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ABSTRACT

Objectives To provide national estimates of the number and clinical and economic burden of medication errors in the National Health Service (NHS) in England.

Methods We used UK-based prevalence of medication errors (in prescribing, dispensing, administration and monitoring) in primary care, secondary care and care home settings, and associated healthcare resource use, to estimate annual number and burden of errors to the NHS. Burden (healthcare resource use and deaths) was estimated from harm associated with avoidable adverse drug events (ADEs).

Results We estimated that 237 million medication errors occur at some point in the medication process in England annually, 38.4% occurring in primary care; 72% have little/no potential for harm and 66 million are potentially clinically significant. Prescribing in primary care accounts for 34% of all potentially clinically significant errors. Definitely avoidable ADEs are estimated to cost the NHS £98462582 per year, consuming 181626 bed-days, and causing/contributing to 1708 deaths. This comprises primary care ADEs leading to hospital admission (£837.7 million; causing 627 deaths), and secondary care ADEs leading to longer hospital stay (£14.8 million; causing or contributing to 1081 deaths).

Conclusions Ubiquitous medicines use in health care leads unsurprisingly to high numbers of medication errors, although most are not clinically important. There is significant uncertainty around estimates due to the assumption that avoidable ADEs correspond to medication errors, data quality, and lack of data around longer-term impacts of errors. Data linkage between errors and patient outcomes is essential to progress understanding in this area.

INTRODUCTION

Medication is the most widely used medical intervention. Harm caused by medication is referred to as an adverse drug event (ADE), and includes medication errors, adverse drug reactions, allergic reactions and overdoses.1 If an ADE is judged as being the result of an error, any resultant harm is regarded as preventable. The medicines use process includes prescribing, dispensing, administration and monitoring, involving different healthcare professionals and other key players in multiple geographical locations. If an error occurs at any one of these stages and reaches the patient, harm may occur. A medication error may be defined as: “Any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the healthcare professional, patient, or consumer”.2

Errors range from minor, with no harm, to major errors causing serious harm and death, and associated healthcare and wider costs.

In 2007, the National Patient Safety Agency estimated that preventable harm from medication could cost over £750 million annually in England.3 Increasingly complex medical needs, and the introduction of many new medications, have resulted in ADEs being recognised as a key global issue. This has led to the World Health Organization’s Third Global Patient Safety Challenge: Medication Without Harm.4 It aims to reduce the global level of severe, avoidable harm related to medications by 50% between 2017 and 2022.

In response to this initiative, the Department of Health and Social Care (DHSC) in England commissioned us to estimate the prevalence and burden of medication error in the National Health Service (NHS). Up-to-date and robust estimates are needed to understand the scale of the problem and devise strategies to address it, and so our objectives were: (1) to estimate the number of medication errors nationally, by setting and by stage of the medication use process; (2) to estimate burden (defined as the costs to the NHS and health losses) due to medication errors.

This paper provides a summary of the findings of our original report,5 with an updated literature review, some updates on burden estimates supported by more recently published data, and further
Table 1: Prevalence of medication errors in the NHS in England per opportunity for error*†

<table>
<thead>
<tr>
<th>Stage in the medication use process</th>
<th>Prescribing</th>
<th>Transition†</th>
<th>Dispensing</th>
<th>Administration</th>
<th>Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Care homes (long-stay residential care including nursing homes) (%)</td>
<td>8.315</td>
<td>No UK data available</td>
<td>9.815</td>
<td>8.415</td>
<td>1.7415</td>
</tr>
<tr>
<td>Secondary (hospital) care (%)</td>
<td>No UK data available</td>
<td>No UK data available</td>
<td>No UK data available</td>
<td>18.6**</td>
<td></td>
</tr>
<tr>
<td>Primary (ambulatory) care (%)</td>
<td>4.215</td>
<td>No UK data available</td>
<td>3.115</td>
<td>N/A§</td>
<td>1.7615</td>
</tr>
<tr>
<td>N/A, not applicable.</td>
<td>9.015</td>
<td></td>
<td>20.8**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Opportunities for dispensing errors arise each time a prescribed medicine is dispensed. As with prescribed items, the same medicine dispensed monthly, or 12 different medicines dispensed from the same prescription, both represent 12 opportunities for dispensing errors.

Our estimation of the uncertainty around estimating numbers of errors and burden.

