

SUPPLEMENTARY MATERIAL

Estimating the impact on patient safety of enabling the digital transfer of patients' prescription information in the English NHS

Literature reviews

Prevalence of transition medication errors at interfaces between care locations in the UK (Review 1)

A rapid review of the literature was completed to identify studies that reported the prevalence of transition medication errors in England. The search strategy comprised terms for epidemiologic outcomes, care transitions, and medication errors. Prevalence was defined as the total number of items prescribed that have an error divided by the total number of items prescribed (i.e. the proportion of items prescribed that have a medication error). Observational (prospective or retrospective) studies that aimed to estimate the prevalence of medication errors were included. Incident reporting systems under-report errors (one study found that an error reporting system reported only 2.3% of those found by retrospective case note review [1]) so are not useful for deriving error incidence/prevalence. Studies of interventions designed to reduce the rate of transition medication errors were included if the baseline (pre-intervention) or control group error rates were reported.

Costs and health burden associated with these transition medication errors in the UK (Review 2)

A rapid review was carried out to identify published estimates of harm from all types of medication errors, not just transition medication errors. The primary aim of the search was to identify papers relating to the UK NHS or Irish healthcare systems. This search was not restricted to harm from transition medication errors only, to maximise the likelihood of identifying relevant papers. The search strategy was derived from a recent systematic review related to patient harm associated with ADEs [2] which used terms to identify ADEs and harm outcomes. Database searches were supplemented by citation and chain-searching five key publications in the field [3-7].

Impact of interoperable prescription information systems on transition medication errors (Review 3)

A rapid review was carried out to identify published estimates of benefits of interoperability systems designed to reduce transition medication errors at interfaces between care locations and transcription. Key recent reviews were the starting point for studies of interoperability solutions to support medicines safety at care location transitions in the UK setting [8-12]. We included all comparative study designs where the intervention was carried out at a care location transition and measured one of: transition medication error rates, costs, patient outcomes. This broad inclusion criterion was a pragmatic decision to identify a range of studies that were relevant to the evaluation. Study types included primary comparative studies, reviews (systematic, rapid, narrative, meta-analyses) and reviews of reviews.

Derivation of model parameters

Estimates of error prevalence

We used transition medication error rates reported in the studies identified during the reviews to estimate the prevalence of transition medication errors in England as a whole. Extrapolation methods were determined by data availability.

Methods to estimate medication errors undetected by medicines reconciliation

The added value of an interoperable prescription information system, relative to current practice, is to reduce the number of medication errors that remain undetected by standard medicines reconciliation at care transitions. However, the prevalence of these undetected transition medication errors was not

reported in the literature. Instead, the literature on medication errors at care transitions often reports transition medication errors detected during routine activities in standard care, for example, the number of errors detected by standard medicines reconciliation at admission or discharge. Therefore, the number of transition medication errors detected by medicines reconciliation were subtracted from the estimated total number of transition medication errors at four care transitions: admission, intra-hospital transitions, inter-hospital transitions, and discharge. In the absence of relevant data around the total number of transition medication errors at these care transitions, these were estimated by applying the treatment effect for medicines reconciliation versus no medicines reconciliation to the observed prevalence of transition medication errors detected by medicines reconciliation from Review 1 according to Equation 1. A Cochrane review of randomised controlled trials reported a relative risk reduction in items prescribed with a transition medication error of 0.13 following medicines reconciliation versus no medicines reconciliation [9].

Equation 1 – method for estimating the number of transition medication errors undetected by standard medicines reconciliation

$${}^1 error^{UD} = \left(\frac{error^{MR}}{(1-RR)} \right) - error^{MR}$$

where $error^{UD}$ is the total number of transition medication errors undetected by medicines reconciliation, $error^{MR}$ is the total number of transition medication errors detected by medicines reconciliation, and RR is the relative risk reduction of transition medication errors after medicines reconciliation compared with no medicines reconciliation.

Methods to estimate the total number of transition medication errors per year

The following section describes, for each specified care transition, how the prevalence estimates were scaled to population-level estimates for England.

Admission to hospital: The number of transition medication errors at admission was estimated by multiplying the prevalence of transition medication errors (Review 1) by the total number of items prescribed per year at hospital admission in England (46,521,652 items). The total number of items prescribed per year at admission was calculated by multiplying the mean number of items prescribed per inpatient ($n=4.78$ items) [13] with the total number of finished elective and emergency admission episodes in England (9,741,243 episodes) [14]. The total number of finished elective and emergency admission episodes was calculated by subtracting the number of day case finished consultant episodes (7,386,255 episodes) from the total number of finished admission episodes (17,127,498 episodes) reported by NHS Digital between 2018-19 [14]. Data from this year were chosen to exclude effects of the COVID-19 pandemic on hospital admissions.

