Videography in Pediatric Emergency Research
Establishing a Multicenter Collaborative and Resuscitation Registry

Benjamin T. Kerrey, MD, MS,†‡ Karen J. O'Connell, MD, MEd,§|| Sage R. Myers, MD, MSCE,¶ Andrea S. Rinderknecht, MD,* Mary E. Frey, MSN, RN,*‡ Jenna R. Dyas, BS,*‡ Stephanie Boyd, PhD,*‡ Allison L. Mak, BS,¶ Niall Cochrane, BS,§|| and Aaron J. Donoghue, MD, MSCE#*

Objectives: High-quality clinical research of resuscitations in a pediatric emergency department is challenging because of the limitations of traditional methods of data collection (chart review, self-report) and the low frequency of cases in a single center. To facilitate valid and reliable research for resuscitations in the pediatric emergency department, investigators from 3 pediatric centers, each with experience completing successful single-center, video-based studies, formed the Videography In Pediatric Emergency Research (VIPER) collaborative.

Methods: Our initial effort was the development of a multicenter, video-based registry and simulation-based testing of the feasibility and reliability of the VIPER registry. Feasibility of data collection was assessed by the frequency of an indeterminate response for all data elements in the registry. Reliability was assessed by the calculation of Cohen κ for dichotomous data elements and intraclass correlation coefficients for continuous data elements.

Results: Video-based data collection was completed for 8 simulated pediatric resuscitations, with at least 2 reviewers per case. Data were labeled as indeterminate by at least 1 reviewer for 18 (3%) of 524 relevant data fields. The Cohen κ for all dichotomous data fields together was 0.81 (95% confidence interval, 0.61–1.0). For all continuous (time–based) variables combined, the intraclass correlation coefficient was 0.88 (95% confidence interval, 0.70–0.96).

Conclusions: Initial simulation-based testing suggests video-based data collection using the VIPER registry is feasible and reliable. Our next step is to assess feasibility and reliability for actual pediatric resuscitations and to complete several prospective, hypothesis-based studies of specific aspects of resuscitative care, including of cardiopulmonary resuscitation, tracheal intubation, and teamwork and communication.

Key Words: endotracheal intubation, resuscitation, video review

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From the *Division of Emergency Medicine, †Center for Simulation and Research, Cincinnati Children's Hospital Medical Center, and ‡The University of Cincinnati, College of Medicine, Cincinnati, OH; §Division of Emergency Medicine, Children's National Medical Center, and ||George Washington University School of Medicine and Health Sciences, Washington, DC; and Departments of ¶Pediatrics, and #Anesthesia and Critical Care Medicine and Pediatrics, Children's Hospital of Philadelphia, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA.

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Reprints: Benjamin T. Kerrey, MD, MS, Division of Emergency Medicine, Cincinnati Children's Hospital Medical Center, 3333 Burnet Ave, ML 12000 Cincinnati, OH 45229 (e-mail: benjamin.kerrey@cchmc.org).

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There are numerous obstacles to the optimal resuscitation of patients in a pediatric emergency department (PED). Patients with impending or existing organ failure, who are in need of critical care decision making and resuscitative procedures, are relatively uncommon, particularly at the provider level.[1] Care teams in a PED are frequently formed ad hoc and consist of providers of highly variable levels of knowledge and skill, often lacking experience as a team. Little to nothing is known about the patients before presentation, despite many having complex medical histories. The intense, fast-paced environment raises provider anxiety, threatening clear thinking and effective communication. The time-sensitive nature of resuscitations requires a high level of team coordination and skill, yet carries a significant risk of complications.

Research in pediatric resuscitative care is challenging for similar reasons. Accurate data collection is especially difficult, as the traditional methods of data collection in clinical research, that is, chart review and direct observation, have significant limitations during a resuscitation. Chart review is essentially self-reporting, with the risk of significant recall and other biases. The care environment is fast paced, often chaotic, and because of their sporadic occurrence, direct observation of resuscitations is logistically challenging. Video review has demonstrable advantages for data collection during resuscitation, especially the accurate measurement of time-based data essential to valid and important investigation in this setting.[2,3] A further and critical advantage of video review is the potential minimization of the "Hawthorne effect," as providers are less likely to consciously alter their performance in a setting where video review is a routine part of clinical activities. Video review for data collection is robustly represented in the literature for surgical skills training, acute trauma care, and neonatal resuscitation.[4–7] More recently, video-based studies of resuscitative care in PEDs have begun to emerge.[2,3,7–11]

