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Calculating the cost of medication errors: A systematic review of approaches and cost variables

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ABSTRACT

Introduction Medication errors are an unnecessary cost to a healthcare system and patients of a country. This review aimed to systematically identify published cost variables used to calculate the cost of medication errors and to explore any updates on findings already known on calculating the cost of medication errors during the past 10 years.

Methods A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Electronic databases, PubMed, Scopus, Emerald and JSTOR were searched, using keywords "medication error" AND "cost" and predetermined inclusion criteria. Duplicate articles were removed. Quality check was done using 10 criteria. Cost variables used in calculating the cost of medication errors were extracted from each article.

Results Among 3088 articles, 33 articles were selected for review. Most studies were conducted in Western countries. Cost variables used (types and number) by different studies varied widely. Most studies (N=29) had used direct costs only. A few studies (N=4) had used both direct and indirect costs for the purpose. Perspectives considered when calculating cost of medication errors also varied widely. A total of 35 variables used to calculate medication error costs were extracted from selected articles.

Conclusion Variables used to calculate the cost of medication errors were not uniform across studies. Almost a decade after systematic reviews previously reporting on this area, a validated methodology to calculate the cost of medication errors has still not been reported to date and highlights the still pending necessity of a standard method to be established.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Cost of medication errors is reported using different methodologies and no standard methodology was published up to 2016.

⇒ We aimed to identify any updates on calculating the cost of medication errors during the past 10 years.

WHAT THIS STUDY ADDS

⇒ A standard methodology nor a list of cost variables to calculate the cost of medication errors is still not available in the literature almost a decade after the previous review.

⇒ Cost variables used in calculating the cost of medication errors in related publications were collated.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Cost variables identified through this review provide an evidence base for policy-makers to develop a standard methodology/guideline for calculating the cost of medication errors.

INTRODUCTION

Medication error can be defined as a 'failure in the treatment process that leads to or has the potential to lead to, harm to patient'. Medication errors can happen at any stage of the treatment process[1] be it prescribing, compounding, dispensing, medication administration or monitoring.[2] They are medication related, always preventable and would, therefore, include preventable adverse drug reactions as well.[2] In addition to the unacceptable harm caused to patients, medication errors are an unnecessary cost to a healthcare system and patients of a country.[3] This study focuses on the cost of medication errors.

Cost of healthcare can differ according to the perspective that is being considered; provider, patient or third-party payer (insurance companies). The cost to the provider would be, the expenses of delivering healthcare services to patients. For the patient, it is the cost that they have to pay out of pocket for healthcare. Cost for third-party payer would be the amount that they pay to the providers for the services rendered for their client (patient).[4 5]

There are three types of healthcare costs. They are direct costs, indirect costs and intangible costs. Direct costs are the monetary costs directly related to prevention, treatment and diagnosis of the disease and include fees for services such as professional, medication, surgery, hospital stays, diagnostic tests like X-rays, ambulances and food. Indirect costs are also monetary costs, but they are not directly related to treating the disease. They

include losses due to an inability to engage in normal daily activities, work, domestic responsibilities and loss of income. Intangible costs are social, emotional and human costs (damage or loss to people). They are not related to money and are not measurable. Costs of pain, worry and other suffering that a patient or his family might endure are examples of intangible costs.[6] The cost of a medication error is ideally the sum up of all direct, indirect and intangible costs spent due to that error. Evaluation of direct and indirect costs is quite objective while evaluation of intangible cost is subjective.[7]

Appropriate and feasible cost variables (or elements, or parameters) of direct and indirect costs should be established first in order to calculate the cost of medication errors, and for these costs to be comparable across settings and countries.[8] These variables could vary by country because healthcare services and resources differ from country to country depending on their economy.

Among related studies, there were two systematic reviews that collated research on cost of medication errors. Patel *et al*[8] and Walsh *et al*,[9] reporting in 2016 and 2017 respectively, assessed the cost variables used in calculating the cost of medication errors by different research groups. Different perspectives of calculating costs, using a multitude of variables were reported, but neither reviews concluded on a universal/standardised set of variables that could be considered to compute the cost of medication errors, nor a formula or a model that could be used globally for this purpose.[8]

Patel *et al*[8] conducted a systematic review to identify approaches for calculating medication error costs across healthcare settings and included studies from 1993 to 2015. The review concluded that, a standard approach for exploring the costs of medication errors was lacking. He reported inconsistencies in the terminology used, and in the methods used to calculate cost of medication errors. The review found different methodologies used to derive the cost while in some cases, the same methodology was applied in different ways. Cost inputs used varied across studies, were not explicitly defined and did not describe how the cost inputs were relevant to medication errors. The number of cost inputs used to calculate medication error cost varied across studies based on subjective judgement of researchers. Therefore, Patel *et al*[8] recommended that future research is required to determine the most appropriate context-specific method for calculating costs.