Intra-hospital transition: In the absence of directly measured data, the proportion of inpatients who experience an intra-hospital transition was estimated by proxy from the proportion of patients who move between wards. A freedom of information request for 42 hospital Trusts found that the proportion of inpatients who transition between wards ranged between 9% and 88% of inpatients [15]. Boncea *et al* (2022) [16] report a case-control study of intra-hospital transitions and hospital-acquired infections in elderly patients. An intra-hospital transition was defined as moving between a ward or unit resulting in a change of ward ID. In the control cohort (i.e. patients without hospital-acquired infection), 71.7% of patients had at least one intra-hospital transition during their inpatient stay. Given the elderly nature of the estimation sample (median age: 79 years), this proportion of patients who moved between wards is likely to

be an overestimate for the average inpatient population. Therefore, we assumed conservatively that 17.9% of inpatient stays resulted in a ward transition (i.e. one-quarter of 71.7%). Whilst this estimate falls within the observed range (9% to 88% of inpatients), there is considerable uncertainty in its true value. This proportion was multiplied by the total number of finished elective and emergency admission episodes (9,741,243 episodes) [14] to estimate the total number of inpatient transitions per year (1,746,118 transitions). The total number of items prescribed at intra-hospital transitions (8,339,006 items) was calculated by multiplying the number of transitions with the average number of items prescribed as above ($n=4.78$ items) [13]. The number of transition medication errors during intra-hospital transitions was calculated by multiplying the number of items prescribed at intra-hospital transitions by the prevalence of transition medication errors during intra-hospital transfer identified by Review 1.

Inter-hospital transition: The number of medication errors during movement to a new hospital was calculated by multiplying the number of items prescribed at inter-hospital transitions (1,064,006 items) by the prevalence of transition medication errors when moving between hospitals identified by Review 1. In the absence of directly collected data, the number of items prescribed during inter-hospital transitions was calculated by multiplying the annual inter-hospital transitions (222,794 transitions) by the average number of items prescribed as above ($n=4.78$ items) [13]. The annual number of inter-hospital transitions was estimated from the most recent total number of inter-facility transition incidents (category 1 to 4) reported in the Ambulance System Indicators for England over a 12-month period (2021-22) [17]. This was the first complete dataset available that was not collected during the main COVID-19 pandemic period.

Discharge from hospital admission: The number of transition medication errors at discharge was estimated by multiplying the prevalence of transition medication errors from Review 1 by the total number of items prescribed per year at discharge in England (83,518,624 items). The total number of items prescribed per year at discharge was calculated by multiplying the mean number of items per discharge prescription in Lloyd *et al.* ($n=4.9$ items) [18] with the total number of finished admission episodes (FAE) (17,127,498 episodes) reported by NHS Digital between 2018-19 [14].

Estimates of transition medication error burden

Some medication errors do not lead to harm, others can lead to serious harms and death [19]. Ideally, the data needed to assess impact of medication errors occurring are sufficient to encompass all effects of the error and patient outcomes (intermediate measures such as primary and secondary health care utilisation, fatal and non-fatal serious harm outcomes (such as GI bleed, stroke, death rates), health status, life-years gained (LYG)/lost, quality-adjusted life-years (QALYs)). The costs associated with harm can be viewed from a healthcare provider perspective, as we have done in this study, or more broadly from a societal perspective. However, the evidence directly linking medication errors to patient harm and/or costs is sparse. Therefore, it has been necessary to utilise existing sources of data to allow the estimation of burden in terms of patient harm and cost to the NHS. 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 used was to identify available UK-based case studies of estimates of burden from ADEs and extrapolate to estimate the impact for England per annum. Data from non-UK case studies were used to supplement this evidence where UK studies were not available. For our base-case, we considered the number of hospitalisations (readmissions) and deaths associated with discharge to primary care with an error, and increased length of hospitalisations and deaths associated with admission, intra- and interhospital transfer errors. The key assumption is that definitely

avoidable ADEs approximate the harm from medication errors; hence these studies were considered acceptable.

Methods for estimating the potential of reported transition medication errors to cause harm

The proportion of inpatient episodes where a definitely avoidable ADE occurs (i.e. inpatients who have harm from a medication error) was derived from Davies *et al* (2009) [3] to be 0.9%. This figure was calculated by multiplying the proportion of inpatient episodes during which an ADE occurs (14.7%) by the proportion that were categorised as definitely avoidable (6.4%). The total number of FAEs used in the estimation of the number of transition medication errors was multiplied by 0.9% to estimate the number of patients with harm from a transition medication error. Davies *et al* (2009) also reported that 131 out of the 733 ADEs they observed (17.9%) related to drugs that were initiated prior to hospitalisation (i.e. drugs that they would have been taking at admission). This was applied to the number of patients with harm from a transition medication error to estimate the number of patients with harm from a transition medication error at the point of admission. The number of people with harm from an admission medication error was divided by the number of people with an admission medication error to generate the proportion of people who had a transition medication error who experience harm. This proportion was used throughout the modelling to estimate the number of patients experiencing harm based on the number of transition medication errors that occurred at the different transitions.

