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ORIGINAL RESEARCH ARTICLE

Prevalence, Nature, Severity and Risk Factors for Prescribing Errors in Hospital Inpatients: Prospective Study in 20 UK Hospitals

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Abstract

Introduction It has been suggested that doctors in their first year of post-graduate training make a disproportionate number of prescribing errors.

Objective This study aimed to compare the prevalence of prescribing errors made by first-year post-graduate doctors with that of errors by senior doctors and non-medical prescribers and to investigate the predictors of potentially serious prescribing errors.

Methods Pharmacists in 20 hospitals over 7 prospectively selected days collected data on the number of medication orders checked, the grade of prescriber and details of any prescribing errors. Logistic regression models (adjusted for clustering by hospital) identified factors predicting the likelihood of prescribing erroneously and the severity of prescribing errors.

Results Pharmacists reviewed 26,019 patients and 124,260 medication orders; 11,235 prescribing errors were detected in 10,986 orders. The mean error rate was 8.8 % (95 % confidence interval [CI] 8.6–9.1) errors per 100 medication orders. Rates of errors for all doctors in training were significantly higher than rates for medical consultants. Doctors who were 1 year (odds ratio [OR] 2.13; 95 % CI 1.80–2.52) or 2 years in training (OR 2.23; 95 % CI 1.89–2.65) were more than twice as likely to prescribe erroneously. Prescribing errors were 70 % (OR 1.70; 95 % CI 1.61–1.80) more likely to occur at the time of hospital admission than when medication orders were issued during the hospital stay. No significant differences in severity of error were observed between grades of prescriber. Potentially serious errors were more

Key Points

Foundation year 1 and year 2 doctors were both more than twice as likely to prescribe erroneously when compared against medical consultant error rates.

No significant differences in severity of error were observed between grades of prescriber.

Interventions are needed for all grades of staff, not just junior doctors, to reduce potentially serious prescribing errors.

On behalf of the EQUIP study.

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likely to be associated with prescriptions for parenteral administration, especially for cardiovascular or endocrine disorders.

Conclusion The problem of prescribing errors in hospitals is substantial and not solely a problem of the most junior medical prescribers, particularly for those errors most likely to cause significant patient harm. Interventions are needed to target these high-risk errors by all grades of staff and hence improve patient safety.

1 Introduction

Improving patient safety in healthcare settings is a major concern globally [1]. Medicines are the most commonly used clinical intervention in healthcare, and errors involving the prescribing, dispensing, administration and monitoring steps of medication use are common [2–4]. Such medication errors can prolong hospital stay and lead to significant patient morbidity and even death [5, 6]. Each year in England alone, the cost of preventable harm from medicines has been estimated at £750 million [7].

Prescribing errors in hospitals are particularly common; our systematic review of 65 studies, which used a variety of data collection methods, found a median prescribing error rate of 7 % (interquartile range [IQR] 2–14) per medication order, 52 errors (IQR 8–227) per 100 hospital admissions and 24 (IQR 6–216) per 1000 patient days [2]. Error severity was assessed in 74 % of studies, but comparison between studies was impossible due to the disparity of assessment methods used. Most previous studies were also conducted in only one or two hospitals. Two recent studies conducted in up to nine hospitals in Britain found that 10.9 and 7.5 % of medication items were prescribed incorrectly [8, 9]. Errors have been presumed to be made more commonly by junior doctors, particularly those in their first year after graduating from university [10]. The PROTECT study [9] found that doctors who were in their first and second years of training made more errors than did consultants (7.4 and 8.6 vs. 6.3 %), but Seden et al. [8] found no difference between error rates of different grades of doctor.

Severity of errors has been measured in a variety of ways in published studies, making direct comparison between studies impossible in our systematic review [2]. Recent work has suggested there was no association between grades of doctors and the proportion of errors categorised as significant or higher [8] when correcting for types of prescription and ward speciality. However, whether other factors such as type of drug or route of administration affect the risk of harm to patients is not known.

This study aimed to identify the prevalence of prescribing errors made by junior doctors compared with those made by their senior colleagues and other non-medical prescribers and to investigate predictors of the potentially serious prescribing errors they made.

