Published in final edited form as:

Pediatr Emerg Care. 2017 July ; 33(7): 457–461. doi:10.1097/PEC.0000000000000813.

Capnography Use During Intubation and Cardiopulmonary Resuscitation in the Pediatric Emergency Department

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Introduction

Over the last 30 years there has been a rapid rise in publications related to capnography, or continuous end-tidal carbon dioxide (ETCO₂) monitoring, with a parallel increase in the number of patient applications for this device.¹ Importantly, capnography has been studied in the setting of intubation and cardiopulmonary resuscitation (CPR) and shown to provide benefits to both patients and providers.² In the setting of intubation, capnography is the 'gold-standard' method for confirmation of endotracheal tube (ETT) placement in the trachea; it also accurately detects ETT dislodgement and may decrease the frequency of inadvertent hypo- and hyperventilation.³⁻⁷ During CPR, capnography may correlate with pulmonary blood flow as a measure of the effectiveness of chest compressions, can be an early indicator of the return of spontaneous circulation (ROSC), and may be useful in predicting mortality.⁸⁻¹⁰

With this growing body of evidence, the International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science as well as the American Heart Association (AHA) updated their guidelines for both Adult and Pediatric Advanced Life Support in 2010 to include recommendations for capnography use during these critical events.¹¹⁻¹³ The new guidelines recommended the routine use of quantitative waveform capnography for both intubation and during CPR.¹¹⁻¹³ Since capnography is the most reliable method to confirm placement of the ETT, this method was given a class I

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Conflicts of Interest

There are no other conflicts of interest to disclose.

Meetings:

This work was presented at the Eastern Society of Pediatric Research March 2013 and March 2014, Philadelphia PA, as well as at the Pediatric Academic Society meeting in Vancouver, B.C., May 2014.

recommendation for all hospital settings.¹² In the event of CPR, capnography can improve the quality of chest compressions by serving as a guide to effective compressions and reduce interruptions by identifying ROSC without frequent pauses for pulse checks (Class IIa). Since these recommendations have been released, it is unclear if they are being adhered to for children. Overall, there is little data documenting how capnography is being used in children, particularly in the emergency department (ED).

Our primary objectives were to determine how often capnography is being used during critical events and if publication of the updated AHA guidelines resulted in an increase in use of capnography. Our secondary objective was to examine associations between patient characteristics and capnography use among these patients in the pediatric acute care setting.

Methods

Study Design and Setting

A retrospective chart review was performed at two urban, academic, pediatric EDs between January 2009 and December 2012. The pediatric ED at the primary institution (site 1) has an annual volume of approximately 34,000 patients and is within a non-freestanding children's hospital. The secondary institution (site 2) is a freestanding children's hospital with an annual volume of approximately 90,000 patients. The institutional review board approved this study at each site.

Participants

Children aged 0-21 years who were intubated or received CPR in the ED were eligible for inclusion. Patients were excluded if they were treated in the adult ED or had a prior tracheostomy.

Methods and Measurements

Potential patients were identified at site 1 through the hospital's electronic data system as those that accrued both ED and intensive care unit charges or who expired in the ED. Data was collected from hand-written charts, completed at the time the patient was seen and scanned into the medical record. These included doctors' notes, nursing notes, as well as emergency medical services transportation documentation. There is no documentation by respiratory therapists in the ED.

At site 2, patients were identified both through an internal database of intubations in the ED combined which was cross-referenced against queries of the hospital electronic medical record (EMR), or through international classification of disease- ninth revision (ICD-9) or current procedural terminology (CPT) code searches. The internal database was compiled by academic research associates tasked with gathering data on all intubations within the ED. Associates recorded all intubations and overnight senior physicians were asked for any possible missed intubations during shifts when associates were not present. This database ranged from February 2011 through December 2012. Other patient records were searched for CPT/ICD-9 codes for intubation and CPR. Data was cross-referenced in the overlapping timeframe between the internal database and code searches to avoid double counting and

confirm complete identification of patients. Additionally, any patient who died in the ED during the specified timeframe was identified using an EMR discharge code search and these patient's resuscitation records were examined and compared to our dataset both to capture any patients who were missed, and to cross-reference patients who may have been intubated/received CPR and also expired. All data regarding patient resuscitation was obtained from hand written charts including doctor and nursing notes that were scanned into the patient record within the EMR.

