown' or had been modified for local use (Christakis et al. 2001; Davis et al. 2007; Farrar et al. 2003; Fontan et al. 2003; Kim et al. 2006; Lehmann et al. 2006; Potts et al. 2004; Vardi et al. 2007), and three papers did not specify which system was in use (Killelea et al. 2007; Kirk et al. 2005; McPhillips, Stille, & Smith 2005).

An important component of EP systems is the nature of the CDSS functions. Although CDSS functionality varied between the EP systems used in children, over half of the studies reported the presence of dose related features, such as dose checking, auto calculations, dosage schedules and age or weight dependent dosing guidelines. One study reported the absence of any CDSS and two did not specify the level of CDSS. Table 5 summarises the levels of CDSS present in all 28 studies, defined as either basic or advanced, based on an adaptation of categories by Kuperman et al (2007).

Table 5: Levels of clinical decision support within EP systems used in paediatric patients

First author (year)	Basic clinical decision support					Advanced clinical decision support					Other*
	Drug-allergy checking	Basic dosing guidance	Formulary decision support	Duplicate therapy checking	Drug-drug interaction checking	Dosing support for paediatric patients	Dosing support for renal insufficiency	Guidance for medication related laboratory testing	Drug-disease contraindication checking	Order sets and/or sentences, corollary orders and rules	
Abboud (2006)			✓					✓			✓
Bizovi (2002)		✓									
Bogucki (2004)	✓	✓		✓	✓					✓	
Chisolm (2006)										✓	
Christakis (2001)										✓	
Cordero (2004)	✓	✓		✓	✓	✓					
Davis (2007)										✓	
Del Beccaro (2006)	✓					✓				✓	
Farrar (2003)						✓					
Fontan (2003)		✓	✓		✓						
Han (2005)	✓				✓						✓
Holdsworth (2007)		✓				✓					
Kaplan (2006)			✓								✓
Keene (2007)										✓	
Killelea (2007)						✓	✓				
Kim (2006)			✓			✓		✓			
King (2003)	*	*	*	*	*	*	*	*	*	*	*
King (2007)											✓
Kirk (2005)		✓									✓
Lehmann (2006)		✓				✓					
McPhillips (2005)											✓
Potts (2004)	✓	✓			✓					✓	
Taylor (2008)				✓	✓	✓					
Upperman (2005)										✓	
Vardi (2008)						✓	✓				✓
Walsh (2006)	✓	✓			✓	✓				✓	
Walsh (2008)	✓	✓			✓	✓				✓	
Wrona (2007)								✓		✓	

* Other includes alerts e.g. weight-age alerts, no specific details of clinical decision support characteristics and clinical evidence modules.

2.2.2.4 Study design

Randomised controlled trials are considered the most robust study design with the least risk of bias in the results, whereas other study designs are thought to provide a lower grade of evidence. However, there have been only two studies of EP in children which used randomised controlled trials (Christakis et al. 2001; Davis et al. 2007). In both these studies, the prescriber was randomised to either receive evidence based prompts at the point of prescribing or not. Of the remainder, quasi-experimental designs were used most often, with eighteen studies involving a comparison of outcomes before and after implementation and six non-controlled comparative trials (Chisolm et al. 2006; Fontan et al. 2003; King et al. 2003; Kirk et al. 2005; McPhillips, Stille, & Smith 2005; Wrona et al. 2007). Two of the publications used observational studies to assess outcomes post intervention (Killelea et al. 2007; Walsh et al. 2006).

2.2.2.5 Outcome measures

Several different outcome measures have been studied to assess the effect of EP including one or more of: patient safety related outcomes i.e. mortality and medication errors (table 6), adherence to guidelines and policies (table 7), time spent by healthcare professionals, users' views, financial impact and length of stay (table 8). These are described in detail in the following sections.

2.2.2.5.1 Patient safety related outcomes

A majority of the studies (19/28) assessed patient safety related outcomes. Three studies measured mortality rates (Del Beccaro et al. 2006; Han et al. 2005; Keene et al. 2007), whilst sixteen used a process based approach and studied the effects on medication errors. A third (10/16) of the medication error studies focussed specifically on prescribing errors, with three of these involving dosing errors (Cordero et al. 2004; Kirk et al. 2005; McPhillips, Stille, & Smith 2005). Of the remainder, one assessed the effect of EP on administration variances (Taylor et al. 2008), one both prescribing and documentation errors (Kim et al. 2006), one both prescribing and administration errors (Fontan et al. 2003), three included all types (prescribing, dispensing, administration or monitoring) of errors (Holdsworth et al. 2007; King et al. 2003; Upperman et al. 2005) and one studied the frequency and types of computer related errors (Walsh et al. 2006). Six studies considered actual or potential adverse drug events secondary to medication

errors (Holdsworth et al. 2007; King et al. 2003; Potts et al. 2004; Upperman et al. 2005; Walsh et al. 2008; Walsh et al. 2006).

It is important to consider the detection method when interpreting results of medication error studies, as the error type and rates will be influenced by the choice of method. Chart review was used most often to detect medication errors (Cordero et al. 2004; Fontan et al. 2003; Holdsworth et al. 2007; Kim et al. 2006; McPhillips, Stille, & Smith 2005; Walsh et al. 2008; Walsh et al. 2006). This method is particularly useful for detecting prescribing errors, especially those that have not been intercepted, though it will also detect other types of medication errors (Kaushal 2002). Non-intercepted prescribing errors are more likely to be detected by pharmacist identification using prescription review. Farrar et al. (2003) and Potts et al. (2004) used pharmacist review of prescriptions to detect errors at the ordering stage. One study of dosing errors used a method analogous to prescription review: Kirk et al. (2005) queried the database of a computerised prescribing system to assess the effect of computer calculated dosing on dose prescribing errors. There was one study of medication administration variances using observation (Taylor et al. 2008), a method which is considered to be most suitable for studying administration errors. Two studies used analysis voluntary reports (King et al. 2003; Upperman et al. 2005). This method is considered least successful in detecting medication errors and ADEs, as demonstrated by the low numbers reported in these two studies. King et al. (2003) detected merely 18 ADEs and 804 medication errors over a six year period; Upperman et al. (2005) reported ADEs rates of 0.3 ± 0.04 and 0.37 ± 0.05 per 1000 doses, pre and post CPOE respectively.

The results indicate that on the whole, there was a positive effect on medication errors across all stages of the medicines use process following the implementation of EP with or without CDSS. In one study there was a 6% fall in the prescribing error rate (Bizovi et al. 2002). Another study reported a much larger reduction of 95.9% in the overall medication prescribing error rate as well as a 40% reduction in potential ADEs on a paediatric critical care unit (Potts et al. 2004). A recent study by Walsh et al. (2008) showed a 7% fall in the level of non-intercepted serious medication error rates, but found no change in the rate of harm secondary to errors after CPOE.

Others have demonstrated the benefits of EP on dosing errors, which are considered the commonest type of error in this patient group. For instance, Cordero et al. (2004) reported that gentamicin dosing errors were eliminated after the introduction of CPOE.

Similarly, Kirk et al. (2004) found that dosing errors were lower (28.2% vs. 12.6%) in prescriptions generated using a computerised calculator for medication dosing.

A reduction in administration and transcription errors was also seen. Taylor et al. (2008) showed a statistically significant reduction in medication administration variances from 19.8% to 11.6% of all administrations. Upperman et al. (2005) reported that transcription errors were eliminated after CPOE.

Conversely, two studies (Han et al. 2005; Walsh et al. 2006) showed a negative outcome as a consequence of CPOE implementation. Walsh et al. (2006) assessed the number of preventable adverse drug events and serious medication errors that were either directly caused by or not prevented by the computer system. They found four new types of errors with the computer system that would not normally be seen with handwritten prescriptions: duplication medication orders, drop-down menu selection errors, keypad entry errors and order set errors. Errors not prevented by the computer system included failure to change therapy in view of laboratory results. Han et al. (2005) reported an unexpected increase in mortality rates in paediatric ICU patients who were transferred in for special care and suggested that this may in part be attributed to program implementation and systems integration issues rather than the CPOE system itself. However, two subsequent studies involving similar methods and patient populations found no association between implementation of CPOE and increase in mortality (Del Beccaro et al. 2006; Keene et al. 2007).

Table 6: Studies of EP in children reporting patient safety outcomes (mortality and medication errors)

First author (year)	Country	Intervention	Study Design	Study population	Outcome measure	Findings
Del Beccaro (2006)	US	CPOE with clinical decision support	Retrospective data abstraction pre (13 months) and post (13 months)	Paediatric ICU	Mortality rate	No clinically significant change in mortality following implementation
Han (2005)	US	CPOE with decision support	Retrospective data extraction pre (13 months) and post (5 months)	ICU – children admitted via interfacility transport	Mortality rate	Mortality rate increase from 2.8% (39/1394) pre to 6.57% (36/548) post implementation; odds ratio 3.28, 95% Confidence Interval: 1.94-5.55
Keene (2007)	US	CPOE	Retrospective pre (two 6 month periods) and post (6 months)	Paediatric ICU and neonatal ICU	Mortality rate	No clinically significant change in mortality following implementation
Bizovi (2002)	US	Computer assisted prescription writer	Retrospective pre-post (2 months each, 1 year apart)	Emergency department	Prescribing error and pharmacist clarification rate	Fall in prescribing error rate from 8.2% (20/244) to 2.4% (2/84); clarification rate from 11.1% (27/244) pre to 2.4% (2/84) post
Cordero (2004)	US	CPOE with decision support	Retrospective review of charts and notes pre (6 months) and post (6 months)	Neonatal ICU Very low birth infants	Medication (gentamicin dosing) error rates	No medication dosing errors post implementation.
Farrar (2003)	UK	Re-design of electronic prescribing screens for 16 drugs	Before and after audit (not clear but appears to be prospective chart review by pharmacist; time of study also unclear, number in study not explicit)	All children prescribed drugs involved in change	Prescribing error (no definition provided)	Prescribing error rate reduced from 76% to 12% for non-paediatricians and from 26% to 4% for paediatricians
Fontan (2003)	France	Computerised prescribing plus ward stock distribution system	Prospective 8 week review of prescription and medication administration record.	Nephrology unit: children admitted to 12 randomly chosen wards during the study period	Prescribing and administration errors	Prescription errors lower: 10.6% in computerised compared to 87.9% in handwritten prescriptions; clinically significant errors also lower 2.9% vs. 4.8% Administration errors overall rate of 23.5%, lower at 22.5% for computerised compared to 29.3% for handwritten

CPOE = computerised physician order entry; ICU = intensive care unit

Table 6 - continued

First author (year)	Country	Intervention	Study Design	Study population	Outcome measure	Findings
Holdsworth (2007)	US	CPOE with substantive clinical decision support system	Prospective pre (9 months) and post (7 months)	Paediatric ICU and general paediatric care unit	Preventable and potential adverse drug events	Total ADEs (preventable) per 100 admissions Pre = 6.3 (3.8) Post = 3.1 (2.2) per 1000 patient days Pre = 7.5 (4.5) Post = 4.8 (3.5) Potential ADEs per 100 admissions Pre = 7.9 Post = 2.9 per 1000 patient days Pre = 9.3 Post = 2.4
Kim (2006)	US	CPOE designed to address failure modes previously identified through failure mode and effect analysis	Before and after study, 2 phase daily audit for 241 days before and 296 days after CPOE deployment	Paediatric oncology, all orders during study periods	Impact of CPOE on process errors using successful correct completion rates of specific steps of high importance	Post (RR=relative risk) <ul style="list-style-type: none"> • improper dosing less likely RR 0.26 95% CI 0.11-0.61 • incorrect dose calculations RR 0.09 95% CI 0.03-0.34 • missing cumulative dose RR 0.32 95% CI 0.14-0.77 • incomplete nursing checklist RR 0.51 95% CI 0.33-0.80 • no difference in improper dosing on treatment plan • higher likelihood of not matching orders to treatment plans
King (2003)	US	CPOE	Retrospective cohort study (2 medical with CPOE vs. 1 medical + 2 surgical without) 3 years before and 3 years after using spontaneous incident reports	Paediatric inpatients on 3 medical and 2 surgical wards	Medication error (all types) and adverse drug event rates.	804 MEs and 18 ADEs overall ME rate of 4.49/1000 patient days. ME rate/1000 patient days increased from 4.80 to 5.19 in control group compared to a 40% fall 4.48 to 3.13 in intervention group

ADE = adverse drug event; CI = confidence interval; CPOE = computerised physician order entry; ME = medication error; ICU = intensive care unit

Table 6 - continued

First author (year)	Country	Intervention	Study Design	Study population	Outcome measure	Findings
Kirk (2004)	Singapore	Computer calculated dose as part of EP + clinical decision support system	Prospective cohort study over 6 months	Outpatient clinic, emergency department and discharge; two drugs (paracetamol and promethazine)	Medication dosing errors (underdose, overdose, no frequency, no dose, excessive total daily dose)	Overall medication error rate 19.5% (833/4274), with lower rates (12.6% vs. 28.2%) for computer calculated doses. Computer calculated dose errors all due to changing or overriding computer recommendation.
Lehmann (2006)	US	Web-based calculator + clinical decision support system	Pre (5 weeks) and post (6 weeks and 3 days)	Paediatric inpatients receiving continuous intravenous infusions	Prescribing errors and pharmacy dispensing/preparation errors	55% errors in all handwritten orders vs. 6% calculator generated orders.
McPhillips (2005)	US	CPOE not paediatric clinical decision support system	Population based retrospective survey (2 year period)	Ambulatory paediatrics (22 drugs of interest)	Prevalence of potential medication dosing errors ($\pm 10\%$ or out of adult dose ranges = error)	1933 children, 15% (280) potential medication errors (147 overdose, 133 underdose) <ul style="list-style-type: none"> • No difference in site with CPOE except better weight documentation • Dosing error in 1 in 5 under 4yrs, 1 in 5 on prn, 1 in 6 on analgesics • 22 drugs accounted for 1/3 of all drugs, no effort to ascertain if deviation in dose intentional
Potts (2004)	US	CPOE + advanced clinical decision support system	Prospective cohort study pre and post (2 months each)	Paediatric critical care unit	Errors that occur during ordering process	13828 orders, 514 patients, 268 pre and 246 post. <ul style="list-style-type: none"> • Potential ADEs 2.2/100 orders vs. 1.3/100 orders • ME (prescribing) 30.1 vs. 0.2/100 orders • Rule violations 6.8 vs. 0.1/100 orders All statistically significant.
Taylor (2008)	US	CPOE	Prospective pre (11 months) and post (9 months) observational study	Neonatal ICU	Administration variances	Variance rate decreased from 19.8% to 11.6%, risk ratio 0.53, after CPOE. Initially higher rate in "rollout" period (26.5%)

ADE = adverse drug event; CPOE = computerised physician order entry; EP = electronic prescribing; ICU = intensive care unit; ME = medication error

Table 6 - continued

First author (year)	Country	Intervention	Study Design	Study population	Outcome measure	Findings
Upperman (2005)	US	CPOE	Retrospective evaluation and prospective analysis pre and post (9 month study period).	Children's hospital	Any error in prescribing, dispensing, administering and monitoring medication regardless of outcome.	<ul style="list-style-type: none"> • Transcription errors eliminated (no figures stated) • All ADEs pre 0.3 ± 0.004 per 1000 doses vs. post 0.37 ± 0.05 ($p=0.3$) • Harmful ADEs pre 0.05 ± 0.017 per 1000 doses vs. post 0.03 ± 0.003 ($p=0.05$) • NNT = CPOE would have prevented 1 ADE every 64 pt days (95% CI 25-100)
Vardi (2007)	US	CPOE + clinical decision support system	Prospective cohort study pre (1 year) and post (2 years)	Children's hospital, paediatric critical care department	Prescribing errors	3 errors before and non afterwards
Walsh (2006)	US	CPOE with decision support	Retrospective review using an active surveillance method (3 to 12 months after implementation)	Urban teaching hospital General and surgical inpatients, PICU and NICU	Frequency and types of computer related errors (CREs)	<p>24 handwritten orders during study periods, none which contained errors.</p> <p>26 ADEs of which 12 = errors</p> <p>Total 104 errors; 71 serious MEs of which 46 reached patient. 71% of these were in ordering stage – 4 of these resulted in patient in injury (not caused or prevented by computer) and 33 had little potential for harm</p> <p>20 CREs, 7 of which serious</p> <p>4 categories: duplicate orders 2, drop down menu selection errors 9, keypad entry error 1 and order set errors 8</p>
Walsh (2008)	US	CPOE with decision support	Time interrupted series regression analysis pre (7 months) and post (9 months)	Urban hospital, PICU, NICU and surgical and medical paediatric ward beds	Non intercepted serious medication errors	7% drop in the level of rates of non-intercepted serious medication errors ($p=0.0495$); no change in the rate of injuries as a result of error after CPOE.

ADE = adverse drug event; CPOE = computerised physician order entry; ME = medication error; NICU = neonatal intensive care unit; NNT = number needed to treat; PICU = paediatric intensive care unit

2.2.2.5.2 Adherence to guidelines and policy

Ten out of the 28 studies investigated the effect of EP on adherence to drug use guidelines, clinical recommendations and medication policies.

The use of EP systems with computerised reminders (Bogucki, Jacobs, & Hingle 2004), real time messages to prescribers displaying evidence based recommendations for the treatment of specific conditions (Christakis et al. 2001; Davis et al. 2007; King et al. 2007) and condition specific order sets (Abboud et al. 2006; Chisolm et al. 2006; Wrona et al. 2007) resulted in optimised drug use. Bogucki et al. (2004) studied the effect of a computerised reminder within the CPOE system on methylprednisolone usage during a national shortage and reported a 55% relative reduction in the drug's use. A change in prescriber behaviour was seen following the presentation of real time messages displaying evidence based recommendations for the treatment of specific conditions (Christakis et al. 2001; Davis et al. 2007; King et al. 2007). In a randomised controlled trial, Christakis et al. (2001) reported a 34% greater reduction in the number of antibiotic prescriptions for less than ten days by prescribers randomised to receive real time messages displaying evidence based recommendations for the treatment of otitis media. Similarly Davis et al. (2007) found that prescribers randomised to receive real time messages displaying evidence based recommendations for a number of conditions showed a 8% improvement in prescribing practices compared to controls. The authors reported that the intervention effectiveness did not decrease with time. Likewise King et al. (2007) reported a 13% fall in antibiotic use after the implementation of a clinical evidence module integrated in CPOE.

Documentation of clinical monitoring parameters was better as a result of using order sets within EP system (Abboud et al. 2006; Wrona et al. 2007), but the effect on actual monitoring was variable, with one study showing no difference in aminoglycoside monitoring (Abboud et al. 2006) and another reporting improved monitoring of respiratory rate in children using patient controlled analgesia (Wrona et al. 2007).

There was one study of physician acceptance of dosing and frequency decision support elements; only one third of the suggestions were accepted exactly, with the remainder being altered by the physicians at the time of prescribing (Killelea et al. 2007).

Compliance to verbal order policies improved by 12% to 15%, with fewer verbal orders following the implementation of EP (Kaplan et al. 2006; Upperman et al. 2005).

Table 7: Studies measuring effect on adherence to guidelines and policy

First author (year)	Country	Intervention	Study Design	Study population	Outcome measure	Findings
Abboud (2006)	US	Aminoglycoside corollary order screen in CPOE with decision support	Before and after study (3 months each)	Tertiary care children's hospital	Rate of compliance with laboratory monitoring of aminoglycoside levels and the effect of computerised corollary orders	No difference between study periods. Overall 86.9% compliance with recommendations; no change with the introduction of computerised corollary orders. 31 each with no monitoring, reasons similar for both except more without explanation pre compared to post (p=0.06)
Bogucki (2004)	US	Computerised reminder on CPOE system	Sequential before and after case study (1 month each)	Children's hospital	Impact on methylprednisolone use during a national shortage	55% relative reduction in methylprednisolone use from 209(65%*) to 112(35%*) **% of all corticosteroid orders (n=2124)
Chisolm (2006)	US	CPOE	Quantitative pre and post order set implementation. Qualitative focus group study (2 year period)	Children's hospital	Evaluate relationship between asthma order set use and processes of care using 1)use of systemic corticosteroids 2)use of pulse oximetry and 3) use of metered dose inhalers.	261 pre-set (pre-implementation), 63 no-set (post but not used) and 466 order set (post and used) patients Significant improvement in all three outcomes in order set patients even when adjusted for age, admit type, co-morbidities and length of stay. No differences in cost or length of stay.
Christakis (2001)	US	Point of care evidence based message system integrated in an on-line prescription writer	Randomised controlled trial (8 months)	Primary care paediatric outpatient clinic affiliated with university training program	Proportion of prescriptions for otitis media that were for <10 days and frequency with which antibiotics were prescribed	34% greater reduction in antibiotics for < 10 days in intervention group and less likely to prescribe antibiotics than control.
Davis (2007)	US	Point of care evidence based message system integrated in an on-line prescription writer	Cluster randomised controlled trial (50 months at one site and 18 months at another)	Outpatient teaching clinic and a clinical practice site; and primary care paediatric clinic	Changed physician behaviour in accordance with the intervention message: combined and separate for each condition	Prescriptions dispensed in accordance with evidence improved in intervention group (adjusted difference 8%, 95% confidence interval 1%-15%). Intervention effectiveness did not decrease with time.

CPOE = computerised physician order entry

Table 7 - continued

First Author	Country	Intervention	Study Design	Study population	Outcome measure	Findings
Kaplan (2006)	US	Electronic prescribing as part of a larger integrating clinical information system	Retrospective review pre, during and post intervention (1 week each month: 9 months handwritten and 18 months electronic)	Tertiary care children's hospital All areas except haematology-oncology	Rate of verbal orders (signed and unsigned).	2094±65 (10%) verbal orders post compared to 22% pre (unsigned dropped from 43% to 9% p=0.0001)
Killelea (2007)	US	CPOE with dosing clinical decision support	Retrospective analysis (8 and ½ months)	Paediatric inpatients at a large urban teaching hospital	Acceptance of CPOE generated dose and frequency suggestions	8822/27313 orders with suggestions (32.3% acceptance). Of the remaining, 47.1% changed for dose, 13.3% for frequency and 39.6% for both.
King (2007)	Canada	Clinical evidence module integrated in CPOE	Pre and post (4 months each, one year apart)	Tertiary care paediatric hospital	Frequency of ordering of antibiotics, bronchodilators and corticosteroids	Antibiotic use fell from 35% to 22% (p = 0.016); no change in steroid use; less variation in bronchodilator prescribing.
Upperman (2005)	US	Electronic prescribing	Pre and post retrospective evaluation and prospective analysis (9 months)	Children's Hospital	Verbal order compliance	Verbal order compliance 80% pre vs. 95% post
Wrona (2007)	US	Computerised order sets within CPOE	Retrospective analysis comparing no order set, patient controlled analgesia order set with (anaesthesia) or without (general) acute pain service input (15 months)	Children's hospital	Frequency of order set use, relationship between order set type and documentation compliance and negative occurrence	Surgical unit and PICU more likely to use anaesthesia order sets compared to pulmonary and haematology/oncology units who preferred no order sets (p≤ 0.0001). Appropriate monitoring and documentation of respiratory rate and oxygen saturation more likely with anaesthesia order set use.

CPOE = computerised physician order entry

2.2.2.5.3 Time

Two studies assessed the effect of EP on time taken for activities within the medicines use process. Cordero et al. assessed the effect of EP on the time interval between initiation and completion of pharmacy orders in a neonatal intensive care unit. They reported a reduction in medication turnaround time for caffeine, and an increase in the proportion of doses administered within 2 and 3 hours of prescribing in a neonatal intensive care unit (Cordero et al. 2004). Vardi et al. (2007) reported a statistically significant reduction in the time required to prepare a resuscitation drug order form in a paediatric critical care department, following the implementation of CPOE with CDSS, from nearly 15 minutes to 2 minutes 14 seconds for a single user.

2.2.2.5.4 Users' views

Few studies of EP in children have assessed users' views. Chisolm et al. (2006) used focus groups to explore physicians' perspectives about CPOE and computerised order set use, but only reported on utility of order sets rather than perspectives about CPOE. King et al. (2007) carried out a survey of students and residents to address utilisation, usefulness, potential improvements and general applicability of a clinical evidence module integrated in CPOE on the management and clinical outcome of children with bronchiolitis. All respondents in this study agreed that the module had been educational and point of care evidence had merit if expanded to other clinical conditions.

2.2.2.5.5 Financial Impact

The financial impact of EP systems in paediatric patients has not been evaluated formally, but two studies reported this as a secondary outcome. One study found a coincidental annual cost reduction of \$36,552 following the implementation of a computerised reminder system within CPOE during a national methylprednisolone shortage (Bogucki, Jacobs, & Hingle 2004). The second study considered financial impact of order set use within CPOE on the basis of length of stay, pharmacy costs and inpatient charges, but found no differences (Chisolm et al. 2006).

2.2.2.5.6 Length of stay

Only one study (King et al. 2007) compared length of hospitalisation following introduction of a clinical evidence module but found no differences (2.8 days before, 2.9 days after; $p = 0.125$).

Table 8: Studies of EP in children using non-clinical outcome measures

First author (year)	Country	Intervention	Study Design	Study population	Outcome measure	Findings
Studies measuring effect on time						
Cordero (2004)	US	CPOE with decision support	Retrospective pre (6months) and post (6 months)	Neonatal ICU Very low birth infants	Time interval between initiation and completion of pharmacy and radiology orders	Medication turnaround time reduced from 10.5±9.8hrs pre to 2.8±3.3hrs post implementation. Caffeine administered within 2 hours increased from 10 to 35%, within 3 hours increased from 12 to 63%
Vardi (2007)	US	CPOE + clinical decision support system	Prospective cohort study pre (1 year) and post (2 years)	Children's hospital, paediatric critical care department	Time required for preparation of resuscitation drug order form	Mean time to completion of the simulated drug order form (vs. printing computerised one) was reduced from 14minutes 42 seconds to 2 minutes 14 seconds for a single user (p<0.000)
Studies incorporating user surveys						
Chisolm (2006)	US	CPOE	Quantitative pre and post order set implementation. Qualitative focus group study (2 year period)	Children's hospital	Attitudes and determinants of asthma order set use	2 main themes from focus groups – social determinants and quality determinants.
King (2007)	Canada	Clinical evidence module integrated in CPOE	Pre and post (4 months each, one year apart)	Tertiary care paediatric hospital	Trainee use of perception of the system	55% unaware of availability; more medical students found the review clinically helpful than paediatric residents (all vs. 29%); all agreed that it was educational.
Studies assessing financial impact and length of stay						
Bogucki (2004)	US	Computerised reminder on CPOE system	Sequential before and after case study (1 month each)	Children's hospital	Impact on methylprednisolone use during a national shortage	55% relative reduction in methylprednisolone use from 209(65%*) to 112(35%*) *% of all corticosteroid orders (n=2124) Co-incident cost saving
Chisolm (2006)	US	CPOE	Quantitative pre and post order set implementation. Qualitative focus group study (2 year period)	Children's hospital	Financial outcomes on the basis of lengths of stay and inpatient charges.	No differences in total cost, pharmacy cost or length of stay
King (2007)	Canada	Clinical evidence module integrated in CPOE	Pre and post (4 months each, one year apart)	Tertiary care paediatric hospital	Hospital length of stay	No change (pre = 2.8 days, post = 2.9 days; p = 0.125)

CPOE = computerised physician order entry; ICU = intensive care unit

2.3 Discussion of the literature on EP in children

The papers reviewed here suggest benefits in reduction of medication errors (up to 96%), and potential ADEs (up to 40%), though there is insufficient research to draw conclusions about the effects on actual patient outcomes. This positive effect on medication error rates is consistent with that seen in adult patients. A recent systematic review on the effect of EP on medication errors and ADEs (27 studies included of which 7 involved paediatric patients) reported relative risk reductions of 13%-99% in medication error rates, 35%-95% in potential ADEs and 30%-84% in ADEs (Ammenwerth et al. 2008).

Other benefits of EP in adult inpatients have on occasion been shown to include improvements in the quality of prescribing, medication turnaround times, physician time, nurse drug administration time, and financial gain (Bates et al. 1998; Bates, Boyle, & Teich 1994; Franklin et al. 2007; Kaushal et al. 2006; Mekhjian et al. 2002).

However, there is limited evidence to assume similar benefits in the outpatient setting (Eslami, Abu-Hanna, & de Keizer 2007). There are only isolated studies which have assessed these outcomes in paediatrics (Bogucki, Jacobs, & Hingle 2004; Chisolm et al. 2006; Cordero et al. 2004).

Research into the effects of EP in children is predominantly from the US hospital inpatient setting and has assessed the impact of EP either in specialist inpatient areas or using a limited number of drugs. The only UK study involving prescribing errors in hospitalised children is weak in design (Farrar et al. 2003). Of the few studies that have assessed the impact of EP in the paediatric outpatient setting, none have been from the UK. Due to differences in delivery of healthcare across countries, different settings and the EP systems used (including level of CDSS), it is not possible to generalise the findings.

The majority of the publications in this review involved before and after studies, with only two randomised controlled trials. The latter is considered the gold standard of study design, but is near impossible to achieve, and indeed of questionable value, in this field due to the complicated nature of the technology as well as local differences e.g. patient groups involved and level of clinical decision support systems installed.

Iterative evaluations, specific to the organisation, may be more appropriate in providing insights into human factors such as usability, workflow integration and clinician time, as

well as outcomes of patient safety and financial benefit (Barber 2004; Classen, Avery, & Bates 2007).

2.4 Barriers to EP adoption and utilisation

Despite global policies and incentives to promote the use of EP or CPOE for improving patient safety, uptake and utilisation has been slow, probably due to the limited supporting evidence. US figures indicate adoption rates in the hospital setting as low as 5-10% for CPOE (Pedersen, Schneider, & Scheckelhoff 2008; The Leapfrog Group 2008) and about 7% of 560,400 for office-based physicians, with 73% of 57,500 pharmacies actively receiving electronic prescriptions (Steinbrook 2008). In the UK, the NPfIT has faced delays and the original deadline for EP implementation in acute Trusts, which was due in 2005, has lapsed. General practitioners in the UK have been using computers to prescribe for over a decade, but the electronic transmission of prescriptions service is a recent development, with the electronic prescription service being used for over 24% of daily prescription messages (NHS Connecting for Health 2008).

The literature on barriers to EP adoption and utilisation is limited. A study involving senior management from 26 hospitals in the US identified physician and organisational resistance, high CPOE cost and lack of capital and product/ vendor immaturity as the top three barriers to implementation (Poon et al. 2004). Similarly, in the outpatient setting, cost, time to install the system and change office procedures, and uncertainty about acceptance of electronic prescriptions by local pharmacies were the three main barriers as perceived by physicians (Pizzi et al. 2005). Another collaborative study identified ten key barriers based on focus group input from clinicians and office staff: (1) previous negative technology experiences, (2) initial and long-term cost, (3) lost productivity, (4) competing priorities, (5) change management issues, (6) interoperability limitations, (7) IT requirements, (8) standards limitations, (9) waiting for an “all-in-one solution,” and (10) confusion about competing product offerings (Halamka et al. 2006). A more recent US survey shows similar findings for the use of electronic health records in general, with capital costs, not finding a system to meet responders needs, uncertainty about return of investment and concern that the system would become obsolete as the commonest barriers to adoption in ambulatory care (DesRoches et al. 2008).

The diffusion of innovations theory by Rogers may be used to explain the perceived barriers which have been identified in these studies and understand the reasons for the sluggish uptake of EP. EP in the healthcare setting is a complex innovation being used in an equally complex organisation. Rogers (2003) describes an innovation as ‘an idea, practice or object that EP is perceived as new by an individual or other unit of adoption.’ The diffusion of an innovation is the process by which the innovation is communicated through certain channels over time among the members of a social system. Hence there are four key elements to the diffusion process: 1) the innovation itself, 2) communication channels to share ideas, 3) time at the individual as well as diffusion process level and 4) the social system, which may be individuals or organisation, through which the innovation diffuses. Five attributes of the innovation, as perceived by the potential adopters, influence the rate of adoption: relative advantage over the idea it supersedes, compatibility with existing values and practices, simplicity and ease of use, trialability and finally observable results (Rogers 2003). In the studies described earlier, a number of the barriers to EP adoption may be matched to these five attributes. For example, all the studies identified cost as one of the barriers (DesRoches et al. 2008; Halamka et al. 2006; Pizzi et al. 2005; Poon et al. 2004). This is a relative *disadvantage* compared to the previous system. Similarly product immaturity (Poon et al. 2004), systems that do not meet users needs (DesRoches et al. 2008), need to change office procedures (Pizzi et al. 2005) and other change management issues (Halamka et al. 2006) suggest *incompatibility* with existing values and practices.

Some of the perceived barriers, such as lost productivity (Halamka et al. 2006) may be considered undesirable consequences of technology adoption. Rogers defines undesirable consequences as ‘the dysfunctional effects of an innovation to an individual or to a social system’ (Rogers 2003).

2.5 Undesirable and unintended consequences of EP

Emergent literature suggests that whilst electronic prescribing may have a role in reducing or minimising certain types of errors, others will remain unchanged and some new types may be introduced (Koppel et al. 2005; Nebeker et al. 2005; Walsh et al. 2006; Zhan et al. 2006). These errors may directly result in adverse patient outcomes.

Alternatively, new risks may be introduced due to unanticipated consequences resulting in changes to health professionals’ practice and care delivery, as seen by the increase in mortality in a study involving children (Han et al. 2005). Another example comes from

a Danish study in which use of a CPOE system unintentionally transformed three parts of the medication process (prescribing/ ordering, dispensing and continuing medication at discharge/ admission) (Wentzer, Bottger, & Boye 2007). In this study, users found workarounds to make the system fit into their workflow, there were changes in doctors and nurses collaboration and co-operation, and additional work for prescribers and nurses at discharge and readmission. For instance, prescribers would memorise details of three or four patients during a ward round and then go to the stationary personal computers on the ward, which were away from the patients, to enter orders and other information in the medical record. Previously nurses and doctors worked collaboratively to agree on the best treatment for the patient. With EP, nurses and doctors access were different, thus nurses could not make amendments to doctors orders without approval from the doctors. To get around this, doctors would log on and allow nurses to make the required changes. A UK evaluation reports similar issues with work restructuring causing changes in communication between health care professionals, which may not necessarily be desirable, and the potential of error and more/new work due to the introduction of forcing functions (Barber, Cornford, & Klecun 2007).

Ash's group in the US has done the most comprehensive work in this area of undesirable or unintended consequences, based on an expanded version of Roger's diffusion of innovations framework. In one study involving five hospitals in three organisations, they found nine major types of unintended consequences: more/ new work for clinicians, workflow issues, never ending system demands, paper persistence, changes in communication patterns and practices, emotions, new kinds of errors, changes in the power structure and overdependence on technology (Campbell et al. 2006). Another study of CPOE in use at four large outpatient clinics at one organisation focussed on unanticipated consequences, which were desirable and/or undesirable. Positive changes to patient-physician interchange were found to be a desirable unintended consequence of having a computer in the room. Undesirable direct consequences were error concerns and potential security concerns, whereas undesirable indirect consequences related to issues with alerts, workflow and ergonomic issues. An interesting finding was that some unintended consequences could be viewed as desirable or undesirable depending on the participant group e.g. nurse or physician, whereby what one group considered desirable was undesirable to the other. These included workflow issues, interpersonal issues and reimplementation concerns (for system upgrades or replacement) (Ash et al. 2007a). In a further survey to representatives from 176 US hospitals, the group established that these unintended

consequences appear to be widespread, with respondents ranking those related to new work/ more work, workflow, system demands, communication, emotions and dependence on technology as most severe (Ash et al. 2007b).

Unintended consequences are not limited to EP systems, but are a wider health informatics issue. In a viewpoint paper, authors from three different countries highlight two main categories of latent errors fostered by patient care information systems. The first is errors in the process of entering and retrieving information because of difficulties in the human-computer interface, and cognitive overload by overemphasising structure and completeness of information. The second category is errors in communication and coordination processes due to misrepresentation of collective, interactive work as linear, clear cut and predictable, and misrepresenting communication as information transfer. The authors conclude with various ways to address these two categories of silent errors including education, systems design, implementation and research. They emphasise the need to use qualitative research techniques to gain deep insight, identify problems and answer the how and why questions (Ash, Berg, & Coiera 2004).

2.6 Summary

Medication errors in children are a concern, but the magnitude of the problem is not known, especially in the UK where research on paediatric medication errors is sparse. Health information technologies such as EP are increasingly being advocated as one of the solutions for improving patient safety by experts in the field as well as policy makers. However claims that these can improve medication safety have not been clearly demonstrated. Literature on the use of EP is predominantly from the US, and indicates that EP has promise in reducing medication errors and possibly preventable adverse drug events. The evidence base for use in children is weak, especially in the UK. In addition, there is growing evidence of errors and unintended outcomes secondary to EP in all patient groups. Moreover, social factors and organisational policies may influence adoption, utilisation and ultimately, effectiveness of these systems. Any evaluation must therefore include social factors and be alert to unintended consequences. Outcomes demonstrated in one setting using a particular system cannot be assumed or transferred to other organisations, countries or EP systems.

2.7 Aims and objectives

The aim of this thesis was to investigate and evaluate the implementation of EP, a relatively new technology to the UK hospital environment, at a children's hospital. The research questions were:

- What is the effect of an electronic prescribing system on prescribing errors?
- How does it affect patient safety?
- Are there any changes in practice and workflow patterns of healthcare professionals following implementation of the electronic prescribing system?
- What are the stakeholders, users, patient and parent/carer's views of the EP system?

The evaluation method used to address these research questions will be presented in Chapter 4. The next chapter sets the context, provides a narrative of the study setting and a description of the EP system.

Chapter 3 Study setting & EP system description

'Cancer drug mistake killed my child'

(BBC News Online - Health 2001)

3.1 Context

Patient safety was placed on the UK political agenda following publication of 'An organisation with a memory' in 2000. The report promoted the patient safety agenda in the NHS, with an emphasis on the need to analyse and learn from experience through improved reporting. Additionally, four specific risks were targeted for action including the aim to reduce by 40% the number of serious errors in the use of prescribed drugs (Department of Health 2000). A subsequent report set out the governments plans for patient safety. This report identified other additional areas where action could provide some early gains in risk reduction. One of these areas was to examine across the board the potential for computers to reduce the occurrence and impact of error (Department of Health 2001). Further to this the National Program for Information Technology (NPfIT) was established in October 2002. NPfIT has been described as "the world's biggest civil information technology programme" (Brennan 2005) and is deliverable by the NHS agency Connecting for Health. The vision statement of the program was "to deliver a 21st century health service through the efficient use of information technology by:

- *Improving the quality and convenience of care by ensuring that those who give and receive care have the right information, at the right time; and*
- *Implementing projects vital to the NHS modernisation programme using IT to directly improve the patient experience and clinical care."* (Department of Health 2002)

The program is estimated to have a projected cost of over £12.5 billion and has experienced several delays. Reasons include lack of suitable solutions in terms of functionality, transfer from or compatibility with the different IT systems already in use, and the inability to engage clinicians. Some elements such as picture archiving and communications systems (PACS) have been deployed successfully, and others like the electronic prescriptions service in primary care are now underway. However, implementation of EP in the hospital setting has continued to face delays, forcing local organisations to consider alternative interim solutions.

The present study was conducted at one such organisation. The aim of this chapter is to provide a brief narrative of the study site, implementation areas and the reasons for introducing EP. The second part of the chapter outlines the medicines use process at the hospital and describes the EP system that was implemented.

3.2 Study site

Great Ormond Street Hospital for Children (GOSH) became the first paediatric hospital in the UK to implement a commercially available electronic prescribing and medicines administration (EPMA) system in October 2005.

The hospital opened on 14 February 1852, as the first children's hospital in the English speaking world. It is an acute tertiary care hospital in central London, offering the widest range of paediatric specialties in the UK, including 21 medical, 11 surgical and eight diagnostic specialties, plus eight paramedical and other clinical support services including pharmacy, physiotherapy, psychology, dietetics and speech and language therapy. GOSH has 314 beds on 31 wards (Great Ormond Street Hospital for Children NHS Trust website) and recorded 71,890 occupied bed days, 28,349 finished consultant episodes, 22,813 operations and 107,412 outpatient attendances in the financial year 2006/2007 (Great Ormond Street Hospital for Children NHS Trust, Annual report 2007).

In July 1997, a 12 year old boy died at the hospital following a series of events which culminated in a fatal medication error (BBC News Online - Health 2001). Following the findings of an internal inquiry in 1998, the then Clinical Services Manager decided to allocate funding for an EPMA system to improve patient safety and the quality of care. It was perceived that the system would enable drug prescribing and administration to occur at the patient's bedside and clinicians would be presented with up-to-date, accurate, complete drug information with basic decision support providing clinical checking for correct dosage, route, drug interactions and allergies. Easy access to on-line standard texts, hospital formularies and treatment guidelines would further facilitate informed prescribing and, consequently, an improved quality of care provided to the patient (Conner 2003).

However, very little progress was made until the appointment of a new Chief Pharmacist in 2000. The project was initiated in 2002 after a project lead was recruited, and the system was implemented in 2005. Implementation was independent of NPfIT, but intended to inform national development of a paediatric EP system.

3.2.1 Implementation areas

A phased roll out approach was used for implementation, beginning with the nephro-urology unit, which consists of a renal ward, a urology ward and the respective

outpatient clinics, and then continuing with the rest of the hospital. As patients from the urology ward attended a specific theatre, this too was included in the first phase of implementation. This unit was chosen as the clinicians were keen to be involved and it would allow the system to be used in diverse areas: on a medical ward, a surgical ward and in theatres.

3.2.1.1 Renal ward and renal outpatients

The renal unit comprises a 16-bedded ward, the Renal Transplant Unit and the Haemodialysis unit. The renal ward had 24 regular nurses and employed regular bank and/or agency staff almost on a daily basis. The clinician team consisted of eight consultants, one nurse consultant, three registrars and two senior house officers (SHOs). Surgical care of end-stage renal failure patients was provided by a team of four transplant surgeons.

3.2.1.2 Urology ward and one theatre

The urology ward had 16 beds, of which four were for day cases. Children were admitted from birth (if over 1.82kg) to 16 years (if seen from birth). The range of dependency was from day case to 3 months stay and there was cross cover with the renal ward as many of the children had co-existing renal problems.

The nursing team, led by a sister comprised twelve band 5 and nine band 6 nurses. The ward was staffed with five nurses during the day and 3 or 4 at night.

Surgery was performed four days a week, Monday to Thursday by four consultant teams, consisting of one registrar each with one additional registrar to cover study or other leave, and two SHOs, although it was rare that both senior house officers were working at the same time due to rotation on nights, and leave.

3.2.1.3 Ward 3

After the nephro-urology unit, this was the third ward to implement the EPMA system. Ward 3 was a mixed rheumatology and dermatology ward with ten inpatient beds and an ambulatory day care service, which could see approximately fifteen to twenty patients per week.

The rheumatology team consisted of seven consultants, two registrars and 5 nurse specialists. The dermatology team comprised 4 consultants, 2 registrars and 2 nurse specialists. There were no SHOs on ward 3.

3.3 Medicines use process

In this section, the medicines use process using the previous paper system is described first and then changes as result of the EP system are highlighted. Illustrations of both paper and electronic prescription charts have been used to complement the text; patient details have been anonymised or a test patient has been used.

3.3.1 Previous medication system

3.3.1.1 Prescribing

Prior to EP, all medicines were handwritten onto approved designated stationary for prescribing which had sections for essential patient and drug information i.e. patient name, date of birth, hospital number, weight, allergy details, dose/route, frequency and duration. These were then used for drug administration charting and dispensing. For inpatients, this was primarily a pre-printed yellow prescription chart for drugs intended for once only (stat), regular use and on an as required basis (figure 2).

Separate charts were used for intravenous infusions, chemotherapy prescriptions (via the computerised Chemocare system), total parenteral nutrition (TPN), patient/ nurse controlled analgesia, specialist/ complex medication regimens e.g. infliximab and in theatres where often, the anaesthetic chart was used as a prescription chart. Medicines to take away/ out (TTA/ TTO) at discharge were written on a pre-printed form which had four colour coded carbonless copies, one of which was sent to the general practitioner, one kept in pharmacy, one in the medical notes and one was given to the patient. The TTA fulfilled dual functions of a discharge prescription and discharge summary letter. Outpatient prescriptions were handwritten on a pre-printed prescription sheet (figure 3).

Figure 2: Example of a yellow inpatient paper prescription chart.

Past transplant Chart 1 2 3 4 5. Number of Charts in use: 1 2 3 4 5

PRESCRIPTION CHART

Great Ormond Street Hospital for Children
NHS Trust and the Institute of Child Health
Great Ormond Street, London, WC1N 3JH

WARD: **VICTORIA**

SURNAME: _____ FIRST NAME: _____ HOSPITAL NUMBER: _____ CONSULTANT: **SDP** COST CODE: _____

ALLERGIES: **Nil known**

WEIGHT: **18.2 kg** SURV AREA: **1.8 m²** DOB: _____ AGE: **15 yrs** WEIGHT (kg): **64.3 kg** **37.8 kg** **61.9 kg** **30.5 kg**

ONCE ONLY DRUGS

DATE	TIME	DRUG	DOSE	ROUTE	SIGNATURE	GIVEN	PHARMACY
30/8/05	12:00	Morphine (at discretion)	320	IV	SDP		
30/8/05	12:00	Fentanyl (at discretion)	600ug	IV	SDP		
30/8/05	12:00	Metoprolol (at discretion)	100mg	IV	SDP		
30/8/05	12:00	Tacrolimus (at discretion)	9.5mg	PO	SDP		
30/8/05	12:00	HYDROCHLORAZINE	5mg	IV	R. Wainwright		
30/8/05	22:30	HYDROCHLORAZINE	10mg	IV	R. Wainwright		
31/8/05	09:45	FUROSEMIDE	60mg	IV	R. Wainwright		
31/8/05	18:20	FUROSEMIDE	30mg	IV	SDP		
2/8/05	22:20	FUROSEMIDE	30mg	IV	SDP		
21/8/05	04:30	FUROSEMIDE	30mg	IV	SDP		
1/9/05	16:30	Furosemide	30mg	IV	SDP		
8/9/05	17:00	Furosemide	30mg	IV	R. Wainwright		

MEICS - PLEASE READ
1. Sign name and initials in blue ballpoint pen.
2. Write CLEARLY using approved forms. BLOCK LETTERS & numeric digits.
3. Check dosage by hand or write and abbreviate in the space provided.
4. One change of dose is permitted on this form unless already cancelled - from new charge, date, and grade in the "CANCELL" instructions box.
5. Do not use a white pen, apply it, with your initials and date of cancellation.
6. You have five lines (plus) for additional notes and alterations.