At their respective institutions, the authors of the current report have independently led and published quality improvement and clinical research efforts using video review of actual resuscitations in the PED. Investigators at Children's National Medical Center (CNMC) have investigated teamwork, provider workload, and checklist use in pediatric trauma care.[6,7,11] Investigators at Cincinnati Children's Hospital Medical Center (CCHMC) have reported on outcomes and complications associated with airway management in the PED.[2,3,8,12,13] Finally, investigators at Children's Hospital of Philadelphia (CHOP) have reported on cardiopulmonary resuscitation (CPR) quality and adherence to published guidelines for CPR.[9,10]

In 2012, investigators from the above centers founded the Videography In Pediatric Emergency Research (VIPER) collaborative, the purpose of which is to facilitate multicenter, high-quality clinical research and quality improvement initiatives for children undergoing resuscitation in a PED, with video review as the primary method of data collection. The VIPER collaborative consists of a multidisciplinary group of investigators from the PEDs of the above 3 pediatric institutions.

Although the individual VIPER investigators have published important video-based studies, pediatric resuscitations in the PED are infrequent, making multicenter studies necessary to conduct valid research. The purposes of the current report are (1) to describe our efforts to establish the collaborative, including the development of the initial registry database; (2) to describe simulation-based analyses of the feasibility and reliability of data collection; (3) to discuss the current challenges and limitations of the collaborative; and (4) to discuss plans for future studies and efforts to refine the registry and address the collaborative's limitations.

METHODS

Existing Video Review Programs

Resuscitative care in the PED at each of the 3 centers is video recorded as part of peer-reviewed, intradivisional, continuous quality assurance programs. Patient/parent consent is obtained as part of consent for treatment. Video and audio recordings occur continuously, using a set of synchronized digital cameras and microphones and including multiple views of the patient/bay and of the bedside monitor (LiveCapture, BLine Medical, Washington, DC [CHOP and CCHMC]; DigitalTec Solutions, Newark, Del [CNMC]). A sample screenshot from 1 the 3 systems is provided in Figure 1. Videos are reviewed independently from care, and deidentified data are collected by each center on common resuscitative procedures, including tracheal intubation and CPR. Following data collection, videos are deleted and are never included in the medical record.

VIPER Database Creation

We conducted a series of on-site meetings with team members from all 3 centers to develop a multicenter data registry. Initial steps in registry development consisted of reviewing the current approach to video-based data collection at each site, forming strategies for methods of joint data collection, drafting a list of desired data elements, and setting a preliminary plan for assessing the feasibility and the reliability of all data fields. During subsequent meetings, we refined and categorized the list of data elements, finalizing the data dictionary. Operational definitions for each data element were determined and refined by consensus. Standard definitions were used where applicable, including those from the relevant American Heart Association's (AHA's) guidelines and standard texts.[14–16] Elements pertinent to tracheal intubation were adapted from definitions used by the CCHMC investigators in previous studies.[3,8] Study data were collected and managed by a research coordinator, with significant experience with data abstraction by video review, using REDCap electronic data capture

