Structured Inspection of Medications Carried and Stored by Emergency Medical Services Agencies Identifies Practices That May Lead to Medication Errors

Douglas F. Kupas, MD, Meghan A. Shayhorn, MD, Paul Green, PharmD, Thomas F. Payton, MD

Abstract

Background. Medications are essential to emergency medical services (EMS) agencies when providing lifesaving care, but the EMS environment has challenges related to safe medication storage when compared with a hospital setting. We developed a structured process, based on common pharmacy practices, to review medications carried by EMS agencies to identify situations that may lead to medication error and to determine some best practices that may reduce potential errors and the risk of patient harm. **Objective.** To provide a descriptive account of EMS practices related to carrying and storing medications that have the potential for causing a medication administration error or patient harm. **Methods.** Using a structured process for inspection, an emergency medicine pharmacist and emergency physician(s) reviewed the medication carrying and storage practices of all nine advanced life support ambulance agencies within a five-county EMS region. Each medication carried and stored by the EMS agency was inspected for predetermined and spontaneously observed issues that could lead to medication error. These issues were documented and photographed. Two EMS medical directors reviewed each potential error for the risk of producing patient harm and assigned each to a category of high, moderate, or low risk. Because issues of temperature on EMS medications have been addressed elsewhere, this study concentrated on potential for EMS medication administration errors exclusive of storage temperatures. **Results.** When reviewing medications carried by the nine EMS agencies, 38 medication safety issues were identified (range 1 to 8 per EMS agency). Of these, 16 were considered to be high risk, 14 moderate risk, and eight low risk for patient harm. Examples of potential issues included carrying expired medications, container-labeling issues, different medications stored in look-alike vials or prefilled syringes in the same compartment, and carrying crystalloid solutions next to solutions premixed with a medication. When reviewing medications stored at the EMS agency stations, eight safety issues were identified (range from 0 to 4 per station), including five moderate-risk and three low-risk issues. No agency had any high-risk medication issues related to storage of medication stock in the station. **Conclusion.** We observed potential medication safety issues related to how medications are carried and stored at all nine EMS agencies in a five-county region. Understanding these issues may assist EMS agencies in reducing the potential for a medication error and risk of patient harm. More research is needed to determine whether following these suggested best practices for carrying medications on EMS vehicles actually reduces errors in medication administration by EMS providers or decreases patient harm. **Key words:** emergency medical services; patient safety; medication safety.

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Introduction

Medication errors may have serious, even fatal, consequences, and medication administration errors have been suggested to be among the most commonly recognized medical errors in emergency medical services (EMS).[1] A consensus group listed "administration of wrong drug or drug dose" as one of nine common and potentially serious errors in EMS.[2] In a study that used EMS provider focus groups, interviews, and anonymous reporting to classify EMS patient safety events, Fairbanks et al. noted that 15% of the 61 events reported were related to medications.[3] Despite this recognition that medication administration errors may be important causes of medical errors in EMS, methods for carrying and storing medications by EMS with attention to patient safety have not been well studied. Furthermore, Lubin et al. identified wide variation among states in the way that they regulate the formularies of medications carried on EMS vehicles.[4] When compared with the hospital setting, the EMS environment is unique and presents its own set of challenges in ensuring medication safety. Organizations such as the Institute for Safe Medical Practices (ISMP) have many guidelines and suggested safe practices for medication storage and administration,[5] but these patient safety initiatives are often not directly applicable to the

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Address correspondence and reprint requests to: Douglas F. Kupas, MD, Department of Emergency Medicine, Geisinger Health System, 100 North Academy Avenue, Danville, PA 17822-2005. e-mail: dkupas@geisinger.edu

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out-of-hospital setting. Bruce et al. suggested ways in which the 2004 Joint Commission patient safety guidelines could be used by EMS agencies, but it is clearly difficult to directly apply hospital safety guidelines to the EMS setting.[6]

