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Incidence and prevalence of intravenous medication errors in the UK: a systematic review

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ABSTRACT

Objectives Medication error is the most common type of medical error, and intravenous medicines are at a higher risk as they are complex to prepare and administer. The WHO advocates a 50% reduction of harmful medication errors by 2022, but there is a lack of data in the UK that accurately estimates the true rate of intravenous medication errors. This study aimed to estimate the number of intravenous medication errors per 1000 administrations in the UK National Health Service and their associated economic costs. The rate of errors in prescribing, preparation and administration, and rate of different types of errors were also extracted.

Methods MEDLINE, Embase, Cochrane central register of clinical trials, Database of Abstracts of Reviews of Effectiveness, National Health Service Economic Evaluation Database and the Health Technology Appraisals Database were searched from inception to July 2017. Epidemiological studies to determine the incidence of intravenous medication errors set wholly or in part in the UK were included. 228 studies were identified, and after screening, eight papers were included, presenting 2576 infusions. Data were reviewed and extracted by a team of five reviewers with discrepancies in data extraction agreed by consensus.

Results Five of eight studies used a comparable denominator, and these data were pooled to determine a weighted mean incidence of 101 intravenous medication errors per 1000 administrations (95% CI 84 to 121). Three studies presented prevalence data but these were based on spontaneous reports only; therefore it did not support a true estimate. 32.1% (95% CI 30.6% to 33.7%) of intravenous medication errors were administration errors and 'wrong rate' errors accounted for 57.9% (95% CI 54.7% to 61.1%) of these.

Conclusion Intravenous medication errors in the UK are common, with half these of errors related to medication administration. National strategies are aimed at mitigating errors in prescribing and preparation. It is now time to focus on reducing administration error, particularly wrong rate errors.

INTRODUCTION

Medication errors are the most common form of medical error and have been the subject of much previous research. It is estimated that medication errors have contributed to 12 000 deaths per year in the National Health Service (NHS) and that the wider problem of medication errors may contribute to an additional £0.75 billion–£1.5 billion in additional healthcare expenditure.¹ The burden of mortality and morbidity associated with medication error is such that the WHO has committed

to a global programme of work to reduce harm to patients caused by medication errors by 50% by 2022.²

Intravenous medication is associated with the greatest risk of medication error.³ They can be technically complex to prepare and administer,⁴ and when they are administered in error, the negative effects of these preparations are more difficult to mitigate due to the immediate and complete absorption and distribution into the blood stream. In 2017, the ECRI Institute declared intravenous medication errors to be the number one threat to patient safety in the USA; however, this review focused on the use of physical fail-safes to prevent intravenous free flow events, which technological interventions may lead practitioners to overlook.⁵ The Institute of Safe Medical Practice's 'high alert drugs' list is dominated by injectable medications.⁶ As medicine becomes more complex, intravenous therapy is a field that continues to grow.

BACKGROUND

The risks of medication error with intravenous medicines are well documented. Errors occur at any and all stages of prescribing, preparation and administration of intravenous medicines. Errors in preparation and administration have included wrong drug selection, using the incorrect diluent for diluting and wrong rate of infusion. A number of interventions have been designed to mitigate these errors,^{7–9} double checking of intravenous drugs,¹⁰ preprogrammed infusion pumps that offer a check of rate and dose ('smart' pumps)¹¹ and provision of ready to administer drug formulations.¹² While some interventions have proven beneficial, baseline error data used to assess their efficacy is often of poor quality. As a result, the merit of many interventions has been questioned. Furthermore, due to their use in a single setting, the findings of any evaluations have lacked generalisability. Heterogeneity of study design and outcome measures in the literature obscure the true nature and size of the problem. Additionally, the practice encompassing intravenous therapy and costs of healthcare-associated morbidity are different between health economies and provider systems such that it may not be appropriate to extrapolate incidence and/or prevalence data from one geographical healthcare setting to another. To date, for numerous reasons, the incidence of intravenous medication errors in the UK is unknown, as data in previous reviews have been synthesised in the context of highly focused and specific questions, or without acknowledgement of geographical/economic differences. Thus, before

the efficacy of further interventions aimed at reducing administration error rates in the UK can be evaluated, it is necessary to understand the incidence of intravenous medication errors in this country.