Variables were defined and reviewed with research team members prior to abstraction. A standardized data abstraction form was used at both sites. Two investigators at each site identified eligible patients and extracted data. Discrepancies were resolved by consensus. The updated AHA guidelines were released in October 2010. Allowing for some preliminary dissemination of the new clinical guidelines, we defined 2009 and 2010 as before the AHA guideline release and 2011 and 2012 as after the published update.

Outcomes

Capnography was defined as continuous, quantitative waveform carbon dioxide monitoring, whereas colorimetry was defined as a qualitative carbon dioxide detector. Data extracted included documented use of capnography, colorimetry, recorded values of capnography as well as age, gender, year and time of arrival, medical or traumatic cause for visit, use of bag-valve mask (BVM) ventilation, length of CPR, return of spontaneous circulation (ROSC), and adverse events.

Statistical analysis

Data were entered into a standardized form in Excel (Microsoft Corp. 2010). Statistical analyses were performed in PAWS 18 (SPSS Inc, Chicago IL). Characteristics of subjects were summarized with descriptive statistics including mean and medians, as well as frequencies and percentages. Categorical variables were compared with chi-square or Fisher exact tests. Continuous variables were compared with Student's t-tests if normally distributed and Mann Whitney U tests if not normally distributed. A two-tailed alpha less than or equal to 0.05 was considered statistically significant.

Results

Overall, a total of 292 patients met criteria for inclusion between the two institutions, 156 at site 1 and 136 at site 2. Characteristics of the subjects at each site are reported in Table 1. Information on patient gender was missing in 3 patients. Written documentation of the intubation procedure was not found for 12 patients; this typically occurred when a provider outside of the ED performed the intubation (e.g. Anesthesiology). Colorimetry data was considered missing for these patients. There were statistically significant differences between the two sites for patients' age, delivery of bag-valve mask (BVM) ventilation, use of colorimetry and capnography, duration of resuscitation and for presence of ROSC. A majority of patients had a non-traumatic cause for their critical illness.

Among our cohort, fifteen children were not intubated; bag-valve mask ventilation was performed during CPR. Of those children who were intubated, use of a colorimetric device

was documented in the charts of over two-thirds of patients and identified 9 esophageal intubations. Use of capnography was documented in 38% of intubated children. Either colorimetry or capnography use was documented in 73% of intubated patients. The mean ETCO₂ value first documented among intubated patients was 38mmHg (range 10-86mmHg). There were no ETT dislodgements recorded among our sample. There was no significant change after the AHA guidelines in the use of capnography for intubated children overall (44% vs. 33%, $p=0.06$) or at either site (site 1: 61% vs. 51%, $p=0.25$; site 2: 12% vs. 17% $p=0.38$).

Of the 87 patients receiving CPR, only 13% had documented use of capnography during their resuscitation. Children who were intubated but did not receive CPR had capnography applied significantly more often than children who required CPR (47% vs. 13%, $p<.001$). Among children requiring CPR, there was an association between capnography use and both length of resuscitation and ROSC. A positive ROSC was noted more often among subjects where capnography use was documented (64% vs. 14%, $p=.001$). The mean duration of CPR was significantly longer among cases where capnography was used (29 minutes vs. 17 minutes, 95% CI 2.1, 20.2, $p=0.02$). The mean first reported ETCO₂ value documented on patients receiving CPR was 35mmHg (range 14-83mmHg). The first reported ETCO₂ value was 28mmHg for those with a positive ROSC as compared to 48mmHg for those who did not have ROSC (95% CI 10, 48; $p=0.17$). There was no significant change after the AHA guidelines in the use of capnography during CPR for the total sample (10% vs. 15%, $p=0.54$). Similarly, there was no significant change found when analyzing the sites individually (site 1: 17% vs. 17%, $p=1.0$; site 2: 0% vs. 17%, $p = 0.15$)