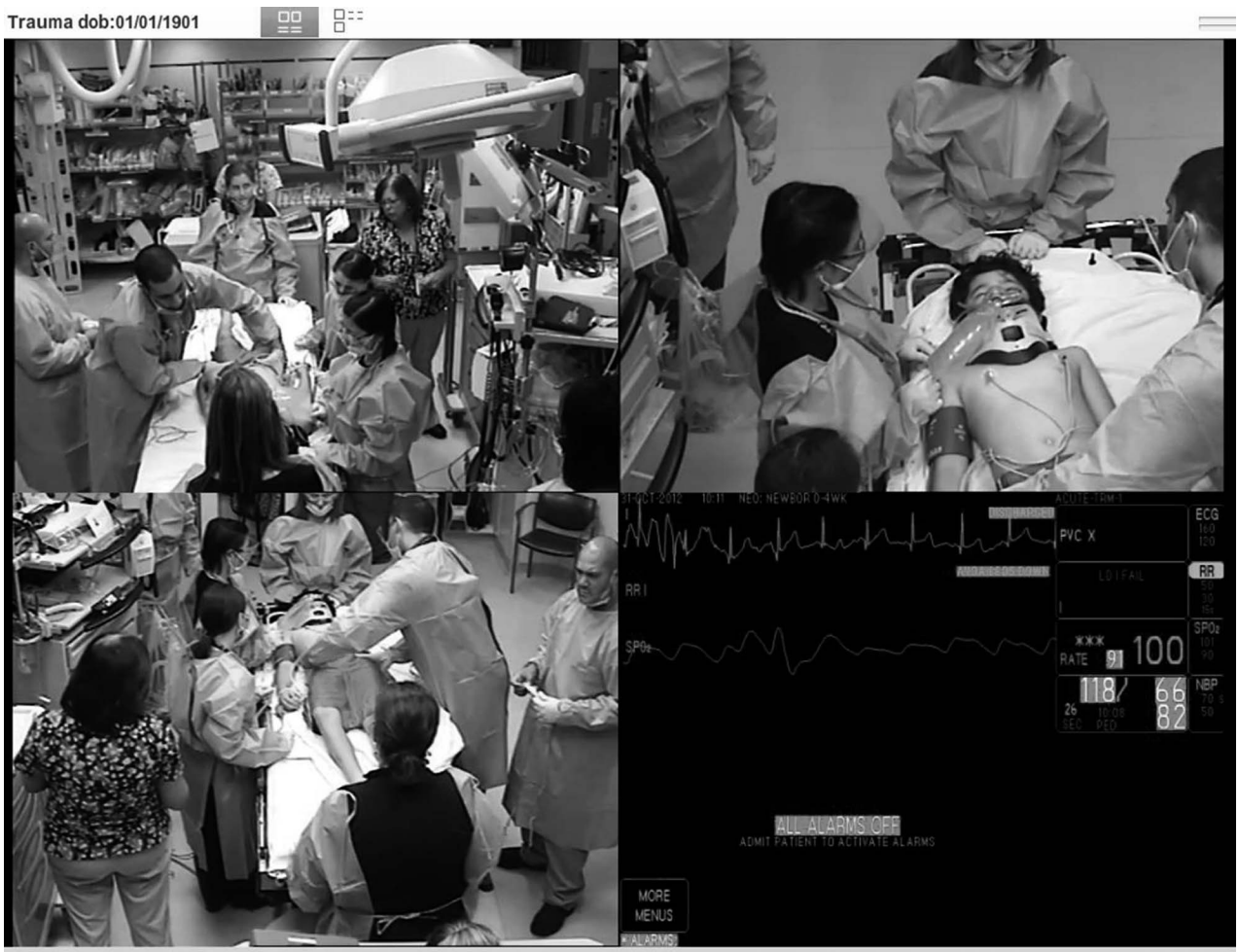

FIGURE 1. Representative screenshot from the video recording system at one of the 3 centers participating in the VIPER collaborative (CHOP[a]). [a]Simulated resuscitation, permission granted from all participants and the simulated patient for distribution/publication.

tools hosted at CHOP.[17] The research coordinator reviewed all revisions to each data element for consistency and accuracy. The main sections of the registry are patient monitoring and vital signs, performance of the primary survey, basic interventions, tracheal intubation, and CPR. The complete set of data elements is presented in Table 1, stratified by section.

Simulation-Based Assessment of Feasibility and Reliability

To assess the feasibility and reliability of data collection using the VIPER registry, we completed a simulation-based study, using a series of simulated pediatric resuscitations conducted in one of the participating PEDs. The study was reviewed and approved by the institutional review board (IRB) of CHOP prior to commencement. The simulations were performed as a part of a general pediatric resident education program, with all care team roles filled by pediatric residents; no changes to the existing educational program were made to accommodate video-based data collection. The scenarios were directed by emergency medicine faculty and fellows with ad hoc learning objectives. Video recordings were made with at least 2 camera feeds plus a recording of the simulated vital sign monitor, a setup nearly identical to each center's existing system. The recordings of the simulations were stored on a password- and firewall-protected server at the site where the simulations were conducted. Remote site access for video review and data collection was obtained for the non–primary site investigators.