With these facts in mind, we set out to explore the incidence and prevalence of intravenous medication administration errors in the UK healthcare system. Our aim was to systematically review previous studies of the incidence of intravenous medication errors in the UK healthcare system and attempted to appraise the potential costs associated with harm from these errors.

METHODS

This review was conducted in line with the statement on Preferred Reporting Items for Systematic Reviews and Meta-Analyses.¹³

Search strategy

The electronic repositories of six databases were searched: MEDLINE, Embase, Cochrane central register of clinical trials, Database of Abstracts of Reviews of Effectiveness, NHS Economic Evaluation Database and the Health Technology Appraisals Database. This search was conducted in each database from inception up to July 2017. The search strategy was developed by a health economist (MC), and an abbreviated search strategy is available as an online supplementary file. Grey literature was also searched, including publicly available reports from UK safety agencies (eg, National Reporting and Learning Services (NRLS)) and major safety conferences (eg, National Association for Medical Device Training for Healthcare Professionals (NAMDET)). The citation lists of included papers were also hand searched for additional publications that may not have

been revealed by the literature search. This review protocol was not registered with any systematic review registry. The results of the search strategy are presented in figure 1.

Inclusion and exclusion criteria

The review included studies published in English only. Systematic and narrative reviews and case reports were excluded. Conference abstracts were included where they were unique. Where a later published paper was identified relating to a conference abstract, the abstract was then excluded from the synthesis. Titles and abstracts were reviewed by the lead author (AS) against the following inclusion criteria:

- ▶ The study was set (at least in part) in the UK.
- ▶ The study reported any data pertaining to the rate of intravenous errors, presented either as an incidence or prevalence.

Additionally, studies were also identified if they presented an economic analysis of the costs of intravenous medication errors in the UK. All suitable studies that contained epidemiological data relating to errors associated with intravenous medicines were included, including descriptive, observational, before–after studies and randomised controlled trials.

Data extraction and synthesis

The full text of all included papers was then reviewed independently by members of the wider review team (MR, EW, JC, AS and TS), and the evidence was extracted using a purpose-developed proforma. The proforma was piloted to ensure consistent data extraction by both the same and different reviewers using the test retest method. Data extraction was completed by two reviewers, and disagreements were resolved by consensus. Where results were unclear, study data sets were requested from

