

Medication Prescribing Errors Involving the Route of Administration

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Abstract

Context: Administration of medications by the wrong route or as a wrong dose for the ordered route presents significant risk for adverse drug events.

Objective: To quantify and identify the characteristics of prescribing errors involving the route of drug administration.

Design: Evaluation of medication orders with errors involving the route of administration detected by pharmacists in a 631-bed tertiary care teaching hospital over a 42-month period.

Main Outcome Measures: Type, frequency, characteristics, potential for adverse effects, contributors, and enabling factors of medication prescribing errors involving the route of administration.

Results: A total of 862 prescribing errors were detected. Sixty-one different types of route-related prescribing errors, involving 135 different medications, were detected. The most common type of these errors involved prescribing the wrong route of administration (39.2%) and prescribing the same or similar medications to be given concurrently by two routes (21.1%). The most common class of medications involved were cardiovascular agents (23.5%). The most common medication characteristic identified as contributing to route-related prescribing errors was the common and routine use of a drug by multiple routes (75.9%).

Conclusions: Prescribing errors involving the route of administration are common, occur in a wide variety of ways, and involve a wide variety of medications. A number of commonly recommended medication safety practices should reduce risk to patients from route-related medication prescribing errors.

Keywords — medication errors, route of administration, prescribing error prevention, adverse drug events

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tion of drugs by the wrong route is substantial. While errors in the route of drug administration are usually associated with mistakes made when medications are given,^{11–20} they also occur when medications are prescribed.^{5–7,10,21–28} Fortunately, prescribing errors are often detected and averted prior to drug administration.²⁹ However, in our experience and in the experience of others,^{22–27} orders to give a drug by the wrong route or at a dose inappropriate for the route of administration will sometimes be carried out and pose significant risks to patients. Our ongoing observations suggest, like many medical errors, route-related prescribing errors are common, and risk to patients occurs in a complex and nuanced manner. Improved understanding of the nature of and contributors to errors involving the route of drug administration will be useful in the prioritization, design, and implementation of error prevention strategies. In order to better define the frequency and characteristics of prescribing errors involving the route of drug administration, these errors were systematically evaluated in a 631-bed tertiary care teaching hospital.

METHODS

Identification of Medication Prescribing Errors

The study was conducted in a 631-bed tertiary care teaching hospital in northeastern New York State; the institutional review

Medication prescribing deficiencies are the most common cause of actual and potential adverse drug events.^{1–3} Understanding how specific factors and characteristics of the medication-use process contribute to

errors is necessary to design and implement effective error prevention and recovery processes.^{1,4} As part of an ongoing medication safety effort, we have successfully used information from detected and prevented errors (“near misses”), along with errors reaching the patients, to better understand risks to patients.^{5–10} Risk of adverse drug events occurring after administra-

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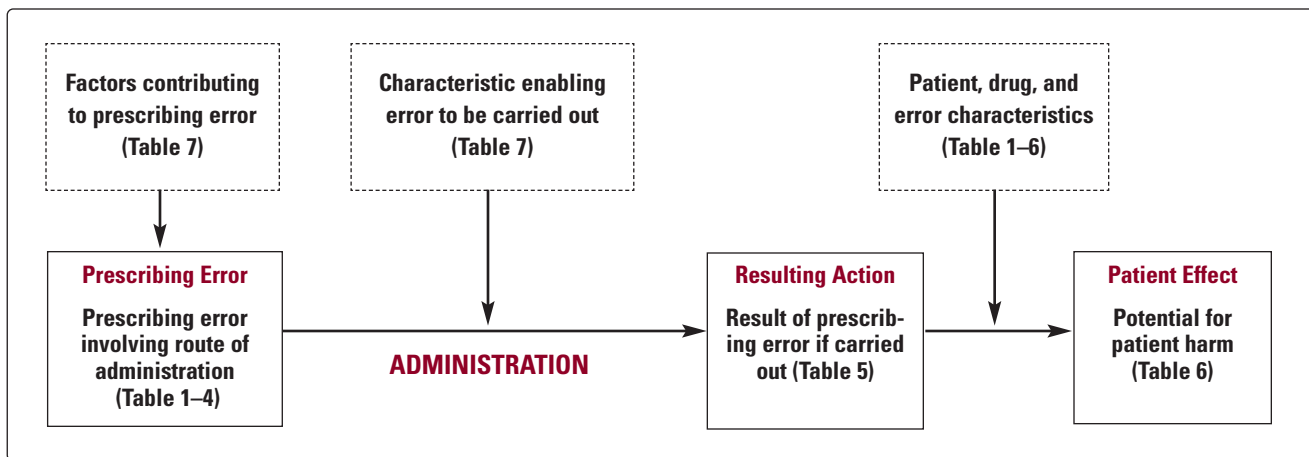


Figure 1. Framework for assessment of prescribing errors involving the route of administration.