One investigator from each center (B.T.K., K.J.O., A.J.D.) reviewed the study videos independently and then entered all relevant data into the VIPER registry. All data fields contained a response option of "cannot tell" to indicate indeterminate data. To assess feasibility, we calculated the frequency of the "cannot tell" response as a proportion of all relevant data fields for any reviewer. Because the simulated cases were sampled from an existing educational program and not designed by the study team, not all fields in the database were relevant to each case; we report the completeness of data collection as a proportion of the relevant data fields. To assess reliability, interrater agreement was analyzed, for dichotomous data by Cohen κ and for continuous (time-based) data by intraclass correlation coefficients using a 2-way random-effects model. Cohen κ was calculated for all data fields in aggregate and by the registry section, that is, monitors and vital signs, primary survey, basic interventions, tracheal intubation, and CPR. All analyses were completed using StataSE 12 (College Station, Tex).

RESULTS

We reviewed 8 simulated resuscitations. Three reviewers collected data from 5 resuscitations for patient monitoring and vital signs, primary survey completion, and basic assessments and interventions; 2 of these same 5 resuscitations were reviewed for tracheal intubation. The other 3 resuscitations involved a patient with a shockable rhythm where defibrillation was indicated; these 3 cases were reviewed by 2 reviewers for cardiac arrest and CPR data fields only.

Combining responses from all raters for all 8 cases, data were labeled as indeterminate by at least 1 reviewer for 18 (3%) of 524 relevant data fields. The proportion of relevant data fields successfully collected by at least 1 reviewer was, by content area, as follows: vital signs, 49/50 (98%); primary survey, 37/40 fields (93%); basic assessments and interventions, 45/50 (90%); tracheal intubation, 30/32 (94%); CPR, 206/206 (100%).

The Cohen κ for all dichotomous data fields together was 0.81 (95% confidence interval [CI], 0.61–1.0). For all continuous (time-based) variables combined, the intraclass correlation coefficient was 0.88 (95% CI, 0.70–0.96). The results of interrater agreement analyses for both individual categorical and continuous data fields stratified by content area are shown in Table 2.

DISCUSSION

The results of our preliminary testing through simulation suggest the feasibility and reliability of multicenter, video-based data collection during resuscitations in a PED. Moreover, these results support the viability of our collaborative. We intend to further refine the VIPER registry and infrastructure and determine feasibility and reliability for actual resuscitations. The fully realized VIPER registry will serve as the foundation for studies of actual pediatric resuscitations based on a highly valid approach to data collection and with sufficient sample sizes to permit adequately powered studies of even relatively rare patient presentations, procedural skills, and quality improvement efforts.

Most research on pediatric resuscitation is based on review of existing medical records or self-report. Recently, video review has gained traction as a potentially superior method of data collection for resuscitative care. Members of the VIPER collaborative have successfully used video review to complete studies of trauma care, tracheal intubation, and CPR.[3,8–12] In one of these studies, video review was demonstrated to have superior accuracy to medical record review for describing tracheal intubation, especially the time-based data elements critical to understanding the performance of this procedure.[2]

Investigators from CNMC published on the use of video review to assess teamwork, provider workload, and primary survey performance for injured children undergoing trauma team evaluation.[6,7,11] The primary survey was completed in only 50% of cases, and the secondary survey in only 13%. Introduction of a checklist work aid resulted in a 12% increase in survey completion, whereas self-reported workload by ED clinicians was not increased. Investigators from CCHMC have published several video-based studies of tracheal intubation in the PED. In their first study, video review revealed a first-attempt failure rate of almost 50% and an oxyhemoglobin desaturation rate of 33%.[3] In a separate analysis, they demonstrated that attempt duration, a data element uniquely available by video review, was independently associated with oxyhemoglobin desaturation.[12] Their group then completed a successful quality improvement initiative, where a checklist-based intervention was associated with improved attempt success and a 50% reduction in desaturation events (33%–16%). Finally, investigators from CHOP have used video review in the PED to assess adherence to current AHA guidelines for CPR.[9] For 33 CPR events over a 15-month period, chest compressions were performed at a rate of 100 to 120 per minute less than half the time (43%), pauses in compressions were less than 10 seconds only 67% of the time, and ventilations exceeded 12 breaths per minute 70% of the time. In a separate analysis comparing the findings of video review with data from a CPR feedback device, chest compression rate was reliably measured by both data sources, whereas compression quality (depth and chest wall release) was inaccurate and unreliable by video review.[18]