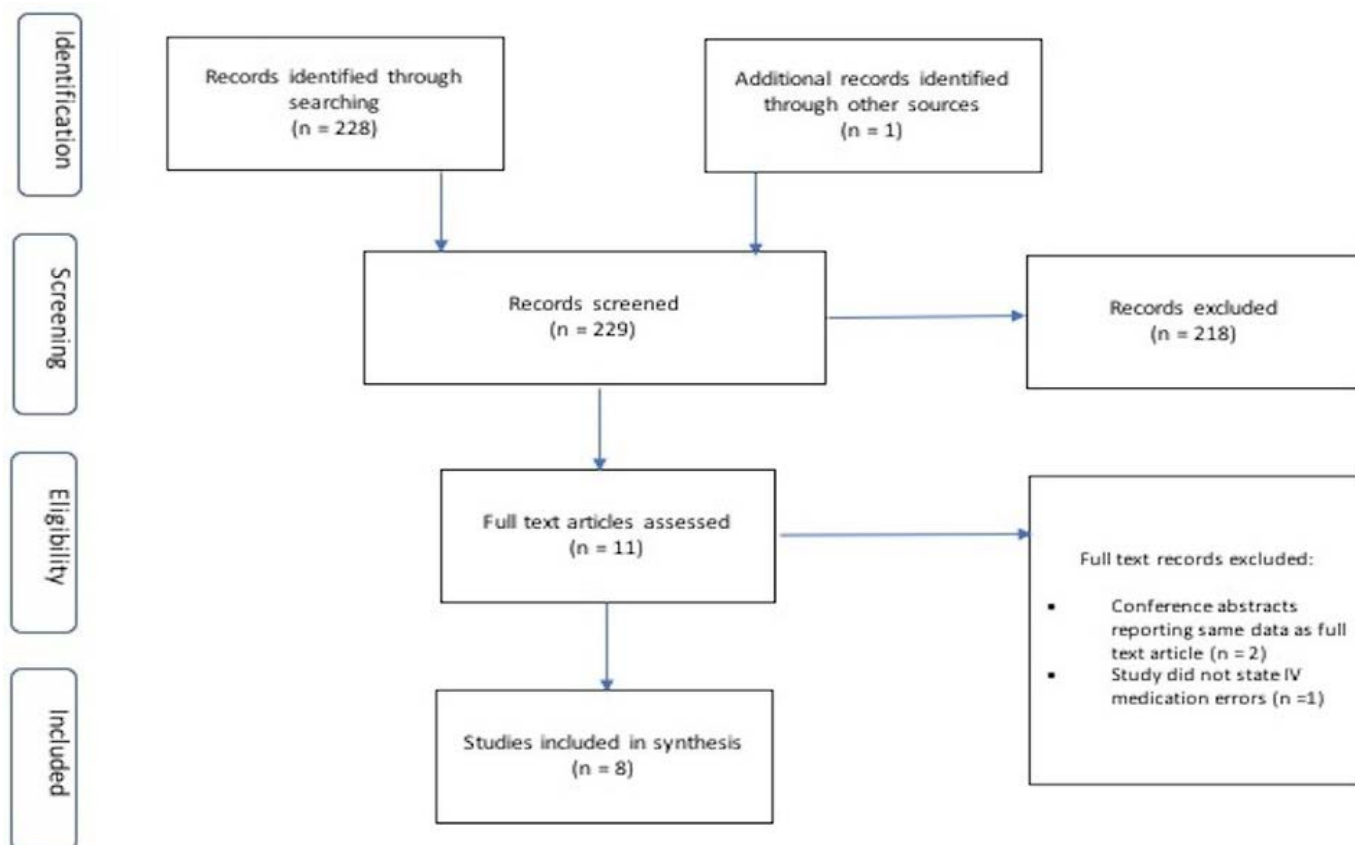


Figure 1 PRISMA diagram of literature screening. Preferred Reporting Items for Systematic Reviews and Meta-analyses.

authors for the review team to extract the data themselves. In this situation, the data set was assessed, and errors were categorised as either intravenous or non-intravenous. Non-intravenous reports included pump failures, blood products and parenteral nutrition, oral medication, pump failures with no medication information and reports relating to adverse drug reactions. All other intravenous-related reports were included in the data extraction as per the protocol. This was required for a single study (Thomas *et al*).

Data for a range of outcomes were extracted. The primary outcome of interest was the overall incidence of intravenous medication errors (per 1000 administrations). Estimates for the overall incidence used the total number of observed infusions as the denominator and were then multiplied up to 1000 administrations to support comparison. Weighted means for administration error rates and 95% CIs of the incidence of errors for these pooled estimates were then calculated. The prevalence of intravenous medication errors (per 1000 patient bed days (pbd)) was extracted where possible.

The incidence of intravenous medication errors was further analysed by stage of the medication process (prescribing, preparation and administration). Subsequently, administration errors were further analysed based on the type of error reported (wrong dose, wrong time, wrong rate, wrong drug, wrong diluent, wrong pump setting and dose omission.) Data for these outcomes were extracted from studies regardless of study design. Rates were calculated using the observed number of errors as the denominator.

RESULTS

In total, eight papers were included in this review of the incidence of intravenous medication errors in the UK.^{14–21} None involved an economic analysis. The characteristics of these studies are summarised in table 1. Six studies were reported in England, one in Scotland, one in Northern Ireland and none in Wales. All studies were conducted in hospitals: two in general hospitals, five in a specialist hospital setting and one study did not state its setting clearly. Five studies were in mixed ward environments, one that focused specifically in critical care units and two

studies did not report their study field. Four studies specifically studied the incidence of medication errors in children and young people's health services with one limited to adult care contexts. Three studies did not specify the population being investigated. All studies were observational in design with five prospective and three retrospective. All retrospective studies used spontaneous error reports as their outcome of interest, while prospective studies used disguised observation.

Defining errors and severity

Four of the eight studies used a single definition of an intravenous medication error derived from Taxis and Barber.¹⁹ This definition included all deviations from a doctor's prescription, the hospital intravenous drugs policy and/or the manufacturer's/technical instructions. No study differentiated between the policy deviated from; therefore, it was possible that multiple deviations were involved in a single error. Other studies used other definitions with different criteria. In total, an error was defined in five different ways across the eligible studies. Only one study used a definition based on clinical importance (Ghaleb *et al*) that had been developed in a previous study.²² Another study used a definition derived from the National Coordinating Committee Medication Error Reduction Programme (NCC MERP)²³ that was then used to support severity classification (Narula *et al*). This was the only study that evaluated harm associated with errors, all being in the 'No harm' category.