The EMS environment is significantly different from the hospital setting. In addition to caring for a diverse population of patients with a wide variety of clinical conditions in a limited amount of time, EMS providers are generally unable to access a patient's medical records and often are unable to verify or have very little time to obtain a patient's medical history, including current medical problems, medications, and allergies. EMS providers practice in a high-stress environment with limited time for optimal error-prevention strategies used within the hospital. Additionally, they have limited resources to immediately research medication issues and generally do not have the availability of immediate consultation with a pharmacist regarding medication choice and dosage.[1]

A hospital code team response to a cardiac arrest is a situation that has some similarity to the medication environment of an EMS response—the situation is highly stressful, rescuers may have little knowledge of patient history, medications are given on verbal orders, and medications are given without the usual redundancies and double-checking that are part of usual hospital pharmacy practice. A report published by the ISMP in February 2011 showed that the most common errors occurring during an in-hospital code involve medication administration.[7] These errors include dosage errors, drug selection errors, drug preparation errors, drug administration errors, and drug omission errors. Examples of such errors that have been reported to the ISMP include choosing the wrong concentration of the drug (for example, a physician prescribes dextrose 50% intravenously for an infant, instead of dextrose 10%) and look-alike drugs (for example, a vial of furosemide instead of midazolam is used on the code cart; both came in the same-size vials with orange caps).[7]

Issues regarding the effect of temperature on EMS medications have been studied, and the results show that the potency of medications used by EMS is influenced by temperature.[8,9] Several studies have documented variations in the temperature of medications carried in EMS ambulances that are outside of both minimum and maximum recommended temperatures for storing medications.[10–14] Encouragingly, in 2002 Mehta et al. showed a significant increase in the number of New Jersey ambulances that are using temperature-controlled compartments and monitoring drug storage temperatures on ambulances.[15] Because of the previous work related to the effect of temperature on EMS medications, our study does not further address the effects of temperature on medications stored in ambulances.

Potential medication errors in EMS also include drug selection errors, dosing errors, adverse drug interactions, drug preparation and infusing errors, protocol and judgment errors, and administration of expired medications. Previous solutions to EMS medication errors have focused on preventing dosing errors. Brennan et al. noted that medication dosing mistakes are a potential source of serious medication-related adverse events in EMS systems.[16] Meisel et al. suggested that a variation of the commonly used pediatric height-based dosing tape could be adapted into a symptom-specific reference to aid EMS medication administration to adults.[17]

Suggestions to decrease risk related to EMS medication administration have generally not focused on issues related to how medications are carried within the "drug bag." By identifying and describing situations for potential medication errors by EMS agencies, we hope to increase awareness and propel change that will ultimately improve the safety of patients in the prehospital setting.

The purpose of this study was to identify and describe potential patient safety issues related to EMS practices, when carrying and storing medications, by using a structured inspection process based on common pharmacy practices. Based on the observed issues, we have also suggested some potential best practices to avoid medication administration errors in the EMS setting.

METHODS

This was a prospective observational inspection of the medication carrying and storage practices of all nine advanced life support (ALS) EMS agencies within a five-county region. Oxygen and oral glucose are the only medications that must be carried on a basic life support (BLS) ambulance in Pennsylvania; therefore, BLS ambulances were excluded from this study. At the time of the study, Pennsylvania did not have an intermediate level of EMS practitioner between an emergency medical technician and a paramedic; therefore, all ALS vehicles are equipped to provide care at the paramedic level. Because air ambulances are permitted to carry medications beyond those listed on the state ALS formulary, the air ambulance agency in the region was excluded from the study. Prior to inspection visits to the EMS agencies, the authors developed a structured plan for the inspections, including a data form to collect observations of interest.

