Frequency and determinants of drug administration errors in the intensive care unit*

Patricia M. L. A. van den Bemt, PhD; Roel Fijn, PhD; Peter H. J. van der Voort, PhD MD; Annet A. Gossen, BSci; Toine C. G. Egberts, PhD; Jacobus R. B. J. Brouwers, PhD

Objective: **The study aimed to identify both the frequency and the determinants of drug administration errors in the intensive care unit.**

Design: **Administration errors were detected by using the disguised-observation technique (observation of medication administrations by nurses, without revealing the aim of this observation to the nurses).**

Setting: **Two Dutch hospitals.**

Patients: **The drug administrations to patients in the intensive care units of two Dutch hospitals were observed during five consecutive days.**

Interventions: **None.**

Measurements and Main Results: **A total of 233 medications for 24 patients were observed to be administered (whether ordered or not) or were observed to be omitted. When wrong time errors were included, 104 administrations with at least one error were observed (frequency, 44.6%), and when they were excluded, 77 administrations with at least one error were observed (frequency, 33.0%). When we included wrong time errors, day of the week (Monday, odds ratio [OR] 2.69, confidence interval [CI] 1.42–5.10), time of day (6–10 pm, OR 0.28, CI 0.10–0.78), and drug class (gastrointestinal, OR 2.94, CI 1.48–5.85; blood, OR 0.12, CI 0.03–0.54; and cardiovascular, OR 0.38, CI ,0.16–0.90) were associated with the occurrence of errors. When we excluded wrong time errors, day of the week (Monday, OR 3.14, CI 1.66–5.94), drug class (gastrointestinal, OR 3.47, CI 1.76–6.82; blood, OR 0.21, CI 0.05–0.91; and respiratory, OR 0.22, CI 0.08–0.60), and route of administration (oral by gastric tube, OR 5.60, CI 1.70–18.49) were associated with the occurrence of errors. In the hospital without full-time specialized intensive care physicians (which also lacks pharmacy-provided protocols for the preparation of parenteral drugs), more administration errors occurred, both when we included (OR 5.45, CI 3.04–9.78) and excluded wrong time errors (OR 4.22, CI 2.36–7.54).**

Conclusions: **Efforts to reduce drug administration errors in the intensive care unit should be aimed at the risk factors we identified in this study. Especially, focusing on system differences between the two intensive care units (e.g., presence or absence of full-time specialized intensive care physicians, presence or absence of protocols for the preparation of all parenteral drugs) may help reduce suboptimal drug administration. (Crit Care Med 2002; 30:846–850)**

KEY WORDS: medication errors; drug administration; intensive care unit; determinants; frequency; protocols; specialized intensive care physicians

Medication errors are associated with a substantial increase in patient morbidity and mortality rates (1–5). Prevention of these errors is likely to improve patient outcome in hospitals. Most errors are not incidents but symptoms of a failing system. Establishing preventive measures requires insight into factors that contribute to medication errors (1, 3). Errors may occur throughout the entire drug distribution system, from prescribing to the administration of drugs (6). The administration of drugs is a very critical step because the possibilities of correcting errors at this stage are limited and errors at this level may directly harm the patient. This is especially the case for drugs that are parenterally administered compared with drugs given by other routes.

Patients in the intensive care unit (ICU) are at high risk for administration errors for three reasons. First, ICU patients usually receive many drugs. Second, the majority of these drugs are given parenterally, and third, patient often are sedated and therefore cannot detect and correct possible errors themselves.

A few studies have addressed administration errors in the ICU (7–9). From these, the study by Tissot et al. (9) is the only one that used the disguised-observer technique, which is the recommended method for studying medication errors. This technique involves the observation of all medication administrations by one or more nurses, without revealing the aim of this observation to the nurses (10). Tissot et al. (9) showed that administration errors occur frequently in the ICU. None of the published studies looked into the determinants that are associated with the occurrence of administration errors. Therefore, we conducted a study to identify these determinants as well as the frequency of administration errors in the ICU.

MATERIALS AND METHODS

Setting. The study was performed in the ICUs of two Dutch hospitals (hospitals 1 and 2). The two hospitals use different distribution systems in the ICUs, so this system difference was analyzed as a determinant in our study. Both ICUs were of the mixed medical/surgical type.