These preliminary studies, and the knowledge and experience they represent, served as the basis for the VIPER collaborative and registry. In addition, these successful single-center efforts offer compelling targets for planned multicenter investigations through VIPER and provide the collaborative credibility for applications to fund those investigations. Moreover, investigations using VIPER would directly address many of the limitations of the single-center studies, including limited sample sizes and lack of generalizability. Rather than requiring repetition at other centers, successful studies through VIPER could be immediately

TABLE 1. Data Elements in the VIPER Registry, by Category, With Type of Data Element and Coding

Data Element	Categorical/Dichotomous*	Continuous/Time Based†
A. Vital Signs		
Heart rate/3-lead electrocardiogram	Monitor placed	Time of placement
Initial heart rate value from monitor	Obtained	Time obtained
Pulse oximetry	Monitor placed	Time of placement
Initial pulse oximetry value from monitor	Obtained	Time obtained
Blood pressure (BP)	Monitor placed	Time of placement
Initial BP value from monitor	Obtained	Time obtained
Respiratory rate	Monitor placed	Time of placement
Initial respiratory rate from monitor	Obtained	Time obtained
Temperature	Measured	Time of measurement
B. Primary Survey		
Airway assessment	Performed	Time performed
	Verbalized	Time verbalized
	Prompted by supervising clinician	—
Breathing assessment	Performed	Time performed
	Verbalized	Time verbalized
	Prompted by supervising clinician	—
Circulatory assessment (pulse check)	Performed	Time performed
	Verbalized	Time verbalized
	Prompted by supervising clinician	—
Mental status assessment	Performed	Time performed
	Verbalized	Time verbalized
	Prompted by supervising clinician	—
Glasgow Coma Scale	Performed	Time performed
Exposure	Performed	Time performed
C. Basic Interventions		
NP or OP airway placement	Performed	Time performed
Suctioning	Performed	Time performed
Tracheostomy change	Performed	Time performed
Supplemental oxygen administration	Performed	Time performed
	Method of administration	—
NIPPV administration	Performed	Time performed
	Method of administration	—
BVM ventilation	Performed	Time performed
Vascular access	Performed	Time performed
	Method	—
IVF administration	Performed	Time performed
	Method	—
Cardioversion (electrical)	Performed	Time performed
	Energy dose	—
	Result	—
Cardioversion (medical)	Performed	Time performed
	Medication	—
	Result	—
Vasoactive infusion administration	Performed	Time performed
	Medication	
Transcutaneous pacing	Performed	Time performed
Dextrose check	Performed	Time performed
Anticonvulsant administration	Performed	Time performed
Temperature control (warming or cooling)	Performed	Time performed
D. Tracheal Intubation		
Decision to intubate discernible from video	Performed	Time of decision
Crash intubation	Performed	—

Continued next page

TABLE 1. *(Continued)*

Data Element	Categorical/Dichotomous*	Continuous/Time Based†
Premedication administration	Performed	Time performed
	Medication	—
Sedative administration	Performed	Time performed
	Medication	—
Paralytic administration	Performed	Time performed
	Medication	—
Oxygenation prior to laryngoscopy	—	Time started/stopped
Laryngoscopic technique	Direct versus video	—
Time of laryngoscopy	—	Time of blade in/out
Suctioning		—
Cricoid pressure applied		—
External laryngeal manipulation by intubator		—
Apneic oxygenation used		—
Tube insertion	Performed	Time performed
Tube removal (during attempt)	Performed	Time performed
Confirmation of tube placement (exhaled CO_2)	Performed	Time performed
	Method	—
Complications		
Hypoxemia[c]	Occurred	Duration of each event, from time <90% to time >90%
Bradycardia or cardiac arrest with chest compressions performed	Occurred	Duration of each event
Esophageal intubation	Occurred	
E. Cardiopulmonary Resuscitation		
Entire event		
Location	In-hospital vs out-of-hospital	—
Witnessed event	Present	—
Bystander CPR	Performed	—
Total CPR time	—	Time of start/stop
Chest compression fraction	—	Percent
ROSC	Present	—
Survival to hospital admission	Present	—
Per compression segment		
Provider category	Physician, nurse, technician, paramedic, other	—
Time of compression segment	—	Time of start/stop
Hand position	2-finger; 1 hand; 2 hands	—
Stepstool used		—
Audiovisual feedback used		—
During pauses in compressions		
Length of pause	—	Time of start/stop
Actions performed during pause	Compressor change, rhythm check, pulse check, airway maneuver, defibrillation)	—
Defibrillation		
Shockable rhythm	Yes/no	Time acknowledged
Defibrillation	Dose	Time performed
	Result	—
CPR quality: verbal prompts by supervisor		
Prompt given	Yes/no	First prompt time
What was prompted	Compression rate, depth; ventilation rate; end pause)	—