The data-collection form listed all 51 medications on the Pennsylvania Department of Health–approved EMS ALS formulary at the time of the study. In Pennsylvania, ALS EMS agencies are required to carry every medication that is mandated in the statewide EMS protocols, but agencies may optionally carry other medications that are listed on the approved ALS formulary. Therefore, there is a variation in the number of

medications carried by EMS agencies. During state licensure inspections, medications on EMS vehicles are inspected for their presence and expiration date, but there are no specific requirements related to the bag or container in which medications are carried, the ways in which the medications are supplied (e.g., vials, ampoules, prefilled syringes), or the forms of a medication that are carried; therefore, the standardized data-collection form was developed by consensus using the EMS, emergency department, and pharmacy medication safety experiences of the authors.

Data were collected on each medication carried or stored by each EMS agency. The data form included an alphabetical list of all medications on the state ALS formulary, with columns for information related to each medication carried or stored by the EMS agency, including the quantity carried, whether multiple concentrations were carried, whether the medication was in the original packaging, whether the medication was stored with a "look-alike" medication in the same compartment, and whether the medication had reached its expiration date. Except for lorazepam, medications were considered to be expired if they had exceeded the expiration date on the label. The state permits EMS agencies to carry lorazepam without refrigeration for a period of 60 days after removal from refrigeration. Therefore, the data form indicated that any lorazepam carried must be relabeled by the EMS agency to reflect the new expiration date if carried outside of a refrigerator.

Within each ALS agency, the same type and style of bag is used to carry medications on all of the agency's ALS vehicles, and these are generally stocked in a similar manner. Therefore, each issue identified was listed only once for each agency, even if it recurred in other bags within the agency.

Inspection visits to the EMS agencies were made by a team of authors, but the same emergency medicine pharmacist and emergency medicine resident physician visited every agency for consistency in data collection. The agency visits were unannounced. At the time of the visit, the investigators provided the EMS manager or provider on duty with an introductory letter that explained the study. Participation was voluntary, and agency representatives had the opportunity to refuse to participate after reading the introductory letter. No incentives were given to those who chose to comply with the study, and the visit was not associated with any other business that may have coerced the agency to participate. The investigators were granted permission to conduct the inspection at all agencies within the five-county EMS region. The investigators inspected the medications stored on every vehicle available at the station during the visit and inspected the medication stock stored at the station. The inspection team made a single visit to each agency and inspected all medication bags for ALS vehicles that were at the station during the visit. Vehicles that were out on a call or otherwise away from the station were excluded from inspection. The medication stock of every licensed ALS vehicle that was on site was inspected. The inspected vehicles were generally staffed vehicles that were available for an emergency call, but if the vehicle was unstaffed, it was still a licensed vehicle that would have been placed into service immediately if needed. The inspection team did not collect information on the EMS agency's procedures or policies related to "shift" checks of each vehicle's stock and equipment. To ensure anonymity, unique identifiers were used to specify each EMS agency and each EMS vehicle "drug bag."

During the inspection, for each medication, the team systematically went though the list of medication data and predetermined issues on the data-collection form, and the form served to ensure that the inspections were uniform. In addition to the review of predetermined safety issues, the investigators also recorded spontaneously observed situations that may, in the opinion of the inspection team, represent potential patient safety risks. During the visit, all potential medication errors were documented on the data-collection form and each issue was photographed.

The authors developed a priori definitions for categories of risk related to issues identified by the inspection. There are not generally accepted definitions for categories of risk posed by EMS medication storage and carrying practices; therefore, the authors defined these categories as follows: *high-risk* issues are those with potential to cause immediate or serious patient harm if a medication administration error were to occur; *moderate-risk* issues may cause morbidity or may lead to an outcome that is not optimal if they were to occur; and *low-risk* issues are those not consistent with generally accepted pharmacy practices.

After all visits were completed, two authors (who are each board-certified emergency physicians, paramedics, and EMS agency medical directors) together reviewed the photographs of each identified medication safety issue for risk of producing patient harm and assigned each to a category of high, moderate, or low risk. Because the definitions for each of these categories are subjective, any discrepancies in assignment were resolved by consensus.