NURSING STAFF - PLEASE READ
1. Read all orders given.
2. If a drug is not administered, tick the box and complete the "Drugs Not Administered" Section.
3. Enter the number of charts in fact on the chart as indicated by the asterisk printed.

GPO

REGULAR DRUGS

COTRIMOXAZOLE

DOSE: **960** ROUTE: **PO**

30/8/05 2000 800mg + 800mg

8	
12	
16	
20	
24	

ASPIRIN

DOSE: **75** ROUTE: **PO**

30/8/05 2000 75mg

8	
12	
16	
20	
24	

RANITIDINE

DOSE: **50** ROUTE: **IV**

30/8/05 2000 50mg

8	
12	
16	
20	
24	

Changed to 100mg 1/9/05

NEUPTRENSOLONE

DOSE: **45** ROUTE: **PO**

30/8/05 2000 45mg

8	
12	
16	
20	
24	

Changed to 90mg 1/9/05

TACROLIMUS

DOSE: **2.5** ROUTE: **PO**

30/8/05 2000 2.5mg

8	
12	
16	
20	
24	

Figure 3: Example of a pre-printed outpatient prescription sheet

GREAT ORMOND STREET HOSPITAL NHS TRUST LONDON W1N 3JH PATIENT PRESCRIPTION FORM					Allergies NONE	
SURNAME	FIRST NAME				Pharmacy Dept. Only	
UNIT	JOB	WEIGHT (kg)		and Date		
Consultant	Cost Code					
Drug	Dose/Route	Frequency	Duration	Date	Quantity	Disp.
(MHP) Mycophenolate	500mg morning	3/12			2x100 (250mg)	
	750mg evening				3x50 (500mg)	
Sardo-K	1tablettbd	3/12				
Dofetilone	120mg	1/2tablettbd	3/12		1x60 (6mg)	
Potassium Chloride	10mmolbd	3/12				
Prescriber's Signature & Print Name:	Date:	Bleep No.	Ext. No.	Disp. by	initials	
MAXIMUM 28 DAYS SUPPLY OR NEAREST ORIGINAL PACK Exceptions for medicines only available from: (DOS) or agreed by Drugs and Therapeutics Committee.				Next appointment due:		
Total potassium chloride dose 20mmol/day						

Only doctors and supplementary (and later independent) nurse and/ or pharmacist prescribers could prescribe.

3.3.1.2 Dispensing and clinical pharmacy service.

On wards, most commonly used drugs were available as floor stock. Non-stock items including TPN and cytotoxic agents and other prescriptions such as TTAs and outpatient scripts were dispensed by the pharmacy department, which also provided an extensive Centralised Intravenous Additive Service (CIVAS).

All non-stock items, and TTAs were reviewed prior to dispensing by a pharmacist who checked for appropriateness of the medication in view of the patient's age, diagnosis and clinical condition. This took place either on the ward as part of the clinical pharmacy service, which was provided to all wards and involved at least one ward visit by a pharmacist, or in the dispensary. In case of query or clarification, the pharmacist contacted the prescriber and annotated the handwritten prescription with details of any changes agreed. In case of illegibility, the pharmacist rewrote that part of the prescription to clarify it. The prescription was signed or initialled by the pharmacist

who performed the clinical review, and supply details were documented on the prescription.

The Ascribe pharmacy software system was used for stock control, general dispensing, CIVAS and TPN (Ascribe plc.).

3.3.1.3 Administration

Administration of medicines was only possible against a prescription written by the prescriber or using a patient group direction (PGD), with the exception of clinical emergencies e.g. a cardiac arrest, when drugs were administered against verbal orders and a record was made after the event.

Drug administration on wards was primarily done by qualified nursing staff and occasionally, student nurses under supervision; patient or parent administration was permitted for certain drug formulations e.g. inhalers and creams. In acute areas such as theatres, doctors often prescribed and administered medication themselves. In all cases, a record of administration was made against the prescription by signing or documenting a reason for non-administration. Selected drugs e.g. IV chemotherapy, required a second check by another 'administrator' and this too was documented on the prescription chart.

3.3.2 Electronic prescribing and medicines administration system

The JAC electronic prescribing system is an integrated electronic prescribing, medication administration and pharmacy system (JAC Computer Services Ltd) linked to the hospital patient information management system (PIMS) and was intended to replicate the paper process. In order to access the EP system, the user had to log on to the Trust's network which hosted the program on a server. Access was through personal computers (PCs) that had been set up for EP or dedicated laptops on mobile carts/ notes trolleys (figure 4). To perform an action on the EP system, including view the medication chart, the user had to select the relevant program e.g. prescribing for inpatients or outpatients (these are two distinct programs within the EP system), nurse administration or dispensing and then select the patient. The patient list was populated automatically via PIMS. Patients were selected using a hospital number, by name or by location in the inpatient setting; for outpatients, the clinic code had to be selected first, before searching by patient name or hospital number. The same patient could not be

selected by more than one user at any one time i.e. if the patient record was being used for dispensing, then it was 'locked' to the nurses and doctors who would be unable to view administration and prescribing details.

Figure 4: Nurse using a laptop in a mobile cart at the patients bedside



The EP system did not change the fundamental principles or policies for prescribing, administration or dispensing, but the processes involved did change as explained below.

3.3.2.1 Prescribing

For new patients, allergy status and weight of the child, which were mandatory fields, had to be completed by the prescriber before proceeding; height could be entered at this stage, but was not mandatory. Prescriptions could be ordered as new items, renewed from a previous admission or selected to continue at discharge from the inpatient medication list (figure 5). For new items drug selection was from a menu of formulary items, listed alphabetically by the approved name, strength and formulation (figure 6).

Figure 5: Discharge prescription ordering screen illustrated using a test patient

TTASL - Select Orders for TTA

BEN SIMPSON TEST JAG

Consultant: MR TONY KING Ward: LAGUNA WARD

Hospital No. X294915 NHS No. Date of Birth: 17-May-1974

Allergies: PENICILLINS Height: 170 cm Weight: 90.000 kg BSA: 2.01 sq m

Status	Drug Name	Dose	Frequency	Route	Start Date/...	Stop Date/...	BNF	GP C...	Supply	Select
Regular Medications										
	FERROUS FUMARATE 140 mg L...	280 mg	BD - TWIC...	Oral	21-May-200...		Nut...	Yes	14	<input checked="" type="checkbox"/>
	ERYTHROMYCIN STEARATE 50...	1 Tablet	QD - FOU...	Oral	21-May-200...	28-May-20...	Infe...	No		<input type="checkbox"/>
	LANSOPRAZOLE 30 mg Capsules	30 mg	OM - Ever...	Oral	22-May-200...		Ga...	Yes	14	<input checked="" type="checkbox"/>
	CLARITHROMYCIN 500 mg Tabl	500 mg	BD - TWIC...	Oral	22-May-200...		Infe...	No	14	<input checked="" type="checkbox"/>
	THEOPHYLLINE (UNIPHYLIN)	200 mg	BD - TWIC...	Oral	22-May-200...		Re...	Yes	14	<input checked="" type="checkbox"/>
As required (PRN) Medications										
	MENTHOL 1% IN AQUEOUS Cr...	1 applica...	PRN	Topical	21-May-200...		Skin	No	14	<input checked="" type="checkbox"/>
	CO-CODAMOL 30/500 Tablets	2 Tablet	QD - FOU...	Oral	21-May-200...		Ce...	Yes	14	<input checked="" type="checkbox"/>

Medicines to continue at discharge have been selected for transfer to the discharge prescription.

Figure 6: Drug selection screen, ordered alphanumerically by generic drug name, strength and formulation.

Drug Selection ACCEPT JAG

Search Options: Prescribable Approved Proprietary Treatment Protocols

Drug(s): FLUCLO Route: <<ALL ROUTES>> Search

Prescribing Name	Treatment Protocol
FLUCLOXACILLIN 1000 mg Injection	
FLUCLOXACILLIN 125 mg in 5mL Oral Solution	
FLUCLOXACILLIN 250 mg Capsules	
FLUCLOXACILLIN 250 mg in 5mL Oral Solution	
FLUCLOXACILLIN 250 mg Injection	
FLUCLOXACILLIN 500 mg Capsules	
FLUCLOXACILLIN 500 mg Injection	

Ok Close Help

Details of route, dose, frequency, number of days to supply, start date and for outpatients, whether or not the general practitioner (GP) needs to continue to the prescription were entered in the next stage. Dose and route were mandatory fields; the frequency was mandatory for drugs which were for regular use but not for once only/stat or as required prescriptions. Alternative dose and description was an automated field which calculated the number of dose units or in the case of liquid medicines, the number of mls for the prescribed dose for some drugs. There was a 'notes' facility to enter free text notes related to the drug (figure 7).

Figure 7: Prescription details screen

Once prescribed, items could be suspended, modified or discontinued. Modifications could only be made to dose, frequency, regular/PRN status or stop date. To change the route and formulation, the prescription had to be discontinued and represcribed.

After all the drugs had been entered, the prescription could be printed either in the outpatient clinic/ward or directly in pharmacy, although the latter was restricted to outpatient prescriptions only.

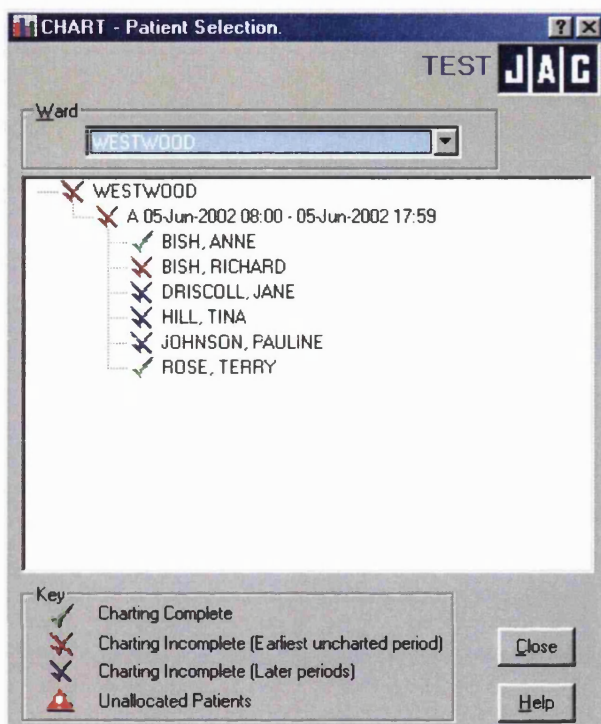
The system was not used for complex prescriptions e.g. continuous infusions, total parenteral nutrition (TPN). These continued to be prescribed on pre-existing specialised charts, with a cross reference on the EP system with the advent of 'dummy drugs.'

3.3.2.2 Administration

Nurses used the system to review and record drug administration and to document the use of patient group directions (PGDs). Laptops on mobile carts were used when preparing the medicines in the treatment room and then wheeled to the patient's bedside for administration where it was recorded on the system. For drugs that required a double check, both users entered their username and password details before the administration was recorded.

Medication administration was recorded within the system either from the prescribing program for an individual patient or through the nurse administration program for a single patient, a group of patients or a whole ward (figure 8).

Figure 8: Patient selection from a ward list through the nurse administration program



The key difference between the two ways of accessing the charting program was that the prescribing program route displayed all the drugs that the patient was on (figure 9), unlike the administration program which only listed items that were due within the next hour (figure 10).

Drug administration within the system was scheduled over a 24 hour time period, called the medication administration schedule (MAS). This was a manual task that needed to be reset or 'run' at 4am each day to schedule doses for the next 24 hours. All doses needed to be recorded as administered or reason for non administration entered before the MAS could be run.

Figure 9: Administration charting accessed from the prescribing program showing all the drugs that the patient is prescribed.

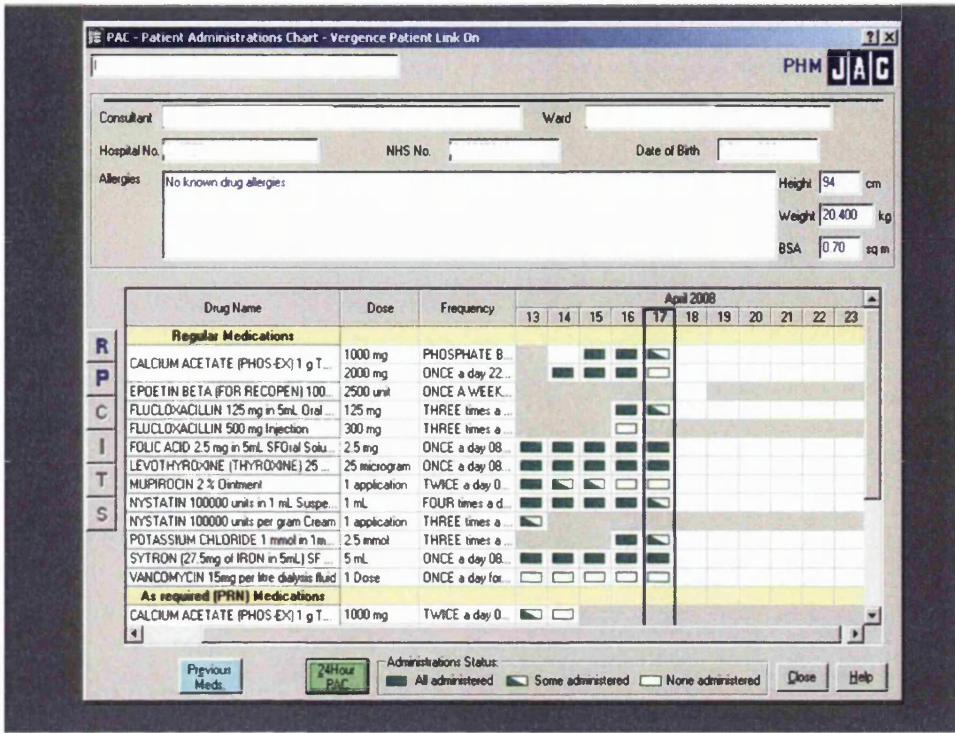
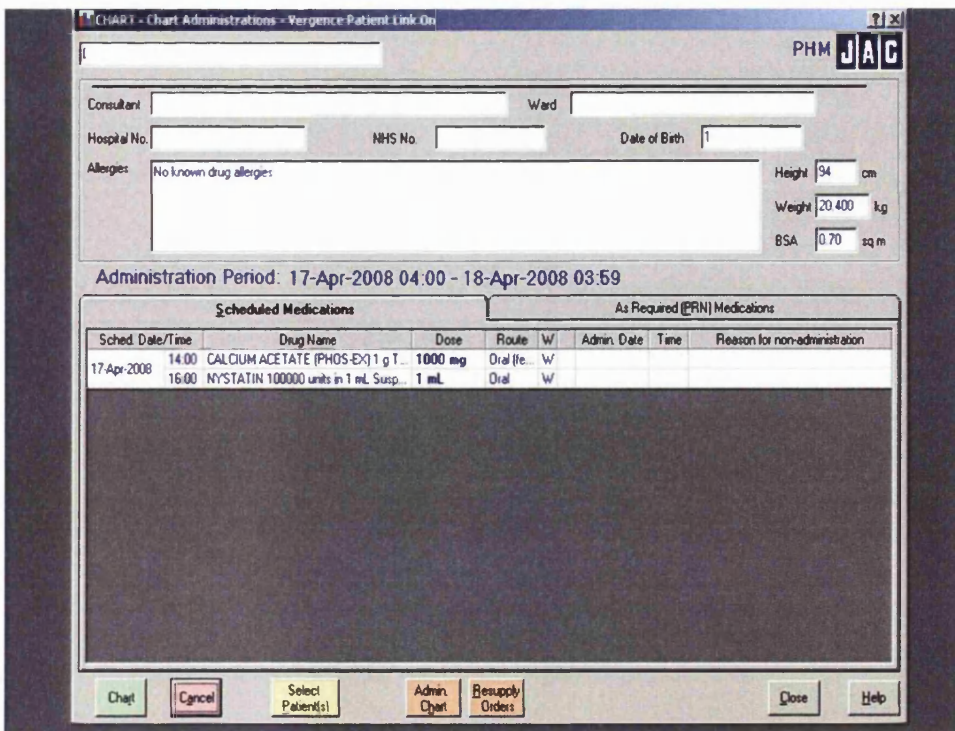


Figure 10: Administration charting accessed from the nurse administration program displaying medication that is due in the next hour.



3.3.2.3 Dispensing

The JAC dispensing module was implemented in the pharmacy in April 2005, and was well established when the EPMA module was implemented in October 2005. Items were dispensed against a written or printed prescription or as ward floor stock.

Outpatient prescriptions were transmitted electronically and printed after a clinical review had been done. Inpatient requests were also printed after a clinical pharmacist review. TTA prescriptions were printed on the ward, and a clinical review performed using a combination of the electronic inpatient chart and the printed TTA prescription.

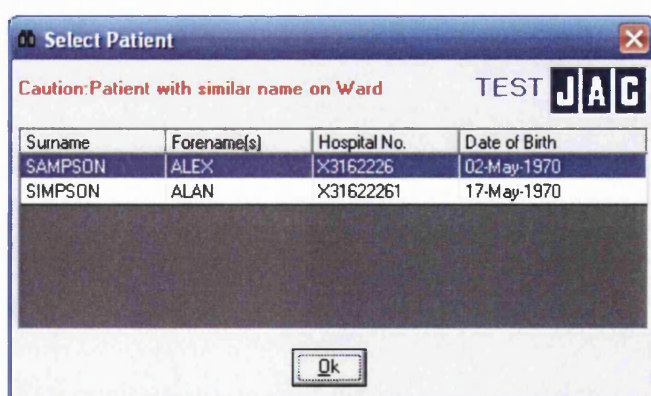
The Ascribe pharmacy system continued to be used for TPN and CIVAS, whilst awaiting the relevant modules to be developed on JAC.

3.3.2.4 Clinical decision support

One of the key features that was requested prior to EP implementation was age and weight related alerts. The EP system alerted the prescriber if the height or weight entered was outside the expected range based on the child's age. Tables for height and weight based on age were set locally. The system prompted for weight to be updated if date of previous entry exceeded the specified time period for the age of the child e.g. for older children, the weight needed to be revalidated on a monthly basis.

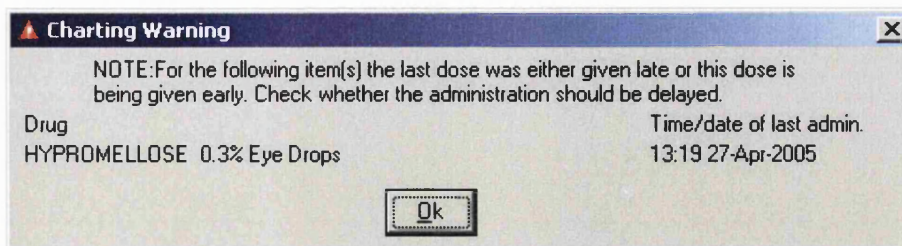
In addition, the EP system provided various other informative alerts e.g. log in failure, similar name alert for patients with a similar name on the same ward,

Figure 11: Similar patient name alert



if an action contradicted previously entered information e.g. restart date for suspended items, discontinue date for items with stop dates, early or late administration alert

Figure 12: Wrong administration time alert



Clinical information and decision support was provided using the Multilex (First DataBank Europe) clinical drug database. A drug monograph including information on indications for use, contra-indications, normal dosage (not paediatric specific), interactions and side effects for a specific prescribed drug was available by selecting the relevant option from patient's current drugs list. In addition, the EP system had the functionality to provide drug-allergy, exact drug duplication, drug-drug interaction and therapeutic drug duplication alerts. However, only drug-allergy and exact drug duplication alerts were activated during the study period.

3.4 Summary

The JAC EP system, a commercially available system, was implemented at GOSH in 2005, with the explicit aim of improving patient safety and quality of care by improving practices within the medicines use process. The implementation was independent of the NPfIT, which did not yet have a suitable solution for prescribing in children.

Chapter 4 Evaluation method

“A common mistake that people make when trying to design something completely foolproof is to underestimate the ingenuity of complete fools.”

Douglas Adams, English author

(<http://www.memorable-quotes.com/douglas+adams,a98.html>)

4.1 Introduction

In the previous chapters, I have argued that paediatric drug errors are a significant problem and that EP has promise as a solution. I have also discussed the system introduced at GOSH. In this chapter, I explain the philosophy underlying the evaluation presented in the following chapters.

EP is a new, multi-faceted IT system being introduced in the UK hospital environment. Evaluation is an integral component of EP systems implementation in healthcare. However the evaluation should not be of the technology alone. It is important to gain an understanding of how people and technologies interact, because “technical systems have social consequences” and “social systems have technical consequences” (Coiera 2004). The gold standard approach of randomised controlled trials was not deemed appropriate or possible for the present study as implementation was within a specialist hospital and a suitable control could not be found. Additionally, a controlled trial would not provide understanding of ‘how’ and ‘why’ questions regarding EP implementation and effectiveness. Therefore a theoretical approach was used to find a suitable method for evaluation.

4.2 Evaluation of health information technology

The approach to evaluation of health IT systems has changed over time, with focus shifting from studying the technical and functional aspects to a wider study of the system in use (Ammenwerth & de Keizer 2005). The phases at which a health IT system is evaluated depends on the circumstances, but may be any one or more of the following: need for the resource, the development process, the resource’s intrinsic structure and functions through to actual impact on users, patients and the organisation (Friedman & Wyatt 1997).

Research at each of these stages is important and necessary, to build on the emerging picture which highlights the complexities of healthcare as well as the technologies used within. Whilst accepting that ongoing system development is likely to occur, the latter two stages (resource structure and functions, and actual impact) are of greater interest and relevance for this thesis as the focus is evaluation of implementation. Though the JAC EP system is one that has been used in adult hospitals for many years, the system structure and functions are of interest and need to be studied as this is the first implementation of the system in a children’s hospital. It is important to evaluate the

impact on users and the organisation as well as patients, as the effects on work practices and usability are likely to influence acceptability to individual users. Organisation structure and the process of implementation may influence overall project management and outcomes, and how the system is perceived locally and beyond.

4.2.1 A theory based approach

Research into the implementation and use of EP systems has mainly involved outcome based studies, with very few investigators, such as Ash's group, employing a theory based approach. Hardly any researchers have used a combination of methods to evaluate both quantitative outcomes as well as the human and organisational effects. One of the first groups to use a combination of qualitative and quantitative methods has been from the UK (Barber et al. 2007; Franklin et al. 2007), though others are underway (Westbrook et al. 2007).

In the broader field of health information systems research a variety of theories, models and frameworks have been used to explain IT usage and to evaluate IT systems. These include the diffusion of innovation theory, technology acceptance model, actor network theory and sociotechnical theory (Kaplan & Shaw 2004). A common thread amongst all of these is the interaction between human users and the technology in an organisation.

4.2.1.1 Sociotechnical approach

The sociotechnical approach provided the basis of the framework used in this thesis. This approach aligns itself to the study of information systems as it focuses on the fit between the social and technical systems which together make up an organisation. The social system consists of the employees and their knowledge, skills, attitudes, values and needs in the work environment as well as the reward system and authority structures that exist in the organisation. The technical system comprises the devices, tools and techniques required to convert inputs into outcomes. Key to this approach is that any changes introduced to the organisation need to be harmonious and result in joint optimisation of both technical and social systems for maximum benefit to the organisation. Therefore the interdependency of each component must be studied and understood.

Applying these principles to the health care setting, a framework for evaluating information and communications technology (ICT) systems has been proposed by Cornford, Doukidis, & Forster (1994); it has been used successfully to evaluate two

different electronic prescribing systems in adult inpatient settings in the UK (Barber et al. 2006). A framework approach is one where the objectives of the investigation are typically set in advance and data collection is targeted towards the issue under scrutiny. Although data collection primarily involves qualitative methods, analysis is often linked with quantitative findings (Bowling & Shah 2005; Pope, Ziebland, & Mays 2000).

4.2.2 The Cornford framework

The Cornford framework is based on Donabedian's (1966) structure, process and outcome model for assessment of quality outcomes and is applied at three main levels: the systems functions, human perspectives and organisational context (Cornford, Doukidis, & Forster 1994). A similar framework was subsequently proposed by the Department of Health in the UK for evaluating information systems projects (Department of Health 1996).

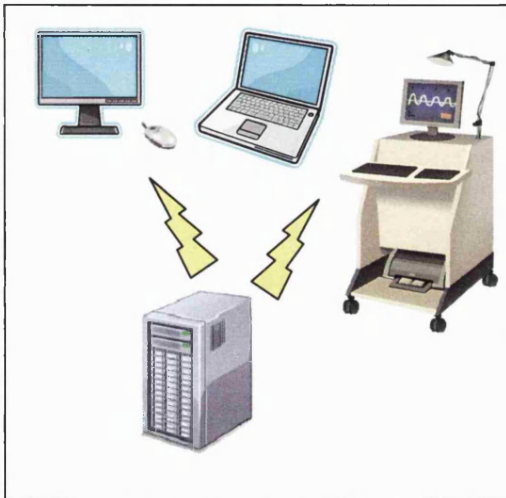
By applying Cornford's framework (table 9), an evaluation of the three key components of an EP system, the system itself, human users and the organisation (figure 13) can be performed. The framework encompasses technical details and EP system processing; work conditions and requirements; human participation and social interactions, and considers sustainability in the wider setting. Additionally, it has parallels with Reason's human error theory (errors are considered a consequence of failures in the whole system: organisational process, work conditions, technology, team or individual), which is particularly relevant for this thesis, where the focus is patient safety. Another advantage of the framework is that enables the use of qualitative and quantitative methods to collect all the relevant data needed for analysis. Quantitative methods allow the objective measurement of outcomes. A comparison between pre and post implementation groups can be used to demonstrate statistically significant effects of the intervention. Qualitative methods provide information on the experiences of the individuals or groups involved.

Table 9: Cornford's framework

	Systems functions	Human perspectives	Organisational context
Structure	Technical detail	Work conditions and implied requirements	Sustainability, opportunity costs, management needs, skills requirements
Process	Information processing; correct and valid	Human participation in tasks; social interaction	Altered delivery and practice
Outcome	Relevant, applicable, reliable	Quality of service and outcomes	Effect in the world

Figure 13: An illustration of the three key components of electronic prescribing (using Great Ormond Street Hospital as an example)

System



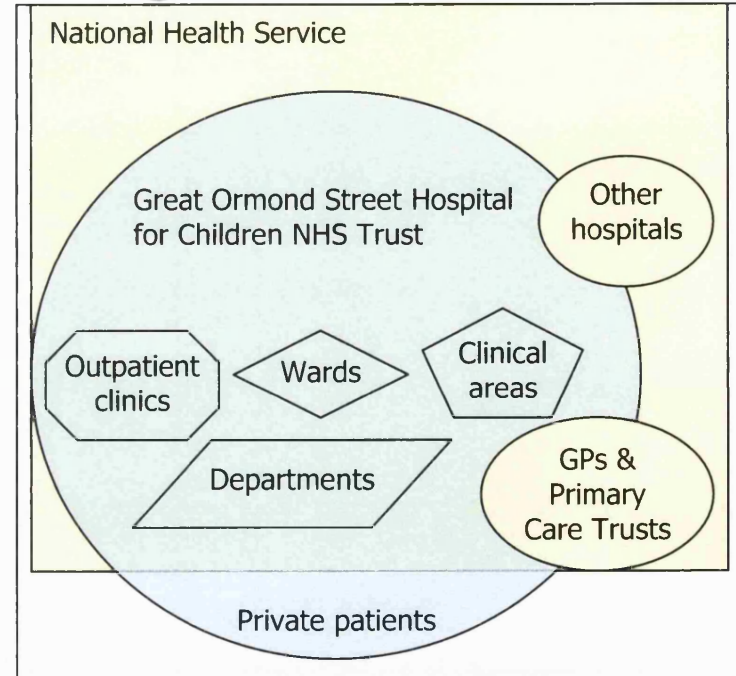
Software and hardware e.g. programs, user interface, servers, personal computers, laptops, mobile units, wireless network, printers.

Human users



Individuals and teams: doctors, nurses, pharmacists, pharmacy technicians, students, agency and locum staff, IT staff.

Organisation



For this thesis, a number quantitative and qualitative of methods were used to address the different aspects of the framework and these will be highlighted as each element is explained.

The **system functions** column deals with the efficiency and effectiveness of the system itself. The *structure* cell entails the technical detail and how it is constructed i.e. hardware and software requirements, software architecture, full set of system components and how all these work together in a technical sense. Information on this was obtained using qualitative methods i.e. analysis of the project team meeting minutes, interviews with project team members, observation and the user manual.

The *process* considers the method by which the system transforms data or the series of operations by which a task is accomplished, and whether information processing is correct and valid. This data was collected by observation of the system in use and interviews with the users. The user manual, training guides produced by the project team and minutes from project team meeting were used to supplement the information gathered. Clinical decision support alerts generated within the system were studied to assess alert characteristics and appropriateness.

Outcome is the impact or visible effect as a result of the system in use. Here we consider whether the results are relevant, applicable and reliable, and whether the system meets the required specifications. As the key function of the electronic prescribing and medicines administration system was to replace and improve existing means for prescribing and administering medicines, a quantitative study of medication errors was the primary means of data collection.

Human perspectives takes into account experiences and acceptability of the system, and how it is perceived by the various stakeholders and participants:

- the project board and team who were responsible for the management and implementation,
- the users whom the system aids in providing healthcare and
- the patients and parents whom the system is expected to benefit.

Therefore, most of this information was obtained directly from the stakeholders using semi-structured interviews and observation.

Structure within this section considers whether the system is seen as a reasonable, cost effective alternative to the existing tools in use, any changes to staffing structure or working conditions and practices i.e. physical environment and skill requirements and

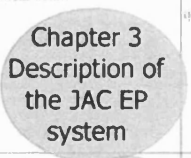
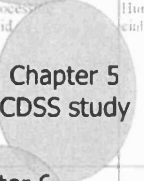
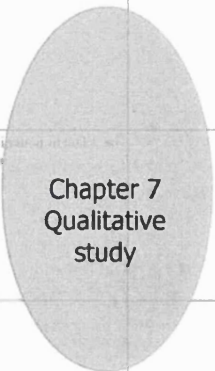
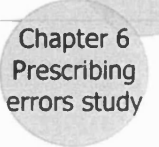
whether patients/ parents are required to modify their behaviour in any way. The *process* row deals with changes in mode of operation, character of the job and the patient/ parent experience of health care as a result of the system. *Outcome* reports the overall effectiveness within the healthcare system, and whether use of the system results in changes in quality of service and better health.

The final column involves the **organisational context** i.e. the consequences for the actual organisation and healthcare system where the innovation is introduced. The *structure* takes into account how the system fits in with existing infrastructure of the organisation, the balance between demands for resources and skills, and whether the system can be sustained and supported. *Process* considers the effects on practice, delivered quality across the whole organisation and how the information is used in management functions, and *outcome* considers the overall effect on the healthcare system from the organisation's viewpoint. Data for this column was collected using semi-structured interviews with members of the project board and team, analysis of project meeting minutes and documents, and observations during project team meetings.

Data was collected to address aspects of the framework as illustrated in figure 14.

Details of methods and results for each component are presented in the following three chapters.

Figure 14: Mapping data collection to the Cornford framework

	Systems functions	Human perspectives	Organisational context
Structure	Technical detail 	Work conditions and implied requirements	Sustainability, opportunity costs, management needs, skills requirements
Process	Information process correct and valid 	Human participation in social, technical interaction 	Altered delivery and practice
Outcome	Relevant, applicable, reliable 	Quality of service and outcomes	Effect in the world

4.2.3 Ethics approval

This research project was approved by the Institute of Child Health/Great Ormond Street Hospital Research Ethics Committee.

Chapter 5 Prescribing errors

“To err is human, but to really foul things up requires a computer.”

Farmer's Almanac, 1978

(<http://www.answers.com/topic/farmer-s-almanac>)

5.1 Introduction

Prescribing for children is complicated because doses are often based on rapidly changing age and/or body weight and/or body surface area. Many medicinal products are not licensed for use in children and this means that the formulations may not be appropriate for doses needed in children. Children may not be able to communicate information about any medication errors or adverse events experienced. In addition, when medication errors do occur, there is reduced capacity to deal with them. This puts children at greater risk of harm resulting from errors, particularly dose errors which may result in 10 times the intended dose, often due to poor quality of prescribing e.g. use of ambiguous abbreviations or illegibility (Wong et al. 2004).

Most of the positive effects from electronic prescribing (EP) systems are expected in the quality of prescribing by ensuring clear, legible and complete prescriptions, thus minimising the risk of errors. The presence of advanced clinical decision support including dose calculations and checking is expected to further reduce the error rate and severity (Fortescue et al. 2003; Wang et al. 2007).

This chapter addresses the *system-outcome* cell of the Cornford framework using quantitative methods. The main anticipated outcome of using an EP system at GOSH was to improve the quality of patient care with improvements in the medicines use process. The aim of this study was to assess the impact of the EP system on prescribing errors. The objectives were to determine the incidence and types of prescribing errors in the paediatric outpatient and inpatient settings, and in discharge prescriptions, and to assess the effect of an EP system on these errors. A secondary objective was to assess the effect of EP on the incidence and severity of dosing errors.

5.2 Methodological approach

The approaches to prescribing error detection and assessing severity of errors will be considered in this section.

5.2.1 Prescribing error detection

Prescribing errors may be detected either before (intercepted) or after (non-intercepted) they reach the patient. Several methods have been used to detect prescribing errors including pharmacists' identification during prescription review, medical notes review, use of trigger tools and analysis of voluntary or spontaneous incident reports (Dean et

al. 2005). Every method has strengths and limitations as discussed in the following paragraphs.

Prescribing errors identified during routine prescription review by pharmacists are likely to include intercepted as well as some non-intercepted errors. An advantage of this method is that the data collection can be done prospectively as part of the pharmacist's routine practice thus minimising labour and cost (Dean et al. 2002a). However, the detection rate is dependent on the individual pharmacist's knowledge, identification and documentation of the error (Barber et al. 2006) and more minor errors may be detected (Dean et al. 2005).

Non-intercepted prescribing errors, which may have resulted in some degree of harm (i.e. preventable ADEs), are most likely to be detected using medical notes review (Kaushal 2002). Trigger tools have also been used, but detect a lower rate of errors compared to medical notes review (Barber et al. 2006; Jha et al. 1998; Olsen et al. 2007). Each of these methods has some disadvantages. Medical notes review is reliant on the documentation, which may be inadequate and lead to inaccuracies in prescribing error identification (Dean et al. 2005). In addition, there may be poor reliability in preventability assessment of the adverse events identified (Hayward & Hofer 2001; Kunac et al. 2006). Likewise, it may not be easy to differentiate prescribing errors with the use of trigger tools, and there may be a higher number of false positives depending on the specificity of the tool (Dean et al. 2005). Finally, both medical notes review and trigger tools are more labour intensive compared to prescription review (Barber et al. 2006; Jha et al. 1998; Olsen et al. 2007).

Use of spontaneous reports as a method to detect prescribing errors detection is considered the least effective due to underreporting as well as a bias towards reporting administration errors (Kozer et al. 2006a; Taylor et al. 2004).

With little overlap in terms of types of errors identified using different methods, ideally, a combination of methods should be used. However, this may not always be feasible due to time and resource restraints. Prescription review by pharmacists has a distinct advantage of being able to identify both intercepted and some non-intercepted prescribing errors prospectively as part of the pharmacists' routine duties. This is particularly useful when studying the impact of an intervention on the quality as well as safety of prescribing as in the current study.

5.2.2 Assessing severity of errors

The most widely used methods to assess seriousness of medication errors are based on reviewers' (usually two clinicians, either physicians or pharmacists or one of each) judgement of actual or potential harm to the patient. Errors with the possibility of death, permanent injury or irreversible damage are considered the most severe, and errors resulting in no harm the least (NCC MERP Index for Categorizing Medication Errors). The validity or reliability of these judgements have seldom been assessed. Differences in reviewers' judgements are usually resolved by discussion or consensus. Although some studies have assessed the reliability using the κ statistic, there has been poor agreement between reviewers for seriousness of paediatric medication errors (Buckley et al. 2007; Kunac et al. 2006).

However, one severity scoring tool has been validated both in the UK and in Germany using administration error cases with known outcomes; the reliability of this tool has been assessed using repeated measures analysis of variance and the generalisability theory (Dean & Barber 1999; Taxis, Dean, & Barber 2002). This method enables the severity of medication errors to be scored without requiring knowledge about patient outcome. The tool has since been validated for prescribing error cases as well (unpublished study by Dean et al.).

5.3 Methods

For the purpose of this study, pharmacists' detection by prescription chart review was used. The definition of prescribing errors used was one which has previously been derived using the Delphi technique involving health care professional from the UK (Dean, Barber, & Schachter 2000; Ghaleb et al. 2005). Dosing errors, often associated with greatest harm, are considered to be the most common type of prescribing error in children (Wong et al. 2004). Therefore the severity rating of prescribing dose errors was determined using the scoring tool developed by Dean & Barber (1999).

5.3.1 Definition and classification

A prescribing error is one which occurs when, as a result of a prescribing decision or prescription ordering (original definition states "writing") process, there is an unintentional significant (a) reduction in the probability of treatment being timely and effective or (b) increase in the risk of harm when compared with generally acceptable practice (Ghaleb et al. 2005).

Types of events to be included as prescribing errors were based on exemplar scenarios (appendix A) that were classified as: prescribing errors, not prescribing errors or those that may be considered prescribing errors depending on the clinical situation (Ghaleb et al. 2005). These scenarios included missing essential information, illegibility, ambiguity in the prescription due to abbreviations and in some cases, failure to state the formulation. The absence of formulation on the prescription, or incorrect formulation were only considered prescribing errors if this was required due to the nature of the drug based on the definition and criteria. Similarly, ambiguity in the prescription due to abbreviations was difficult to ascertain as the use of abbreviations was standard practice. However, some abbreviations, such as 'µg', 'u', 'IU' or 'iu' have been implicated in harmful errors (Institute for Safe Medication Practices 2005a). Therefore, only the use of these abbreviations was included in the definition of an error. Error types were classified as shown in figure 15. Each drug could be classified as having more than one type of error.

5.3.2 Inclusion criteria

Prescriptions from the nephro-urology directorate, where EP was first implemented, were studied. All prescriptions written during the study periods on the renal ward and outpatients were included. Only discharge prescriptions were included from urology. Inpatient prescriptions from the urology ward were excluded as the ward pharmacy service was provided by several different pharmacists, rather than one regular one; data collection by more than one ward pharmacist would have been a confounding factor. Prescribing in urology outpatients was minimal, and so this area was excluded as well. Figure 16 illustrates the data collection periods with respect to implementation dates.

5.3.3 Sample size calculation

In a UK study, the overall incidence of prescribing errors for paediatric inpatients was 10%, over half of which were as a result of incomplete prescriptions (Ghaleb 2006). This prescribing error rate was used to perform a sample size calculation to detect a 50% reduction in prescribing errors from 10% to 5% (significance level 5% and power 90%), resulting in an estimated sample size of 577 prescribed items in each phase before and after EP.

Data collection continued beyond the required sample size, as incidence of outpatient prescribing errors in the UK was unknown, and due to delays in implementation.

Figure 15: Prescribing error classification

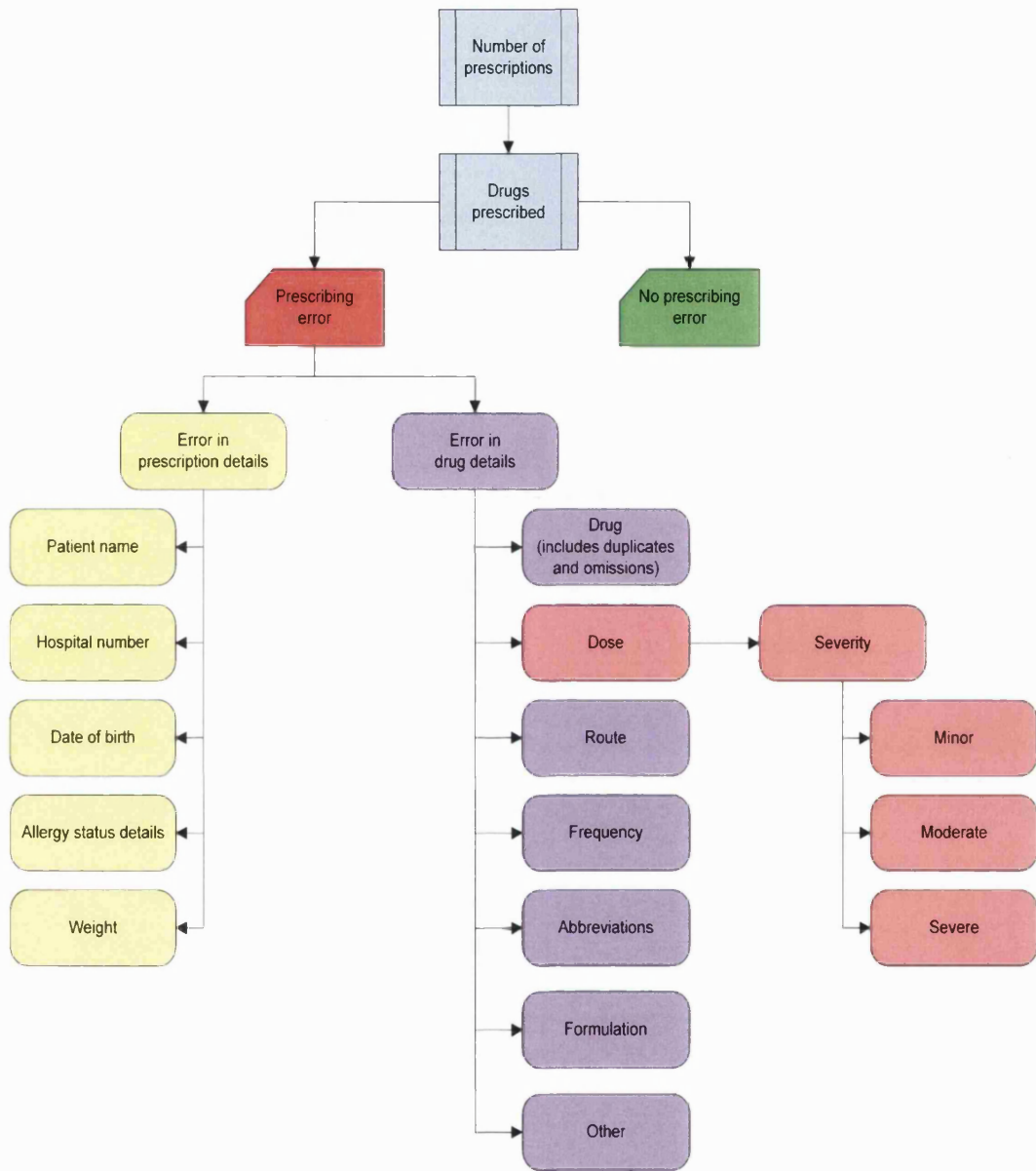
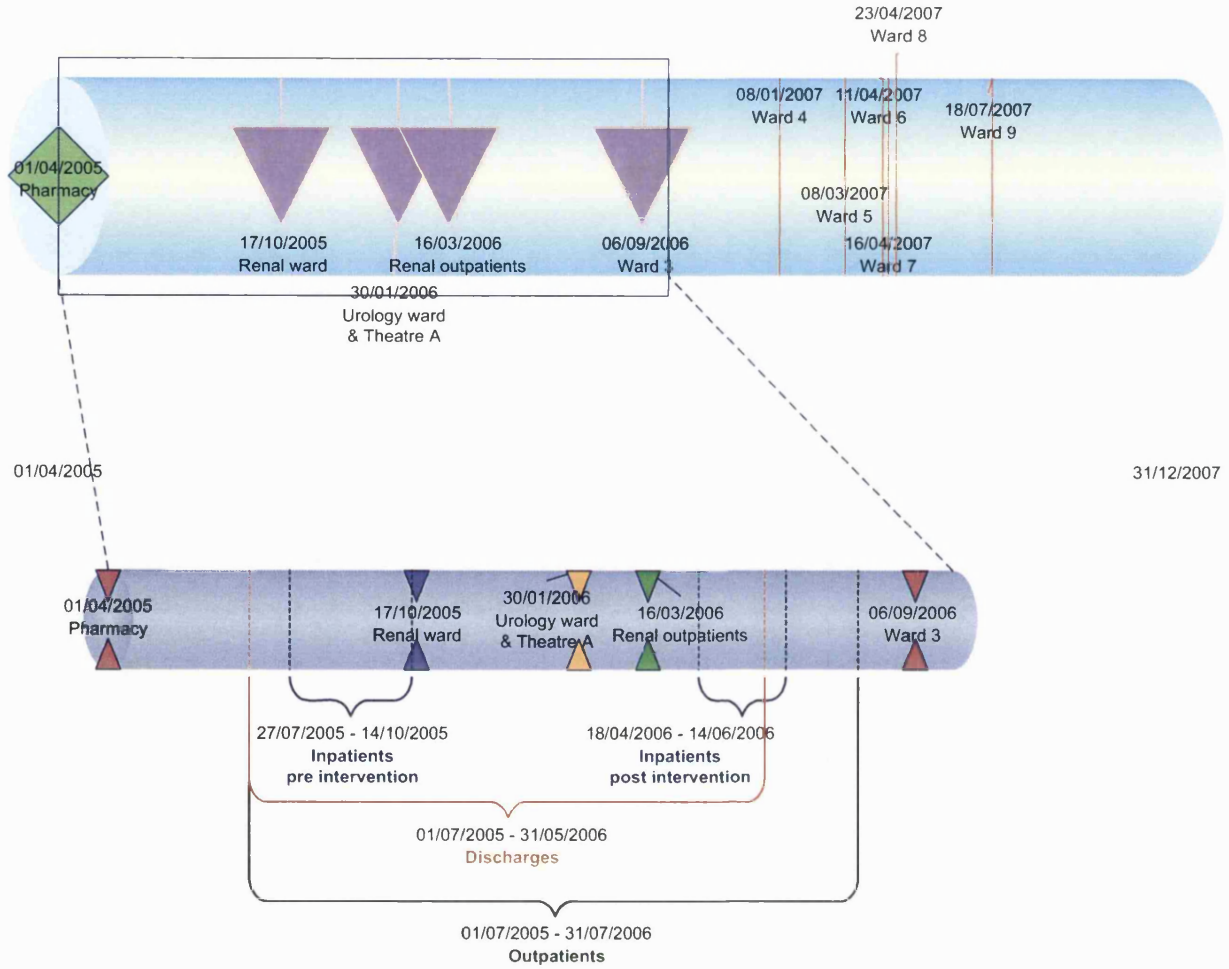


Figure 16: Implementation timeline and data collection periods



5.3.4 Data collection

Data was collected by Yogini Jani, Dr Maisoon Ghaleb - currently Postdoctoral Research Fellow at the Department of Policy and Practice (outpatient and discharge prescriptions) and a senior paediatric pharmacist (inpatient prescriptions).