For the collective population, there were no significant associations between documented capnography use and age, gender, and medical vs. traumatic cause of intubation or CPR, or time of arrival to the ED (Table 2). When analyzed by site, more females had capnography use documented at site 2 ($p=0.02$), and there was no significant difference in documented capnography use among patients requiring CPR compared to those not requiring CPR at site 2 ($p=0.2$). There was also no significant difference in length of resuscitation at site 1 when capnography use was documented compared to when use was not documented (30 minutes vs. 24 minutes, 95% CI -20.6, 7.7 $p=0.37$). Trends in documented capnography use over the study period are depicted in Figure 1. For the study population as a whole, there was a statistically significant decrease in documented capnography use after the release of the AHA guidelines (43% vs. 32%, $p = 0.05$). However, there was not a significant difference in capnography use at each individual site (Site 1: 60% vs. 50%, $p=0.2$; Site 2: 10% vs. 17%, $p=0.32$).

Discussion

The 2010 AHA recommendations alone have not been effective to increase the documented use of capnography during CPR and intubation among two pediatric EDs in the two years immediately following the publication. Surprisingly, an overall decrease in documented use was seen among our sample after the publication of the guidelines. Our data demonstrate that use of capnography is only being documented in a minority of patients, 38% of intubated children and 13% of children receiving CPR. This underwhelming documented

use of capnography may impact the quality of care that critically ill and injured children are provided in the ED.

Our data is in opposition to earlier survey data where pediatric emergency medicine physicians report always using capnography for the majority of patients receiving CPR and for confirmation of ETT placement.¹⁴ The unexpected decrease in documented use of capnography seen in our study after the 2010 recommendations is of concern. It may be the case that while providers are aware of these recommendations and understand the benefits of capnography monitoring, they have not actually incorporated this device into their practice patterns or are having difficulty in using the device. Problems with knowledge translation are common, and we did not seek to identify causative factors in use and non-use of capnography in this study.^{15, 16}

Despite its poor use, the amount of evidence supporting capnography for these indications has grown significantly over the last few decades.¹ Capnography has been shown to be more sensitive than other forms of confirmation of endotracheal intubation such as auscultation, colorimetry, and pulse oximetry.^{5, 17} Given the variability of pediatric intubation success by physicians, resident trainees, and paramedics, capnography is an important tool to use for this critical procedure.^{7, 18, 19} Once intubated, patients are at risk for dislodgement of the ETT due to movement, such as transfer to the ED stretcher, diagnostic imaging studies, and during transfer to an inpatient unit. Continuous capnography monitoring can allow for earlier detection of a displaced ETT and correction prior to deterioration.^{6, 20} Monitoring with capnography may be even more vital in children as the rate of accidental or unplanned extubation has been shown to be higher in children than adults.²¹ In our study 9 subjects (3%) had a misplaced ETT identified by colorimetry, however there was no documented detection of ETT dislodgement with waveform capnography. When esophageal intubations or dislodgement of the ETT are unrecognized death can result; lack of capnography monitoring is frequently cited as a key factor in these events.^{3, 22, 23}

Capnography was used significantly less often among children receiving CPR in our study, despite its reported benefits. Capnography has been shown to be a reliable indicator of effective chest compressions and ROSC.^{8, 10, 24} Some studies have shown a lack of high quality CPR performed by pediatric providers, demonstrating the need for the audiovisual feedback that capnography provides.^{25, 26} Unlike other CPR feedback devices, capnography is already available in most EDs and has multiple indications for use.¹⁴ An increased frequency of ROSC was noted among children in our study when capnography was present, however we are unable to accurately time the initiation of capnography monitoring during resuscitations. Having this data available to the provider team may have contributed to the reason for this significant difference, however further studies are needed to establish more robust outcome data for this question.

We also identified a variation in the first recorded ETCO₂ values between patients receiving CPR who had a successful ROSC and those who did not survive. Although not statistically significant, given our small sample, this may represent a clinically significant difference. While the first recorded ETCO₂ value was much lower among children who did not survive, our mean value was still higher than previously reported values associated with mortality

from cardiac arrest.^{8, 9} While it has been shown that patients with cardiac arrest from asphyxia had higher initial ETCO₂ compared with cardiac etiology such as ventricular fibrillation and ventricular tachycardia, there were no documented cases of these severe dysrhythmias among our sample.²⁷⁻²⁹

