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Safety Events in High Risk Prehospital Neonatal Calls

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Abstract

Objective—The objective of this study was to quantify and characterize patient safety events during high-risk neonatal transports in the prehospital setting.

Method—We conducted a retrospective chart review of all “lights and sirens” ambulance transports of neonates 30 days old over a four-year period in a metropolitan area. Each case was independently reviewed for potential patient safety events that may have occurred in clinical assessment and decision making, resuscitation, airway management, fluid or medication administration, procedures performed, and/or equipment used.

Results—Twenty-six patients 30 days old were transported by ambulance using lights and sirens during the four-year study period. Overall, safety events occurred in 19 patients and severe safety events (potentially causing permanent injury or harm, including death) occurred in ten. The incidence of safety events related to medication administrations was 90% (70% severe), resuscitation 64.7% (47.1% severe), procedures 64.7% (35.3% severe), fluid administration 50% (25% severe), clinical assessment and decision making 50% (30.8% severe), airway management 47.6% (28.6% severe), equipment use 25.5% (10.0% severe), and systems processes 19.2% (7.7% severe).

Conclusions—High-risk neonatal calls are infrequent and prone to a high incidence of serious patient safety events.

Keywords

emergency medical services; patient safety; infant health; emergency medicine

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Introduction

Children account for 4 to 22% of all emergency medical services (EMS) transports,^{1–3} with infants less than one year of age being among the most common.⁴ Children transported by ambulance for emergency care are often higher acuity than those who arrive by other means¹; yet, EMS providers have limited experience,⁵ pediatric-specific training,^{6,7} and resources^{3,8} to make critical decisions in caring for sick pediatric patients, creating a low-frequency, high-stakes situation at risk for patient safety events.

Neonatal patients may represent a particular challenge in the EMS setting. Neonates (especially newborns) have different physiology and anatomy than older children and are more susceptible to hypothermia and hypoglycemia. As a result, presenting complaints, equipment, and resuscitation protocols for newborns differ substantially from those used for other age groups. While previous work has highlighted the challenges of pediatric care in the EMS setting, there is a paucity of literature describing the care of neonates specifically, and the objective of this study was to evaluate and characterize the incidence of patient safety events during neonatal lights and sirens ambulance transports.^{5,9–20}

Methods

Study Design, Setting, and Patient Population

We conducted a retrospective chart review of all EMS records from Multnomah County, Oregon between 2008 and 2011. Multnomah County includes Portland, Oregon, the largest metropolitan area of the state, which has a population of over 700,000 residents. All ambulance transports of neonates with lights and sirens transport priority were included. Inclusion was based on transport priority only and not dispatch priority in order to reflect the impression of the treating provider that the patient was critical. In this system, the urgency of transport (e.g., lights and sirens) is at the discretion of the treating paramedic with the exception of trauma system entries that are mandatory lights and sirens transports. This metro area's EMS system consists of dual advanced life support responses from public fire agencies and private ambulance transport agencies that respond to all calls. Ambulances from the private agency respond with two paramedics in each ambulance. Fire units consist of four to five person crews with at least one paramedic per crew. Fire crews work 24-hour shifts, and transport crews work rotating shifts with experienced paramedics equally distributed throughout all hours of the day. The fire units respond to 90% of calls within 7 minutes and transport units respond to 90% of calls within 8 minutes. Neonatal Resuscitation Program (NRP) certification is not required for paramedics in participating agencies and was not offered by the agencies during the study period. All agencies in the Portland Metro area use a locally developed length-based pediatric resuscitation guide. This includes appropriate equipment size and medication doses. It also includes the neonatal resuscitation program algorithm. Intubation can be performed by paramedics in this system for any age patient, although a maximum of two attempts are specified in the protocols with use of a backup (e.g., bag-valve mask ventilation) thereafter. There are no supraglottic devices in use in this system suitable for neonates.

Finally, there are two local pediatric specialty transport teams run by pediatric specialty hospitals that perform interfacility transfers only and do not provide field care. This analysis includes neonates transported by ambulance between facilities but does not include any neonates transported by pediatric specialty transport teams.

Analyses were conducted using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA). The study was approved by the Oregon Health & Science University (OHSU) Institutional Review Board, which waived the requirement for informed consent (IRB Number 00006942).