Table 10: Prescription error data collectors

<i>Prescription type</i>	<i>Pre or post implementation</i>	<i>Data collected by</i>
Outpatients (renal only)	Pre (until November 2005)	Dr Maisoon Ghaleb
	Pre (from November 2005)	Yogini Jani
	Post	Yogini Jani
Discharges (renal and urology)	Pre (until November 2005)	Dr Maisoon Ghaleb
	Pre (from November 2005)	Yogini Jani
	Post (until November 2005)	Dr Maisoon Ghaleb
	Post (from November 2005)	Yogini Jani
Inpatients (renal only)	Pre and post	Senior paediatric pharmacist

5.3.4.1 Outpatient and discharge prescriptions

All prescriptions were reviewed by a pharmacist either on the ward or in the dispensary, prior to dispensing as part of their normal routine. In case of query or clarification, the pharmacist contacted the prescriber and annotated the handwritten or printed prescription with details of any changes agreed; in case of illegibility, the pharmacist rewrote that part of the prescription. Any changes made to the prescription by the pharmacist were considered potential errors. The reviewing pharmacists were blinded as they were unaware that the study was being conducted. Prescriptions written during the study period were collected prospectively and were evaluated for the presence of a prescribing error at a later date by the two researchers.

5.3.4.2 Inpatients

The senior paediatric pharmacist, who was the renal ward pharmacist, identified the prescribing errors, based on the definition and guidance provided (appendix A), and recorded it using data collection tools (appendix B). The data collection tool was modified for the post EP period, as some of the demographic data was easily retrievable from the electronic system by the researcher (Yogini Jani) and did not need to be recorded by the ward pharmacist. The researcher reviewed all reports to confirm

that they met the criteria and definition for a prescribing error. The same ward pharmacist was involved in data collection during both periods.

5.3.5 Severity rating

Five experienced healthcare professionals were asked to score prescribing dose errors in terms of potential patient outcomes on a scale of 0 to 10, where 0 represents a case with no potential effect and 10 a case that would result in death. The mean score for each error was used as an index of severity, whereby a mean score less than 3 was considered to be of minor outcome, a mean score between 3 and 7 was considered to be of moderate outcome, and mean scores greater than 7 were considered to be of severe outcome (Dean 1993).

The dose errors were scored by judges in two stages: outpatient and discharge prescription dose errors initially, and then inpatient dose errors. The judges were blinded to the prescription type i.e. they were not aware if a particular error had taken place using the electronic system or not. Judges were selected purposively and comprised a mixture of pharmacists and doctors as shown in table 11.

Table 11: Professional background of judges

<i>Prescription type</i>	<i>Judge</i>	<i>Professional background</i>
Outpatient and discharge prescriptions	Doctor 1	Paediatric renal consultant from the renal unit
	Doctor 2	Clinical pharmacologist (not based at GOSH)
	Doctor 3	Paediatric clinician with special interest in medication errors (not based at GOSH)
	Pharmacist 1	Senior paediatric pharmacist from the renal unit
	Pharmacist 2	Senior paediatric pharmacist from the renal unit
Inpatients*	Doctor 1	Paediatric renal consultant from the renal unit
	Doctor 2	Clinical pharmacologist (not based at GOSH)
	Doctor 3	Paediatric clinician with special interest in medication errors (not based at GOSH)
	Doctor 4	Specialist registrar from the renal unit
	Pharmacist 2	Senior paediatric pharmacist from the renal unit

* For inpatient dose errors, one of the judges was substituted, as that judge was the ward pharmacist involved with the primary data collection for inpatient errors. GOSH = Great Ormond Street Hospital for Children

5.3.6 Data analysis

The overall prescribing error rate was calculated as the number of items with at least one error divided by the total number of items prescribed. The error rates for different types of prescribing errors was calculated by dividing the total number of errors identified of each type by the total number of items prescribed. The proportion of outpatient visits that were error free were the number of patient visits with no prescribing errors as a fraction of the total number of visits that required a prescription, expressed as a percentage.

The dosing error rate was calculated as the number of dose errors divided by the total number of items prescribed, expressed as a percentage. Proportions of dose errors in each severity outcome category were compared before and after EP. This was calculated by dividing the number of dose errors of a given severity by the total number of dose errors and expressed as a percentage.

95% confidence intervals of proportions before and after EP, and their differences, were calculated (Altman et al. 2000). Statistical tests were used as follows to determine significance of differences between the groups: Chi squared tests for gender and presence of an error, unpaired t-tests (if normal distribution) and Mann-Whitney tests (not normal distribution) for age and length of stay.

5.3.6.1 Reliability of results

Inter-rater reliability for error identification in outpatient and discharge prescriptions was calculated using the Kappa (κ) co-efficient for five percent of handwritten prescriptions as two researchers were involved in the data collection.

Even though the severity rating assessment tool has previously been validated for both prescribing (unpublished work by Dean et al.) and administration (Dean & Barber 1999; Taxis, Dean, & Barber 2002) errors in adult inpatients, the reliability in a paediatric population or the outpatient setting has not been assessed. Therefore, repeated measures analysis of variance and the generalisability theory was used to determine reliability of severity rating scores using 95 dose errors and 4 judges, two from each profession (scores from all the judges could not be used as there was an odd number of judges, and the calculation requires an even number from each profession). This theory is based on the concept that in any measurement situation there are multiple sources of error variance and consists of two parts, a generalisability or 'G' study and a decision or 'D' study. The G-study is used to determine the major sources of variability. Once all the

sources of variance are determined, these are used to construct coefficients to reflect different decision situations; this is known as the D-study (Streiner & Norman 2003). A generalisability coefficient of 0.8 or more is considered to represent an acceptable level of reliability (Dean & Barber 1999).

In the present study, the G study was used to determine variability in the assessment of the severity of medication errors. The potential sources of variance are the medication errors or cases themselves, the judges and the profession of the judge. As each judge can only be from one profession, judge was nested within profession. Therefore, the model used for the G-study was Case x Judge:Profession, where the colon indicates nesting. First, repeated measures analyses of variance for scores from two pharmacist and two doctors were carried out by using the Statistical Package for the Social Sciences (version 15.0 SPSS Inc., Chicago, IL). The resulting values for the mean squares were then used to calculate the variance attributable to each source by using equations for the expected mean squares based on those described by Streiner and Norman (2003) and Cronbach et al (1972). If estimated variance components were computed to be negative, a value of zero was assumed. The D study was used to determine the generalisability coefficient for using five judges from any profession to score the errors, as used in this study.

5.4 Results

A total of 8723 items prescribed during 2297 patient episodes were studied over a thirteen month period (table 12). A patient episode was an outpatient visit that resulted in a prescription, a discharge from the ward which required a prescription, or an inpatient admission.

Table 12: Number of prescribed items studied

<i>Prescription type</i>	<i>Time period</i>	<i>Patient episodes (n)</i>	<i>Prescribed items (n)</i>
Outpatients	1 July 2005 to 31 July 2006	1133	2222
Discharge prescriptions	1 July 2005 to 31 May 2006	817	3155
Inpatients	27 July 2005 to 14 October 2005 and 18 April 2006 to 14 June 2006	347	3346

5.4.1 Overview of prescribing error rates

A considerable reduction in overall error rates was seen after EP in outpatient and inpatient prescriptions, but not in discharge prescriptions where there was an increase. Legibility related errors were eliminated, and the greatest decrease was in errors due to missing information. Some examples of the prescribing errors detected are given in table 15. Detailed results for each type of prescription are presented in the following sections.

5.4.1.1 Outpatients

520 patients had 2242 items prescribed during the study period. Of these 8 patients corresponding to 20 prescribed items were excluded from analysis due to incomplete information. There was good agreement between the two researchers for error identification ($\kappa = 0.65$, 95% CI 0.46 to 0.85). Although there was a higher number of prescriptions included in the pre EP phase, the demographics show that the two groups were similar (table 13).

Following the introduction of EP, the overall prescribing error rate decreased from 1219/1574 (77.4%) to 33/648 (5.1%) as illustrated in figure 17. This 72.3% reduction was statistically significant (95% CI -74.6% to -69.3%, $p < 0.001$, Chi squared test), and resulted in a corresponding increase in the number of patient visits that were error free from 185/883 (21%) to 225/250 (90%), 95% CI of difference in proportions, 64% to 73.4%. After excluding missing information and legibility related errors, all errors involving drug details were lower post implementation, with the exception of wrong drug which was higher (table 14).

Table 13: Outpatient demographics

	<i>Pre EP</i>	<i>Post EP</i>	<i>p-value</i> ^{\$}
Number of patients*	451	176	-
Female	355 (40.2%)	89 (35.6%)	0.188
Mean age at time of prescribing in months (standard deviation)	105.5 (67.8)	106.8 (66.2)	0.785
Number of patient visits that resulted in a prescription	883	250	-
Number of drugs prescribed	1574	648	
Median number of drugs/prescription (range)	1 (1-13)	2 (1-11)	

* >512 as 115 patients received a prescription during both phases.

^{\$} using Chi-square for gender, t-test for age.

Figure 17: Comparison of outpatient prescribing error rates before and after electronic prescribing (EP)

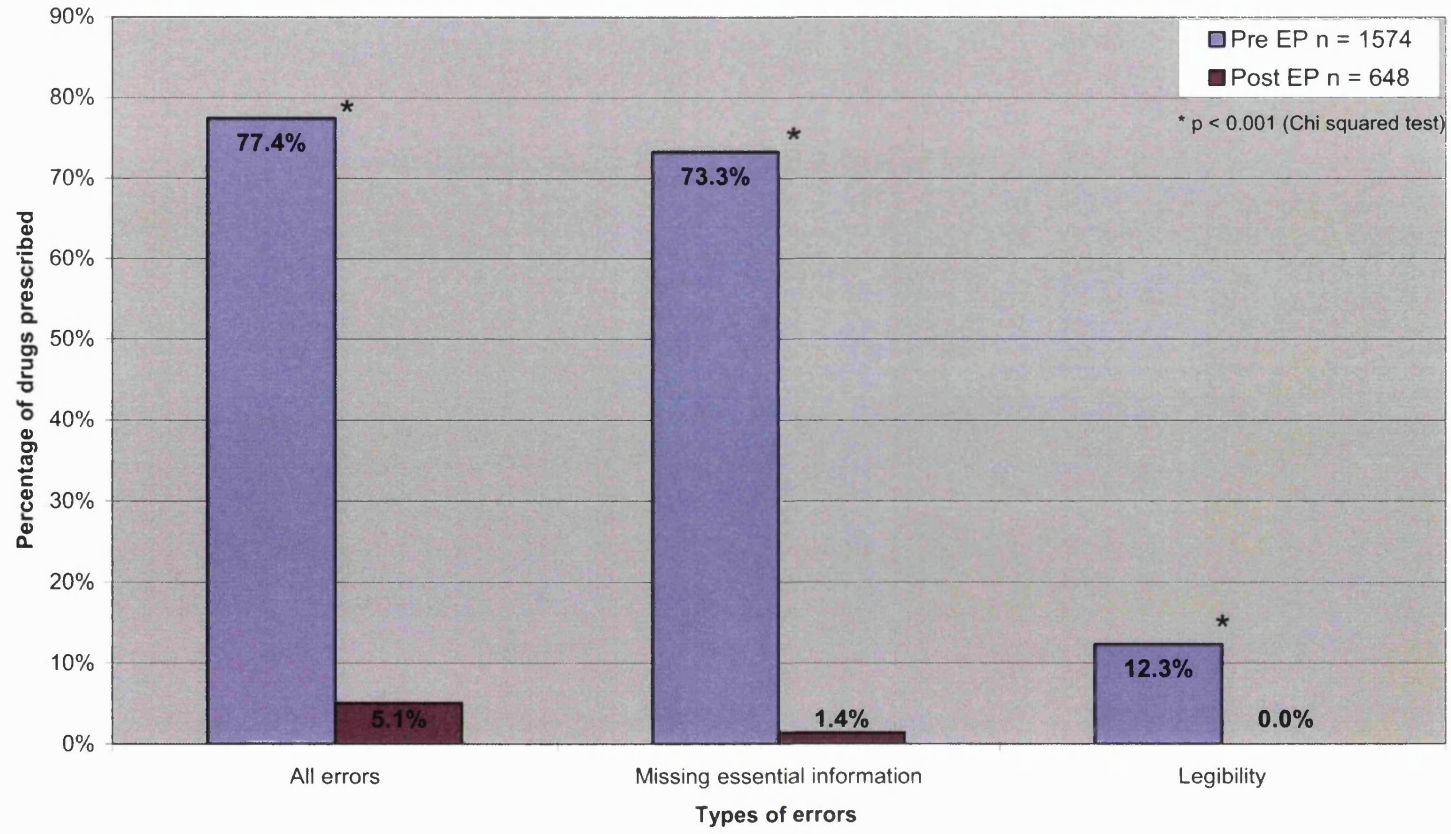


Table 14: Comparison of types of errors pre and post implementation of electronic prescribing (EP) in an outpatient clinic

<i>Error type</i>	<i>All errors</i>			<i>Excluding missing information and legibility errors</i>		
	Number (%) Pre EP	Post EP	95% CI of difference in proportions	Number (%) Pre EP	Post EP	95% CI of difference in proportions
	n=1574	n=648		n=1574	n=648	
Patient name	100 (6.4)	0	-7.7 to -5.1	41 (2.6)	0	-3.2 to -1.7
Hospital Number	16 (1)	0	-1.6 to -0.3	7 (0.4)	0	-0.9 to 0.2
Date of birth	91 (5.8)	0	-7 to -4.5	9(0.6)	0	-1.1 to 0.07
Weight	354 (22.5)	3 (0.5)	-24.1 to -19.8	1(0.1)	0	-0.4 to 0.5
Allergy	489 (31.1)	0	-33.4 to -28.8	0	0	-
Drug**	65 (4.1)	10 (1.5)	-3.9 to -1.0	6 (0.4)	10 (1.5)	0.3 to 2.45
Dose	137 (8.7)	8 (1.2)	-8.9 to -5.5	38 (2.4)	8 (1.2)	-2.1 to 0.4
Route	870 (55.3)	1 (0.2)	-57.5 to -52.6	4 (0.3)	1 (0.2)	-0.5 to 0.6
Frequency	70 (4.4)	8 (1.2)	-4.5 to -1.7	3 (0.2)	2 (0.3)	-0.3 to 0.9
Other	32 (1.7)	2 (0.3)	-2.6 to -0.7	0	2 (0.3)	-0.02 to 1.1
Abbreviations	112 (7.1)	0	-8.5 to -5.8			
Total number of errors ^s	2336	32	-	109	23	-

^s total number of errors exceeds 100% as each medication prescribed may have more than one type of error. ** includes duplicates and omissions. 95% CI = 95% confidence interval.

Table 15: Examples of prescribing errors detected during the study period

Error type	Description	Prescription format
Drug (includes duplication and omissions)	Prescribed levothyroxine, instead of levamisole, 50 mg on alternate days.	Handwritten
	Patient already on prednisolone 12.5 mg once a day as part of clinical trial, was also prescribed non trial prednisolone 12.5 mg once a day.	Electronic
Route	Prescribed Varilix 0.5 mL intra-muscular instead of by subcutaneous injection.	Handwritten
	Prescribed azathioprine 50 mg by intravenous injection instead of orally.	Electronic
Frequency	Total daily dose of calcium carbonate prescribed as 750 mg tablets five times a day, instead of 750 mg with each daytime feed and 1500 mg with overnight feed.	Electronic
Dosing: underdose	Tacrolimus oral 0.4 mL twice a day instead of 0.4 mg (0.8 mL) twice a day	Handwritten
	Tacrolimus 3.5 mg once a day instead of twice a day	Electronic
Dosing: overdose	Amlodipine 10 mg twice a day instead of once a day	Handwritten
	Fluconazole oral 36 mg once a day for a patient in renal impairment instead of 18 mg once a day	Electronic

5.4.1.2 Discharge prescriptions

567 patients had 3156 items prescribed across the two study wards. One prescription item was excluded due to incomplete information. There was good agreement between the two researchers for error identification ($\kappa = 0.81$, 95% CI 0.67 to 0.93). A higher number of prescriptions were initiated in the post EP phase; the demographics show that the gender distribution in the two groups was similar, but there were more children who were older post EP (table 16).

Table 16: Patient demographics for all discharge prescriptions

	<i>Pre EP</i>	<i>Post EP</i>	<i>p-value</i> [§]
Number of patients*	281	335	-
Female	97 (28.4)	137 (28.8)	0.881
Median age at time of prescribing in months (quartile range)	43 (18-106)	58 (19-127)	0.058
Number of prescriptions	342	475	-
Number of drugs prescribed	1098	2057	-
Median number of drugs/prescription (range)	2 (1-16)	3 (1-19)	-

* > 567 as 49 patients received a prescription during both phases.

[§] using Chi squared for gender; and Mann Whitney for age (not normal distribution)

After the introduction of EP, the number of drugs with at least one error increased significantly from 839/1098 (76.4%) to 1777/2057 (86.4%), a 10% rise (95% CI 7.9% to 12.9%, $p < 0.001$, Chi squared test), as illustrated in figure 18. This was mainly due to the absence of the patient's weight (a mandatory field on the EP system) from the paper copies of the discharge prescriptions which were printed from the EP system to dispense against. There was a significant ($p < 0.001$, Chi squared test) reduction in errors involving the patient name, hospital number, drug choice, dose and route after EP (figure 19). The change in dosing frequency errors was not statistically significant ($p = 0.6$, Chi squared test).

Figure 18: Comparison of prescribing error rates for discharge prescriptions pre and post electronic prescribing (EP)

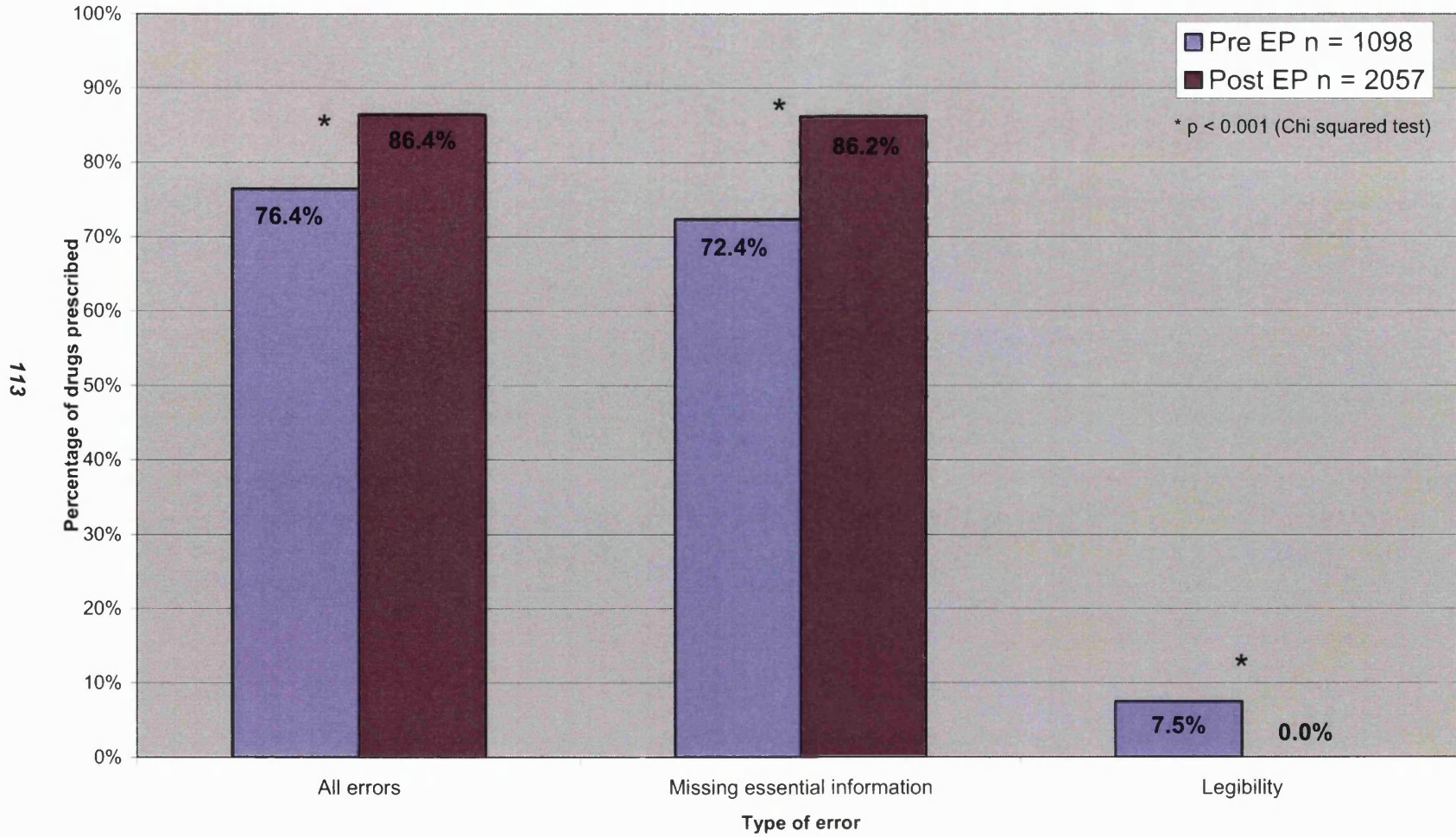
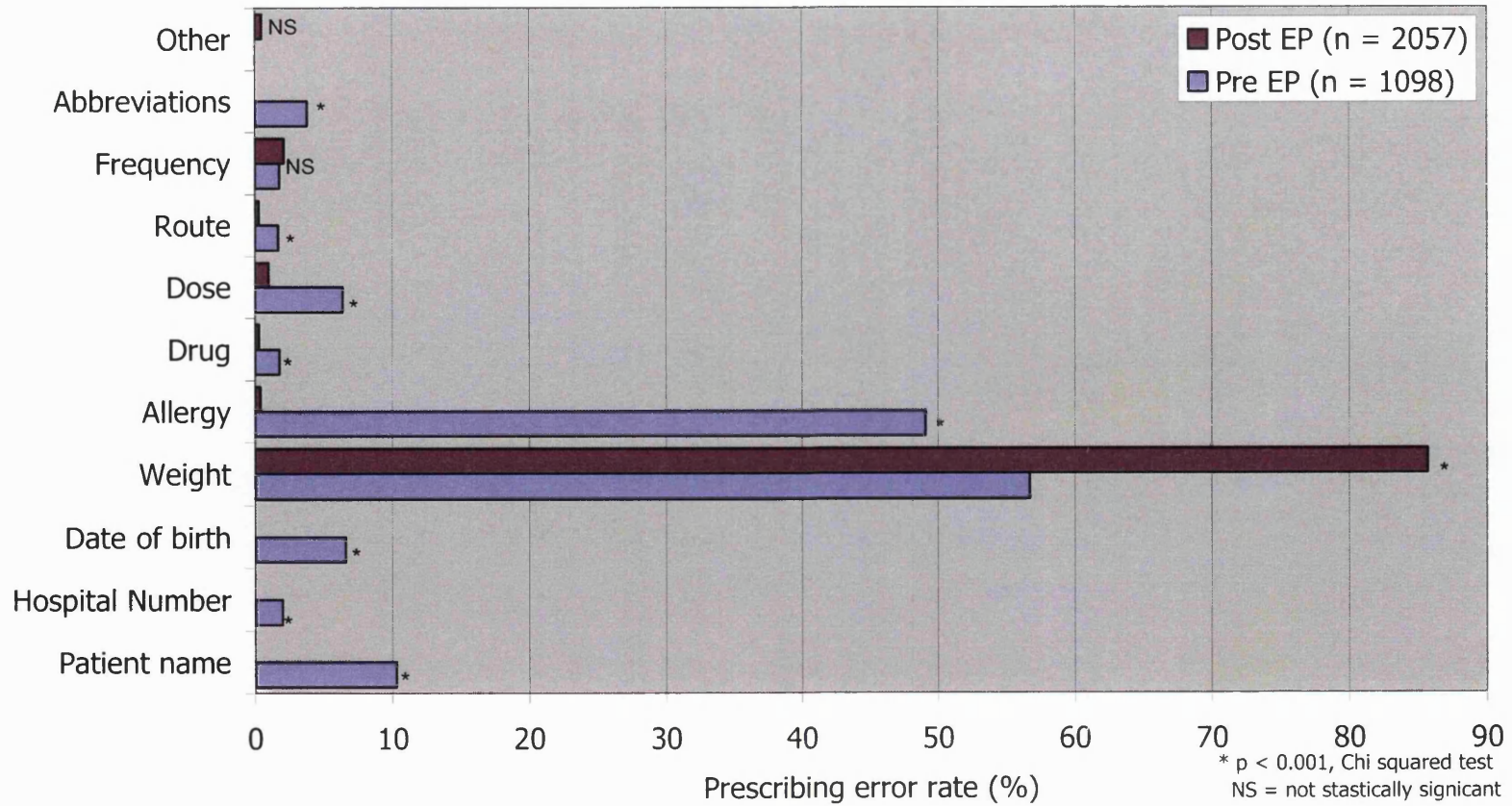


Figure 19: Types prescribing errors for discharge prescriptions pre and post electronic prescribing (EP)



5.4.1.3 Inpatients

Before EP, 1267 items were prescribed for 98 patients during 182 admissions involving a total of 959 inpatient days. After EP, 2079 items were prescribed for 85 patients during 165 admissions involving 782 inpatient days. Gender distribution and median length of stay were similar in both periods, but more young patients were admitted in the post EP phase (table 17).

Table 17: In-patient demographics

	<i>Pre EP</i>	<i>Post EP</i>	<i>p-value (test)</i>
Number of admissions*	182	165	
Female (%)	75 (41.2)	57 (34.5)	0.202 (Chi square)
Mean age at admission (months \pm SD)	93 (\pm 66)	77 (\pm 58)	0.016 (unpaired t-test)
Median length of stay in days (quartile range)	3 (0 to 63)	2 (0 to 81)	0.175 (Mann-Whitney)

* number of admissions exceeds number of patients as patients may have had multiple admissions

The ward pharmacist identified 115 and 145 medication related problems respectively during each phase of the study. Approximately one third of these problems did not meet the definition and/or criteria of a prescribing error when reviewed by the researcher. Examples of problems that were considered prescribing errors and those that were excluded are given in table 18.

After EP, the overall prescribing error rate fell from 85/1267 (6.7%) to 96/ 2079 (4.6%), (-2.3%, 95% CI, -3.4% to -0.5%, $p=0.009$ Chi squared test) and missing information errors from 49/1267 (3.9%) to 6/ 2079 (0.3%), (-3.6%, 95% CI -4% to -2.6%, $p<0.001$). There were only 3 legibility related errors before EP and these were eliminated (not statistically significant) after EP.

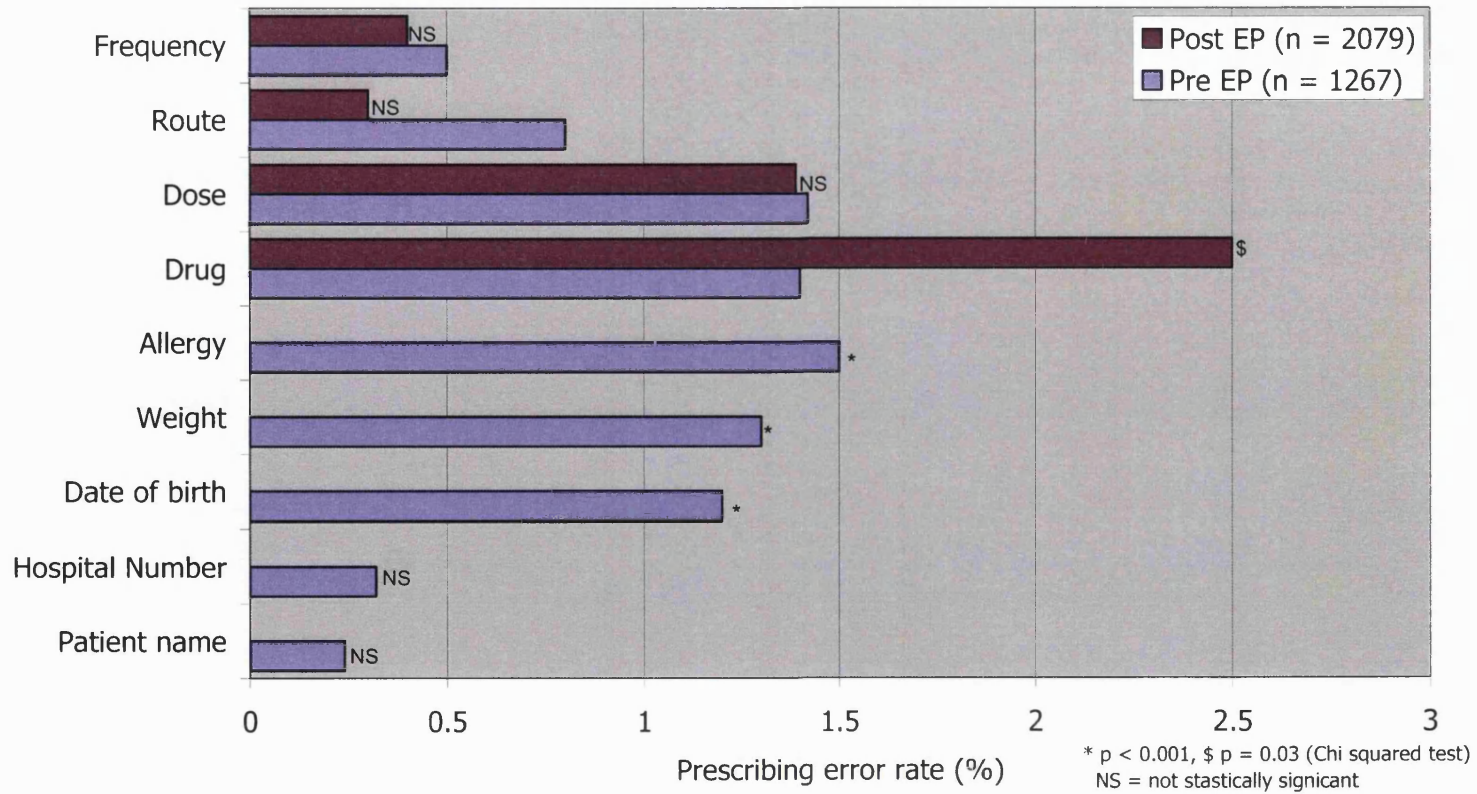
The main differences in types of errors before and after EP were seen in missing essential information errors and those concerning the drug choice/name (figure 20). Missing patient information errors i.e. those involving the patient name, hospital number, age, weight and allergy status, were eliminated post EP. Errors involving the drug choice i.e. wrong drug, duplication, omission and continuation when no longer

indicated, were increased after EP. Many of these were due to failure to prescribe, or once completed, discontinue 'dummy' drugs i.e. cross reference to paper prescription charts in use or reminder to monitor levels, for example tacrolimus levels, dialysis charts, patient controlled analgesia charts. Rates of dose, route and frequency errors were not significantly different in the two phases. However, if missing information and legibility related errors were excluded, there was a marginal increase in wrong route errors post EP. This was a result of default routes associated with formulations e.g. Maxitrol eye ointment being used topically on gastrostomy sites, failure to update the route following changes in dialysis status and complex prescriptions e.g. heparin infusion.

Table 18: Examples of medication related problems that were considered prescribing errors

<i>Medication related problems that were not prescribing errors</i>	<i>Medication related problems that were prescribing errors</i>
Dosage change < $\pm 25\%$ of appropriate dose	Wrong or missing formulation errors due to that nature of the drug e.g. nifedipine.
Consultant name was not documented on the prescription chart	Failure to prescribe a drug that was clinically indicated.
Wrong formulation was considered to have been prescribed, when the prescribed dose was not possible to administer using the formulation prescribed, when a more suitable alternative formulation was available or due to patient preference.	Continuation of a drug that was no longer clinically indicated.

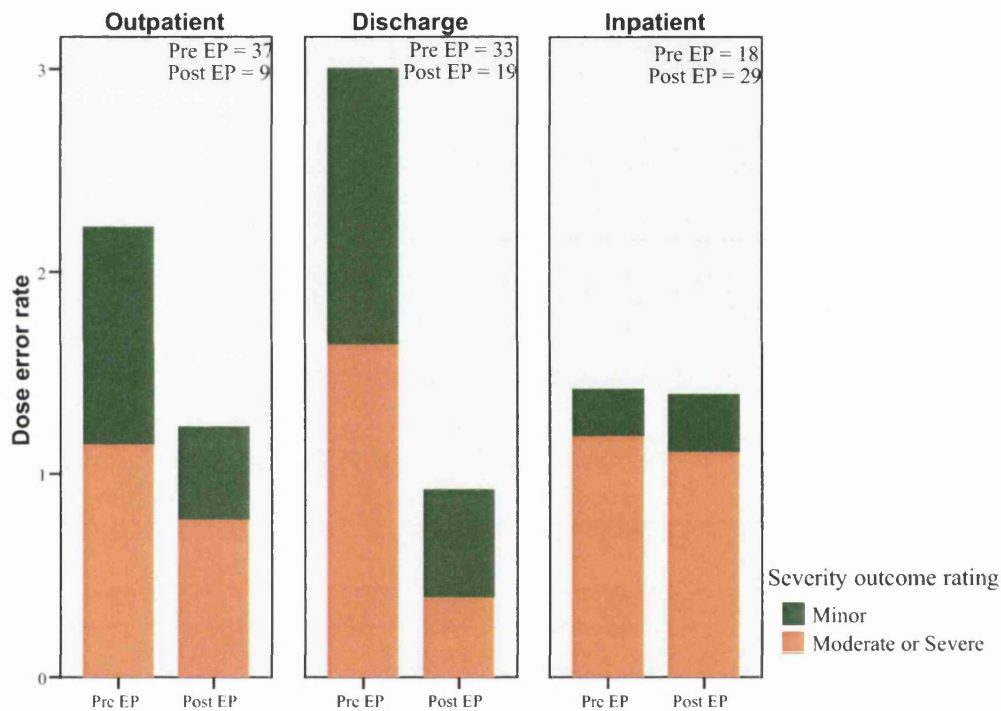
Figure 20: Types prescribing error rates inpatient prescriptions pre and post electronic prescribing (EP)



5.4.2 Severity

There were 145 dose errors in 8723 prescriptions of all types i.e. inpatient, discharge and outpatient. Dose errors occurred in 88 out of 3939 (2.2%) prescriptions before EP compared to 57/4784 (1.2%) after (-1%, 95% CI -1.6% to -0.5%, $p < 0.001$ Chi squared test). A breakdown by prescription type and severity rating is illustrated in figure 21.

Figure 21: Dose error rate and severity outcome ratings pre and post electronic prescribing (EP)



Although dose errors with minor outcome reduced after EP, there appeared to be an increasing trend in the proportions of dose errors with moderate or severe outcome after EP: errors with minor outcome 35/88 (39.8%) pre vs. 21/57 (36.8%) post; moderate and severe outcome 53/88 (60.2%) pre vs. 36/57 (63.2%) post. However, this was not statistically significant ($p = 0.72$, Chi squared test). Examples of dose errors in each category are given in Table 19.

Table 19: Examples of the severity assessed by the panel for each outcome

<i>Severity</i>	<i>Prescription format</i>
<i>Minor outcome</i>	
Oxybutynin 1.25ng three times a day was prescribed instead of 1.25mg three times a day	Handwritten
Fluticasone 125 microgram CFC free evohaler was prescribed instead of 250 microgram. Dose was 1 puff twice a day.	Electronic
<i>Moderate outcome</i>	
Alfacalcidol oral once a day was prescribed as 1000 nanograms instead of 100 nanograms	Handwritten
Sodium bicarbonate oral four times a day was prescribed as 7 mg instead of 7 mmol	Handwritten
Trimethoprim oral twice a day was prescribed as 2.5 mg instead of 25 mg	Electronic
Co-trimoxazole oral 360 mg was prescribed once a day, twice a week instead of twice a day, twice a week.	Electronic
<i>Severe outcome</i>	
Clonidine oral four times a day was prescribed as 15 mg instead of 15 micrograms.	Handwritten
Prednisolone oral prescribed as 15 mg once a day for 2 days, 10 mg once a day for 2 days, 7.5 mg on alternate days for 2 days, 10 mg on alternate days for 2 days, 5 mg on alternate days for 2 days and 2 mg on alternate days for 2 days. All doses were prescribed to start on the same day (total dose for that day = 49.5mg).	Electronic

5.4.2.1 Reliability of severity rating scores

Ninety five errors scored by two doctors and two pharmacists from the first stage were used for assessment of reliability.

G study: the main source of variance was the error description or case itself (table 20). There was little variance due to the judge and their profession. The generalisability coefficient equivalent to inter-rater reliability for any one judge within the same profession was 0.479, which indicated that there was 47.9% agreement on the severity of a medication error among four individual judges.

The D study, which had been carried out to assess the level of agreement amongst five individual judges of any profession as used in this study, resulted in a generalisability coefficient of 0.82. This means that there was 82% agreement among the five judges.

Table 20: Sources of variance

<i>Source</i> *	<i>Variances</i>
Case	2.766
Profession	0.201
Judge:profession	0.6326
Case x profession	-0.1223
Case x judge:profession	3.0085

*using the Model = case x judge: profession for 95 errors scored by 2 judges each of 2 professions

5.5 Discussion

As mentioned previously, the literature on paediatric medication errors in the UK is scarce, and only one study has assessed the effect of EP on these errors. Most of the studies in this field are from the US inpatient settings, where there are marked differences in healthcare delivery. Cognizant of these limitations, the following sections attempt to set the current findings against the existing literature and highlight the factors that contributed to the outcomes seen following the implementation of EP.

5.5.1 Incidence of prescribing errors

Before EP, there was a high incidence of prescribing errors in outpatient and discharge prescriptions, with at least one error in nearly three quarters of the prescription items studied. As this is, to the best of the researcher's knowledge, the first study of prescribing errors in a UK paediatric outpatient clinic, it is not possible to compare these results with existing literature. Likewise studies of prescribing errors in other countries are from emergency departments or primary care settings (Al Khaja et al. 2007; Rinke et al. 2008; Taylor, Selbst, & Shah 2005) where there may be differences in care delivery. There appear to be no other studies reporting prescribing error rates in paediatric discharge prescriptions either.

The overall incidence of inpatient prescribing errors was 6.7%, which is slightly lower than the 10.1% reported by a UK multicentre study using similar methodology (Ghaleb 2006). The difference may be because Ghaleb (2006) included a mixture of medical wards, surgical wards and ICUs, whereas the current study was on a renal ward and did not include ICUs. Other UK studies of paediatric prescribing errors which also used prescription review reported much higher rates of 20%-76%. The variation in error rate may be explained by the differences in definitions for prescribing errors in each of the studies. In addition the settings were also dissimilar, with all three studies being conducted on paediatric wards of general hospitals (Davey, Britland, & Naylor 2008; Farrar et al. 2003; Keady et al. 2005).

In all three prescription types, the majority of the errors involved missing essential information, which is consistent with one UK study (Ghaleb 2006), but different from the published literature, which indicates that dosing errors are more common (Ghaleb et al. 2006). However, many studies do not include missing information within the definition of an error, and this influences the reported rates for this type of error.

5.5.2 Effect of EP on prescribing errors

The results show that EP significantly reduced overall prescribing error rates, dose error rates and increased the number of outpatients visits that were error free. The effect size varied with the type of prescription.

Outpatient errors fell by 72.3% ($p < 0.001$, Chi squared test). A much smaller reduction of 2.5% (7.4% for handwritten; 4.9% of CPOE generated prescriptions, $p = 0.0048$) was reported in the only comparable study set in outpatient clinics of a tertiary academic centre in the US (Varkey et al. 2007). The US study involved both adult and paediatric patients, but the authors did not differentiate the error rate for paediatric patients. In addition, the definition used in that study appears to exclude missing information errors, although interventions due to legibility and clarification were considered prescribing errors. The exclusion of missing information errors may explain the lower prescribing error rates in handwritten prescriptions compared to the present study.

Inpatient prescribing errors decreased significantly by 2.1% ($p = 0.009$, Chi squared test). This reduction is much smaller than that reported in other paediatric studies. For example Potts et al. (2004) reported a 95.9% reduction in medication prescribing errors following the implementation of a CPOE system which had advanced CDSS. Similarly, the only UK study by Farrar et al. (2003) reported reductions of 22%-64% following redesign of EP screens (by reducing choice and discretion for junior doctors) to aid prescribers with paediatric dosing. One reason for the difference may be that Farrar et al. (2003) and Potts et al. (2004) studied the effects of EP systems with either advanced CDSS or dose related decision support, unlike in the current study where only basic decision support was in use. However, the 2.1% decrease seen here is consistent with UK studies in adult inpatients, which report 1.8%-2.7% reductions in prescribing error rates following implementation of EP systems with no advanced CDSS (Fowle et al. 2000; Franklin et al. 2007; Shulman et al. 2005).

A ten percent increase was seen in errors on discharge prescriptions ($p < 0.001$, Chi squared test), which was because of the print setup within the EP system. One UK study of discharge prescriptions reported a 1.6% reduction in prescribing errors on an adult orthopaedic ward after EP (Fowle et al. 2000). There appear to be no other studies of the effect of EP on prescribing errors involving discharge prescriptions.

There was a one percent absolute reduction in dose error rates ($p < 0.001$, Chi squared test). Three studies have assessed the impact of EP on paediatric dosing errors (Cordero

et al. 2004; Kirk et al. 2005; McPhillips, Stille, & Smith 2005). One study showed a 15.6% reduction in dose error rates for paracetamol and promethazine (Kirk et al. 2005), whereas another reported that there were no gentamicin dosing errors after EP (Cordero et al. 2004). The larger reductions in dose errors in these studies may be explained by the fact that both EP systems included dose calculations or recommendations unlike the JAC EP system which did not. The third study found no difference in dosing errors between two sites, only one of which used CPOE but had no dose related decision support (McPhillips, Stille, & Smith 2005).

5.5.2.1 Quality of prescribing

The greatest impact of EP was due to improvements in the quality of prescribing, resulting in more complete, clear and legible prescriptions. Prior to EP, omission of essential information was the commonest error, probably because there was no surety that the prescriber would write all the required information on the paper prescription. In the electronic version, mandatory fields meant that essential information had to be completed before the next field was presented.

When prescribing for children, clarity and completeness of prescriptions are important. Information such as age and/or weight is vital to ensure appropriateness of the dose. Similarly, the route needs to be explicit as often preparations are used 'off-label' to provide the necessary dose and therefore the drug formulation may not be indicative of the intended route (Hill 2005). Although potential harm secondary to omission errors is difficult to quantify because of an indirect association with adverse outcomes, lack of information about the patient or the drug has been shown to be one of the main causes of preventable adverse drug events, especially those related to prescribing errors (Leape et al. 1995; Lesar, Briceland, & Stein 1997). Another consequence of missing or unclear information is the time taken to resolve the problem. Where spotted, this is likely to have workload implications for the pharmacist, nurse and the prescriber, and in the outpatient setting, takes the time of patients and their carers. An additional factor in the outpatient setting is that medicines are administered by the patient, parent or carer rather than a nurse, thereby making complete and unambiguous information vital to aid correct administration.

Quality of prescribing was further improved with the elimination of abbreviation use after EP. For example, a review of outpatient and discharge prescriptions showed that before EP, dose unit was most likely to be abbreviated (154/2672 of handwritten items)

followed by drug name. Over half of the dose unit abbreviations involved those in the ISMP not recommended list i.e. ‘µg’, ‘u’, ‘IU’ or ‘iu’ (Institute for Safe Medication Practices 2005a). Drug name was abbreviated in 90 of the 2672 items prescribed and involved 20 drugs. Tacrolimus was abbreviated to the pre-marketing name ‘FK506’ in two instances, and potassium chloride (as ‘KCl’) was also abbreviated twice. Both these drugs have a narrow therapeutic index and are considered high risk. The potential for harm associated with the use of unapproved abbreviations was removed with the implementation of EP.