board approved the study. Medication prescribing error data used for study analysis were collected concurrently and systematically over a 42-month period from January 1, 2001 to June 30, 2004 as part of an ongoing error prevention/quality improvement program. This process has been described previously.⁵⁻¹⁰ At the study hospital, medications are prescribed by handwriting on a standard unformatted (“blank”) hospital prescriber order sheet or by completing pre-printed order sets, pathways, and protocols (computer prescriber order entry is not available). All medication orders that had been written, provided via telephone, or given verbally by a credentialed prescriber to a nurse or pharmacist during the study period were included. Pharmacists reviewed all medication orders prior to dispensing or shortly after removal from unit medication supplies (primarily automated dispensing cabinets). Following the identification of a questionable (incomplete, illegible, ambiguous, etc.) medication order or a potential error, the pharmacist contacted the prescriber or a “covering” prescriber assigned to the patient to

obtain additional information and to discuss the orders in question. The medication order(s) in question were either confirmed as written, clarified, changed, or discontinued following the discussion between the pharmacist and the credentialed prescriber. All questioned medication orders (orders that were confirmed as errors and changed, and orders that were not changed following pharmacist-

prescriber communication) were further reviewed by the author or a clinical pharmacist within 24 hours. Information and insights obtained from review of these “questioned” orders is routinely applied in ongoing educational and procedural improvement initiatives in the study hospital. All confirmed medication prescribing errors were abstracted, coded, and entered into a commercial relational database

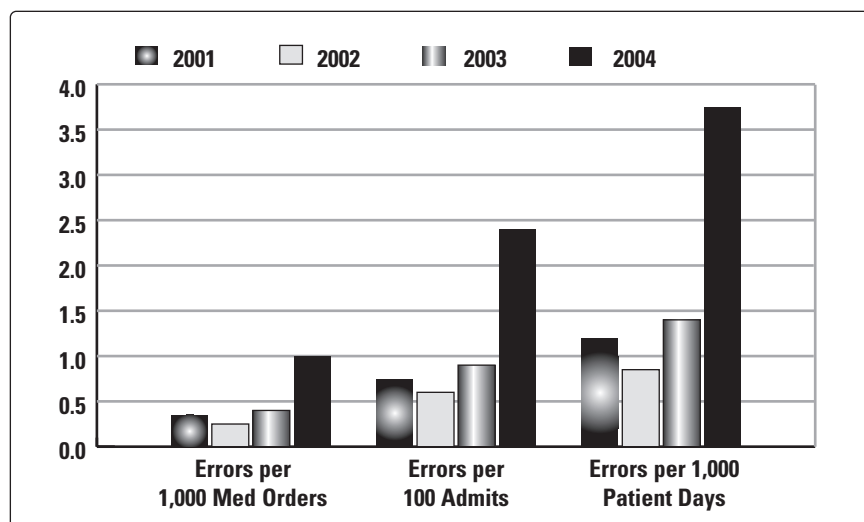


Figure 2. Rate of medication prescribing errors related to the route of administration per 1,000 medication orders written, per 100 hospital admissions, and per 1,000 patient days provided, detected for each year of the study.

Table 1. Medication Prescribing Errors Related to the Route of Administration: Description of Specific Errors Occurring More Than 5 Times

<i>Error Description</i>	<i>No. Errors (% total)</i>	<i>Number of Severe/Serious Errors</i>
Order to administer controlled-release dose through nasogastric tube	135 (14.4)	6
Order to administer correct/appropriate/intended IV medication orally	86 (10)	7
Order to administer correct/appropriate/intended oral medication IV	81 (9.4)	17
Same/similar drug ordered IV and oral	78 (9)	3
Oral dose ordered for intended IV administration	76 (8.8)	34
IV dose ordered for intended oral administration	75 (8.6)	4
IM route ordered instead of correct/appropriate/intended subcutaneous	71 (8.2)	1
Same/similar drug ordered transdermal and oral	48 (5.6)	1
Order to administer correct/appropriate/intended IV medication IM	17 (2)	1
Oral dose regimen ordered for intended transdermal administration	15 (1.7)	0
Overdose when converting from oral to IV administration	15 (1.7)	1
Same/similar drug ordered IV and subcutaneously	14 (1.6)	10
Order to give enteric-coated doseform per tube	13 (1.5)	0
Same/similar drug ordered IM and oral	12 (1.4)	0
Same/similar drug ordered orally and inhaled	11 (1.3)	2
IM route ordered instead of correct/appropriate/intended IV	9 (1)	0
Order to administer correct/appropriate/intended subcutaneous medication IM	9 (1)	0
Same/similar drug ordered IV and added to parenteral nutrition solution	9 (1)	0
IM route ordered instead of correct/appropriate/intended oral	8 (0.9)	1
Order to administer correct/appropriate/intended subcutaneous medication IV	8 (0.9)	1
Order to administer correct/appropriate/intended oral medication subcutaneously	7 (0.8)	3

IV: Intravenous
IM: Intramuscular

to allow analysis and application in process improvement initiatives.

The database was queried to identify all errors related to the route of administration, which were detected from January 1, 2001 to June 30, 2004. The identified errors were evaluated and assessed using the framework shown in Figure 1. Route-related errors were defined as the following: 1) an order for a medication to be administered by an inappropriate route, based on specific patient and medication characteristics (eg, vancomycin ordered to be given orally to treat a systemic infection);

2) an order to administer the same or a similar drug by more than one route (eg, orders for concurrent isosorbide mononitrate and nitroglycerine ointment); 3) an incorrect dose ordered for the intended and prescribed route of administration (eg, order for morphine 2 mg orally in an adult), including errors made when converting from one route of administration to another (eg, an order to “change enalapril 10 mg orally every 12 hours to intravenous” without altering the dose); 4) an order to give medication by route of administration that disrupts critical dosage formu-

lation (eg, order to administer nifedipine 90 mg sustained-release tablet by nasogastric tube).