Walsh *et al*[9] conducted a systematic review to quantify the economic burden of medication errors and also to identify methods and parameters used when calculating the cost of medication errors. This review included studies from 2004 to 2016 and reported similar findings to that of Patel's review. Further, Walsh *et al*[9] observed that the difference between calculated costs of medication errors was as large as €100 000 between studies which confirmed the lack of a standardised methodology for this purpose. His findings were mostly related to the hospital setting and lacked the social perspective of economic burden. Importantly, Walsh *et al* too noted the variability in financial information sources used to determine costs.

The burden of medication errors needs to be costed or otherwise its gravity cannot be justified against the investment made to avoid them. It is beneficial to have a universal formula which can be adjusted according to the country and healthcare setting, and enable objective comparisons across countries. According to Patel *et al*[8] and Walsh *et al*,[9] a standard methodology for calculating the economic burden of medication errors was lacking as at 2016. The current review aimed to explore any updates to this information based on recent research, and to systematically identify published cost variables used to calculate the cost of medication errors in local and international literature during the past 10 years (2011–2021).

METHODOLOGY

The systematic review was conducted based on the methodology specified in Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[10] The search was carried out in electronic databases, PubMed, Scopus, Emerald and JSTOR using keywords "medication error" AND "cost". Related articles published from 1 January 2011 to 13 November 2021 in English language were searched in databases using

Table 1 Inclusion criteria and exclusion criteria used for systematic review

Inclusion criteria	Exclusion criteria
Full-text articles	Review articles including systematic reviews, case studies and case series
Articles published in English language	Abstracts/conference proceeding where no full article was published
Articles published in the last 10 years (1 January 2011–13 November 2021)	Non-peer reviewed articles For example, technical reports, letters to editor, newspaper articles
All randomised controlled trials (RCT), non-RCTs, cohort, case–control, cross-sectional studies	Articles on interventions of new technologies to reduce medication errors and related cost savings
Studies focusing on medication errors that happen in healthcare settings	Articles focusing on impact of medication errors/preventable ADR/drug-related problems without a cost calculation
Studies having a component of calculating the cost of medication errors	Articles which could not be downloaded as full-text articles

ADR, adverse drug reaction.

predetermined inclusion and exclusion criteria specified in table 1.

Title and abstract screening were done simultaneously, relevant articles were selected by two reviewers, and discrepancies were resolved through discussion. Duplicate articles were removed by EndNote V.X9 software. Then, full texts were read by first reviewer to assess if articles were compatible with inclusion criteria. Articles including the rejected ones were reviewed by a second reviewer and any discrepancies were resolved until 100% agreement was reached. Final articles to be included in the systematic review were decided. Quality of each selected article was checked through a checklist of 10 criteria as done by Elliott *et al*.[11] Cost variables used in the calculation of medication error cost were extracted from each article.

RESULTS

A total of 3088 articles resulted from the initial keyword search in stated databases. Among them, 1485 articles were removed after limiting for language and year of publication, and 50 were removed due to duplicating of articles. After the title and abstract screening, 188 articles were selected for full-text reading. After removing articles which did not comply with inclusion criteria, 52 articles were selected for detailed analysis. Discrepancies were resolved through discussion among the two reviewers until 100% agreement was reached to include 33 articles for the systematic review. PRISMA flow diagram of articles selected for systematic review is shown in figure 1.

When quality of each article selected for the systematic review was assessed, only 6 articles matched 9 out of 10 criteria (18.18%) considered. Criteria such as, clearly mentioning the objective/s of the study, recruiting/selecting all subjects from the same or similar populations and reliability of the method of collecting data (medication errors), were met by all articles (100%).

Online supplemental table gives the general details of studies selected. We reviewed 33 articles which resulted from the systematic procedure explained in the methodology. They were from different countries (USA=7, UK=3, Brazil=3, France=3, Spain=2, Netherland=2, South Korea=1, Taiwan=1, Singapore=1, Romania=1, Ireland=1, Sri Lanka=1, Arabia=1, Germany=1, Iran=1, Malaysia=1, Switzerland=1, Mexico=1 and Canada=1). Most of the studies in the systematic review were conducted in western countries (78.78%).