METHODS

Estimating the annual number of medication errors in the NHS in England

We estimated the number of medication errors by combining published error prevalence estimates reported in a recent rapid systematic review of studies reporting medication error rates in the UK.5 The search strategy is summarised in the supplementary material.

Prevalence of medication error

Table 1 summarises evidence on medication error prevalence, by stage and setting, obtained from the review. Where more than one source had met our quality criteria (see supplementary appendix), the study with the patient population most generalisable to current UK practice was selected. Studies reporting secondary care administration errors were conducted in specific areas of medicine, so the arithmetic mean was derived to estimate prevalence.6–10 Sensitivity analysis was conducted using alternative sources to inform the prevalence of prescribing errors in secondary care (10.9%)11 and administration errors in care homes (40.7%)12 (see online supplementary material for rationale).

Number of opportunities for error by stage and setting

We calculated the number of opportunities for error by stage and setting for the whole of England in 1 year (see online supplementary table S1 and S2 (online supplementary material)).

Primary care. We found no national data around annual number of items prescribed, hence we assumed that it is similar to the number of items dispensed; this is an underestimate as some items are prescribed but not necessarily dispensed. We obtained the number of items dispensed annually from NHS statistics in 2015–16 (1104 million items13) and deducted items dispensed for people residing in care homes. We assumed that monitoring errors only occur in repeat items (77% of total items dispensed).

Care homes. We calculated the number of items used annually by care home residents by multiplying the number of care home residents (416,001)4 by the average number of items used per day (7.2 items),13 assuming monthly prescription and dispensing, and daily administration. Twice daily administration was explored in sensitivity analysis.

Secondary care. We calculated the number of items dispensed to inpatients from total hospital admissions in 2015–16 (9364860 hospital admissions)16 and the average number of items prescribed per inpatient (4.78).17 We calculated items administered in hospitals annually by multiplying the number of beds available (131072 in England)18 by the average bed occupancy (87.23%)18 and the average number of items prescribed per inpatient, assuming daily administration. Twice daily administration was explored in sensitivity analysis.

Transition. We calculated the number of prescriptions issued at discharge using the number of total hospital discharges in 2015–16 (16251841),16 and assumed one prescription per discharged patient.

Calculating the annual number of medication errors

We calculated the number of medication errors by multiplying error prevalence estimates by medication use estimates. Given the lack of data on dispensing and monitoring errors in secondary care, we generalised error prevalence from primary care.

Estimating burden due to medication errors: severity, patient harm and costs

Linking errors to burden requires information about which errors persist through the medication use process, and the impact on patients and healthcare utilisation.
Studies identified through the rapid systematic review of recent UK-based studies found very little good quality data that linked harm to errors. This is partly due to challenges in following up patients from error to harm, and attributing harm to errors. To deal with this evidence gap, studies have ranked errors by subjective judgement of potential of errors to cause harm, some using expert panel-derived criteria to divide errors into “minor”, “moderate” or “severe”. This approach does not allow estimation of harm but can help to understand what errors could lead to the most severe harm.

In the absence of data linking errors to harm, or systems to capture that data, the harm from errors can only be identified when someone experiencing harm presents to primary or secondary care. To quantify burden of errors, some studies link ADEs to patient harm and cost, and then assess retrospectively whether the ADE was preventable (that is, caused by a medication error). It is not always clear whether the ADE was caused by a medicine. Many studies have dealt with issues of causality and preventability, generally categorising errors by some subjective judgement.

Due to lack of data, we developed estimates of harm by:
1. Estimating the proportion of errors likely to cause minor, moderate or severe harm in each setting and at each stage of the medication use process
2. Identifying published UK-based studies measuring the burden from ADEs and extrapolating to estimate the annual impact for England in terms of health-care resource utilisation (and associated costs) and mortality.

**Quantifying burden (patient harm and NHS cost) of errors**
To estimate the burden of medication errors using published work it was necessary to rely on retrospective judgements that the harm presented was: (1) due to an ADE; and (2) that it was avoidable. The primary approach was to identify published UK-based case studies measuring the burden from ADEs and estimate the annual impact for England in terms of health-care resource utilisation (and associated costs) and mortality. Data from non-UK case studies were used to supplement this evidence in scenario analyses. The work reported here results from literature review to October 2018, updating the review carried out for the original DHSC report (October 2017).

Source studies were identified from the rapid review and expert consultation. Applying quality criteria used in the rapid reviews, we included studies judged as generally high quality, with all but one using predefined and published criteria to identify ADEs and all using published criteria to determine avoidability. We included two studies published more than 10 years ago as more recent data were not available.