The incidence and prevalence of intravenous medication errors

Five studies reported error rates (in per cent) obtained through disguised observation, with a denominator of observed administrations. This enabled some limited manipulation and generalisation of the data (table 2). The crude observed incidence per 1000 administrations across all studies was 265 (range 55–940; 95% CI 249 to 283), and when adjusted to the weighted mean, the incidence of errors was 101/1000 administrations (range 38–643; 95% CI 84 to 121). Three studies reported longitudinal data relating to prevalence of errors in different populations.

Table 1 Included papers and their characteristics; options available as follows:

Author	Year	Country	Setting*	Ward type†	Population ‡	Study design	Definition of error	Detection method
Cousins <i>et al</i> ¹⁴	2005	England	Hospital – general	Mixed	Not stated	Prospective observational	Definition from Taxis (2003).	Disguised observation
Ghaleb <i>et al</i> ¹⁵	2010	England	Hospital – specialist	Mixed	Paediatrics	Prospective observational	Ghaleb <i>et al</i> ²²	Disguised observation
Narula <i>et al</i> ¹⁶	2011	England	Hospital – specialist	Mixed	Paediatrics	Retrospective observational	National Coordinating Council for Medication Error Reporting and Prevention ²³	Spontaneous reporting
O'Hare <i>et al</i> ¹⁷	1995	Northern Ireland	Hospital – specialist	Not stated	Paediatrics	Prospective observational	United States Pharmacopoeia (USP) ³³	Disguised observation
Ross <i>et al</i> ¹⁸	2000	Scotland	Hospital – specialist	Mixed	Paediatrics	Retrospective observational	Local definition	Spontaneous reporting
Taxis and Barber ¹⁹	2003	England	Hospital – general	Mixed	Not stated	Prospective observational	Local definition	Disguised observation
Thomas and Taylor ²⁰	2014	England	Not stated	Critical care units	Adults	Retrospective observational	Local definition ³⁴	Spontaneous reporting
Wirtz <i>et al</i> ²¹	2003	England	Hospital – specialist	Not stated	Not stated	Prospective observational	Definition from Taxis (2003). ¹⁹	Disguised observation

*Hospital (general); hospital (specialist); ambulatory care unit; home; not stated.

†Medical; surgical; critical care unit; operating theatre; emergency department; mixed; not stated.

‡Adults; paediatrics; neonates; not stated.

Table 2 Rate of errors extracted from studies

Author	Denominator	N	All infusions >1 error (%)	Adjusted to/1000 infusions	Weighted mean/1000 administrations
Cousins	Observed infusions	273	185 (67.8)	678	463
Ghaleb*	Observed medication preparation and administration	1554	85 (5.5)	55	38
O'Hare	Observed infusions	179	168 (94)	940	643
Taxis	Observed infusions	430	212 (49.3)	493	337
Wirtz	Observed infusions	140	34 (24.3)	243	166
Total		2576	684	Mean errors=265 (95% CI 249 to 288)	Weighted mean errors=101 (95% CI 84 to 121)

*Data reported all types of error but certain intravenous error types were extractable and are presented.

These are reported in table 3. Together these studies present 854 errors over 600 000 pbd, equating to 1.4 errors per 1000 pbd. However, further estimates are not supported by the data as the studies were so different: Ross *et al* is 20-year-old data and Narula *et al* focused on a highly centralised and controlled therapy (parenteral nutrition). Thomas *et al* reported medication related incidents between 2009 and 2012 in 12 critical care units. Six hundred and ninety-nine reported intravenous medication incidents over 246 552 pbd were identified, yielding an estimated prevalence of intravenous medication errors of 2.84/1000 pbd. Further reliable data extraction from this data set was not possible.

Incidence of errors in different stages of the medication process

This is summarised in table 4. The majority of intravenous medication errors identified occurred during the administration phase with a mean rate of 32.1% of errors occurring at this phase (range 5.5%–91.4%) compared with 8.65% of errors occurring during preparation (range 1%–31%). The only studies that presented data for prescribing errors were those using spontaneous reporting methods. Thus, although the incidence of prescribing errors appear to be very low (141/3433; 0.05%) within the studies that reported prescribing error rates, the rates were quite high – 21.4% to 30% of incident reports.