Methods for developing estimates of burden of medication errors

For transition medication errors that occurred during a process of admission (i.e. inpatient admission, intra-hospital transition, inter-hospital transition), the associated harm and burden were derived from the study of inpatient ADEs in a UK hospital by Davies *et al* (2009) [3]. In that study, of the people who had an ADE, 26.8% of people had an extended hospital admission, with a mean additional length of stay of 4 days. The excess bed day cost in the NHS (as a weighted mean of the cost for elective and non-elective admissions) was multiplied by 4 days for 26.8% patients with a transition medication error on admission. The excess bed day cost was most recently reported in the NHS schedule of reference costs in 2017/18 [20]. This value was inflated to a 2020/21 price year using the NHSCII pay and prices index [21]. Davies *et al* (2009) also reported that of the people who have an ADE, 0.18% of them die as a result. The number of people estimated to have a transition medication error during an admission process was multiplied by 0.18% to estimate the number of deaths.

For transition medication errors that occurred at the point of discharge following an inpatient stay the associated harm and burden were derived from a prospective cohort study across five NHS hospitals by Parekh *et al* (2018) [5]. This study reported that of the people with medication-related harm following hospital discharge, 21.1% were re-admitted to hospital. This value (21.1%) was multiplied by the estimated number of people with a transition medication error at discharge to estimate the number of people readmitted. The cost of these readmissions was estimated based on the mean cost of non-elective hospital admissions in the NHS in 2020/21 [22]. Osanlou *et al* (2022) published a recent observational study of adults admitted to an English hospital where an ADE was the reason for admission [23]. This study reported that the median duration of admissions due to ADEs was 6 days, which we used to estimate the number of bed days associated with these errors. Osanlou *et al* (2022) also reported that 0.42% of people admitted to hospital due to an ADE died as a result. This percentage (0.42%) was multiplied by our estimate of the number of people who were readmitted to hospital due to an error to estimate the number of people who died.

RESULTS

Table S1. Number and burden of transition medication errors and estimated reduction for different effect sizes following implementation of an interoperable prescription information system

	Admission	Intra-hospital transition	Inter-hospital transition	Discharge	TOTAL
Number of transition medication errors					
Pre-implementation	946,487	50,285	21,647	807,694	1,826,113
10% fewer errors	94,649	5,029	2,165	80,769	182,611
20% fewer errors	189,297	10,057	4,329	161,539	365,223
30% fewer errors	283,946	15,086	6,494	242,308	547,834
40% fewer errors	378,595	20,114	8,659	323,078	730,445
50% fewer errors	473,243	25,143	10,824	403,847	913,057
60% fewer errors	567,892	30,171	12,988	484,617	1,095,668
Number of patients episodes with harm from a transition medication error					
Pre-implementation	16,348	869	374	14,013	31,604
10% fewer errors	1,635	87	37	1,401	3,160
20% fewer errors	3,270	174	75	2,803	6,321
30% fewer errors	4,904	261	112	4,204	9,481
40% fewer errors	6,539	348	150	5,605	12,642
50% fewer errors	8,174	434	187	7,007	15,802
60% fewer errors	9,809	521	224	8,408	18,963
Excess bed days due to transition medication errors					
Pre-implementation	17,653	938	404	17,709	36,704
10% fewer errors	1,765	94	40	1,771	3,670
20% fewer errors	3,531	188	81	3,542	7,341
30% fewer errors	5,296	282	121	5,313	11,011
40% fewer errors	7,061	375	161	7,084	14,682
50% fewer errors	8,826	469	202	8,855	18,352
60% fewer errors	10,592	563	242	10,625	22,022
NHS cost of excess bed days due to transition medication errors					
Pre-implementation	£6,560,165	£348,717	£150,039	£10,704,318	£17,763,238
10% fewer errors	£656,016	£34,872	£15,004	£1,049,196	£1,755,088
20% fewer errors	£1,312,033	£69,743	£30,008	£2,098,393	£3,510,177
30% fewer errors	£1,968,049	£104,615	£45,012	£3,147,589	£5,265,265
40% fewer errors	£2,624,066	£139,487	£60,016	£4,196,785	£7,020,353
50% fewer errors	£3,280,082	£174,358	£75,019	£5,245,981	£8,775,442
60% fewer errors	£3,936,099	£209,230	£90,023	£6,295,178	£10,530,530
Deaths due to transition medication errors					

Pre-implementation	30	2	1	12	45
10% fewer errors	3	0	0	1	4
20% fewer errors	6	0	0	2	9
30% fewer errors	9	0	0	4	13
40% fewer errors	12	1	0	5	18
50% fewer errors	15	1	0	6	22
60% fewer errors	18	1	0	7	27

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