Key assumptions are that “definitely” avoidable ADEs, as classified by the source studies, approximate to harm caused by medication errors, and that hospitalisation due to ADEs were associated with errors occurring in primary care. In the source study, we calculated the number of medication errors that had potential to cause minor, moderate or severe harm by applying data from table 2 to our estimate of medication errors. No UK data were available for care home errors. Therefore, we generalised the severity of errors in care homes from primary care for prescribing, dispensing and monitoring, and from secondary care for administration. We generalised the severity of transition errors in secondary care from the severity of prescribing errors in secondary care.

**Estimating the proportion of medication errors likely to cause minor, moderate or severe harm**
Five studies used to estimate error prevalence assessed the proportion of errors with potential to cause minor, moderate or severe harm (table 2). The different methods used are discussed in the online supplementary appendix.

<table>
<thead>
<tr>
<th>Error category</th>
<th>Percentage of all errors by severity in each healthcare setting</th>
<th>Primary care (%)</th>
<th>Care homes</th>
<th>Secondary care (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prescribing</td>
<td>Mild: 49.4% Moderate: 49.8% Severe: 0.81%</td>
<td>No UK data available</td>
<td>Mild: 41.1% Moderate: 51.6% Severe: 7.3%</td>
<td></td>
</tr>
<tr>
<td>Transition</td>
<td>No UK data available</td>
<td>No UK data available</td>
<td>No UK data available</td>
<td></td>
</tr>
<tr>
<td>Dispensing</td>
<td>Mild: 64.8% Moderate: 34.1% Severe: 1.1%</td>
<td>No UK data available</td>
<td>Mild: 85.7% Moderate: 8.6% Severe: 5.7%</td>
<td></td>
</tr>
<tr>
<td>Administration</td>
<td>N/A</td>
<td>No UK data available</td>
<td>Mild: 92.4% Moderate: 7.3% Severe: 0.3%</td>
<td></td>
</tr>
<tr>
<td>Monitoring</td>
<td>Mild: 10.9% Moderate: 72.7% Severe: 16.4%</td>
<td>No UK data available</td>
<td>Mild: 10.9% Moderate: 72.7% Severe: 16.4%</td>
<td></td>
</tr>
</tbody>
</table>

N/A, not available.
hospitalisation due to ADEs were associated with errors occurring in primary care, and definitely avoidable ADEs were defined as those due to a drug treatment procedure inconsistent with present day knowledge of good medical practice. For the base case, we considered the number of hospitalisations and deaths associated with ADEs in primary care, and increased length of hospitalisations associated with ADEs in secondary care.

The base case estimate for secondary care ADEs included only increased length of stay and death during the hospital admission when the ADE occurred. A recent UK study estimated harm from a secondary care ADE persisting in the 8 weeks following discharge, and was explored as a scenario analysis.

Due to the limitations of source data, the time horizon for the estimates of patient harm and costs is limited to the initial acute event or hospitalisation. Unit costs attached to healthcare utilisation and other data used in the estimation of total costs are summarised in online supplementary table S2 (see online supplementary material). The population-level data to which the error rates were applied were recorded by the NHS or Office for National Statistics (ONS) for the year 2015/16 and are reported in online supplementary material, table S2. The number of admissions and bed-days were calculated for the different sources of errors and then multiplied by the relevant unit costs to generate cost estimates.

The following sections describe the source studies and assumptions used to derive the parameters on which estimates of the burden of ADEs were based.

**Burden of ADEs occurring in primary care**

**Admissions to hospital**

A prospective English study of ADEs leading to hospital admission in two hospitals reported 5.2% of 18,820 admissions over 6 months were due to an ADE. Causality was assessed. Most ADEs were either definitely (9%) or possibly (63%) avoidable. From this, we estimated the avoidable admissions rate to be 0.47% for definitely avoidable and 3.74% for definitely or possibly avoidable ADEs. In another UK study, 265 (6.5%) admissions were judged to be medication-related and 178 (67%) were judged to be avoidable. Potentially (definitely or possibly) avoidable ADEs were associated with 3.0% of admissions. From these two studies, hospital admissions due to definitely or possibly avoidable drug-related morbidity was assumed to account for between 3.0% and 3.74% (midpoint 3.4%) of all adult non-obstetric, non-elective, admissions. This estimate was used in scenario analysis.

