Pediatric Patient Safety in Emergency Medical Services

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In 1991, Leape et al.1 published their seminal study on medical errors that lead the Institute of Medicine (IOM),2 in a 2000 report, “To Err Is Human,” to conclude that medical errors were the seventh leading cause of death in the United States, with a preventable cost between $17 and $29 billion. From this work, an entire patient safety movement was born with subsequent elucidation of the epidemiology and contributing factors to errors and progress toward safety solutions. Most of research, however, has focused on hospital-based safety targeting areas such as surgical procedures and inpatient medication administration. Few studies, by comparison, have focused on patient safety in the prehospital setting, with even fewer attending to the challenges and needs of pediatric patients.

The potential risks to patient (and provider) safety in the prehospital setting are great: emergency medical services (EMS) personnel practice in a complex and frequently chaotic environment, often with little information to inform care decisions, in small teams with limited resources and backup, and under pressure to perform their duties accurately and quickly. Also, although first responders and EMTs are expected to care for patients from birth to old age, pediatric patients are frequently perceived as the most challenging.3-9 Children have unique anatomical, physiologic, and developmental characteristics that make them particularly vulnerable. They often cannot express their needs or articulate their medical problems. Equipment and medications are size and weight based, creating additional challenges to care. Moreover, pediatric transports comprise a
small portion of EMS exposure, with true pediatric emergencies occurring rarely, creating high-stakes, low-frequency events that are high risk for adverse events and patient harm.

In a 2006 report, “Emergency Care for Children: Growing Pains,” the IOM acknowledged both the risk to pediatric patient safety and the need for data systems, research, and systems to assure safe and high-quality care, calling on the US Department of Health and Human Services to fund studies on pediatric prehospital safety.11

In their 2012 systematic review of the patient safety in EMS literature, however, Bigham et al10 found only 88 citations meeting their inclusion criteria, concluding, “it appears that EMS patient safety research is in its infancy.” Based on this review, Canadian EMS experts convened the Niagara Summit from which a number of recommendations to improve safety in EMS were made, including efforts to increase awareness of patient safety principles, improve event reporting, support clinical decision making of EMS personnel, and adopt patient safety strategies from other disciplines.11

Despite the limited high-quality evidence to direct patient safety efforts in the EMS setting, relevant high-risk areas have been suggested. Some of these, such as pediatric airway management, the care of children with special health care needs, and the care of specific conditions such as seizures and pain management in children are discussed elsewhere in this issue. Similarly, pediatric equipment and new technologies, as well as strategies for regionalization and research, are covered in depth in separate articles. This article will review the literature around 3 areas of pediatric prehospital care related to safety: ground transport safety, cervical spine immobilization, and medication errors.

**SAFE TRANSPORT OF PEDIATRIC PATIENTS**

**Epidemiology**

The National Highway Traffic Safety Administration (NHTSA) estimates that EMS receives approximately 30 million emergency calls annually, resulting in 6.2 million transports, of which 10% involve children.11 Unfortunately, emergency medical vehicle collisions are a frequent occurrence during transport, resulting in significant property damage, injury, and death. Although the precise epidemiology of emergency vehicles (police, fire, ambulance) crashes is unknown because of a lack of a single EMS data set, NHTSA data between 1991 and 2000 identified more than 300 000 emergency vehicle collisions, with an alarming increase in annual incidence across this period.12 Although accidents involving police cars represent the largest absolute number of emergency vehicle collisions, the relative risk of injury and death are highest when an ambulance is involved.12 Between 1987 and 1997, a total of 339 fatal collisions were reported, totaling 405 deaths and 838 injuries.13 The morbidity and mortality figures above include EMS personnel, ambulance occupants, and nonoccupant victims. The exact number of pediatric injuries and fatalities related to EMS transport accidents is unknown.

**Contributing Factors**

Analyses of contributing factors to injury or death in ambulance crashes have shown that most fatal accidents occur during daytime and good weather, on improved and straight roads; however, most occurred during emergency (lights and sirens) use and at intersections.12-14 Although a greater absolute number of ambulance crashes occur in the urban setting, those in rural settings are associated with greater severity of injury, likely due to higher rates of travel speed.15,16

Rear compartment and unrestrained occupants are more likely to be injured than those in the front seat and those appropriately restrained; only half of vehicle drivers and front-seat occupants in serious accidents were wearing occupant restraints, and only 15% of nonpatient occupants in the rear compartment were restrained in one study.14 Moreover, studies of EMS provider knowledge, opinions, and behavior suggest significant gaps in appreciation for and understanding of proper provider and patient restraint during transport,17 and organizational policy on seatbelt use has been identified as a potentially modifiable factor.18

**Recommendations for the Safe Restraint of Children During Ground Transport**

In 2008, NHTSA began a project to identify solutions to safely transport children in emergency vehicles. A working group panel of experts was formed to build consensus and develop best-practice recommendations for the proper restraint of children in ground ambulances. Their recommendations were published in 2012 and address 5 separate transport situations, which are summarized in Table 1.11 The recommendations include both ideal transport conditions and suggestions for when ideal conditions are neither practical nor achievable, or when resources are limited.

