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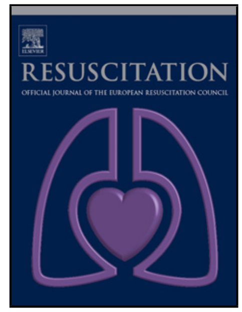

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Hospitals with More-active Participation in Conducting Standardized *In-situ* Mock Codes have Improved Survival After In-hospital Cardiopulmonary Arrest.

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Abstract.

Aim: The American Heart Association (AHA) and the Institute of Medicine have published a national "call-to-action" to improve survival from in-hospital cardiopulmonary arrest (IHCA). Our aim was to determine if more-active hospital participation in standardized in-situ mock code (ISMC) training is associated with increased IHCA survival.

Methods: We performed an ecological study across a multi-state healthcare system comprising 26 hospitals. Hospital-level ISMC performance was measured during 2016-2017 and IHCA hospital discharge survival rates in 2017. We performed univariate and multivariate analysis of the hospital-level association between more-active ISCM participation and IHCA survival, with adjustment for hospital expected mortality as determined by a commercial severity scoring system. Other potential confounders were analyzed using univariate statistics.

Results: Hospitals with *more-active* ISMC participation conducted a median of 17.6 ISMCs/100 beds/year (vs 3.2/100 beds/year in *less-active* hospitals, p=0.001) in 2016-2017. 220,379 patients were admitted and 3,289 experienced IHCA in study hospitals in 2017, with an overall survival rate of 37.4%. Hospitals with more-active ISMC participation had a mean IHCA survival rate of 42.8% vs. 31.8% in hospitals with less-active ISMC participation (p<0.0001), and a significantly reduced odds ratio (OR) of 0.62 for IHCA mortality (95% CI: 0.54-0.72; p<0.0001) which was unchanged after adjustment for hospital-level *expected* mortality (adjusted OR: 0.62; 95% CI: 0.54-0.71; p<0.001).

Conclusions: Hospitals in our healthcare system with more-active ISMC participation have higher IHCA survival. Prospective trials are needed to establish the efficacy of standardized ISMC training programs in improving patient survival after cardiac arrest.

Trial Registration: N/A

Keywords: Simulation; in-situ mock code; in-hospital cardiopulmonary arrest; mortality; basic life support, cardiopulmonary resuscitation,ecological study design.

Introduction.

Over 200,000 in-hospital cardiopulmonary arrests (IHCAs) occur annually in the United States (1,2). Forty to 50% of patients who undergo resuscitative efforts experience return of spontaneous circulation, but ultimately only 20-30% survive to discharge (2-7). High quality adult basic life support (BLS) and cardiopulmonary resuscitation (CPR) have been recognized as key treatment-related factors influencing IHCA survival (2,6). However, the quality of BLS/CPR delivered to patients and IHCA survival rates vary greatly between different hospitals (4,5,8-10) and this has been recognized as a significant gap in patient care in the American Heart Association (AHA) Consensus Statement in 2013 (11). This publication was followed by calls for action from the Institute of Medicine (IOM) to initiate specific actions to improve CPR and IHCA survival (12) and from the AHA Emergency Cardiovascular Care Committee to increase the IHCA survival rate in the U.S. to 35% by 2020 (13). The AHA's list of specific actions needed to help improve CPR quality included: "To determine the method of education, as well as its timing and location, at a system level to ensure optimal CPR performance and patient outcome" (11). In-situ mock codes (ISMCs) are a promising intervention to study in answer to this call. ISMCs allow interprofessional teams to learn to work together to attain cognitive and psychomotor skills necessary to provide optimal BLS/CPR in a realistic environment in which patient safety is not at risk, and performance can be accurately measured to provide feedback for improvement (14-16). The primary aim of our study was to determine whether more-active hospital participation in standardized in-situ mock code (ISMC) training is associated with increased IHCA survival.

Methods.

We performed a descriptive study of ISMC performance measures in our hospital system and an ecological study of the association between hospital-level participation in a standardized ISMC program and hospital survival s/p IHCA.