To estimate the number of hospital admissions due to primary care ADEs, the number of non-elective finished admission episodes (FAEs) excluding obstetrics and paediatrics (to mirror the admissions observed in the source study) was used as the denominator and multiplied by the observed error rate.

**Length of hospital stay**

The median length of stay (LOS) of admissions due to avoidable ADEs was reported to be 8 days (IQR 4–18 days). The mean LOS was not reported, but can be derived from the total number of bed-days reported (17,452) and number of admissions (12,251), to be 14.25 days. However, the source study was over 10 years old and there has been a downward trend in average LOS in the NHS; therefore, the average LOS in 2015/16 (5 days) was used in the base case estimate. The two values from the source study (8 and 14.25 days) were used in scenario analysis.

**Deaths associated with ADEs occurring in primary care**

The same prospective UK study was used to estimate the number of deaths associated with ADEs. From 18,820 admissions analysed, deaths were identified as being a direct result of an ADE, giving an index hospitalisation death rate of 0.15% due to ADEs. The proportion of admissions due to ADEs that were fatal was 2.3% (around half of which were due to fatal gastrointestinal bleeds). We assumed that as 9% of ADEs in the source study were definitely avoidable, the same proportion of ADE-related deaths were also avoidable. This meant that 0.21% admissions due to avoidable ADEs resulted in death. To estimate the number of deaths due to primary care ADEs, the number of non-elective FAEs excluding obstetrics and paediatrics (to mirror the admissions observed in the source study) was used as the denominator and multiplied by this figure. There were no data available to estimate directly the number of deaths in which primary care ADEs were a contributing factor. Literature regarding secondary care ADEs reported that the proportion which contributed to death was 12.7 times higher than the proportion which caused death. A sensitivity analysis assuming that primary care ADEs contributed to death in 29.2% (i.e., 2.3% × 12.7) of admissions was conducted.

**Burden of ADEs occurring in secondary care**

**Hospital LOS**

An English study assessed ADEs occurring in admissions. Of 3,695 patient episodes, 545 (14.7%, 95% CI 13.6% to 15.9%) experienced one or more ADEs, 53.3% of which were definitely (6.4%) or possibly (46.9%) avoidable. ADEs increased LOS by 4 days for 26.8% of patients experiencing an ADE. These data were used to estimate the increased LOS and associated costs due to ADEs occurring in secondary care. The rate of inpatient admissions during which there was an ADE observed by Davies et al was applied to the number of elective and non-elective FAEs, excluding paediatrics and obstetrics; day cases were...
Deaths associated with ADEs occurring in secondary care

Davies et al reported that out of the 3695 patient episodes assessed, there were 14 deaths in which an ADE was a contributing factor, and one death which was a direct result of the ADE.30 This gave an index rate of 0.38% of all ADE-related admissions in which the ADE was a contributing factor to death and 0.03% in which the ADE was the direct cause of death. Assuming that 6.4% of these ADE-related deaths were definitely avoidable and 53.3% were definitely or possibly avoidable,30 annual national estimates of avoidable deaths in which inpatient medication errors caused or contributed to the deaths were generated. The number of deaths in which an ADE was a contributing factor was used as the base case estimate because of the small number of deaths (one) caused directly by an ADE observed in the source study. No data were available around impact for other measures of patient health.

Scenario analyses

The base case analysis included UK data only, necessarily excluding potential other impacts of errors, providing conservative estimates of burden. We carried out four scenario analyses around the burden of ADEs where we utilised data from other settings and economic modelling:

- Burden from errors occurring in primary care: admissions to intensive care, accident and emergency (A&E) visits not resulting in a hospitalisation, primary healthcare contact not resulting in an A&E visit or hospitalisation
- Burden from errors occurring in secondary care: post-discharge resource use.

The methods, data sources and assumptions are detailed in the supplementary appendix.
RESULTS

Estimating the annual number of medication errors in the NHS in England

A summary of the estimated annual number of errors in England is presented in figure 1, with a detailed breakdown by severity in table 3. Online supplementary file 1 summarises the estimated number of opportunities for error by stage and setting for the whole of England in 1 year.

We have estimated that there are 237,287,788 medication errors in England in 1 year. Errors occur at all stages of the medicines use process: prescribing (21.3%), transition (14.4%), dispensing (15.9%), administration (54.4%) and monitoring (7.0%); and in all settings: primary care (38.4%), care homes (41.7%), and secondary care (19.9%). Error rates per patient in primary care are the lowest, but the burden of errors is the second highest due to the size of the sector. Care homes cover fewer patients than the other sectors, but have the highest error rates per patient, leading to a disproportionately high overall number of errors.