Assessment of potential adverse outcome of each error was based on available patient and pharmacologic information regarding risk for adverse events. The clinical significance of each error was based on the potential of the error to be carried out, and if carried out as ordered, to result in adverse consequences. The potential adverse drug events were classified as the following: 1) increased risk of adverse effects due to excessive pharmacologic effects; 2)

Table 2. Medication Prescribing Errors Related to the Route of Administration: Characteristics of Types of Errors

<i>Type of Error</i>	<i>Total Errors (% total)</i>	<i>Serious or Severe Errors (% severe/serious)</i>	<i>Most Common Medications Involved (n)</i>	<i>Most Common Drug Classes (n)</i>
ERROR CLASS: WRONG ROUTE OF ADMINISTRATION ORDERED				
Drug ordered IV instead of intended or correct/appropriate oral administration	86 (10)	7 (6,9)	Benzodiazepine (10) Acetylcysteine (9) Metronidazole (9)	Antibiotics (16) Diuretics (12)
Drug ordered orally instead of intended or correct/ appropriate IV administration	81 (9.4)	17 (16.8)	Morphine (14) Magnesium sulfate (12) Potassium phosphate (10)	Electrolytes (26) Antibiotics (23) Opiates (16) Cardiovascular (14)
Drug ordered IM instead of correct/ appropriate subcutaneous administration	69 (8)	1 (1)	Phytonadione (63)	Vitamin (63)
Drug ordered IV instead of correct/ appropriate IM administration	17 (2)	1 (1)	Hydroxyzine (16)	Antihistamine (16)
Other	85 (9.9)	11 (10.9)		
Total wrong route of administration ordered	338 (39.2)	38 (37.6)		
ERROR CLASS: DRUG OR SIMILAR DRUG ORDERED TO BE GIVEN CONCURRENTLY BY MORE THAN ONE ROUTE				
Concurrent oral and IV administration ordered	78 (9)	3 (3)	Ketorolac (60)	NSAIDs (60)
Concurrent oral and transdermal administration ordered	48 (5.6)	1 (1)	Isosorbide mononitrate/ nitroglycerin (35)	Cardiovascular (48)
Concurrent IV and subcutaneous administration ordered	13 (1.5)	10 (9.9)	Heparin (13)	Anticoagulant (13)
Concurrent oral and IM administration ordered	11 (1.3)	0 (0)	Ketorolac (11)	NSAIDs (11)
Other	33 (3.8)	3 (3)		
Total of drug or similar drug ordered to be given concurrently by more than one route	183 (21.1)	17 (16.8)		

(continued)

unique toxic effects due to administration of specific dosage form by ordered route; 3) an inadequate therapeutic response; 4) a combination of risks. The potential significance of errant orders was evaluated using a previously described rating scale (Appendix).⁵⁻¹⁰ Consistency and agreement of assigning an error severity classification to specific errors have been previous-

ly evaluated.^{6,7} All errors classified as "potentially severe," "potentially serious," "potentially significant," or "problematic" were included in this study.

Orders that were unlikely to be carried out because of product characteristics, physical and mechanical factors, or common drug distribution and preparation processes were not considered sig-

nificant. In orders considered to have a reasonable potential to be carried out, the contributing characteristics of medications were determined and classified into the following categories: selection error and/or confusion for drug with multiple common routes of administration and dose formulations available; controlled-release form or enteric-coated oral dose-

Table 2. Medication Prescribing Errors Related to the Route of Administration: Characteristics of Types of Errors (Cont.)

<i>Type of Error</i>	<i>Total Errors (% total)</i>	<i>Serious or Severe Errors (% severe/serious)</i>	<i>Most Common Medications Involved (n)</i>	<i>Most Common Drug Classes (n)</i>
ERROR CLASS: FAILURE TO PRESCRIBE CORRECT DOSE FOR ORDERED/INTENDED ROUTE				
Oral dose ordered to be given IV	76 (8.8)	34 (33.7)	Metoprolol (21) Ranitidine (21)	Cardiovascular (48) Gastrointestinal (21)
IV dose ordered to be given orally	75 (8.7)	4 (4)	Clindamycin (22) Morphine (14) Metoprolol (11)	Antibiotics (36) Opiates (18) Cardiovascular (16)
Other	21 (2.4)	1 (1)		
Total of failure to prescribe correct dose for intended route	172 (20)	39 (38.6)		
ERROR CLASS: ROUTE OF ADMINISTRATION ORDERED THAT DISRUPTS CRITICAL DOSAGE FORM				
Controlled-release form ordered to be given per tube	135 (15.7)	7 (6.9)	Isosorbide mononitrate (28) Nifedipine (18) Morphine (14)	Cardiovascular (81) Anti-epileptic (18) Opiates (18)
Enteric-coated oral solid ordered to be given per tube	13 (15)	0 (0)	Bisacodyl (7)	Gastrointestinal (7)
Total of route of administration ordered which disrupts critical dosage form	148 (17.1)	7 (6.9)		
ERROR CLASS: ERROR WHEN CONVERTING ROUTES OF ADMINISTRATION				
Error when converting from oral to IV route	16 (1.9)	1 (1)	Enalapril (12)	Cardiovascular (15)
Error when converting from IV to oral route	3 (0.3)	0 (0)		
Other	2 (0.2)	0 (0)		
Total of errors when converting routes of administration	21 (2.4)	1 (1)		
TOTAL ALL ERRORS	862	101		

form; dose regimen change needed with route change; specific or special technique of administration needed. The medication and error characteristic enabling the detected prescribing errors to be carried out (ie, administered to patient as ordered) was also identified for each error. These enabling characteristics were characterized as the following: multiple common

routes of administration and dose formulations available, injectable doseform available for drug, controlled-release or enteric-coated form that can be disrupted, oral liquid doseform available, dose regimen change with route change, special alternative techniques of administration, and availability of a liquid-filled capsule.