After completion of the study, the blinded results were shared with the EMS agency medical directors and ALS agency operations directors through the regional medical advisory committee in the hopes of changing the practices that were felt to have risk for potential medication error.

This study was determined to be exempt by the Institutional Review Board of Geisinger Health System and was approved by the Pennsylvania Department of Health Bureau of EMS.

RESULTS

At the time of the study, the nine ALS EMS agencies had 28 ALS vehicles. EMS vehicle medication bags for 15 of the ALS vehicles were successfully inspected; the other vehicles were not at the station at the time of the unannounced visits. Medication carrying and storage issues were recorded for each of the nine ground ALS agencies within the region. We observed a total of 46 potential medication errors or issues—38 on ambulances and eight within the EMS stations.

There was variation in the number of medications carried by each EMS agency—ranging from 21 to 30 different medications per agency.

When reviewing the medications carried on a total of 15 ALS vehicles, 38 medication safety issues were identified (range of 1 to 8 in each EMS agency). Of these, 16 were considered to be high risk, 14 moderate risk, and eight low risk for patient harm. At least one high-risk finding was identified at eight (89%) of the agencies, and the median numbers of findings per agency were two of high risk, one of moderate risk, and one of low risk. A description of each issue and its level of risk is listed in Table 1. Examples of potential issues included carrying expired medications, container-labeling issues, different medications stored in look-alike vials or prefilled syringes in the same compartment, and carrying crystalloid solutions next to solutions premixed with a medication. Photographs of some selected examples are shown in Figures 1–4.

Ten of the issues identified were not listed on the data-collection form but were spontaneously observed by the inspection team. The spontaneously observed issues included the following: controlled substances carried in a separate bag that was not double locked (5), a method of securing controlled substances within a separate container that precluded EMS providers from visualizing the integrity of the medication or checking its expiration date (2), aminophylline carried in medication bag but not listed on the state formulary (1), a medication bag held closed by large rubber bands (1), and unit doses of medications for nebulization carried in an eyeglass container (1).

When reviewing medications stored at the EMS agency stations, eight medication storage errors or issues were identified (range of 0 to 4 per station), with a median of one medication storage issue per agency (Table 2). These include five moderate-risk and three low-risk issues. No agency had a high-risk medication issue related to medication storage in the station.

FIGURE 1. High-risk example: 250-mL bags of normal saline solution and lidocaine solution found in the same pocket of an ambulance medication bag.

FIGURE 2. High-risk example: look-alike vials (similar size, with identical green caps) carried side by side in an ambulance medication box.

TABLE 1. List of Potential Medication Errors Observed in Advanced Life Support "Drug Bags" Carried on Ambulances