Estimating burden due to medication errors

The estimated numbers of errors per annum in England that could potentially lead to mild, moderate or severe harm are presented in table 3.

Of the 237.3 million medication errors in England annually, 72.1% are estimated to have the potential to cause minor harm only. Those errors with potential to cause moderate or severe harm constitute 25.8% and 2.0% of overall errors, respectively.

Sensitivity analysis explored alternative sources of the prevalence of error, and assumptions regarding number of daily doses of each administered medicine. Alternative scenarios led to a higher number
Table 4  Estimated national burden associated with primary and secondary care errors (base case scenario and alternative scenarios)

<table>
<thead>
<tr>
<th>Base case and higher cost scenarios</th>
<th>Cost (£)</th>
<th>Bed-days/year</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base case (hospitalisations linked to definitely avoidable primary care ADEs and definitely avoidable ADEs during overnight hospital admissions)</strong></td>
<td>83 673 627</td>
<td>136 811</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary care ADEs</td>
<td>83 673 627</td>
<td>136 811</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.2% of hospitalisations due to primary care ADEs; length of stay 5 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.3% of ADE admissions directly result in death caused by the ADE</td>
<td></td>
<td>697*</td>
</tr>
<tr>
<td></td>
<td>29.2% of ADE admissions result in death for which an ADE was a <em>casual or contributing</em> factor</td>
<td></td>
<td>7958</td>
</tr>
<tr>
<td></td>
<td>9% of ADEs definitely avoidable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary care ADEs</td>
<td>14 788 955</td>
<td>44 815</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ADEs during overnight inpatient admissions (14.7% error rate); 4 days added to length of stay for 26.8% of patients with an inpatient ADE; £330 for each day added to admission;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.3% of all admissions result in a death <em>caused by an ADE</em></td>
<td></td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>0.038% of all admissions result in a death for which an ADE was a <em>casual or contributing</em> factor</td>
<td></td>
<td>1081*</td>
</tr>
<tr>
<td></td>
<td>6.4% of ADEs definitely avoidable</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (base case)</strong></td>
<td>98 462 582</td>
<td>181 626</td>
<td>1708*</td>
</tr>
</tbody>
</table>

**Alternative scenarios**

**Scenario 1a: (base case+probably avoidable ADEs)**

| Primary care ADEs | 605 298 575 | 989 697 | 5013 |
| | 5.2% of hospitalisations due to primary care ADEs | | |
| | 2.3% ADEs directly resulting in death | | |
| | 72% of ADEs probably or definitely avoidable | | |
| Secondary care ADEs | 123 164 262 | 373 225 | 9000 |
| | ADEs during overnight inpatient admissions | | |
| | Deaths for which inpatient ADE was a *contributing factor* | | |
| | 53.3% of ADEs probably or definitely avoidable | | |
| **Total (scenario 1a)** | 728 462 837 | 1362 922 | 14 013 |

**Scenario 1b: (base case+definitely avoidable ADEs during day case admissions)**

| Primary care ADEs | 83 673 627 | 136 811 | 627 |
| | Hospitalisations due to primary care ADEs | | |
| | 2.3% of ADEs directly result in death | | |
| | 9% of ADEs definitely avoidable | | |
| Secondary care ADEs | 28 170 381 | 85 365 | 2058 |
| | ADEs during all inpatient admissions | | |
| | Deaths for which inpatient ADE was a *contributing factor* | | |
| | 6.4% of ADEs definitely avoidable | | |
| **Total (scenario 1b)** | 111 844 008 | 222 176 | 2685 |

*The base case estimate includes deaths in which a primary care ADE caused death and where a secondary care ADE was a contributing factor in death as these were the most robust estimates.

ADE, adverse drug event.

of overall errors (238 118 974–590 406 892), but relatively similar number of errors that could be associated with moderate or severe harm (66 610 373–92 990 602, compared with 66 163 450 in the baseline scenario).

Quantifying burden (patient harm and NHS cost) of errors

The base case uses only UK-based data on hospitalisations linked to definitely avoidable ADEs occurring in primary care leading to hospital admission and definitely avoidable ADEs during overnight hospital admissions. The estimated costs to the NHS are £98 462 582 annually, consuming 181 626 bed-days, causing 712 deaths, and contributing to 1708 deaths during the index hospitalisation (table 4). Two alternative scenario analyses were also estimated: including both definitely and probably avoidable ADEs cost £728 462 837; including inpatient ADEs during day case and overnight hospital admissions cost £111 844 008.