5.5.2.2 Dose errors

If omission and legibility errors were excluded, there was minimal difference in inpatient, outpatient and TTA prescription error rates for categories such as route, and frequency errors. However dose errors were reduced in all three types of prescriptions, even though the severity outcome had they not been intercepted was unchanged after EP. Dose errors fell from 2.2% to 1.2% of all prescriptions written. This small but significant reduction is an important change because the literature indicates that dose errors are the commonest type and most likely to be involved in potential ADEs in this patient group (Kaushal et al. 2001). The effect of EP on dose errors may be due to a number of reasons. Patient weight is a mandatory field on the EP system and the user is alerted to update this at regular intervals according to preset criteria i.e. every day for neonates, every week for children under one year of age and every month for all other children. Therefore an up-to-date patient weight is always available at the point of prescribing. Moreover, the patient’s date of birth is automatically uploaded from the hospital management system, thus ensuring that the child’s exact age is also present. Together, these increase the likelihood of the correct dose being calculated at the point of prescribing. Likewise, improved legibility, including the inability to use unapproved abbreviations within the electronic system, may have contributed to the decrease in dose errors by reducing the risk of confusion with units, misreading or misplacing decimal points and the resultant risk of ten-fold or 1000 fold errors.

5.5.2.3 Change in practice

One major change for prescribers when using EP was the requirement to select formulation at the point of prescribing. The absence of formulation on the prescription or prescribing the incorrect formulation were not considered prescribing errors unless the formulation was needed based on the definition and criteria used in this study

(appendix A). However it was interesting to note that the formulation was rarely specified before EP, even if it was required in order to administer or dispense the drug, whereas it was always present after EP. Prior to EP, 47 items required the formulation to be specified but did not have this information. 24 were for outpatients, 16 for discharge prescriptions and 7 for inpatients. There were three main reasons why the formulation needed to be specified:

- when more than one strength or formulation could be given for different indications e.g. movicol and mesalazine
- for liquid doses of drugs which are available in more than one strength prescribed by volume only, e.g. co-amoxiclav
- due to the nature of the drug e.g. nifedipine and ciclosporin, where different formulations are not bioequivalent.

The formulation was specified but incorrect on five occasions in all prescription types before EP. For example, mupirocin ointment was ordered, but cream more appropriate for the indication.

After EP, the pharmacist reviewing the prescription considered the formulation selected by the prescriber to be incorrect on 102 occasions: 22 were for outpatients, 55 for discharge prescriptions and 25 for inpatients. Reasons included the fact that more suitable dosage forms were available for the dose or indication, the prescribed dose was not possible using the formulation prescribed, due to the nature of the drug or due to patient preference (see table 21 for examples).

Table 21: Examples of formulation errors

<i>Type</i>	<i>Drug (including formulation prescribed)</i>	<i>Dose prescribed</i>	<i>Suitable alternative</i>
More suitable dosage form available	Maxitrol eye drops for the gastrostomy site	-	Maxitrol eye ointment
Dose not possible using formulation prescribed	Alfacalcidol 1 micrograms capsules	0.5 micrograms	0.5 micrograms capsules
Formulation not appropriate	Nifedipine 5mg capsules	-	Modified release preparation
Patient preference	Alfacalcidol 1 micrograms capsules	-	Liquid preferred

5.5.2.4 New types of errors

Recently, there has been increased awareness of the potential for new types of errors to be introduced by computerisation (Campbell et al. 2006; Koppel et al. 2005; Walsh et al. 2006). Whilst this study was not designed to evaluate causes of errors, examples of how this may occur were observed and recorded.

In one instance, the wrong formulation was selected because it appeared first on the alphabetical picking list, and consequently the wrong route was prescribed.

Azathioprine 50mg injection with a default route of 'intravenous' was selected instead of Azathioprine 50mg tablets for oral use. This is an example of a new type of error directly as a result of computer use.

EP system software utilisation and set up also led to errors that would not otherwise have occurred. For example, a duplicate prescription for prednisolone was possible even though exact drug duplication alerts were in use, as the system would alert if the same drug name, strength and formulation was prescribed again, but not if a different strength or formulation of the same drug was prescribed. Another example of a software related error is that the patient weight did not appear on the TTA printout that was used for dispensing and sent to the GP for information. Patient weight is an important element of paediatric prescribing, and inaccuracies or omissions could result in errors that may be propagated across the primary/ secondary care interface. The issue of patient weight on TTAs was subsequently resolved, when the layout of the document was revised and tabulated to resemble the previous paper TTA form.

Finally, implementation of EP affected the steps involved in the prescribing task especially in the inpatient setting. Before EP, prescribing for discharge involved transcribing from the drug chart to a TTA form. This was eliminated with the EP system. However after EP, the prescriber had to select whether or not the GP was to continue a prescription and specify the duration of treatment. Both of these were set to default values to minimise work for the prescriber, but resulted in errors. For example the duration of treatment was wrong on seven occasions, mostly because the default setting for TTAs was 28 days on the EP system. If a shorter duration was required, the prescriber had to change the default value. Likewise, the 'GP to continue' selection was incorrect for five of the 2705 discharge items prescribed. One case was a patient on long term penicillin V prophylaxis where 'no' was selected instead of 'yes'; another involved a renal patient on short term oral potassium supplements where the default

value of 'yes' was left instead of changing it to 'no'. Both of these errors have the potential to result in patient harm.

These examples suggest that implementers need to give serious consideration to new and unforeseen errors that may arise following implementation of EP either directly due to selection errors or indirectly due to the way in which the EP system is set up or used. It is important to monitor and follow-up any issues that arise during the initial stages following implementation as well as with continued use because not all problems can be anticipated. Robust risk management strategies and reporting systems need to be in place to identify and rectify or minimise these unanticipated consequences.

5.5.3 Limitations

This study has some limitations. Firstly, a quasi-experimental, before-after study design was used. However, a controlled trial (randomised or non-randomised) was considered unfeasible as the EP system was implemented on one ward at a time at a children's hospital where each ward involved a different specialty. Therefore, it would have been difficult to find a matched control. Similarly, randomisation of either prescribers or patients would have been difficult to control and impractical as the implementation was across the entire ward/ clinic.

Secondly, due to the nature of the implementation in outpatients, pre and post implementation data were collected concurrently. This means that there was varying degrees of familiarity with the system amongst the prescribers. It is possible that some of the new errors identified were due to unfamiliarity with the system and may resolve over time.

Another limitation is the inclusion of missing information and legibility errors. It may be argued that legibility is subject to interpretation and over time, recognition of handwriting and/or prescribing practice may develop. Similarly missing information was either elicited or understood by the relevant individual. The likely harm as a consequence of omission and legibility errors was not assessed in this study, but the potential of misinterpreting any part of the prescription, especially dose, due to lack of clarity has serious implications in children.

The method used to identify prescribing errors is a process based one, which focused on intercepted errors i.e. all detected errors were corrected and therefore the patients experienced no resultant harm. It is possible that some errors may have been missed. A few studies have compared the yield of medication errors using the different methods

(Jha et al. 1998; Kunac & Reith 2008; Olsen et al. 2007), including one from the UK which focused on prescribing errors (Barber et al. 2006). All these studies conclude that different methods identify different errors, with little overlap between methods. Barber et al. (2006) reported that most of the 262 prescribing errors detected in their study were identified using a retrospective review form (198, 75.6%), followed by prospective prescription review by the ward pharmacist (78, 29.7%). Application of a trigger tool and use of spontaneous reporting were the least effective (2 errors each, 0.8%). Only 5-7% of prescribing errors were identified by both the retrospective review form and the prospective prescription review by pharmacists. Therefore, it is likely that in the current study, only a third of the total prescribing errors were detected using prescription review by pharmacists. However it was anticipated that the greatest effect of the JAC EP system, which had minimal clinical decision support activated at the time of study, would be on errors relating to legibility and clarity of prescriptions. These errors are more likely to be identified by prescription review. Two researchers were involved in the data collection for outpatient and discharge prescription errors, but inter-rater reliability using the κ statistic showed good agreement between the researchers. The focus of this study was prescribing errors rather than actual harm due to the errors. However, the severity rating scale allowed relatively objective measurement of potential patient outcomes had the error not been intercepted. Although severity outcome was assigned by five different judges from different professions, use of the generalisability theory showed that there was 82% agreement between the judges.

5.6 Conclusions

The purpose of this study was to quantitatively assess the outcome of using the JAC EP system in a children's hospital. On the whole, there was a positive effect with a reduction in prescribing errors in outpatient and inpatient prescriptions following EP. The benefits were mainly due to improved quality of prescribing which led to more complete, clear and legible prescriptions. Some unintended and unanticipated effects were also seen, partly due to EP system software and partly due to the effects on health care professionals' work practices. The latter will be explored further in chapter 7, which presents the findings from a qualitative study of the EP system in use. Advanced CDSS integrated within an EP system has been shown to have additive effects on the reduction of medication errors and this will be discussed in the next chapter.

Chapter 6 Computerised Clinical Decision Support

“The real problem is not whether machines think but whether men do.”

B. F. Skinner, American Psychologist

(http://en.wikiquote.org/wiki/B._F._Skinner)

6.1 Introduction

Clinical decision support systems (CDSS) are important safety tools which may be incorporated into electronic prescribing (EP) systems. One definition of CDSS is "active knowledge systems which use two or more items of patient data to generate case-specific advice" (Wyatt & Spiegelhalter 1991).

Computerised CDSS have been shown to have a positive impact on patient outcomes such as adverse events and medication errors, as well as clinician behaviour/performance, e.g. prescribing practices. The research in this field has been summarised by three systematic reviews (Garg et al. 2005; Kaushal, Shojania, & Bates 2003; Wolfstadt et al. 2008). Kaushal et al. (2003) reviewed 12 trials on the effects of CPOE and CDSS on medication safety. The authors reported a significant reduction in medication error rates with the use of CPOE with CDSS, with greatest benefits at two sites with "home grown" systems. However, they found that most studies were not powered to detect differences in ADEs. In a second paper, Garg et al. (2005) reviewed 100 controlled trials evaluating the effects of computerised CDSS on practitioner performance and patient outcomes. This review included worldwide studies of a mixture of "home grown" and commercially available systems for diagnosis, disease management, reminder systems for prevention and systems for drug dosing and prescribing. Twenty nine of the 100 trials involved CDSS for drug dosing and prescribing; 19 of these showed an improvement in practitioner performance. Studies in which the authors had developed the CDSS software were more successful than those in which the authors were not the developers. Moreover, like Kaushal et al. (2003), the authors noted that patient outcomes were either understudied, or if studied, most had inadequate statistical power to detect a clinically important improvement. In the most recent review on CPOE with CDSS, Wolfstadt et al. (2008) focussed on the rates of ADEs. They included 10 studies set in hospitals or ambulatory care, and found that CPOE with CDSS contributed to a statistically significant reduction in ADEs in 50% of the studies.

The effect size of CDSS on medication errors and ADEs appears to be related to the level of CDSS. In a quantitative systematic review of the effect of EP on medication errors and ADEs, Ammenwerth et al. (2008) found a positive effect of EP offering advanced CDSS; 14 studies with advanced CDSS reported a higher relative risk reduction in ADEs compared to 11 studies with limited or no decision support.

In paediatrics, where prescribing is almost always based on individual patient data such as age or weight, it seems intuitive to expect CDSS to be beneficial. Certainly, most of the EP systems that have been used in paediatrics included some level of CDSS as discussed in Chapter 2 (table 5). However, one of the main problems with CDSS is the way in which it is integrated into the EP system, and the effect this has on the user. Benefits are only realised if there is a balance between effective support provided at point of care and minimal disruption to the workflow (Kawamoto et al. 2005; van Wyk et al. 2008). Use and acceptance of the support provided is dependent on the sensitivity (a measure of the ability to pick a true positive) and specificity (a measure of the ability to pick a true negative) of these alerts. Risk of alert-fatigue and increased likelihood of overriding the alert due to excessive and unnecessary alerts are common problems of CDSS (van der Sijs et al. 2006)

The purpose of this chapter is to provide a detailed description of the CDSS within the JAC EP system, to study the characteristics of the CDSS alerts generated within the first year of EP implementation and make recommendations for improvement.

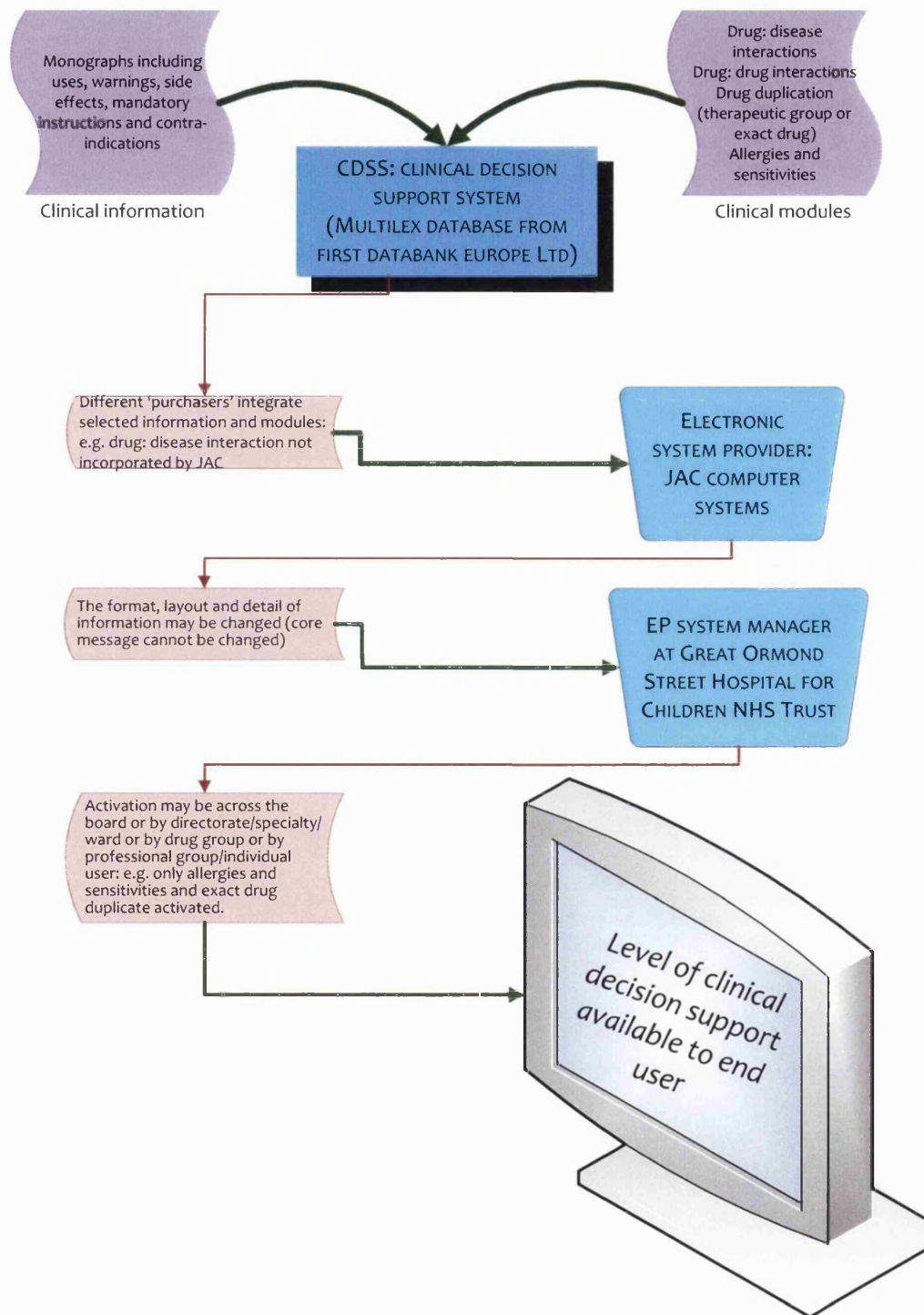
6.2 CDSS within the JAC EP system

The level of CDSS within EP systems is often classified as either basic or advanced. Basic CDSS includes features which are considered straightforward, such as drug-allergy checking, basic dosing guidance, formulary decision support, duplicate therapy checking, and drug–drug interaction checking. Advanced CDSS is more complex and takes into account disease states and high risk patient groups e.g. dosing support for renal insufficiency, guidance for medication-related laboratory testing and drug–disease contraindication checking (Kuperman et al. 2007).

In practice, CDSS within most EP systems is not quite so clear cut. With the exception of a few ‘home-grown’ systems, most involve the incorporation of commercially available drug and clinical information into an EP system, with some flexibility for local tailoring. CDSS within the JAC EP system is one such example: the clinical information is provided by First Data Bank Europe Ltd as illustrated in figure 22.

Advice from the JAC EP-CDSS is in the form of intrusive alerts to the user. These alerts are either rules based informative/ instructive alerts or clinical information based conflict alerts. Alerts are activated centrally by the EP system manager (i.e. individual users cannot turn them off) and have been ratified by the Drugs and Therapeutics Committee at the hospital.

Figure 22: Level of clinical decision support that may be available to the end user



6.2.1 Rules based alerts

The rules based alerts instruct the user to enter mandatory information such as allergy status and patient weight before prescribing, as well as providing information involving patient demographics and timing of a drug/dose as detailed below.

- Prompts for allergy status entry.
- Prompts for weight entry.
- Alerts the prescriber if the height or weight entered is outside the expected range based on the child's age. Tables for height and weight based on age have been set locally.
- Prompts for weight to be updated if date of previous entry exceeds the specified time period for the age of the child e.g. for older children, the weight needs to be revalidated on a monthly basis.
- Alerts for weight change of $\pm 10\%$ compared to the previous weight entry
- Alerts for patients with a similar name on the same ward
- Alerts if an action contradicts previously entered information e.g. restart date for suspended items, discontinue date for items with stop dates, early or late administration alert

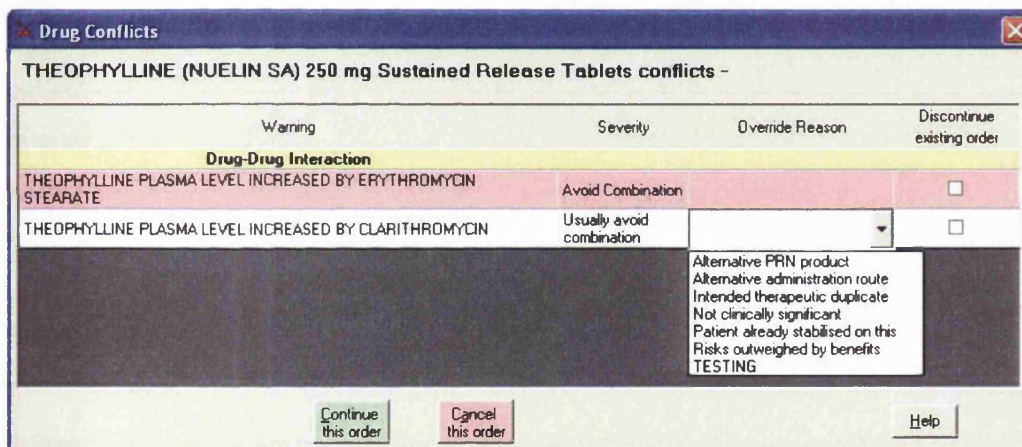
6.2.2 Clinical information based conflict alerts

Conflict alerts are based on coded information in the EP system, using the Multilex Drug Data File UK (First DataBank Europe Limited). Four categories of clinical conflict alerts may be generated within the JAC EP system: drug-allergy interaction, exact drug duplication, drug-drug interaction and therapeutic drug duplication or drug double. Alerts are generated if a conflict is detected either at the point of prescribing a new drug or when allergy status, which is a mandatory field for all patients, is amended. Alerts are generated on the basis of coded information; uncoded information or information entered as 'free-text' would not result in an alert. Unlicensed medicines, non-drug allergies and free text entries for allergy status are not coded and therefore would not trigger conflict checking. For example, if a patient is documented as being allergic to peanuts, which is an uncoded non-drug allergy, the system would not check for or detect any conflicts with this.

During the study period, some alerts were suppressed so that even though they were generated, they were not visible to the end user. Visibility of alerts was determined centrally by the EP project team. For visible alerts, the alert content consisted of the nature of the conflict and options for further action to be taken. Visible alerts may be heeded or overridden; warnings could be heeded either by backing out i.e. not continuing with the new order, or by discontinuing the existing conflicting medication and ordering the new one. Entering override reasons was not mandatory during the study period, but could be done by selection from a dropdown menu if the prescriber chose to do so (figure 23).

Situations in which each of the four types of conflict alert would be generated are described in the following sections.

Figure 23: Example of a conflict alert window presented to the prescriber



6.2.2.1 Drug-allergy interactions

The prescriber was alerted if the patient was known to be allergic to the drug being prescribed, or subsequently found to be allergic to a drug already prescribed. Drug-allergy interaction alerts would be triggered in the following situations:

- if there was an exact drug: patient allergy match
- a patient allergy group contained the drug being prescribed e.g. prescribing gentamicin to a patient with documented allergy to 'aminoglycosides.'
- selected drug matched another drug in a common patient allergy group e.g. prescribing ibuprofen for a patient with documented allergy to diclofenac.
- selected drug matched another drug in a common patient allergy cross reactor group e.g. prescribing cefalexin for a patient with a documented allergy to amoxicillin.

- a group patient allergy in the same cross reactor group e.g. prescribing cefalexin for a patient with a documented allergy to ‘penicillins.’

6.2.2.2 Exact drug duplicate

This would be presented to the prescriber if the exact formulation *and* strength of a drug already prescribed for a patient was selected again for prescribing.

6.2.2.3 Therapeutic duplicate or drug double

This alert would be generated if a different formulation and/ or strength of an already prescribed drug is selected for prescribing or if the new selection is in the same therapeutic group as a drug that has already been prescribed.

6.2.2.4 Drug-drug interactions

An alert is generated for two interacting drugs if one of the drugs is prescribed for a patient who is already on the other drug. The alert consists of the name of the interacting drug, and the nature of the interaction. There are 4 levels of drug-drug interactions, which are rated by level of risk from one to four stars as shown in table 22.

Table 22: Levels of risk for drug: drug interactions and recommended actions

<i>Level</i>	<i>Level of Risk</i>	<i>Recommended action</i>
4 Star	High	Risk outweighs possible benefit. Do not combine.
3 Star	Significant	Combine in special circumstances only having considered the risk to benefit ratio for the patient.
2 Star	Moderate	Combine with caution having considered the risk to benefit ratio for the patient.
1 Star	Low	Combine having considered the risk to benefit ratio for the patient.

6.2.2.4.1 Risk assessment and assignment

The following information was provided in an e-mail by the Head of Knowledge Base Services at FDBE.

Drug: drug interaction levels are assigned by the clinical team at FDBE based on an assessment of potential risk to the patient as a result of co-prescribing interacting drugs. The potential risk is determined primarily by their pharmacists, who take into account any documented evidence, using the following key reference sources: the Summary of Product Characteristics (SPC), Stockley's Drug Interactions, the British National Formulary (BNF), Martindale and Evaluation of Drug Interactions (produced by FDB INC in the US) and www.torsades.org. For herbal medicines, the European Scientific Cooperative On Phytotherapy monograph and the 3rd edition of Herbal Medicines by Barnes, Anderson and Phillipson are used as references.

In some cases, for example, any interaction that decreases the effect of an anti-epileptic, the star rating would always be high as the potential effect on a patient's life of a single epileptic fit could be devastating. Similar considerations apply to reduced effect of oral contraceptives. On the other hand, an interaction that resulted in increased sedation where one of the interacting drugs already has coded warnings relating to sedation and driving would be less highly rated. The majority of cases are determined taking into account the clinical risk to the patient of the interaction - again, a raised plasma level of penicillin is not usually highly clinically significant, but a raised plasma level of lithium or warfarin would be classed as significant. The likelihood of an interaction, or its reported frequency, are not taken into account when judging star ratings - the judgement is always based on the risk to the patient should the interaction occur.

The clinical database is updated each month to include new drugs and amendments to existing drugs. For new drugs, manufacturer's information is the main reference source, and therefore some general rules are applied. For example, if a new drug states that it prolongs the QT interval, then there will be considered to be an increased risk of prolonged QT interval with other drugs that are also known to prolong the QT interval. Similarly drugs that are documented as being substrates of enzymes such as human cytochrome P450 enzyme CYP 3A4 will be considered to have the potential to interact with drugs that are known to induce or inhibit the enzyme. For deduced interactions such as this, the terms 'may increase/decrease' plasma level are used whereas in cases where this is documented, 'increases/decreases plasma level' is the term used (Head of Knowledge Base Services at FDBE 2008).

6.3 Aims and objectives

The CDSS in the JAC EP system involves alerts that are either based on EP system rules or a commercially available clinical database. The aim of this study was to assess the characteristics of the latter; the objectives were:

- To review clinical information CDSS alerts that were visible to the user when using the EP system and assess their effect on users' practice.
- To examine the additional number and categories of alerts that would appear if varying levels of the CDSS elements were activated.
- To examine the rationale of different levels of alerts and make recommendations for improvement.

6.4 Method

All CDSS alert information recorded by the system as 'conflict logs' over a one year period was retrieved from the EP system using a Crystal report designed by the company on the researcher's request. The results of the Crystal report were transferred to SPSS which was used to aid analysis. The following outcomes were studied:

- Number and categories of conflicts recorded in the first year of the system in use from 17th October 2005 to 17th October 2006, based on prescription type i.e. outpatient or inpatient (includes TTAs)*, and user grade and/ or profession when the conflict was recorded.
- Number of conflicts that were visible to the user.
- Action taken by the user as a result of visible alerts.
- Number of conflicts that would be visible to the user if all drug: drug interactions were activated.
- Drugs and/ or drug combinations involved in suppressed conflicts.

* TTAs were included with inpatient prescriptions as these were ordered using the same module within the EP system and more likely to be a continuation of inpatient medication. Outpatient prescriptions were ordered using a different module if new medicines or a resupply of existing medication was required for a patient seen in the outpatient clinic

6.4.1 Terminology and data analysis

The total number of conflicts recorded within the system are called ‘conflict alerts.’ Conflicts that were visible to the users are called ‘visible alerts’ and those that were not visible, ‘suppressed alerts.’

The alert rate was calculated and reported per 100 prescription orders as follows:

$$\frac{\text{number of alerts}}{\text{number of new prescriptions}} \times 100$$

The number of new items ordered or prescribed during the study period was retrieved from the system using a second Crystal report. Chi squared tests were used to compare differences between groups, and 95% confidence intervals of proportions were calculated (Altman et al. 2000).

6.5 Results

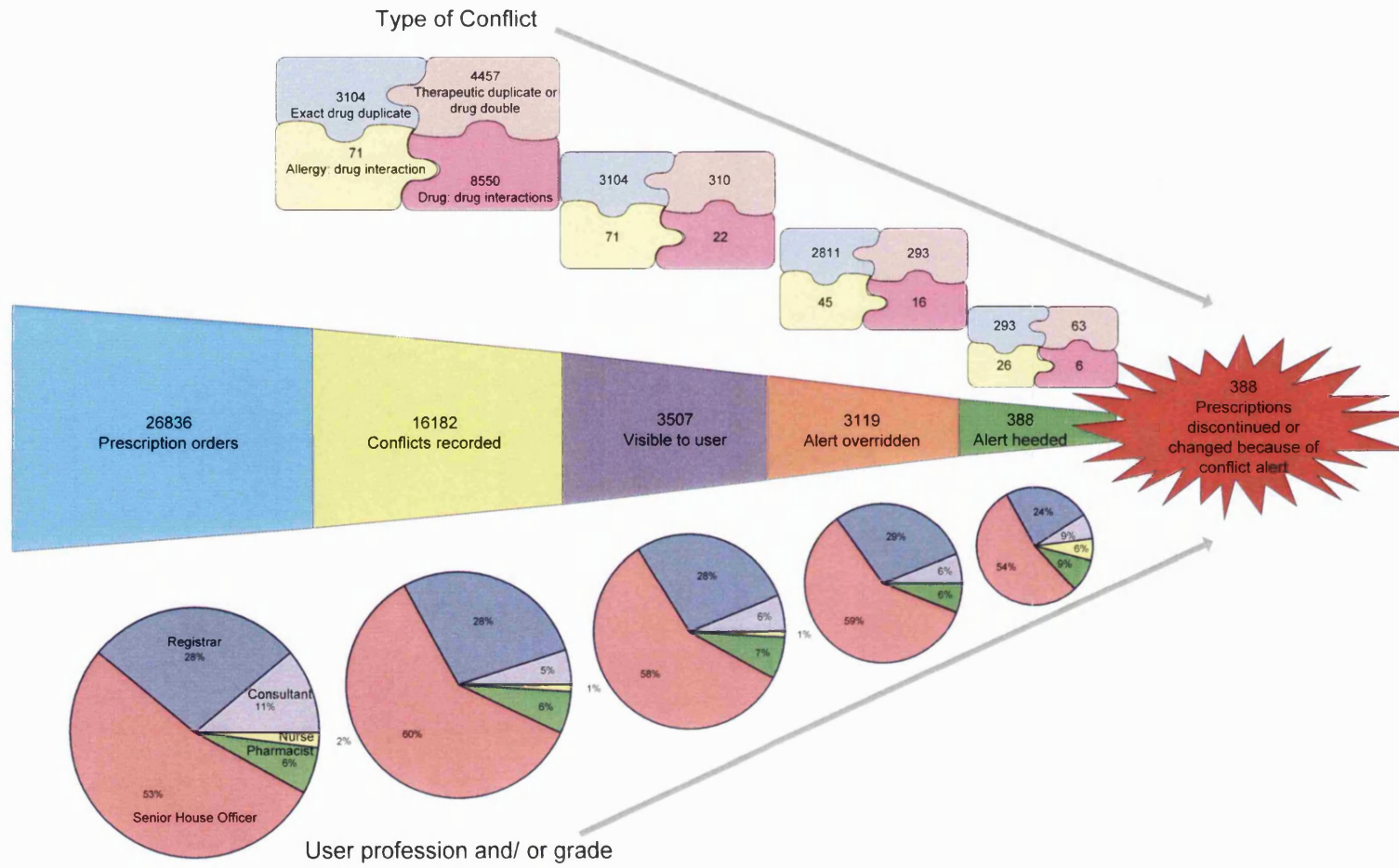
6.5.1 Overview

During the first year since implementation, 16182 conflict alerts were recorded when ordering 26836 items, resulting in 60.3 conflict alerts generated for every 100 prescriptions ordered (95% confidence interval (CI), 59.7 to 60.9). Of these, 13 alerts were visible to the user per 100 prescription orders. The remaining conflict alerts were logged, but not visible to the user (i.e. suppressed), either due to inactivation of certain conflict checking functionalities by the EP pharmacist or if the drug had been ordered as part of a protocol (conflict checking is not performed if drugs are ordered within a preset protocol). Details of conflict alerts types and users who initiated the prescription are shown in figure 24.

It was interesting to note that some drug-drug interactions and therapeutic duplication or drug double conflicts were visible to users, even though the EP team had made a conscious decision not to activate these during the initial implementation phase. There was no obvious explanation for this.

Figure 24: Characteristics of conflict alerts generated within the EP system

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6.5.2 Type of conflicts in different settings

With the exception of drug: allergy alerts, conflicts were more likely to be generated when prescribing inpatient and TTA items, compared to outpatient prescriptions.

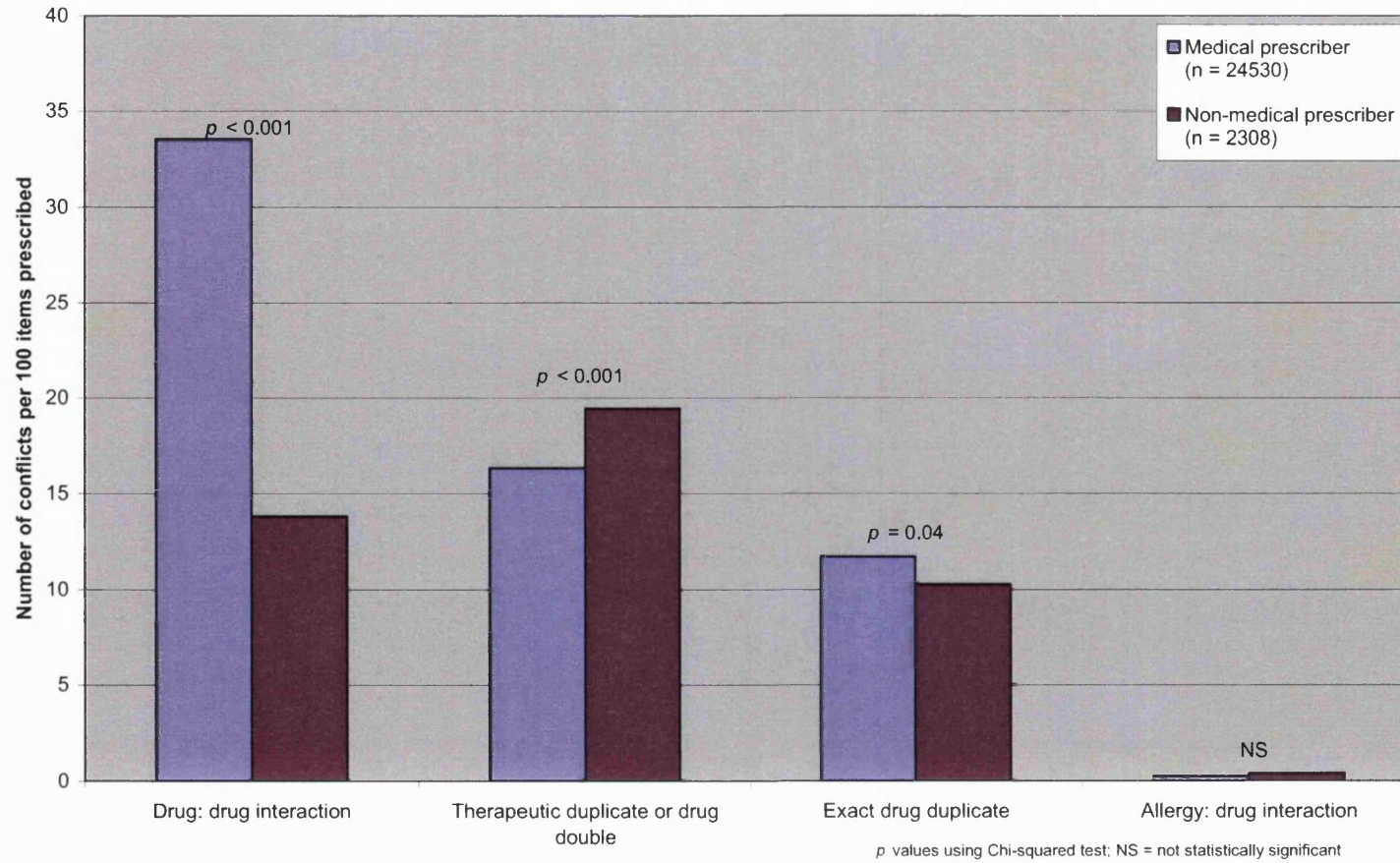
Table 23: Types of conflict alerts generated in the inpatient and outpatient settings

<i>Type of conflict</i>	<i>Number (rate per 100 prescription orders)</i>		<i>p-value</i>
	Inpatient & TTA n = 25928	Outpatient n = 908	
Drug interaction	8404 (32.4)	146 (16.1)	< 0.001
Therapeutic duplicate or drug double	4366 (16.8)	91 (10)	< 0.001
Exact duplicate	3047 (11.8)	57 (6.3)	< 0.001
Allergy	69 (0.3)	2 (0.2)	0.79
Total conflict alerts	15886 (61.3)	296 (32.6)	< 0.001

6.5.3 Type of conflicts based on user profession

The majority of the prescribing was performed by medical prescribers, who prescribed 24530 items. Other users were nurses who used the system to record PGDs for a limited number of drugs, and pharmacists, who used the system to change or initiate prescriptions following discussion with the prescriber. Non-medical prescriber ordering accounted for 2308 items initiated during the study period. Medical prescribing resulted in 61.8 conflict alerts per 100 items prescribed, compared to 43.9 conflict alerts per 100 items ordered by non-medical prescribers ($p < 0.001$, Chi squared test). A breakdown of conflict category by user profession is illustrated in figure 25.

Figure 25: Conflict category based on prescriber profession



6.5.4 Action taken for visible alerts

3507 of the 16182 conflict alerts generated were visible to the user, resulting in a visible alert rate of 13 per 100 prescription orders. This means that the prescriber would see one alert for every 8 drugs prescribed. Approximately 90% (3119/3507) of all visible alerts were overridden by doctors and there was no difference in alert override rate based on seniority of medical prescribers ($p = 0.3$, Chi squared test); nurses were most likely to heed an alert (figure 26). Allergy: drug interaction alerts were the most heeded, and exact drug duplication alerts the least (figure 27).

6.5.5 Reasons for overriding an alert

3119 visible alerts were overridden, and a reason was entered for just 44 (1.4%) of these; 43 involved drug: allergy conflicts. The commonest reason given for an override was 'aware will monitor'. One of the override reasons was 'not clinically significant' but this reason was never selected (figure 28).

6.5.6 Suppressed alerts

Nearly 75% of all conflict alerts generated were suppressed and therefore not visible to the user. Drug: drug interaction conflicts accounted for two thirds of all suppressed alerts. Over half of these were level 3 interactions, with 26 level 4 drug: drug interactions recorded (figure 29).

6.5.7 Drugs involved in conflict alerts

Drugs involved reflected the usage and practice on the renal unit which was the first area to go-live, with prednisolone, tacrolimus and paracetamol as the top three. Phenytoin was involved in 25 of the 26 level 4 drug: drug interaction conflicts.