Hospital 1 uses a stock floor distribution system in the ICU, whereas in hospital 2 the pharmacy dispenses a substantial part of all drugs per patient daily (in comparison, in the United States the pharmacy distribution usually is performed with a computerized drug

***See also p. 944.**

From Hospital Pharmacy Midden-Brabant (PMLAB, TCGE), TweeSteden Hospital and St. Elisabeth Hospital, Tilburg, The Netherlands; Groningen University Institute for Drug Exploration (GUIDE), Division of Pharmacoepidemiology and Drug Policy (RF, JRBJB) and Department of Social Pharmacy and Pharmacoepidemiology (AAG), Groningen, The Netherlands; and the Intensive Care Unit (PHFV), Medical Centre Leeuwarden, The Netherlands.

cabinet or stock system). Both hospitals use unit-dose packaging. In hospital 1, ICU nurses use handwritten day-charts to administer drugs; these charts are transcribed from handwritten doctor's orders. In hospital 2, medication charts printed by the pharmacy (handwritten doctor's orders are entered into the pharmacy computer) are used to administer drugs. Protocols for the preparation and administration of parenteral drugs are available for all drugs in hospital 1, whereas in hospital 2 these protocols are available only for drugs that are administered by syringe pump.

In the ICU of hospital 1, full-time specialized intensive care physicians are employed, whereas in hospital 2 the ICU is under the part-time responsibility of anesthesiologists. Being a specialized ICU, the ICU in hospital 1 usually has patients who are relatively more critically ill than the ICU of hospital 2. Although Acute Physiology and Chronic Health Evaluation scores were not specifically determined in both ICUs during this study, the median Acute Physiology and Chronic Health Evaluation score of all patients of both ICUs in the year previous to the study was determined (as part of a special national quality project in The Netherlands). For hospital 1 this median was 19, and for hospital 2 it was 17. Another factor showing that patients in the ICU of hospital 1 are more critically ill is the availability of continuous venovenous hemofiltration in this ICU compared with the ICU of hospital 2.

The ICU of hospital 1 has 11 beds, and the ICU of hospital 2 has 7 beds. In both ICUs, a single nurse generally cares for one individual patient per shift, including the administration of drugs. The nurse-to-bed ratio (a raw measure for workload) is 1:1 in both ICUs. The working experience of nurses in both ICUs is 5–10 yrs.

In both hospitals, the hospital pharmacists attend the daily meetings in which the patients are reviewed. The same hospital pharmacists visit the ICUs of both hospitals, so the working experience of pharmacists is the same for both ICUs. These general characteristics of both ICUs are summarized in Table 1.

Study Design. An administration error was defined as any error in the preparation and administration of drugs by nurses, that is, a deviation from written, printed, or verbal medication orders (used by the nurses to administer drugs); a deviation from the drug information sheets provided by the manufacturer or from the information in a handbook on injectable drugs (11) (both contain information on preparation and administration of parenteral drugs and on drug-drug compatibility); or a deviation from general nursing procedures used in the hospitals.

Administration errors were detected by using the disguised-observation technique (10). Nurses were unaware of the goal of the study (they were told that the observer was studying the drug distribution system). One observer followed the nurses preparing and administering drugs in both hospitals on five consecutive days from 7 am to 10 pm. This observer had a bachelor's degree in pharmacy. To become familiar with the regular proceedings in the ICUs, the observer followed a 2-day training period on each ICU. During this period the observer also became familiar with the technique of disguised observation.

All observations (patient and drug name, dose, time) were noted on a data collection form designed especially for the study. Afterward, the observations were compared with the written or printed medication orders. Observations also were compared with the drug information sheet and information in the handbook (11) to detect errors in preparation and in drug-drug compatibility. Finally, the observations were compared with general nursing protocols (e.g., when drugs are administered through a gastric feeding tube, nurses should rinse the tube before and after administration). Although general nursing protocols require the disinfection of vials before preparing parenteral drugs, this disinfection commonly is omitted in both ICUs. Therefore, omission of disinfection was not considered an error in this study. Including this error would result in a 100% error rate, which would make it impossible to detect factors that potentially are related to other errors. Because disinfection was omitted by all nurses in both ICUs, excluding this particular error is valid. However, as a general indicator for quality, the omitting of disinfection is a serious error because it could increase the risk of catheter infection. Therefore, this observation will be used in educational sessions for the nurses.