Chart Review Tool

We developed a chart review tool based on the tools used in the landmark Utah, Colorado and Harvard medical practice studies that were the foundation for the Institute of Medicine Report “To Err is Human.”^{21,22} The tool was iteratively revised by a multidisciplinary research team and finalized through several rounds of pilot testing on a sample of 30 EMS charts. The process of chart review tool development and review process were rigorous and mirrored the process of landmark safety studies.^{21,22} First, a paramedic and a physician independently reviewed all 26 charts. These reviewers came from a panel of 13 paramedics and 7 physicians in the context of a larger chart-review study. Subsequently, one of two pediatric emergency medicine physicians with experience in EMS, who was not part of the review panel, reviewed each chart to arbitrate differences between the initial paramedic and physician reviews. The two pediatric emergency physician reviewers achieved a kappa of 0.62, indicating substantial agreement, for the presence of a safety event in the various domains on an initial dual review of charts. Reviewers identified safety events in any of the following areas: assessment and clinical decision making, resuscitation, airway management, fluids and medication, procedures, equipment, environment, and systems. Within each domain, evaluators determined whether a safety event occurred, the characteristics and potential etiology of the safety event, as well as the potential harm to the patient. The degree of potential harm was defined as: 1) no harm likely or a near miss; 2) mild or temporary harm, including additional treatment; and 3) permanent or severe harm, including death.

Analysis and Outcomes

We used descriptive statistics to categorize the clinical condition as a cardiopulmonary arrest, respiratory distress, trauma, seizure or altered level of consciousness, allergic reaction/anaphylaxis or other (e.g., birth) as determined by the clinical impression and actions of the EMS providers. Next, we categorized all safety events identified by the reviewers and assessed the level of harm assigned by the reviewers.

Results

From a total of 11,328 pediatric transports (age < 18 years old) during the study period, we identified 497 lights and sirens transports (497/11328 or 4.4%), 26 of which were neonatal transports (26/497 or 5.3%). Table 1 displays the characteristics of the 26 neonates included in the study. Fourteen of 26 patients (53.8%) were in the first 24 hours of life, and 61.5%

were male. Eight neonates were transferred from clinic/hospital to a tertiary referral hospital: of these eight, three newborns were transferred from local birthing centers, two were transferred from clinics, and three were transferred from an emergency department. The majority of neonatal calls were for either cardiopulmonary arrest (8/26, 30.8%) or respiratory distress (8/26, 30.8%). Table 2 shows the procedures performed by EMS personnel. Nearly 1/3 of patients received either bag-valve mask (BVM) or cardiopulmonary resuscitation (CPR), but the majority, 85% had no intravascular or intraosseous access (none had IV access, and 15% of patients had intraosseous access).

Table 3 shows the proportion of cases with any safety event and those categorized by the reviewers as potentially severe. Safety events were identified in all eight cases of cardiopulmonary arrest with more than half (5/8, 62.5%) considered to have potentially resulted in severe or permanent harm, or death.

Table 4 displays the domains of clinical care where patient safety events took place. There were a total of 68 safety events among the 26 patients with an average of 2.6 safety events per patient and a range from zero to six events per patient. Ninety percent of patients who received a medication had a medication-related safety event. Sixty-five percent of patients who received resuscitation or procedures had a related safety event.

Table 5 provides a description of the severe safety events based on the reason for dispatch and the domain of care.

Medication-related safety events included: two cases of failure to administer epinephrine when indicated and three cases of tenfold epinephrine overdoses. Resuscitation safety events encompassed safety events across all domains of care. Of note, in four cases (4/19, 21%) the team used techniques from the wrong resuscitation protocols, using pediatric advanced life support (PALS) or advanced cardiac life support (ACLS) rather than neonatal resuscitation (NRP) for cases of newborn resuscitation. The most common procedure-related safety event was failure to obtain IV/IO access when indicated. Assessment/Decision Making safety events included inadequate vital sign monitoring in five cases and failure to check glucose when indicated in six cases. Airway management safety events included three or more intubation attempts in two cases, using a size 2.5 endotracheal tube when a 3.5 size was indicated, failure to use BVM (or any other type of ventilation) in four cases, and failure to properly confirm endotracheal tube placement with capnography in two cases.