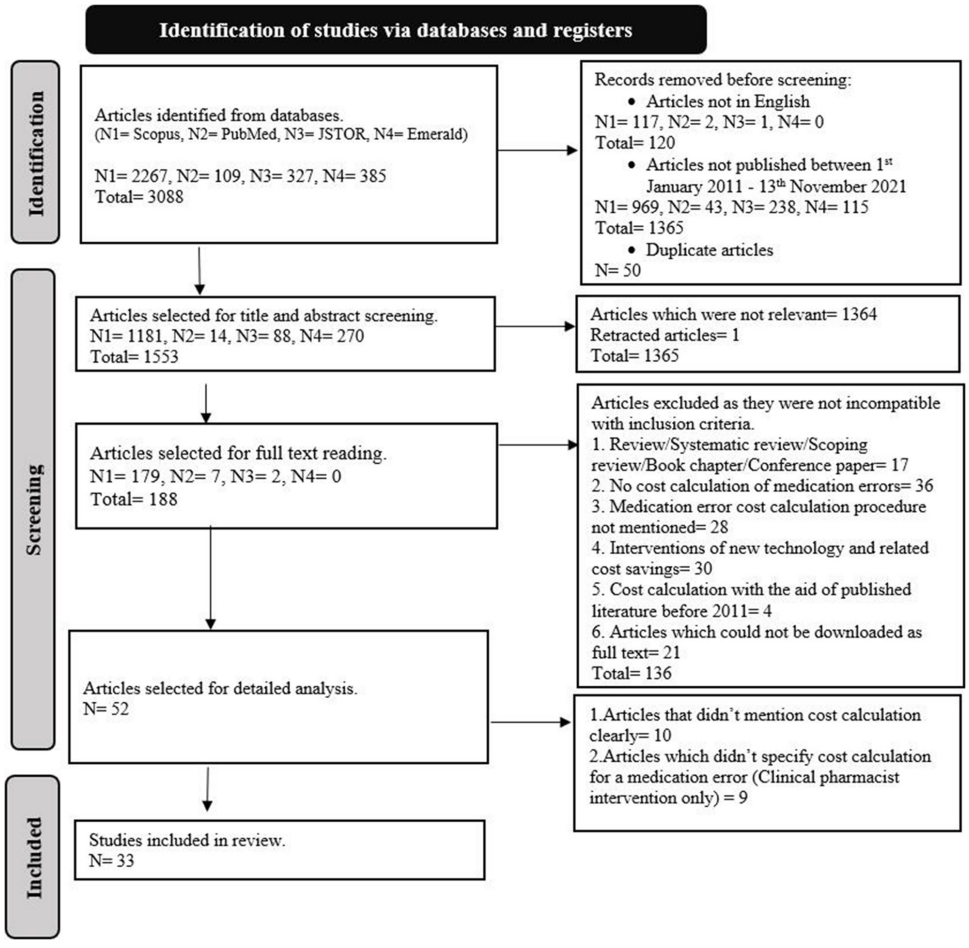

Figure 1 PRISMA flow diagram of articles selected for systematic review. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Perspectives considered when calculating medication error cost differed considerably. Seven approaches of perspectives were considered in studies; provider perspective (N=10), patient perspective (N=3), insurance company perspective (N=1), patient and insurance company perspective (N=2), provider and patient perspective (N=2), provider, patient, and insurance company perspective (N=1), and no perspective defined (N=14). Most studies had not defined the perspective.

The type of medication errors considered for calculating costs varied among studies. Some studies had calculated the cost of any medication error,[3 12–14] while some had considered prescribing errors only.[15 16] Some studies had limited the scope to more specific types of errors like, DePuy *et al*[17] had calculated cost for antiretroviral-related errors.[17] Forster *et al*[18] had calculated cost for inaler handling errors, Al-lela *et al*[19] had calculated cost for imunisation dose errors, and Ranchon *et al*[20] had calculated the cost for hospital readmissions due to drug-related problems[21 22] and cost due to adverse drug reactions.[23–25]

Cost variables used for calculating cost of medication errors identified by each article were extracted and are shown in table 2.

DISCUSSION

As in previous systematic reviews,[8 9] our systematic review also showed that different studies calculated cost of medication errors in different ways. There was a wide variation in the methodologies used to calculate the cost of medication error. Some studies had used economic models to calculate medication error cost,[3 14 18] some had calculated cost avoidance due to clinical pharmacists' interventions where avoided costs were mainly medication cost in most studies.[17 22 26–30] Some studies had calculated incremental cost-effective ratios.[21 24 31] There was still no reported research on a validated methodology to calculate the cost of medication errors.

Cost variables used (types and number) by different studies also had a wide variation, similar to findings by Patel *et al*[8] and Walsh *et al*.[9] Most studies (N=29) had used direct costs only. Even then, some studies (N=21) had specified the type of direct cost variables such as, cost of hospitalisation, medication costs, nursing care costs, diagnostic tests costs and emergency department visit cost,[23 32] while some (N=8) had just only mentioned direct costs without disaggregating the variable.[17 33 34] Some studies (N=4) had used both direct and indirect costs to calculate medication error costs.[18 21] Studies such as by Karapinar-Çarkıt *et al*[21] had described the cost variables used in their study very clearly. Where indirect costs variables were used, the cost variables often used were cost for absenteeism from paid and unpaid work, and cost of permanent harm to patient.[18 21 35 36] Litigation cost variable was rarely considered in studies. However, McCullagh and Slattery,[37] in a 6-year review about medication related litigation in Ireland, stated that 'the median total cost, in purely financial terms, of a medication-related claim that closed with a payment to the plaintiff was €60 991, including median damages of €33 858'.[37] This suggests that litigation costs are also an impactful cost variable to consider.