Additional recommendations include securing all monitoring devices and equipment, use of restraint
systems by EMS personnel and all occupants, and not allowing parents, caregivers, or others to hold children unrestrained in the ambulance.11

Controversies: Lights and Sirens
As discussed under contributing factors above, the use of lights and sirens during transport has been identified as a risk factor for ambulance crashes. The relative risk vs benefit thus depends on the stability of the patient, the time-sensitive nature of patient injuries or illnesses, and the potential time saved with use of lights and sirens. Considerable controversy remains around the appropriate use of lights and sirens during transport, and policies and laws vary by state and agency. A number of studies in both rural and urban environments have demonstrated a mean time saved with use of lights and sirens ranging from 44 seconds to 3.6 minutes, casting doubt as to the true benefit in light of the known risks.19-22 Furthermore, in a retrospective review of 504 recorded EMS calls in one urban trauma center, Lachner and Bausher23 found that 62% of pediatric transports used lights and sirens, of which 39% (123/312) were classified as inappropriate (ie, patients with normal vital signs for age, normal mental status, no abnormalities on examination and EMS comment on stability of the patient). Further study is needed to identify the most appropriate, effective, and safe use of ambulance lights and sirens; national guidelines are lacking, and current regulations vary by state and transporting agency.

TABLE 1. NHSTA best practice recommendations for safe child transport.6

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<tr>
<th>Situation</th>
<th>Ideal</th>
<th>Other Options</th>
</tr>
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<tbody>
<tr>
<td>Healthy child (accompanying another patient)</td>
<td>Transport in nonemergency vehicle in size-appropriate child-restraint system</td>
<td>Transport in size-appropriate restraint system in front passenger seat with airbags off; transport in forward-facing or rear-facing EMS provider seat in size-appropriate child-restraint system; or leave the non-ill/injured child under appropriate adult supervision on-scene.</td>
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<td>Ill/injured child not requiring continuous or intensive monitoring/intervention</td>
<td>Transport in size-appropriate child-restraint system secured appropriately on cot</td>
<td>Transport in size-appropriate restraint system in forward-facing or rear-facing EMS provider seat; or secure child to the cot, head first, using 3 horizontal restraints across the chest, waist, and knees and 1 vertical restraint across each of the shoulders.</td>
</tr>
<tr>
<td>Ill/injured child requiring continuous or intensive monitoring/intervention</td>
<td>Transport in size-appropriate child-restraint system secured appropriately on cot</td>
<td>Secure child to the cot, head first, using 3 horizontal restraints across the chest, waist, and knees and 1 vertical restraint across each of the shoulders. Restraints may be temporarily removed as needed to provide interventions, but should be replaced; consider stopping the ambulance during interventions.</td>
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<td>Child requiring spinal immobilization or lying flat</td>
<td>Secure to size-appropriate spine board and secure board to the cot, head first, with tether at the foot, using 3 horizontal restraints across the chest, waist, and knees and 1 vertical restraint across each of the shoulders</td>
<td>Transport using space available in a nonemergency mode, exercising extreme caution and driving at reduced (below legal maximum) speeds.</td>
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<td>Multiple-patient transport (eg, newborn with mother, multiple children)</td>
<td>If possible, transport individually as above (1-4); transport in forward-facing EMS provider seat in size-appropriate child-restraint system; for mother and newborn, transport newborn in size-appropriate child-restraint system in the rear-facing EMS seat that prevents lateral and forward movement, leaving the cot for the mother. Do not use a rear-facing only seat. Never transport a newborn on an adult parent’s lap or arms.</td>
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CERVICAL SPINE INJURY IN CHILDREN: PREHOSPITAL CONSIDERATIONS

Epidemiology

Fewer than 1% of children evaluated after blunt trauma are found to have cervical spine injury. Moreover, the age distribution among children with cervical spine injury is skewed toward older children and teenagers, with fewer than 5% of injuries occurring in children younger than 2 years; boys are almost twice as likely to be injured as girls.