Errors and where they occur in the administration process

It was possible to identify further data on the types of administration errors in seven papers (table 5). The majority of errors detected during intravenous medication administration were wrong rate errors. The mean incidence of wrong rate administration errors was 57.9% (range 8.8%–100%; 95% CI 54.7% to 61.1%). The next most common error type associated with intravenous administration errors was wrong time administration with a mean rate of 20.4% (range

26.4%–83.3%; 95% CI 18% to 23.2%); however, this was only identified in two studies. Remaining errors types (wrong dose, wrong diluent, wrong volume, wrong pump setting and dose omission) contributed less than 20% of remaining error types.

Quality of the evidence extracted

Studies were evaluated for validity and reliability of methods used to detect error. Retrospective studies all used spontaneous error reports; therefore, it cannot be assured of having captured all possible errors and error types. There was also a predominance of administration errors reported in these studies, suggesting a reporting bias to only those clinically significant events. All prospective studies used the disguised observation approach, but measures to ensure validity of detection were mixed. Only one study (Ghaleb) stated that data collection tools had been piloted and validated prior to commencing the study. Three studies all used the same methodology (Taxis, Wirtz and Cousins)^{19 21 24} with a standardised data collection tool, but these methods all reported using a single trained observer in each site, therefore are weak to observer bias. It is notable that all data collectors in the included studies were pharmacy professionals, and their role and experience in intravenous medication administration was uncertain in all papers.

Most studies reported strategies to ensure the reliability of the data collected, with training offered to all data collectors. However, multicentre studies used different observers, and no study reported any evaluation of inter-observer variation and reliability. Severity was assigned to errors in a single study (Narula)¹⁶ using a readily available tool (NCC MERP) and agreed by consensus.

Table 3 Prevalence of errors extracted from studies

Author	Setting	Denominator	N	Intravenous infusion errors	Adjusted to /1000 patient bed days
Ross	Tertiary children's hospital	Patient bed days	335 835	109	0.32
Narula	Tertiary children's hospital	Patient bed days	18 588	46	2.47
Thomas	Critical care units (n=12)	Patient bed days	246 552	699	2.84
Total			600 975	854	1.42

Table 4 Rates of error at different stages of the intravenous administration process (% expressed as proportion of errors)

Author	Number of included infusions	Prescribing (%)	Preparation (%)	Administration (%)
Cousins	273		3 (1)	182 (66.7)
Ghaleb*	1554			85 (5.5)
Narula	46	14 (30.4)	18 (39.1)	14 (30.4)
O'Hare	291		25 (8.6)	266 (91.4)
Taxis	430		62 (14.4)	155 (36)
Thomas	699	147 (21.1)	172 (24.6)	385 (55.1)
Wirtz	140		17/77 (22)	17/63 (26.9)
Total	3433	161 (0.05)	297 (8.65)	1104 (32.1)

Spaces left blank indicate no reported data pertaining to intravenous medicines.

*Data reported all types of error but certain IV error types were extractable and are presented.

Table 5 Administration errors by type (columns may not equate due to infusions with >1 error type)

Author	Number of errors	Wrong drug N (%)	Wrong dose N (%)	Wrong rate N (%)	Wrong diluent N (%)	Wrong volume N (%)	Wrong time N (%)	Wrong pump setting N (%)	Dose omission N (%)
Cousins	185		1 (0.5)	132 (71.4)	2 (1.1)		49 (26.4)	0	0
Ghaleb	85			85 (100)					
Narula P	46			7 (15.2)					
O'Hare	168			114 (67.9)	1 (0.6)	24 (14.3)	140 (83.3)		2 (1.2)
Ross	195			32 (16.4)					
Taxis	212		12 (5.6)	163 (76.7)	36 (17)				12 (5.7)
Wirtz	34			3 (8.8)	27 (79.4)				10 (32.3)
Total	925		13 (1.4)	536 (57.9)	66 (7.1)	24 (2.6)	189 (20.4)		24 (2.6)

Spaces left blank indicate no reported data pertaining to intravenous medicines.

DISCUSSION

Approximately 10.1% of intravenous medication administrations are associated with an error. The most common administration error identified in this review is 'wrong rate' errors, which account for 57.9% of reported errors. 'Wrong time' errors are the second most common with 20.4% of reported errors. However, the available studies are of low quality.