The two systematic reviews by Patel *et al* and Walsh *et al* which were on medication error cost calculation at the initial literature survey of this study were mostly outside the study period considered in this review. In fact, we deliberately selected the study period to avoid these two systematic reviews so as to avoid duplication of findings and to explore if any changes had taken place since. Patel *et al*[8] and Walsh *et al*[9] included studies up to 2015 but the current search was from 2011 January to 2021 November. We found 19 related articles which were published after 2017 which contributed to our systematic review, and 6 articles which were published before 2017 but not included by Patel *et al* and Walsh *et al*. The current systematic review had eight articles that overlapped with Patel *et al*'s (24.2% overlap), and six articles that overlapped with Walsh *et al*'s (18.18% overlap). There were only seven articles that overlapped between Walsh *et al* and Patel *et al* (21.21% overlap). Considering that there was minimum overlap between the current systematic review and past literature, it is noteworthy that the findings of research conducted after 2015 had not changed. Still, the most appropriate context-specific method for calculating the cost of medication errors has not been established as recommended by Patel *et al*.[8] Clear description of cost sources and explicit cost calculations were not available as recommended by Walsh *et al*.[9] We were able to extract the various cost variables that were used for the purpose of calculating the cost of medication errors, but as found in previous reviews, they were not systematically used by all. The appropriateness, adequacy, relevance and feasibility of using these cost variables were not assessed and appeared to be subjective.

There are some limitations to this systematic review to be acknowledged. We only included studies related to the past decade, mainly to avoid duplications in findings with previous reviews. However, by including articles from 2011 onwards we may have missed some important articles which are related. We used only "medication error" AND "cost" as keywords which may have led to miss some important articles. Electronic databases search was limited to four databases, and some articles which we felt were relevant could not be downloaded (N=21).

CONCLUSION

This systematic review revealed that different studies had used different cost variables to calculate the cost

Table 2 List of cost variables for calculating the cost of medication errors identified from articles reviewed and variability in terminology used to denote variables

Serial no.	Types of cost variables* used by researchers and variability in terminology	Related research that used the cost variable
1	Cost of medication	Ranchon *et al*[20]
	Drug costs	Oñatibia-Astibia *et al*[31]; Shanika *et al*[22]; Assiri *et al*[30]; Gharekhani *et al*[26]; Samp *et al*[36]; Nerich *et al*[15]; Al-lela *et al*[19]; Hug *et al*[23]; Aceves-Avila *et al*[35]
	Costs for prescription drugs	Karapinar-Çarkıt *et al*[21]
	Cost for non-prescription drugs (OTC)	Karapinar-Çarkıt *et al*[21]
	Direct acquisition costs of medications	Malfará *et al*[28]
	Drug-related costs	Piazza *et al*[24]
2	Direct medical cost	Rozenblum *et al*[16]; Al-lela *et al*[19]; Leendertse *et al*[38]
3	Costs of medical hospital material and medications	Paulino *et al*[13]
	Medicines cost and health accessories cost	da Rocha *et al*[33]
	General equipment cost	Leguelinel-Blache *et al*[32]
4	Pharmacy cost	Leguelinel-Blache *et al*[32]; Piazza *et al*[24]
	Cost of pharmaceutical care	Chen *et al*[29]
5	Treatment cost	Jones *et al*[14]
6	Blood products costs	Piazza *et al*[24]
7	Cost of haemodialysis	Chen *et al*[29]
8	Drug monitoring cost	Samp *et al*[36]
9	Extra tests costs	Jones *et al*[14]
	Diagnostic tests cost	Leguelinel-Blache *et al*[32]; Chen *et al*[29]
	Medical procedures cost (diagnostic tests)	Leendertse *et al*[38]
10	Medical transport cost	Leguelinel-Blache *et al*[32]
11	Laboratory tests cost	Paulino *et al*[13]; Karapinar-Çarkıt *et al*[21]
	Biological exams cost	Leguelinel-Blache *et al*[32]
	Clinical laboratory cost	Piazza *et al*[24]
12	Radiological examinations costs	Paulino *et al*[13]; Piazza *et al*[24]
13	Cost of hospitalisation	Jones *et al*[14]; Neumiller *et al*[39]; Neag *et al*[40]; Forster *et al*[18]; Choi *et al*[3]; Hug *et al*[23]; Piazza *et al*[24]; Ranchon *et al*[20]
	Average cost of hospitalisation per day	Park *et al*[27]; Najafzadeh[41]
	Cost of hospital stay	Nerich *et al*[15]
	Cost for a bed	Chen *et al*[29]
14	Hospital admission cost	Oñatibia-Astibia *et al*[31]; Hohl *et al*[25]; Karapinar-Çarkıt *et al*[21]
15	Hospitalist managed cost	Park *et al*[27]
16	Emergency department visit cost	Oñatibia-Astibia *et al*[31] ; Neumiller *et al*[39]; Forster *et al*[18]; Najafzadeh[41]; Hohl *et al*[25]; Karapinar-Çarkıt *et al*[21]
17	Cost for intensive care unit/day	Karapinar-Çarkıt *et al*[21]
18	Physician office visits cost	Neumiller *et al*[39]; Forster *et al*[18]
19	Specialist consultation cost	Leguelinel-Blache *et al*[32]; Leendertse *et al*[38]; Karapinar-Çarkıt *et al*[21]
20	Costs of contacts with the general practitioner	Karapinar-Çarkıt *et al*[21]
	GP consultation at practice	
	GP home visit	
	GP contact by phone	
21	Inpatient costs	Meier *et al*[42]
22	Outpatient visit cost	Hohl *et al*[25]