Mechanisms of blunt cervical spine injury are diverse. The most common cause of injury in children is motor vehicle crash. Another frequent mechanism among younger children is being hit by motor vehicles while walking or riding recreational equipment. Children are also injured by mechanisms with lower biomechanical force such as falls in younger children and sports and recreational impacts in older children. Diving puts children at greatest risk for cervical spine injury. Child abuse is a rare cause of cervical spine injury; however, when penetrating spine injury is considered, violence is the third most common cause of spinal cord injury among youth.

Outcomes after cervical spine injury are variable and directly related to the level of injury, with upper cervical spine injuries carrying a 23% mortality compared with 4% mortality with injuries to the lower cervical spine. Overall, up to one third of children with cervical spine injury sustain permanent neurologic injury.

Contributing Factors

Factors that are associated with cervical spine injury in children have been identified: altered mental status, focal neurological complaints, any of the following: complaint of posterior midline neck pain, limited range of neck motion on exam, substantial injury to the torso, high-risk MVC, diving injury, predisposing conditions: able to ambulate, place in cervical collar for transport, transport without cervical precautions.
mental status, focal neurologic deficit, neck pain, torticollis, substantial torso trauma, high-risk motor vehicle crash, diving, and predisposing conditions. Although not prospectively validated, these factors are highly sensitive for cervical spine injury and, along with validated adult screening criteria, should serve as the basis for developing clinical guidelines for children. Figure 1 contains a suggested guideline for determining which children warrant spine precautions for cervical spine injury after blunt trauma.

Appropriate Immobilization
Presently, there is considerable variability in techniques used for spine immobilization in children, particularly the very young. It is likely that this variability is due to both the lack of established guidelines and a lack of appropriately sized equipment. Recently, the National Association of Emergency Medical Services Physicians and the American College of Surgeons Committee on Trauma released a position statement that addresses the use of prehospital spinal precautions. Figure 1 illustrates how these recommendations might be used in a pediatric prehospital spine immobilization guideline. The statement advocates for limiting the use of the rigid long board to those patients who are at greatest risk for spine injury and who are unable to ambulate.

For those children who are neurologically normal and ambulatory, and in whom cervical spine injury is a consideration, transportation on a mattress gurney with safety straps is acceptable. When used, the rigid long board can both increase a child's risk of developing decubitus ulcers and force their neck into flexion due to their disproportionately large head relative to their torso. Thus, care should be taken to provide padding beneath the child to both relieve pressure from contact areas and bring the spine and the child's airway into anatomical alignment. In accordance with the position statement, all patients for whom cervical spine injury is a consideration should be transported with a properly fitted cervical collar in place. Improperly fitted collars can lead to abnormal separation of the vertebrae. This is an important consideration in treating young children because most disposable field collars are inadequately sized for children younger than 2 years. Neutral positioning can be maintained in this age range by using specialized pediatric boards that are padded and have head rests and strapping, which help maintain neutral positioning. For children who sustain isolated penetrating trauma, spinal immobilization may interfere in care and worsen outcomes and should be avoided.

Destination Decision Making
Centers for Disease Control and Prevention field triage criteria specify that children with signs of acute neurologic injury be transported preferentially to the highest level of pediatric care within the defined trauma system. Recent evidence demonstrates that children with cervical spine injury who are transported directly from the scene to pediatric trauma centers have improved outcomes. However, if the transport time to the nearest pediatric trauma center is long and the child has either respiratory or hemodynamic instability, it is appropriate to stop at the nearest trauma center for stabilization.

Untoward Effects of Spinal Immobilization
The practice of cervical spine immobilization has been poorly studied. Even for the rare child who has sustained a cervical spine injury, the efficacy of spinal immobilization in limiting neurologic injury during EMS transport is unknown. In fact, there is evidence that challenges the efficacy of spinal immobilization in providing neutral positioning and in limiting neurologic injury for those patients with cervical spine injury. Furthermore, for those at greatest risk for cervical spine injury, immobilization is associated with significant adverse effects including encumbered airway management and ventilation, elevated intracranial pressure, and decubitus ulcers.