RESULTS

Frequency of Errors

A total of 862 confirmed “clinically significant” medication prescribing errors involving the route of medication administration were detected during the 42-month study. During this time period, 90,170 patients were admitted to the study hospital and 578,921 patient days were provided. An

Table 3. Medication Prescribing Errors Related to the Route of Administration: Medications Involved in 10 or More Errors

<i>Medication</i>	<i>Number of Errors Total = 862 (% total)</i>	<i>Severe/Serious Errors Total = 101 (% of severe/serious)</i>
Vitamin K	75 (8.7)	1 (1)
Ketoralac/other NSAID	71 (8.2)	0 (0)
Isosorbide mononitrate	60 (7)	0 (0)
Metoprolol	49 (5.7)	18 (17.8)
Morphine	40 (4.6)	4 (4)
Ranitidine	29 (3.4)	0 (0)
Clonidine	23 (2.7)	0 (0)
Clindamycin	22 (2.6)	0 (0)
Nifedipine	21 (2.4)	2 (2)
Diltiazem	19 (2.2)	3 (3)
Enalapril	19 (2.2)	0 (0)
Hydroxazine	18 (2.10)	0 (0)
Heparins	15 (1.7)	11 (10.9)
Magnesium sulfate	14 (1.6)	0 (0)
Venlafaxine	13 (1.5)	0 (0)
Valproic acid/divalproex	12 (1.4)	0 (0)
Vancomycin	12 (1.4)	7 (6.9)
Acetylcysteine	11 (1.3)	0 (0)
Famotidine	11 (1.3)	0 (0)
Potassium phosphate	11 (1.3)	0 (0)
Labetalol	11 (1.3)	5 (5)
Albuterol	10 (1.1)	2 (2)
Carbamazepine	10 (1.1)	0 (0)
Cefuroxime	10 (1.1)	0 (0)
Metronidazole	10 (1.1)	0 (0)

A total of 61 different specific types of route-related prescribing errors were detected. Thirty-seven specific errors occurred more than once and 21 occurred 5 or more times. The most common errors were orders for the administration of a controlled-release dosage form via nasogastric tube (14.4%), orders for a drug to be given orally instead of by the correct IV route (10%), and orders for a drug to be given IV instead of by the correct oral route (9.4%) (Table 1). The most common types of error involved a prescription for the wrong route of administration (39.2%), an order for coadministration of the same or similar medications by 2 different routes (21.1%), and a failure to administer the correct dose for the ordered/intended route (20%) (Table 2). The most common individual medications involved were phytonadione (8.7%), ketorolac (8.2%), and isosorbide mononitrate (7%) (Table 3). The most common medication classes involved were cardiovascular agents (23.5%), antimicrobials (10.7%), vitamins (8.8%), and nonsteroidal anti-inflammatory agents (8.8%) (Table 4). The most common medications and medication classes involved in each type of error is shown in Table 2.

approximate total of 2,112,000 medication orders were written. A total of 10,875 significant prescribing errors of all types were documented during the study period. The numbers of route-related errors detected per 1,000 medication orders, per 100 hospital admissions, and per 1,000 patient days for each year (annualized for 2004) are shown in Figure 2.

Prescribers, Error Types, and Medications Involved

Medical services patients were

involved in 450 errors (52.2%), 59 of which were potentially severe or serious. Surgical services patients were involved in 277 total errors (32.1%) and 29 severe/serious errors. Pediatric services patients were involved in 78 total errors (9%) and 5 severe/serious errors. Emergency services patients were involved in 29 total errors (3.4%) and 5 severe/serious errors. Obstetric/gynecologic services patients were involved in 28 total errors (3.2%) and 3 severe/serious errors.

Potential for Adverse Events

Prescribing errors most commonly presented an “end effect risk” for administration of a drug in an appropriate dose but by the wrong route (27.5%) and overdoses for the route of administration (21.8%) (Table 5). The most common medications and medication classes involved for each resulting error that presented an “end effect risk” are shown in Table 5. The most common potential patient adverse effect when errant orders had been carried out were those

Table 4. Medication Prescribing Errors Related to the Route of Administration: Drug Classes Involved in Errors

