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Cost-Benefit Analysis of the Detection of Prescribing Errors by Hospital Pharmacy Staff

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Abstract

Objective: Prescribing errors are a major cause of iatrogenic patient morbidity and therefore interventions aimed at preventing the adverse outcomes of these errors are likely to result in cost reduction. However, it is unclear whether the costs associated with these preventive measures are outweighed by the cost reductions (benefits). Therefore, a study was set up to analyse costs and benefits of detecting prescribing errors by hospital pharmacy staff.

Design: During 5 consecutive days in two Dutch hospitals in February 2000 all medication orders, in which prescribing errors were detected, were analysed. A cost-benefit analysis was performed, based on direct medical costs only. The benefit-to-cost ratio was calculated by taking into account the net time hospital pharmacy staff needed for the prevention of the error (this included potential time saving for nursing staff, when an error was prevented by hospital pharmacy staff instead of nursing staff), as well as taking into account the possible consequences of the prescribing error (were the error not prevented).

Results: A total of 3540 orders, of which 351 contained prescribing errors (9.9%), were analysed. During the 1-week period investigated, time-investment of the pharmacy staff had net costs of EUR285 (2000 values). During the same period estimated benefits related to this investment were EUR9867. The finding of higher benefits than costs was robust in sensitivity analysis.

Conclusions: From this study it can be concluded that prevention of prescribing errors by hospital pharmacy staff results in higher benefits than the costs related to the net time investment.

Adverse drug events occur frequently in hospitalised patients.[1] In a recent review article an incidence of 0.7 to 6.5% was reported and 28 to 56% of these events were preventable.[2] Preventable adverse drug events result from medication errors.[3] Bates et al.[4] estimated that the annual costs attributable to preventable adverse drug events are $US2.8 million (1993 values) for a 700-bed teaching hospital. Therefore, prevention of medication errors will not only result in less drug related morbidity for the patient, but also in reduced costs. As prescribing errors are a major cause of preventable adverse drug events, interventions aimed at preventing these errors are likely to result in cost reduction. Several studies have shown that prescribing errors may be reduced when computerised physician order entry is used.[5-7] Another possibility for the reduction of prescribing errors is the use of clinical pharmacy services. Preventable adverse drug events caused by prescribing errors decreased by 66%, when a pharmacist participated on physician rounds in the intensive care unit.[8] Furthermore, clinical pharmacy services are associated with decreased hospital mortality rates[9,10] and decreased cost of care.[11,12]

In The Netherlands, computerised physician order entry is not yet feasible in most hospitals, but written medication orders are generally entered into a computer by the hospital pharmacy staff. Prescription errors are detected at that stage and prescribing physicians are subsequently contacted by hospital pharmacists regarding all serious prescription errors. Furthermore, the hospital pharmacy staff contact nurses to clarify medication orders that are not clear or that contain less serious errors. In this way hospital pharmacy staff prevent potential adverse drug events caused by prescribing errors. However, it is unclear whether the costs associated with this effort in prevention outweigh the benefits of lower costs associated with adverse drug events. This study analyses costs and benefits of detecting prescribing errors by the hospital pharmacy staff.

Methods

Setting

The study was conducted within the departments of clinical pharmacy of two general hospitals in the Northern region of The Netherlands: one 600-bed teaching hospital (hospital I) and one 300-bed non-teaching hospital (hospital II).

Data Collection

During 1 week in each hospital in February 2000 all medication orders, in which prescribing errors were detected during routine control by hospital pharmacy staff, were collected. In both pharmacies, prescriptions are entered into a pharmacy computer system by pharmacy assistants. The computer system alerts for wrong dosages, drug-drug interactions and (pseudo) double medications. Before entering the prescription into the computer, the pharmacy assistants clarify unclear prescriptions by contacting nurses (e.g. illegible handwriting, missing information). Because entering the prescriptions into the computer is a routine task for the hospital pharmacy (necessary for drug distribution tasks), in the cost-benefit analysis no account is taken for the time spent by hospital pharmacy staff on prescriptions without errors.

