Medication Errors in Hospitalized Cardiovascular Patients

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Background: The Institute of Medicine’s report To Err Is Human: Building a Safer Health System recommends pharmacist participation in patient rounds as an immediate approach to reducing medical errors. In the same report and in prior publications, cardiovascular drugs have been commonly associated with severe adverse drug events.

Methods: We systematically reviewed the experience of a clinical pharmacist on the cardiology wards between September 1, 1995, and February 18, 2000. We classified medication errors according to the type of error, medications involved, personnel involved, stages of drug administration involved, and time of year most frequently associated with errors.

Results: Among 14,983 pharmacist interventions, 4,768 were related to medication errors, or 24 medication errors per 100 admissions. The most common errors involved the wrong drug (36.0%) or wrong dose (35.3%), and cardiovascular medications were involved in 41.2% of the errors. Prescribers were associated with most of the errors, and the transition from outpatient to inpatient was the most common point in the system for the occurrence of these medication errors. Higher numbers of errors were also identified during the transition period of house staff, and the total number of errors increased during the study period.

Conclusions: Through the clinical pharmacist’s identification and correction of medication errors, 2 areas of improvement that may reduce medication errors were identified. The first is ensuring accurate knowledge of a patient’s outpatient medication regimen. The second involves improving the education and support of new interns during their initial months of training. This work exemplifies the approach recommended by the Institute of Medicine to reduce medical errors through systematic analyses rather than ascribing fault to individuals.

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lected included patient identifiers, date, specific medical service, form of intervention (oral, written, both, or requested consultation), medications involved in the intervention, and whether recommendations were followed. In addition, at the time of data entry, each intervention was categorized by the specific type of intervention or recommendation made by the clinical pharmacist, including a category for medication errors. For all interventions that were classified as medication errors, a textual description of the event was entered into the database. Interventions were not recorded when the clinical pharmacist was absent because of vacation, illness, or leave. During these periods, alternate pharmacists covered the service who did not record interventions in the database.

CLINICAL PHARMACIST ROLE

The clinical pharmacist was specifically trained in cardiovascular medicine and actively participated in patient care with physicians and nurses on cardiology services. As it was not possible for a single pharmacist to participate on physician rounds with 4 cardiology services simultaneously, the pharmacist intervention occurred throughout the day and evening. The pharmacist’s activities paralleled those of the physicians in working up new patients as they arrived, preparing paperwork and counseling as patients were discharged, and responding to questions or problems. This work included reviewing medications for all patients on the cardiology wards, taking medication histories directly from patients, communicating with physicians and nurses regarding medication issues directly or through entries in the medical chart, conducting discharge counseling, providing a series of lectures for medical house staff regarding cardiovascular medications, participating on physician rounds with one of the cardiology teams daily, and responding to queries from physicians and nurses whenever needed. This integration into the team allowed the clinical pharmacist to evaluate a large number of patients and provide teaching to medical house staff and nurses without significant increases in the time required for rounds. Medication errors were addressed as soon as they were identified through the physicians, nurses, and pharmacy.

IDENTIFICATION AND ANALYSIS OF ERRORS

For this study, we focused on interventions that were considered to represent medication errors, including changing an inappropriate drug, dosage, or drug combination; resumption of an inadvertently missing medication; stopping or adjusting therapy because of a known allergy; or discontinuation of a medication being given to the wrong patient. Most of these medication errors were identified and corrected before an ADE occurred; therefore, they represent potential ADEs.

Once identified, medication errors were then sorted according to the type of error, using the approach of the ADE Prevention Study Group: wrong dose, wrong drug, wrong patient, drug interaction, allergy, missing medication, or wrong dosage form. The numbers of errors per year, errors per month, errors per 100 admissions, and medications most frequently associated with errors were calculated. For medication errors that included textual descriptions, we identified the provider involved and the point at which the error occurred within the drug administration process. For this subset, we also evaluated the number of errors by provider type per intern rotation for the most recent 26 rotations. Because intern rotations varied from 3 to 5 weeks, we calculated the mean number of errors per week by provider type to compensate for the different length rotations. The Duke University Institutional Review Board reviewed and approved this study.