The first case of multiple intubation attempts involved a 30-day old infant who had a witnessed respiratory arrest. BVM was initiated followed by five intubation attempts despite normal oxygen saturation. The initial attempt was aborted due to inability to visualize the vocal cords. An endotracheal tube was inserted on the second attempt but then removed after failure to obtain an end-tidal CO₂ reading. Ambulance and fire charts do not provide details regarding the last three attempts. In the second case, a newborn was delivered in the ambulance and noted to be unresponsive and apneic. Following suctioning and a short period of BVM, three intubation attempts were made with the third being successful. The reason for failure in the first two cases was not clearly described.

Discussion

This study assessed safety events in a cohort of neonatal EMS transports. We found that neonatal lights and sirens transports are infrequent but have a high risk of serious safety events. The patients in this study were critically ill with the majority of transports relating to cardiopulmonary arrest or respiratory distress, and one-third of patients received resuscitative measures including either CPR or BVM. Though there were high rates of safety events across all domains of care, the most common source of safety events were medications. The specific nature of the safety events ranged from failure to perform important actions to performance of unnecessary interventions.

We believe this is the first study to evaluate patient safety in neonates in EMS. Our findings are similar to those observed in previous pediatric simulation studies, which similarly identified problems with airway management, inadequate ventilation, cardiac support, delays and failure to obtain vascular access, and medication dosing errors.^{13–15} Also, our findings are similar to a retrospective clinical study evaluating the incidence of medication errors in children less than 11 years that found that epinephrine errors were present 60% of the time it was used.¹⁶

Younger children transported by EMS are more likely to suffer from life-threatening emergencies compared to older children.¹ Younger patients are also the most dissimilar to adults and, in general, may be the pediatric age group at greatest risk for safety events. A previous hospital-based study found that neonates had high rates of potential adverse drug events compared to both adults and other pediatric age groups.²³ This was also true in our EMS cohort, where we observed tenfold epinephrine dosing errors. Epinephrine is a particularly high-risk medication with the potential to confuse milligrams with milliliters, which, using the standard 1:10,000 concentration, can lead to 10-fold dosing errors. In a 5-kg neonate, for example, the epinephrine dose is 0.05 mg, which is 0.5 mL of 1:10,000 solution. When using a prefilled 10-mL epinephrine syringe commonly used by EMS for adult cardiac resuscitation, accurate delivery of such a small volume can be very difficult and inaccurate, and use of a stopcock is complex and may also have inherent inaccuracies.

Newly born patients have a physiology that differs significantly from older children and adults as a result of the transition from intra-uterine circulation, where oxygenated blood comes from the umbilical cord, to extra-uterine circulation, where oxygenation occurs in the patient's own lungs. This critical and unique physiologic transition is the basis for important and substantial differences in the approach to resuscitation of the newborn (neonatal resuscitation protocol or NRP) compared to the older child (PALS). We found several cases in which the PALS or even ACLS protocol, rather than NRP, was applied to a newborn. EMS providers care for adult cardiac arrests on a regular basis, while pediatric arrests are quite rare.²⁴ Given the rarity of the pediatric arrests, and even lower frequency of neonatal arrests, remembering the details of the NRP protocols may be difficult, and EMS providers may default to more familiar resuscitation algorithms.

Assuring neonatal patient safety in the EMS setting is challenging. First, critical neonatal calls are quite rare for any individual agency or EMS provider making development of a

clinical experience base challenging. Many states do not require pediatric training for initial certification or recertification of EMS providers.⁶ In addition, educational interventions may be challenging to sustain since it appears that PALS resuscitation skills deteriorate relatively quickly after training and return to baseline after six months.²⁵ Simulation-based training is an attractive option to augment limited patient exposure, however, this approach is labor-intensive and specialized neonate patient simulator equipment may not be available, which may preclude its feasibility for some agencies. EMS agencies have limited training time and many topics to cover, and it may not be feasible to provide the training at the frequency needed to maintain a knowledge base that is rarely used. Given the inherent limitations of training, technological innovation related to improving drug delivery and cognitive aids may be more likely to have an impact on improving safety.