Agency	Risk	Description
A	High	250-mL bags of lidocaine 1-g/250-mL solution and NSS carried next to each other in the same compartment of the medication bag
	High	Adenosine, terbutaline, and ondansetron stored in vials in a medication box compartment clearly labeled "ondansetron"
	Moderate	Unlabeled, single-locked narcotic bag
	Moderate	Epinephrine (1:1,000) carried three different ways in the medication bag: 1-mL vial, 1-mL ampoule, and 30-mL multidose vial
	Low	Medication bag closed with rubber bands
B	High	Calcium chloride is expired
	High	Aminophylline 250 mg/mL carried in the medication bag, but not an approved drug on the state EMS formulary
	High	500-mL bags of lidocaine 2-g/500-mL solution and NSS carried next to each other in the same compartment of the medication bag
	Moderate	Unlabeled, single-locked narcotic bag
	Moderate	No documentation of narcotics carried (amounts, lot numbers, or expiration dates) in the narcotic bag sealed with a numbered snap lock
C	High	Morphine and diazepam carried in similar syringe cartridges (Carpuject®) syringes stored side by side in separate compartments in the same container
D	High	Midazolam and diazepam in same-size vials in the same compartment of the medication bag (one clear vial, one opaque vial)
	High	Diphenhydramine 50-mg/mL and ondansetron 4-mg/2-mL vials in the same compartment (one green top, one gray top) in the medication bag
	High	Morphine and fentanyl syringe cartridges carried next to each other in separate side-by-side compartments in the same container in the medication bag
	High	In a pediatrics medication box, ondansetron 4 mg/2 mL and midazolam 5 mg/mL (both in vials with green tops) stored in the same compartment
	Moderate	Single-locked narcotic box
	Moderate	Aspirin stored in a small container, not in its original packaging, with no expiration date
	Moderate	Dextrose 50% 25-g and dextrose 25% 2.5-g prefilled syringes next to each other in the medication bag
	Moderate	Bicarbonate 8.4% 50-mEq and 4.2% 5-mEq prefilled syringes next to each other in the medication bag
E	High	All medications in the narcotic box carried in similar syringe cartridges with the same green top
	Low	Adenosine 6-mg and 12-mg prefilled syringes carried side by side, with the same concentration, 3 mg/mL
F	High	Adenosine 6 mg/2 mL and diphenhydramine 50 mg/mL stored in similar clear vials in the same compartment in the medication bag
	Moderate	Adenosine 6 mg/2 mL carried in two different size vials in the same compartment
	Low	Albuterol carried as a 2.5-mg/3-mL prefilled syringe and as a 5-mg/mL bottle with a dropper in the same compartment
G	High	250-mL bags of lidocaine 1-g/250-mL solution and NSS carried next to each other in the same compartment of the medication bag
	High	Enalaprilat 1.25 mg/mL and oxytocin 10 unit/mL stored in similar clear vials with the same green top in the same compartment in a medication box within the medication bag
	Moderate	Single-locked narcotic box
	Low	Diphenhydramine 50 mg/mL carried in both syringe cartridges and vials
	Low	Single-dose packages of albuterol and ipratropium carried together, not in the original packaging; labeling embossed in the clear plastic of the package and difficult to read
	Low	Single-dose packages of albuterol and ipratropium carried in an eyeglass container
H	Moderate	Aspirin not carried in the original packaging, with no expiration date
	Moderate	Dextrose 50% 25-g and dextrose 25% 2.5-g prefilled syringes next to each other in the medication bag
	Moderate	Bicarbonate 8.4% 50-mEq and 4.2% 5-mEq prefilled syringes next to each other in the medication bag
	Moderate	Single-locked narcotic box
I	High	10-mL prefilled syringes of magnesium sulfate 5 g/10 mL and furosemide 10 mg/mL carried in similar orange-colored and similar-sized boxes in the same compartment within the medication bag
	High	500-mL bags of lidocaine 2-g/500-mL solution and NSS carried next to each other in the same compartment of the medication bag
	Low	Single-dose plastic packages of albuterol and ipratropium carried together in an open foil bag (outer packaging) labeled by the manufacturer as albuterol
	Low	Adenosine 6-mg and 12-mg prefilled syringes carried side by side, with the same concentration, 3 mg/mL

NSS = normal saline solution.

DISCUSSION

In reviewing our observations and data collected, we have recommended some potential best medication practices that EMS agencies may consider when attempting to reduce the possibility of medication-related errors in patient care. These suggestions are opinions of the authors based on their experiences with common medication practices in EMS, emergency departments, and hospital pharmacies (Table 3).

Issues Identified by Authors as High Risk for Causing Error or Harm

Some of the high-risk issues identified and recommended possible solutions are worth additional

FIGURE 3. Moderate-risk example: adenosine syringes with different volumes but the same concentration carried side by side in an ambulance medication bag.

discussion. One observation was the variation in medications carried by each agency. While some agencies carried primarily the core medications that are most frequently used or most critically needed in EMS care or just one option for various classes of medications (e.g., benzodiazepine, narcotic analgesic, or antidysrhythmic medications), other agencies carried many uncommonly used medications and multiple options and formulations of medications side by side in their medication bags. Many of these were different medications carried in vials or cartons of similar sizes or colors. We noted that labels were particularly difficult to read when carried in syringe cartridges (for example, Carpuject syringes) or in single-dose packages of solution for nebulization.