2 Methods

This large prospective study was undertaken in 20 UK National Health Service (NHS) hospitals located across the north-west of England, with data being collected over 7 selected weekdays, each approximately 1 month apart. Three of the hospitals used electronic prescribing at some or all stages of a patient's admission. We used an established definition of a prescribing error as "one which occurs when, as a result of a prescribing decision or prescription-writing process, there is an unintended, significant reduction in the probability of treatment being timely and effective, or increase in the risk of harm when compared with generally accepted practice" [11]. The definition has been extensively used in previous studies [2, 8, 9] and is accompanied by lists of situations that should be included and excluded as prescribing errors.

Lead pharmacists from each of the hospitals involved in the study attended two training events, each followed by a question and answer session conducted by DMA and PJL. The lead pharmacists subsequently provided training on data collection at their hospitals to all pharmacists participating in the study, supported by an information booklet providing detailed information on definitions and study requirements. At the study hospitals, inpatient medication orders were written by prescribers (or rewritten when required) directly onto a combined prescription and nursing administration chart, known as 'the drug chart' (normal UK practice). Hospital pharmacists screened all newly prescribed or rewritten inpatient medication orders for prescribing errors as part of their routine pharmacy practice. Data collection occurred between 08:30 and 17:00, Monday to Friday, but included a review of prescriptions written outside these hours. In the UK, ward-based clinical pharmacists routinely check inpatient prescriptions at, or soon after, patient admission, when medicines reconciliation is undertaken. Errors identified at hospital admission may include incorrectly ascertaining and prescribing patients' usual long-term medication. Inpatient drug charts are routinely checked at least daily during weekdays by ward-based clinical pharmacists. Discharge prescriptions are also checked and authorised by a pharmacist prior to supply of medication. Electronic prescription orders could be checked either on the hospital wards or in the hospital pharmacy. Pharmacists may amend or clarify some aspects

Table 1 Details of prescriber types in the study hospitals

Prescriber types in hospital practice	Description
Foundation year 1	Doctors who have recently completed their undergraduate medical degree and who have provisional registration with the UK GMC, in their first year of post-graduate training
Foundation year 2	Doctors in their second year of post-graduate medical training who are fully registered with the GMC
Fixed-term specialty training appointments	Doctors in speciality training programmes (usually for 6 years)
Non-consultant career grade staff	Doctors who have reached a certain level in training and stay working at that level without completing their training
Consultants	Doctors who hold a certificate for the completion of training (usually after 8 years of training)
Pharmacist prescribers	Supplementary or independent prescribing pharmacists registered with the General Pharmaceutical Council
Nurse prescribers	Supplementary or independent prescribing nurses registered with the Nursing and Midwifery Council

GMC General Medical Council

of prescribing or discuss with the clinical team any recommendations or safety issues at these points of care.

Data were collected on the number of medication orders checked, the grade and type of prescriber (Table 1), the stage of admission when prescribed (on admission, newly prescribed or rewritten during the stay or at discharge) and the number and nature of any prescribing errors. Medications involved in errors were categorised according to the relevant chapter in the British National Formulary (BNF) [12].

2.1 Error Validation

Two validation panels were formed, both comprising two hospital clinicians and two pharmacists, and both of them met on several occasions to assess prescribing errors reported by pharmacists. The panels verified that each report represented a genuine prescribing error, categorised the type of error that it represented and judged its perceived severity. Panel members discussed each error until consensus was achieved. Severity categories included minor, significant, serious, or potentially lethal errors and were based on rating scales used in previous medication error research [13, 14]. Additional details about the severity classification scheme are provided in the appendix available in the Electronic Supplementary Material.

2.2 Data Analysis

The denominator for calculating the prescribing error rate was the number of newly written regular, 'when required' and discharge medication orders screened by hospital pharmacists, including any medication orders omitted [15]. All confidence intervals (CIs) were calculated at 95 %.

Univariable and multivariable logistic regression models were developed to examine the potential impact of the following variables on the likelihood of a prescribing error: type of prescriber, type of prescription (handwritten vs. electronic), and the stage of hospital stay at which the medication order was issued. Multinomial logistic regression models identified factors predicting the severity of a prescribing error, particularly which factors were associated with a significant or potentially serious error rather than a minor error. All regression models were also adjusted for clustering by hospital site.