Figure 26: Action taken by different prescribers for visible alerts

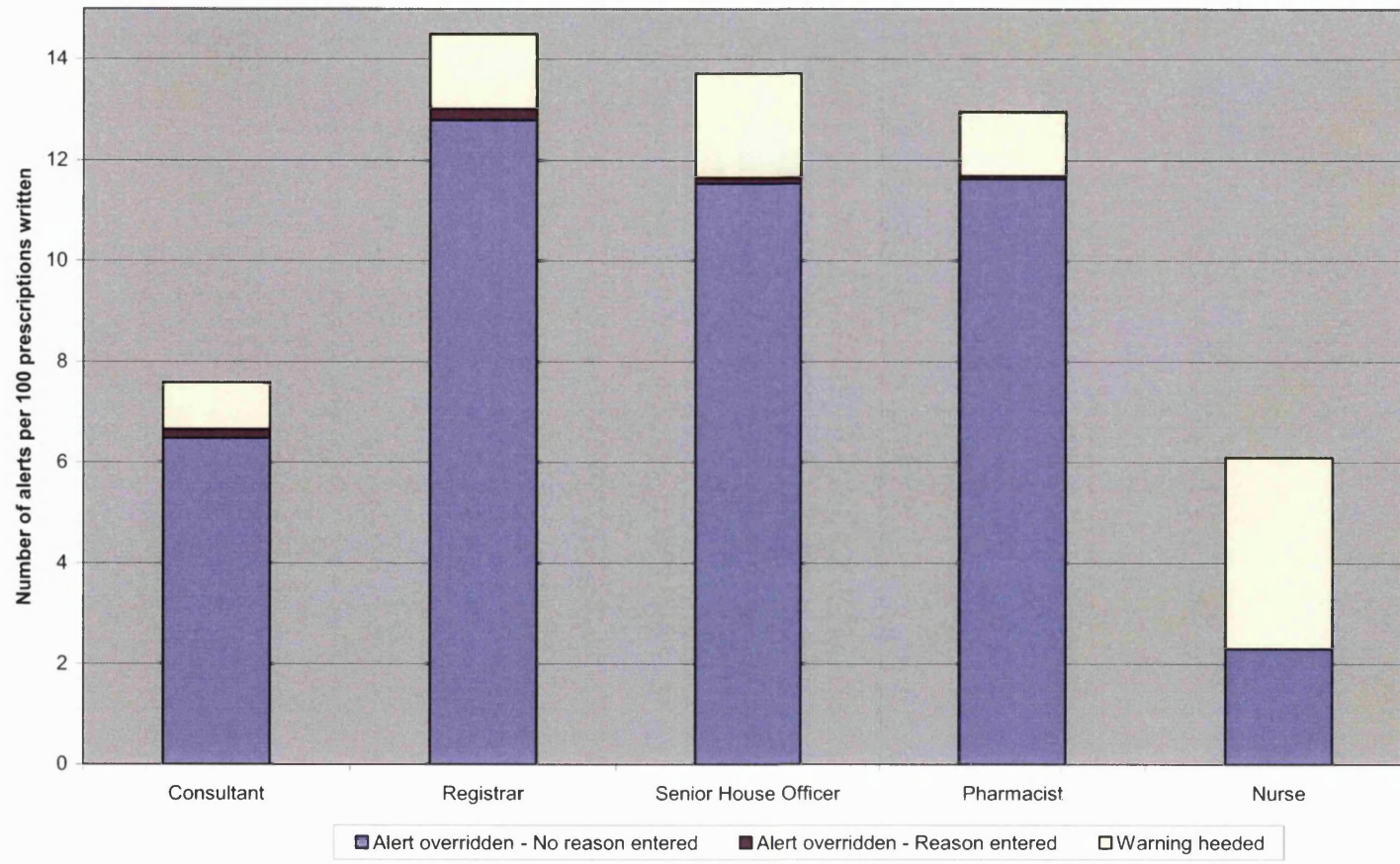


Figure 27: Action taken for different categories of visible conflicts

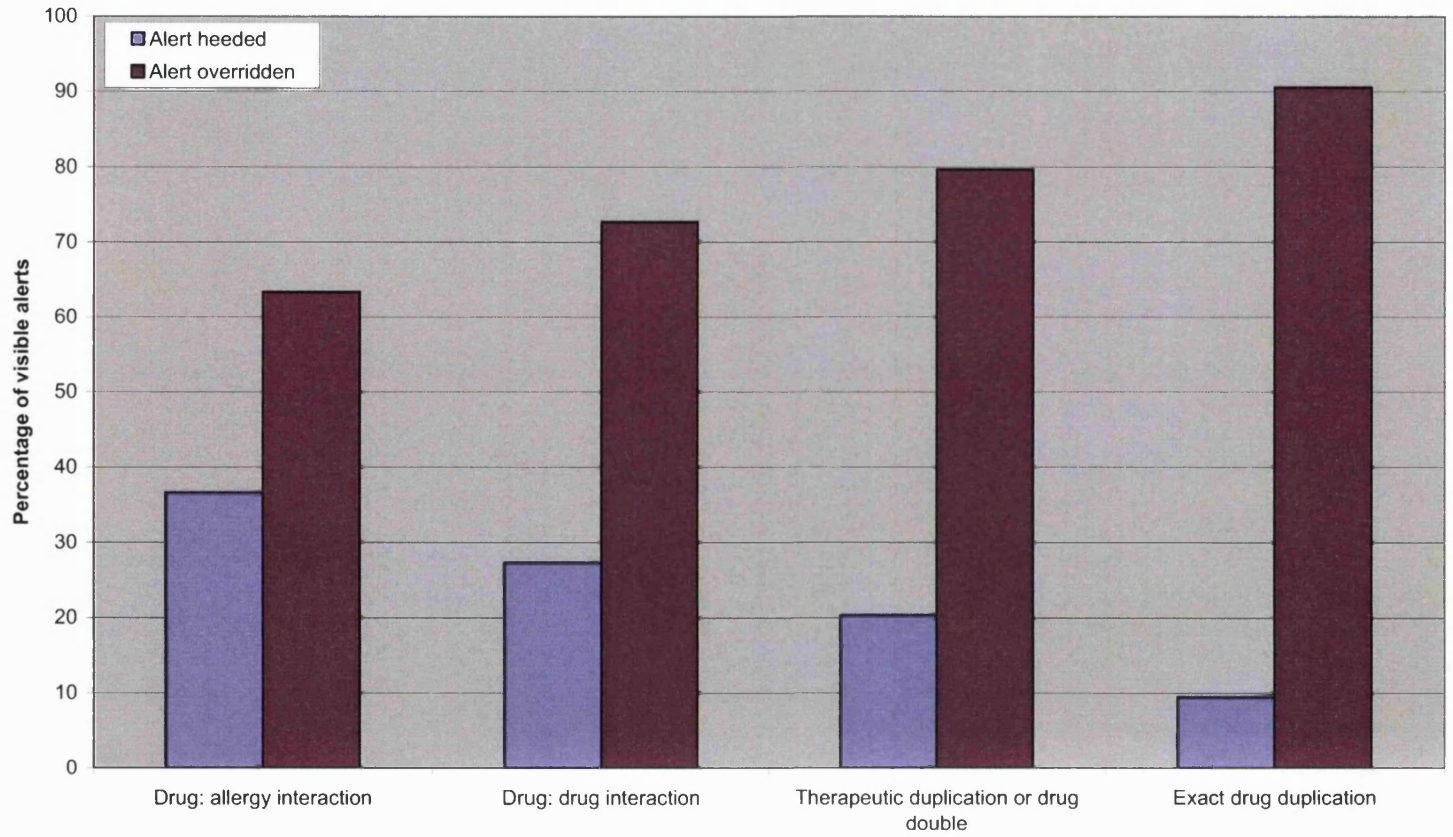


Figure 28: Reasons for overriding alerts

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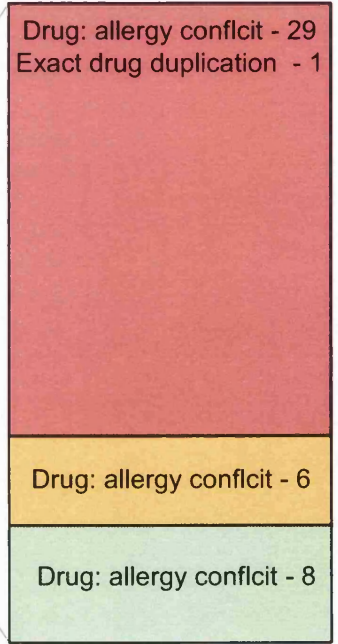
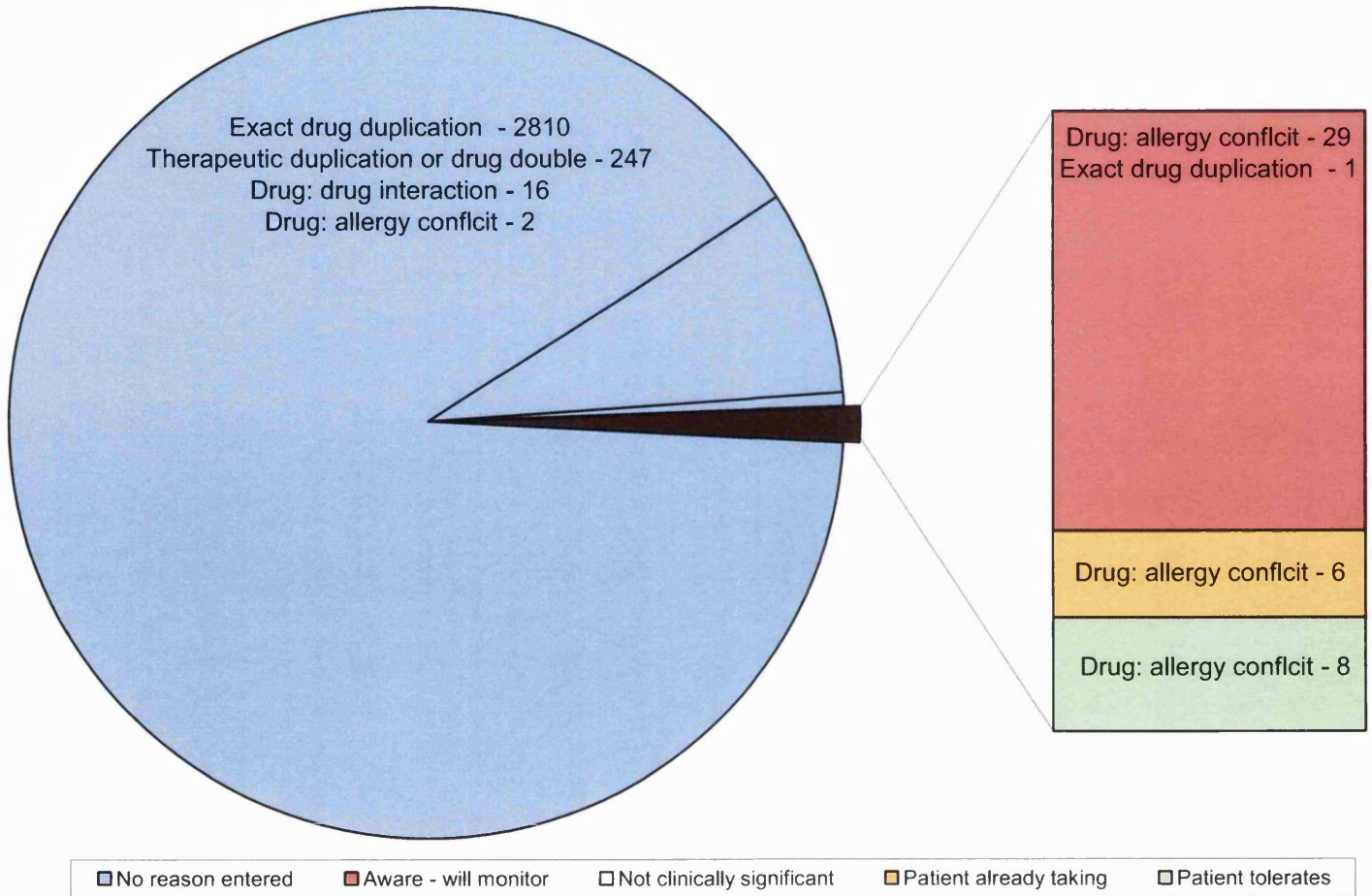
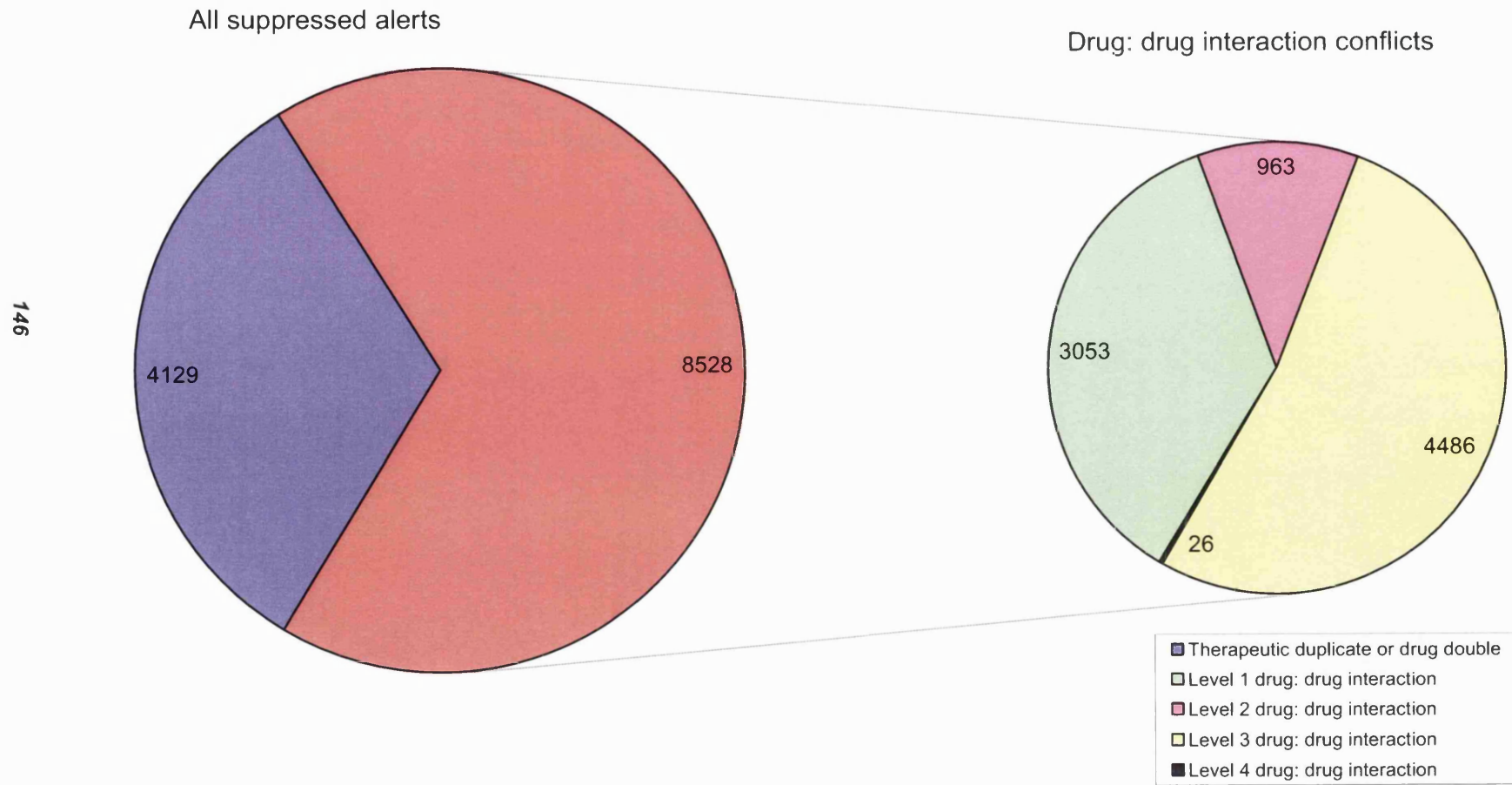


Figure 29: Characteristics of suppressed conflict alerts



6.5.8 Implications of activating all levels of CDSS

With the existing level of CDSS, there are 13 alerts visible to the user for every 100 prescription items ordered (95% CI, 12.8 to 13.6); approximately 90% of these are overridden. In the 10% (388/ 3507) of cases where the alert was heeded, there was just one case of the existing interacting drug being discontinued. For the remainder, the prescriber backed out i.e. the new prescription was not continued. If heeded alerts were used as a measure for alert effectiveness, then this would translate to a rate of 1.4% (95% CI, 1.3% to 1.6%) for all prescriptions ordered.

If all the alerts were visible, there would be 3 alerts generated for every 5 prescriptions ordered. Table 24 illustrates the change in visible alerts with varying levels of CDSS.

Table 24: Number of visible conflict alerts depending on activation of CDSS components

<i>CDSS feature</i>	<i>Number of alerts per 100 prescription orders</i>	
	Single feature	Cumulative total
Drug: allergy conflict	0.3	1*
Exact drug duplicate	12	13
Therapeutic duplicate or drug double	17	30
Level 1 & 2 drug: drug interactions	15	45
Level 3 & 4 drug: drug interactions	17	62

*rounded to a whole number

6.6 Discussion

Over 16,000 conflicts were recorded in the first year of using the system, but most of these were suppressed and therefore not visible to users. A high override rate (90%) was seen for the alerts that were visible, but this is consistent with that reported in the literature. Nightingale et al. (2000) reported that 92% of 'low' level and 43% 'high' level warnings, about contra-indications, drug interactions and exceeding maximum recommended doses, were disregarded by prescribers using a computerised prescribing system at a renal unit in the UK. As with the present study, the warning levels were set depending on the seriousness of the warning. In another study by the same group, the authors reported a lower overall alert override rate of 52%, but found that 85% of drug interaction warnings were overridden (Anton et al. 2004). Barker & Kay (2007) also reported an alert override rate of 90.9% in an audit of prescribing decisions on two acute medical wards at a UK district general hospital, where the JAC EP system was in use. A study of primary care physicians also reported override rates of 85%-96% for drug: allergy and drug: drug interaction alerts (Weingart et al. 2003).

The number of visible alerts generated varied by setting as well as professional group and grade. The alert rate was higher in the inpatient environment, which may be because of the complexity and changeability of prescriptions in that setting.

Additionally, most inpatient prescribing was done by junior doctors, who were more likely to generate an alert, compared to consultants who predominantly prescribed in outpatient clinics. It was interesting to note that unlike other studies, there were no differences in the override rate for visible alerts due to the grade of prescriber. Anton et al. (2004) found that junior doctors were less likely to disregard warnings compared to senior doctors. Likewise, Weingart et al. (2003) reported that junior doctors were less likely to prescribe an alerted medication compared to staff physicians (odds ratio 0.26, 95% CI 0.08-0.84). However, the present study only involved duplication and drug: allergy conflict alerts, whereas the other studies included drug: drug interactions as well. The latter, though clinically important, are often reported by prescribers as being less specific (Glassman et al. 2006). It is possible that senior doctors are more likely to exercise clinical judgement and override the drug: drug interaction alerts compared to junior doctors (Anton et al. 2004).

Exact duplicates alerts were generated most frequently, but were also the most likely to be overridden. During the study period, exact drug duplications were necessary due to

system limitations in complex and variable dose prescribing. For example a dose of tacrolimus 4 mg in the morning and 3 mg in the evening, would need to be entered as two orders, and result in an (unnecessary) exact duplicate alert. Unless functionality to enable variable doses to be prescribed was available, this problem was likely to be amplified if therapeutic duplicate/ drug double checking was activated, as the latter would result in an alert if more than one strength or formulation of the same drug were prescribed.

Drug: allergy conflict alerts were the most heeded, and showed no differences by setting, user profession or grade. One inference is that these alerts were more sensitive than other visible alerts, although the fact that nearly two thirds of the drug: allergy conflict alerts were overridden raises questions about alert specificity and the accuracy of allergy status documentation. It is possible that the drug allergy status documentation was incorrect; over 30% (14/45) patients were already taking the conflicting drug or were known to tolerate it. In the remaining 29 cases, the prescriber indicated an intention to pursue the prescription and monitor the situation despite an awareness of the conflict. Nevertheless, the override rate for drug: allergy alerts was 64%, which though slightly lower than the 80%-90% reported in adults (Hsieh et al. 2004; Weingart et al. 2003), was for comparable reasons. Hsieh et al. (2004) reported that most frequent reasons given by prescriber for overriding allergy alerts were: “Aware/Will monitor” (55%), “Patient does not have this allergy/Tolerates” (33%), and “Patient taking already” (10%) (Hsieh et al. 2004).

Several reasons have been suggested in the literature for overriding alerts, including alert design (content and physical characteristics) and sensitivity/ specificity of the alert to the patient (van der Sijs et al. 2006). Problems with one or more of these may result in false positives and over-alerting, but an understanding of these factors can improve acceptance rates for alerts. This was demonstrated in one study which had a comparatively higher acceptance rate (67%) for interruptive alerts. The authors of this study improved clinician acceptance of drug alerts by designing a selective set of clinically significant drug alerts and minimising workflow disruptions by designating only critical to high severity alerts to be interruptive to clinician workflow (Shah et al. 2006).

6.6.1 Limitations of the existing CDSS

Many CDSS, like the one described here, are designed on the assumption that decisions involving the use of medicines occur in a linear fashion, and are made by an individual prescriber. However, this was not the case at the study hospital, and indeed unlikely to be at other hospitals. The prescribing act is usually the final step, reflecting decisions made by a team in conjunction with the patient and executed by individuals as shown in figure 30.

The purpose of CDSS, by definition is to generate case specific advice based on two or more patient parameters. In the system described here, advice is generated in the form of an alert based on the medication history, including allergy status of the patient and the new medication being ordered. One could therefore argue that the CDSS is based on *drug* specific parameters rather than *patient* specific ones.

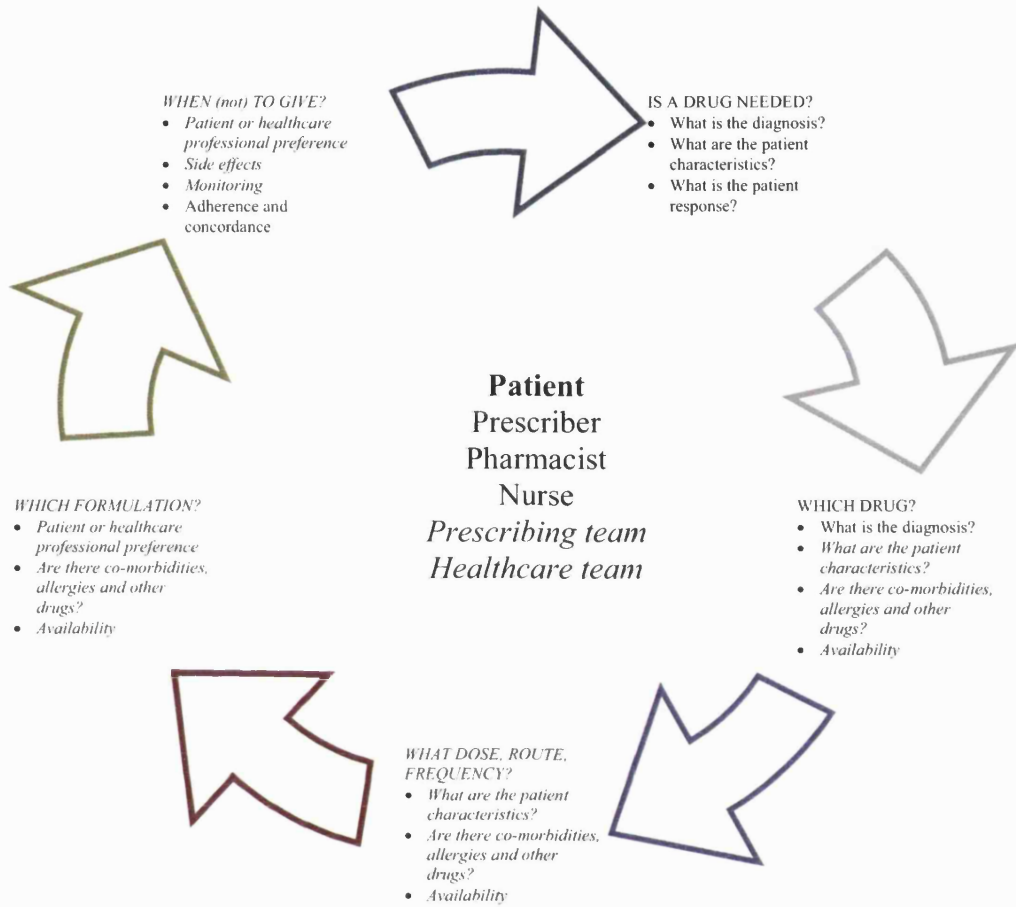
The advice generated may require the prescriber to:

- take no further action i.e. active provision of information that may or may not be pertinent for this particular patient.
- change in monitoring i.e. relevant and useful, but change in medication not required.
- change in medication i.e. relevant and patient specific.

Whilst all three may be beneficial, the latter two are most useful to the prescriber at the point of care for a specific patient, as these may result in a change in behaviour. The fact that 90% of the alerts were not heeded suggests poor specificity.

A further limitation of the system described here was the narrow scope for local tailoring of conflict alerts. For example, if therapeutic duplication checking was activated, drug double checking would also be active, as these were set as one category in the clinical information database. Likewise, the severity rating of drug: drug interactions could not be assigned or altered locally. It was possible to control visibility of each type of conflict alert by user grade, profession or speciality, but this may be undesirable from a practical perspective (liable to be time consuming to set this at the individual user and/or drug level) as well as a patient safety viewpoint. The literature indicates that although users desire selective activation of CDSS, there may be problems due to differences in individual practitioners knowledge base as well as prescribing practices (Feldstein et al. 2004; Lapane et al. 2008; Tamblyn et al. 2008; van der Sijs et al. 2006).

Figure 30: Stages of decision making in the medicines use process - a simplified view



Decisions which are currently not supported by CDSS within EP systems
 Decisions that are supported (partly or completely) by CDSS within EP systems

6.6.2 Considerations for improvement

A number of reports, viewpoint papers, policy statements and systematic reviews have been published on designing and implementing effective computerised CDSS (Bates et al. 2003; Kawamoto et al. 2005; Kuperman et al. 2007; Miller et al. 2005; Teich et al. 2005), a few of which provide specific guidance for paediatric patients (Connecting for Health 2007; Council on Clinical Information Technology 2007; Gerstle, Lehmann, & the Council on Clinical Information Technology 2007; Spooner & the Council on Clinical Information Technology 2007). Based on the guidance in these publications, the following sections highlight ways in which the JAC EP-CDSS may be improved.

6.6.2.1 Design characteristics

The design of CDSS alerts play a key role in their use and acceptability. In the JAC EP system, all information, whether informative or requiring action by the prescriber, is presented as an alert and this should be reviewed. Whilst there is evidence to indicate that alerts are more effective than reminders or guidelines which the prescriber has to seek actively (Tamblyn et al. 2008; van Wyk et al. 2008), there is a risk of alert-fatigue and increased likelihood of overrides as a result of excessive and unnecessary alerts (Weingart et al. 2003). This was seen in the present study with users reporting similarity and repetitiveness of alerts. Not many researchers have attempted to address the physical design features which optimise the use of alerts, though some have studied the content of alerts to identify the most effective design. Respondents in these studies reported that easy to understand messages which provided alternative actions were more useful than general information (Glassman et al. 2002; Ko et al. 2007).

6.6.2.2 Minimise disruption

For optimal effectiveness, the nature of the CDSS needs to cause minimal disruption to the workflow, whilst providing optimal support to the prescriber at point of care . Therefore designers need to consider the best way of getting information across for different types of conflicts – alerts which interrupt workflow may be more appropriate for safer prescribing whereas informative messages that allow the prescriber to access other screens may be more suitable to ensure effective prescribing. Similarly mandatory entry of override reasons is a useful tool to capture information for audit and accountability purposes, but may increase disruption and work for the prescriber. Hence these need to be used judiciously e.g. for high risk conflicts.

6.6.2.3 Optimising specificity

One of the key challenges in CDSS is optimising specificity of the alerts to the patient. This is particularly difficult with stand alone systems such as the JAC EP, as it does not interact with other clinical systems which may have helped specificity using rules and algorithms based on patient parameters e.g. pathology results. One study showed that changing from a drug based alert to an age based alert reduced the alert burden when prescribing for older patients even though there were no significant differences in prescribing practice as a result (Simon et al. 2006). Others have shown improved dosing in renal impairment as a results of targeted CDSS (Chertow et al. 2001; Galanter, Didomenico, & Polikaitis 2005).

Improving drug: drug interaction alerts is another area for optimising the specificity of the JAC EP-CDSS. Studies indicate that although prescribers consider drug: drug interaction alerts as important, useful and educational with a key patient safety element, there is high over-ride rate (Glassman et al. 2006; Ko et al. 2007). This may be because not all drug: drug or drug: disease interactions are clinically significant. Even for those that are, co-prescribing with additional monitoring and/ or dose adjustments may be justified in certain circumstances. In the present system, if drug: drug interaction levels 3 and 4 were activated, there would be an extra 17 alerts per 100 prescriptions ordered. However, many of the level 3 interactions though serious are not contra-indicated. Some may not be relevant to the paediatric population or require additional measures to manage the interaction e.g. more intense monitoring (therapeutic drug levels and/ or biochemical parameters) or additional precautions (alternative contraceptive methods). Ideally these could be built in as rules to take into account patient specific parameters.

6.6.2.4 Paediatric specific functionality

Age and weight based dose calculations and dose checking have been identified as key areas in CDSS development to improve medication prescribing in children. However, the only study of computer generated dosing suggestions for paediatricians reported a 32% acceptance rate and a high variation (>50%) in the dose prescribed compared to the CDSS dose (Killelea et al. 2007). The authors conclude that more work needs to be done to optimise the effect of CDSS on medication safety in the paediatric inpatient setting. The JAC EP-system had no dose checking or calculation functionality at the time of study, though it was expected in the next version of the software. Once implemented, this needs to be evaluated to assess effectiveness.

6.6.3 Study limitations

There are a number of limitations to the study conducted here. Firstly, the analysis included alerts generated in the first year of use when only two wards were using EP. Therefore the results may not be representative of alert characteristics with hospital wide use of the system. Secondly, the data was retrieved retrospectively from the JAC computerised database using Crystal reports that have not been formally validated. It is possible that there may be inaccuracies in data retrieval. However, Crystal reports are recommended by JAC as the method for data retrieval from the EP system. Third, the alerts were reviewed retrospectively, thus the results reported here may have overestimated the override rate. For example, if the prescriber chose to override an alert to complete the prescribing process, but subsequently discontinued the medication before the patient received any doses, this would still be recorded within the system as an override. Finally, the study reports alert characteristics and does not take into account resultant patient outcomes or the effects on the prescriber. A prospective study using alternative methods may provide more insight on the effects of CDSS on patient outcomes and prescriber practice.

6.7 Conclusions

The literature suggests that CDSS have a beneficial, cumulative effect on minimising medication errors and improving medication safety. However, much work remains in this field when considering medicines use in children, as the complexities which result in increased risk to this patient group (rapidly changing doses based on weight and age, calculations and off-licence use of medicines) also pose the challenges in finding a solution. It is also important to understand factors that influence user acceptability in order to ensure optimal decision support whilst minimising disruptions and information overload due to excessive alerts, low sensitivity and specificity. Some of these factors will be discussed in the next chapter: a qualitative study designed to understand the dynamics between the technology, users and the organisation.

Chapter 7 Qualitative study

“If you put tomfoolery into a computer, nothing comes out but tomfoolery. But this tomfoolery, having passed through a very expensive machine, is somehow ennobled and no one dares criticize it.”

Pierre Gallois, French air force brigade general and geopolitician.

(<http://www.memorable-quotes.com/pierre+gallois,a2074.html>)

7.1 Introduction

It has long been recognised that a successful IT system is not just one which is technologically sound, but one that is usable and acceptable to the user as well. Both of these may be influenced by factors of system functionality and user interface. Similarly, the technology is implemented in a pre-existing environment which has its own culture, policies and processes. Therefore an understanding of the human: technology interaction in context is key to any evaluation of IT systems. The framework selected for this project addresses all these issues. In this chapter, the aim was to inform the human and organisational elements of the framework using a qualitative study. The objectives were

- To determine health care professionals' views of the implementation process and of the EP system.
- To determine patient and parent/carer's views of the EP system
- To identify changes in practice and workflow patterns of healthcare professionals following implementation of the electronic prescribing system.

7.2 Methodological approach

Qualitative methods usually consists of three main components: interviewing, observations and document analysis (Bowling & Shah 2005). The exact method used for each of these is dependent on the research question. Interviews may be unstructured, semi-structured or structured, depending on the level of information sought. Unstructured interviews allow the respondent to offer information on a topic area, with little or no prompting from the interviewer. This type of interview is useful when eliciting data, often historical, in the respondent's own words. Semi-structured interviews are guided by the interviewer towards topics of interest, but give the respondent enough flexibility to volunteer information which may be novel but relevant. Structured interviews follow a set format and are useful to compare responses from different respondents.

Observations may be overt where the subjects under observation are fully aware of being observed, or covert where the researcher joins the group under observation without revealing their purpose. Observation may be as a participant i.e. ethnographical, or as an onlooker. Each type of observation technique has strengths as well as drawbacks. For instance, in non-participant observation, the observer may not

get a true feel for what the participants are experiencing, whereas with an ethnographical approach, they are part of the group and experience things from the inside. Therefore, participant observation may take considerable time and training before the observer is accepted as part of the group. In contrast, overt observation allows use of recording tools, documentation and the opportunity to ask questions, but may affect the behaviour of those being observed. However, the observer effect is temporary and subjects revert to normal behaviour with continued observation.

Document analysis may be used to extract quality data from records or using a structured quantitative approach, and is a useful way of corroborating information gained using interviews or observation.

7.3 Methods

The purpose of this part of the study was to gain an insight into project team, user and patient/ parent perspective on the implementation and use of an EP system. Therefore an ethnographical based approach using semi-structured interviews and overt observations was adopted for data collection. Semi-structured interviews were selected to enable an in depth exploration of the key areas identified from the literature review (Chapter 2), whilst allowing new and context specific information to emerge. Overt observations were the preferred option, as this allowed the researcher an opportunity to see the system in use and to question the user in case of uncertainty during observations. Documents including user manuals, training booklets and minutes of project meetings were used to support the primary findings from interviews and observations. The methods used were based on those that have previously been described, used and recommended by Barber et. al. (2006).

7.3.1 Recruitment

All wards and areas that had or were going to implement the EP system during the study period were included. The following key stakeholder groups were included:

- EP project board members and EP project team: all members of the EP project team who consented were interviewed. Members of the EP project board were selected based on recommendation by the EP project team leader.
- Healthcare professionals (nurses, doctors and pharmacists) that worked in areas where EP had been or was going to be implemented were selected purposively to include staff from each professional group at senior and junior grades.

- Patients and/or parents on wards where EP had been implemented were selected following discussion with the nurse in charge of the ward. Non English speaking patients or parents were excluded.

7.3.2 Interviews

Semi-structured interviews were conducted using an interview guide which explored themes reported in the literature and issues that were highlighted during preliminary fieldwork i.e. initial EP project team meetings and individual discussions with the project team members. The interview guide (appendix E) was based on one that has previously been used in the UK (Barber et al. 2006) as well as evidence from studies in the US which indicate that EP systems may have a positive as well as negative effect on patient safety (Han et al. 2005; Koppel et al. 2005). A number of reasons have been put forward for this, including EP system usability, compatibility with existing infrastructure, acceptability by the user, changes in work practices and implementation and training strategies (Ash et al. 2007b; Campbell et al. 2006). Therefore the interviews sought in-depth information on how EP affected medication safety, benefits and problems associated with its use, resultant changes in practice, the implementation strategy, training delivery and acceptability to the user. Interviews were conducted in a number of settings, some on the ward, either whilst conducting observations of the system in use or in one of the ward offices and others on neutral ground in the cafeteria. Informed consent was obtained from all participants and the interviews were audio recorded.

7.3.3 Observations

Over a 2 year period, the researcher attended project team meetings as well as training sessions for doctors, nurses and anaesthetists in the second phase of implementation, as an overt observer. Prescribing processes in renal outpatients were observed for two mornings, once before and once after EP implementation. The processes of prescribing and administration on the study wards and use of the system in the pharmacy were observed over a number of days. Participants were informed about the observation study one week in advance, with the aid of posters and communication via the nurse in charge of the ward. All participants were given the opportunity to opt out on the day of observation.

7.4 Data analysis and validation of analysis

The main researcher (Yogini Jani) received training on interview technique and performed two pilot interviews with doctors on the renal ward, to practise interview technique and to test and refine the interview guide. Responses from these were not included in the final results as the interview guide was modified for the main data collection.

Handwritten observation and field notes were made by the main researcher whilst observing the system in use, in training sessions and during meetings. These notes were typed by the main researcher at the earliest opportunity. The typewritten notes were used to verify and support the information provided by interview respondents.

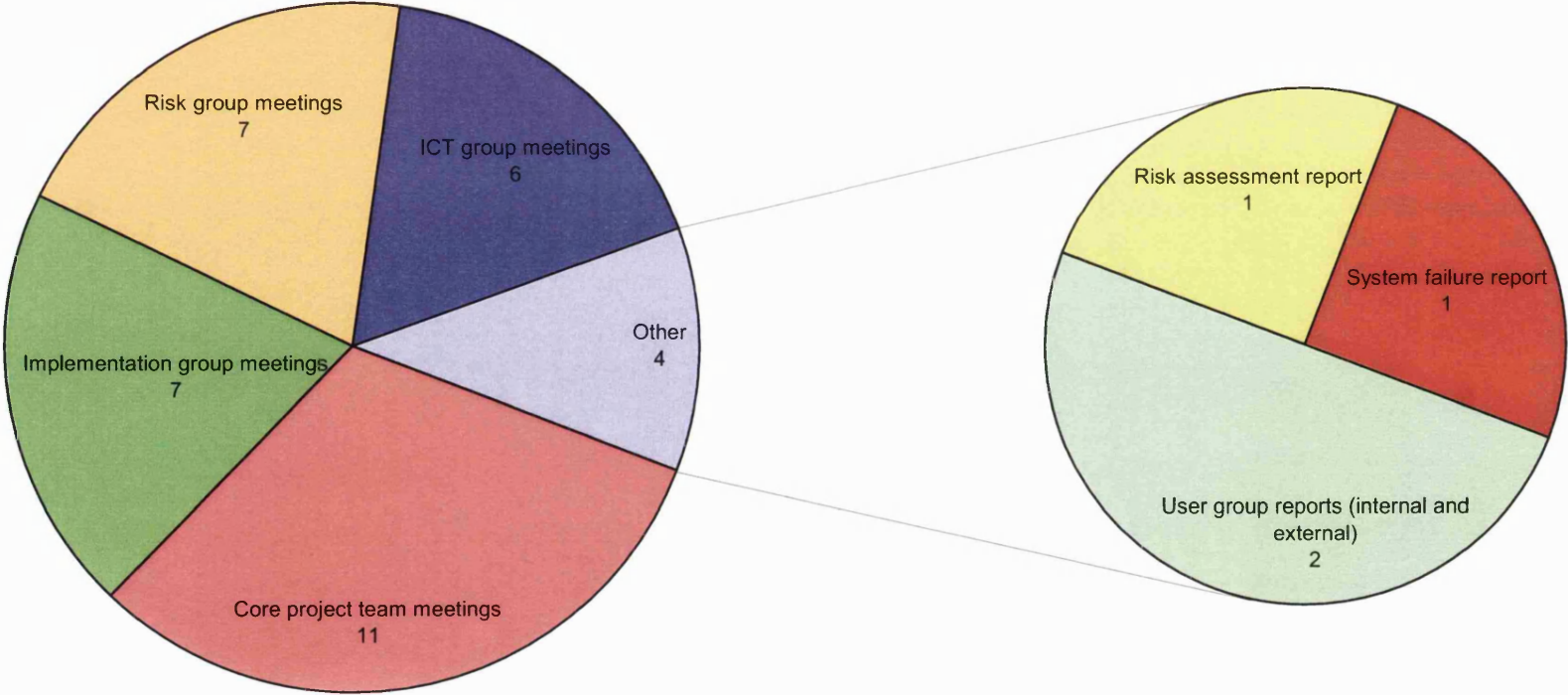
All interviews, except one, were recorded and transcribed by the main researcher. One interviewee consented to being interviewed, but not to audio recording. Therefore a summary of the discussion was typed from handwritten notes and sent to the interviewee for a check of content accuracy before coding. Thirty-one project group meeting minutes and four project related documents (figure 31), were also coded.

Although a framework approach was being used to collect the data, to begin with, the qualitative data was analysed by coding the data independently of the framework. This was to make sure that all new and context specific information could be captured without being restricted to the key concepts of the framework. Three interviews were coded individually by two researchers (Yogini Jani and Claire Planner, a postgraduate research assistant at the Centre for Paediatric Pharmacy Research who has completed an MSc in Social Research Methods, Social Policy Research). The two coding frames were then compared and differences discussed to agree a revised coding frame. All remaining interviews were coded by Yogini Jani using this revised frame. A computerised qualitative data analysis package (MAXqda) was used to aid the coding process. The coding frame was used to develop themes, which in turn were used to address the three dimensions of the Cornford framework as follows.

- The *system*: what it was, how it worked, who used it, initial problems and what it is like now.
- *Human perspectives*: what they needed to change to use the system: about themselves, their routine and the environment; how they felt about the changes; what happened as a result of the changes in terms of their practice, how they interacted with others and what their views were on the changes and the outcomes.

Figure 31: Number and source of minutes and documents used in the analysis

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- *Organisational context*: why EP was implemented, what they did to bring it in, how it fit in with existing systems and infrastructure, the planned vs. actual implementation strategies, expected and unanticipated problems and how these were overcome; progress to date; lessons learnt, plans for the future, including changes and wider implementation.

The interpretative process was discussed regularly with a third researcher (Professor Nick Barber), who also reviewed three of the coded interviews. The final analysis was sent to the EP project lead for review. Some points required further clarification by the main researcher, but were resolved on discussion with few changes

7.5 Results

7.5.1 Characteristics

42 interviews (resulting in 378 pages of typed transcripts from approximately 21 hours of recordings, table 25) and field notes from 35 observations (table 26) were included for analysis. Originally, 44 interviews were conducted, however two of these were excluded, one of a doctor, due to poor sound quality of the recording, and one nurse interview as the interviewee had not yet been aware of or had any interaction with the EP system.

Table 25: Number of interviews and respondent profession

<i>Profession</i>	<i>Specialty/ Ward</i>						Total
	Project team/board	Renal	Urology	Ward 3	Theatre	Pharmacy	
Doctors	1	3	2	3*	1	-	10
Nurses	3	4	6	4*	1 [#]	-	17
Parents	-	2	2	2	-	-	6
Patients	-	1	-	-	-	-	1
Pharmacists	4	-	-	-	-	1	5
Other	2	-	-	-	-	-	3
Total	10	10	10	9	2	1	42

* one doctor and two nurses were interviewed before as well as after implementation.

[#] one group interview with 5 nurses

Table 26: Activities observed whilst the system was in use

<i>Activity</i>	<i>Number of occasions</i>
Administration episodes *	18
Prescribing episodes *	4
Ward rounds (+/- prescribing)	4
Training sessions	4
Pharmacist review (+/- dispensing)	4
Pain team nurse review	1

* each episode involved one or more drugs being prescribed or administered

7.5.2 Overview

The findings from the qualitative study are presented according to the framework, beginning with system functions, followed by human perspectives, and finally the organisational context. Each of these components is discussed in terms of the structure, process and outcome; differences in views from the different healthcare professionals and in different roles are highlighted. Although it was sometimes difficult to adhere to these subheadings, insight into the whole picture comes from considering the relationship between the cells of the framework, rather than each cell or column in isolation.

7.5.3 The system

The workings of the EP system have been described in detail in Chapter 3; there were no software updates during the study period. In this section, the key technology components are considered in terms of hardware and software requirements/ architecture, information processing and the resultant outcome.

7.5.3.1 Structure

The system, based on an adult system in use at other hospitals, was being enhanced for paediatric use according to a specification developed by the EP project team in consultation with the other children's hospitals in the UK. It was initially implemented on one ward and gradually rolled out across the whole Trust. The key technology components were as follows:

- Two servers, one live and one shadow server, each holding both patient and pharmacy databases.
- A stand alone personal computer (PC) connected to a high speed printer, situated in pharmacy, which runs off an uninterrupted power supply and acts as back up to the main shadow server.
- Software program delivered from the central server via a third party thin client platform already in use at the Trust.
- Minimum of one laptop per ward/ theatre fitted into a special mobile trolley (sometimes called mobile cart) used for drug administration by nurses.
- Minimum of one laptop per ward/ theatre for use by doctors, which was placed on the medical notes trolley on the ward and on the anaesthetic machine in theatres.
- Access to all EP system functionality including medication review, prescribing and administration recording from PC(s) at nurses station and doctors offices that have been set up to run the software.
- Direct access to the system for the vendor in case of upgrades.

The system is the JAC medicines management system - a commercially available prescribing, medicines administration charting and pharmacy dispensing and stock control system which does not interact with other clinical systems (e.g. pathology or PACS), except for the patient information management system (PIMS) which automatically provides demographic information to the EP system i.e. name, hospital number, NHS number, date of birth and location (ward or clinic) of the patient. The information flow is one way from PIMS to EP. The prescribing and dispensing applications within the program were used separately, though long term this was planned to be more integrated once the interface improved.

At the time of implementation, not all the paediatric specific software functionality was available, but features considered to be essential by the EP team were: mandatory weight entry, height entry, and validation of height and weight against age, mandatory allergy status entry and though not used in the end, the ability to add a daily fluid target value.

All records in the drug files had to be modified by the pharmacy department to make them available for prescribing. This involved setting up drug route(s) and clinical decision support levels for individual drugs, specialities and/or users. Non-formulary drugs were set as non-prescribable and therefore did not appear on the selection list presented to the prescriber.

Access was via a thin client server called Citrix and access levels were set depending on user role rather than profession i.e. as a prescriber or limited prescriber. There were initial problems with the IT infrastructure, including the wireless network, interaction with PIMS and in some areas, old PCs which were below the Trust's minimum specification required for access to clinical systems.

Problems with the wireless network caused time-lags and loss of connection, resulting in patient records being "locked" i.e. not accessible to users. Possible causes identified included interference of the signal due to metal lids on mobile carts and computer game devices used by children on the ward. Loss of connection was considered dangerous as this led to sessions remaining open and subsequently presenting to other users without having to log on to the system. Immediately prior to the go-live, the decision was taken to install the application locally (FAT – refer to glossary) on PCs until the server and wireless network combination was stable. The urology ward experienced most instability with the wireless system, with crashes or problems occurring on a daily basis.

"...probably every shift you would log on and it will say like server down, and you expect, normally it's not for very long 10 minutes or so and you go back in or you can just try one of the other ones." Nurse 10

These were of such magnitude that the project team considered halting the evaluation phase until they were resolved.

*The changes... have not improved the situation ...unless there is an improvement ... usability of the system must be questioned and the alternative is to return to using paper drug charts. The problems must be resolved before the system is rolled out across the Trust...*Project team meeting minutes, three months after go-live.

The system stabilised after a number of measures were taken: installation of additional wireless points to strengthen the signal, external Cisco cards (refer to glossary) rather than inbuilt technology for laptops to improve wireless connectivity and in some instances, replacing the laptops with an alternative make. In theatre, a local area network (LAN) point originally installed for another clinical system was used for EP, thus reducing the reliance on the wireless network. These measures allowed implementation of the system entirely via the thin client in subsequent areas. However, occasional locked records continued and this was attributed to locked thin client sessions, corrupt thin client profiles and the use of generic usernames and

passwords. The pharmacy dispensary continued to access the program through FAT installation due to printing problems experienced when accessing the system via the thin client.

Other technology problems included log-on issues and battery life of the mobile devices. Battery life was a concern as complete battery drainage resulted in locked patient records. This resolved following the purchase of additional longer life batteries and with continued use, practice and training. Logging on to the system was problematic, mainly because in order to access EP, the computer needed to be turned on and logged into the hospital network using a generic ward username and password. Each user then needed to log into the thin client and subsequently the EP system. A second reason was that for EP, log on was case sensitive and had to be performed using capital letters, unlike other systems in use at the Trust, which were case insensitive.

“...first of all you have to get into your computer, then you have to use one password, then you have to log into your Novelle then you enter your Citrix which is another password and then you enter JAC which is yet another password. And half of them are caps lock and half of them aren't, so you go into JAC and you forget to put your caps lock on and you put in your name and you press it and it doesn't say you're in the wrong case, it just completely goes again; you have to start all over again for the screen to come up. So it's not the JAC system that's painful, it's the process of how you get in there.” Nurse 1, EP team

There was an automatic time-out in both EP as well as thin client sessions after a period of inactivity initially set at 15 minutes and 30 minutes respectively. This was monitored and revised based on time taken to prescribe and administer drugs. For example, nurses on wards with multiple and complex medication requested a longer period of 30 minutes, whereas those on other wards found this too long. Similarly, for doctors the automatic time-out period was extended in the outpatient setting to minimise the need for repeated logging on.

There were some limitations of the EP screens, including the inability to

- maximise screen size, which was considered small and busy in comparison to the actual visual display unit (VDU) screen size.
- tailor the screen layout to aid administration, for example, by highlighting emergency medicines or sorting the list alphabetically when in the nurse

administration charting program (this defaulted to the last view in the prescribing screen).

- view all the details on the entire chart at all times, rather than the specific screen e.g. prescribing or administration.
- see who is logged on when the system is in use.
- in the case of locked records, see who is accessing the system.
- perform certain functions from the nurse charting screen e.g. view name of the prescriber.

7.5.3.2 Process

The system stabilised and replaced outpatient and discharge prescriptions and the main drug chart on the renal ward, but had several limitations which were dealt with by the creation of 'dummy drugs' which were created to indicate where paper charts were still in use in areas of complex prescribing e.g. patient controlled analgesia, infusion and dialysis fluids. Dummy drug prescriptions included the drug name and dose, but not the administration details e.g. rate of infusion or additional hydration fluids and provided a reference to the relevant paper chart which was the legal prescription. Dummy drugs were also used as prompts for therapeutic drug level monitoring e.g. amikacin levels in patients with and without renal impairment. EP was used for all patients on the ward, with the exception of those who were 'outliers' from other specialities.

Due to phased implementation, the medication history records and the current medicines administration charts (MAC) were printed out for patients being transferred to non EP areas for any length of time. Printouts were also used for prescriptions of cytotoxic drugs which were prepared as unit doses by the pharmacy. In order to mimic previous processes, four copies of the TTA printout were used by pharmacy to dispense from, rather than electronic transmission. Layout and content of printed documents were based on specifications set by the EP team and resembled the original non EP prescriptions. However, some of these did not contain information that was previously available on the drug chart i.e. height, weight and allergy status.

Prescribing was performed using PCs in the doctor's office or using the laptop on the notes trolley on the ward. The bedside chart review was possible if a laptop cart was wheeled around, but this option was rarely chosen by junior doctors who preferred to prescribe at fixed terminal PCs. On the renal ward, a PC with two projectors was used in their seminar room for formal consultant ward rounds to review and revise

medication; a laptop on the notes trolley was used during 'walk around' ward rounds by registrars and senior nurses. For wards with multiple teams conducting ward rounds at the same time, the latter was considered to be a problem as there was only one laptop for the medical notes trolley.

Inpatient and outpatient prescribing were not integrated, but it was possible to view both records using the 'previous medications' functionality. The inpatient medication history provided a complete record of the patient's hospital medication, whereas each outpatient EP record consisted of drugs prescribed for that outpatient attendance i.e. may not reflect the patient's complete current medication record. A 'notes' functionality was sometimes used to document all other medication the patient was receiving, to ensure a complete medication history was recorded at an outpatient attendance.

To prescribe, the user was presented with an alphabetical listing of all formulary items as a string of generic drug name, strength and formulation e.g. Flucloxacillin 500mg capsules. Some doctors found this informative in terms of the different preparations available, whereas others found it hard to find the drug they wanted and considered the extensive list a risk with the potential to prescribe inappropriately and create new errors.

"Citrate for instance is found under tricitrate but only if you know it. If you put in citrate it won't find it um and one alfacalcidol umm you will only find if you enter the A-L-F-A alfa so not as 1 not as calcidol and not alfa with A-L-P-H but only with A-L-F so these are the moments when you say just give me a paper prescription and I'll write it down." Consultant 2.

Use of system specific abbreviations for frequency rather than Latin abbreviations caused some confusion.

"The other issue about this program... we couldn't use Latin. QDS would have been so much better than 4x 3x ... it's not very obvious when you first look at childrens' charts, 2x 3x 4x you're trying to work out how many times a day they have that drug, you can see it but it isn't obvious straight away." Nurse 1

The system did not allow retrospective prescribing, but permitted recording of late administration. This inability to backdate prescriptions caused considerable problems in theatres where all records for prescribing and administration were done retrospectively, and affected timing of subsequent doses.

"... by the time you give paracetamol in the anaesthetic room, you go into theatre, you write it up, you can't backdate it. And that's a real issue, because

that means that the nurses on the ward won't give it, if it's a four hour case and you don't do the prescription till two hours after you gave it, that patient will be without that, you know if it's a six hour prescription, they'd be without it for eight hours. Because there's a two hour period that you can't account for... You then have to write notes ...you know saying this was actually given at such and such ..." Consultant 4

Allergy status and weight entry were mandatory fields, but posed problems initially, due to multiple screens for entering this information, and because prescribing could not progress unless this was done. As implementation progressed, there were additional issues with mandatory weight entry.

Some wards have drugs, which are prescribed a week in advance of admission of the patient and some are based on age rather than weight.....
[ophthalmology consultant] is keen to use electronic prescribing, but his patients are not weighed in Out-Patients. Minutes of project team meeting, May 2007.

"...if you're giving a topical medication the weight is irrelevant and you think oh for goodness sake. Why can't I just show some professional intelligence here and let me bypass this detail?" Consultant 3.

In outpatients, if weight was unavailable, the doctors reverted to paper prescriptions to minimise delays.