RESULTS

Data were collected for 54 months from September 1, 1995, through February 18, 2000, during which 24,538 patients were admitted to the cardiology wards. There were 14,983 documented interventions, including 11,112 medication errors with textual descriptions. Ten medication errors with textual descriptions were eliminated from this study because they involved laboratory errors. An additional 3,666 interventions met our definition of a medication error, resulting in 4,768 medication errors included in this study. This represented about 5.3 medication errors per day worked, or about 19 errors per 100 admissions (24 errors per 100 admissions, excluding months when the clinical pharmacist was not available).

The number of errors per 100 admissions per year increased by 59.5% between 1995 and 1999 (Table 1). The number of errors per month during each year is presented in Figure 1A. In general, there appeared to be an increase in the number of errors during the summer. Adjusting the number of errors per month by the number of admissions for each month did not noticeably alter the trends seen for each year (Figure 1B). Table 2 shows the frequency of each type of medication error, including an example of an error that was classified within each type. The most commonly identified types of medication errors were administration of the wrong drug (1718, 36.0%) or wrong dose (1685, 35.3%). Errors by medication class are presented in Table 3. Cardiovascular medications accounted for 41.2% of the medications involved in the errors. Among cardiovascular medications, 48.4% of errors were related to digoxin or antiarrhythmic agents. From the subset of 1102 errors with textual descriptions, prescribers (physicians and physician assistants) were associated with 692 medication errors (62.8%), pharmacists with 284 errors (25.8%), nurses with 53 errors (4.8%), and multiple disciplines with 73 errors (6.6%). Of the errors attributed to prescribers, 374 (54.0%) were classified as admission errors, ie, errors related to an unintended change in medications or dosages from what the patient was taking before admission. Another 284 (41.0%) of the medication errors from prescribers were attributed to lack of drug knowledge, and 28 (4.0%) were related to errors at discharge.

In 1998, the mean number of errors by provider type per week during each rotation was greater during the summer and the December and January holidays than at any other times of the year (Figure 2A). This same trend

<table>
<thead>
<tr>
<th>Table 1. Errors per 100 Admissions</th>
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<tr>
<td>Year</td>
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<tr>
<td>1995</td>
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*In 1997, no intervention data were collected for approximately 3 months. The number of errors per 100 admissions was calculated by using the total admissions for 9 months.
was seen with physician and physician assistant medication errors in 1998. In 1999 (Figure 2B), there was a trend toward more total errors and physician and physician assistant errors in the summer, but the trend was less pronounced than in 1998. No increase in errors occurred around the December and January holidays in 1999. Overall, the mean number of errors per year did not appear appreciably different.

**COMMENT**

This study documents the identification and prevention of more than 4000 medication errors during routine pharmacist participation on physician rounds during 4 1/2 years on a cardiology teaching hospital service. The rate of medication errors of 24 per 100 admissions was more than 4 times the rate of errors reported by Lesar and colleagues from northeast New York but much less than the 66 errors per 100 admissions reported by Bates and colleagues when missing doses were included as medication errors. Whereas not all medication errors will result in an ADE, and not all ADEs are due to medication errors, our rate of errors was also greater than the rate of potential ADEs reported in the literature. Our findings that administration of the wrong drug was the most common type of medication error also differed from prior results. Other studies have reported use of the wrong dose as the most commonly identified cause for medication errors or ADEs.

Three notable medication error trends were identified in our study, including: (1) a high number of errors attributed to lack of knowledge of the patient’s drug therapy before admission, (2) an increase in errors during periods of house staff transition, and (3) a gradual increase in the number of medication errors during the study period. These findings confirm the potential for pharmacist participation in physician rounds to identify and markedly decrease medication errors. These results are directly applicable to the approximately 400

**Figure 1.** A, Number of monthly errors, 1995 to 2000. B, Number of monthly errors per 100 admissions, 1995 to 2000.
and are also likely to be pertinent to the remaining hospitals to the extent that medication errors occur outside of medical training settings.