3 Results

Over the 7 days of data collection, 26,019 patients and 124,260 medication orders were reviewed by pharmacists. Of these, 10,986 medication orders had prescribing errors, resulting in 11,235 prescribing errors being detected. The mean prescribing error rate was 8.8 % (95 % CI 8.6–9.1) errors per 100 medication orders. Prescribing error rates presented by type of prescriber and stage of hospital stay are shown in Table 2.

When expressed by the stage of hospital stay, the error rate associated with medication orders at the time of hospital admission (13.3 %, 95 % CI 12.8–13.8) was higher than when newly prescribed medication was initiated during the hospital stay (7.5 %, 95 % CI 7.1–7.9) or when medication was prescribed on discharge from hospital (6.3 %, 95 % CI 5.9–6.7). Foundation doctors (FY1 and FY2) wrote the majority of medication orders (68 %) and

Table 2 Prescribing error rates per medication order written by prescriber and prescribing stage

Prescriber	Description	On admission	During stay	When drug chart re-written	At discharge	Missing	Total
FY1	Orders written	14,487	10,365	7567	16,271	1326	50,016
	Errors (*n*)	1936	919	312	1032	87	4286
	Errors [% (95 % CI)]	13.4 (12.4–14.3)	8.9 (8.2–9.5)	4.1 (3.5–4.8)	6.3 (5.8–6.9)	6.6 (4.8–8.3)	8.6 (8.2–8.9)
FY2	Orders written	14,259	7089	4008	8127	1229	34,712
	Errors (*n*)	2144	610	132	548	112	3546
	Errors [% (95 % CI)]	15.0 (14.1–16)	8.6 (7.7–9.5)	3.3 (2.7–3.9)	6.7 (6–7.5)	9.1 (7–11.2)	10.2 (9.7–10.7)
FTSTAs	Orders written	6612	4929	1901	2782	539	16,763
	Errors (*n*)	777	294	89	161	37	1358
	Errors [% (95 % CI)]	11.8 (10.5–13)	6.0 (5.1–6.8)	4.7 (3.3–6.1)	5.8 (4.5–7.1)	6.9 (4.2–9.5)	8.1 (7.5–8.7)
NCCGs	Orders written	1261	1433	819	622	239	4374
	Errors (n)	125	78	29	37	10	279
	Errors [% (95 % CI)]	9.9 (7.1–12.7)	5.4 (4.1–6.8)	3.5 (0.3–6.8)	5.9 (3.3–8.6)	4.2 (1.4–7)	6.4 (5.2–7.6)
Consultants	Orders written	1072	1424	168	446	108	3218
	Errors (*n*)	53	67	6	25	2	153
	Errors [% (95 % CI)]	4.9 (3–6.9)	4.7 (3.6–5.8)	3.6 (0–7.4)	5.6 (3.2–8.1)	1.9 (0–4.5)	4.8 (3.8–5.7)
Pharmacist prescribers	Orders written	12	41		131	3	187
	Errors (*n*)	6	0		0	0	6
	Errors [% (95 % CI)]	50.0 (0–101.7)	0.0 (–)		0.0 (–)	0.0 (–)	3.2 (0–7.2)
Nurses prescribers	Orders written	456	366	32	114	56	1024
	Errors (*n*)	21	22	0	6	4	53
	Errors [% (95 % CI)]	4.6 (2.3–6.9)	6.0 (2.1–9.9)	0.0 (–)	5.3 (0.7–9.9)	7.1 (0.1–14.2)	5.2 (3.3–7)
Missing prescriber details	Orders written	6337	3367	694	3009	559	13,966
	Errors (*n*)	848	192	30	180	55	1305
	Errors [% (95 % CI)]	13.4 (11.9–14.8)	5.7 (4.7–6.7)	4.3 (2.2–6.5)	6.0 (4.8–7.2)	9.8 (5.9–13.8)	9.3 (8.6–10.1)
Total	Orders written	44,496	29,014	15,189	31,502	4059	12,4260
	Errors (*n*)	5910	2182	598	1989	307	10,986
	Errors [% (95 % CI)]	13.3 (12.8–0)	7.5 (7.1–7.9)	3.9 (3.5–4.4)	6.3 (5.9–6.7)	7.6 (6.5–8.7)	8.8 (8.6–9.1)

CI confidence interval, *FY* foundation year 1 or 2 medical trainee, *FTSTA* fixed-term specialty training medical appointment, *NCCGs* non-consultant career grade medical staff