Following weight and height entry, the system automatically calculates body surface area, but does not perform dose calculations based on the child's age or weight. The system also shows the dose in terms of dose units. In some liquid preparations, this provided the associated volume.

"Yes it will calculate how much in mLs... but in terms of other I mean, it's not intelligent as in it won't change doses or whatever or the child's grown or..."
Staff nurse 4.

The system alerts the prescriber but has been set up so that it does not prevent the chosen action for any of the following conflicts detected by the system:

- drug: allergy conflict,
- weight out of range or significant change since previous entry,
- weight entry not recently updated,

- similar patient name,
- exact drug, strength and formulation duplication and
- if time of drug administration is too close to the previously administered dose (i.e. if administered within 75% of prescribed frequency interval).

Allergy status can be set by selecting a specific drug, a class of drugs or a non drug allergy. Though non-drug allergies did not generate any alerts for conflict, this was considered a useful documentation tool to alert the prescriber to other contra-indications and cautions e.g. if epilepsy worsens with the use of specific drugs, inborn errors of metabolism and allergies to preservatives and colourings. Developments were in progress to address the failure to alert for non drug allergies and unlicensed medicines.

“But actually First Data Bank did say they were looking at linking those special things and JAC are going to come up with a, a, an alert, that says this product ... hasn't been allergy checked. So...at least they will be aware...”

Pharmacist 2, EP team

Alerts were considered too similar and excessive by all the users and likely to be ignored as a result, especially those for height and weight.

“unfortunately the 0.4 centile [for weight range by age] means that um1 in 250 children should be below that, whereas at GOS it's probably 200 out of 250 because so many of them are small.” Consultant 1

“I think they're all a little bit too similar, so you think you're reading the one that you read yesterday ... they all look the same and they have the word weight somewhere and you think you're reading one that says its out of range or below the normal range for the child, when actually it's saying things have decreased by 10%.” Nurse 3

The 'notes' functionality can be utilised by any user to provide information or as a communication tool. 'Notes' are always visible at log on to all users who access the patient and in addition, may be marked to appear each time when a nurse administers the drug. The 'notes' functionality was a useful tool to record changes to treatment made over the phone. However, it was quickly recognised, that 'notes' may be used inappropriately and were sometimes repetitive. The project team needed to review the types of 'notes' that were available for posting on the system, simplify the process of entering 'notes' and revise training to encourage users to suppress 'notes' that were no longer relevant.

...there might be training issues related to the notes being written. Doctors will require training in how to suppress notes. Users should only look at notes applying to them. Minutes of project team meeting, October 2005.

“we don't give them all the options to notes they had in the beginning ...”

Pharmacist 1

Functionality such as 're-prescribe', 'suspend' and prescribing set courses by specifying the discontinue date, made prescribing easier and more streamlined. 'Represcribe' could be used for readmissions when no changes to therapy had occurred. 'Suspend' function was used for patients on short term leave and for patients being transferred. It was easier to prescribe discharge (to take away – TTA) medication as transcribing was no longer necessary and the forms did not need to be signed after the initial phase, as the 'electronic signature' was considered adequate. Amending discharge prescriptions posed problems as there was no clear indication of previous activity e.g. whether it had been printed and sent to pharmacy or not.

Nurses used the system to review and record drug administration and to document the use of PGDs. The EP system was used at the beginning of each shift to plan drug administration. A written list would be made and EP would subsequently be accessed only when drugs were due. Laptops on mobile carts were used when preparing the medicines in the treatment room and then it was intended they be wheeled to the patient for administration which was recorded on the system.

Drug administration within the system was scheduled over a 24 hour medication administration schedule (MAS) period. Doses could not be deferred to the next MAS period which started at 4am, and this introduced the risk of missed doses. Occasional problems with running the MAS resulted in reverting to paper in the early phase.

“It only happens with the MAS at 4 o'clock in the morning, if you haven't given a drug like paracetamol because they haven't quite needed it, you have to acknowledge you're not gonna give it, so you like lose doses. Which can cause a problem. That happens with antibiotics as well, if you're slightly behind, then you have to sign for it and then you can't give it early; so end up just wasting that dose or omit doses.” Nurse 11

For drugs which were double checked, the EP system required both users to enter their username and password details before the administration was recorded. This process of

witnessing was linked to the route rather than by user. Witnessing could be overridden, but was time consuming.

“We made the intravenous route a witnessed route. So that means if somebody gives an IV injection, they have to get a witness. There is a way of overriding it but it means you have to go through a series of clicks saying yes I want to override it, and you have to put your username and password in again ... if you do a stat dose with that, you not only have to prescribe it, you then have to go in to administration and actually administer the drug.” Pharmacist 2, EP team

This was especially difficult for some drugs and in some areas where doctors rather than nurses administered the drugs e.g. theatres, and an alternative route of administration – ‘IV/ not witnessing required’ was set up as a temporary measure until the issue could be resolved at a Trust level.

Checking patient identity was problematic with EP. Previously, for certain long term patients e.g. dialysis patients, photographs were attached to paper prescription charts to aid patient identification, which was no longer possible. Secondly, when administering medicines, the mobile carts did not always get taken to the bedside due to concerns of manual handling and manoeuvrability. Therefore it was not possible to check the patient name and hospital number against the identity bracelet which patients’ wore.

“We are supposed to wheel them to the patient, but in theory, it’s not very practical, especially when you’ve got patients on the other side of the ward you have to get it through the [treatment room] doors, another set of doors [if patient on other side of the ward or in a separate cubicle]; sometimes it’s just not practical.” Nurse 10.

Several nurses remarked they would prefer handheld devices which were easier to transport.

The administration chart display caused confusion as well. For example, it listed all the medicines the patient has ever been prescribed, even if they had since been discontinued and it was not always clear to see from the chart whether the dose had been given or whether it was on an as required basis. Doctors specifying formulation as part of the prescription caused confusion for nurses who initially misread the dosage form as the dose. Using paper and EP concurrently led to some confusion and disruption in work practices, as there was a risk of overlooking items prescribed on paper charts.

The pharmacy used a combination of the JAC and ASCRIBE systems as described in chapter 3. Pharmacists continued to review prescriptions, but this was often done remotely on EP using a specific program that listed all prescription items that had not been verified by the pharmacist. This function could be used to dispense from, but was discouraged due to confusion with screen layouts, and for TTAs resulted in inaccurate stock control: dispensing labels were generated without deducting stock on the system. Automated requests for non stock inpatient items was also possible from within the system, but this was considered unsuitable for paediatric dispensing.

“it will sort out stock drugs and non-stock drugs, so it will send an order down for a non-stock drug... Now on an adult ward that’s, that’s one thing, but on a paediatric ward, you know if you dispense one bottle of frusemide, it could last for weeks...months depending on the size of the child...” Pharmacist 2.

Another new function for pharmacists within EP was to ‘hold’ a prescription i.e. make it unavailable for administration, if it required further clarification or correction, as well as being able to use the notes function available to all users, for messages to the prescriber or nurse. The ‘hold’ function was used judiciously by the pharmacists.

“It’s one of the you know if the pharmacist verification, there’s a little thing to say hold. I wouldn’t just hold it and leave it until I go up later. It depends, it depends on what it is. Something like that I wouldn’t ... straight to the doctors and say you don’t mean this...” Pharmacist 1.

There was a need for real time admission data on PIMS so that patients would automatically get admitted on to EP. This automatic link between PIMS and EP was tested, but did not always ‘admit’ the patient to the ward or clinic on the EP system or there was a lag, thereby making them unavailable to prescribe for. Similarly, patients who attended the ward for short treatments, but were not classed as day case patients, did not transfer across as they did not have an inpatient status on PIMS. For these patients or for pre-ordering drugs which required preparation in pharmacy in advance of the patient’s admission, the nurses had to manually ‘admit’ patients onto EP.

Entries on the EP system, once made, could not be deleted. This led to problems in the record, as the documentation looked as though an error had occurred even though it had not. For example changes could not be made once the patient had been discharged, therefore errors detected after this point could not be corrected in the record.

“the only thing we could do, is put a note actually saying they have prescribed it twice, but actually the drug was only given the once... We’d contact the ward tell them what had happened, put a note on about it that that had been done. That’s really the only thing we can do after the event and a bit of a problem really.

That was something, you know it always felt like anything that was going wrong, you know we were having to write a note about everything on the way...” Nurse

2

Some problems persisted with the software due to the order in which entries were made or changed on the screen e.g. start date defaulted to the date and time of prescription entry for variable doses and stat doses if changes were made after date/time had been selected. Not all drugs and dose frequencies were available from the drop down menus on the system and these needed to be added on request as implementation progressed. Certain prescriptions were more difficult within the set format of EP e.g. drugs with variable dose schedules as these had to be prescribed as new prescriptions for each change in dose. Prescribing variable doses was particularly problematic for TTAs as the start and stop dates did not appear on the printout.

Another problem was due to printing from the system. In outpatients, the system was set up to transmit the prescription electronically and print directly in pharmacy. However, there were concerns about this due to stray printing of pathology test requests in pharmacy, as well as the prescriptions and this prevented further roll out of EP in other outpatient clinics. TTA printouts also caused confusion as the original paper prescriptions consisted of four, no carbon required, colour coded copies, but those from EP were all printed on white paper. As a result, copies were sometimes given to the patient, rather than retaining copies for the medical notes and GP.

Planned and unplanned system downtime

Procedures were in place for planned and unplanned downtime, and included the need to update information from paper printouts to the EP system once the system was available again. These were circulated and displayed prominently on all EP wards. Printing paper was the last resort, and if the system was unavailable for 30 minutes or more, the decision to revert to paper would be taken by the pharmacy systems manager or the resident pharmacist if out of hours.

Initially, the backup was performed from the live system during planned downtime, but this was subsequently changed to the shadow server so that it would not affect the

system availability. Scheduling of planned downtime for clinical information updates took a long time to resolve as this needed to be during a quiet period; required IT input and at a different time to the MAS schedule. Ultimately, 15 minutes planned downtime at 9pm once a month was agreed. Wards were encouraged to restart laptops after running the MAS each day and after generator tests to ensure effective running.

There were 4 occasions of unplanned downtime in 15 months since go-live when the system was effectively unavailable: due to network failure, when the clocks went back, back up process failure and wireless network failure. In the first three incidents, the EP system was not available and paper prescriptions had to be printed from the backup PC in pharmacy. In the final one, EP was not affected, but mobile carts could not be taken to the patient due to problems with the wireless network; additional wireless access points were installed to minimise a recurrence. The failure to back up from the shadow server only came to light after one of the unplanned downtimes, when there was a 90 minute delay before even paper prescription charts could be printed. This was seen as a “show stopper” which required urgent resolution. As more wards started using the system, there was concern about the contingency of being able to printout charts from the back up system in a timely fashion for all wards using the EP system and forced the EP team to consider availability of a local PC and printer on each ward rather than being reliant on the single one in pharmacy.

Some commonly used computer key strokes caused problems within the EP e.g. use of CTRL+ALT+DEL to end a JAC EP program caused a lock, resulting in failure to backup.

7.5.3.3 Outcome

The system continued to be used and implementation to other areas progressed.

Implementation of software which provided users with a single sign-on made it easier to log on to the EP system. Over-alerting due to use of ‘notes’ improved with training and changes to the ‘notes’ system. Mobile cart problems were recognised as a manual handing risk by the occupational health department, and alternatives such as more easily transferable devices were trialled once available.

The system continued to develop on the basis of the original specification, and the local EP project team identified several system improvements, based on feedback from users. Some of these related to administration charting e.g. deferring doses across the MAS period, ability to override witnessing by user and/ or drug, ability to view all the

information that appeared on the prescribing screen on the charting screen as well and 'if charted in error' a further dose to be generated. However, most requests for improvements related to the overall view of the medication record. Screen improvements included a fully maximised screen, presence of user name on prescribing and administration screens, and in the case of a locked patient record, name of user who is accessing the patient. Protocols were desired for ease of complex prescribing e.g. drugs with varying morning and evening doses. Other enhancements were for printing and the need for additional information on the printouts e.g. reprints of prescriptions for information, clinic contact details on outpatient prescriptions, and start/ stop dates for variable dose schedules on the TTA. Some improvements were related to ways of working in specific situations – ability to allow retrospective timing in certain situations e.g. theatres and printing orders to enable preparation of medicines required for patients who were pre-admitted.

A few of the desired improvements, such as backup PCs on individual wards in addition to the main pharmacy backup, dose calculations/ checking and protocol prescribing were expected with the next release of the software. Complex prescribing i.e. intravenous infusions, intravenous chemotherapy regimens and TPN were planned as longer term developments, as was the discontinuation of the MAS.

There was a reduction in the overall medication error rates as discussed in chapter 4, but new types of errors were introduced.

7.5.4 Human perspectives

7.5.4.1 Structure

A project manager and a project pharmacist were employed to facilitate implementation of EP across the Trust, and two additional pharmacists were employed on a short term basis (6 weeks) to set up the drug files. Change agents were deployed to assist with training and support. There were no changes in the staffing structure on the wards. Inpatients and their parents were not required to modify their behaviour in any way, but due to electronic transmission, outpatients no longer needed to take a paper prescription to pharmacy if medication was required.

All permanent members of staff involved in prescribing, dispensing or administering medication were trained to use the system including clinical response nurses (CRN) who provided assistance to any ward areas that needed help on a daily basis e.g.

covering break times or assisting with drug administrations and clinical site practitioners (CSP) who managed the running of the hospital at night. Ward clerks had access to enable management of patient admission and discharges. Operating department assistants were given 'view only' access so that they could call up the patient medication profile for the anaesthetist to view.

Although all medical staff received training, urology consultants never used EP as most of the inpatient prescribing was done by SHOs and occasionally registrars. Ward 3 did not have any SHOs or ward clerks. Therefore registrars did all the inpatient prescribing, and nurses and clinical nurses specialists admitted patients on the PIMS system.

It soon became apparent that unless other staff e.g. short term agency or locum staff and student nurses, had some access to the system to fulfil their normal duties or training, the workload of permanent staff members would increase.

“When we first brought it in, it was quite difficult because we couldn't get agency nurses on it, we couldn't get students on it to check their meds, they're not giving anything but they need to look at to see when their children are due medication to correlate their feeds or their care and we couldn't get that at the beginning...” Nurse 3.

Student nurses were subsequently provided with 'view only' access. Agency nurses and locum doctors access to the system was problematic due to lack of training and access to the Trust IT system through which EP was delivered. A system was set up for issuing emergency usernames and passwords to locums and agency staff including out of hours.

Environmental changes were necessary on most wards in order to accommodate the mobile carts, but the magnitude of change varied from ward to ward. On one ward, a patient cubicle was converted to additional storage space to make room for mobile carts in the drug treatment room, whereas on another, only minor rearrangements were required for this. Placement of the laptop in theatres was important, as anaesthetists needed EP to be accessible whilst maintaining access to the anaesthetic machine and having space to prepare medicines if needed. A laptop holder which could be attached to the anaesthetic machine was obtained to enable this.

Replacement of old computer hardware e.g. screens was necessary on most wards, with power sockets and additional wireless network points being required by some. All wards were given laptops in carts. Additional laptops were purchased to enable

exchange in the event of failure of existing devices and discussions were held about the possibility of installing a second backup printer in a location other than pharmacy.

Training and introduction to the system

A demonstration was arranged to introduce the system to areas that were due to go live. Training content and duration were tailored to the user's role and anticipated use of the system and changed over time as the trainers gained more experience as the implementation progressed.

“However when you're first bringing a system in, everybody needs to know everything because there is nobody else to do that for them. So there are different types of training depending on what um whether it's new to them or just new to the whole ward or what type of user they are, because you know we've got different you know different levels whether they're agency nurses whether they're nurses who just need give drugs whether they're nurses who need to check other people giving drugs or whether they're nurses who need to be in charge of the ward..... For an agency nurse ... who is only literally going to look at the system and do everything under supervision, I can show them around the system in 15 minutes.” Nurse 3

The theatre nurses do not use the system and therefore will require little if any training. Minutes of project team meeting, December 2005.

Training for the EP team was provided by the vendor over a number of days. EP team members identified and trained core nurse trainers and practice educators who subsequently provided cascaded training to the other nurses during protected teaching time. All doctors were trained by the pharmacists on the EP team, with the exception of anaesthetists who received individual training from change agents, project team nurses and theatre core trainers. Pharmacy dispensary staff required additional training for dealing with requests from EP wards. Resident pharmacists were trained as a matter of priority as they were the out of hours first line support.

Initially a one to one format was used, with duration ranging from 45 to 90 minutes for regular users and 15-20 minutes for locum and agency staff. Longer term, training large groups at the same time was considered more efficient. Staff were not trained too far in advance as they were liable to forget and require further training. All staff were provided with a quick reference training booklet containing illustrated instructions and contact numbers in case of problems.

One of the main challenges was to train doctors in a timely fashion. New staff were trained at induction, but there were problems due to non attendance and/ or delays in arranging access to Trust IT systems, as well as unwillingness to be trained.

A continuing problem is that some staff do not receive their Novell or Citrix log-ins in time. This means that they cannot be set up for prescribing immediately after their training. Minutes of project team meeting, September 2006.

Extra support in the initial post implementation period was provided by change agents and practice educators for the nurses and ward pharmacists for doctors. The on call pharmacist provided first line support, with backup from CSPs once trained. Technical problems with the EP system itself were referred via the pharmacy systems manager to the company, who provided a 24 hour support service via the telephone. On going updates and information pertaining to EP were originally provided using a weekly newsletter, but then less frequently. The newsletter addressed issues common to all users, as well as location specific ones. Non-urgent communication on training issues and changes was via e-mail and staff notice boards. Information folders on the server system were also considered for this purpose.

Two of the doctors had used EP previously, one in another country and the other had used computerised chemotherapy ordering at another hospital, and the JAC system whilst on call on the renal ward. None of the remaining respondents had any experience with EP.

Most users, including EP team members, found the training adequate to introduce the system which they felt was easy to learn, but took a while to get used to, especially for senior staff and those who had used written prescriptions for many years. Computer knowledge was considered important for learning to use the system.

"I just sat down with it. I mean I had used it in the dispensary for that time and I mean if you're used to using computers and having used it in the dispensary, it's quite easy really." Pharmacist 2

"...it's not a big thing, but it's easy to think it's a big thing...It's not really that much it's just knowing how to use the computer." Nurse 12

"I think there's a generation gap that the people who didn't grow up with computers have a lot more difficulties, a lot more opposition to it than the younger ones." Consultant 2

“when I started working there were about 6 D grades and that is of course the younger nurses and we were you know quite happy to just get on with it, whereas you’re got the senior staff nurses who’ve been here 5-6 years nursing ... used to their paper drug charts and ...[they] were like ...this is just not working.” Nurse 5

There was agreement that the most effective way of learning was through experience, with continued use and from other users who were more familiar with the system.

“...then because we’re quite a smallish team, everyone can help each other, you know there’s the handbooks, but also there’s quite a few people who have taught themselves things, little ways of getting round things or getting you know started how this has happened, someone else says oh I’ve had that before this is what you do sort of thing. So I think everybody helps each other really...” Sister 1

Infrequent users took more time to become familiar with the system and were less willing to use the system. This was a particular problem with staff who came to assist on the ward but had not previously been trained, clinicians who practised at other hospitals and so used the system less frequently, and users providing cover out of hours.

One incident concerned an on-call locum SHO who did not know how to use EP and could not prescribe antibiotics. He had had training, but said he could not understand it. He had seemed very disinterested whilst being trained. Minutes of EP risk group meeting, one year after go-live.

Anaesthetic staff felt the training was insufficient and not all staff had been trained, despite ongoing training and support from the change agents and other EP team members, who were available from the beginning of theatre lists at 7:30am. This sentiment was echoed by Ward 3, where users felt that the training was rushed and they did not have enough time to get used to the system.

Pharmacists were seen as the main contact in case of problems, but other experienced users were recognised as a good source of support. There was a tendency for users to find workarounds or seek support internally or from the EP team members rather than contacting the IT helpdesk in case of problems.

“We can come out of the system altogether, if we shut down the system or come out and get someone else’s password to log in and usually that works..... we’re lucky we’ve got [renal ward] been using it a lot more so...we could go and ask them.” Nurse 9.

This reluctance to contact the IT helpdesk became problematic as more areas started using the system and when the change agent team reduced from 4 to one. Out of hours support caused the most concern, due to difficulties and delays in obtaining assistance.

“IT after 5 is quite difficult when you go through switchboard.” Sister 2

Existing users were encouraged to meet new implementers to discuss risks they had experienced and users were expected to report incidents formally so they could be followed up. However, the EP risk group recognised that incidents would not always be reported, especially if the incident was resolved, and staff were encouraged to keep an informal log book to record any ‘minor’ incidents. Familiarity with the system resulted in a lower number of incidents being reported.

Ward and theatre processes were modified / tightened to ensure that all patient weight and allergy details were entered on the system, and that the medication profile was available as view only in theatre to minimise problems for the anaesthetists.

7.5.4.2 Process

“...electronic prescribing is black and white, there are no shades of grey...”

Pharmacist 2, EP team.

Most respondents from the renal ward felt they were involved with the implementation process either directly or through representatives on the EP team, but hardly any from the other two wards did. This was reflected in the knowledge about the implementation reasons and team structure. The renal ward was clear on both aspects, whereas Ward 3 and the urology ward *assumed* the reason for implementation was to improve safety and reduce errors; respondents were aware of individuals involved in the implementation but very few were aware of the exact makeup and structure of the project board and team.

Initially, there were mixed reactions about the EP system, ranging from enthusiasm to complete resistance. Computer literacy amongst users varied considerably and some users felt their inexperience with computers had an effect on EP usability. Generally, doctors were more confident with computers than nurses.

“I’ve used quite a lot of different computer systems so, I found it quite straight forward to use.” SHO 2

“I’m not a favourite of computers, a lot of frustration with the electronic prescribing comes from computers”. Nurse 5

“I had a few moans from some of the older nurses at the start who don’t even use the computer on a daily basis, can’t even check their e-mail basically and they were like you want me to use this, it’s ridiculous.” Sister 3

A problem was identified where a night shift on [ward 3] was being covered by two bank/agency staff - neither had used PC before. Minutes of project team meeting, September 2006.

The EP team had anticipated logging on and off the system to be problematic, due to password sharing or failure to log off especially in protected areas such as theatres. However, all users considered EP password security important because of accountability and medicines use being a ‘high risk’ process. There was one report of a nurse failing to log off, but the real difficulty arose in the actual process of logging on, which was considered lengthy, time consuming, cumbersome and annoying. These aspects were apparent during observations, when there were very few cases of successful log on at the first attempt, and occasional failure to log off the system by the users.

All users felt EP provided easy, remote access to clear, complete, legible charts and medication records, unlike paper charts which were liable to be mislaid, illegible and/or unclear.

“The fact that you have black and white literally what the patient is actually getting. Often [there is] confusion with our children we talk in milligrams, the parents are talking millilitres and sometimes on the previous letter either ml [or] mg and that can be confused. What you actually have in the electronic prescribing system is one defined amount then there is no confusion about it at all. And you can immediately see what the patient really has got prescribed and for how long and when it was stopped and that’s um in the long term, that’s, that’s fantastic I think.” Consultant 2

On the other hand, some aspects of the electronic record were not always kept up to date.

“one of the problems is with these dummy drugs is that they’re not very good at taking them off... they kind of forget because it’s not a real drug if you like. So you know I think there are sometimes probably when things are not a hundred percent. You would have to, you would have to go up and look at the PCA chart to see to get a full record of all the things they’ve had.” Pharmacist 1

The greatest difference was the visual change, from being able to see the whole chart including prescribing, administration and pharmacy endorsement details to a list of drugs with separate screens for some of these.

“There’s quite a few screens you have to go through so initially the first chart will tell you the medications for, what they’re charted for and then you have to go onto another screen to see when they last had a dose and then another screen to administer it so, like on the paper chart it’s all there on one page tick the box and you were alright.” Nurse 8

“...[The computer is] vastly inferior because you’ve got multiple buttons to press to view whether a drug has been administered and etcetera and you know the duration. You just have to press numerous buttons to view various windows. You cannot beat the appearance on paper of something.” Registrar 2.

This was thought to be potentially harmful in some situations and inconvenient in others.

“...in terms of if a drug is too high an amount and we can’t get a doctor to chart or change it straight way, we’d obviously give the right amount and put a note, we can add notes, but unless someone sees that as they’re logging in, I don’t think, you could, that could be easily missed, that a different dose has been given because that doesn’t come up as an alert, it’s something that you have to physically look in and go in to.” Nurse 9

For patients who previously had multiple charts, EP was considered to make viewing all the medication comparatively easier and safer. The EP printouts were also clearer and easier to read compared to the original prescription charts.

A major advantage over the paper system was the fact that it was harder to lose charts, and this resulted in a comparative reduction in

- medication history errors
- risk of having two drug charts and therefore duplicate dosing
- time spent looking for the drug chart

However, locked patient records due to another user viewing the record was seen as a problem similar to drug charts being off the ward.

Although most respondents had claimed the system was easy to learn, they found it harder to use compared to paper.

"...because it's all computer based, you end up having to go to the computer to look for what medicines are due and when it's due and stuff. Which is a lot harder than just picking up paper." Nurse 4

"Sometimes finding the correct name for the medication can be difficult and just sort of learning my way around how to do certain things like prescribing an ongoing course of a reducing medication. There are ways to do it, but it can be a bit umm it's not quite so easy as writing things on a paper drug chart."

Registrar 1

There was some lack of trust in the system,

"I would feel, even though pharmacy information is on the computer, I won't be happy with that I'll always use BNF if I've got a query. I won't rely on it to help me." Nurse 6.

"I think with a paper chart, I'm much more certain of what I'm prescribing and I think from my point of view the main reason for that is that on a paper chart the only thing that is going to be written is what I write. Whereas with the electronic prescribing as I've mentioned, it changes things or adds in extra bits ... that would never happen with a paper chart." SHO 2

as well as a belief that the system instils a false sense of security.

"I think there's an element of people thinking ah it's on computer on now I can't make a mistake. Although everyone's been told that's not the case, when you see a computer package in front of you that's what you automatically you know think ah this going to have some really groovy things that's going to stop me doing it." Nurse 12

All respondents expressed that errors were possible with either system, but some errors were more likely with one than the other. This was either due to change in practice directly as a result of using the EP or due to the software itself. For example, use of dual systems i.e. paper and EP led to some missed doses as well as duplicate prescribing. The latter was a particular concern for patients returning from theatres who were most likely to have paper charts for nurse or patient controlled analgesia. Some errors were due to the way of working in the theatre. In one instance, an alert appeared on retrospective documentation of drugs administered during a procedure and highlighted that errors may occur unnoticed, which are subsequently picked up on entry to the EP. Others were due to the way in which the system was set up. For example,

use of defaulted route for Pethidine restricted the prescriber to the licensed IV route, who then prescribed it on a paper chart to overcome this. This resulted in a prescribing error as a second opiate was prescribed on the EP system.

On the whole, EP was considered to be safer as it was believed to reduce prescribing errors but more importantly, drug administration errors. Some errors were eliminated i.e. due to illegibility, transcription, lack of allergy status and patient weight information. Administration errors secondary to poor or unclear documentation were thought to have reduced e.g. signature on drug chart to indicate administration is more likely to be present; less confusion with dose units; clear time of when last dose was administered, especially for prn dose; improved documentation of therapeutic monitoring. Nurses reported that doses were more likely to be given on time, and there was less likelihood of missed doses.

Documentation errors were more likely with EP, as once charted, entries could not be amended e.g. inadvertently marking an item as given or entering a reason for non-administration. This applied to TTAs as well, which could not be changed once the patient was discharged, therefore even if errors were detected, they could not be corrected. There was an increased possibility of 'click errors' i.e. selection errors from dropdown menus and errors in prescribing if using 'represcribe' function without checking for changes which may not have been recorded on EP.

Some errors remained unchanged and this was attributed to the absence of advanced clinical decision support e.g. wrong dose, wrong drug choice, dose adjustment for renal patients, therapeutic duplicate drug duplication and drug: drug interactions, but senior nurses felt that these were picked up by existing mechanisms e.g. nurse or pharmacist check.

Users felt that the actual numbers of errors were unlikely to have changed, as although some types of errors decreased, others were unchanged and new ones were introduced. All respondents commented on the potential to reduce errors further by using dose calculations and dose checking. This was the main expectation that was not met.

"I would expect it to tell you if you had a drug prescription error in the 10s of, you know in the order of 100s or 1000s multiplication error or something like that I would expect it to tell you and I'm not sure whether it does either."

Registrar 1.

"...well I thought that it would be more advanced in the fact that if you, if the doctors had prescribed it wrong it would alert them." Nurse 12.

Respondents did acknowledge that certain requirements e.g. dose checking would be challenging because of the extensive use of unlicensed medicines due to the nature of the hospital. Equally, if all decision support was activated, there was a risk of over-alerting.

"...sometimes we will not always give the recommended dose and the physician wants something different..." Registrar 3

"If you know, if every single time you did a drug and it says not recommended in children, not recommended in children, can you imagine what that would do to you?" Pharmacist 1

Another unmet expectation was improvements in the TTA ordering process, in particular, the ability to print directly in pharmacy, and being able to monitor progress. The continued need to print and sign TTAs was seen as unnecessary by both nurses and doctors.

"So for instance with the TTOs, with the discharge summary, you can't print them directly down in pharmacy, you have to print them on the ward and then have them physically taken down to pharmacy. You can't see if they've been printed already, you can't see on the computer where they are in their journey as it were, so whether they've been printed and taken down to pharmacy, whether pharmacy have dispensed them. That doesn't give you any more information." SHO 2

"The only thing that is annoying though is that you can't check for the, you can see if TTOs have been done, it'll come up at the bottom of the screen, but you don't know whether they've been printed out on paper and sent to pharmacy."

Nurse 9

Despite individuals reporting some time savings, nearly all users agreed that overall, using EP was more time consuming, due to initial unfamiliarity, slow wireless connections, lengthy log on process and insufficient computers for the number of patients.

Initially, all users needed to work together to learn the new system, resulting in better communication and a team spirit. For most part, respondents felt there was no difference in the overall time and interaction with parents or other professionals. There

was a positive effect on the doctor-pharmacist interaction, but the nurses reported detrimental effects on their working relationship with the doctors.

“I think we do their[Doctors] heads in more than the other way round, because we’re the ones making mistakes causing them to have to go ... so I think that’s caused quite a few problems for them...” Nurse 12

“I think it’s increased frustration with doctors in that sometimes you think why is it taking so long for it to be prescribed I asked you half an hour ago, what’s the problem ...” Nurse 6.

“we do have a hassle a bit more about writing up a stat dose, whereas before if they wrote it, you know if they wrote it up 4 times a day, now it’s 10 o’clock they wanted to be given you have get them to write up a dose for 8 o’clock in the morning because a dose won’t come up until midday.” Nurse 1.

Doctors

Most practices remained unchanged e.g. prescribing in an emergency situation would still be recorded retrospectively, but there was a belief that if sufficient staff were present, this would be easier and more likely to be done in real time on the EP system. This was observed during ward rounds, when use of EP increased if more than one junior doctor was present. However, the order in which things are done and the actual process of putting pen to paper versus using the computer was very different. As one doctor described,

“I mean with a new system there is a change in process and how people um do um an action. So for example with outpatient prescribing you’re trying to find the pad, sometimes it’s in the notes and do the prescription copy do a copy to give to the patient to go to the pharmacy. Completely different obviously in electronic prescribing where it was going in through the computer system which sometimes takes a while, so they haven’t got time or the computer system is open but also x-ray results, you’ve got your outpatient information, you’ve got your PIMS system which is all the information about the next appointment, you’ve got your e-mail and they’ve got our own unit hard drive where you record the last letters because very often they’re not in the notes. So you got all these systems open and you’re opening up another system, electronic prescribing, which just slows down and so that process had to change for me in that I don’t actually order patient blood forms and investigations until the end of the consultation.

So I wait till I've done the electronic prescribing, everything has gone through."

Consultant 1.

Although the process of prescribing was considered more time consuming, on the wards this was balanced by not having to rewrite paper drug charts, being able to renew prescriptions that had not changed since previous admission(s), not searching for drug charts, or struggling with legibility.

Junior doctors felt that the biggest change for them was selecting the drug preparation as part of the prescribing process. They saw this as being the role of the pharmacist or the nurse at point of dispensing or administration; a sentiment echoed by most nurses and pharmacists. In contrast, senior doctors considered it good, routine prescribing practice to specify formulation and strength. Some doctors reported that a more accurate record of what the patient received was available, and that there was greater discussion with the patient/ parent as a result.

"I mean it's, it's better for the patient and it's worse for the doctors. I mean some doctors because they feel all they want is the dose and drug, but in fact it makes sense to know and have an accurate record of what the patient's taking for future admission." Consultant 1

Doctors found selection from dropdown menus restrictive and the system inflexible for prescribing complex dose regimens and multiple routes

"sometimes I find the tight dosage timings sometimes can be inflexible, whereas on a paper chart you can prescribe all sorts of times that you wanted to. Here you can only prescribe what the computer will give you." Registrar 1.

"It's very rigid so it can be quite difficult...if you want to do things like a reducing dose... or if you want to change doses, that's often very difficult to do if you wanted paracetamol to be prescribed IV or orally or rectally, which you would be able to do on a paper chart and then the nurses would choose the most suitable route. You can't do that on this..." SHO 2

There was a view that you had to know the system well to get the most from it.

"Noting that the top right hand corner of the prescribing unit has associated stat order saves a lot of time and trouble. It's just picking up on the little things takes a while to pick those little things up. Labour saving devices that have been put in and are thought about but we don't always get, doesn't always come across to us it's there..." SHO 1

A point that the EP team were aware of.

“you do need to know how your way round stuff and you need to be trained properly, but no I think if you don't know what you're doing then the computer is definitely in control.” Nurse 3, EP team.

Doctors realised the potential for selection errors, and were more vigilant when prescribing.

“I think one of the things that always worries me about this and I have to keep double checking is that yes I've got the right patient listed and yes I have got the right drug, yes I have put it down for twice a day rather than every other day or every Tuesday you know it's so easy to pull up from your click list you know twice on Fridays or something like that. Whereas when you write you know exactly what you've put. So I'm constantly kind of checking what I've selected.” Consultant 3.

Though they preferred the paper BNF over the clinical information available on the system, the ability to sort prescribed drugs by BNF category was seen as a useful tool to force medication review.

“you actually get a list of medication it does come up potentially in the grouping of the chapters of the British National Formulary, hopefully soon the BNFC, the British National Formulary for children. And I think when you have grouping of drugs together, you actually start thinking about it. You know are you really wanting those patients to be on five antihypertensives when you haven't maximised dose of three of them?” Consultant 1

Senior doctors felt that EP would influence the information seeking behaviour of junior staff.

“They wouldn't be looking up in the books anymore because they're reliant that the computer will do everything for them automatically, I mean if it gives you the guidelines right then and there it would actually be beneficial, they would actually look at the guidelines then.” Consultant 2.

Another useful function was the dose to dose unit conversion as this sometimes prompted them to review the dose prescribed in terms of ease of administration.

“I mean obviously when it's tablets it will say you know give 1.6 tablets and you think yeah, I think we will just give one and a half coz you can't really do 1.6.”

So ... that's a useful reminder ... when it's coming out with a ml dose then it's very useful, just to make life a little bit easier for nurses." SHO 1.

Entering the time of administration as part of prescribing was another change in practice as this was mandatory for the prescriber on EP but had not always been done by the doctor on the paper system. Therefore, it had to be highlighted during training to ensure doses were not being missed.

"...noticing that if you if you want a drug at 6, 2 and 10 and you prescribe it at 5 past 2... assumptions ... that the nurse would have known to give it 2 o'clock even if it's 5 past, whereas the computer doesn't know that." Nurse 3, EP team

"You know really looking at the times and getting your head around you know the fact that you need to give a stat dose at the same time. Before you could circle something three times you know you could say to the nurse, even if it's 2 o'clock oh just give that dose late they could do it on the chart, but of course they can't do that on the system." Pharmacist 1, EP team.

Doctors felt that the amount of contact and time spent with patients was largely unaffected, but EP made the job a lot smoother. In outpatients, they perceived a more efficient process with electronic transmission rather than waiting for the parents to take the prescription to pharmacy.

"...the big advantage obviously is that the prescription prints out in the pharmacy so that by the time the parents come down um I'm not actually sure if it is ready then but here the medication could be ready it's better than going down handing in the prescription and waiting there." Consultant 2

In reality, this was not necessarily the case. During one of the observations, the pharmacist needed to access the patient record before dispensing but could not do so for around 20 minutes as it was 'locked' by another user. Apparently this was not an unusual occurrence.

One of the major changes in practice on the renal ward was the format of the ward round where the electronic chart and other results were projected side by side onto a screen.

"...when you're sitting there on the consultant ward rounds you know Monday's and Friday's is that they've actually got the thing there. They haven't got to say what drugs is this patient on and the doctor's kind of thumbing through the notes and they've not been very well written." Pharmacist 1

Urology doctors did not see the reason for implementing EP in the absence of any obvious benefits.

“Is it adding anything extra to make the process more streamlined or convenient or safe? Umm particularly in paediatrics where the dose is often given according to weight in kg, that’s not connected, so again, why bother? Why bother with it?” Registrar 2.

New doctors were more likely to make errors because they selected an inappropriate formulation selection or time of administration, at the start of their employment.

EP resulted in extra work for doctors as a result of:

- Re-prescribing due to charting errors made by nurses which resulted in doses no longer being available (e.g. entered a reason for non-administration and then needed to give a dose before the next dose was scheduled) or if doses need to be deferred across the MAS period.
- Prescribing on behalf of non-users e.g. locums or other teams who did not have access to EP.
- Prescribing post-operative doses of antibiotics and analgesics that were previously prescribed on the paper chart by anaesthetists.
- Updating information on the system after short term transfers e.g. ward closure over holiday periods.

Doctors felt the system could be more intuitive and user friendly.

Nurses

Nurse reported no change to the fundamental principles of drug administration, but the physical tasks required a change e.g. taking the mobile cart to the patient instead of the drug chart or for inpatient items that required dispensing, they could call through with requests rather than taking paper charts to pharmacy.

An initial problem was the difficulty in adjusting to the different way of viewing the prescription chart. However, as one member of the EP team pointed out, new staff often find paper charts just as challenging.

“ I think you know like anything there’s a lot of things to read, but it’s only just that’s using a different system and there really is, there were a lot of boxes and a lot of things on the yellow drug chart but I’m sure when I first saw those as a student nurse year ago I thought gosh I don’t know if I ever understand it. And

also if you go over to the intensive care unit and have a look at all their different charts it takes you a few minutes to work those through too.” Nurse 3.

The system made it easier for them to document the use of PGDs compared to paper. The consensus amongst nurses was that a clear audit trail and legible records were a benefit, especially in case of errors and queries.

“... you feel a bit more secure in the fact that you’re signing to something you’re accepting it, nobody can change that, it’s not pen and paperno-one can mess with it...” Nurse 12.

In addition, EP was thought to have improved communication about drug treatment e.g. more information about stop and start dates and the medication history was particularly useful for transfers to other hospitals or wards. However, even though the EP system had all, if not more, information that the paper charts did, they reported that it was more complex to read, understand and to review the whole picture. There was a feeling that due to this difficulty, the whole chart may not be reviewed.

“...with the paper chart you can, as I said before you can open them up and see exactly what’s due during the day. Now you can do that on the computer, but a lot of the time if you’re busy, you’ll just click on what’s due next” ...Sister 1.

One nurse reported they were more likely to double check doses with easy access to electronic pharmacy guidelines and eBNF via the computer, though most nurses preferred the paper version.

Lack of trust in the system, and the need to check up on other users, mainly doctors, resulted in increased vigilance by nurses when using the system. This combined with the need to interact with the computer were just two of the reasons why nurses considered EP to be safer. Others included prescribing using generic names, correct spelling and improved legibility.

Nurses found one alert particularly useful, but not the fact that it could be overridden.

“... if you were to try and give the drug for example if it was prescribed 6 hourly and you were trying to give it sooner than that it will come up, flag up to say that this drug has been given at such and such a time do you still wish to continue to give? But you can override that and just say yes and still go ahead. Whereas it would be sensible for it to not allow you to go ahead and do that.”

Nurse 8

They also expressed interest in self tailored alerts.

“you could probably put alerts on it for yourself. To alarm when your child's drugs were due. So that you know that is something we wanted you know we've put forward as wouldn't that be great? Some time in the future so you could program it if your child, you've got this handheld for this particular child and so everything about their care. So it would alert you to the fact that it's 2 o'clock and it needs antibiotics and that type of thing, so that would be even better.”

Nurse 1, EP team.

Compared to the paper system, EP gave a better overview of drug administration on the ward as whole. This ability to review all the patients' administration records and whether they were up to date on a single screen was an extremely useful tool for senior nurses in managing the ward. However, individual nurses reported they were less in control of planning when medication was due and felt dictated to by the computer. They were frustrated by the inability to change times of administration and expressed concern at the inflexibility especially for patients going to theatre, for IV drugs and drugs which were due for administration around the 4am MAS time.

“Yes so they have to select time for the drugs to be given and then when you get round to that time is when it's available for administration. The time of day when the patient's due in theatres, so you want to give it a couple of hours late then you lose the dose by the time you get to that 4 o'clock time, so you can't catch up.” Nurse 11

“... at the moment it's quite inflexible... it's more to do with the time... say if you had a child with multiple IVS and only one cannula you kind of have to change certain times you can't run something with something else ...but there's not much scope to, whereas on the paper chart we would change times slightly so they were still having them, but not at the same time that they might be having other drugs that are infusions.” Sister 2

There was an acceptance that the time of administration would often not match the prescribed time as a result. All nurses expressed the desire to increase the one hour window for administration, and the ability for “super-users” to change times of administrations.

The time taken to administer drugs was the same as before implementation once they were used to the system, although it did take longer whilst they were learning.

However, there was an increase in their workload due to lack of access for some staff, phased implementation and the need to admit patients in real time. Phased implementation meant nurses were responsible for printing medication administration charts (MACs) and medication administration profile (MAPs) from the EP system e.g. for patients being transferred to non EP areas or in the care of non-users. In addition, as only one theatre was using EP, nurses had to check each time a patient went to theatres to see if printouts were required i.e. if going to a non EP theatre or if an anaesthetist in the dedicated theatre was not EP trained.

“Normally they let us know the night before, so we have it done in advance and then our night staff get out the notes going to do that and print all of them. Occasionally we don’t know until the morning which is a bit of a disaster, but normally we would know the night before.” Sister 2

If new drugs were initiated or doses were administered on the paper printouts whilst in theatres then the ward based doctor and nurse had to update the EP system with this information.

Nurses were frustrated by other peoples unwillingness to use the system.

“It’s very infuriating when you take your patient to, to theatre and then they administer drugs down there and then they do not put it on the prescription chart there ...” Nurse 5.

“It’s very frustrating you get someone who doesn’t know the system or if you get a night reg[istrar] who doesn’t really.....you do still get people who aren’t sure how the system works or they don’t want to know how the system works.”
Nurse 6.

Senior nurses hoped that certain work practices would improve and be more efficient with EP. Ease of accessing information, in particular medication history facilitated this.

“... it can be more efficient as well ... what we find is when they’ve been admitted to the ward previously on paper, it’s maybe taken the doctor to that evening to actually prescribe the drugs ... or you’re having to chase them to actually sit down and rewrite the prescription ... when the chart runs out you’re having to chase them to follow up the chart, but you don’t have any of that problems because from day one when they’re admitted all of their medications are automatically put on to the system and the doctor’s have found it better

because if there is a repeat admission they can just copy the drug chart I think, which is easier and it's making life easier.” Sister 3, post implementation.

Anaesthetists and theatre staff

The main change for anaesthetists working in the theatre where EP was implemented was that instead of having everything on paper, they had to use the computer to access information for patients from EP wards.

“They, they always have paper printed out for them. So, they're completely capable of using, don't get me wrong they're very IT literate people, but they never used them. Everyone printed paper, theatre list for them et cetera, so they going round with their bit of paper.....” Nurse 2

Incomplete documentation of mandatory fields e.g. weight and allergy status on the wards, affected the anaesthetist's ability to prescribe and resulted in delays. The clinical lead for anaesthetics had expected pre-prescribing to help in theatres, but this did not happen as the real time link with PIMS did not allow prescribing in advance of the patient's admission.

“They have something like 4-5 minutes per patient normally quite a lot of them don't come on time... they should have the 1st patient anaesthetised by 8:30 you know so, they've got a very, very small window.” Nurse 2

Interaction between surgical wards and theatres was affected as patients were sent down with either a paper prescription chart or no chart if due to the real time PIMS link, they had not appeared on the EP system. Workarounds were explored to overcome this e.g. for patients seen at pre-admission clinics, it was suggested that nurses could order routine drugs in advance using PGDs and thus save time for anaesthetic staff.

Another reason for EP being more time consuming was that they were required to perform two separate records for prescribing and administration of IV drugs, and because of the need to override witnessing (the IV route was set up as a witnessed route, and if this was not required e.g. in theatres, then the user would need to enter their password twice to confirm that witnessing was not required).

Anaesthetists were also more aware of the fact that the error rate may seem higher than it was due to errors in documentation rather than actual errors in prescribing or administration. Moreover, due to retrospective recording, they were concerned about the possibility of duplicate dosing as previous administrations had to be recorded using

the notes functionality and would not appear on the administration chart. Some surgeons, anaesthetists and recovery nurses considered EP to be risky for the theatres environment as they had to turn away from the patient to prescribe or record administration.

“...in this environment it is difficult because there’s one on one with the patient that’s very often unconscious in here and the priority has to be on the patient and not on the computer, so sometimes I find it difficult to log information and look at the patient.” Sister 4

Therefore, anaesthetists were less likely to prescribe and record drug administration on EP, choosing to use the anaesthetic chart instead. They only prescribed the doses that were due at induction, with post theatre doses being prescribed by doctors on the ward, whereas previously they would have done so themselves.