Finally, this study addressed a patient cohort transported with lights and sirens priority. Ambulance transports running lights and sirens have relatively high rates of traffic accidents and higher rates of fatal traffic accidents than transports not running lights and sirens.^{26–28} Lights and sirens priority has been shown to have a modest reduction in transport times, which may not be clinically significant.^{29–32} In some cases with low survival, such as infant cardiac arrest, the risks and benefits of lights and sirens should be carefully considered by the EMS agency.

Our study has several limitations. First, it is a retrospective study that relies on information documented in the medical record. In some situations, the medical record review methodology prevents us from effectively judging some important aspects of care such as the quality of ventilations in newborn resuscitation. However, we believe that overall the medical record review method is most likely to result in an underestimation of the true incidence of safety events. Next, patients were included in the study based on transport priority, which was made at the discretion of the paramedics on scene. This may introduce bias as paramedics might tend to over triage neonates depending on their comfort level; however, the majority of calls involved cases of cardiopulmonary arrest or respiratory distress, supporting the critical nature of their transports. Additionally, the determination or presence of a safety event and its severity relied on the judgement of the reviewer. We used a rigorous chart review tool development process and had good inter-rater reliability among reviewers, which suggests our results have validity. Finally, the small sample size from a single geographic area may limit its generalizability to other EMS systems. In addition, the EMS system in this study has at least three paramedics respond to all calls, is in an urban area, and has short transport times. Other settings with fewer resources may experience more frequent safety events.

Conclusion

High-risk neonatal EMS calls occur infrequently and have a high risk of potentially life-threatening safety events.

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Table 1

Patient characteristics and agency response to 26 neonatal critical ambulance transports during 2008–11 in the Portland, Oregon metropolitan area

	Transports [*]	
Age		
Less than 1 Day	14	(53.8)
1–10 Days	5	(19.2)
11–30 Days	7	(26.9)
Sex		
Female	10	(38.5)
Male	16	(61.5)
Scene Location		
Home	18	(69.2)
Hospital/Clinic	8	(30.8)
Reason for Dispatch		
Cardiopulmonary Arrest	8	(30.8)
Respiratory Distress	8	(30.8)
Trauma	2	(7.7)
Seizure or ALOC	1	(3.8)
Allergic Reaction	1	(3.8)
Other (including birth)	6	(23.1)
Interfacility Transport [†]	8	(30.8)
Agency Response		
Response Time	4:56	(7:10)
Scene Time	13:57	(24:83)
Transport Time	11:94	(23:12)
Fire Response	9	(34.6)

^{*} Categorical variables are presented as number (percentage) of patients among 26 transports. Time variables are presented as mean (90th percentile) in minutes:seconds.

[†] Interfacility Transport is a secondary code and does not count towards total *n*.

Table 2

Critical procedures performed on 26 neonatal critical ambulance transport patients during 2008–11 in the Portland, Oregon metropolitan area

	Patients <i>n</i> (%)[*]	
Critical Procedures [†]		
CPR	9	(34.6)
INT	6	(23.1)
BVM	9	(34.6)
IV	0	(0.0)
IO	4	(15.4)

BVM: bag valve mask; CPR: cardiopulmonary resuscitation; IV: intravenous line; IO: intraosseous infusion; INT: intubation.

^{*} Percent of patients with the procedure among 26 transports.

[†] A case may have had one or more of the listed procedures (BVM, CPR, IV, IO) performed or no procedures performed.

Patient safety events by presenting complaint among 26 neonatal critical ambulance transports during 2008–11 in the Portland, Oregon metropolitan area

Table 3

	No. Patients	Patients with One or More Safety Event (n, %)*	Patients with One or More Severe Safety Event (n, %)*
All Patients	26	19 (73.1)	10 (38.5)
Reason for Dispatch [†]			
Cardiorespiratory Arrest	8	8 (100.0)	5 (62.5)
Respiratory Distress	8	5 (62.5)	2 (25.0)
Trauma	2	2 (100.0)	1 (50.0)
Seizure or ALOC	1	1 (100.0)	1 (100.0)
Allergic Reaction/Anaphylaxis	1	1 (100.0)	1 (100.0)
Other (including birth)	6	2 (33.3)	0 (0.0)

ALOC, altered level of consciousness.