Table 3 Frequency of prescribing errors by error type

Error type	Errors	
	N	% (95 % CI)
Need for drug therapy		
Omission on admission	3197	28.46 (26.96–29.95)
Omission on rewrite of prescription chart	105	0.93 (0.72–1.15)
Omission on discharge	675	6.01 (5.29–6.72)
Premature discontinuation	21	0.19 (0.1–0.27)
Drug not prescribed but indicated	92	0.82 (0.63–1.01)
Continuation for longer than needed	84	0.75 (0.57–0.93)
No indication	109	0.97 (0.76–1.18)
Duplication	605	5.38 (4.85–5.92)
Selection of a specific drug		
Significant allergy	38	0.34 (0.23–0.45)
Clinical contra-indication	120	1.07 (0.86–1.27)
Continuation after ADR	24	0.21 (0.12–0.31)
Drug interaction	60	0.53 (0.39–0.68)
Unintentional prescription of drug	344	3.06 (2.71–3.42)
Selection of dosage regimen		
No maximum dose	396	3.52 (3.1–3.95)
Drug interaction not taken into account	14	0.12 (0.05–0.2)
Dose/rate mismatch	1	0.01 (0–0.03)
No dosage alteration after levels out of range	6	0.05 (0.01–0.1)
Daily dose divided incorrectly	49	0.44 (0.3–0.57)
Overdose	948	8.44 (7.88–8.99)
Underdose	1226	10.91 (10.24–11.58)
Administration of drug		
Incorrect route	117	1.04 (0.81–1.27)
Incorrect formulation	403	3.59 (3.18–3.99)
Administration times incorrect/missing	736	6.55 (6.01–7.09)
IV instructions incorrect/missing	106	0.94 (0.69–1.2)
Start date incorrect/missing	84	0.75 (0.41–1.09)
Provide drug product		
Product/formulation not specified	450	4.01 (3.56–4.45)
Strength/dose missing	850	7.57 (7–8.14)
Route missing	111	0.99 (0.77–1.2)
No signature	210	1.87 (1.55–2.19)
Controlled drug requirements incorrect/missing	53	0.47 (0.33–0.61)
Not recorded	1	0.01 (0–0.03)
Total	11,235	100

ADR adverse drug reaction, *CI* confidence interval, *IV* intravenous

had the highest prescribing error rates (FY1 8.6 %, 95 % CI 8.2–8.9; FY2 10.2 %, 95 % CI 9.7–10.7) in comparison with other types of prescriber.

3.1 Types of Prescribing Errors, Drug Classes Involved and Severity of Errors

Omission of required drug therapy at the time of hospital admission was by far the most common type of error, occurring almost three times as frequently as the next most numerous type of error, and accounting for 28.5 % of all prescribing errors (Table 3). Under-dosage (10.9 %) and over-dosage (8.4 %) of medication were the next most common error types. Almost half of the errors related to the need for drug therapy (43.5 %), 5.2 % related to selection of a specific drug, 23.5 % related to selection of a dosage regimen, 12.9 % related to administration of a drug, and 14.9 % related to providing a drug product.

Cardiovascular, central nervous system, respiratory, endocrine, and gastrointestinal drugs were the five most common therapeutic categories associated with prescribing errors, accounting for 73.1 % of all medications involved in errors. Severity grading found that 41.1 % of prescribing errors were minor, 51.6 % were significant and the remaining 7.3 % were serious or potentially life threatening. The rate of potentially serious prescribing errors was higher for consultants and nurse prescribers than all other types of prescriber, as shown in Table 4.

3.2 Predictors of Likelihood of Prescribing Error

After controlling for the type of prescriber, prescribing stage and type of prescription, significant differences were observed for all three explanatory variables (Table 5). The multivariable model indicated there were significantly higher rates of prescribing errors for all types of prescriber when compared against consultant prescribing error rates, with FY1 (odds ratio [OR] 2.13; 95 % CI 1.80–2.52) and FY2 (OR 2.23; 95 % CI 1.89–2.65) doctors being more than twice as likely to prescribe erroneously as consultants. No significant differences were identified for prescribing error rates for pharmacists (OR 0.84; 95 % CI 0.36–1.93) or nurse prescribers (OR 1.00; 95 % CI 0.71–1.39) when compared against consultant prescribing error rates.