Errors were classified into eight categories (Table 2) (10). A wrong time error was defined as the administration of a drug $\geq$60 mins earlier or later than prescribed. In addition, administration errors were classified into nine classes of seriousness derived from the National Coordinating Council for Medication Error Reporting and Prevention taxonomy of medication errors (12): A, an error is made but the medication does not reach the patient; B, an error is made and the medication reaches the patient, but no harm is done (B1, medication not administered; B2, medication administered but no harm); C, an error is made that results in an increased frequency of monitoring, but no harm is done; D, an error is made and harm is done (D1, temporary damage necessitating treatment; D2, temporary damage resulting in an increased length of hospital stay; D3, permanent damage; D4, patient nearly dies); E, an error is made that results in the patient's death. The errors were classified independently by two hospital pharmacists. For those errors that were classified in different classes, the two pharmacists reached consensus.

All drugs were classified according to the Anatomical Therapeutic Chemical code (13).

Data Analysis. The observation period was primarily chosen to enable us to study $\geq$200 opportunities for medication administration. Assuming an average error frequency of 20%,

Table 1. General characteristics of both intensive care units

Hospital 1	Hospital 2
Stock floor distribution system	Dispensing by pharmacy of a substantial part of all drugs per patient daily
Unit-dose packaging	Unit-dose packaging
Handwritten day-charts used by nurses to administer drugs	Printed medication charts from pharmacy used by nurses to administer drugs
Parenteral drugs prepared by nurses (not by pharmacy)	Parenteral drugs prepared by nurses (not by pharmacy)
Protocols for preparation and administration of parenteral drugs available for all drugs	Protocols for preparation and administration of parenteral drugs available only for drugs given by syringe pump
Full-time specialized intensive care physicians	Anesthesiologists with part-time intensive care responsibility
Patients relatively more critically ill (median APACHE score in the year previous to the study, 19)	Patients relatively less critically ill (median APACHE score in the year previous to the study, 17)
CVVH available for treating renal insufficiency	CVVH not available for treating renal insufficiency
11 beds	7 beds
1 nurse responsible for 1 patient	1 nurse responsible for 1 patient
Nurse-to-bed ratio 1:1	Nurse-to-bed ratio 1:1
Working experience of nurses, 5–10 yrs	Working experience of nurses, 5–10 yrs

APACHE, Acute Physiology and Chronic Health Evaluation; CVVH, continuous venovenous hemofiltration.

an α of .05, and a power of 80%, we should be able to identify relative differences between the two settings of approximately 50%. Based on the previously mentioned calculation, we chose an observation period of 5 working days.

The following variables were registered and entered into a database (Microsoft Access 97; Microsoft, Redmond, WA): patient age and gender, hospital, drug and Anatomical Therapeutic Chemical code, day and time of administration, route of administration, number of drugs and number of dosages administered to a patient that day, whether an error was made, error category, and error seriousness class.

These data were analyzed by using the Statistical Package for Social Sciences (SPSS) version 9.0 (SPSS, Chicago, IL). The association between potential determinants (patient age and gender, hospital, drug class, day and time of administration; categorized), route of administration (categorized), number of drugs and number of dosages administered to a patient that day, and the occurrence of errors was studied by using univariate logistic regression analysis. In this way, for each determinant an odds ratio (OR) was calculated together with a 95% confidence interval (CI). We used regression analysis, because data on many variables were obtained in this study and in general it is preferable to use advanced statistical methods that analyze all variables instead of using a series of simple analyses. Because the outcome variable (error or no error) was binary, we used logistic regression analysis.

The frequency of errors (fE) was calculated by dividing the number of administrations with one or more errors (nE) by the sum of the number of observed drug administrations (whether ordered or not) (nA) and the number of drugs observed to be omitted (nO). Thus,

$$fE = \frac{nE}{nA + nO}. \qquad [1]$$

The error frequency (fE) was reported as a percentage (fE $\times$ 100%).

Because wrong time errors generally are considered less serious than other errors (10), the overall results are reported both including and excluding these errors.