<i>Drug Class</i>	<i>Total No. (% total)</i>	<i>No. Severe/Serious Errors (% of severe/serious)</i>	<i>Most Common Medications in Each Class (n)</i>
Cardiovascular	246 (23.5)	45 (44.6)	Isosorbide mononitrate (60) Metoprolol (49) Clonidine (23) Nifedipine (21) Diltiazem (19) Enalapril (19)
Antimicrobials	92 (10.7)	18 (17.8)	Clindamycin (22) Cefuroxime (10) Vancomycin (12)
Vitamin	76 (8.8)	(1)	Phytonadione (75)
Nonsteroidal anti-inflammatory	76 (8.8)	0 (0)	Ketorolac (71)
Gastrointestinal	60 (7)	1 (1)	Ranitidine (29) Famotidine (11)
Opiate	55 (6.4)	5 (5)	Morphine (40) Oxycodone (8)
Electrolyte/mineral	38 (4.4)	4 (4)	Magnesium sulfate (14)
Respiratory	29 (3.4)	4 (4)	Acetylcysteine (11) Albuterol (10)
Antiepileptic	25 (2.9)	0	Carbamazepine (10) Valproic acid (12)
Hormonal	21 (2.4)	1 (91)	Prednisolone (8)
Anticoagulant	20 (2.3)	14 (13.9)	Heparins (15)
Antihistamine	19 (2.20)	0 (0)	Hydroxyzine (18)
Diuretic	13 (1.5)	0 (0)	Metolazone (9)
Psychiatric	12 (1.4)	2 (2)	Bupropion (5)
Vaccine	12 (1.4)	1 (1)	Haemophilus influenzae vaccine (5)
Sedative/hypnotics	11 (1.3)	1 (1)	Chloral hydrate (6)
Other	155 (18)	4 (1)	
TOTAL	862	101	

due to excessive pharmacologic effects (ie, an overdose), which accounted for more than half of the cases (Table 6). The most common medications and medication classes causing each type of potential adverse event type are shown in Table 6. The medications most commonly associated with potentially severe/serious adverse events

were metoprolol and heparins (unfractionated heparin/low molecular weight heparin). The number of severe/serious errors for each specific error type, error class, specific medication, medication class, resulting error end-effect, potential resulting adverse drug event, and contributing/enabling factor are listed in Tables 1-7.

Contributing and Enabling Factors

The most commonly assigned medication characteristic contributing to prescribing errors was the common use of a drug by multiple routes of administration (654 errors [75.8%]). Similarly, the most common factor enabling the prescribing errors to be carried out as ordered was the availability of a drug in multiple dosage formulations (41.9%) (Table 7).

DISCUSSION

Administration of medications by the wrong route is well recognized as a cause of serious patient harm. Prescribing errors involving the route of administration have been reported²²⁻²⁷ but not systematically evaluated. Prescribing is the starting point of the medication use process, and errors at this step are often averted but may be carried out with resulting adverse patient outcomes.¹⁻³ Route-related errors are commonly detected by pharmacists, and we have previously reported that errors specifically involving the wrong route accounted for 15% of dosage form-related prescribing errors and approximately 3.5% of all prescribing errors.^{5,6,7,10} Concurrent evaluation of these orders demonstrated a wide variety of ways in which the route of administration plays a role in prescribing mistakes. Route-related prescribing errors were noted to occur because of inadvertent mistakes or “slips” and intentional, yet incorrect, prescriptions that were caused by a likely knowledge or information deficit. This led us to examine route-related medication prescribing errors using a broad definition in order to capture the multiple ways route of administration prescribing errors contribute to patient risk. Using the broader definition of “route-related” errors, as

Table 5. Medication Prescribing Errors Related to the Route of Administration: Resulting Effect of Prescribing Errors Involving Route of Administration

<i>Effect of Prescribing Error</i>	<i>Total Errors (% total)</i>	<i>Severe or Serious Errors (% severe/serious)</i>	<i>Most Common Drug Classes (n)</i>	<i>Most Common Drugs (n)</i>
Administration of drug by wrong route for patient, drug, or intended use	237 (27.5)	12 (11.9)	Vitamin (76) Cardiovascular (19) Antihistamine (17)	Phytonadione (75) Hydroxyzine (17)
Overdose	188 (21.8)	49 (48.5)	Cardiovascular (74) Antimicrobial (41) Gastrointestinal (31)	Metoprolol (22) Ranitidine (22) Enalapril (19)
Underdose	146 (16.9)	24 (23.7)	Opiate (38) Cardiovascular (30) Mineral/electrolyte (24)	Morphine (34) Magnesium sulfate (12) Metoprolol (11)
Duplicate concurrent drug therapies	139 (16.1)	7 (6.9)	NSAID (68) Cardiovascular(40)	Ketorolac (68) Isosorbide mononitrate (31)
Disrupted special dosage form	135 (15.7)	7 (6.9)	Cardiovascular (80) Anti-epileptic (16)	Isosorbide mononitrate (28) Diltiazem (16) Nifedipine (16)
Wrong dosing frequency	17 (2)	0 (0)	Cardiovascular (16)	Clonidine (16)
TOTAL	862	101		

in this study, we found that these errors account for almost 8% of all detected prescribing errors in our hospital.

Common Error and Medication Characteristics

As expected, this systematic evaluation demonstrated that route-related errors occur in a variety of ways, with 61 different specific types of errors detected during the study period. Almost every possible wrong route or wrong dose for prescribed route was detected. Errors varied from subtle problems, such as administration of vaccines subcutaneously instead of the recommended intramuscular route, to serious and obvious errors, such as orders for intravenous administration of procaine penicillin. The most common errors were, expectedly, those in which the wrong route of adminis-

tration was ordered. However, errors involving inappropriate dosing of medications for ordered route of administration, ordering of medication by multiple concurrent routes, and ordering medications to be administered by a route that would disrupt important dose formulations also occurred frequently.