Every additional medication or additional type of packaging adds the potential for a medication dosing or administration error. EMS agency medical directors should consider this when selecting medications to be carried in EMS medication bags, and we recommend that other safeguards be considered that reduce the risk of these errors. Some possible solutions include reassessing the need for all medications carried, and carrying some infrequently used medications in a drug cabinet within the vehicle.

One common and extremely high-risk situation that we encountered was carrying premixed medication solutions next to similarly sized bags of crystalloid solution. Accidentally infusing a bolus of a bag of solution containing premixed medications such as lidocaine or vasopressors can cause severe adverse effects or even death. We recommend that these premixed medication solutions be carried within a separate compartment in the medication bag, and the premixed medications should be packaged with an additional packaging (zippered compartment, plastic bag, etc.) that would serve as a barrier that must be "broken" before a premixed medication solution can be selected.

Multiple Concentrations of the Same Medication

EMS agency managers and medical directors should also consider standardizing the concentrations of medications that the agency carries. We recommend that most medications that must be given by continuous infusion be carried in premixed solutions when available. Agencies should develop standard concentrations for those medications that are mixed by EMS personnel on scene. If agencies have vials of dopamine

FIGURE 4. Low-risk example: repackaged aspirin stored in an ambulance medication bag.

TABLE 2. List of Potential Medication Errors Observed in Medications Stored in the EMS Agency Station

Agency	Risk	Description
A	Low	Multiple over-the-counter and prescription medications stored together in a locked medication cabinet; most over-the-counter medications were not on the state EMS formulary and were for personal use of the EMS providers
B	Moderate	Procainamide vials in station storage were expired
	Moderate	Enalapril vials in station storage were expired
	Low	Storage bin containing multiple vials of stock ondansetron labeled "Phenergan"; Phenergan was not on the state EMS formulary
	Low	Storage container labeled "MISC" contained vials of dopamine, procainamide, enalapril, adenosine, and hydrocortisone
D	Moderate	Medications stored in a non–air-conditioned room in the station
E	Moderate	Medications stored in a non–air-conditioned room in the station
F	Moderate	Prefilled syringes and medication vials all stored together in the same container

EMS = emergency medical services.

or epinephrine that providers are expected to dilute for continuous infusion, each agency or region should consider standardizing the method of mixing these infusions and each medication bag should carry a "recipe" card for situations when it is necessary to mix these on scene.

While some medications may be needed in several concentrations, EMS agency medical directors and managers should consider whether each concentration is needed. For example, 50% dextrose is commonly used in adult patients with hypoglycemia in the United States, but it carries a risk of tissue injury if it extravasates and has the risk of accidentally being given to a pediatric patient. On the other hand, 25% dextrose has less risk of extravasation and can be used effectively for adult patients in addition to pediatric patients.

Miscellaneous Logistic Issues

Several agencies in this study had inadequate methods of tracking the narcotic analgesics that they carry in

TABLE 3. Strategies or Practices That May Prevent or Reduce the Possibility of a Medication Error