RESULTS

We observed 233 drug administrations to 24 patients (19 male; mean age, 67 yrs; range, 26–87 yrs; 13 patients from hospital 1). When wrong time errors were included, 104 administrations with at least one error were observed (frequency = 104 of 233, 44.6%), and when they were excluded 77 administrations with at least one error were observed (frequency = 77 of 233, 33.0%). In hospital 1 the error frequency was 45 of 149 (30.2%) when we included wrong time errors and 32 of 149 (21.5%) when we excluded wrong time errors. In hospital 2, these frequencies were 59 of 84 (70.2%) and 45 of 84 (53.6%), respectively.

Because each administration could involve multiple errors, 131 errors were observed when wrong time errors were included and 79 when they were excluded. In Table 3, the errors for both hospitals are divided into categories and into classes of seriousness, with examples for each category and class.

Table 4 shows the association between the occurrence of administration errors and several determinants, for all errors as well as for all errors excluding wrong time errors. Day of the week was analyzed as a categorized variable, and this analysis did not show any difference in error rate between Tuesday through Friday, but the error rate on Monday was higher. Therefore, Tuesday through Friday was taken as the reference category, and the OR for the occurrence of errors on Monday was determined.

When we included wrong time errors, time of day (6–10 pm, OR 0.28, CI 0.10–0.78) and drug class (blood, OR 0.12, CI 0.03–0.54; and cardiovascular, OR 0.38, CI 0.16–0.90) were associated with a lower probability of administration errors. Hospital (2 vs. 1, OR 5.45, CI 3.04–9.78), day of the week (Monday vs. all other days, OR 2.69, CI 1.42–5.10), and drug class (gastrointestinal, OR 2.94, CI 1.48–5.85) were associated with a higher probability of administration errors.

When we excluded time errors, drug class (blood, OR 0.21, CI 0.05–0.91; respiratory, OR 0.22, CI 0.08–0.60) was associated with a lower probability of administration errors. Hospital (2 vs. 1, OR 4.22, CI 2.36–7.54), day of the week (Monday vs. all other days, OR 3.14, CI 1.66–5.94), drug class (gastrointestinal,

Table 2. Categories of errors

Category	Definition
Omission error	Drug prescribed, but not administered
Unordered drug error	Drug administered, but not prescribed
Wrong dose preparation error	Drug prepared in wrong way (e.g., dissolved in wrong solute)
Wrong dose form error	Drug given in wrong dosage form (e.g., cream instead of ointment)
Wrong route error	Drug given by wrong route of administration (e.g., parenteral drug given intravenously instead of intramuscularly)
Wrong administration technique error	Drug administered by using a wrong technique (e.g., drug infused too rapidly)
Wrong dose error	Dosage too high or low
Wrong time error	Drug given ≥60 mins early or late

Table 3. Administration errors for hospital 1 (n = 57) and hospital 2 (n = 74) divided into categories and classes of seriousness

	Hospital 1, n (%)	Hospital 2, n (%)	Example
Categories			
Omission error	—	7 (9.5)	Ipratropium/salbutamol inhalation fluid omitted
Unordered drug error	—	3 (4.1)	Ipratropium given instead of salbutamol/ipratropium
Wrong dose preparation error	8 (14.0)	16 (21.6)	Erythromycin powder for intravenous infusion not completely dissolved
Wrong dose form error	—	—	
Wrong route error	—	—	
Wrong administration technique error	22 (38.6)	14 (18.9)	Omeprazole and dopamine on same intravenous catheter
Wrong dose error	5 (8.8)	4 (5.4)	One vial of ciprofloxacine intravenously instead of two vials
Wrong time error	22 (38.6)	30 (40.5)	Levothyroxine tablet 2 hrs late
Seriousness			
Class B2	28 (49.1)	53 (71.6)	Wrong time error
Class C	29 (50.9)	21 (28.4)	Unordered drug error

Table 4. Association of administration errors (both with and without wrong time errors) with determinants