Prescribing errors were defined as errors in the name, strength or dosage form of a drug, in the dosage, in the route of administration, in the instructions for use, in the length of therapy or in the combination with the other medication used by the patient. As hospital pharmacy staff do not routinely check whether the drug is indicated for that specific patient, wrong indication was not included in the prescribing errors. As dosage is dependent on indication, a dosage was only considered to be too high when it exceeded the maximum dosage for all indications.

Prescribing errors were classified in six classes of seriousness according to (a modified version of) the National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP) taxonomy of medication errors:[13]

- A1 – a prescription error has been made, but the error is so minor that the medication order cannot be misunderstood [e.g. aspirin (acetylsalicylic acid) 100 instead of aspirin 80; 100mg tablets are not available];

- A2 – a prescribing error has been made, but the nurse cannot administer the medication without having to gather additional information [e.g. salbutamol (albuterol) 0.4mg is prescribed without including the dosage form];
- B – a prescribing error has been made but administration to the patient will have no clinical consequences (e.g. dose frequency too high, but total daily dosage not too high);
- C – a prescribing error has been made, that could potentially result in the need for an increased frequency of patient monitoring (e.g. dosage of metoclopramide too low);
- D – a prescribing error has been made, that could potentially result in damage to the patient (e.g. dosage of opioid drug too high);
- E – a prescribing error has been made, that could potentially result in the death of the patient (e.g. insufficient treatment of serious infection).

The errors were classified independently by two hospital pharmacists. For those errors that were classified in different classes, the two pharmacists came together to reach consensus.

For every prescribing error the potential consequences for the patient (were the error not detected) were estimated, as well as the need for monitoring or treatment of these consequences. As error prevention by the pharmacy staff could result in time saving in the nursing staff – in particular for A2-errors – this was also recorded as a possible consequence.

Finally, the time needed to prevent the prescribing error for the pharmacy staff (pharmacists and assistants) was recorded.

Each prescribing error (one medication order could contain several errors) was entered into a database system as a case. For each case the following parameters were recorded: age and gender of patient, medical speciality, hospital (teaching or non-teaching), drug, type of error (e.g. drug-drug interaction, no maximum dosage prescribed on an 'as needed' order), seriousness, consequence and need for monitoring/treatment, time saving for nursing staff, time for pharmacy assistant and time for hospital pharmacist.

Cost-Benefit Analysis

We performed a cost-benefit analysis,[14] based on direct costs of time investment of pharmacy, nursing and medical staff, drugs, diagnostic procedures and medical interventions. This means that indirect costs of production losses were not included, i.e. our study is from the healthcare perspective. Production losses may occur if, for example, overdose causes poisoning, causing an increased length of stay in the hospital. No costs of intangibles, such as those related to pain and suffering, were included in the analysis. Our focus on direct medical costs only therefore corresponds to a conservative estimate of the benefits. As costs and benefits several aspects were considered:

1. As the pharmacy assistant's salary [EUR15.43 (2000 values) per hour] is lower than the average of the nursing staff (EUR17.24 per hour), correcting a prescription by an assistant instead of a nurse involves lower time-investment costs and net benefits were counted (this concerned all errors of seriousness class A2 and some of class B). If, however, a pharmacist is involved, higher time-investment costs may occur as the pharmacists' salary (EUR51.28 per hour on average) surpasses that of the nursing staff and net costs were counted.
2. If an overdose was prescribed, the difference with the lower market price of the correct dosage was counted as net benefit. For too low a dosage similar reasoning was applied to count net costs.
3. If the wrong medication was prescribed, a correction involves benefits of the size of the costs of the wrong medication. Market prices of the correct prescription were counted as costs.
4. If a medication error would require the use of another drug to treat the adverse drug event resulting from the error, market prices of the additional drug prescription were counted as benefits.
5. If a medication error would require a follow-up or increased monitoring, 10 minutes of nursing

Table I. Estimated unit cost prices in EUR

Physician visit	9[16]
Regular hospital day	250[16]
Intensive care hospital day	1139[16]
PTCA	5849[17]
Myocardial infarction	6557[17]

PTCA = percutaneous transluminal angioplasty.

time was assumed and costed. This figure was then counted as benefit of preventing the medication error.