Observed Medication Issues	Suggested Solutions
Medication bags stocked differently (types, amounts, doses, and concentrations) in each EMS agency	Standardize medications carried in bags in all EMS vehicles within an agency or region
Carrying medications that must be mixed prior to use	Carry premixed solutions whenever possible
Intravenous crystalloid fluids and premixed medication solutions (e.g., lidocaine) carried in the same compartment within the medication bag	Keep premixed solutions in a separate compartment from intravenous fluids and place premixed medication solutions within another barrier wrapper that must be opened to access these medications
Carrying multiple concentrations of the same medication	Carry one concentration of a medication whenever possible, preferably standardized within the region, unless there is a compelling clinical reason to have several concentrations
All medications, those frequently and infrequently used, carried together in the medication bag	Consider carrying medications that are used infrequently and not needed for time-dependent illness in a compartment within the vehicle rather than in the medication bag
Carrying medications removed from their original packaging	Carry and store medications in their original packaging
Look-alike medications stored in the same compartment	Keep medications that look alike (same color or size vials or syringe cartridges) in separate compartments within the medication bag
Carrying multiple medications of the same class in the medication bag (e.g., multiple different benzodiazepines, narcotic analgesics, or antidysrhythmics)	Carry one mediation of each particular class within the medication bag
Narcotics carried in different ways (ampoules, vials, syringes, and syringe cartridges [e.g., Carpuject®]) with easy access to forms that can easily be replaced with another solution, leading to risk of diversion	Carry narcotics in one form with attention to security that may prevent diversion—ampoules may be the best deterrent to diversion from stock on vehicles or in the station
Expired medications found in the vehicle	Establish a process for logging expiration dates and review these dates and replenish medication stock prior to expiration dates
Not all agency staff aware of medications carried in the medication bags	Periodically review all medications carried, stored, and used with all agency staff; follow a structured checklist process that ensures regular inspection of all medications in vehicles (probably every shift) and in station storage
Medications in the vehicle medication bag and station stock that are not on the state EMS formulary	Ensure administrative compliance and understanding of EMS medication formulary regulations
Narcotics carried in bags that are not appropriately secured or that are secured in a way that does not permit inspection of the medication (e.g., expiration date or damage) because of security measures	Ensure that narcotics are stored in a way that enables inspection for integrity without compromising security

EMS = emergency medical services.

various separate narcotic "pouches" or compartments within their medication bags. Frequently, these narcotics were carried in administration devices or storage devices that allow for easy diversion of the medication. Carrying controlled substances in ampoules is a good method to reduce the chance for diversion from the medication bag between calls. Relatively minor issues with the use of ampoules include the small risk of laceration when opening and the need to draw medications from ampoules using a filter needle.

Expired medications were found in the ambulance and station storage at one EMS agency. In two other agencies, aspirin was repackaged into a container that had no expiration date. Although we did not obtain information related to the process or frequency with which each agency checks its medications, we recommend that agencies require its EMS providers to inspect the stock of each ambulance at the beginning of every shift and the stock of the medication storage area on a defined regular basis. EMS agencies should develop a method of documenting each of these checks by the date, time, and accountable EMS provider who completed the check. Furthermore, we recommend that medications such as aspirin and nitroglycerine be left in their original containers with original expiration dates.

The approach to pediatric medications varied in this region. Some agencies carried a separate pediatric medication bag. While this has the advantage of reducing the chance for giving a higher adult concentration of a medication if it is not contained in the pediatric bag, this strategy has its own issues. EMS providers may forget to take the infrequently used pediatric bag to the patient on a call. The pediatric bag also adds cost by duplicating many of the medications carried on the vehicle and increases the amount of medications on the vehicle that must be continuously inspected for issues of expiration and damage. We do not believe that either of these approaches to carrying pediatric medications is significantly better than another, but each EMS agency manager and medical director should thoughtfully assess whether their method reduces the risk of administering adult medication concentrations or dosages to pediatric patients.

In addition to enhanced attention to EMS medication carrying practices at the local agency level, another approach would be for state or regional EMS authorities to standardize the requirements related to how medication bags are stocked, the concentrations of medications carried or administered, and how medications are stored. A 10-year study by Lubin et al. looked at variability among statewide EMS medication formularies. Despite a trend toward tighter central control, they found substantial variation among state EMS agencies.[4]

In our study, nine agencies in relatively close proximity to each other had different methods and policies on which medications they carried and how they were stocked and stored in their ambulances. A standardized storage system defined by regional or state EMS authorities may lead to improved safety when multiple agencies interact on the same scene. Some regions have used drug box exchange programs to replace drugs, and this is another possible way to standardize the drugs carried and provide hospital pharmacy oversight of medication issues.