*Yes/no.

†Time expressed in h:min:sec.

‡Defined as SPO_2 dropping less than 90% any time between the initial attempt and the endotracheal tube being secured.

OP indicates oropharyngeal; NP, nasopharyngeal; NIPPV, non-invasive positive pressure ventilation; BVM, bag-valve mask; IVF, intravenous fluids; ROSC, return of spontaneous circulation.

TABLE 2. Interrater Agreement From Video Review of 8 Simulated Pediatric Resuscitations in 1 PED in the VIPER Collaborative

Data Category	Categorical/ Dichotomous Data: κ (95% CI)	Continuous Data: Intraclass Correlation Coefficient (95% CI)
Vital signs	0.83 (0.51–1.0)	0.91 (0.90–0.98)
Primary survey	1.0	0.76 (0.56–0.91)
Basic interventions	0.73 (0.38–1.0)	0.97 (0.97–0.99)
Tracheal intubation	0.81 (0.58–1.0)	0.99 (0.98–0.99)
CPR	0.85 (0.71–1.0)	0.89 (0.71–0.94)

generalizable to similar, primarily academic PEDs, accelerating the transfer of knowledge to the bedside.

Challenges

The 3 VIPER centers have encountered common challenges when establishing their video-based programs. Video recording of pediatric resuscitations has potential legal implications, in particular the possibility of the videos being discoverable. In response, each institution has developed a written policy concerning the use of and destruction of the videos (as with all identifiable data), as well as the intention to use the video recordings solely for quality assurance, peer review, and IRB-approved clinical research activities. These policies are institution specific and were developed in consultation with legal counsel.

The use of video review for data collection and quality improvement presents unique challenges for the protection of human patient subjects. Distribution of the video recordings, internally or externally, could result in the sharing of sensitive patient and provider information, risking violations of privacy if used for purposes other than those strictly outlined by the site's legal and IRB reviews. In response, each center has established ongoing, working relationships with their respective IRB representatives, engaging them well before protocol submission. For our current, planned studies through VIPER, we have been granted a waiver of informed consent from each IRB. The confidentiality of providers and potential impact on quality of care was especially considered when developing the video-based programs. To protect provider confidentiality, each center has established guidelines for the use of the video recordings for peer review, quality assurance, and formally approved projects only. Further, all videos are stored on secure servers and encrypted/password-protected computers.

Although the policies and procedures at each institution will apply to all VIPER projects, the sharing of identifiable data from different sites potentially introduces novel legal, patient, and human subjects–protection and provider-protection challenges and will be clearly outlined in inter-site legal and IRB agreements.

Limitations

There are several limitations to the VIPER collaborative and registry that could impair the feasibility, efficiency, and validity of future efforts. We are addressing each of these limitations by a specific "next step" in the development of the collaborative. First, data collection and assessment of reliability and feasibility have been conducted only on a limited sample of simulated cases from 1 center. Video review itself, however, was completed by investigators from each center, who have also demonstrated the feasibility of video-based data collection and quality of their video systems through previous studies.[2,3,7,11] We will further address this limitation by completing a multicenter study of actual patients undergoing medical resuscitation, repeating the same feasibility and reliability testing performed on simulated cases.