Likewise, the stage of hospital stay was also found to be an important predictor of the likelihood of prescribing errors after controlling for the type of prescriber and the type of prescription. Medication orders issued at the time of hospital admission were 70 % more likely to be associated with a prescribing error (OR 1.70; 95 % CI 1.61–1.80) than those issued during the hospital stay. In contrast, prescribing errors were 52 % less likely (OR 0.48; 95 % CI 0.43–0.52) on drug charts that were rewritten and 23 % less likely on discharge prescriptions (OR 0.77; 95 % CI 0.72–0.82) than medication orders issued during the hospital stay. Electronic prescriptions were 12 % less likely to be associated with a prescribing error than were

Table 4 Number and rates of errors by severity and prescriber

	Potential severity				
	Minor	Significant	Serious and potentially lethal	Missing	Total
Foundation Y1	1761 (40.3 [38.3–42.3])	2285 (52.3 [50.3–54.3])	323 (7.4 [6.5–8.3])	0	4369 (100)
Foundation Y2	1480 (40.7 [38.5–43])	1911 (52.6 [50.3–54.8])	245 (6.7 [5.8–7.7])	0	3636 (100)
FTSTAs	582 (41.9 [38.3–45.5])	693 (49.9 [46.1–53.7])	113 (8.1 [6.4–9.8])	1 (0.07 [0–0.21])	1389 (100)
NCCGs	143 (50.0 [41.9–58.1])	125 (43.7 [35.8–51.6])	18 (6.3 [3.3–9.2])	0	286 (100)
Consultant	68 (43.3 [34.8–51.8])	71 (45.2 [36.4–54])	18 (11.5 [6.4–16.5])	0	157 (100)
Pharmacist	0	6 (100.0)	0	0	6 (100)
Nurse	23 (43.4 [29.7–57.1])	23 (43.4 [30.6–56.2])	7 (13.2 [4.7–21.7])	0	53 (100)
Not recorded	563 (42.0 [38.4–45.7])	685 (51.2 [47.4–54.9])	91 (6.8 [5.2–8.4])	0	1339 (100)
Total	4620 (41.1 [39.9–42.4])	5799 (51.6 [50.3–52.9])	815 (7.25 [6.7–7.8])	1 (0.01)	11,235 (100)

Data are presented as *n* (% [95 % CI])

CI confidence interval, *FY* foundation year 1 or 2 medical trainee, *FTSTA* fixed-term specialty training medical appointment, *NCCG* non-consultant career grade medical staff, *OR* odds ratio

Table 5 Predictors of errors per order

Factor	Univariable	Multivariable
Prescriber		
Consultant	1.0	1.0
Foundation Year 1	1.9 (1.61–2.24)	2.13 (1.8–2.52)
Foundation Year 2	2.24 (1.9–2.65)	2.23 (1.89–2.65)
FTSTAs	1.89 (1.59–2.24)	1.84 (1.54–2.19)
NCCGs	1.42 (1.16–1.75)	1.58 (1.29–1.94)
Pharmacist	0.55 (0.24–1.27)	0.84 (0.36–1.93)
Nurses	1.15 (0.83–1.58)	1 (0.71–1.39)
Electronic order		
No	1.0	1.0
Yes	0.87 (0.79–0.95)	0.88 (0.79–0.97)
Prescribing stage		
During stay	1.0	1.0
On admission	1.83 (1.74–1.93)	1.7 (1.61–1.8)
When drug chart re-written	0.51 (0.47–0.56)	0.48 (0.43–0.52)
Discharge prescription	0.82 (0.77–0.88)	0.77 (0.72–0.82)

Data are presented as OR (95 % CI)

CI confidence interval, *FY* foundation year 1 or 2 medical trainee, *FTSTA* fixed-term specialty training medical appointment, *NCCG* non-consultant career grade medical staff, *OR* odds ratio

handwritten prescriptions (OR 0.88; 95 % CI 0.79–0.97) after controlling for type of prescriber and the prescribing stage at which the medication order was issued.

3.3 Predictors of Severity of Prescribing Error

There were no significant differences in severity of error in the multinomial logistic regression model between types of prescriber or whether the medication order was handwritten or generated electronically (Table 6). Potentially serious prescribing errors were significantly less likely to occur on admission (OR 0.46; 95 % CI 0.33–0.66) or when a drug chart was rewritten (OR 0.62; 95 % CI 0.39–0.98) compared with when a medication order was issued during the hospital stay.

