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Elliott, Rachel, Camacho, Elizabeth, Faria, Rita orcid.org/0000-0003-3410-1435 et al. (2 more authors) (2020) Economic analysis of the prevalence and clinical and economic burden of medication error in England. BMJ Quality & Safety. pp. 1-10. ISSN 2044-5423

https://doi.org/10.1136/bmjqs-2019-010206

Economic analysis of the prevalence and clinical and economic burden of medication error in England

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 United Kingdom-based prevalence of medication errors (in prescribing, dispensing, administration and monitoring) in primary care, secondary care and nursing home settings, and associated healthcare resource use, to estimate annual number and burden of errors to the NHS. Burden (health care 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, 71% 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 £98,462,582 per year, consuming 181,626 bed-days, causing/contributing to 1,708 deaths. This comprises primary care ADEs leading to a hospital admission (£83.7 million; causing 627 deaths), and secondary care ADEs leading to a longer hospital stay (£14.8 million; causing 85 deaths; contributing to 1,081 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 health care 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 health care 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 (WHO) 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 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 exploration 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 United Kingdom (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 Supplementary Material for rationale.

Table 1: Prevalence of medication errors in the NHS in England per opportunity for error*$

$Stage in the medication use process	Setting		
	Primary (ambulatory) care (%)	**Care homes (long-stay residential care including nursing homes) (%)**	**Secondary (hospital) care (%)**
Prescribing	4.2[13]	8.3[14]	9.0[15]
Transition**	No UK data available	No UK data available	20.8[16]
Dispensing	3.1[17]	9.8[14]	No UK data available
Administration	N/A***	8.4[14 $$]	18.6[$$$]
Monitoring	1.76[13]	1.74[14]	No UK data available

*Opportunities for prescribing and monitoring errors arise each time an item is prescribed, so the same medicine prescribed monthly, or 12 different medicines on the same prescription both represent 12 opportunities for prescribing and monitoring errors.

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.

Opportunities for administration errors arise every time a dose is administered or omitted in error, and so one medicine taken three times daily, or three medicines taken once daily, both represent three opportunities for error.

Opportunities for transition errors arise each time a discharge prescription is issued, regardless of the number of items on it.

**medicines prescribed and dispensed on discharge from hospital to primary care or care homes;

***administration in primary care assumed to be patient-led and not under the control of health care professionals, this is generally referred to as “adherence”, in this study we excluded any “errors” that might arise from suboptimal adherence;

$Data are all from England

$$administered doses;

$$$unweighted arithmetic mean derived from five UK studies set in specific patient populations, this includes both oral and parenteral administration[6-10]

UK: United Kingdom

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 one year (see Table S1 and S2 (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 (1,104 million items[18]) 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 number of care home residents (416,000[19]) by average number of items used per day (7.2 items[14]), assuming monthly prescription and dispensing, and daily administration. Twice daily administration was explored in sensitivity analysis.

Secondary care. We calculated number of items dispensed to inpatients from total hospital admissions in 2015-16 (9,364,860 hospital admissions[20]) and the average number of items prescribed per inpatient (4.78[15]). We calculated items administered in hospitals annually by multiplying the number of beds available (131,072 in England[21]) by the average bed occupancy (87.23%[21]) 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 (16,251,841[20]), 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.[5 13 22] 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 judgment of potential of errors to cause harm, some using expert panel-derived criteria to divide errors into "minor", "moderate", or "severe".[23] 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 judgment.[24-26]

Due to lack of data, we developed estimates of harm by:

1) Estimating 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 healthcare resource utilisation (and associated costs) and mortality.

Estimating 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[7 13 15 17 27] (Table 2). The different methods used are discussed in the Supplementary Appendix.

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.