Continued

Table 2 Continued

Serial no.	Types of cost variables* used by researchers and variability in terminology	Related research that used the cost variable
23	Labour cost	Al-lela *et al*[19]
	Cost for a social worker	Karapinar-Çarkıt *et al*[21]
	Cost for a psychologist	Karapinar-Çarkıt *et al*[21]
	Cost for a psychiatrist	Karapinar-Çarkıt *et al*[21]
	Cost for physiotherapist	Karapinar-Çarkıt *et al*[21]
	Cost for manual therapist	Karapinar-Çarkıt *et al*[21]
	Cost for dietician	Karapinar-Çarkıt *et al*[21]
	Cost for complementary therapists	Karapinar-Çarkıt *et al*[21]
24	Nursing care cost	Leguelinel-Blache *et al*[32]; Chen *et al*[29]; Piazza *et al*[24]
25	Administration cost	Leguelinel-Blache *et al*[32]
26	Surgery cost	Piazza *et al*[24]
	Surgical procedures cost	Hohl *et al*[25]
27	Cost for anaesthesia	Piazza *et al*[24]
28	Central supply cost	Leguelinel-Blache *et al*[32]
29	Dietetics costs	Leguelinel-Blache *et al*[32]
30	Security costs	Leguelinel-Blache *et al*[32]
31	Social services costs	Leguelinel-Blache *et al*[32]; Karapinar-Çarkıt *et al*[21]
32	Transportation costs	Leendertse *et al*[38]
33	Litigation cost	McCullagh and Slattery[37]
34	Estimated cost of permanent harm to patient	Samp *et al*[36]
35	Indirect costs	Forster *et al*[18]
	Costs of absenteeism and presentism (absenteeism—work time missed per week, Presentism—impairment while at work per week)	
	Cost of the days of work lost by the patients due to their possible aggravation	Aceves-Avila *et al*[35]
	Productivity loss costs one admission	Leendertse *et al*[38]
	Costs due to productivity losses	
	Cost for absenteeism from paid and unpaid work	Karapinar-Çarkıt *et al*[21]

*Similar cost variables using different terminology were collated.
OTC, Over The Counter.

of medication error. Most studies used one or two variables only, and a very few had considered different possible cost variables. That too, the appropriateness, feasibility and relevance of the variables used were not established nor validated and appeared to be subjective. Almost a decade after systematic reviews reporting on this area, a validated methodology to calculate the cost of medication error has still not been reported to date and highlights the still pending necessity of a universal formula or standard method to be established.

RECOMMENDATIONS AND PRACTICE IMPLICATIONS

Absence of a universal formula or at least a standard list of cost variables to calculate the cost of medication errors has led to inconsistencies and generation of non-comparable medication errors costs across countries. This systematic review is evidence for these irregularities, and thus, we recommend that a standard methodology that is universally acceptable should be devised on calculating the cost of medication errors which could be adjustable according to a healthcare setting of interest. Also, cost variables identified through this systematic review provide an evidence base for policy-makers in the world on developing a standard methodology/guideline for calculating cost of medication errors. The cost variables identified through this review could be a draft to finalise a standard list of cost variables with the help of experts in healthcare such as doctors, nurses, pharmacists, cost accountants and statisticians. Once a universally acceptable standard list of cost variables

has been established, the appropriateness, accessibility and measurability of each of these cost variables would have to be explored for a particular country before implementation. Deviations from the standard methodology (or standard list of cost variables) could be disclosed when publishing costs of medication errors in order to overcome limitations in comparability.