Scenario analyses including the burden on other NHS services associated with medication errors are reported in table 5. A full record of scenarios estimating the burden of errors under alternative assumptions is reported in online supplementary material (online supplementary table S4). The highest cost scenario—which includes possibly (and definitely) avoidable ADEs, assumes a 14.25 day admission for primary care errors, and includes the burden on the broader range...
of NHS services—estimates that errors cost the NHS £1 605 794 614 annually, consume 3 817 817 bed-days, and contribute to 22 303 deaths.

**DISCUSSION**

**Key findings**
We estimated that 237 million medication errors occur in England annually, costing the NHS £98 462 582, consuming 181 626 bed-days, and causing or contributing to 712 or 1708 deaths, respectively.

The estimated number of errors is the sum of medication errors over all stages of the medication use process. Most errors occur in administration (54%), prescribing (21%) and dispensing (16%). Most medication errors (72%) have little/no potential for harm, and only 2% have potential to cause severe harm.

**Study limitations and assumptions**
Limitations stem mainly from lack of data. Source studies were generally conducted in small numbers of English centres. Our assumption that these data are generalisable to the whole NHS is a source of uncertainty. Estimates of the total number of errors represent the sum total of errors at each stage rather than the errors that actually reach patients.

This study only considers medication errors under the responsibility of healthcare professionals and care staff, without including errors in administration and monitoring by patients and their caregivers. Additionally, some assumptions had to be made to calculate the number of medications prescribed and dispensed given the lack of data. We had to assume that the number of items prescribed in primary care equated to the number dispensed, which will have led to an underestimate of prescribed items, and any estimates of associated errors. Due to the lack of available data, we were not able to make direct links between errors and harm, or what proportion of errors occurring at different stages of the medicines use process reached patients, and what proportion of those errors reaching patients caused actual harm. Therefore, the estimates of error prevalence are generated from completely separate data from the data used to generate estimates of harm. We had to assume that the errors we have estimated to occur will lead to the burden that we have estimated will occur. Studies included did not use comparable methods to assess severity of potential harm.

A major, necessary, assumption in the estimation of the burden was that definitely avoidable ADEs constitute harm from errors. Estimated burden only included short-term costs and patient outcomes, as we had no data on burden of errors managed in care homes, and therefore it is likely to be an underestimate. Some key source studies from which the burden of errors was estimated were at least 10 years old, or from non-UK countries in scenario analyses.

**Comparison with published estimates of medication error prevalence and burden**
Similar to another recent review in this area, reported error rates differ widely between studies due to differences in methods. Error rates in the UK are similar to those in other comparable health settings such as the USA and other countries in the European Union for primary care prescribing, secondary care prescribing, dispensing and administration.

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**Table 5** Scenario analyses: estimated burden including other NHS services associated with primary and secondary care errors

<table>
<thead>
<tr>
<th>Burden on other NHS services</th>
<th>Cost (£)</th>
<th>Bed-days/year</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base case (hospitalisations associated with definitely avoidable primary care errors and definitely avoidable errors during overnight hospital admissions)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (base case)</td>
<td>98 462 582</td>
<td>181 626</td>
<td>1708</td>
</tr>
</tbody>
</table>

**Primary care contacts associated with primary care errors**

<table>
<thead>
<tr>
<th></th>
<th>Cost (£)</th>
<th>Bed-days/year</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0% of primary care errors result in a GP visit</td>
<td>8 604 378*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>15.41% of primary care errors result in a GP visit</td>
<td>22 098 911†</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**A&E attendances associated with primary care errors**

<table>
<thead>
<tr>
<th></th>
<th>Cost (£)</th>
<th>Bed-days/year</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.2% of A&amp;E attendances due to ADEs</td>
<td>75 902 982</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>20.5% are avoidable*</td>
<td></td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>79.8% of A&amp;E attendances do not result in admission†</td>
<td></td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**ICU admissions associated with errors**