6. Poisonings were assumed to require an extra visit of the medical doctor and the costed visits were then counted as benefits.

7. If a medication error would cause an increase of the duration of hospital stay, the excess duration of stay was costed and then counted as a benefit.

8. If a medication error would require follow-up diagnostic testing, these tests were costed and counted as benefits.

9. Costs related to potential complications averted by preventing the prescribing error were counted as benefits. Where possible, a risk assessment was done to estimate the probabilities of several complications. For example, in counting the benefits of preventing an overdosage of a nonsteroidal anti-inflammatory drug (NSAID) we estimated a relative risk of gastrointestinal toxicity of 2, based on a meta-analysis in which low dosages of NSAIDs are compared with high dosages.[15]

Correct doses and market prices of drugs were derived from the Dutch Physicians Desk Reference ('Farmacotherapeutisch Kompas'). Diagnostic tests were monetarily valued using Dutch healthcare tariffs.[16] Table I lists the other estimated cost prices used in the analysis.[17,18]

Our estimated benefit-to-cost ratio reflects net benefits divided by net costs. Net costs were defined as the monetary value of time investment by the pharmacy staff minus that of the time investment averted in the nursing staff (see point 1 above). Net benefits were derived from the monetary values of the consequences of averting a prescription error (points 2 through 9 above). Total benefits were defined as net benefits of consequences minus net costs of investment.

A sensitivity analysis was performed by:

- exclusion of the major cost drivers
- assuming 20 instead of 10 minutes of nursing time for follow-up and monitoring
- assuming salaries of nurses are equal to pharmacist salaries (as is often the case in the US).

Table II. General characteristics of the prescribing error cases

Mean age in years (SD)	60.0 (20.2)
Gender (% female)	60
Hospital (% teaching hospital)	81
Medical speciality [n (%)]	
Gynaecology	72 (21)
Internal medicine	63 (18)
Surgery	56 (16)
Neurology	51 (15)
Cardiology	35 (10)
Other[a]	74 (21)
Drug class [n (%)]	
CNS (mostly opioids)	113 (32)
Gastrointestinal system (mostly antiemetics)	69 (20)
Blood (mostly anticoagulants)	49 (14)
Respiratory tract (mostly inhalation preparations)	37 (11)
Cardiovascular system (e.g. nitrates)	25 (7)
Other[b]	58 (17)
Seriousness of error[c] [n (%)]	
A1	18 (5)
A2	189 (54)
B	13 (4)
C	67 (19)
D	62 (18)
E	2 (0.6)

a Category 'other' consists of: oncology, psychiatry, respiratory, orthopaedics, paediatrics, geriatrics and intensive care.

b Category 'other' consists of: skin, female reproductive system, hormones, antimicrobials, eye, musculoskeletal system.

c **A1**: a prescription error has been made, but the error is so minor that the medication order cannot be misunderstood; **A2**: a prescribing error has been made, but the nurse cannot administer the medication without having to gather additional information; **B**: a prescribing error has been made but administration to the patient will have no clinical consequences; **C**: prescribing error has been made, that could potentially result in the need for an increased frequency of patient monitoring; **D**: prescribing error has been made, that could potentially result in damage to the patient; **E**: a prescribing error has been made, that could potentially result in the death of the patient.