	With wrong time errors, OR (95% CI)	Without wrong time errors, OR (95% CI)
Patient characteristics		
Age	1.00 (0.98–1.01)	1.00 (0.99–1.02)
Gender (reference category is female)	1.16 (0.63–2.14)	1.60 (0.81–3.17)
ICU characteristics		
Hospital (reference category is hospital 1)	5.45 (3.04–9.78)	4.22 (2.36–7.54)
Time characteristics		
Day[a] (Monday)	2.69 (1.42–5.10)	3.14 (1.66–5.94)
Time class[b]		
7–10 am	Ref.	Ref.
10 am to 2 pm	0.66 (0.32–1.37)	0.54 (0.25–1.18)
2–6 pm	0.76 (0.37–1.55)	1.08 (0.53–2.21)
6–10 pm	0.28 (0.10–0.78)	0.56 (0.21–1.55)
Drug characteristics		
Drug class[c,d]		
Gastrointestinal	2.94 (1.48–5.85)	3.47 (1.76–6.82)
Blood	0.12 (0.03–0.54)	0.21 (0.05–0.91)
Cardiovascular	0.38 (0.16–0.90)	0.55 (0.23–1.34)
Hormonal	2.26 (0.64–7.92)	1.74 (0.52–5.88)
Antimicrobial	1.11 (0.63–1.94)	1.47 (0.81–2.64)
CNS	1.04 (0.31–3.49)	0.44 (0.09–2.07)
Respiratory	0.81 (0.41–1.60)	0.22 (0.08–0.60)
Eye	5.07 (0.56–45.81)	8.49 (0.93–77.33)
Route of administration[b]		
Oral	Ref.	Ref.
Intravenous	0.59 (0.22–1.59)	1.49 (0.49–4.48)
Rectal	3.33 (0.29–38.08)	—[e]
Inhalation	0.80 (0.27–2.37)	0.37 (0.09–1.47)
Local	0.56 (0.16–1.91)	0.40 (0.08–1.95)
Oral by gastric tube	2.74 (0.90–8.28)	5.60 (1.70–18.49)
Number of drugs/day/patient	0.97 (0.90–1.04)	0.97 (0.90–1.05)
Number of doses/day/patient	0.97 (0.94–1.00)	0.98 (0.95–1.02)

OR, odds ratio; CI, confidence interval; ICU, intensive care unit; Ref., reference category; CNS, central nervous system.

[a]Initially analyzed as categorized variable; presented OR is for Monday vs. all other days (see Results section), so "all other days" is the reference category; [b]categorized; [c]reference category consists of all other values (e.g., the reference category for gastrointestinal is all other drug classes); [d]Drug classes: gastrointestinal, drugs acting on the gastrointestinal system (e.g., H2-antagonists, proton pump inhibitors); blood, drugs acting on the blood (e.g., anticoagulants, iron salts, plasma expanders); cardiovascular, cardiovascular drugs (e.g., antihypertensive drugs, drugs used in heart failure, drugs used in angina pectoris, lipid lowering agents); hormonal, hormones (e.g., corticosteroids); antimicrobials, antibacterial and antiviral drugs, drugs against parasites; CNS, drugs acting on the CNS (e.g., opioid analgesics and other analgesics [with the exclusion of nonsteroidal anti-inflammatory drugs], antidepressants, antipsychotics); respiratory, drugs acting on the respiratory system (e.g., beta-2-agonists for inhalation); eye, drugs used for eye diseases (e.g., drugs against glaucoma); [e]number of errors too small to calculate an OR.

OR 3.47, CI 1.76–6.82), and route of administration (oral by gastric tube, OR 5.60, CI 1.70–18.49) were associated with a higher probability of administration errors.

DISCUSSION

In this study on administration errors in two Dutch ICUs, a high frequency of errors was observed: 33% when we excluded wrong time errors. Of the published studies on administration errors in the ICU (7–9), the study by Tissot et al. (9) is the only one that also used the disguised-observer technique. This technique has proven reliability for the studying administration errors (14). Tissot et al. (9) observed 2,009 drug administrations during 30 days in one ICU, by using two observers accompanying two nurses. In that study, an error frequency of 6.1% (when wrong time errors were excluded) was found, which is considerably lower than ours. This may be caused by a number of reasons. First, in the study by Tissot et al. (9), the nurses were aware of the study goal, whereas in ours they were not. Second, the authors carried out observations during 6 hrs per day, excluding weekends and nights. We also observed on Monday through Friday during the daytime but during more hours per day. Finally, in our study all errors were considered to be of minor (category B2) or significant (category C) seriousness, whereas Tissot et al. (9) had a substantial portion of life-threatening errors. The difference in frequency therefore may be explained by the fact that we included more minor errors as an administration error in our study. Although these errors are not harmful to the patient, they may indicate flaws in the distribution system that may lead to more serious errors.