Anaesthetists felt that the user interface was not friendly and therefore not a suitable alternative to paper. They would prefer to have personalised menus which could be set up with their most commonly prescribed drugs.

Pharmacists

For pharmacist’s the main change was in providing support for the EP system, both in terms of arranging training and passwords, as well as in case of problems, especially out of hours. The greatest effect was on resident pharmacists who had to provide passwords and minimum training for those who had slipped through the training program or for locum doctors and deal with occasional IT related issues and minor queries from users who did not know how to use the system properly. The resident pharmacists were generally able to resolve these queries. EP related calls reduced as with more areas going live wards contacted each other for support and as users were encouraged to contact ICT helpdesk rather than the resident pharmacist.

Effect on ward pharmacy service was likely to vary from ward to ward, but on the whole, practice remained unchanged, except for format of the prescriptions.

Pharmacists liked the ability to review prescriptions remotely and identify newly prescribed items on a single screen as they felt this afforded a time efficient way of managing their workload. This was particularly useful on surgical wards for patients going to theatre, when the paper prescription chart may not be available until after the procedure. They did recognise the need for continued contact and interaction at ward level and did not feel it reduced their patient or ward contact time.

“It was quite good to be able to print off a dispensing list which showed sort of the new items that had been prescribed and that hadn’t been on the ward previous day... you could just go up to the ward with a list of patients and just click into each one and you could also from any computer go into the Rx select option which would show up new things had been prescribed. I do that when I’m on call, because you can then kind of predict if they were going to need anything..... So it was good that if I’d done the ward in the morning, and then there were going to be several patients going for surgery, I could then check in the afternoon from downstairs what, what new things they needed instead of maybe going back up again.” Pharmacist 4

Nurses noticed this change as they reported that remote access improved interaction with the pharmacy department by reducing the need to take charts down to the dispensary, but felt that there was reduced contact with the ward pharmacist and considered this a disadvantage.

“we see the pharmacist less which is a shame because she can now do half her work from her office, which is a real shame because you know we still see her a lot but we used to see her a lot more than we do.” Nurse 3

Pharmacists had full prescribing access, and felt more comfortable about making changes to the prescription on the EP system due to the clear audit trail. They were more inclined to make changes rather than using the ‘notes’ function. All pharmacists missed the whole chart view. Some felt that pharmacy interventions/ endorsements were not well represented compared to the paper charts and found it difficult to change from the culture of endorsing additional information on prescription charts to writing fewer ‘notes’ in comparison. This concept of less ‘notes’ had to be incorporated in the clinical ward pharmacy training and reinforced by senior pharmacists.

“but I do feel that they’re not on the main screen as they would be on the drug chart, I felt like I wasn’t getting the message across to nurses as I felt like the pharmacy interventions aren’t very well represented on the system, because it wasn’t too obvious, there’s a visual symbol to look for notes, but people might not know what that is or it’s not sort of very clear, it’s not very noticeable on the system you know so it wouldn’t really prompt people to really go in and see what it says.” Pharmacist 4

Whilst pharmacists agreed that it was important to capture information about drug formulation, specifying this at point of prescribing was thought to be complex due to patient preference, a particular issue with this age group.

“In an ideal world yes it would be lovely [for] the doctor to be able to say yes I want prednisolone, I want the ordinary prednisolone not the soluble, and that’s fine and you know you may think child under five years they’re bound to have the soluble, you know, but they don’t...we have a fifteen year old at the moment who only takes liquids. And it’s not, you know it doesn’t follow... the next dose they have they might say I didn’t like that suspension last time. Can you give me rather than 5mls of that one, could you give me 10mls of this one coz I prefer the flavour to that one. But then the next time they come along, and they’ll say I don’t like that either.” Pharmacist 1

Ideally, recording the formulation administered for each dose using bar-codes on drug packaging was suggested as a better way of capturing this information longer term.

Endorsements on TTAs were more time consuming as pharmacists now needed to document any changes on 4 printed sheets compared to once on the previous carbonless copy TTA form. The inability of ward based users to see the status of a TTA i.e. whether it was printed or being dispensed, affected pharmacy as sometimes duplicate prescriptions would be sent for dispensing. Ward pharmacists reported extra work due to doctor’s not prescribing/ discontinuing ‘dummy drugs’, as the pharmacists would then take on this task to ensure an up to date EP record.

“So you know if a child’s on a PCA, for example I’ll have to prescribe that chart because they forget, and then I think this patient’s stopped so I can take it off.”

Pharmacist 1

Pharmacists were excited by the implementation and happy with their involvement. EP team pharmacists felt there were too many different programs e.g. setting up prescribable drugs, stock control, performing clinical screen and dispensing, and could see areas for further development. There was a feeling nurses did not like the EP system to begin with, but soon got used to it. On the whole, the pharmacists considered the system to have been well received by the users, especially junior doctors who would miss it when they moved on to new jobs.

ICT

The project was thought to have raised the profile of the IT department.

“Maybe prescribing has played it’s part in that, but also just the national program as well. IT is playing a very high profile at the moment. So IT is being considered important at last.” IT1

The maintenance burden and workload for IT increased due to the use of laptops as well as setting up local printers and FAT installation of the EP program. Failure to contact the IT helpdesk for all EP related problems was seen as a disadvantage as it prevented the department from sharing the lessons learnt from other users experiences.

“I would prefer they all come to me, so that we actually know the problem exists. If it’s a recurring problem and I don’t hear about it, I can’t fix it.” IT1

However, the failure to contact the IT helpdesk was as a result of perceived delays in response time from the IT department, both during hours as well as out of hours.

Parents/ Patients

Two parents had experience with the EP system only. The remaining 4 parents and one patient had experienced both the paper prescription chart as well as the EP system. Those on the renal ward were initially intrigued and wanted to look at the electronic chart, and one parent who saw it in use thought it was really good. All of them were aware of the process for medication administration, and had not noticed any changes as a result of the EP system. Parents knew that nurses could only administer what the doctor had prescribed.

“The nurses don’t make decisions about drugs. I’d have to wait for the doctor to make the decision anyway.” Parent 6.

EP was considered to be more secure and confidential as it required password access, and there was a perception that records were less likely to go missing if they were electronic. However, the patient and a couple of parents, expressed concerns about technology failure, and felt that electronic records were more vulnerable whereas paper was longer lasting.

“...if you have paper, it will be kept for longer you know. You can easily go back to it...but like computers or electronics, they easily go wrong, they get broken and stuff like that...” Patient

“How quick can they access that information ... they need to know the medication if there is any problems...once it’s written down it’s there in the file.” Parent 5

Most parents felt there were several advantages for health care professionals: easier to use, more efficient and time saving due to reduced paperwork, less rewriting and amendments, ease of searching – one respondent gave the analogy of internet search engines, better communication amongst staff as well as between wards and reduced risk of misreading due to clear up to date records.

The disadvantages for them were that they were no longer able to review the drug chart, some reported that drug administration took longer with EP and inflexibility in time of administration affected one parent who was unable to start the normal routine of giving the medication as a result. In a paper system, the nurse would have been able to administer the dose at an earlier time or change the time on the drug chart.

The loss of access to the prescription chart especially affected parents who were more involved and knowledgeable about the child's care. One parent found this extremely frustrating and thought the time taken for nurses to provide the information the parent sought was too long. She felt a loss of control in terms of involvement with the child's care, and expressed dismay at the thought of a complete electronic patient record.

Parent 4: Oh no, no, no. You mean those little things like temperature and blood pressure and everything?

Researcher: Yes

Parent 4: Oh I think no, aww [makes a face and laughs]

Researcher: ...You like to keep in touch with what's happening?

Parent 4: Yeah I like to keep [an eye on] her temperature, her blood pressure, everything...

Another reported the difficulties in obtaining a copy of the inpatient medications from the EP system at discharge, compared to the ease of photocopying the paper prescription chart.

Parents expected a level of decision support as a result of computerisation.

"I should think the computerised way has got alarms built in to it saying that this things been given sign it off, or actually, it's a better thing I think." Parent 2

"... all sorts of checks in there, umm to maybe prompt you whether or not somebody's taking medication that's contra-indicated or if the dose was wrong or you know..." Parent 3

However, there were mixed views about the effect on errors. Whilst some respondents thought the EP system was safer because of less uncertainty about missed doses and better documentation of administration, others recognised that certain errors would continue.

"I suppose it's down to what you put in you know. You can put an extra or the wrong thing down or, um or both." Parent 5

"... because computers only as good as the input it's been given..." Parent 6

"Umm they both will have risk you see, like paper is obviously it's easy to do something wrong with it and also depends on the computer for example whether the computer talk to something like the network or something in case of bug virus and stuff like that. So the rest is probably about the same, I don't know I'm not too sure." Patient

Potential for errors due to changes in practice was commented on.

"Um with the manual system, normally her file is there, drug charts there, doctor will be writing and talking to me. If they then have to go and enter that in the system, that's where the errors can occur." Parent 6

Two examples of errors were cited by parents which they thought may or may not be attributed to the EP system:

A child on reducing dose of prednisolone, who went home for weekend leave should have been on 25mg a day was given medication labelled as 5mg to be taken once a day.

"...I don't know, I don't understand... was it putting it on the computer, was it just something, I don't know..." Parent 5

There was also a case of continuation of medication on the EP system that should have been discontinued.

"...the computer had said that the drug should have continued,... I knew the drug she was on in here wouldn't harm her..." Parent 6

7.5.4.3 Outcome

"I think ... everything is going on to computers now anyway, time to move forward really." Sister 1

The system was well received and accepted on the renal ward and on ward 3. Acceptance on the renal ward was largely influenced by involvement of two senior

nurses and one consultant from the ward, who promoted the privilege of being the first ward to implement the system. There was poor acceptance from the urology ward and theatres, partly due to problems reported by the first ward.

“Initially they were all quite negative about it. We knew the other ward started a few months before us. We knew the issues they had so we were reluctant to take it on.” Nurse 11

A lot of the respondents in these areas would have preferred to return to paper prescriptions as they saw no clear benefits over the previous paper system. Although local customisation for anaesthetic staff improved usability of the system, it did not fully resolve issues of acceptability.

EP was believed to reduce prescribing and drug administration errors, especially those due to illegibility, transcription, lack of allergy status and patient weight information and incorrect time of administration. There was no change in some types of errors due to human failure i.e. lack of knowledge or inability to use the system optimally, rather than system failure.

New risks as a direct result of EP were identified and included failure to check patient identity against prescription details when the wireless network failed or if mobile carts were not taken to the patient’s bedside due to the size. The former was considered to be uncontrollable and advice was sought from the legal department about staff vulnerability in this situation. The brief period after downtime when EP was being updated and paper printouts were still available was considered a potential risk as the patient could receive the medications twice. It was therefore agreed that paper printouts would be avoided unless there was no EP capability at all. This was reflected in the advice from the legal department:

If the JAC System is working but the wireless connection is unavailable, staff should use a static PC instead of the mobile cart and should continue to use Electronic Prescribing rather than revert to paper charts. The risk to the patient of having both the electronic chart and paper chart available for medicines administration is greater than not using the mobile cart. Minutes of EP risk group meeting, January 2007.

Users felt it was comparatively easier to use EP in adults than for children.

“...look at the dose in this column you don’t look at the preparation. I mean in adults it wouldn’t matter so much but obviously in children it’s, it’s more important.” Pharmacist 2.

“Now we went many places and saw it being used and it seemed unbelievably straightforward in adults. They’re all on 6 hourly meds, they do a drug round and it’s a whole different ball game.” Nurse 1.

The majority of the respondents liked the system, but identified various improvements that would make it easier to use and therefore more acceptable. Users, especially doctors, were more inclined to recommend an improved version of the existing system, or an ideal ‘better EP system’ to others rather than the present system.

“I think if you had a well designed system then in theory it could be much better than a paper chart that would be excellent”. SHO 2

There was a sense of inevitability amongst doctors and nurses about EP implementation within the Trust. Pharmacists expressed a more positive view and considered it suitable for all specialities. Patients and parents were largely unaffected by the changeover from paper to EP.

The EP record was seen as the main, more reliable medication record, rather than the medical notes.

Adequate support and intensive training were considered essential for successful implementation in other areas. Overall, all respondents considered that an EP system with advanced paediatric specific clinical decision support was the ideal to improve medication use and patient safety.

7.5.5 Organisation

7.5.5.1 Structure

EP was one of several major changes and IT projects within the Trust. It was a key priority to improve patient safety by optimising the quality of prescribing and medicines administration. The main driver for implementation was patient safety, with the initial decision made in 1998 following a fatality secondary to a medication error. EP was just one of many clinical systems that would come ultimately together to form a complete electronic patient record.

“ a strategy to move us ... so that people are frankly more used to turning to the screen not to the notes at some point... it's moving a culture in that direction.”

EP project and Trust board member.

The timing of the project coincided with the launch of the National Program for Information Technology raising some concerns about it's future. However, there was an impetus to ensure that the national solution would consider paediatric specific issues and the Trust was given the go-ahead on the premise that the work would inform the National Program.

Specific funding was allocated for the initiative and managed over a 3 year period using PRINCE methodology for project management. A dedicated project board and team were formed. The project was led by pharmacy, with full support from the Trust Board and clinical leadership from the divisional lead for anaesthesia. Clinical and operational decisions regarding the EP system were discussed within the EP project team and ratified by the Drugs and Therapeutics Committee or EP project board respectively. The project team comprised the project lead, a renal consultant, three senior pharmacists, two senior nurses, a change agent and a senior member of staff for the ICT department. The project board and team were keen to promote the system as a Trust system rather than a pharmacy system. The EP team set up two other groups to deal with specific issues: the ICT group and the risk group. The risk group assessed and dealt with the overall risk of EP on all aspects of patient safety.

In order to enable Trustwide use of EP, two underpinning systems were essential: the pharmacy system and the IT infrastructure. The pharmacy system was changed from ASCRIBE to JAC, but the previous system continued to be used for TPN and CIVAS until these modules could be delivered by JAC as part of the contract. The Trust IT infrastructure had planned the use of a wireless network, but EP provided the momentum to drive this forward, and became the major clinical system to utilise it.

IT audits were conducted in each area prior to go-live to assess suitability of existing PCs for EP and wireless network strength and connectivity. Project funds were used to purchase laptops, extra batteries with longer life, Cisco cards for laptops (to enable wireless connectivity), computer mice, keyboards and mobile carts for each ward where EP was implemented. Some equipment e.g. device to hold the laptop onto the notes trolley and ruggedized tablets with a docking station were on loan from companies on a trial basis for testing with the option to purchase if selected. Choice of device took into consideration infection control issues, and ruggedized devices were preferred. Other

costs i.e. installation of additional wireless points and that of replacing existing hardware e.g. PCs and printers, was payable by the directorate/ ward where the system was being implemented, and this caused difficulties for areas that did not have their own budget e.g. theatres.

EP was included in the Trust's central system for providing access to the main clinical IT systems in use; notification of starters and leavers by line managers was an important factor to enable and disable access.

7.5.5.2 Process

The project team membership remained stable, with one change early during the planning stages, but none since implementation. Team members had all worked at the hospital for more than 5 years, and the longest was 30 years. The project team linked with other groups in the Trust e.g. technical standards group, which needed to approve the mobile carts and any subsequent changes in choice of carts. Team membership was due to be revised following the first phase of implementation, with users for each area being implemented joining the group as required. However, this model was abandoned in favour of implementation groups consisting of a lead clinician, pharmacists, senior nursing staff and practice educators from each area. The main project team met less frequently for decision making and overall project review; implementation groups were encouraged to identify potential problems for practices and commonly prescribed drugs in their specialties.

The early stages of implementation were seen as a discovery process as although the mechanics were known, the actual effect in practice was uncertain. Therefore, this phase was used to identify operational risks, and the processes which needed to be in place to prevent risk. Distinction was made between setting up and ongoing maintenance/ support e.g. for PCs on which the EP program was installed, the pharmacy department was responsible for setting up, but the ICT department for maintenance. The main mechanisms for capturing information about errors and new risks was through formal and informal incident reports.

The initial aim when implementing EP was to replicate existing systems and processes to minimise change. Ultimately, the intention was to identify ways of improving health care professionals' practices around medicines use with the aid of technology. It was envisaged that EP would enable tighter control of the medicines use process and better role definition for professionals.

“So they [at board level] felt half of the benefit was that only people who can prescribe are, have access to prescribe.” Nurse 1, EP team.

However, this was abandoned due to a number of reasons. Firstly, it was resource intensive for the project team as well as ward managers.

“one of my other concerns is about the upkeep of the background system...as a manager of the girls saying you can have access to this, this and this and when you’ve done this drug book I’ll give you access to this.... that’s a lot of access to keep changing that’s a bit time consuming from a manager point of view..... you have to open the system up rather than close it down so it’s safer that way.” Nurse 3, EP team

Secondly, there was a mismatch between practices that were normal but not necessarily according to policy or guidance.

“... but actually that happens quite a lot, that when you sit down with people, they just don’t, they always give you how it should happen, but often it doesn’t. So I think there were quite a few things popped up with that, that the system was surprising because people hadn’t flagged them up”. Pharmacist 5

“So sometimes the project team had unrealistic expectations of how things really work in the clinical...” Nurse 1, EP team

This raised questions around user accountability and the use of EP to enforce medication related policies and practices within the Trust. This balance between access rights, professional responsibilities and possibility of misuse was a risk management issue which needed to be addressed at Trust level.

...issues of professional responsibility needed to be discussed ... within the Trust... to consider whether or not the features available within the electronic prescribing system should be used to prevent various staff grades from performing tasks such as giving IVs without being witnessed. Internal user group meeting, February 2006, 5 months after implementation.

In 2006, the team reported that the project was delayed by one year. Several factors affected the implementation timetable: Redevelopment and ward moves around the Trust presented both opportunities as well as hindrance to the project. Some implementation dates were postponed but enabling works allowed identification and installation of new network points and access to EP. Other factors that influenced implementation choice and timetable included the following:

- Staff numbers, turnover and time of junior doctor rotations – wards with small number of staff and minimal turnover or cross-cover were considered earlier; the initial timetable was set for implementation in February and August to coincide with junior doctor changeover and this caused large gaps between wards going live.
- IT infrastructure – software and operational compatibility was essential; single sign-on was seen as a way of minimising log on problems encountered by early implementers; printing problems delayed implementation in outpatient clinics significantly
- Implementation in areas with complex prescribing was influenced by the presence of other clinical systems e.g. Carevue in critical care units or Chemocare on haematology-oncology wards, where ability to view the existing system at the same time as EP was important.
- Complexity of the ward e.g. wards with protocol based prescribing were considered to be easier, but those with multiple specialities more difficult.
- Real time admissions and bed management on PIMS were considered vital, especially for surgical patients. Therefore this area was delayed until a centralised admissions unit was in place.
- Stability of the EP system within the IT infrastructure and improving software capability - the next software release which would allow protocol prescribing was key to implementation across the remaining surgical wards and theatres.
- Clinician interest e.g. ophthalmology outpatients were scheduled for implementation ahead of in-patients due to interest from consultants, but remaining surgical ward implementation was delayed due to resistance from anaesthetists.
- EP team resources for training and support.

Though theatres proved a challenging area in every way, the team and the anaesthetist felt that this was the best time to implement, as issues were identified early, and most wards at some stage would transfer patients to theatre.

A few problems were anticipated, and the team actively sought to identify and resolve these, in some instances by drawing on the experiences of other hospitals e.g. procedure and scheduling of monthly clinical information updates; wireless infrastructure; label printers mismatch. However this did not always provide answers e.g. IT structure was similar at another Trust using the same system, but unlike GOSH, they did not experience any problems with wireless LAN or Citrix.

There were several unexpected factors during implementation. IT infrastructure and the wireless network issues had been challenging but not insurmountable and it was considered groundbreaking to use such technologies for critical processes like prescribing. However, IT support structure, especially out of hours, needed to be tightened to deal with this as more wards went live. On site ICT support out of hours was not considered feasible due to financial and human resources required, but would be considered in the future if the demand justified it.

The EP team needed to explore the different levels at which customisation could be achieved for things like default frequencies, routes, and times of administration.

“there is a lot more work to be done to actually get it to the situation which we’d all like to, the benefits for all units in the Trust because each ward is complex; works in very, very different ways; what one ward wants can actually be very different to another ward.” Consultant 1

Training and support for areas going live was more resource intensive than expected, and ongoing support from the change agent team was not guaranteed as other IT projects were going live around the same time. Extra funding was used to release staff to provide training to nursing and medical staff in areas where the system was being implemented and for out of hours support by the EP team pharmacist. In August 2007, a major change in junior doctors training schemes meant that there were no SHOs. This had significant human and financial implications, as the team were expected to train over a hundred registrars. Mode of training delivery was reviewed, with e-learning using a training CD being the favoured model, as this would allow more flexibility for staff receiving the training.

A robust mechanism for issuing usernames and passwords to agency nurses and locum doctors was necessary. This proved more challenging for doctors as the underlying processes for arranging this were less clear than for nurses who could be as many as 40-50 in one shift per night across the whole Trust, but were booked in advance, thus allowing some planning.

Requests of software improvements which were not part of the original specification, were taken to an external user group via the EP team pharmacist. All the team members contributed in prioritising the items to take forward to this group. The user group in turn had a voting system to prioritise the list of items for national development.

7.5.5.3 Outcome

“they’re not a perfect supplier, it’s not a perfect system, but it is working.

There’s ... been hiccups both technically and non-technically along the way, but it is going ahead. And I think it’s proving to be a success.” IT 1, EP team

The project was seen as a success by the board and the project team despite technical problems experienced during the initial implementation phase. The EP team felt that implementation progress was satisfactory and on the whole the system was accepted by the users, despite early difficulties, especially with the hardware. However, they recognised that usability of this evolving system with multiple screens and programs, within complex work systems e.g. theatres was challenging. There were mixed views about the type of wards that may benefit most, but a feeling that medical wards with extensive prescribing were more likely to than quick turnover surgical wards.

Managing the change process and resistance to change were more challenging rather than using the system itself. This was the most important aspect to ensure successful implementation. The project team had to adapt their implementation strategy from that used in the initial area, which had a very long buy in period.

“There’s no reason why it shouldn’t be in all the other types of ward like that in my view and um you know so that I will qualify that, up to now, money well spent. If we take another four years, not money well spent.” EP project and Trust board member.

Though the details were not fully determined, EP was seen as a powerful tool which could, and in some instances did, enforce medication related practice and policy across the Trust to achieve the original goal of improving patient safety e.g. to ensure witnessing of IV drugs; documentation completed in a timely fashion; weight and allergy status present on every prescription; by controlling user access. Individual wards utilised system functions to influence practice on their ward.

...requested that the facility for prescribing medication at 8am/8pm be taken off the system. This time period conflicts with handover and often causes delays in administration of meds. Minutes of implementation team meeting ward 4.

The system also forced work planning e.g. arranging cover for medical staff due to be on leave. Audit trail was seen as an advantage, and some of the EP team anticipated requests from senior managers of reports of data captured by the system. This ability to

audit use of medicines using EP was expected to help with the Trust gaining Level 3 CNST (clinical negligence scheme for NHS Trusts) which focuses on auditing practice.

Even though the original business case clearly stated that financial benefits were unlikely as a result of implementing EP, there was interest in alternative financial benefits e.g. time savings were perceived, and work to assess whether this really was the case was planned.

“it’s not always that ...you would save money as a result of electronic prescribing ... ultimately[EP] will be more cost effective and sort of process efficient, but it really was about safety I think. For me it was. There are other projects that I would have put ahead of it if I wanted to save money.” EP Project and Trust board member.

As the implementation project drew to an end, the team recognised the need for continued maintenance and input by a dedicated EP pharmacist, as more complex IV software was still to follow and would involve a major re-implementation.

Implementation of EP was one step forward on the path to the Trust board’s long term vision to have an integrated electronic record system.

“Well what we’re talking about is the clinical, is a front end if you like, of the systems. So to the user it looks as if it’s one system...integrate it on a screen so that the clinician would go in and see their home page as it were ... with a workflow attached... So rather than in and out of fifty different systems you’ve actually got it brought together for you...” EP project and Trust board member.

It was hoped that in future the system would allow transfer of information across the interface.

“I would really like to think we would get them out very, very quickly to GPs now that they’re produced in a legible format, you know the information is available and I know up in Ayr, who have got the same system, they’re actually e-mailing them out.” Pharmacist 5, EP team and project board.

There was national interest in the system raising the Trust’s profile, as demonstrated by visits from external agencies.

“it is very good for an organisation as a whole to be seen to be doing some innovative work...we’ve had a lot of visitors who’ve come to see our system. For example yesterday we had Connecting for Health who came to look at the

system, we've had the Children's Commissioner come, The Royal College of Paediatrics and Child Health, people are interested in taking this forward to make paediatrics safer." Consultant 1.

The project team and board had considered a 'big bang' approach for implementation appealing, but would recommend phased implementation to others as it helped them identify issues early which could be resolved for wider implementation, thus making it more acceptable.

"My tip to them would be whilst you're biting off the bits so that you could eat the elephant, make sure that you worry about the rest of the elephant... I don't think you need to prove the do-ability of it, it's all about the change management ... that you do worry about how you're managing the tail of it as opposed to the big deal issues of getting it live in the first area really." EP and Trust board member.

7.6 Summary

The EP system had been adopted by the Trust as a whole to improve patient safety by reducing the risks associated with the use of medicines in a paper based system. Individuals were aware of the national drive for a complete electronic patient record, and the Trust's commitment to deliver this as seen by various other IT projects that were in progress at the same time as EP. The implementation strategy included individuals from all professions and departments likely to be affected. This resulted in the system being viewed as a Trust one, rather than a pharmacy system. Early implementers had a greater sense of involvement and ownership, but late implementers felt their concerns were also addressed. Lack of benefits in the short term affected acceptance in some areas; one of the main expectations and area for further development was dose related clinical decision support. On the whole, there was recognition of potential advantages longer term as the system continued to develop and most users reported a favourable view of EP, with an overall acceptance of the system.

Table 27: Summary of findings

	System	Human perspectives	Organisational context
Structure	<p>Commercially available prescribing, dispensing, administration charting and pharmacy stock control system.</p> <p>Enhanced for paediatric use, but based on an adult system. At the time of implementation, not all the paediatric specific software functionality was available.</p> <p>No interaction with other clinical systems, except for the patient information management system which automatically linked demographic information.</p> <p>Access was via a thin client server and wireless network. There were initial problems with the IT infrastructure.</p> <p>Logging on to the system was problematic.</p> <p>There were some limitations of the EPMA screens including the size.</p>	<p>A project manager and pharmacist were employed to facilitate implementation of EP.</p> <p>Change agents were deployed to assist with training and support.</p> <p>Environmental changes were necessary on most wards in order to accommodate the mobile carts, but the magnitude of change varied from ward to ward. Extra computers, printers, wireless network points and power sockets were required.</p> <p>All staff involved in the medicines use process were trained to use EP.</p> <p>Training content and duration was tailored to user role.</p> <p>Agency nurses and locum doctors access to the system was problematic due to difficulties in training and access the Trust IT system through which EPMA was delivered.</p>	<p>EP was a key priority to improve patient safety by optimising the quality of prescribing and medicines administration.</p> <p>The timing of the project coincided with the launch of the National Program for Information Technology and the Trust was given the go-ahead on the premise that the work would inform the National Program.</p> <p>A dedicated project board and team were formed; it was led the divisional lead for anaesthesia, with full support from the Trust Board.</p> <p>The EP team set up two other groups to deal with specific issues: the ICT group and the risk group.</p> <p>Project funds were used for additional hardware e.g. mobile carts and laptops, but ongoing and upgrade costs were payable by the directorate/ward where the system was being implemented.</p>
Process	<p>Replaced outpatient and discharge prescriptions and the main drug chart on the renal ward, but complex prescribing continued on specialist paper charts with a cross reference on the EP system.</p> <p>Some functionality made prescribing easier and more streamlined</p> <p>The system alerted the user to some conflicts detected by the system, but these were considered too similar and excessive and likely to be ignored.</p> <p>Automatic link between PIMS and EP did not always 'admit' the patient to the ward or clinic on the EP system or there was a lag.</p> <p>Printing from the system was problematic in outpatients.</p> <p>Entries on the EP system once made could not be deleted. Therefore there were more documentation errors rather than actual errors.</p> <p>There were 4 occasions since go-live when the system was effectively unavailable, including one when the third backup server was also offline.</p>	<p>There were no changes to the fundamental principles of the medicines use process, but the approach was different with EP.</p> <p>Initially, all users needed to work together to learn the new system, resulting in better communication and a team spirit.</p> <p>Users found the software relatively easy to learn and use, but were frustrated by hardware, IT infrastructure/ log-on issues, over alerting and phased implementation problems. Majority of users agreed that overall, using EPMA was more time consuming.</p> <p>The visual change from a whole chart view of prescribing, administration and pharmacy endorsement details to separate screens for each of these was a big difference for all and considered a disadvantage of the EP system.</p> <p>Doctors found selection from dropdown menus restrictive and the system inflexible for prescribing complex dose regimens and multiple routes.</p> <p>New doctors were more likely to make errors due to inappropriate formulation selection and specifying times of administration.</p> <p>EP gave a better overview of drug administration on the ward as whole compared to the paper system, but nurses were frustrated by the inability to change times of administration.</p> <p>Pharmacists liked the ability to review prescriptions remotely as they felt this afforded a time efficient way of managing their workload.</p> <p>Parents/ patients considered EP to be safer, more secure and confidential, but felt they were no longer able to review the drug chart.</p>	<p>The early stages were used to identify operational and clinical risks, and the processes which needed to be in place to prevent risk.</p> <p>The initial aim was to replicate existing systems and processes to minimise change. It was envisaged that EP would enable tighter control of the medicines use process and better role definition for professionals in the long term.</p> <p>There was a mismatch between normal practices and policy/ guidance, resulting in a Trustwide risk management issue around access rights, professional responsibilities and possibility of misuse.</p> <p>Several factors affected the implementation timetable a lot of which were beyond the control of the EP team.</p> <p>Some problems were expected, which the team actively identified and resolved, in some instances by drawing on the experiences of other hospitals.</p> <p>Despite this, the team faced several unexpected factors during implementation.</p>
Outcome	<p>The local EP project team identified several system improvements, based on feedback from users. A few of these including dose calculations/ checking and protocol prescribing were expected in the next software release.</p> <p>Failure to take mobile carts to check the patient identity resulted in a new risk.</p> <p>There was an increased possibility of 'click errors' i.e. selection errors from dropdown menus</p> <p>Prescribing certain drugs e.g. variable doses continued to be problematic.</p> <p>Overall error rates decreased significantly.</p>	<p>The system was well received and accepted on two wards, but there was poor acceptance from the urology ward and theatres.</p> <p>EPMA provided easy, remote access to clear, complete, legible charts and medication records, unlike paper charts which were liable to be mislaid, illegible and/or unclear.</p> <p>On the whole, EP was considered to be safer, but some errors remained in the absence of advanced clinical decision support and new errors were introduced due to change in practice.</p> <p>Majority of the respondents liked the system, but identified various improvements that would make it easier to use and therefore more acceptable.</p> <p>Users, especially doctors, were more inclined to recommend an improved version rather than the present system.</p> <p>Patients and parents were largely unaffected by the changeover from paper to EP.</p>	<p>The project was considered a success by the board and the project team with relatively few major problems or surprises.</p> <p>The system remained in use and implementation to other areas progressed.</p> <p>EP was seen as a useful tool to enforce good practice and policy across the Trust.</p> <p>The project team and board had considered a 'big bang' approach for implementation, but would recommend phased implementation to others as it helped them identify issues early.</p> <p>Managing the change process and resistance to change were more challenging than use of the system itself.</p> <p>There was a need for continued maintenance and input by a dedicated EP pharmacist at the end of the project, which needed funding.</p> <p>Long term the Trust hoped to have an integrated electronic patient record system.</p> <p>National interest in the system raised the Trust's profile.</p>

Chapter 8 Discussion

“Technology presumes there's just one right way to do things and there never is.”

Robert M. Pirsig, American writer and philosopher

(<http://en.wikiquote.org/wiki/Technology>)

8.1 Introduction

This thesis aimed to investigate and evaluate the implementation of an electronic prescribing (EP) system at a children's hospital. The focus of the evaluation was patient safety, as one of the main reasons for implementing EP at the study site was to improve patient safety. It was anticipated that EP would improve the quality of prescribing and administration processes, reduce the risks associated with a paper based system and provide clinical information at the point of prescribing. The objectives of the thesis were formulated based on the knowledge that medication errors are a significant patient safety concern, particularly in children and the proposition that EP systems may be one of the solutions. The project began in 2005 when much of the literature on understanding the barriers to EP adoption and unanticipated events that may arise following implementation was emerging, based on the use of EP in children in the US, as well as adults in the UK (Ash et al. 2004; Han et al. 2005; Koppel et al. 2005; Barber et al. 2006). As a result, the scope of this project extended beyond an outcome based study to incorporate system, human and organisational factors, structured using the Cornford framework. The underpinning argument for using this framework, which is based on a sociotechnical approach, is that the introduction of a technology in the healthcare environment will result in changes to the structure, process and outcomes of the social system.

In this chapter, the overall findings are discussed by considering the effect of the system on prescribing errors, examining the influence of the system on human perspectives and organisational context and making recommendations for EP system improvements. This is followed by reflection on the methodology used. Further areas of study are identified to build on and add to the research in the field. The conclusion draws attention to the original contribution made by this work.

8.2 Use of EP at a children's hospital in the UK

The evaluation presented in this thesis showed that the EP system was largely accepted by the users, despite some initial resistance from areas where there were minimal apparent benefits, such as surgery and theatres. The implementation was made successful by a number of factors. Firstly, the project was supported from the highest level in the Trust and was a key component of the hospital's IT strategy and 'zero harm' policy. Adequate resources (human and financial) were allocated to enable implementation. Furthermore, all relevant stakeholders were involved in the EP project

team, and users were invited to join implementation groups at each stage of the roll-out process. Robust risk identification and management processes enabled the EP team to address problems that arose with the technology as well as work practices and facilitated the recognition of new types of errors.

The anticipated benefits in patient safety through improvements in the medicines use process were realised to an extent as demonstrated by the prescribing errors study. Medication prescribing errors were reduced noticeably, especially those related to completeness and clarity of prescribing. Provision of complete drug information with basic decision support providing clinical checking for correct dosage, route, drug interactions and allergies was yet to be fully realised. The CDSS study highlighted the potential risks of alert fatigue, especially if all the available functionality for conflict checking was activated. Results of the CDSS study prompted activation of level 4 drug: drug interaction, whilst options for improving the specificity of the remaining suppressed alerts could be considered.

At the time of submitting this thesis, the JAC EP system will have been implemented across all wards and theatres, with the exception of intensive/ critical care units, at Great Ormond Street Hospital for Children. The implementation process, using a project based approach, took a total of three years since the first ward went live with the EP system. The EP project team will also have been disbanded, and instead, an advisory/ user group, which will report to the Drugs and Therapeutics Committee, will have been formed to aid the EP pharmacist with ongoing monitoring of the EP system in use, and implementation of new software releases as they occur. A major software release incorporating functionality to prescribe (and record administrations of) intravenous infusions is anticipated in 2010.

8.3 Electronic prescribing, errors and patient safety

EP in paediatrics appears to have some beneficial effects by reducing prescribing errors, mainly by ensuring clarity and completeness of prescriptions in this patient group, where misplaced decimal points and ambiguity have been known to cause clinically significant overdoses (Wong et al. 2004). Effects on patient outcomes remain to be seen, as errors are not always indicative of harm, and indeed there may be new types of errors. Table 28 summarises the different ways in which errors may be affected as a result of EP, as observed in the prescribing errors study, and reported in the qualitative study. Errors involving legibility and omission of essential information such as allergy

status, are likely to be reduced. Some errors remain unchanged in the absence of advanced CDSS, whilst others become more visible because of improved documentation.

New errors may be introduced by the way in which the system is set up, because of immaturity of system functions or as a result of changes in working practices. These findings are consistent with those reported in the literature. Potts et al. (2004) reported an approximately 95% reduction in prescribing errors, most of which related to completeness of prescriptions and rule violations. In contrast, Walsh et al. (2006) and Koppel et al. (2005) highlighted that new types of errors may be facilitated or exacerbated with the advent of EP.

8.4 Unintended consequences

A number of changes to practice were expected as EP became embedded in the work environment. In fact, this was one of the main drivers for implementation: to improve safety in the medicines use process by forcing good practices such as mandatory weight entry, allergy status entry and performing a second check for specific drugs and/or route according to policy. However there were resultant implications for individual users, as well as the organisation. The system design also led to some unintended and unexpected outcomes.

8.4.1 System workarounds

Although the system was designed to optimise practice, cases of mismatch between system design and normal practice resulted in users finding alternative ways to complete the task.

For instance, the paper prescription chart was often used as a means of communicating other information such as sensitivities or non drug allergies which had implications for prescribing, e.g. if epilepsy worsens with the use of specific drugs, inborn errors of metabolism and allergies to preservatives and colourings. Though the EP system was not designed for this type of communication, users chose to use the allergy status field for this purpose by entering information as 'non-drug allergies' using free-text.

Another example involved going from digital or electronic systems back to paper to aid workflow. Some nurses reported that the EP system was used at the beginning of each shift to plan drug administration. A written list would be produced and EP would subsequently be accessed only when drugs were due.

Table 28: Effect of the JAC electronic prescribing system on medication errors

<i>Effect on errors</i>	<i>Type of errors</i>	<i>Suggested reasons</i>
Reduction	Overall Transcription errors Administration time Missed or delayed administration	Clear, complete, legible prescriptions; increased vigilance No need to rewrite drug chart; accurate medication history Alert if given early Clear record of administration or reason for non-administration
Increase	Duplicate doses Selection/ click errors Administration Missed Delayed Wrong dose Wrong patient	Dual paper and EP system; documentation errors Drop down menus Dual paper and EP system; MAS period; inability to backdate prescribing; inability to change prescribed time; documentation errors Formulation as part of prescription Failure to take mobile cart to the patient
Unchanged	Prescribing wrong dose Drug choice	No dose calculation, checking or guidance No checking for drug: drug interaction or therapeutic drug duplication
Reduced detection	Some prescribing errors	If using administration charting without viewing full prescription chart (only drugs due in the next hour are displayed)
Increased visibility	Prescribing and administration	Inability to change any entries; clear documentation

Some of the workarounds had the potential to introduce risk. For example, for drugs which required a double check of administration, the EP system required both users to enter their username and password details when recording the administration at the patient's bedside. In practice, this was more likely to occur in the preparation area, as mobile carts were rarely wheeled to the patient. Similarly, in theatres, some surgeons, anaesthetists and recovery nurses considered EP to be risky for that environment as they had to turn away from the patient to prescribe or record administration. A workaround for this was to prescribe doses that were due at induction on the EP system, peri-op doses on the anaesthetic record and post theatre doses being prescribed by junior doctors on the ward. This created additional work for doctors on the ward, as well as multiple records of drugs administered in a relatively short period. Before EP, all the prescribing would have been done on the paper prescription chart by the anaesthetists themselves. There are some parallels of this theatres example with use of computers by GPs in the primary care setting (Mitchell & Sullivan 2001; Sullivan & Wyatt 2005). However, in the latter setting, the concerns related to detrimental effects on the consultation process and doctor-patient communication rather than the potential of direct adverse patient outcomes as perceived in theatres.

8.4.2 Implications for individuals

It has been argued that IT systems are often designed on the basis of individual cognition, whereas most decision making is done by distributed cognition (Hazlehurst, Gorman, & McMullen 2008). This is especially true in the healthcare environment where several individuals are involved in decision making about medicines use in a non-linear fashion, whereas EP assumes that an individual follows a linear process. In the current study, a key change to individuals was the approach to the task: not just in terms of the skills required, but also in the role definition. For example with EP, the prescribers had to specify the formulation, which was considered good practice by many of the senior doctors. The importance of knowing which formulation of a drug the patient is on has been recognised for certain high risk drug groups, such as opiates by national safety agencies (National Patient Safety Agency 2008b). Therefore it can be argued that EP was promoting good prescribing practice which will ultimately improve medication safety. Another change for prescribers was the need to specify the time of administration. Although this was considered the role of the prescriber according to the local medication policy, nurses would often change the time on the paper prescription chart to suit the patient's and wards needs. From the individual practitioners viewpoint,

these changes in the approach to prescribing added work. Previously choice of formulation was a distributed task which involved all members of the medicines use process i.e. patient, nurse, pharmacist and the prescriber. With EP, the prescriber had to make the decision; if the choice was unsuitable or wrong, it created more work to amend the record, or resulted in an error if left unchanged. Likewise, nurses previously had more flexibility with the time of administration if circumstances required this (e.g. patient away from ward or awaiting monitoring), but with EP they felt restricted as this was no longer possible.

Similarly, mandatory entry field frustrated individual users who felt the system was excessively controlling and resulted in loss of autonomy.

“...if you’re giving a topical medication the weight is irrelevant and you think oh for goodness sake. Why can’t I just show some professional intelligence here and let me bypass this detail?” Consultant 3.

8.4.3 Implications for the organisation

The organisation was committed to progressing the use of technology and to improve medication safety within the Trust. EP afforded the opportunity to favourably review some work practices such as the improved format of formal ward rounds on the renal ward. However, use of EP unmasked deficiencies in the organisation’s processes for staffing and IT access, which had a negative influence on EP use. A particular problem was in allowing access to the Trust IT system through which EP was delivered, especially for new starters and for locums and agency staff who were often recruited at short notice.

Although savings were not anticipated, the financial status of the Trust was changing during EP implementation and questions were raised about benefits other than medication safety. Additionally, the most unexpected consequence for the organisation was the resource required for training, which was greater than anticipated. A recent study also reported that personnel costs, a proportion of which related to training and support, formed a significant portion of the unexpected costs of implementing a computerised patient record at a children’s hospital (Randolph & Ogawa 2007).

8.5 EP system improvements

The theory underpinning the Cornford framework provided a means of analysing the JAC EP system in context of the social system where it was being used. However,

Coiera argues that the socio-technical theory provides more than a means of critiquing current practices and ICT systems (Coiera 2007). He states that design and evaluation are ongoing processes of an information system whereby outcomes of one evaluation drive the design of the next version of the software (Coiera 2003). On this premise and based on the results of the current evaluation, the following are suggested as ways of improving the JAC EP system and its use.

- a) Streamline log on processes within the Trust to facilitate easier access to the JAC programs.
- b) Improve screen design so that it can be maximised to fit the entire VDU screen.
- c) Differentiate formulation selection from drug selection in the prescribing process, so that pharmacists and nurses, who may not have prescribing access, may be able to modify the formulation at the point of dispensing or administration to suit the patient's needs.
- d) Differentiate specifying time of administration from specifying dosing frequency in the prescribing process, so that other users may select the optimal time of drug administration based on the drug and patient characteristics.
- e) Integrate outpatient and inpatient prescribing modules and records so that a complete medication history may be reviewed without needing to access different parts of the EP system.
- f) Improve physical characteristics of alerts generated by the system by distinguishing between informative, instructive and safety alerts.
- g) Consider ways of improving the specificity of drug: drug interaction and therapeutic duplicate/ drug double alerts to optimise acceptance and utilisation of CDSS.

8.6 Lessons learned

One of the criteria for implementation was to inform the national program for IT in the UK. The lessons learnt though specific to GOSH in some ways, have enough generic aspects to be relevant to other organisations who are considering implementing EP. This is because although the NHS is diverse in many ways, there are similarities in certain overarching processes, procedures and practices.

Lessons learnt to ensure successful implementation were as follows.

- a) An overall strategic vision, leadership and commitment from the Trust board were essential for project initiation.
- b) IT infrastructure and compatibility were crucial to deploy the system, and enable mobile and bedside use.
- c) Phased implementation was the most appropriate strategy for this complex intervention as it helped identify issues at an early stage which could be resolved for wider implementation.
- d) It was important to involve members of staff from each area that was due to start using the system in the implementation process, as they became local champions who promoted the short and long term benefits of EP for that area.
- e) EP is a constantly changing entity which develops through use. Commercial systems may not 'fit' all organisations or even all clinical areas within one organisation. Customisation for local use requires expertise and resources.
- f) The cost of implementing and sustaining EP is considerable and ongoing resources (human and financial) are a necessity to maintain and update this constantly evolving system.
- g) There were some expected as well as unexpected outcomes as a result of EP. A robust risk assessment and follow up process ensured that these were highlighted and resolved where possible.
- h) Appropriate management of the change process was more important than the functionality available within the EP system for user engagement and acceptance.

8.7 Reflection on methodology

The framework used in this study allowed the evaluation to focus on the three main components of EP: the system itself, human users and organisational context, whilst taking into consideration the structure, process and outcome. At the same time it provided the flexibility of using mixed methods. The quantitative studies showed the outcome on prescribing errors and the nature of alerts recorded within the system. However, this would not have been sufficient to answer the 'how' and 'why' questions, and some of the new and unintended outcomes may have been overlooked. Therefore it was important to have an ethnographic component to the evaluation as human and organisational factors were affected by EP, despite careful planning in the design and implementation of the EP system.

The qualitative study involved analysis of the data initially using a coding frame and then by application of the framework. One difficulty was in arranging the data into the appropriate part of the framework, as often there was overlap between the cells. For example, the EP system was designed to allow remote access. This was part of the system's structure, but it also affected human processes and outcomes: remote access was considered time efficient and was reported as a benefit by users, but there was a resultant negative outcome on working relationships (pharmacists visited the wards less frequently) and potentially, patient safety (possibility of doctors prescribing remotely instead of coming to the ward to see the patient). Likewise, as the EP system was continually developing and being implemented across the Trust, the outcomes in one area became the structure for the next one.

Nevertheless, applying the framework to the data was a useful way of translating basic themes into more complex ideas by making links across different cells of the framework.