Table III. Most frequently occurring error types and associated benefits when error is prevented (total benefits = net benefits minus net costs)

Error type	n (%)	Benefits in EUR
Instructions on dosage or use lacking	155 (44.1)	60[a]
Maximum dose on 'as needed' order lacking		
opioid drug	21 (6.0)	373[b]
metoclopramide (n = 17)/domperidone (n = 2)	19 (5.4)	67[c]
paracetamol (acetaminophen)	7 (2.0)	252[d]
antipsychotics	6 (1.7)	25[c]
Name of drug wrong or unclear	27 (7.7)	1[a]
Dosage form lacking with inhalation drugs	22 (6.3)	2[a]
Two benzodiazepines used in one patient	15 (4.3)	23[e]
Double medication (numerous drugs)	13 (3.7)	225[f]
Dosage too low (e.g. antibacterials)	12 (3.4)	1482[g]
Dosage of NSAIDs too high	7 (2.0)	156[h]
Other	47 (13.4)	6916[i]
Total	**351 (100.0)**	**9581**

a When error would not have been detected by hospital pharmacy staff, this would take extra time for nursing staff to clarify the prescription.

b Error results in possibility of overdosage of opioid drugs, requiring extra monitoring time for nursing staff and possible use of antidote (naloxone).

c Error results in possibility of overdosage of metoclopramide/domperidone/antipsychotics, requiring extra monitoring time for nursing staff and possible use of antidote (biperidene).

d Error results in possibility of overdosage of paracetamol, requiring extra monitoring of liver function and possible use of antidote (acetylcysteine).

e Error results in possibility of drowsiness and increased risk of falling, requiring extra monitoring time of nursing staff.

f Benefits result mainly from preventing the use of a drug that is not needed, because the drug is already given (e.g. in another form, or by another name); sometimes double medication results in overdosage requiring extra monitoring time of nursing staff.

g This error type contains one of the major cost drivers, namely insufficient dosage of dalteparin in a patient with an acute coronary syndrome.

h Error results in possibility of gastric toxicity, requiring treatment with a proton pump inhibitor therapy for 1 week.

i This error type contains the three other major cost drivers, namely flucytosine (benefits EUR2402), bisoprolol (EUR493) and amoxicillin (EUR3422) as well as several drug-drug interactions.

NSAIDs = nonsteroidal anti-inflammatory drugs.

Results

In hospital I a total of 2620 medication orders were collected in 1 week and in hospital II 920 orders were collected. In this total of 3540 orders 351 prescribing errors were discovered (9.9%). Some general characteristics of the prescribing error cases can be found in table II.

During the 1-week period investigated, time-investment of the pharmacy staff had estimated net costs of EUR285 (time investment of nursing staff for correcting errors was deducted). During the same period estimated net benefits related to this investment together with the associated net benefits when the errors are prevented, were EUR9867.

Table III shows the error types occurring most frequently, together with the associated benefits when the error is prevented. The costs associated with lacking information (e.g. instructions on dosage lacking) are the lowest. These errors always require further clarification before the drug can be administered. When the prescription is clarified by pharmacy assistants the costs are lower than when it is done by nursing staff, which explains the benefits in most error types. For wrong or unclear name of drug, the hospital pharmacist often resolved the error. Therefore, this error type is associated with increased costs instead of benefits, because nursing time is cheaper than pharmacist time. However, pharmacy assistants were more often involved in preventing these types of errors, so costs are outweighed by total benefits.

Figure 1 shows the distribution of the benefits over the different error seriousness classes. Major cost drivers in this study were dalteparin (dosage too low; possible consequence is an acute coronary intervention or myocardial infarction), bisoprolol (used in patient with asthma; may result in bronchoconstriction and therefore an increased length of hospital stay), flucytosine (incorrect monotherapy; possible consequence is emerging resistance of the fungus and therefore an increased length of hospital stay) and amoxicillin (non-documented route of administration and therefore lack of efficacy and sepsis, resulting in 3 days of intensive care treatment). The benefits involving the major cost drivers constitute 79% of total benefits. In table IV the possible consequences of the prescribing errors and their associated costs are shown. The increased length of hospital stay is related to the errors with bisoprolol, flucytosine and amoxicillin, while the acute coronary intervention is related to the error with dalteparin.