Table 2: Potential of errors to cause harm from UK studies

Error category	Percentage of all errors by severity in each health care setting		
	Primary care (%)	**Care homes**	**Secondary care (%)**
Prescribing	Mild: 49.4% Moderate: 49.8% Severe: 0.81%[13]	No UK data available	Mild: 41.1% Moderate: 51.6% Severe: 7.3%[15]
Transition	No UK data available	No UK data available	No UK data available
Dispensing	Mild: 64.8% Moderate: 34.1% Severe: 1.1%[17]	No UK data available	Mild: 85.7% Moderate: 8.6% Severe: 5.7%[27]
Administration	N/A	No UK data available	Mild: 92.4% Moderate: 7.3% Severe: 0.3%[7]
Monitoring	Mild: 10.9% Moderate: 72.7% Severe: 16.4%[13]	No UK data available	Mild: 10.9% Moderate: 72.7% Severe: 16.4%[15]

Quantifying burden (patient harm and NHS cost) of errors

To estimate the burden of medication errors using published work it was necessary to rely upon retrospective judgements that the harm presented was firstly due to an ADE and secondly 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 healthcare 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.[24 28-31] Applying quality criteria used in the rapid reviews,[32] we included studies judged as generally high quality, all but one[29] using pre-defined and published criteria to identify ADEs and all using published criteria to determine avoidability. We included two studies published more than ten years ago as more recent data were not available.[24 30]

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, hospitalisation due to ADEs were associated with errors occurring in primary care[30], definitely avoidable ADEs were defined as those due to a drug treatment procedure inconsistent with present day knowledge of good medical practice.[25] For the base-case, we considered the number of hospitalisations and deaths associated with ADEs in primary care,[24 30] and increased length of hospitalisations associated with ADEs in secondary care.[31]

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.[33]

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 Table S2 (see 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 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 upon 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.[30] Causality was assessed.[25] 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%) judged avoidable.[24] 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 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[30]) was used as the denominator and multiplied by the observed error rate.[30]

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).[30] The mean LOS was not reported, but can be derived from the total number of bed-days reported (17,452) and number of admissions (1,225), 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.[20] 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 number of deaths associated with ADEs.[30] 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 GI bleeds). We assumed that as 9% ADEs in the source study[30] 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[30]) 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.[31] A sensitivity analysis assuming that primary care ADEs contributed to death in 29.2% (i.e. 2.3% x 12.7) of admissions was conducted.

Burden of ADEs occurring in secondary care

Hospital length of stay

An English study assessed ADEs occurring in admissions.[31] Of 3695 patient episodes, 545 (14.7%, 95% CI 13.6–15.9%) 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.[31] was applied to the number of elective and non-elective FAEs, excluding paediatrics and obstetrics; day cases were excluded from the base case estimate. A scenario analysis was conducted in which day cases were included.

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 of which was as a direct result of the ADE.[31] 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,[31] annual national estimates of avoidable deaths in which inpatient medication errors caused or contributed to 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 analysis: post-discharge resource use associated with ADEs occurring in secondary care

Parkeh et al reported that 37.0% of over 65s who are discharged from a non-elective hospital admission experienced some medication-related harm in the following 8 weeks, 74.0% of which were related to a prescription issued in secondary care.[33] The authors also reported that 4.6% of medication-related harm involved a medication error (3.4% medication error alone; 1.2% ADE plus medication error). Therefore 1.3% (i.e. 4.6% of 74.0% of 37.0%) of non-elective admissions were associated with a medication error. Of these medication errors, 74.4% required some type of healthcare resource use. This included GP consultations (71.7%), outpatient clinic attendances (2.7%), and out-of-hours visits (1.8%). These estimates were applied to the number of non-elective admissions, excluding obstetrics and paediatrics, in 2015/16.

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 visits not resulting in a hospitalisation, Primary health care 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

Number of errors

Number of opportunities for error by stage and setting in the NHS in England

Table S2 (Supplementary Appendix) summarises the estimated number of opportunities for error by stage and setting for the whole of England in one year.

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.

<<Figure 1 here>>

We have estimated that there are 237,287,788 medication errors in England in one year. Errors occur at all stages of the medicines use process: prescribing (21.3%), transition (1.4%), 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

Estimating proportion of medication errors likely to cause minor, moderate or severe harm

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

Table 3: Estimated number of errors per annum in England overall and for each stage of the medication use process in each setting, presented according to potential to cause harm