Spinal immobilization of children at low risk for cervical spine injury may actually cause harm. The most common adverse effect of spinal immobilization is musculoskeletal pain. Full spinal immobilization has been reported to cause substantial pain, which may last well beyond the immediate period of immobilization. The pain caused by spinal immobilization may be confused with pain caused by true injury leading to unnecessary diagnostic evaluations. Thus, given the lack of established guidelines for clinical clearance of cervical spine injury in children, emergency physicians may overly rely on radiographic imaging for diagnostic evaluation.
Gaps and Future Directions

To date, there have been no prospective clinical trials to develop prehospital protocols for children at risk for cervical spine injury. Future studies should aim to develop easy-to-use prehospital pediatric cervical spine injury risk assessment tools that aid the provider in determining which children are and which are not at risk and in need of immobilization. In addition, there is a need to establish best practices in prehospital management for children at risk for cervical spine injury, which includes advances in prehospital equipment to more safely and comfortably transport injured children.

MEDICATION ERRORS IN THE PREHOSPITAL SETTING

Medication errors have garnered the greatest attention within the hospital-based patient safety movement framed by the 1999 IOM report, “To Err is Human,” and remained a primary focus for safety in the subsequent 2006 IOM report, Emergency Medical Services at the Crossroads. Some work has identified pediatric medication errors as a particularly high-risk area within hospital-based care. However, except for airway management, there has been little focus on medication errors in the prehospital setting and even less in regard to the pediatric prehospital population.

Epidemiology and Quality Improvement Efforts

The first study to examine pediatric prehospital medication dosing errors was carried out in Los Angeles and Orange Counties. Kaji et al examined the dose error rate for epinephrine for children in cardiac arrest. From 1994 to 1997, they found that 66% of all epinephrine doses were incorrect. They also noted a trend that dose errors were less frequent when the Broselow-Luten Tape (BLT) was used.

These data led to an extensive quality improvement campaign that included preprinted prehospital dosing cards based on weight (with doses in milligrams), paramedic (EMT-P) training on use of the BLT, hospital radio base-station training, and EMT-Ps caring for pediatric patients in cardiac arrest had to contact their hospital base station after the first dose of epinephrine was administered to confirm the dose. After this intervention, the epinephrine dose error rate was reassessed in 2003 to 2004, and the error rate had decreased to 35% of doses. Kaji et al's achievement of reducing these errors by half was very impressive. However, this study also demonstrated that there were factors, as yet undiscovered, still contributing to a significant error rate.

In 2009, Lammers et al published a study in which EMT-Ps throughout Michigan participated in simulated pediatric scenarios (sepsis, asthma, cardiac arrest). For these scenarios, a trailer was built that had an area that approximated a bedroom and included a crib with a high-fidelity simulation mannequin, as well as a separate simulation control room complete with video monitoring cameras. Paramedic EMTs responded to the trailer location in their ambulance and used their ambulance equipment during the scenario. The dose error rate for this study ranged from 68% to 73%, similar to the study of Kaji et al. They also found that EMT-Ps failed to use the BLT in 50% of the asthma cases, and when it was used, it was used incorrectly in 47% of the cardiac arrest cases.

A study published in 2012 by Hoyle et al examined the medication dosing errors in an administrative EMS database in Michigan for children 11 years and younger. Patients 11 years and younger were included because the last listed weight on the BLT of 36 kg approximates the 50th percentile for an 11-year-old. This study examined 8 EMS agencies that served approximately 10% of Michigan's population between 2004 and the first quarter of 2006 and examined the prevalence of dosing errors for multiple drugs including the following: albuterol, atropine, dextrose, diphenhydramine, epinephrine, and naloxone. A medication dosing error was defined as a 20% or greater difference in the documented dose vs the weight appropriate dose, based on the documented patient weight EMT-Ps listed in the database. Over the study period, there were 5547 children cared for by EMS in the database, with 230 (4.1%) receiving a total of 360 drug administrations. The patients who received drugs represented 2.5% of all pediatric (≤17 years old) encounters and 0.16% of all EMS patient encounters for the study period. During the 27-month study period, 132 (31.1%) of 425 EMT-Ps administered a medication to a patient 11 years or younger. The mean number of medications administered to patients 11 years or younger by an individual paramedic was 2.7 ± 2.4 (mean ± SD), with a range of 1 to 18. Use of BLT was documented in only 28 (12.2%) of 230 children.

The overall drug dose error prevalence was 35%, with epinephrine having the highest prevalence of incorrect doses. Relative drug dosage errors (with 95% confidence interval) were as follows: albuterol, 23.3% (18.4-29.1); atropine, 48.8% (34.3-63.5); diphenhydramine, 53.8% (29.1-76.8); and
epinephrine, 60.9% (49.9-73.9). The mean % error of intravenous/intraosseous epinephrine overdoses was 808% ± 428%. The mean % error for intravenous/intraosseous epinephrine underdoses was 35.5% ± 27.4%.