The sensitivity analysis showed:

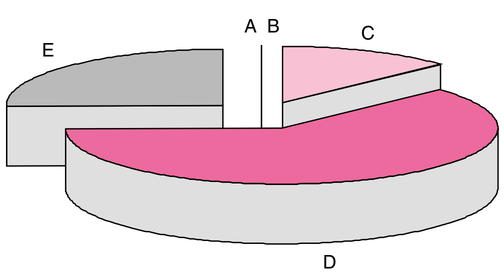

Fig. 1. Distribution of total benefits over the different error seriousness classes (A to E). Total benefits were EUR9581 (2000 values). **A1:** a prescription error has been made, but the error is so minor that the medication order cannot be misunderstood; **A2:** a prescribing error has been made, but the nurse cannot administer the medication without having to gather additional information; **B:** a prescribing error has been made but administration to the patient will have no clinical consequences; **C:** prescribing error has been made, that could potentially result in the need for an increased frequency of patient monitoring; **D:** prescribing error has been made, that could potentially result in damage to the patient; **E:** a prescribing error has been made, that could potentially result in the death of the patient.

Table IV. Consequences of prescribing errors and their associated net benefits when the errors are prevented

Consequence	Net benefits when error is prevented in EUR
Extra monitoring time from nursing staff	256
Extra drug use and extra laboratory tests	1878
Extra length of hospital stay	5950
Acute coronary intervention/myocardial infarction	1235
Other	548
Total	**9867**

- benefits of EUR2012, when excluding the major cost drivers
- benefits of EUR10 123, when assuming 20 minutes extra nursing time instead of 10 minutes spent on an error
- benefits of EUR10 232, when assuming nurses and pharmacists have equal salaries.

Discussion

The costs associated with adverse drug events in general have been described by Bates et al.,[4] while the impact of clinical pharmacy services on the incidence and costs of adverse drug events have also been described.[8-12] However, all these studies are conducted in hospitals in the US. To our knowledge, no studies have been published on the costs and benefits of preventing prescribing errors by the hospital pharmacy staff in Europe. The high benefits in relation to the small net investment costs found in this study would result in a global cost reduction of EUR479 100 per year for the two hospitals (EUR21 per patient) and the prevention of 18 252 errors per year.

Assumptions had to be made on the possible consequences of the prescribing errors, had they not been prevented by the hospital pharmacy staff. Often the assumption relates to increased intensity of nursing, and we, for example, assumed 10 minutes extra nursing time required for monitoring of patients at risk for parkinsonism due to overdosage of drugs. Almost 80% of the benefits were however related to 4 cases (major cost drivers).These major cost drivers will be discussed now to show plausibility of the assumptions and robustness of our results.

The dosage of dalteparin was too low in a patient, who was prescribed this drug for an acute coronary syndrome (this drug is used exclusively for this indication in that specific hospital). A number of studies have been published using a two times higher dosage in acute coronary syndromes, as is shown in a recent meta-analysis.[19] These studies have shown dalteparin to be equally effective to heparin. It seems likely that the use of a much lower dosage does not result in effective treatment of the patient. A patient not treated effectively may experience a myocardial infarction, may die or may require an acute intervention such as percutaneous transluminal coronary angioplasty (PTCA). Furthermore, the error may result in increased duration of hospitalisation in an acute coronary ward. We assumed a 5% chance that an acute PTCA intervention had to be performed and a 15% chance on a myocardial infarction (at 40 days, the risk of recurrent ischaemic events is 20%[19] when placebo is given instead of heparin), and have thus counted 5% of the PTCA costs and 15% of the myocardial infarction costs. Effective treatment prevents 29 events (death or myocardial infarction) per 1000 patients treated,[19] so in reality this patient may not have had a benefit from the correct dosage of dalteparin. The number of interventions prevented by half of the standard dosage of dalteparin is not known. Therefore, in our sensitivity analysis we took the worst case scenario (the error with dalteparin not leading to any costs or benefits).