While route-related errors were found to occur in multiple ways, clear and predictable patterns were found in the characteristics of medications involved. Medications with similar use patterns and available dosage form characteristics were involved in similar errors. As a result, therapeutic use and available formulation characteristics determined which medications were commonly involved in errors. Medications used by multiple routes and available in multiple dosage forms

were, as expected, most commonly involved. Medications available as injectable forms appear to present the greatest risk for error because of the multiple ways and the wide range of doses through which an injectable form can be physically administered. While medications available in injectable forms present the greatest risk, medications in oral liquid form, topical liquids, and even liquid-filled capsules have been administered by injection or in inappropriate doses.^{12,16,19,20,22,23}

Specific routes of administration for a medication may be appropriate in some clinical situations but not in others. Phytonadione, the most common medication involved, serves as an example. Phytonadione is available as an oral tablet as well as an injectable that can be administered intravenously, subcutaneously, or intramuscularly. In patients with

Table 6. Medication Prescribing Errors Related to the Route of Administration: Potential Resulting Adverse Patient Effects

<i>Type of Error</i>	<i>Total Errors (% total)</i>	<i>Severe or Serious Errors (% severe/serious)</i>	<i>Most Common Drug Classes (n)</i>	<i>Most Common Drugs (n)</i>
Adverse drug reaction-excessive pharmacologic effects (overdose)	448 (52)	65 (64.3)	Cardiovascular (171) NSAID (67) Antimicrobial (50) Gastrointestinal (37)	Ketoralac (67) Metoprolol (38) Isosorbide mononitrate (28) Clonidine (23)
Decreased therapeutic effect	152 (17.6)	28 (27.7)	Opiate (38) Antimicrobial (33) Cardiovascular (22)	Morphine (35) Metoprolol (11) Vancomycin (10)
Toxic or other adverse effects due to route or dosage form	148 (17.2)	4 (4)	Vitamin (75) Antihistamine (17) Diuretic (12)	Phytonadione (75) Hydroxyzine (17)
Adverse reaction and decreased therapeutic effects	78 (9)	0 (0)	Cardiovascular (42) Mineral (13)	Isosorbide mononitrate (32) Magnesium sulfate (12)
Excessive pharmacologic effects and toxic effects	26 (3)	4 (4)	Cardiovascular (9) Sedative/hypnotic (9)	Alprazolam (5) Chloral hydrate (5)
Decreased therapeutic effects and toxicity	10 (1.6)	0 (0)	Antimicrobial (6)	Clindamycin (6)
TOTAL	862	101		

coagulation disorders (eg, excessively high prothrombin time), intramuscular injection of phytonadione presents unnecessary risk for hematoma without clinical advantages over other routes. Compared with other appropriate routes, use of intramuscular phytonadione in such cases illustrates the inappropriate use of a common route of administration in patients with contraindications or an increased risk for adverse events.

Medications with significant differences in usual doses for different routes of administration present risk for dosing errors, and the availability of liquid dosage forms makes administration of inappropriate doses possible.²¹ Metoprolol and morphine represent medications with substantial differences in dosage regimens between available dosage forms. Because many of these medications are available

as oral and injectable doseforms, errors in prescribing the correct dose for the ordered route present significant risk for error and subsequent patient harm. This characteristic of a medication is also a primary contributor to errors when patients are “converted” from one route of administration to another.²¹

Medications and medication classes administered by multiple routes also present risk for duplication of therapy. This often appeared to be due to failure of caregivers to recognize the duplicate therapies. Concurrent orders for administration of the same or similar medications appears to be particularly problematic when similar medications are available to be administered by different routes (eg, oral isosorbide mononitrate coadministered with nitroglycerin paste or patch), or for different

indications (eg, oral celecoxib for “arthritis” prescribed concurrently with injectable ketorolac for “pain control”). Errors involving duplicate routes of administration (eg, concomitant intravenous heparin and subcutaneous enoxaparin) may be particularly hazardous.

As previously reported,¹⁰ medications available in special dosage formulations are commonly involved in errors caused by disruption of drug delivery characteristics when administered by the wrong route or technique. Medications available in controlled-release forms such as isosorbide mononitrate, nifedipine, and diltiazem are frequently involved in errors when they are ordered to be administered through a nasogastric tube, which will disrupt the dosage form’s controlled-release characteristics. Drug delivery can be markedly altered when dosage

Table 7. Medication Prescribing Errors Related to the Route of Administration: Primary Medication and Dosage Form Characteristics Contributing to Error, and Factors Enabling Errors to be Carried to Completion