Potentially serious prescribing errors were significantly more likely to be associated with cardiovascular (OR 11.96; 95 % CI 7.92–18.06), central nervous system (OR 6.69; 95 % CI 4.21–10.64), anti-infective (OR 5.48; 95 % CI 3.43–8.76), endocrine (OR 16.48; 95 % CI 10.27–26.46), and musculoskeletal and joint disease drugs (OR 6.95; 95 % CI 4.21–11.49) than gastrointestinal drugs. Parenteral routes of drug administration (intravenous/intramuscular/subcutaneous) were also three times more likely (OR 3.66; 95 % CI 2.98–4.49) to be associated with serious (rather than minor) prescribing errors than was the oral route of drug administration.

Table 7 presents the results from a multinomial logistic regression with interaction terms to explore whether the effect of therapeutic drug group on error severity differed by the route of administration, adjusting for the factors shown in Table 5 to be associated with prescribing error severity. There was a 28-fold increase in the odds of a serious prescribing error rather than minor for gastrointestinal drugs administered parenterally compared with medication orders from the same therapeutic group that were not injected (OR 28.63; 95 % CI 10.59–77.45). For all other therapeutic drug groups, all routes of administration had increased odds of serious errors compared with gastrointestinal drugs, and the odds for potentially serious errors were consistently higher for parenteral medication orders.

Table 6 Predictors of error severity: multivariable multinomial logistic models

Factor	Odds of being a potentially significant rather than a minor error	Odds of being a potentially serious rather than a minor error
Patient age		
Decades	1 (0.96–1.03)	0.93 (0.9–0.96)
Therapeutic drug group (BNF chapter)		
1. Gastrointestinal	1.0	1.0
2. Cardiovascular	6.51 (5.12–8.27)	11.96 (7.92–18.06)
3. Respiratory	1.89 (1.34–2.67)	1.57 (0.61–4.04)
4. Central nervous system	1.79 (1.45–2.22)	6.69 (4.21–10.64)
5. Infections	2.8 (1.91–4.11)	5.48 (3.43–8.76)
6. Endocrine	3.42 (2.6–4.51)	16.48 (10.27–26.46)
7. Obstetrics, gynaecology and urinary tract	–	–
8. Malignant disease and immunosuppression	–	–
9. Nutrition and blood	1.48 (1.16–1.9)	1.13 (0.58–2.2)
10. Musculoskeletal and joint diseases	2.8 (1.82–4.31)	6.95 (4.21–11.49)
Route of administration		
Oral	1.0	1.0
IV/IM/SC	1.07 (0.8–1.43)	3.66 (2.98–4.49)
Inhalers	1.38 (1–1.91)	0.37 (0.12–1.16)
Other	0.65 (0.45–0.92)	0.25 (0.09–0.71)
Error type		
Need for drug	1.0	1.0
Selection of specific drug	0.35 (0.25–0.49)	2.41 (1.63–3.56)
Select dosage regimen	0.32 (0.27–0.38)	0.34 (0.26–0.46)
Administration of drug	0.04 (0.03–0.05)	0.03 (0.01–0.05)
Provide drug product	0.01 (0.01–0.01)	0.04 (0.02–0.06)
Prescriber		
Consultant	1.0	1.0
Foundation Year 1	0.78 (0.48–1.25)	0.63 (0.27–1.45)
Foundation Year 2	0.74 (0.47, 1.16)	0.61 (0.26, 1.42)
FTSTAs	0.75 (0.45, 1.27)	0.68 (0.26, 1.75)
NCCGs	0.61 (0.35, 1.08)	0.39 (0.14, 1.08)
Pharmacist	–	1.01 (0.46–2.22)
Nurses	0.81 (0.33–1.97)	0.6 (0.19–1.92)
Electronic		
No	1.0	1.0
Yes	0.92 (0.76–1.11)	0.97 (0.76–1.23)
Prescribing stage		
During stay	1.0	1.0
On admission	1.35 (1.07–1.71)	0.46 (0.33–0.66)
When drug chart re-written	0.75 (0.51–1.1)	0.62 (0.39–0.98)
Discharge prescription	1 (0.74–1.36)	0.75 (0.51–1.11)