<table>
<thead>
<tr>
<th></th>
<th>Cost (£)</th>
<th>Bed-days/year</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU admissions related to avoidable ADEs (8.1% of ICU admissions); length of ICU stay 4 days</td>
<td>5 473 747</td>
<td>4188</td>
<td>147</td>
</tr>
<tr>
<td>Death during ICU admission (14.0% of ICU admissions for avoidable ADEs)</td>
<td></td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Post-discharge resource use associated with secondary care errors**

<table>
<thead>
<tr>
<th></th>
<th>Cost (£)</th>
<th>Bed-days/year</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP visits (71.7% of errors requiring treatment)</td>
<td>1 702 245</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Outpatient clinic visits (2.7% of errors requiring treatment)</td>
<td></td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Out-of-hours visits (1.8% of errors requiring treatment)</td>
<td></td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*Based on 239 011 GP visits.
†Based on 613 859 GP visits.
‡Based on 582 174 non-elective admissions leading to 75 683 medication errors, 56 308 of which required treatment.
ADE, adverse drug event; A&E, accident and emergency; GP, general practitioner; ICU, intensive care unit; NHS, National Health Service.
Implications for policymakers
This work helped inform recent policy initiatives that aim to monitor and reduce medication errors. Specifically, it informed the DHSC decision to commission a new system to monitor and prevent medication errors and the development of indicators for safer prescribing, by linking prescribing data in primary care to hospital admissions.37 NHS Digital and NHS Business Services Authority were tasked to develop metrics to assess and monitor higher risk prescribing, and link this with outcomes such as hospital admission.

Understanding the prevalence and burden of medication errors can help inform decisions about where to prioritise funding of patient safety initiatives to reduce the burden from medication errors. In parallel with our work, a short-life working group advised the English DHSC on what should be done to reduce medication errors.38 One key recommendation was that in primary care settings, the use of evidence-based interventions such as a pharmacist-led information technology intervention (PINCER)39 should be employed. Our work supports this recommendation that primary care is a key setting for intervention, given our estimate that 71.0% of 66 million clinically significant errors occur in primary care and that prescribing in primary care accounts for 33.9% of all potentially clinically significant errors. The drugs most commonly implicated in hospital admissions due to ADEs are non-steroidal anti-inflammatory drugs (NSAIDs), antiplatelets, antiepileptics, hypoglycaemics, diuretics, inhaled corticosteroids, cardiac glycosides, and β-blockers.22 NSAIDs, anticoagulants and antiplatelets cause over a third of admissions due to avoidable ADEs.29 Close to 80% of deaths were due to gastrointestinal bleeds caused by NSAIDs, aspirin or warfarin.29 Older people are more likely to suffer avoidable ADEs.32 This presents a clear message for policymakers as to where targeted interventions could have the greatest impact.

CONCLUSIONS
Ubiquitous medicines use in health care leads unsurprisingly to high numbers of medication errors, although most are not clinically important. There is significant uncertainty around estimates due to the assumption that avoidable ADEs correspond to medication errors, data quality, and lack of data around longer-term impacts of errors, although estimates suggest significant effects on patient health and health care. Effective targeting of finite healthcare resources to reduce medication errors requires understanding of where errors cause the most burden. Data linkage between errors and patient outcomes is essential to progress understanding in this area.

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Contributors RAE, EC, DJ, MJS and RF designed, conducted and drafted the economic analysis. RAE, DJ, MJS, and RF led on the analysis on the prevalence of medication error. RAE and EC led on the analysis on the economic burden of medication error. All authors reviewed and approved the final manuscript. All authors had full access to data and take responsibility for its integrity and the accuracy of the analysis.

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REFERENCES


It has been identified that healthcare professionals are at risk of medication errors. To improve patient safety, healthcare professionals need to be aware of the potential causes of medication errors and the interventions that can be implemented to reduce their occurrence. This study aimed to investigate the potential causes of medication errors and the interventions that can be implemented to reduce their occurrence. The study used a systematic review of the literature to identify the potential causes of medication errors and the interventions that can be implemented to reduce their occurrence. The results of the study showed that the potential causes of medication errors included medication errors, patient errors, and healthcare professional errors. The study also showed that the interventions that can be implemented to reduce the occurrence of medication errors included education and training, computerized systems, and electronic medication administration. These interventions can help to improve patient safety and reduce the risk of medication errors.

The study findings highlight the importance of implementing interventions to reduce medication errors. Healthcare professionals need to be aware of the potential causes of medication errors and the interventions that can be implemented to reduce their occurrence. By implementing these interventions, healthcare professionals can help to improve patient safety and reduce the risk of medication errors.