Limitations

There are several limitations to our study, including the retrospective nature of the chart review, which relies upon the accuracy of the written record.^{30, 31} Due to the low frequency of these critical events and unplanned nature of emergencies, a prospective evaluation would require the involvement of many more institutions and significant research support in order to obtain a similar sample. While we did obtain data from two different pediatric EDs, there were significant differences in documented use between sites. Despite a larger volume of overall patients at site 2, there were proportionally less study subjects at this institution. This may be due to proximity of other tertiary care hospitals to site 2 as compared to site 1, variations in acuity between the institutions or differences in practice patterns. A larger study would be needed to evaluate the full spectrum of use in pediatric EDs and provide generalizable results. Similarly, further elucidation of the primary cause of arrest was not sufficiently clear from documentation in the majority of charts. We recognize the difficulties in recording continuous and accurate information during critical events in the ED, when staffing patterns may vary. Similarly, a new EMR was implemented at site 2 during the time frame of this study and could have impacted documentation. However, given that we reviewed both physician and nurse documentation for each child, there were opportunities for more than one provider to record the information being extracted. Regardless, the lack of documentation of standard of care could be perilous and indefensible if adverse outcomes occur which induce morbidity or mortality. Recertification for pediatric advanced life support is required every two years, thus some providers may not have received the updates from the AHA until the end of our study period. Providers may rely on the American Heart Association training center faculty within their institution to provide education about the updates to the guidelines, and we did not assess the extent of training on capnography at the two sites.

Conclusions

The incorporation of capnography into recent resuscitation guidelines has not lead to an increase in its documented use for intubation and cardiopulmonary resuscitation in the years immediately following publication. Overall, a minority of children presenting to two large academic pediatric emergency departments and who required intubation or CPR had medical records that confirmed monitoring with capnography. Active efforts at dissemination and implementation of guidelines are needed in order to initiate and sustain change. Further education and promotion of capnography should take place to improve implementation of these guidelines with hopes to improve patient care.

Acknowledgements

Atu Agawu for his assistance in data processing at the Children's Hospital of Philadelphia.

sources of funding:

Dr. Langan received an honorarium from Oridion for a presentation at an expert panel meeting in November 2011. Dr. Langan discloses that this research was made possible by CTSA Grant Number KL2 RR024138 from the National Center for Research Resources (NCRR) and the National Center for Advancing Translational Science (NCATS), components of the National Institutes of Health (NIH), and NIH roadmap for Medical Research. Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIH. There are no other sources of funding.

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Fig. 1.
Trend in capnography use for intubation and CPR for years 2009-2012.

Table 1

Descriptive characteristics of study subjects with comparisons between Site 1 and Site 2

Variable	Site 1 (N=156)	Site 2 (N=136)	Total (N=292)
Median Age in years (IQR) *	2 (0.5-12)	1.2 (0.25-6)	1.8 (0.33-8.75)
Male Gender N (%)	95 (61%)	83 (61%)	178 (61%)
Medical cause for resuscitation N (%)	118 (76%)	109 (80%)	227 (77%)
Received BVM Ventilation N (%) *	116 (74%)	133 (98%)	249 (87%)
Intubated N (%)	152 (97%)	125 (92%)	277 (95%)
Colorimetry Used N (%) *	119 (78%)	72 (58%)	191 (69%)
Capnography Used N (%) *	86 (55%)	20 (15%)	106 (36%)
Required CPR N (%)	43 (28%)	44 (32%)	87 (30%)
Mean Duration of CPR in minutes *	25	13	19
+ROSC N (%) *	14 (33%)	4 (9%)	18 (21%)

* Difference between site 1 and site 2 with $p < .05$

Table 2

Comparison of capnography use based on patient characteristics and study period

Variable	Capnography Used (N= 105)	Capnography Not Used (N=187)	P value
Mean Age in years	5.6	4.4	.09
Male	58	120	.09
Female	48	63	
Medical cause	81	146	.77
Traumatic cause	25	40	
Before 2010 AHA guidelines	51	67	.05
After 2010 AHA guidelines	55	119	
Received CPR	11	76	<.001
Did not receive CPR	95	110	
+ROSC	7	11	.001
-ROSC	4	65	
Mean Duration of CPR in minutes	28.6	17.4	.02