BNF British National Formulary, *CI* confidence interval, *IV/IM/SC* intravenous/intramuscular/subcutaneous administration route, *FTSTA* fixed-term specialty training medical appointments, *NCCGs* non-consultant career grade medical staff, OR odds ratio

Table 7 Effect of route and administration and therapeutic drug group (BNF chapter) on severity of error (adjusted analyses)

Therapeutic drug group (BNF chapter)	Odds of being a potentially significant rather than a minor error (IV/IM/SC)		Odds of being a potentially serious rather than a minor error (IV/IM/SC)	
	No	Yes	No	Yes
1. Gastrointestinal	1.0	4.56 (1.71–12.2)	1.0	28.63 (10.59–77.45)
2. Cardiovascular	7.6 (6.08–9.51)	8.04 (5.34–12.09)	16.66 (10.41–26.64)	64.9 (37.66–111.84)
3. Respiratory	2.77 (2.19–3.52)	2.49 (0.72–8.63)	1.02 (0.51–2.03)	16.78 (1.99–141.79)
4. Central nervous system	2.15 (1.8–2.56)	0.9 (0.5–1.62)	10.87 (6.69–17.65)	12.57 (4.89–32.27)
5. Infections	3.04 (2.18–4.23)	4.52 (2.74–7.46)	11.39 (7.38–17.57)	22.62 (13.82–37.02)
6. Endocrine	4.33 (3.42–5.49)	1.98 (1.19–3.3)	22.17 (15.06–32.62)	92.84 (37.18–231.8)
7. Obstetrics, gynaecology and urinary tract	–		–	
8. Malignant disease and immunosuppression	–		–	
9. Nutrition and blood	1.48 (1.15–1.91)	5.29 (2.12–13.19)	1.24 (0.6–2.56)	21.31 (6.8–66.78)
10. Musculoskeletal and joint diseases	2.91 (1.9–4.46)	5.32 (0.9–31.25)	6.38 (2.54–16.06)	184.05 (33.12–1022.82)

Data are presented as OR (95 % CI)

BNF British National Formulary, *CI* confidence interval, *IV/IM/SC* intravenous/intramuscular/subcutaneous administration route, *OR* odds ratio

4 Discussion

The problem of prescribing errors in hospitals is substantial and not solely, or even primarily, a problem of the most junior medical prescribers. In this large prospective study in 20 NHS hospitals, prescribing errors occurred in 8.8 % of newly prescribed medication orders, occurring more commonly at hospital admission and on hand-written orders than in those generated electronically. Doctors of all grades made prescribing errors, as did non-medical prescribers, but FY1 and FY2 doctors were more than twice as likely to make prescribing errors as consultant doctors. However, they were not more likely to make serious errors than were more senior medical doctors.

This study was not without limitations. The errors were identified by pharmacists as part of their routine work, a common method of prescribing error data collection [8, 9, 16]. Failure either to identify or to record errors would result in our data underestimating the actual error rate. Data were recorded on 1 day per month to reduce the impact of such data collection fatigue. Multiple pharmacists were involved, leading to potential variations in data collection practice, even with training. To minimise the impact, all errors recorded were reviewed by a validation panel, although we recognised this could not address variations where errors were not identified or recorded. Identification of the author of handwritten prescriptions is known to be challenging [17], and the grade of the prescriber was not recorded for 11 % of the medication orders in our study. The impact of misidentification was minimised by having the regular pharmacists, who were familiar with the signatures of the regular doctors, collect the data. Nonetheless, pharmacists only recorded the grade of the doctors writing the prescription, rather than any other doctors involved in making the prescribing decisions. Senior doctors often instruct juniors on ward rounds as to what to write [18, 19], and the error rate described here for senior doctors could be an underestimate as to the erroneous prescribing with which they were involved.

As with other recent British studies [8, 9], we have found that prescribing errors are made by all grades of doctors, not just those in their first year of post-graduate training. Deficiencies in undergraduate medical education can therefore only be part of the cause [20], and changes to it, at best, only part of the solution. If education is to be a means of reducing errors, it must include higher specialist training and the continuing professional development of all prescribers as well as education during the undergraduate years and foundation training. Recent medical education research has identified the importance of minimising the negative effects of transitions [21]. In particular, it is well recognised that an important transition occurs between being an undergraduate student and being an early career practitioner, and it has been consistently shown that 'becoming a prescriber for real' is one of its most dominant, and negative, features [22, 23].