There are several possible explanations for the higher rates of potential ADEs or medication errors than those observed in earlier work.8,7 First, cardiovascular medications have been cited as one of the most common classes of drugs associated with medication errors and ADEs.9,8 The ADE Prevention Study Group found that the odds ratio of severe ADEs with cardiovascular medications was 2.4 times that of other medications. Because our study was conducted on a cardiology service, the greater propensity for using cardiovascular drugs likely increased the potential ADE rate. Second, several prior studies8,5,7 identified ADEs retrospectively by nurse solicitation of voluntary reports or review of hospital charts, potentially failing to identify all events that had occurred previously. Investigations that identified events prospectively relied on pharmacist monitoring from a remote location, potentially further contributing to missed errors.6 The prospective approach to identifying medication errors at the bedside used in our study and the specialized training of our pharmacist regarding medical therapeutics are likely to have contributed to the identification of more errors.

Dosing errors have been the most commonly cited type of medication error or cause of an ADE. Our study found that selection of the wrong drug, rather than improper dosing, was the most common error on the cardiology service. Again, this difference may be because of the manner in which medication errors were identified in our study compared with other studies. Physician ordering has been the most frequently reported source of medication errors and ADEs, and this was also true in our study. However, unlike other studies,5,8 we found that most of these errors were not because of lack of knowledge of the drug, as previously mentioned. The lack of patient information, including knowledge of a patient’s current medications, was the third most common system failure associated with ADEs in a study by Leape et al.5 Without accurate and complete knowledge of a patient’s medication regimen, especially for patients with chronic disease treated with complex medical regimens, the transition from an outpatient setting to an inpatient setting is subject to numerous medication errors. One potential solution to this problem is an electronic medication record that is accessible by any provider and that can be expediently updated in the case of prescription changes. Our institution is implementing several information technology advancements that include electronic access to some ambulatory medication summaries. However, further technological advancements and careful consideration of new patient privacy regulations are needed before additional improvements will be possible. A second potential solution involves the use of clinical pharmacists to obtain medication histories from patients on admission. One study10 found that mortality was reduced in

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### Table 2. Number of Medication Errors Identified by Type of Error

<table>
<thead>
<tr>
<th>Type of Error</th>
<th>No. (%) of Events</th>
<th>Example of Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergy</td>
<td>32 (0.07)</td>
<td>Documented allergy to penicillin; ampicillin was ordered, entered, and sent to patient</td>
</tr>
<tr>
<td>Drug interaction</td>
<td>360 (7.6)</td>
<td>Patient taking a stable dosage of digoxin and amiodarone at home; the digoxin dosage was doubled on admission orders</td>
</tr>
<tr>
<td>Missing medication</td>
<td>488 (10.2)</td>
<td>Patient being treated with cefazidime for hospital-acquired pneumonia; medication voided off medication administration records before course completed, resulting in missed dose before error was found and corrected</td>
</tr>
<tr>
<td>Wrong dose</td>
<td>1685 (35.3)</td>
<td>Patient receiving danaparoid sodium infusion found to have an elevated heparin sodium level; drug discontinued for 1 day while level dropped; when restarting the infusion, a dosage 3 times higher than the original dosage was ordered</td>
</tr>
<tr>
<td>Wrong dose or drug</td>
<td>196 (4.1)</td>
<td>Patient’s discharge medications contained numerous errors in medications and dosages</td>
</tr>
<tr>
<td>Wrong drug</td>
<td>1718 (36.0)</td>
<td>Patient with bradycardia taking metoprolol was switched to timolol; prescriber thought that timolol had intrinsic sympathomimetic activity and would not cause bradycardia</td>
</tr>
<tr>
<td>Wrong dosage or form</td>
<td>276 (5.8)</td>
<td>Patient was receiving intravenous ciprofloxacin but had no contraindication to receiving oral ciprofloxacin</td>
</tr>
<tr>
<td>Wrong patient</td>
<td>13 (0.03)</td>
<td>Order written for 300 mg of clopidogrel bisulfate before a cardiovascular procedure on the wrong patient’s record</td>
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</table>

*Percentages do not sum to 100 because of rounding.