We purposefully did not address the storage temperatures in the EMS vehicles because this has been addressed by other studies as described in the introduction, but to be comprehensive with our suggestions, it is important that each EMS agency also consider the temperatures within their vehicles and the effect this has on their medications. While Pennsylvania has no requirement for refrigeration of medications on EMS vehicles, the Bureau of EMS does require that any agency carrying lorazepam must relabel the carton to alter the expiration date to within 60 days of removing the medication from refrigerated storage. In this study, all agencies carrying lorazepam were compliant with this requirement. In the era of increasing interest in therapeutic hypothermia initiated by EMS, we believe that it is increasingly important that an EMS agency monitor whether their medications and solutions are stored at appropriate temperatures.

Lastly, a pharmacist who is familiar with hospital and emergency department medication practices may be a tremendous resource to an EMS agency when assessing their methods of storing and carrying medications. EMS agency medical directors may consider consulting with a pharmacist with this experience when addressing issues of medication stocking, carrying, storage, and use with the system. These individuals may also be helpful on regional or state EMS medical advisory committees.

LIMITATIONS

This study has some limitations. As a descriptive study, we have accurately described medication issues within nine ground EMS agencies that operate ALS ambulances in a five-county geographic region, but the wide variation in methods used to carry and store EMS medications in our region suggests that there will be disparate results when compared with other systems. It is also possible that some potential risks were not captured if one or more of the agency's vehicles were not available at the station at the time of the visit.

By predetermining the data to be collected for each medication carried or stored and for other storage issues, like similar medications carried side by side in the same compartment, we attempted to reduce variability among inspections and to standardize the inspection process. This methodology did not completely exclude the possibility of bias. For example, the

inspection team used judgment to determine if vials of similar color and size were look-alike medications when carried in the same compartment of the drug bag.

Permitting the inspection team to report spontaneously identified issues also introduces bias and may also be associated with variation in inspection results since these issues were not part of the data form checklist. Since our purpose was to identify possible medication safety issues as comprehensively as possible, we believe that including spontaneously observed issues is appropriate and leads to a more comprehensive descriptive report of the storage and carrying practices that were observed.

We made no attempt to evaluate the accuracy of the inspections or the interagency reliability among the inspection results. Since two of the authors consistently did every inspection and since a predetermined data form was used to collect information during each inspection, we believe that the process was adequately standardized. We also believe that any EMS agency could use a similar data form and inspection process to identify similar issues within the agencies procedures for medication carrying and storage.

Additionally, the categories of high, moderate, and low risk of potential harm are subjective opinions and classifying the issues as such was done by the EMS physician authors. While the subjective nature of this classification can be debated, it is intended to provide a description of the range of severity of potential outcomes from these medication practices. None of the issues identified would be consistent with inpatient hospital pharmacy procedures for safe medication storage.

While we identified common issues related to EMS medication storage and carrying practices that may set an EMS provider up to make a medication administration error or to have a medication-related patient safety incident, this study did not capture the actual administration errors, patient safety events, or actual patient injuries related to these potential issues. Although more study is needed to identify which medication safety issues lead to actual harm, we believe that it is still prudent to take steps to mitigate potential medication safety issues before some of them lead to a medication error or are proven to lead to harm.

Despite these limitations, we believe that this methodology can be used by all EMS organizations during safety rounds or other safety initiatives to recognize and reduce sources of potential medication error in EMS systems.

Conclusion

We observed potential medication safety issues related to how medications are carried and stored at all nine ALS EMS agencies in a five-county region. Understanding these issues may assist EMS agencies in reducing the potential for a medication error and risk of patient harm. Further research is needed to determine whether following these suggested best practices for carrying medications on EMS vehicles actually reduces errors in medication administration by EMS providers or decreases patient harm.

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