Possible system failures that we identified were the system differences between the two intensive care units (e.g., presence or absence of full-time specialized intensive care physicians, presence or absence of protocols for the preparation and administration of all parenteral drugs), changing shifts on Monday, and lack of familiarity with the general nursing protocol on administering drugs by gastric feeding tube.

This is the first study we know of that analyzed determinants associated with the occurrence of administration errors in the ICU and used the most reliable technique to study the errors. Despite these strengths, this study is only an indicative study. Because of the time-consuming nature of the observation method, we limited the observation period to 5 days per ICU. This period may have been too short, resulting in too few

errors, to be able to identify the true determinants of administration errors. However, in general, confidence intervals are not too wide, so for most determinants conclusions can be drawn from our study. Another limitation of this study is the fact that weekends were not considered, which may have effected error rates. Because staffing patterns are identical for weekends compared with Monday through Friday, the effect seems small, however. Additional studies that use longer study periods, including weekends, and that include more determinants such as nurse variables (education, number of years working experience), patient illness variables (Acute Physiology and Chronic Health Evaluation score for patients included in the study), and work load variables may provide information on determinants insufficiently identified by our study.

Our study provides the first clues as to which determinants may be associated with administration errors in the ICU. Hospital is a determinant that is strongly associated with administration errors in the ICU. Because the two hospitals have ICUs that differ systematically (Table 1), these system differences may explain the difference in error frequencies. In hospital 2 more administration errors occurred, both when we included and excluded wrong time errors, despite the fact that this ICU does not use a floor stock system. Administration errors may be more likely to occur with a floor stock system, because the nurses have to pick the right drugs from the stock before preparing and administering them. The fact that our study found more errors in the ICU not using a floor stock system may be explained by the fact that most errors occur in the preparing or dosing stage and rarely in picking the right drug from the stock. Furthermore, the studies showing an increased error rate for floor stock systems generally were conducted in institutions that did not use unit dose packaging. In The Netherlands, all hospitals use unit dosage packaging, which contributes to picking the right drug from the stock.

Another difference between both ICUs is the presence of full-time specialized intensive care physicians. These physicians are more accustomed to working with evidence-based therapy protocols. This facilitated the introduction of protocols for the preparation and administration of parenteral drugs by the pharmacy department in hospital 1. Both factors (specialized physicians and protocols) may contribute to the lower error frequency in hospital 1. The protocols also may explain why the intravenous route of administration was not associated with the occurrence of errors.

In contrast to what might be expected, the number of drugs or doses per patient per day was not statistically significantly associated with the occurrence of an error. One may expect more errors when this number increases, because it would increase the workload of the nurses. However, errors are also more likely to occur when workload is too low (15). The ORs that are smaller than 1 (although not statistically significant) seem to support this presumption. Patients in hospital 1 are relatively more critically ill than in hospital 2 and therefore the workload in hospital 1 is likely to be higher (although the raw measure of nurse-to-bed ratio is 1:1 in both ICUs). This may contribute to the lower error frequency in hospital 1.

Monday seems to be a critical day for making errors, which may be associated with the fact that this is the first day after the weekend (changing shifts of nurses and physicians). Why the group of gastrointestinal drugs was associated with more errors and why drugs acting on the blood, cardiovascular system, and respiratory system were associated with fewer errors remain to be explored. The significance values may be inflated, however, because we used "all other drug classes" as the reference category.

Errors in oral administration of drugs through a gastric feeding tube occur mostly because nurses do not rinse the tube before and after giving the drug. The nurses apparently did not follow general nursing protocol on this subject, so educational measures may prevent these errors in future.

CONCLUSION

The determinants identified in this study illustrate the system failures in the ICU. Possible system failures that we identified were the system differences between the two ICUs (e.g., presence or absence of full-time specialized intensive care physicians, presence or absence of protocols for the preparation and administration of all parenteral drugs), changing shifts on Monday, and lack of familiarity with the general nursing protocol on administering drugs by gastric feeding tube. Preventive measures directed toward these system failures are likely to decrease error rates in the ICU.

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