Error category	Number of medication errors per annum in England			
	Primary care	Care homes	Secondary care	Total for all settings
Prescribing				
Minor	21,170,690	1,447,770	1,663,208	24,281,668
Moderate	21,723,443	1,485,571	2,087,199	25,296,213
Severe	729,367	49,878	293,338	1,072,583
Total	43,623,500	2,983,219	4,043,745	50,650,464
Transitioning				
Minor	No data	No data	1,390,365	1,390,365
Moderate	No data	No data	1,744,801	1,744,801
Severe	No data	No data	245,217	245,217
Total	No data	No data	3,380,383	3,380,383
Dispensing				
Minor	21,295,902	2,281,526	891,667	24,469,095
Moderate	11,208,369	1,200,803	469,298	12,878,470
Severe	373,612	40,027	15,643	429,282
Total	32,877,883	3,522,355	1,376,609	37,776,847
Administration				
Minor	N/A	84,856,111	34,327,365	119,183,476
Moderate	N/A	6,727,552	2,721,538	9,449,090
Severe	N/A	249,169	100,798	349,967
Total	N/A	91,832,832	37,149,701	128,982,533
Monitoring				
Minor	1,582,202	68,225	149,307	1,799,734
Moderate	10,548,013	454,835	995,378	11,998,226
Severe	2,373,303	102,338	223,960	2,699,601
Total	14,503,519	625,398	1,368,644	16,497,561
All medication use errors				
Minor	44,048,794	88,653,632	38,421,912	171,124,338
Moderate	43,479,825	9,868,761	8,018,214	61,366,800
Severe	3,476,282	441,412	878,956	4,796,650
TOTAL	91,004,902	98,963,804	47,319,082	237,287,788

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 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, contributing to 1,708 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.

Table 4: Estimated national burden associated with primary and secondary care errors (base case scenario and alternative scenarios)

Base case and higher cost scenarios	**Cost (£)**	**Bed days/year**	**Deaths**
Base case (hospitalisations linked to definitely avoidable primary care ADEs and definitely avoidable ADEs during overnight hospital admissions)			
Primary care ADEs[30] • 5.2% of hospitalisations due to primary care ADEs • 2.3% of ADE admissions directly result in death caused by the ADE • 29.2% of ADE admissions result in death for which an ADE was a **contributing** factor* • 9% of ADEs definitely avoidable • Length of stay 5 days	83,673,627	136,811	627 7958*
Secondary care ADEs[31] • 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; • 0.38% of all admissions result in a death for which an ADE was a **contributing factor** • 0.03% of all admissions result in a death **caused by** an ADE* • 6.4% of ADEs definitely avoidable	14,788,955	44,815	1,081 85*
Total (base case)	98,462,582	181,626	1,708*
Alternative scenarios			
Scenario 1a: (base case + probably avoidable ADEs)			
Primary care ADEs[30] • 5.2% of hospitalisations due to primary care ADEs • 2.3% ADEs directly resulting in death • 72% of ADEs probably or definitely avoidable	605,298,575	989,697	5,013
Secondary care ADEs[31] • ADEs during overnight inpatient admissions • Deaths for which inpatient ADE was a **contributing factor** • 53.3% of ADEs probably or definitely avoidable	123,164,262	373,225	9,000
Total (Scenario 1a)	728,462,837	1,362,922	14,013
Scenario 1b: (base case + definitely avoidable ADEs during day case admissions)			
Primary care ADEs[30] • Hospitalisations due to primary care ADEs • 2.3% of ADEs directly result in death • 9% of ADEs definitely avoidable	83,673,627	136,811	627
Secondary care ADEs[31] • ADEs during all inpatient admissions • Deaths for which inpatient ADE was a **contributing factor** • 6.4% of ADEs definitely avoidable	28,170,381	85,365	2,058

Base case and higher cost scenarios	Cost (£)	Bed days/year	Deaths
Total (Scenario 1b)	111,844,008	222,176	2,685

*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

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 Supplementary Material (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, 3,817,817 bed-days, contributing to 22,303 deaths.

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

Burden on other NHS services	Cost (£)	Bed days/year	Deaths
Base case (hospitalisations associated with definitely avoidable primary care errors and definitely avoidable errors during overnight hospital admissions)			
Total (base case)	98,462,582	181,626	1,708
Primary care contacts associated with primary care errors[34]			
• 6.0% of primary care errors result in a visit to a GP	8,604,378*	-	-
• 15.41% of primary care errors result in a visit to a GP	22,098,911**	-	-
A&E attendances associated with primary care errors			
• 16.2% of A&E attendances due to ADEs[28] • 20.5% are avoidable[28] • 79.8% of A&E attendances do not result in admission[35]	75,902,982	-	-
ICU admissions associated with errors[29]			
• ICU admissions related to avoidable ADEs (8.1% of ICU admissions); length of ICU stay 4 days; • Death during ICU admission (14.0% of ICU admissions for avoidable ADEs)	5,473,747	4,188	147
Post-discharge resource use associated with secondary care errors[33]* **			
• GP visits (71.7% of errors requiring treatment) • Outpatient clinic visits (2.7% of errors requiring treatment) • Out-of-hours visits (1.8% of errors requiring treatment)	1,702,245	-	-