* Percentage among total number of patients in row.

[†] Reason for Dispatch (Chief Complaint).

Patient safety events by domain of error among 26 neonatal critical ambulance transports during 2008–11 in the Portland, Oregon metropolitan area

Table 4

Domain of Clinical Care [*]	No. Patients [†]	Patients with a Safety Event in the Domain (n, %) [‡]	Patients with a Severe Safety Event in the Domain (n, %) [‡]
Medication	10	9 (90.0)	7 (70.0)
Resuscitation	17	11 (64.7)	8 (47.1)
Procedures	17	11 (64.7)	6 (35.3)
Assessment/Clinical Decision Making	26	13 (50.0)	8 (30.8)
Fluids	4	2 (50.0)	1 (25.0)
Airway Management	21	10 (47.6)	6 (28.6)
Equipment	20	5 (25.0)	2 (10.0)
Systems	26	5 (19.2)	2 (7.7)
Environment	26	1 (3.8)	1 (3.8)

^{*} Of those with care in the specified domain. A case may have safety events in multiple domains of care.

[†] Includes cases in which the domain applies, was indicated, and/or was used.

[‡] Percent among the number of patients in the respective domain of clinical care.

Table 5

Description of cases with one or more severe safety events in neonatal critical ambulance transports

Case	Reason for dispatch	Domain of safety event	Chart Reviewer Description of safety event
1	Cardiopulmonary Arrest	Airway	OPA not used, displaced ETT.
		Medication	Failure to administer epinephrine.
		Procedures	Failure to establish IO access.
2	Trauma	Resuscitation	BVM rate too fast, multiple IO attempts, multiple inappropriate intubation attempts.
		Airway	Multiple inappropriate intubation attempts, ETT too small.
3	Respiratory Distress	Assessment/Decision Making	Patient described as lethargic and no history regarding pregnancy, labor, delivery or other risk factors such as GCS documented; failure to check glucose or monitor ETCO ₂ .
4	Allergic Reaction	Assessment/Decision Making	Did not check glucose in “lethargic” neonate.
		Medication	Tenfold epinephrine overdose.
		Procedures	Did not obtain vascular access.
5	Cardiopulmonary Arrest	Assessment/Decision Making	Did not check glucose; weight estimate high for age; tenfold epinephrine overdose.
		Airway	Report of “no waveform was visible” on ETCO ₂ —possible esophageal intubation as patient deteriorated.
		Fluids	PEA arrest – did not receive IV fluids despite HR of 208, glucose should have been considered.
		Medication	Delay in epinephrine administration. Tenfold epinephrine overdose.
6	Cardiopulmonary Arrest	Assessment/Decision Making	Assessment of need for intubation and CPR did not seem to be correct, and decision to try to intubate multiple times with a baby whose pulse was over 100 likely impeded further efforts to ventilate adequately. Failure to check blood glucose.
		Airway	Decision to intubate was done too early with too many attempts (i.e. three) despite effective BVM and HR over 100 indicating intubation not clearly indicated.
7	Respiratory Distress	Resuscitation	The principles and guidelines of NRP were not followed.
		Assessment/Decision Making	Did not check glucose or deliver appropriate BVM ventilation.
		Airway	Since there was no palpable pulse, they should have attempted to obtain a rhythm.
		Medication	The medication given was not indicated and the dose may have been incorrect.
8	Cardiopulmonary Arrest	Medication	Tenfold epinephrine overdose.
9	Seizure, ALOC	Assessment/Decision Making	Incomplete exam and history; did not check glucose; did not appropriately monitor vital signs (pulse ox, cardiac monitor); did not treat seizure.
		Medication	If actively seizing should have administered benzodiazepine.
		Procedures	Should have obtained vascular access in seizing neonate.
10	Cardiopulmonary Arrest	Airway	Several failed intubation attempts, inadequate BVM ventilation.
		Medication	Indicated medication not given (epinephrine).
		Procedures	Failure to obtain vascular access.

IO: intraosseous; OPA: oropharyngeal airway; ETT: endotracheal tube; ETCO₂: end-tidal CO₂; PEA: pulseless electrical activity; HR: heart rate; CPR: cardiopulmonary resuscitation; BVM: bag-valve-mask ventilation.