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REFERENCES

1 Nr S, Bmy C. Medication safety in hospitals: avoiding medication errors in the medication use process. *Adv Pharmacoepidemiol Drug Saf* 2013;02:03.
2 Aronson JK. Medication errors: definitions and classification. *Br J Clin Pharmacol* 2009;67:599–604.
3 Choi I, Lee S-M, Flynn L, *et al*. Incidence and treatment costs attributable to medication errors in hospitalized patients. *Res Social Adm Pharm* 2016;12:428–37.
4 Kim DD, Silver MC, Kunst N, *et al*. Perspective and costing in cost-effectiveness analysis, 1974–2018. *Pharmacoeconomics* 2020;38:1135–45.
5 Arora V, Moriates C, Shah N. The challenge of understanding health care costs and charges. *AMA J Ethics* 2015;17:1046–52.
6 Yousefi M, Assari Arani A, Sahabi B, *et al*. Household health costs: direct, indirect and intangible. *Iran J Public Health* 2014;43:202–9.
7 Palazzo F, Stirparo G, Terranova L. Can we objectively measure the human cost of disease *J Headache Pain* 2003;4:s26–30.
8 Patel K, Jay R, Shahzad MW, *et al*. A systematic review of approaches for calculating the cost of medication errors. *Eur J Hosp Pharm* 2016;23:294–301.
9 Walsh EK, Hansen CR, Sahm LJ, *et al*. Economic impact of medication error: a systematic review. *Pharmacoepidemiol Drug Saf* 2017;26:481–97.
10 Title TT. PRISMA 2020 expanded checklist. 2021.
11 Elliott RA, Camacho E, Campbell F, *et al*. Prevalence and economic burden of medication errors in the NHS in England. *Policy Res Unit Econ Eval Heal Care Interv* 2018;1–174. Available: http://www.eepru.org.uk/wp-content/uploads/2018/02/eepru-report-medication-error-feb-2018.pdf
12 Elliott RA, Camacho E, Jankovic D, *et al*. Economic analysis of the prevalence and clinical and economic burden of medication error in England. *BMJ Qual Saf* 2021;30:96–105.
13 Paulino GME, Matsuda LM, Matta ACG, *et al*. Costs and root causes of medication errors and falls in a teaching hospital: cross-sectional study. *Texto Contexto - Enferm* 2021;30:1–15.
14 Jones MD, Franklin BD, Raynor DK, *et al*. Costs and cost-effectiveness of user-testing of health professionals' guidelines to reduce the frequency of intravenous medicines administration errors by nurses in the United kingdom: a probabilistic model based on Voriconazole administration. *Appl Health Econ Health Policy* 2022;20:91–104.
15 Nerich V, Borg C, Villanueva C, *et al*. Economic impact of prescribing error prevention with computerized physician order entry of Injectable antineoplastic drugs. *J Oncol Pharm Pract* 2013;19:8–17.
16 Rozenblum R, Rodriguez-Monguio R, Volk LA, *et al*. Using a machine learning system to identify and prevent medication prescribing errors: a clinical and cost analysis evaluation. *Jt Comm J Qual Patient Saf* 2020;46:3–10.
17 DePuy AM, Samuel R, Mohrien KM, *et al*. Impact of an antiretroviral stewardship team on the care of patients with human immunodeficiency virus infection admitted to an academic medical center. *Open Forum Infect Dis* 2019;6:ofz290.
18 Forster R, Ratcliffe A, Lewis M, *et al*. Cost–utility analysis of an intervention designed to reduce the critical handling error of insufficient Inspiratory effort. *Eur J Health Econ* 2018;19:1303–18.
19 Al-lela OQB, Bahari MB, Al-abbassi MG, *et al*. Estimation of immunization providers' activities cost, medication cost, and immunization dose errors cost in Iraq. *Vaccine* 2012;30:3862–6.
20 Ranchon F, Salles G, Späth H-M, *et al*. Chemotherapeutic errors in hospitalised cancer patients: attributable damage and extra costs. *BMC Cancer* 2011;11:478.
21 Karapinar-Çarkıt F, van der Knaap R, Bouhannouch F, *et al*. Cost-effectiveness of a transitional pharmaceutical care program for patients discharged from the hospital. *PLoS One* 2017;12:e0174513.
22 Shanika LGT, Jayamanne S, Wijekoon CN, *et al*. Ward-based clinical pharmacists and hospital readmission: a non-randomized controlled trial in Sri Lanka. *Bull World Health Organ* 2018;96:155–64.
23 Hug BL, Keohane C, Seger DL, *et al*. The costs of adverse drug events in community hospitals. *Jt Comm J Qual Patient Saf* 2012;38:120–6.
24 Piazza G, Nguyen TN, Cios D, *et al*. Anticoagulation-associated adverse drug events. *Am J Med* 2011;124:1136–42.
25 Hohl CM, Nosyk B, Kuramoto L, *et al*. Outcomes of emergency department patients presenting with adverse drug events. *Ann Emerg Med* 2011;58:270–9.
26 Gharekhani A, Kanani N, Khalili H, *et al*. Frequency, types, and direct related costs of medication errors in an academic nephrology ward in Iran. *Ren Fail* 2014;36:1268–72.
27 Park B, Baek A, Kim Y, *et al*. Clinical and economic impact of medication reconciliation by designated ward pharmacists in a Hospitalist-managed acute medical unit. *Res Social Adm Pharm* 2022;18:2683–90.
28 Malfará M, Pernassi M, Aragon D, *et al*. Impact of the clinical pharmacist interventions on prevention of pharmacotherapy related problems in the Paediatric intensive care unit. *Int J Clin Pharm* 2018;40:513–9.
29 Chen CC, Hsiao FY, Shen LJ, *et al*. The cost-saving effect and prevention of medication errors by clinical pharmacist intervention in a Nephrology unit. *Medicine* 2017;96:e7883.
30 Assiri T, Khurshid F, Almutairi M, *et al*. Impact of pharmacist intervention in patient counseling at point of hospital discharge in a specialized cardiac center in Saudi Arabia. *Trop J Pharm Res* 2017;16:1187.
31 Oñatibia-Astibia A, Malet-Larrea A, Mendizabal A, *et al*. The medication discrepancy detection service: a cost-effective Multidisciplinary clinical approach. *Aten Primaria* 2021;53:43–50.
32 Leguelinel-Blache G, Castelli C, Rolain J, *et al*. Impact of pharmacist-led multidisciplinary medication review on the safety and medication cost of the elderly people living in a nursing home: a before-after study. *Expert Rev Pharmacoecon Outcomes Res* 2020;20:481–90.
33 da Rocha C, Carlotto J, Zanis Neto J. Analysis of the interventions in antineoplastic therapy by a clinical pharmacy service at a tertiary hospital in Brazil. *J Oncol Pharm Pract* 2022;28:1049–55.
34 Romero-Ventosa EY, Pérez-Landeiro A, Leboreiro-Enríquez B, *et al*. Short stay unit and emergency department: pharmacotherapeutic interventions and its impact. *Am J Ther* 2016;23:e1307–14.