Insufficient data were available to estimate the severity of these errors, and there were no studies of the economic impacts of these errors. The epidemiology and aetiology of medication errors are multifactorial and poorly understood, and we believe that this is the first systematic review specific to intravenous medication administration errors in the UK. This review is timely in that it comes after the publication of the Department of Health review of the prevalence of medication errors in the NHS in England.²⁵

The results in this review appear to present a high incidence of medication administration error that contradicts reports based on NRLS data.²⁴ However, it is acknowledged that incidents reported via NRLS represent only between 5% and 15% of actual incidents,²⁴ and it is noted that those studies using direct observation identified more errors. Furthermore, those studies on the prevalence of intravenous medication administration errors have demonstrated an increase in reporting habits among healthcare providers. Ross *et al*¹⁸ found 0.32/1000 pbd reported errors, while both Narula and Thomas reported an eightfold higher prevalence likely related to improved reporting cultures implemented after the publication of Ross's study and driven by NHS policy.²⁶ Rates of spontaneous reporting have been correlated with improved safety.²⁷

Moreover, the results of this focused review broadly align with the findings of other work. Elliott *et al*²⁵ identified that medication administration errors account for 54% of medication errors overall in England. Furthermore, Elliott's review identified the elderly and children and young people as at-risk groups. Additionally, that review also failed to identify any economic evaluations of medication error. Our review was not designed to identify risk groups; however, it is important to note that four of the eight included studies were focused on children and young people. Additionally, our estimate of intravenous medication error compares favourably with a recent study published after our search was executed. Lyons *et al* undertook a multicentre prospective observational study in 16 centres across the UK.²⁸ Observing 2008 infusions they identified errors in 11.5% of administered infusions and discrepancies in 53%. Twenty-three errors were considered to be potentially harmful. This study used a pragmatic definition of errors, with minor or intentional deviations from policy (including infusion rate variations and documentation omissions) considered

'discrepancies'. However, this definition has not been used in previous error research and may have resulted in a low estimate of the incidence of errors. However, the definitions used in the studies in this review were broad and heterogeneous so it is also plausible that our estimate is perhaps higher than the true incidence. This goes to demonstrate the methodological difficulties inherent in error research as the very definition of medication error is controversial.

The NHS recognises that intravenous medication is a challenge for patient safety and has moved to drive healthcare organisations to work towards improving reliability²⁹; however, current interventions to improve safety are targeted at prescribing and preparation of intravenous medications.³⁰ In light of this review and given that the majority of administration errors are associated with wrong infusion rates and infusion times, and errors associated with preparation appear to be relatively low, then interventions to mitigate this large group of errors should be considered. Furthermore, Lyons' 2018²⁸ study observed a wide variation in organisational intravenous policies and procedures that was a familiar qualitative finding reported in a number of studies included in this review. Standardisation of these procedures and policies may help improve intravenous infusion safety. Moreover, programmable infusion drivers that automatically calculate dose and rate are already available on the market and are considered effective at reducing medication errors if we can drive this standardisation of intravenous administration processes.³¹

This review is not without its limitations. Our tightly focused review question has undoubtedly limited our search field. Only being interested in those studies from the UK reduced our opportunities for synthesis. For example, a study that included error data from the UK in a pooled analysis of European medication errors, where the UK data were not readily identifiable did not meet our inclusion criteria.³²

Systematic reviews of medication error aetiology are often complicated by the heterogeneity in study design inherent in this field. However, the commonality of denominators and data collection methods in prospective studies has enabled some limited synthesis to assess overall incidence of errors. Comparison of our review with other empirical studies provides some assurance that our estimates are not grossly discordant with other research. However, we must observe that a single study (Ghaleb *et al*)²² included in the synthesis did not clearly differentiate intravenous from non-intravenous observed administrations. Therefore, it is possible that our incidence is an underestimate. However, the study was seminal and highly cited thus was included for completeness, accepting the impact that this had on the final estimate. Additionally, the heterogeneity of studies reporting prevalence of errors in the UK has

not permitted any synthesis and conclusions relating to this outcome cannot be drawn other than to comment on improved error reporting.

We recommend that further research into improving intravenous medication safety be focused on the aetiology of intravenous administration errors, the economic impact of these errors and the cost effectiveness of interventions to reduce their incidence, particularly those associated with incorrect rate of administration.

Contributors AS conceptualised the review. MC executed the literature search and strategy. All authors participated in the data extraction and had material input into the preparation of the manuscript. All authors have had sight of the final manuscript and agreed to its content.

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