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### Table 3. Categories of Medications Involved in Medication Errors

<table>
<thead>
<tr>
<th>Category or Class of Medication</th>
<th>No. (%) of Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticoagulants or antiplatelets</td>
<td>406 (8.5)</td>
</tr>
<tr>
<td>Anti-infectives</td>
<td>709 (14.9)</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>1964 (41.2)</td>
</tr>
<tr>
<td>Endocrinology</td>
<td>348 (7.3)</td>
</tr>
<tr>
<td>Gastroenterology</td>
<td>453 (9.5)</td>
</tr>
<tr>
<td>Neurology</td>
<td>88 (1.8)</td>
</tr>
<tr>
<td>Pain or inflammation</td>
<td>176 (3.7)</td>
</tr>
<tr>
<td>Psychiatric</td>
<td>232 (4.9)</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>75 (1.6)</td>
</tr>
<tr>
<td>Vitamins, minerals, or electrolytes</td>
<td>171 (3.6)</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>146 (3.1)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4768</strong></td>
</tr>
</tbody>
</table>

*Percentages do not sum to 100 because of rounding.*
hospitals in which pharmacists took medication histories on admission.

The increase in the number of medication errors, even when controlling for the number of admissions, is of concern and has been previously reported.6 Although the clinical pharmacist’s responsibilities did not change during the study, reductions in the number of physicians, nurses, and staff pharmacists per patient may have occurred. This reduction might result in the removal of “safety nets” that had previously been in place. The rising medication error rate may have also been associated with an increase in the number of medications integrated into practice during the study. During the study period, several new cardiovascular therapies and new drugs for comorbid conditions were introduced. It is likely that the increasing number of available therapies, many with the potential for adverse effects, has led to more complex medical regimens and higher error rates. As therapeutic choices continue to expand in number and complexity, the potential for error will likely also increase. This increasing complexity of medical regimens, coupled with the inexperience of new house staff, may also be an explanation for the trend toward increases in the number of errors during the summer and December and January holidays. In the study by Lesar et al,6 the highest error rate per 1000 orders occurred in November. However, in that study, no significant increase in errors occurred during the house staff transition period in June and July. Observations from our study suggest that a more rigorous review of medication orders during the summer and improvements in the knowledge and experience base for interns may reduce medication errors in a teaching institution.

Medication errors and ADEs not only have the potential to cause adverse outcomes and death but also can result in longer hospital stays and increased hospital costs.

Adverse drug events have been associated with 1.9 to 4.6 additional days of hospitalization and increased hospital costs of $2262 to $4685 for each event.11,12 Preventable ADEs have resulted in higher costs than nonpreventable ADEs because of longer hospitalization times.11 Most of the medication errors identified in this study were preventable potential ADEs. Therefore, if half of the avoided errors would have resulted in an adverse event, the avoided cost would be between approximately $5 million and $11 million.

Computerized physician order entry systems are effective in reducing some types of medication errors, such as transcription errors, errors related to illegible handwriting, and some dosing errors or drug-drug interaction errors.13 However, their ability to identify and correct other types of errors is not known. The large number of medication errors in this study associated with lack of knowledge of the patient’s home medical regimen would not be solved by the existing computerized physician order entry systems. In addition, the numerous alerts, suggestions, and warnings that can be generated by these systems as more and more sophisticated drug and dosing algorithms are added may lead to a decline in attention to the computer-generated suggestions. Over time, more medication errors could result. The integration of a clinical pharmacist offers an immediate effect on patient safety. By being able to tie together patient-specific factors, medication history, and medical problems with an expertise in drug knowledge, the clinical pharmacist can identify and correct medication errors that would be missed by a computerized physician order entry system.

The main limitation to this study is that one clinical pharmacist collected the data and that the interventions may not universally be considered necessary. However, using a single person to collect the data ensured that
CONCLUSIONS

This study documented 4768 medication errors that were identified and corrected by a clinical pharmacist through routine participation in patient care rounds on a cardiology ward. Through these activities, we have identified 2 possible areas of improvement that may reduce medication errors and merit further study. The first is the development of a system that provides health care providers with accurate, up-to-date medication information at the point of care. The second is more focused education and backup for new interns during their initial months of training. The large and increasing numbers of potential ADEs identified through routine review by a clinical pharmacist strongly support the role of pharmacists in assuring patient safety.

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