35 Aceves-Avila FJ, Benites-Godínez V, Ramos-Remus C. Cost of medication errors in rheumatic patients in Mexico. *Clin Rheumatol* 2011;30:1421–4.
36 Samp JC, Touchette DR, Marinac JS, *et al*. Economic evaluation of the impact of medication errors reported by U.S. clinical pharmacists. *Pharmacotherapy* 2014;34:350–7.
37 McCullagh M, Slattery D. Medication related litigation in Ireland: a 6-year review. *Br J Clin Pharmacol* 2019;85:2155–62.
38 Leendertse AJ, Van Den Bemt PMLA, Poolman JB, *et al*. Preventable hospital admissions related to medication (HARM): cost analysis of the HARM study. *Value Health* 2011;14:34–40.
39 Neumiller JJ, Mandal B, Weeks DL, *et al*. Potential adverse drug events and associated costs during transition from hospital to home. *Sr Care Pharm* 2019;34:384–92.
40 Neag MA, Bocșan IC, Ștefan V, *et al*. The inadequate use of antibiotics in a Gastroenterology Department. *FARMACIA* 2019;67:1066–70.
41 Najafzadeh M, Hospital W. Economic value of pharmacist-led medication. 2017.
42 Meier F, Maas R, Sonst A, *et al*. Adverse drug events in patients admitted to an emergency Department: an analysis of direct costs. *Pharmacoepidemiol Drug Saf* 2015;24:176–86.

Supplementry table - General details of the studies selected for review

Perspective considered	First author, Year, Country	Study title	Study setting and study population
Provider	Rachel Ann Elliott 2021 UK (12)	Economic analysis of the prevalence and clinical and economic burden of medication error in England	Reported medication errors in UK primary care, secondary care and care home settings
Provider	Matthew D. Jones 2021 UK (14)	Costs and cost-effectiveness of user-testing of health professionals' guidelines to reduce the frequency of intravenous medicines administration errors by nurses in the United Kingdom: A probabilistic model based on voriconazole administration	Hospital in patients receiving intravenous voriconazole of all 121 hospital trusts and health boards
Provider	Oñatibia-Astibia A 2021 Spain (31)	The medication discrepancy detection service: A cost-effective multidisciplinary clinical approach	Patients who had a discrepancy between their active medical charts and the medicines they were actually taking in an Integrated Healthcare Organization
Provider	Géraldine Leguelinel-Blache 2020 France (32)	Impact of pharmacist-led multidisciplinary medication review on the safety and medication cost of the elderly people living in a nursing home: A before-after study	Patients in a French nursing home who were older than 65 years and resident in the nursing home for at least six months
Provider	Joshua J. Neumiller 2019 USA (39)	Potential adverse drug events and associated costs during transition from hospital to home	Hospitalized patients 50 years of age or older referred for home care services following discharge
Provider	Maria Adriana Neag 2019 Romania (40)	The inadequate use of antibiotics in a gastroenterology department	Patients consecutively admitted in a gastroenterology department in an emergency county hospital

Provider	Mark McCullagh 2019 Ireland (37)	Medication related litigation in Ireland: A 6-year review	Not Applicable
Provider	Florian Meier 2015 Germany (42)	Adverse drug events in patients admitted to an emergency department: An analysis of direct costs	Patients visiting the ED between 1 to 30 September in a tertiary care hospital.
Provider	Omer Qutaiba B. Al-lela 2012 Malaysia (19)	Estimation of immunization providers' activities cost, medication cost, and immunization dose errors cost in Iraq	Five public health clinics in Mosul
Provider	Corinne M. Hohl 2011 Canada (25)	Outcomes of emergency department patients presenting with adverse drug events	Patients presenting to the emergency department (ED)
Patient	Fatma Karapinar-C 2017 Netherland (21)	Cost-effectiveness of a transitional pharmaceutical care program for patients discharged from the hospital	All admitted patients at the internal medicine department using at least one prescribed drug for chronic use at hospital admission
Patient	Mehdi Najafzadeh 2016 USA(41)	Economic value of pharmacist-led medication reconciliation for reducing medication errors after hospital discharge	High-risk patients
Patient	Francisco Javier Aceves-Avila 2011 Mexico (35)	Cost of medication errors in rheumatic patients in Mexico	Patients attending the rheumatology clinic of a reference hospital
Patient and insurance company	Afshin Gharekhani 2014 Iran (26)	Frequency, types, and direct related costs of medication errors in an academic nephrology ward in Iran	All adult patients who were prescribed at least one drug during their hospital stay in an academic nephrology ward in Iran
Patient and insurance company	V Nerich 2013 France (15)	Economic impact of prescribing error prevention with computerized physician order entry of injectable antineoplastic drugs	Injectable chemotherapy prescriptions, from the regional referral centre in oncology of a university hospital
Insurance company	Florence Ranchon 2011 France (20)	Chemotherapeutic errors in hospitalized cancer patients: Attributable damage and extra costs	Patients receiving anti-neoplastic agents in a teaching hospital.