This study emphasizes many important points. First, administering a drug to a pediatric patient can be a very rare event (may not occur in 27 months) for an individual paramedic. Second, dose error rates for all the drugs examined, including albuterol, which does not require dose calculations, are high. Third, despite the availability to EMT-Ps of a weight and dosing aid in the form of the BLT, it is rarely used. Finally, the authors noted that extrapolating their findings to the larger US population results in an estimated 21 700 children 11 years and younger affected by these errors yearly, marking this as a very significant patient safety issue.

**Contributing Factors**

In a 2012 study, Lammers et al published a root-cause analysis of medical errors made by EMT-Ps from 5 different agencies in Michigan after they participated in 3 simulation scenarios: altered mental status, seizure, and respiratory arrest. To date, this appears to be the first study to examine root causes of pediatric prehospital medical errors. They found significant errors in drug administration with many different causes. Dosing of midazolam for seizures had a 60% active error rate, which included incorrect doses and incorrect route of administration. Dosing of diazepam for seizure had a 47% active error rate. Paramedic EMTs mentioned not knowing the correct doses as well as different doses depending on delivery route as a source of dose errors. They also mentioned difficulty in calculating doses, under stress (affective and cognitive error), yet none used calculators to aid in calculation. However, some did have preprinted dose cards that have been shown to help reduce errors in another study. Paramedic EMTs also had difficulty interpreting the labels on the prefilled diazepam syringe (latent error leading to procedural error). The diazepam syringe is labeled in milliliters, whereas epinephrine syringes are labeled in both milliliters and milligrams. The diazepam syringe markings measure the amount of drug remaining, whereas epinephrine syringes measure the amount administered. These factors both contributed to dosing errors. Other problems related to drug dosing were incorrect weight estimates (procedural error), calculation errors in converting a milligram per kilogram dose to milligrams or milliliters (cognitive error), and failure to do crosschecks of doses (teamwork error).

This study emphasizes that delivering a medication dose to a child in the prehospital environment is a complex task. Four different types of errors (cognitive, procedure, affective, and teamwork) can occur. There are 11 different functions in the process, and error at any 1 of the 11 will result in an incorrect dose being delivered. This study also emphasizes areas to be targeted for intervention in order to decrease errors.

Paramedic EMTs have face many challenges in providing high-quality care for children. First, the prehospital environment is difficult, chaotic, and stressful and, because of these factors, is prone to error. Second, contrary to the multitude of safety systems available in the hospital such as computerized order entry, barcoding of medications, and multiple personnel including pharmacists to cross check doses, prehospital personnel have none of these available and must rely on themselves and their partner, who may have no training in drug dosing such as an EMT-basic, to be the safety net. The BLT is available for use by EMT-Ps, yet it is rarely used, and if so, it is often used incorrectly. Third, EMT-P pediatric encounters are very infrequent. This lack of clinical experience forces one to rely on training. However, EMT-P pediatric training is limited and infrequent. The national requirements lump pediatrics in with “other special needs populations” and require only 3 to 4 hours of continuing education for this category yearly. Most EMT-Ps complete a pediatric specialty course (Pediatric Advanced Life Support, Pediatric Education for Prehospital Professionals, etc) only once every 2 years. However, EMT-Ps have themselves called for increased pediatric training.

**SUMMARY**

Prehospital pediatric medication dosing errors occur with a high prevalence. Infrequent clinical encounters, infrequent training, and a lack of safety systems contribute to these errors. Given these facts, it is exceptionally important for EMT-Ps, EMS medical directors, and researchers to continue investigations into these errors. Rigorous testing of old, new, and innovative safety systems, specific to the prehospital environment, should be carried out. Rigorous testing prior to implementation is absolutely necessary because safety systems that have not been thoroughly tested frequently are fraught with unforeseen hazards. As an
example, in Michigan, the change to an electronic patient care record did away with the paper run sheet that had a pound to kilogram conversion table on it. Now, EMT-Ps have stated that converting a weight they get from a parent (in pounds) to kilograms is more time consuming and difficult. Methods to improve pediatric training for prehospital personnel, both in frequency and in content, need to be developed. Together, such measures should lead to a decrease in these errors, which have a large cost not only to patients but also to providers.

REFERENCES


83. Hoyle Jr JD. Personal communication from John Hoyle on focus group data; 2013.