8.7.1 Limitations

The evaluation was conducted at a specialist children's hospital during the implementation of a commercially available EP system that was continually developing. Moreover, only a limited number of wards were using the system during the study period. Therefore the results may not be generalisable to other areas in the hospital, other hospitals or other systems. However, the findings are consistent with the literature, both for prescribing errors as well as unanticipated consequences. Using similar methodology and definition of a prescribing error, a UK study of adult inpatient prescribing errors reported a 1.8% reduction following the implementation of EP as part of a closed loop medication system, which is comparable to the 2.1% reduction seen in the current study (Franklin et al. 2007). The group also reported some unexpected structuring of the work of staff in the qualitative part of the evaluation (Barber et al. 2007). Likewise US studies report new work/more work, workflow changes and changes in communication between healthcare professionals (Ash et al. 2007a; Ash et al. 2007b). All of these were seen in the present study as well.

A non-randomised, unblinded, pre-post intervention study, without control groups was used for the prescribing error study. There are some limitations of this study design. Firstly, the observed effect may be due to factors other than the EP system i.e. confounding variables and the learning effect (Harris et al. 2006). For example, some

errors may have been as a result of unfamiliarity with the EP system, which may diminish with continued use. Likewise, knowledge of the prescriber may also have influenced the prescribing error rates, as the study included the period when junior doctors changed jobs. New doctors may be unfamiliar with prescribing practices which may lead to an initial increase in errors. Researchers and pharmacist reviewers were not blinded to the stage of implementation i.e. whether errors occurred before or after EP, which may be a potential source of bias. However, the thirteen month study period should, in theory, allow any initial increases in errors due to the learning effect to settle. In addition, the final sample size far exceeded the number calculated to be able to detect a reduction in prescribing errors as a result of the intervention. A comparison of outcomes with a non EP group may have helped to control for these confounders, but this was not possible as wards at the study site were specialty based.

The focus of this thesis was patient safety. Thus other aspects such as an economic evaluation or quantitative study on the effects of time were not incorporated in the evaluation. Medication prescribing errors were used as a process indicator instead of assessing actual patient harm, and administration errors were not studied. Prescription review by pharmacists was used to detect prescribing errors, and therefore the detection rate was dependent on the individual pharmacist's knowledge, identification and documentation of the error. However, the same pharmacist was involved in detection of inpatient errors to minimise the variability. Data for all other errors was collected by two researchers and the inter-rater reliability using the κ statistic showed good agreement between the researchers. Another limitation is that prescription review by pharmacists may have underestimated the incidence of prescribing errors. Barber et al. (2006) reported that approximately 30% of prescribing errors were detected using prescription review, compared to nearly three quarters using a retrospective review form, with little overlap in errors detected using the two methods. However, this outcome measure and detection method was selected on the basis that most benefits of EP are anticipated at the prescribing stage (Department of Health 2004; eHealth Initiative 2004), and that EP mainly reduces errors that are more likely to be detected by clinical pharmacists (Barber et al. 2006).

The qualitative study involved semi-structured interviews with users and key stakeholders. Most of the respondents agreed to be interviewed when approached by the researcher, although a very small number were initially reticent as they felt they did not have positive experiences to report. This may be a potential source of bias, with

users only agreeing to be interviewed if they felt they could report positively, although the likelihood of this is low, as the results show a mixture of positive and negative views about the EP system. Another source of bias is the researcher. All the data was collected and coded by the main researcher. It is possible that the researcher's personal views of EP systems may have influenced interpretation of the data. However, the probability of this is low, as two other researchers were involved in developing the coding frame and the interpretative process. Moreover, triangulation of the data using observations and document analysis corroborated the findings of the interview data. In addition, the final analysis was sent to the EP project lead for review to confirm the credibility of the results.

Finally the nature of IT systems, like the JAC EP system studied here, means that the system has changed and developed since the evaluation began. Therefore, some of the results reported in this thesis may no longer be applicable to the system that is in use at present.

8.8 Further work

It is important that evaluation is integrated into implementation strategies, especially with the extensive investment by the NHS in the UK into the NPfIT. Although this study provides insights into the introduction of an EP system in one specialist children's hospital in the UK, much remains unknown and warrants further investigation.

- a) The effects of EP on actual patient harm has not been investigated in the UK. Medication errors provide a process indicator, but do not reflect on patient outcomes. A study of the effect on preventable adverse drug events, using a combination of retrospective review of medical notes, solicited reports and voluntary reports would be a useful way of ascertaining the consequences of implementing EP on patient outcomes.
- b) The current study focussed on prescribing errors. However EP may also affect administration errors, which like prescribing errors, are considered to be one of the commonest types of medication errors; the effect of EP on administration errors needs to be assessed using direct observation methods.
- c) The implementation of IT systems such as EP is associated with high costs to the organisation and is often a barrier to adoption. Therefore economic evaluations are

- needed to determine the cost effectiveness and efficacy of these systems by considering the cost of implementation against the financial benefits.
- d) Limited research, mainly from the US, indicates that EP may have implications on the time spent by healthcare professionals on patient care and medication related tasks. A mixed method study, with quantitative methods, for example work sampling, would provide an indication of the proportion of time spent on medication related activities, and a qualitative component using interviews and observations would offer insight into the processes that are affected by the technology.
- e) Prescribing is often the final step performed by an individual, following a series of cognitive decision making stages in the medicines use process involving a team of healthcare professionals. However, this is rarely reflected in the design of EP systems, which are based on a linear process undertaken by an individual user. Thus implementation of EP may have an unexpected effects on users practices, working relationships and co-operations, and may influence acceptance and use of EP. Cognitive analysis and considerations of human factors should be used to understand these effects and to inform design/ redesign of EP systems.
- f) EP systems are promoted as one of the tools to improve patient safety. A key component for this improvement is the presence of CDSS as part of the EP. The design and acceptance of the CDSS are closely intertwined and have implications for effectiveness. Quantitative studies like the one in this thesis provide information about one aspect of the CDSS, but do not inform on resultant patient outcomes or the effects on the prescriber. A prospective study using alternative methods, such as review of medical notes may provide more insight on the effects of CDSS on patient outcomes. Effects on the prescriber's decision making may be studied using cognitive evaluations.
- g) The content and knowledge base of CDSS are important factors in user acceptance of and confidence in the support being provided. The knowledge base used in the JAC EP system is one that is commercially available. The risk level of drug: drug interactions is assigned by a team of clinicians (doctors and pharmacists) employed by the vendor, FDBE. Further research to validate the process of assigning risk levels and/or comparing the assigned drug: drug interaction levels against known outcomes would be useful, especially as the Multilex Drug Data File produced by FDBE is the most widely used drug knowledge base in clinical systems in the UK.

h) An important area for future work is the development of CDSS suitable for children. Dosing errors are probably the most common type of error in children due to complexities in prescribing which is based on rapidly changing age and/or body weight and/or body surface area. In terms of the JAC EP system, the results of the prescribing errors study showed a minor decrease in dose errors after EP, but there is scope for further reduction with the advent of automated dose calculations and dose checking. A new release of the prescribing software which has automated dose calculation functionality was installed in the Trust in May 2008, and this warrants further research. There are several challenges in implementing dose related functionality. Firstly, drug files must be set up so that doses can be calculated and checked based on indication for use, age and weight. There is no standard information source for populating recommended doses, taking into account local and national practices for each indication, though the BNF for Children does provide a useful starting point. Secondly, the actual delivery of the solution requires careful design: should it be integrated into the order pathway or be optional for the user to access if desired? In case of excessive dose being entered, what would be more effective and yet acceptable for the user: an intrusive alert or guided recommendation with the ability to override? Once these challenges are addressed, additional research can be conducted to assess outcomes, for example, impact of automated dose calculations on dosing errors, acceptance rate of recommended doses as well as factors that influence the acceptance rate and effect on healthcare professionals practice and skills.

8.9 Conclusions

A commercially available EP system was implemented successfully at a children's hospital in the UK. EP implementation resulted in a significant reduction of most types of prescribing errors including dose errors, but new errors were introduced. There were anticipated as well as unanticipated changes in the practice and workflow patterns of healthcare professionals following implementation. The combined effect of these two factors on patient safety at the study site remains to be established. Stakeholders, users, patient and parents considered EP to be the way forward.

This thesis is an original contribution as it is the first study of prescribing errors in a UK outpatient clinic, one of the few UK studies to evaluate whole organisation implementation of an EP system, and the first at a children's hospital. Additionally, the study contributes to the fields of medication errors research and health informatics as it:

- shows a reduction in prescribing errors following the implementation of EP as a result of improved quality of prescribing in the inpatient and outpatient settings.
- demonstrates a small but statistically significant reduction in the overall incidence of dose prescribing errors.
- adds to the emerging literature on new types of errors that may be introduced by EP.
- makes recommendations for optimising clinical decision support alerts within the JAC EP based on the number and nature of conflicts recorded during the first year of EP use.
- corroborates the existing knowledge on factors that influence successful implementation of an EP system i.e. the IT system design, human interaction with and use of the system, and organisational context and structure.
- identifies lessons learnt during implementation which may be useful to other NHS organisations.

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Appendices

Appendix A - Guidance on prescribing error identification

For the purpose of this study the following SHOULD be considered prescribing errors	
Failure to give essential information correctly	Prescriber's signature missing*
	Writing illegibly*
	Writing an ambiguous medication order that would likely require clarification before dispensing (including the use of ambiguous abbreviations)*
	Prescribing a drug that is based on the weight of the patient, and not writing the final calculated dose in the prescription sheet based on that weight*
	Prescribing a drug to a child without documenting the weight of the child on the prescription sheet*
	Misspelling a drug name*
	Writing a drug's name using abbreviations or other non-standard nomenclature*
	Allergy status missing
* handwritten prescriptions only	Prescribing a drug to be taken when required, without specifying the maximum daily dose of the drug prescribed in the prescription
Errors in transcription	On admission ordering medication that deviates from patient's pre-admission prescription. This includes unintentional omission of medication from the patient's inpatient prescription chart
	Continuing a GP's prescribing error when writing or entering on the electronic system a patient's prescription chart on admission
	Transcribing a medication order incorrectly when rewriting a patient's prescription chart*
	Prescription for discharge medication that unintentionally deviates from the medication prescribed on the inpatient prescription chart
* handwritten prescriptions only	
Dosing errors	Prescription for a drug with a narrow therapeutic index in a dose predicted to give serum levels below the desired therapeutic range
	Prescribing to a patient a dose that is not within $\pm 25\%$ of the recommended dose
	Prescription of a drug in a potentially sub-therapeutic dose
	Prescribing a drug with a narrow therapeutic index in a dose predicted to give serum levels above the desired therapeutic range
	Prescribing a dose that is calculated based on an out of date bodyweight
	Errors in the calculation of drug doses
	Prescription of a drug in a dose above or below that appropriate for the patient's clinical condition (including renal/hepatic function)
Pharmaceutical issues	Prescribing a drug to a patient without adjusting for renal insufficiency.
	Prescribing a dose regimen (dose/frequency) that is not that recommended for the formulation prescribed.
	Continuing a prescription for a longer duration than necessary.
	Continuing a drug in the event of a clinically significant adverse drug reaction.
	Prescribing a drug to a patient without adjusting for body size.
	Prescribing a drug to a patient without adjusting for age.
Errors in choice of drug	Prescribing a drug for a patient who has a specific contra-indication to its use.
	Unintentionally not prescribing a drug for a clinical condition for which medication is indicated.
	Prescribing a drug to a patient while the patient has a known allergy to that drug.
	Prescribing a drug without taking into account a potentially significant drug interaction.
	Prescribing (selecting) the wrong drug on the electronic system due to similar names
The following MAY be prescribing errors if the clinical situation means that they fall within the proposed definition of a prescribing error.	
Choice of a drug	Prescribing a drug for which there is no documented indication for that patient.
	Prescribing a drug in a dose above the maximum dose recommended in the British National Formulary (BNF), Summary of product characteristics (SPC) or reference sources (e.g. Medicines for Children published by the Royal Pharmaceutical Society of Great Britain).
	Prescribing a drug for which there is no evidence of efficacy and safety for use in the patient population
	Prescribing a formulation for which there is no evidence of efficacy and safety for use in the patient population.
Pharmaceutical issues	Prescribing a dose that cannot readily be administered using the dosage form prescribed when more suitable alternatives are available.
Deviation from policy standards and guidelines	Prescribing contrary to hospital treatment guidelines
	Prescribing contrary to national treatment guidelines
	Prescribing to a patient a drug that is not according to standard paediatric references.
For the purpose of the study, the following should NOT in themselves be considered prescribing errors:	
Choice of a drug	Prescribing for a child a drug that is appropriate for the condition but has no product license for use in children
	Prescribing for an indication that is not in the drug's product license.
Deviation from policy standards and guidelines, if there is a valid reason for it. If there is no valid reason for the deviation, it is considered a prescribing error	Prescribing contrary to hospital treatment guidelines
	Prescribing contrary to national treatment guidelines
	Prescribing to a patient a drug that is not according to standard paediatric references.
Pharmaceutical issues	Prescribing a dose that can not readily be administered using the dosage forms available.
Omission of non-essential information	Prescribing a drug for a patient and not including the dosage equation (e.g. mg/kg) on the prescription sheet.
	Prescribing by the brand name (as opposed to the generic name).

Appendix B - Data collection form 1 (Pre EP inpatient prescribing errors)

ELECTRONIC PRESCRIBING AND MEDICINES ADMINISTRATION IN CHILDREN (EPIC) STUDY

REGULAR CHART

DATE:

Ward Name: Victoria

Patient's Details:

Gender: M F Hospital ID:

Patient Name:

DOB: Age:

Weight:

Consultant Name:

Allergy box filled: Yes No

OTHER:

IV CHART/OTHER

Ward Name: Victoria

Patient's Details:

Gender: M F Hospital ID:

Patient Name:

DOB: Age:

Weight:

Consultant Name:

Allergy box filled: Yes No

OTHER:

Grade of prescriber

- House Officer
- Senior House Officer
- Registrar
- Consultant
- Other
- Not known

Prescribing stage

- Prescribing on admission
- Prescribing during stay
- Rewriting drug chart
- Writing TTA
- Not known

Type of prescribing error

- Prescribing decision
- Writing medication order
- Potentially serious**

Appendix Bi – Data collection form 1i (Post EP inpatient prescribing errors)

Appendices

ELECTRONIC PRESCRIBING AND MEDICINES ADMINISTRATION IN CHILDREN (EPIC) STUDY
PRESCRIPTIONS ON JAC

Patient Name	Date	Drug Name (one drug per box)	Type of error	Potentially serious?	Details of incident (what was wrong)
			Prescribing decision <input type="checkbox"/> Prescription ordering <input type="checkbox"/>	Yes <input type="checkbox"/> No <input type="checkbox"/>	Wrong formulation prescribed <input type="checkbox"/> Entered in 'notes' <input type="checkbox"/> Other <input type="checkbox"/> please specify
			Prescribing decision <input type="checkbox"/> Prescription ordering <input type="checkbox"/>	Yes <input type="checkbox"/> No <input type="checkbox"/>	Wrong formulation prescribed <input type="checkbox"/> Entered in 'notes' <input type="checkbox"/> Other <input type="checkbox"/> please specify
			Prescribing decision <input type="checkbox"/> Prescription ordering <input type="checkbox"/>	Yes <input type="checkbox"/> No <input type="checkbox"/>	Wrong formulation prescribed <input type="checkbox"/> Entered in 'notes' <input type="checkbox"/> Other <input type="checkbox"/> please specify
			Prescribing decision <input type="checkbox"/> Prescription ordering <input type="checkbox"/>	Yes <input type="checkbox"/> No <input type="checkbox"/>	Wrong formulation prescribed <input type="checkbox"/> Entered in 'notes' <input type="checkbox"/> Other <input type="checkbox"/> please specify

Appendix C – Data collection form 2 (Outpatient and discharge prescription errors)

**ELECTRONIC PRESCRIBING AND MEDICINES ADMINISTRATION IN CHILDREN (EPIC) STUDY
PRESCRIBING ERRORS IN DISCHARGE (TTA) AND OUT PATIENT PRESCRIPTIONS**

Date Rx written:

Date Rx screened by reviewer:

Ward:

Victoria
Louise

Prescription:

Discharge Paper
Outpatient E-printout

Patient's Details:

Gender: F

Hospital ID:

Patient name:

DOB: Age:

Weight: Missing weight units missing

Consultant:

Allergy box filled: Yes No N/A (i.e. no prompt on prescription or no field on e-printout)

OTHER:

Drugs with incidents/ changes/ errors:

Other drugs prescribed:

Appendix D – Dose error descriptions and mean severity scores

Error Number	Age & Weight*	Description of error	Mean score
Outpatient prescriptions			
1	6 years 23kg	Nalidixic acid 300ml(5ml) once a day was prescribed instead of 300mg (5mL) once a day	5.43
2	6 months 10kg	Trimethoprim oral 20mg twice a day was prescribed instead of 40mg twice a day	2.41
3	16 years 32.2kg	Co-trimoxazole 360mg=7.5mg once a day was prescribed instead of 360mg = 7.5mL once a day	2.49
4	2 months 30kg	Trimethoprim oral 50mg once a day was prescribed instead of 100mg at night	3
5	13 years 48kg	Tacrolimus 6mg was prescribed daily instead of twice a day	6.38
6	3 years 8.5kg	Calcium carbonate 500ng three times a day was prescribed instead of 500mg three times a day	3.81
7	5 years missing	Chlorphenamine oral 2mg was prescribed upto 6 times a day instead of a maximum of three times a day	4.01
8	9 years 28kg	Mycophenolate 500ng twice a day was prescribed instead of 500mg twice a day	5.24
9	11 years 35.2kg	Ferrous sulphate oral 100mg once a day was prescribed instead of 200mg once a day	2.26
10	5 years 19.5kg	Amlodipine 10mg was prescribed twice a day instead of once a day	4.32
11	7 years 20.8kg	Tacrolimus oral 0.4mL twice a day was prescribed instead of 0.4mg = 0.8mL twice a day	6.12
12	7 years 20.8kg	Trimethoprim oral 20mg at night was prescribed instead of 40mg at night	2.5
13	No date of birth, 36.8kg	Co-amoxiclav oral 250mg three times a day was prescribed instead of Co-amoxiclav oral 250mg/125mg three times a day	1.43
14	11 years 45.6kg	Trimethoprim oral 120mg twice a day was prescribed instead of 200mg twice a day	2.01
15	7 years 40kg	Flucloxacillin oral 200mg four times a day was prescribed instead of 250mg four times a day	1.57
16	2 years	Alfacalcidol 0.2mg once a day was prescribed instead of 0.2micrograms once a day	6.52
17	5 years 16.4kg	Sodium resonium po/pr 2mg four times a day was prescribed instead of Sodium resonium po 2g four times a day	7.2
18	14 years 48.6kg	Sytron 20mL twice a day was prescribed instead of 10mL twice a day	2.37
19	11 years 47.8kg	Lansoprazole oral 15mg nocte was prescribed instead of 30mg once a day	1.58
20	2 years 12.3kg	Co-amoxiclav 125mg + 31mg / 5mL SF suspension 5mL was prescribed three times a day instead of twice a day	1.87
21	2 years 12.3kg	Fluconazole oral 36mg once a day was prescribed instead of 18mg once a day (patient in renal impairment)	3.84
22	16 years 63.5kg	Epoetin beta for recopen s/c 20000units once a week was prescribed instead of 7000units in week1, 7000units in week2 and 6000units in week 3	4.32
23	5 years 20.4kg	Desmopressin nasal spray, 2 sprays once a day into both nostrils was prescribed instead of 1 spray; increase to 2 sprays into both nostrils if not responding	1.89

* as and if documented on the prescription

Appendices

Error Number	Age & Weight*	Description of error	Mean score
24	16 years 81.2kg	Tacrolimus oral 4mg twice a day was prescribed instead of 4mg in the morning and 5mg in the evening	3.84
25	5 years 18kg	Epoetin beta 2000 units was prescribed once a week instead of once every two weeks	3.4
26	15 years 46.8kg	Tacrolimus (TWIST study) 3.5mg was prescribed once a day instead of twice a day	6.5
27	1 year 8 months 10.6kg	Potassium chloride 7.50% oral 50mL per day was prescribed instead of 12.5mL four times a day	4.07
28	18 years missing	Tacrolimus oral 7mg once a day was prescribed instead of 4mg in the morning and 3mg at night	4.34
29	14 years missing	Ferrous sulphate 200mg was prescribed once a day instead of twice a day	1.89
30	16 years 34.6kg	Alfacalcidol 1microgram was prescribed twice weekly instead of twice a day	3.57
31	3 years 19kg	Domperidone oral 10mg three times a day was prescribed instead of 5mg three times a day	2.86
32	15 years 67.5kg	Ranitidine 150mg was prescribed once a day instead of twice a day	2.27
33	7 years 18.3kg	Flucloxacillin 125mg four times a day was prescribed instead of 250mg three times a day	2.4
34	14 years 29kg	Sando K oral 1 tablet twice a day was prescribed instead of 12mmol (1 tab) each morning	5.09
35	14 years 29kg	Potassium chloride oral 10mmol twice a day was prescribed instead of 8mmol at night	5.11
36	16 years 50kg	Oxytetracycline oral 500mg four times a day was prescribed instead of 250mg four times a day	2.86
37	1 year 7 months 11.2kg	Paracetamol oral 180mg four times a day was prescribed instead of 120mg four times a day	2.01
38	8 months 6.82kg	Nalidixic acid oral 94mg (1.4mL) once a day was prescribed instead of 85mg (1.4mL) once a day	2.33
39	14 years	Alfacalcidol 0.25mg once a day was prescribed instead of 0.25micrograms once a day	5.73
40	11 years 37.2kg	Thyroxine 25mg once a day was prescribed instead of 25micrograms once a day	7.57
41	17 years 57kg	Atenolol oral 50mg once a day was prescribed instead of 25mg once a day	2.77
42	13 years 36kg	Metronidazole 250mg was prescribed twice a day instead of three times a day	3.54
43	1 year 7 months 9.44kg	Potassium chloride oral 50mL per day was prescribed instead of 12.5mmol qds (50ml = 50mmol)	4.14
44	15 years missing	Prednisolone prescribed as 125 and 5mg on alternate days instead of 12.5mg alternating with 5mg next day.	7.02
Discharge prescriptions			
45	12 years missing	Fluticasone 125 microgram CFC free evohaler was prescribed instead of 250 microgram. Dose was 1 puff twice a day.	2.84
46	13 years 40.3kg	Ethinylestradiol oral 2mg three times a day was prescribed instead of 6 micrograms once a day	5.98
47	No date of birth, weight = 35kg	Paracetamol oral 250mg six hourly was prescribed instead of 250mg-500mg six hourly when required	1.94
48	1 year 7 months 10.7kg	Co-amoxiclav oral 250mg three times a day was prescribed instead of Co-amoxiclav oral 250/62 5mL three times a day	1.84

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Error Number	Age & Weight*	Description of error	Mean score
49	3 years 15kg	Fluconazole oral 45mg once a day was prescribed instead of Fluconazole oral 45mg once a day for 2 days then reduce to 15mg once a day	2.55
50	1 year 1 month 9kg	Oxybutynin 1.25ng three times a day was prescribed instead of 1.25mg three times a day	3.01
51	No date of birth, weight = 25.6kg	Ibuprofen melts 125mg was prescribed. No frequency was stated. Ibuprofen melts 100mg three times a day was dispensed.	3.43
52	2 years 12.9kg	Paracetamol 250mg was prescribed every four to six hours instead of four times a day	3.55
53	2 years 12.9kg	Ibuprofen oral 65ml every six hours was prescribed instead of 70mg four times a day	7.35
54	1 year 3 months 11.1kg	Trimethoprim oral 4mg twice a day was prescribed instead of 45mg twice a day	4.24
55	11 months 10.1kg	Paracetamol oral 100mg four times a day was prescribed instead of 150mg 4-6 hourly	1.61
56	5 years missing	Alfacalcidol oral 400mg once a day was prescribed instead of 800mg once a day	1
57	14 years missing	Tacrolimus oral 5mg twice a day was prescribed instead of 4mg twice a day	4.15
58	1 year 3 months missing	Co-amoxiclav oral 125mg/31mg 2.5mL three times a day was prescribed instead of 5mL three times a day	2.86
59	5 years 15.9kg	Movicol paediatric plain sachets 1 sachet five times a day was prescribed instead of 1 sachet once a day, increasing to a maximum of 5 sachets daily gradually if symptoms do not resolve	3.19
60	4 months missing	Ranitidine oral 3mg twice a day was prescribed instead of 3.75mg twice a day	1.46
61	1 year 10.1kg	Alfacalcidol oral 1000 nanograms a day was prescribed instead of 100nanograms a day	5.37
62	16 years missing	Epoetin beta for recopen 20000 units s/c once a week was prescribed instead of 5000 units s/c once a week	4.94
63	5 months 7kg	Trimethoprim oral 2.5mg twice a day was prescribed instead of 25mg twice a day	4.07
64	3 years missing	Oxybutynin elixir oral 0.625mg twice a day was prescribed instead of 1.25mg twice a day	2.66
65	16 years missing	Amlodipine oral 5mg once a day was prescribed instead of 10mg once a day	3.92
66	16 years missing	Gaviscon oral 2 tablets four times a day was prescribed instead of 1-2 tablets four times a day	1.23
67	11 years missing	Trimethoprim oral 150mg twice a day was prescribed instead of 200mg twice a day	2.06
68	8 years 31kg	Paracetamol oral 250mg was prescribed instead of 250mg-500mg upto four times a day maximum. Frequency or maximum dosage was not specified.	2.66
69	6 years 26.8kg	Trimethoprim oral 50mg twice a day was prescribed instead of 100mg twice a day	2.41
70	14 years missing	Aspirin oral 60mg once a day was prescribed instead of 75mg once a day	1.81
71	16 years 63.6kg	Tacrolimus 3mg was prescribed once a day instead of twice a day	6.18
72	3 years missing	Ranitidine oral 16mg twice a day was prescribed instead of 30mg twice a day	2.54
73	12 years 41kg	Ciprofloxacin oral 80mg twice a day was prescribed instead of 150mg twice a day	3.24

Appendices

Error Number	Age & Weight*	Description of error	Mean score
74	2 years missing	Paracetamol suspension 250mg was prescribed every four hours instead of four times a day	4.06
75	4 years 17.8kg	Trimethoprim oral 18mg once a day was prescribed instead of 35mg once a day	2.4
76	5 years 21.7kg	Paracetamol oral 350mg every six hours instead 250mg every six hours	2.01
77	6 years 32kg	Calcium resonium 30mg three times a day was prescribed instead of 30g three times a day	7.44
78	1 year 5 months 9.2kg	Co-amoxiclav oral 125mg three times a day was prescribed instead of Co-amoxiclav oral 125/31 5mL three times a day	1.58
79	1 year 8.9kg	Co-amoxiclav oral 125mg three times a day was prescribed instead of Co-amoxiclav oral 125/31 three times a day	1.55
80	3 years 16.5kg	Omacor 1capsule was prescribed once a day instead of twice a day	1.94
81	11 years 36kg	Paracetamol oral 700mg four times a day was prescribed instead of 500mg four times a day	2.03
82	10 years 24kg	Co-amoxiclav oral 125/31 5mL three times a day was prescribed instead of Co-amoxiclav oral 250/62 5mL three times a day	2.57
83	9 years 35.6kg	Paracetamol 500 three times a day was prescribed instead of Paracetamol 500mg four times a day. No dose unit was specified.	3.1
84	3 years 16.6kg	Paracetamol oral 180mg four times a day was prescribed instead of 250mg 4-6 hourly prn	1.46
85	8 months 9.1kg	Clonidine 20mg four times a day was prescribed instead of 20micrograms four times a day	8.6
86	4 years 22.5kg	Prednisolone oral once a day was prescribed as 50ml instead of 50mg	3.24
87	3 years 16.7kg	Oxybutynin oral 5mg twice a day was prescribed instead of 2.5mg twice a day	3.5
88	3 years 16.7kg	Co-amoxiclav oral 125/31 5mL three times a day was prescribed instead of Co-amoxiclav oral 250/62 5mL three times a day	2.23
89	3 years 17.1kg	Clonidine oral 30 micrograms three times a day was prescribed instead of 20 micrograms three times a day	4.01
90	2 years 10.5kg	Cefradine oral 30mg once a day was prescribed instead of 50mg once a day	2.37
91	1 year 1 month 6.86kg	Domperidone oral 3.4mg three times a day was prescribed instead of 2.5mg three times a day	3.17
92	1 year 8 months 10.3kg	Cefradine oral 30mg once a day was prescribed instead of 50mg once a day	2.14
93	2 years 12.6kg	Cefalexin oral 250mg once a day was prescribed instead of 125mg once a day	2.97
94	8 years 15kg	Ibuprofen oral 75mg three times a day was prescribed instead of 100mg three times a day	2.25
95	2 years 13.9kg	Trimethoprim 28kg once a day nocte was prescribed instead of 28mg once a day nocte	3.01
96	2 years 13.9kg	Ibuprofen oral 70mg three times a day was prescribed instead of 100mg three times a day	5.07
97	1 year 6 months	Epoetin once a week was prescribed as 500mg instead of 500units	3.87
98	13 years 36kg	Valaciclovir oral 750 mg was prescribed twice a day instead of three times a day	3.86

Error Number	Age & Weight*	Description of error	Mean score
Inpatient prescriptions			
99	6 years 21.5kg	Methylprednisolone IV 47mg stat was prescribed pre-transplant instead of 470mg.	5.68
100	11 years 32.3kg	Ferrous sulphate oral 5mL once a day was prescribed instead of 200mg	2.14
101	14 years	Paracetamol PRN was prescribed. No dose, route, or frequency was specified.	6.48
102	4 months 3.9	Sytron oral 2mL was prescribed once a day instead of twice a day for a patient with ferritin of 65 and haemoglobin 6.	3.78
103	2 years 13.7kg	Sodium bicarbonate oral 7mg four times a day was prescribed instead of 7mmol four times a day	3.86
104	2 months 4.3kg	Infacol oral 1 with feeds was prescribed. No dose units were specified. 1mL was intended.	1.88
105	4 months 3.9kg	Vancomycin 40mg IV was prescribed once a day instead of twice a day	5.5
106	7 months 8.8kg	Clonidine oral 15mg four times a day was prescribed instead pf 15 micrograms four times a day.	7.08
107	18 years 63kg	Ranitidine 60mg IV 6 hourly was prescribed for a patient who was also prescribed oral Ranitidine. Recommended maximum dose is 50mg IV three times a day.	4.94
108	2 years	Weight was not documented and Penicillin V oral 125mg was prescribed as once a day instead of twice a day.	3.3
109	10 years 27kg	Weight was not documented and Heparin IV infusion was prescribed as 10u/kg=250u=250mls@1ml/hr=1u/hr, instead of 200 units per hour.	5.2
110	7 years 22kg	Vancomycin was prescribed as '10mg IV stat and hold for daily levels'. Level was 1.2 after 24 hours, which is subtherapeutic and a dose of 10mg/kg twice a day should have been prescribed.	5.14
111	7 years 22kg	Ranitidine oral 40mg three times a day was prescribed instead of 45mg twice a day.	3.36
112	5 years 18.7kg	Patient prescribed Prednisolone oral daily reducing dose. This was crossed off for 4 days instead of just 3 days that the patient was also prescribed Methylprednisolone IV.	4.6
113	15 years 87.8kg	Tacrolimus oral 12mg once a day was prescribed. Dose is normally capped at 10mg. Level was high. Dose reduced to 8mg.	6.14
114	14 years 39.5	Flucloxacillin IV 500mg was prescribed four times a day instead of 8 hourly for a patient in end stage renal failure.	5.2
115	7 years 18.5kg	Metronidazole IV 270mg stat was prescribed instead of 140mg	3.66
116	5 years 18.7kg	Vancomycin 380mg IV BD prescribed (20mg/kg BD) to a patient with renal transplant and reduced renal function.	6.72
117	11 years 35.5kg	Ciprofloxacin IV 80mg twice a day was prescribed instead of 100mg (2.5mg/kg) twice a day. Patient in acute renal failure.	2.96
118	14 years 44.6	Flucloxacillin IV 750mg three times a day was prescribed for a patient in acute renal failure. This dose is low.	2.46
119	9 years 30 kg	Prednisolone oral prescribed as 15mg once a day for 2 days, 10mg once a day for 2 days, 7.5mg on alternate days for 2 days, 10mg on alternate days for 2 days, 5mg on alternate days for 2 days and 2mg on alternate days for 2 days. All doses were prescribed to start on the same day.	7.02
120	8 months 6.6 kg	Pyridostigmine oral 5mg was prescribed PRN instead of four times a day	5.1

* as and if documented on the prescription

Appendices

Error Number	Age & Weight*	Description of error	Mean score
121	11 years 41.1 kg	Ranitidine oral 150mg twice a day was prescribed instead of 75mg twice a day.	3.04
122	4 years 26.7 kg	Co-amoxiclav 2.5mL twice a day was prescribed instead of 5mL twice a day.	3.5
123	5 years 26.9 kg	Co-amoxiclav 2.5mL twice a day was prescribed instead of 5mL twice a day.	3.88
124	1 year 7 months 11 kg	Calcium resonium oral 1.25g twice a day was prescribed for a patient with a potassium level of 6.5. A higher dose at 1g/kg/day should have been prescribed.	5.58
125	6 years 21.5 kg	Methylprednisolone IV 47mg stat was prescribed pre-transplant instead of 470mg.	5.68
126	10 months 8.1 kg	Ciprofloxacin IV 16mg twice a day was prescribed instead of 20mg (2.5mg/kg) twice a day.	2.26
127	10 months 8.1 kg	Cetirizine oral 2.5mg maximum every 12 hours PRN was prescribed. Dose should have been reduced by 50% as patient in acute renal failure.	5.42
128	7 years 29 kg	Ranitidine IV 60mg was prescribed twice a day instead of three times a day.	3
129	5 years 18 kg	Ondansetron IV 4mg twice a day PRN was prescribed instead of 2mg twice a day PRN.	4.26
130	13 years 50.75 kg	Prednisolone 90mg once a day was prescribed instead of 60mg once a day.	4.24
131	1 month 4.76 kg	BCG intradermal 0.5mL stat was prescribed instead of 0.05mL.	7.14
132	10months 8.1 kg	Chlorphenamine oral 2mg four times a day PRN was prescribed instead of 1mg twice a day PRN.	4.84
133	6 years 21.5 kg	Co-trimoxazole oral 360mg was prescribed twice a week instead of 360mg twice a day, twice a week.	4.08
134	2 years 14 kg	Epoetin beta SC 2000units was prescribed three times a week instead of twice a week.	3.74
135	9 years 30 kg	Methylprednisolone IV 270mg twice a day was prescribed. This dose was ten times too high.	7.76
136	8 years 37.5 kg	Folic acid oral 10mg once a day was prescribed instead of 5mg once a day.	2.16
137	16 years 120.2 kg	Ranitidine oral 50mg once a day was prescribed instead of 150mg once a day.	3.34
138	2 months 2.49 kg	Epoetin beta SC 250 units was prescribed twice a week. Initial dose should be once a week.	3.46
139	5 years 19.8 kg	Penicillin V oral 125mg was prescribed as once a day instead of twice a day	3.42
140	9 years 45.9 kg	Alfacalcidol oral 500nanograms daily and 750nanograms three times a week was prescribed instead of 500nanograms on non-dialysis days and 750nanograms three times a week.	5.1
141	9 years 45.9 kg	Aspirin oral 37.5mg daily and 75mg three times a week was prescribed. It was no longer required at a dose of 75mg three times a week.	4.38
142	6 years 23 kg	Aciclovir IV 360mg three times a day was prescribed. Dose should be 425mg.	4.04
143	14 years 57.7 kg	Aspirin (300mg tablets) oral 60mg once a day was prescribed instead of 75mg once a day.	2.5
144	1 year, 1 month 12 kg	Epoetin beta IV 2500units (900units/kg/week) three times a week. This exceeds the recommended maximum dose of 500units/kg/week.	2.98
145	9 years 44.7 kg	Ranitidine IV 100mg twice a day was prescribed. Recommended maximum dose is 50mg IV three times a day.	3.76

Appendix E – Guide for healthcare professional interviews (pre EP)

General Information	How long have you been working at GOSH? What is your position?
	Who is involved in the introduction of EPMAS?
Introducing EPMAS	Can you tell me about the system and what you know about it?
	Will all grades of staff use the system?
	Will it be used in every area of paediatric prescribing? Will it be used for all drugs? Emergency situation e.g. a cardiac arrest Exceptions/ reasons (Will paper prescriptions be used for any drugs?)
	Will there be any interaction with other systems in the hospital e.g. path lab results, X-ray?
Changes to ward/ hardware	How many PCs do you have on the ward?
	How many will be available at any one time for EPMAS?
	Have any changes been made to the ward in readiness for EPMAS?
Other/ paper systems	Have you had experience with other EPMAS?
	Do you think the EPMAS will make you think more or less about what you do compared to paper-based systems? (<i>prompts: are some things too easy? Does it encourage people to think, to "engage the brain"?</i>)
	How does it compare to other systems (paper or electronic) where you worked before?
Training	Have you had any training on the EPMAS?
	What training did you receive? (<i>in-house/ external, ongoing, online, nominated trainers, assessment, sufficient</i>)
Practice	Do you expect to make any changes to your practice as a result of EPMAS?
	Who is more in control – you or the computer?
TTAs	What will the impact be on prescribing TTAs? (<i>speed, ease, legibility</i>)
	Have you seen any of the printouts? If yes, what are your views on the printout? (<i>duplicates, printing, amendments, layout of printed copy</i>)
Errors	What effect, if any, do you think it will have on medication errors?
	Does the system make you feel safer?
Decision support	What do you understand by the term clinical decision support?
	What sort of decision support exists in the system? (<i>Doses, allergies, height/ weight</i>) OR What would you expect in terms of decision support from the system? <ul style="list-style-type: none"> • round doses to one which is practical and accurate to measure • advise on how to make up infusions when they are prescribed • warn you when a drug dose is prescribed which is higher or lower than it should be for the patient's age or weight or renal function • actually calculate the dose or does the doctor have to do it then prescribe
	Are there any ways it makes dose calculations less safe?
Perceptions/ Acceptability	What is the reaction to the introduction of EPMAS? How do staff feel about it? (<i>did everyone react the same, conflict between different stakeholders regarding its implementation, highlighted problems with other departments e.g. IT</i>)
	What do you think are the advantages of using EPMAS? (<i>fewer dosing errors, faster drug rounds, workload, advantages for the patient, hospital, profession?</i>)
	In your opinion, what will the impact be on patient- staff relationships? (<i>increased/ decreased contact time between patients and staff</i>).
	Do patients/ carers know about the system? What are their views?
	Do you think it will have any impact on relationships at the staffing/ management level?
	How will it affect interaction of pharmacist with ward staff – nurses/drs etc?
	Does EPMAS create an audit trail? If so, what do you think of the fact that there is an audit trail?
Problems/ System improvement	Do you anticipate any problems with using EPMAS? (<i>new demands for summary and audit data, loss of personal contact between HCPs, non-use of decision support, sustainability, foresee any problems in the future?</i>)
Concluding comments	Is there anything you wish to add?

**Appendix Ei – Guide for healthcare professional interviews
(post EP)**

General Information	How long have you been working at GOSH? What is your position?
	Who is involved in the introduction of EPMAS?
Introducing EPMAS	Can you tell me about the system and what you know about it?
	Do all grades of staff use the system?
	Is it used in every area of paediatric prescribing? Is it used for all drugs? Emergency situation e.g. a cardiac arrest Exceptions/ reasons (Are paper prescriptions used for any drugs?)
	Is there any interaction with other systems in the hospital e.g. path lab results, X-ray?
Changes to ward/ hardware	How many PCs do you have on the ward?
	How many are available at any one time for EPMAS?
	Have any changes been made to the ward for EPMAS implementation?
Other/ paper systems	Have you had experience with paper-based systems?
	Do you think the EPMAS makes you think more or less about what you do compared to paper-based systems? (<i>prompts: are some things too easy? Does it encourage people to think, to "engage the brain"?</i>)
	How does it compare to other systems (paper or electronic) where you worked before?
Training	What was it like learning to use the system? Did you have any problems when you first started? How were these resolved? (<i>smooth roll-out</i>)
	What training did you receive? (<i>in-house/ external, ongoing, online, nominated trainers, assessment, sufficient</i>)
Practice	Has your behaviour or practice been changed by the system? If yes, <i>how</i> what has changed? If no, do you expect to make any changes to your practice as a result of EPMAS?
	Who is more in control – you or the computer?
TTAs	What has the impact been on prescribing TTAs? (<i>speed, ease, legibility</i>)
	What are your views on the TTA printout? (<i>duplicates, printing, amendments, layout of printed copy</i>)
Errors	Does the system make you feel safer?
	What effect, if any, do you think it will have on medication errors?
	Does EPMAS actually reduce the risk of errors in children? In neonates? (<i>if so exactly how: flexibility- timing of doses; introducing other types of errors</i>)
	Is the system being used to full capacity in ways which it could reduce errors? (<i>if not, why not</i>)
	What else is it capable of doing? (<i>reminders for TDM drugs, allergies</i>)
	Does it help with ensuring that doses are correct when patients are discharged from hospital or return to hospital? Do you notice any change in the error rate when new doctors first start?
Decision support	What do you understand by the term clinical decision support?
	What sort of decision support exists in the system? (<i>Doses, allergies, height/ weight</i>)
	<ul style="list-style-type: none"> • round doses to one which is practical and accurate to measure • advise on how to make up infusions when they are prescribed • warn you when a drug dose is prescribed which is higher or lower than it should be for the patient's age or weight or renal function • actually calculate the dose or does the doctor have to do it then prescribe
	Is the system capable of more decision support being introduced? If yes- why has it not been introduced? Are there any ways it makes dose calculations less safe?
Perceptions/ Acceptability	What was the reaction to the introduction of EPMAS? How do staff feel about it now? (<i>did everyone react the same, conflict between different stakeholders regarding its implementation, highlighted problems with other departments e.g. IT</i>)
	What do you think are the advantages of using EPMAS? Did it meet your expectations? (<i>fewer dosing errors, faster drug rounds, workload, advantages for the patient, hospital, profession?</i>)
	What has the impact been on patient- staff relationships? (<i>increased/ decreased contact time between patients and staff</i>).
	Do patients/ carers know about the system? What are their views?
	Has it had any impact on relationships at the staffing/ management level?
	How does it affect interaction of pharmacist with ward staff – nurses/drs etc? Does EPMAS create an audit trail? If so, what do you think of the fact that there is an audit trail?
Problems/ System improvement	Are there any problems with using EPMAS? (<i>new demands for summary and audit data, loss of personal contact between HCPs, non-use of decision support, sustainability, foresee any problems in the future?</i>)
	Have you had any problems with the system crashing or 'dropping'? (<i>patient locks, problems with wire less, time lags, is data backed up</i>)
	What is system support like? (<i>on-site, manufacturers</i>)
	Is there anything you would change about the system? If yes, what? (<i>reporting, allergies/ height-weight pop-up</i>)
	What do you do if there is something you think could be improved? Are there procedures in place to deal with system improvement? E.g. users groups? (<i>Probe: How easy is it to get things changed? Feeling of involvement in system development over the years</i>) Would you recommend it to others?
Concluding comments	Is there anything you wish to add?

Appendix Eii – Guide for parent/ patient interviews

Introduction

My name is Yogini Jani, and I'm a researcher at the School of Pharmacy working on the EPIC project. I am seeking the views of patients and/or parents about the computerised prescription and medication administration system which is used on this ward. I would be very grateful if you could spare 15 minutes or so of your time while I ask you some questions. Please feel free to give your honest opinion as everything you say will be treated in the strictest confidence. If you do not want to answer a particular question, then just say so.

Ward:

Patient interview
 Patient consent

Interview number:

Parent interview (patient unable)
 Parent assent/consent (all ages)

1. Is this the first time you/your child has been in a hospital?

Yes No

2. If no, when was the last time you/your child was in hospital?

3. Can you tell me what happens when your/ your child's medicine is due?

4. The ward used to have a paper system of prescription and medication administration on this ward. Do you have any experience of the paper system?

Yes No Don't know

If yes, go to question 7 If no, go to question 5

If don't know, go to explanation and then question 6

5. What images comes to mind when you hear this (i.e. paper system)?

6. This is how the system worked. Details of all medication were written on a paper prescription chart. The nurse would read the drug chart, choose and get the medicine ready and bring it to the bedside with the paper chart.

7. What do you think of the paper system?

Prompts: speed, accuracy/ safety, flexibility, security/confidentiality, (de) personalised

8. Do you think the computerised system has any advantages over the previous paper system?

Age of child [interviewer to complete]

Gender of child [interviewer to complete] Male Female

Appendix F – Publications and posters

Journal articles

Jani, Y. H., Ghaleb, M. A., Marks, S. D., Cope, J., Barber, N., & Wong, I. C. 2008, "Electronic prescribing reduced prescribing errors in a pediatric renal outpatient clinic", *The Journal of Pediatrics*, vol. 152, no. 2, pp. 214-218.

Published conference abstracts

Jani, Y. H., Wong, I. C., & Barber, N. 2008, "Paediatric dosing errors before and after electronic prescribing", Drug Utilisation Research Group (UK & Ireland), Conference 2008. Target driven medicine - is this the end of, prescribing freedom? The Royal Society of Medicine, London, UK, February 7th 2008, *Pharmacoepidemiology and Drug Safety*, vol. 17, pp. 742-750.

Unpublished conference abstracts

Jani, Y. H., Wong, I. C., & Barber, N. 2008, "Electronic Prescribing, Safer Prescribing?" Poster at the International Forum on Quality and Safety in Health Care, Paris, 23-25 April 2008.

Jani, Y. H., Ghaleb, M. A., Wong, I. C., & Barber, N. 2007. Effect of an electronic prescribing system on prescribing error rates in paediatric outpatients. Poster at a 'Show and Tell' session at the International Forum on Quality and Safety in Health Care, Barcelona, 18-20 April 2007.