Both provider and patient	Rebecca Forster 2018 UK (18)	Cost–utility analysis of an intervention designed to reduce the critical handling error of insufficient inspiratory effort	Asthma review data of patients aged 16 years or older using different inhaler types in UK
Both provider and patient	Anne J. Leendertse 2011 Netherland (35)	Preventable hospital admissions related to medication (HARM): Cost analysis of the HARM study	Unplanned (acute) admissions from four universities and 17 general hospitals from all regions in the Netherlands
Provider, patient, and insurance company	V Nerich 2013 France (15)	Economic impact of prescribing error prevention with computerized physician order entry of injectable antineoplastic drugs	Injectable chemotherapy medication orders for patients in the regional referral centre in oncology of a university hospital
No perspective defined	Bogeum Park 2021 South korea (27)	Clinical and economic impact of medication reconciliation by designated ward pharmacists in a hospitalist-managed acute medical unit	Patients admitted to tertiary academic hospital medicine center for more than 24 hours
No perspective defined	Gabriela Machado Ezaias Paulino 2021 Brazil (13)	Costs and root causes of medication errors and falls in a teaching hospital: Cross sectional study	All reports of accidents/falls and medication errors referred to the Patient Safety Center of a teaching hospital
No perspective defined	Camile da Rocha 2021 Brazil (33)	Analysis of the interventions in antineoplastic therapy by a clinical pharmacy service at a tertiary hospital in Brazil	Patients with oncological and hematological diseases in a public tertiary teaching hospital
No perspective defined	Tat Ming Ng 2020 Singapore	Impact of round-the-clock pharmacist inpatient medication chart review on medication errors	Patients with “errors” (cases) were compared with those with “near misses” (controls) in an acute care teaching hospital
No perspective defined	Ronen Rozenblum 2020 USA (16)	Using a machine learning system to identify and prevent medication prescribing errors: A clinical and cost analysis evaluation	Patient who had at least one outpatient encounter with a provider affiliated with Brigham and Women’s Hospital (BWH) or Massachusetts General Hospital (MGH) during the two-year study period

No perspective defined	Ashley M. DePuy 2019 USA (17)	Impact of an antiretroviral stewardship team on the care of patients with human hmmunodeficiency virus infection admitted to an academic medical center	All admissions of patients ≥18 years of age with ≥1 antiretroviral medication indicated for the treatment of HIV-1 infection in an academic medical center
No perspective defined	Márcia Malfará 2018 Brazil (28)	Impact of the clinical pharmacist interventions on prevention of pharmacotherapy related problems in the paediatric intensive care unit	Patients consecutively admitted to the paediatric intensive care unit of a tertiary-care university hospital in Brazil
No perspective defined	L.G.T Shanika 2018 Sri Lanka (22)	Ward-based clinical pharmacists and hospital readmission: a nonrandomized controlled trial in Sri Lanka	Patients those with chronic non-communicable diseases who needed long-term follow-up at the medical clinic in a teaching hospital
No perspective defined.	Chia-Chi Chen 2017 Taiwan (29)	The cost-saving effect and prevention of medication errors by clinical pharmacist: intervention in a nephrology unit	Nephrology ward of the National Taiwan University Hospital (NTUH)
No perspective defined.	Turki Assiri 2017 Saudi Arabia (30)	Impact of pharmacist intervention in patient counseling at point of hospital discharge in a specialized cardiac center in Saudi Arabia	All discharged adult cardiac patients of either sex from adult cardiology wards in a specialized cardiac center
No perspective defined	Elena Yaiza Romero-Ventosa 2016 Spain (34)	Pharmacotherapeutic reports as tools for detecting discrepancies in continuity of care	All the patients older than 16 years who stay more than 24 hours in observation beds of the emergency department and in the short stay unit
No perspective defined	Insun Choi 2016 USA (3)	Incidence and treatment costs attributable to medication errors in hospitalized patients	All patients admitted to two hospitals in New Jersey (U.S. State) over 1/1/2005 -12/31/2006, excluding the emergency room or intensive care unit
No perspective defined	Balthasar L. Hug 2012 Switzerland (23)	The costs of adverse drug events in community hospitals	Patients in six community hospitals
No perspective defined	Gregory Piazza 2011 USA (24)	Anticoagulation-associated adverse drug events	All inpatient anticoagulant-associated ADEs, including adverse drug reactions (ADRs) and medication errors, reported at Brigham and

			Women's Hospital through the Safety Reporting System from May 2004 to May 2009