*Based on 239,011 GP visits; **Based on 613,859 GP visits; ***Based on 5,821,746 non-elective admissions leading to 75,683 medication errors, 56,308 of which required treatment
ADE = adverse drug event; A&E = accident and emergency; ICU = intensive care unit; GP = general practitioner; NHS = National Health Service

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 1,708 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, 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 health care 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 have 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, we had no data on burden of errors managed in care homes, 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

Similarly to another recent review in this area, reported error rates differ widely between studies due to differences in methods.[22] Error rates in the UK are similar to those in other comparable health settings such as the US and other countries in the European Union for primary care prescribing,[36] secondary care prescribing,[37] dispensing,[38] and administration.[39]

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.[40] 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 to our work, a short-life working group advised the English DHSC on what should be done to reduce medication errors.[41] One key recommendation was that in primary care settings, the use of evidence-based interventions such as a pharmacist-led information technology intervention (PINCER)[42] 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 NSAIDs, antiplatelets, antiepileptics, hypoglycaemics, diuretics, inhaled corticosteroids, cardiac glycosides, and beta-blockers.[24] Non-steroidal anti-inflammatory drugs (NSAIDs), anticoagulants and antiplatelets cause over a third of admissions due to avoidable ADEs.[30] Close to 80% of deaths were due to gastrointestinal bleeds caused by NSAIDs, aspirin, or warfarin.[30] Older people are more likely to suffer avoidable ADEs.[33] This presents a clear message for policymakers for 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 healthcare. 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.

Ethical approval

Not needed

Contributorship

RAE, EMC, 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 EMC 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.

Funding

This research is funded by the National Institute for Health Research (NIHR) Policy Research Programme and conducted through the Policy Research Unit in Economic Methods of Evaluation in Health and Social Care Interventions (EEPRU), ref. 104/0001. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care. EEPRU is a collaboration between researchers from two institutions (Centre for Health Economics, University of York and School of Health and Related Studies, University of Sheffield). This research involves a collaboration with colleagues at the University of Manchester.

This research was also funded by PREPARE - Partnership for Responsive Policy Analysis and Research. PREPARE is a collaboration between the University of York and the King's Fund funded by the Department of Health Policy Research Programme.

The views expressed in this report are those of the authors and not necessarily those of the Department of Health and Social Care. Any errors are the responsibility of the authors.

Conflict of interests

None declared

Acknowledgements

Thanks to Professor Bryony Dean Franklin and Professor Tony Avery for contributing their expertise to the original report. We would also like to thank the anonymous reviewers of the original report, whose comments greatly improved our work.

This report is independent research funded by the National Institute for Health Research Policy Research Programme (NIHR PRP) through its Policy Research Unit in Economic Evaluation of Health & Care Interventions (EEPRU, grant reference PR-PRU-104/0001.   The views expressed in this publication are those of the author(s) and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health and Social Care.

We would like to thank Fiona Campbell, Eva Kaltenthaler, Marrissa Martyn St James and Ruth Wong (ScHARR, University of Sheffield) who carried out the rapid reviews that have been used as a source of evidence for this research.

Part of the content of this paper has previously been published as Elliott RA, Camacho E, Campbell F, Jankovic D, Martyn St James M, Kaltenthaler E, Wong R, Sculpher M, Faria R, (2018). Prevalence and Economic Burden of Medication Errors in The NHS in England. Rapid evidence synthesis and economic analysis of the prevalence and burden of medication error in the UK. Policy Research Unit in Economic Evaluation of Health and Care Interventions. Universities of Sheffield and York. http://www.eepru.org.uk/article/prevalence-and-economic-burden-of-medication-errors-in-the-nhs-in-england/

Figure 1 legend

Figure 1: Estimated number of errors per annum in England overall and for each stage of the medication use process in each setting

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