	Total (% total)	Severe or Serious (% severe/serious)	Most Common Drugs (n)	Most Common Drug Classes (n)
Medication characteristics contributing to prescribing errors				
Selection error and/or confusion with multiple common routes of administration and dose formulations available	654 (75.9)	91 (90)	Phytonadione (75) Ketorolac (67) Morphine (35) Metoprolol (33) Isosorbide mononitrate (32)	Cardiovascular (130) Antimicrobials (75) Vitamins (75) NSAID (68) Opiate (36)
Controlled-release form or enteric-coated oral doseform	154 (17.9)	7 (6.9)	Isosorbide mononitrate (28) Diltiazem (16) Nifedipine (16)	Cardiovascular (86) Anti-epileptic (17)
Dose regimen change with route change	30 (3.5)	1 (1)	Clonidine (16)	Cardiovascular (16)
Specific or special technique of administration required	24 (17.2)	2 (2)	Albuterol (5) Nifedipine (5) Nimodipine (5)	Cardiovascular (10) Respiratory (5)
TOTAL	862	101		
Characteristics enabling administration of medication prescribed in error				
Multiple common routes of administration and dose formulations available	362 (41.9)	31 (30.7)	Phytonadione (75) Ketorolac (67) Metoprolol (33) Antimicrobials (57)	Vitamins (75) NSAID (67) Cardiovascular (65)
Injectable and other doseform available for drug	174 (20.2)	53 (52.4)	Metoprolol (33) Enalapril (18) Hydroxyzine (17)	Cardiovascular (81) Antimicrobial (18)
Controlled-release or enteric-coated forms that can be disrupted	141 (17.2)	7 (6.9)	Isosorbide mononitrate (28) Diltiazem (16) Nifedipine (16)	Cardiovascular (86) Antiepileptic (17)
Oral/non-IV liquid doseform available	121 (14)	7 (6.9)	Morphine (35) Acetylcysteine (11)	Opiate (36) Diuretic (12) Benzodiazepine (11)
Dose regimen change with route change	30 (3.5)	1 (1)	Clonidine (16)	Cardiovascular (16)
Alternative techniques of administration	24 (2.7)	0 (0)	Albuterol (5)	Respiratory (5)
Liquid-filled capsule available	10 (1.2)	2 (2)	Nifedipine (5) Nimodipine (5)	Cardiovascular (10)
TOTAL	862	101		

forms are disrupted, presenting risk for adverse effect or diminished therapeutic effect.²⁶

Risk to Patients

Even if an error progresses through the medication prescribing system to the point at which it

“reaches” the patient, only a small fraction of errors in the medication use process result in adverse patient events.³⁰ Because of error

Table 8. Medication Prescribing Errors Related to the Route of Administration: Select Recommendations to Reduce Patient Risk

Educate caregivers about the following items:

- Potential for medication errors involving the route of administration
- Effect of route of administration on drug delivery and effects
- Effect of dosage forms on drug delivery and effects
- Availability of new dosage formulations of previously available medications

Control and limit access to medications.

Require pharmacist review of medications prior to drug administration whenever possible.

Require pharmacist review when the route or technique of medication is changed.

Include proper warnings and checks into computer prescriber order entry systems.

Include warnings and alerts on medication administration records and medication labels.

Include warnings in pharmacy computer systems.

Include warning and alerts when problem-prone medications are removed from unit stock or unit based automated medication dispensing machines.

Never use syringes compatible with needles or IV and other line access ports for nonparenteral medications.

Require time out and individual double-checks whenever medications are administered epidurally or intrathecally.

Maximize pharmacy-based preparation of medications in ready-to-administer forms.

Label all lines and tubes that can be potentially used for drug administration.

Establish and enforce standards for prescribing medication, including the use of abbreviations, legibility, clarity, and completeness.

defenses such as pharmacist and nurse medication order-review and the physical constraints of available medication dosage forms, the vast majority of route-related prescribing errors are averted prior to administration. Unfortunately, in our experience, not all errors were averted, and sometimes they resulted in adverse patient outcomes. A number of the errors reported in this study, some of which resulted in adverse events, were caused by access to the drug prior to the pharmacist's order review. However, a systematic evaluation of the outcome was not performed. This study was limited by the use of "near miss" reports and the ability to determine the risk that the error would be carried out and, if carried out, what harm the patient would experience. During our 20 years of experience,⁵⁻¹⁰ we have found that "near-miss" errors in the medication-use process are pre-

dictive of errors that reach the patient and cause harm.^{26,27} Over half of the errors would, if carried out effectively, result in a significant overdose and present a risk for concentration-related adverse effects. A substantial number of the errors would potentially result in either decreased therapeutic effect or a unique toxic reaction. Given the high number of detected errors, failure of error prevention systems to avert even a small fraction of errors present significant risk for patient harm. The causes of the noted increase in route-related errors are likely multiple and include new medications and dosage forms available, greater patient acuity, shorter length of stay, and greater pharmacist vigilance. Route-related prescribing errors may be particularly dangerous, because voluntary reports of medication errors involving technique or route of administration

are associated with a higher frequency of harm than other types of medication errors;³⁰ therefore, the information this study provides may be of particular importance in the reduction of patient risk.