Second, because the video recordings are not part of the medical record and are deleted after a fixed time, reabstraction of data for intercenter reliability testing will be impossible. We will address this limitation by remote access and review of a subset of each center's videos prior to their destruction.

Third, the collaborative includes only 3 sites, all of which are tertiary pediatric centers. Although our initial 3-center studies would be substantially more valid and powerful than previous single center studies, sample sizes may still be relatively small for some rare but important conditions, and generalizability may still be somewhat limited. The 3 VIPER institutions are also members of the Pediatric Emergency Care Applied Research Network (PECARN), a federally funded pediatric emergency medicine research network in the United States that conducts high-priority, multi-institutional research. In an unpublished survey of the PEDs participating in PECARN, which includes our 3 centers, only 6 of 18 centers (33%) reported using video review in their resuscitation areas, the majority of which used video review for trauma patients only. We have been approached by colleagues at similar academic pediatric centers, including several within PECARN, and will pursue the addition of these centers to VIPER. As additional PECARN hospital systems adopt video review to evaluate pediatric resuscitations, the VIPER collaborative will expand to include additional sites to increase the registry's overall sample size and generalizability. To ease the logistical burden of joining VIPER and to ensure reliable data collection, for future VIPER sites we are developing a manual of operations that explicitly describes both training for video-based data collection and procedures to assess and to ensure reliable collection. We also intend that our initial VIPER studies will continue to demonstrate the unique capabilities of video review and lead to its consideration by additional centers that do not yet perform video review.

Finally, the VIPER registry is currently focused on processes of care rather than patient outcomes. Patient outcomes generally cannot be adequately determined by data collection in the PED. Determining the effectiveness of PED care processes, however, ultimately necessitates determining patient outcomes, and outcomes-centered research is imperative and essential to VIPER's impact. To address this limitation, we will expand the VIPER data collection to include patient outcome data following completion of our initial patient investigations.

Future Studies

We intend to complete several specific, prospective, hypothesis-driven studies. First, we will compare CPR performance both among the 3 centers and to current AHA guidelines. All 3 VIPER EDs have pediatrics-approved defibrillators equipped with monitor and feedback devices that collect real-time data on chest compression and ventilation performance during CPR (R-series; ZOLL Medical, Chelmsford, Mass), permitting the collection of "high-resolution" data on chest compression quality. This dual-method data collection for CPR performance will represent the most thorough and unbiased assessment of pediatric CPR quality to date. Also, members of our group have previously published data on the impact of short-duration, high-frequency training on CPR performance.[19] Implementation of this approach to CPR training across all 3 EDs in our study, coupled with videography-based data collection at the level of individual CPR providers, would permit a direct examination of the impact of refresher CPR training on CPR performance in real patients. Second, we will compare the performance of tracheal intubation among the 3 EDs. The primary study question will focus on whether attempt success/duration and associated adverse events occur with a similar

frequency in the CCHMC ED, where a formal improvement initiative was associated with marked improvements, and the other 2 EDs. If performance gaps exist at the other 2 centers, we would explore implementation of the checklist-based intervention that was associated with improvements in the performance and safety of tracheal intubation at CCHMC. Finally, high-quality teamwork and communication are essential to an efficient and effective resuscitation, but the current version of the VIPER registry does not include data elements to allow their measurement. We will investigate the feasibility and reliability of existing teamwork assessment tools, for example, the Behavioral Assessment Tool,[20] the Nontechnical Skills scale,[21] and the TEAM tool.[22] Determined through application of generalizability theory, the instrument with the best discriminatory capacity for team performance will be added to the VIPER registry. With an established metric for measuring important nontechnical team skills, we will have a platform on which to investigate the effects of teamwork dynamics on real patient outcomes.

CONCLUSIONS

Pediatric resuscitation remains a challenging area for high-quality research. The VIPER collaborative represents a significant advance over successful single-center studies completed at 3 prominent pediatric centers. The VIPER registry and infrastructure will allow the development of robust and minimally biased metrics for clinical performance during the infrequent, high-stakes medical resuscitations in a PED. In addition, data from the registry will serve as a platform for measuring the impact of new and novel training and educational endeavors on critical care in real patients in actual care settings, effectively bridging the gaps between educational methodology, quality improvement, care delivery, and patient outcomes.

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