The use of bisoprolol in a patient with asthma may lead to bronchoconstriction, which responds well to a β_2-adrenoceptor agonist.[20] We assumed an increased length of hospital stay of 2 days because of this bronchoconstriction and treatment with salbutamol/ipratropium bromide inhalation 4 times daily during these 2 days. For patients already hospitalised because of heart failure (probable indication of bisoprolol in the specific hospital), 2 days increase in length of hospital stay for an acute asthma attack seems a plausible assumption.

Flucytosine was used in one patient as a single antimycotic agent. When not combined with amphotericin B, flucytosine is known for a high failure rate of 57%[21-23] often caused by the emergence of antifungal drug resistance.[23,24] Therefore, it was assumed that the therapy failed and that the patient had to remain in hospital for an additional 10 days. For a systemic fungal infection, 10 days extra in hospital seems very modest. Real costs could therefore have been even higher.

Finally, one of the major cost drivers was intrapleural administration of amoxicillin, which involves a nondocumented route. A literature search showed that the intrapleural route of administration is documented for aminoglycosides in patients with chronic empyema or post-pneumonectomy space infection.[25-28] We were not able to identify studies that look into the efficacy and safety of intrapleural administration of amoxicillin, but in one study methicillin was used.[28] However, this was not a controlled, double-blind, randomised study. Therefore, data on the effectiveness of penicillins administered intrapleurally are lacking. We were not able to identify studies that look into the efficacy and safety of intrapleural administration of amoxicillin. The possible consequence of this prescribing error may have been lack of efficacy, resulting in sepsis. We assumed 3 days of hospitalisation in the intensive care unit as extra costs involved with this error. The direct effects of amoxicillin when administered intrapleurally are unknown and are not included in the costs, nor are the costs involved with emergence of resistance which could occur when infections are not treated effectively.

Although our assumptions were plausible, one could argue that in reality most prescribing errors would not have resulted in the consequences we assumed, because nurses and doctors on the hospital wards would prevent many errors. With the high workload though in Dutch hospitals this may, however, be unlikely, and nurses and doctors will surely be unable to prevent all errors.

We have made conservative estimates in this study regarding the costs of the consequences of a prescribing error using the most plausible estimates. To investigate sensitivity of our result we re-analysed the data excluding the four major cost drivers. This limited sensitivity analysis revealed that total benefits of preventing errors by hospital pharmacy staff would still be EUR86 350 per year for the two hospitals considered.

On the other hand our assumptions may be too conservative, e.g. because of assuming not enough time spent on an error by nursing staff or by assuming much lower salaries for nurses than for pharmacists. Therefore, both assumptions were also tested in the limited sensitivity analysis resulting in total benefits of EUR491 900 and EUR497 350 respectively.

The study has a number of limitations. As is already mentioned above, the actual costs of adverse drug events could not be established but had to be estimated. Furthermore, the total duration of the study was very short. Finally, only two hospitals were studied, so generalisation of the results may be difficult.

Notwithstanding these limitations, our study is one of the first to look into the costs and benefits of the detection of prescribing errors. From this study it can be concluded that preventing of prescribing errors by hospital pharmacy staff results in benefits of EUR86 350 to EUR497 350 a year for two Dutch hospitals (or EUR4 to EUR22 per patient).

Conclusions

Hospital pharmacy staff of two Dutch hospitals contribute significantly to cost savings, by preventing prescribing errors. Investments in staffing of hospital pharmacy are likely to pay off in terms of savings in costs of in-hospital patient care.

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