Error Causes and Potential Improvements

A limited number of "factors," such as lack of knowledge or information regarding therapeutics, inadequate availability and use of patient information, confusing prescription and drug nomenclature, need for dose calculations, and inappropriate use of dosage formulations, contribute to the majority of prescribing errors.^{1-3,5-10} Errors in this study involved both apparently "inadvertent" prescribing of medications as well as clearly intentional plans to administer a medication in an inappropriate way. The education that health care providers and patients receive

regarding the properties and proper use of the various medication dosage forms and routes is inadequate. Smetzer and Cohen,^{22,23} reported that 35% of nurse anesthetists were unable to name the proper route of administration of long-acting injectable penicillin preparations and that medical caregivers are often willing to give oral liquids intravenously. Medication-use system improvements, such as computer prescriber order entry (CPOE), could potentially prevent many of the reported errors.³¹ However, CPOE is currently not available in the majority of U.S. hospitals and, in many institutions with CPOE, it is not used universally.^{32,33} Additionally, such systems are not completely effective in the elimination of prescribing errors and will introduce additional errors.^{34,35} More immediate patient safety improvements might be obtained through improved medication-use system processes that include active involvement of pharmacists on patient-care teams and units.³⁶ Providing adequate pharmacy support and staff deployment to allow these services and continuing to provide the safest ready-to-administer medication doses in an appropriate, timely fashion remains a challenge for many hospitals. Therefore, improvement of a number of fundamental medication safety processes, in general, where appropriate, and in specific relation to route-related errors³⁷ appears necessary to reduce patient risk for adverse drug events from route-related errors. Pharmaceutical company formulation, packaging, and labeling improvements as well as the incorporation of messages regarding risk for error in product marketing and advertising may reduce risk for route-related errors. Suggested medication

administration error prevention strategies for health care providers are listed in Table 8.

Study Limitations

This study has a number of limitations. Because of inherent differences in structure and operational components of various health care settings, the findings of this study may not be directly applicable to other hospitals or care environments. Medication-use patterns and patient populations will obviously impact medications involved and errors detected. Identification and resolution of errors by pharmacists was dependent upon individual skills. Potential patient risk from detected errors was based on known population-based drug effects rather than individual patient susceptibility. Although many of the suggested error prevention strategies are based on accepted principles of safe medication systems, they have not demonstrated reduced prescribing errors involving the route of administration in controlled trials.

Conclusions

Prescribing errors related to the route of medication administration are common and occur in complex but predictable ways. These errors present considerable risk to patients for adverse events, and the frequency appears to be increasing. Medications available as an injectable and used by multiple administration routes carry the greatest potential to harm. Similar recurring errors support the concept that prescribing errors are associated with a limited number of identifiable factors and provide an opportunity for targeted improvements in the use of medication. Immediate improvements in medication-use system processes

are necessary to safeguard patients from medication errors related to the route of administration.

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Appendix: Potential Severity Classifications for Order Errors (Adapted from reference 6)

Note: Classification system provides for the assignment of a generalized population-based assessment of risk. It is recognized that errors rated as “fatal or severe” may produce little or no adverse effects in some patients, just as it is recognized that errors rated as “significant” may produce life-threatening adverse effects in some patients.

- A. Potentially Fatal or Severe Adverse Outcomes (cardiovascular arrest, serious arrhythmia, stroke, life-threatening metabolic abnormality, therapeutic failure in life-threatening illness [eg, reaction following administration of a large volume of oral suspension IV])**
- A dose or dose delivery ordered for 10-fold or greater overdose of a medication with a low therapeutic index.
 - A dose or dose delivery ordered for a medication with a very low therapeutic index that would potentially produce severe or fatal adverse effects in a substantial proportion of patients.
 - A drug, dose, or dose delivery ordered that would produce severe or fatal toxicity in a substantial proportion of patients with similar medical characteristics.
 - A drug, dose, or dose delivery ordered for a medication that treats a life-threatening illness or severe disorder that would potentially result in therapeutic failure in a substantial proportion of patients.
 - Drug or doseform ordered to be administered by a route or method that would potentially result in fatal or severe toxicity in a substantial proportion of patients.
- B. Potentially Serious Outcomes (significant cardiovascular decompensation, metabolic disorder requiring urgent treatment, inadequate, incomplete or significantly delayed therapeutic response in serious or severe illness [eg, metoprolol 100 mg ordered IV push every 12 hours])**
- A dose or dose delivery ordered for 4- to 10-fold overdose of a medication with a low therapeutic index.
 - A dose or dose delivery ordered for a medication with a very low therapeutic index that would potentially produce serious adverse effects in a substantial proportion of patients.
 - A drug, dose, or dose delivery ordered that would produce serious toxicity in a substantial proportion of patients with similar medical characteristics.
 - A drug, dose, or dose delivery ordered for a medication that treats a serious illness that would potentially result in therapeutic failure or suboptimal response in a substantial proportion of patients.
 - Drug or doseform ordered to be administered by a route or method that would potentially result in serious adverse events in a substantial proportion of patients.
- C. Potentially Significant Adverse Outcomes (symptomatic hypotension, metabolic abnormality requiring treatment, sub-optimal therapeutic response, gastrointestinal upset, dizziness [eg, isosorbide mononitrate 90 mg ordered to be given via nasogastric tube])**
- A dose or dose delivery ordered for 1.5- to 4-fold overdose of a medication with a low therapeutic index.
 - A dose or dose delivery ordered for a medication that would potentially produce some adverse effects in a proportion of patients.
 - A drug, dose, or dose delivery ordered that would produce adverse effects in some proportion of patients with similar medical characteristics.
 - A drug, dose, or dose delivery ordered for a medication that would potentially result in reduced, incomplete, or delayed therapeutic response in some proportion of patients.
 - Drug or doseform ordered to be administered by a route or method that would potentially result in adverse events in some proportion of patients.
- D. Problematic (minor problem but order presents risk for either minor adverse event or decreased therapeutic effects for a non-serious medical indication [eg, chlorhexidine 15 mL ordered as “swish and swallow” instead of “swish and spit”])**