Trainees' lack of experience in completing prescriptions before they start work is a well-recognised problem [24], as is the inappropriate satisfaction of some of them with writing a prescription that 'looks about right' [25]. Although trainees in other studies have indicated that they want more practical teaching [26], during undergraduate education, at least, they needed the pressure of a summative assessment to motivate them to take it up [27]. In the UK, the General Medical Council (GMC) revised their core guidance for medical education, *Tomorrow's Doctors,* to recommend that formal prescribing skills training and practical experience in the NHS be provided for medical

students [28]. Alongside this, a new national assessment of prescribing competence has also been introduced for all medical students in the UK before they graduate from medical school [29]. It will be important to evaluate the impact of these recent developments on prescribing errors to determine whether they lead to recognisable improvements in patient safety. A study that explored junior doctors' experiences and responses to error found that learning was maximised when errors were formally discussed and constructive feedback was given [30], although Teunissen et al. [31] have shown that trainees' openness to negative feedback depends on whether their primary motivation is to be seen to be competent, or to learn from their mistakes.

Over half the errors found in this study were considered significant with the potential to cause some form of patient harm, similar to that found elsewhere [8], with a further 7.3 % rated potentially serious or life threatening. Serious prescribing errors were far more likely to occur during a patient's hospital stay and when prescribing medication to be administered parenterally. These findings present important early targets for future interventions. Key questions are how and why these errors occur. The quantitative analysis reported here was part of a large mixed-methods study (EQUIP project) in which we also interviewed 30 FY1 doctors about the causes of their prescribing errors, and we draw on this work to interpret our findings [32]. Complex systems were often involved in causing errors, many of which related to the healthcare environment within which doctors worked, including the impact of busy and stressful working environments or unfamiliarity of the system in which the doctor was working. We found that the FY1 doctors often lacked contextual, rather than basic, knowledge and had difficulty framing clinical problems rather than necessarily lacking specific drug knowledge. Prescribing errors were often found to be due to multiple problems, with several active failures and error-provoking conditions acting together to result in errors. Given this, solutions aimed at a single cause of error are likely to have only limited impact, and multi-factorial interventions addressing many parts of the process of prescribing are likely to be needed [33].

The literature on causes of prescribing errors is relatively sparse [33], and the qualitative research previously conducted mainly concentrates on prescribing by junior doctors, usually in the first year of their training. Much less is known about the causes of prescribing errors by doctors further into their training, such as FY2 doctors, and no work has been conducted focusing on causes of errors made by senior doctors or non-medical prescribers, although this study shows that they occur. More needs to be understood about errors made by senior doctors to inform the necessary continuing professional development delivery and systems redesign that is needed to improve patient safety.

Although we found that prescribing errors were 12 % less likely to occur with electronic prescribing systems, we found no difference in the likelihood of serious prescribing errors occurring between hand-written and electronically generated medication orders. This supports the findings from a systematic review of 12 studies that reported computerised provider order-entry systems can reduce minor prescribing errors, with some studies suggesting increasing rates of some more serious errors, such as duplicating orders or failure to discontinue medicines no longer needed [34].

The stage of the patient's hospital stay during which errors, particularly significant errors, were more likely to occur was at the point of admission and, at that stage, failure to prescribe pre-admission medication was the most common error. There is evidence that conducting medicines reconciliations as soon as possible after admission will reduce omission of long-term medicines [35–37]. Medicines reconciliation is the process by which an up-to-date and accurate list of medicines is created at transitions of care, using information collected from multiple sources as to the pre-admission medication, checked with the current prescribed medicines, and any discrepancies communicated in writing with the current care team [38]. Our findings support the need for medication reconciliations to improve medication safety at transition points between healthcare settings.

5 Conclusion

This study found that junior doctors were twice as likely as senior doctors to make prescribing errors, but that they had similar rates of potentially serious prescribing errors. Potentially serious errors were more likely to be associated with prescriptions for parenteral administration, especially for cardiovascular or endocrine disorders. Further research is needed to target interventions to reduce these high-risk errors and to improve patient safety.

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Compliance with ethical standards

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Conflict of interest Darren Ashcroft, Penny Lewis, Mary Tully, Tracey Farragher, David Taylor, Valerie Wass, Steven Williams and Tim Dornan have no conflicts of interest that are directly relevant to the content of this study.

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