Setting. Banner Health is a healthcare system currently comprising 28 acute care hospitals in six western states. Banner Simulation System (BSS) is centrally organized to provide simulation personnel and training resources for the entire healthcare system. BSS provides all standardized resuscitation courses within Banner Health including AHA courses in BLS, advanced cardiac life support (ACLS), and pediatric advanced life support (PALS). When our ISMC simulation program was instituted in 2012, it employed infrastructure and resources required to provide standardized ISMC training across our healthcare system. Twenty-six acute-care hospitals participated in our ISMC program during 2016-2017 (two did not participate), ranging from an inner-city 708-bed university teaching hospital/tertiary referral center to an 18-bed rural critical access facility.

Intervention. Our ISMC program instructional content was based on 2015 AHA BLS/CPR recommendations (6). We used Resusci-Anne CPRD® mannequins equipped with the Skillreporter® CPR quality feedback device (Laerdal Medical, Wappinger's Falls NY), and standardized code scenarios including ventricular fibrillation (VF), pulseless ventricular tachycardia (VT), pulseless electrical activity and asystole, specifically designed for general medical/surgical, obstetrical and pediatric hospital units. We employed two internally-developed electronic documents: the ISMC evaluation checklist and the ISMC debriefing form (see figures 1 and 2). ISMC instructors included facility-level nurse educators, bedside and administrative nurses, respiratory care practitioners and simulation staff. Instructors were required to have successfully completed a standardized internally-developed training course in which instructors viewed videotaped codes and entered performance data in our electronic ISMC evaluation checklist to improve inter-rater reliability. It was recommended that instructors be BLS, ACLS, or PALS certified.

Once training was completed, ISMC simulation instructors at each participating hospital conducted standardized ISMCs on their own initiative, leading to variability in hospital-level ISMC participation rates. ISMCs were all located in active patient care units and involved clinicians that were available to participate at the moment the mock code was "called". ISMC teams included nurses, respiratory care practitioners, physicians and other healthcare providers. ISMC instructors used our electronic ISMC evaluation checklist to collect BLS/CPR performance data during the ISMC. When time-critical clinical actions were completed during the ISMC (e.g. initiation of compressions, defibrillation of pulseless VT, etc.) the instructor immediately clicked "done" on the checklist and the time the action occurred was electronically recorded. The CPR quality feedback device was used to capture CPR rate and depth. The checklist also prompted subjective evaluation of other specific aspects of CPR quality, such as the effectiveness of team leadership and the use of closed-loop communication (see table 1). The duration of ISMCs was limited to five minutes. Performance data recorded in the checklist was uploaded at the end of each ISMC, and an ISMC debriefing form (figure 2) was immediately generated for formative team assessment. This form included a timeline of all critical actions taken and was used to focus debriefing on specific opportunities for performance improvement exhibited during the simulation.

Variables. Hospital-level ISMC participation was defined as the number of ISMCs performed at each hospital, per 100 hospital beds, per year. We used three evidence-based metrics to describe ISMC performance: composite CPR quality, defibrillation in less than two minutes (8,10), and composite team dynamics (see table 1). Composite CPR quality was defined as the mean proportion of ISMCs in which each of the following aspects of CPR were performed correctly: initiation of CPR within 20 seconds with interruption no more than once per CPR cycle of no longer than 10 seconds (17-18), depth of compression $\geq$5cm (19-20), compression rate $\geq$100 cpm (21-22), and respirations given at 30:2 compression/respiration ratio or at a rate 8-10 bpm for more than 80% of CPR cycle (23-24). Composite team dynamic was defined as the mean proportion of ISMCs in which effective leadership and closed-loop communication were demonstrated (14,25-27).

The main outcome variable was the hospital survival rate to discharge for patients experiencing IHCA. Potential hospital-level confounding variables included number of licensed beds, annual number of admissions, annual number of IHCAs, proportion of pediatric IHCAs, observed hospital mortality, expected hospital mortality, proportion of admissions to ICU, mean (Acute Physiology and Chronic Health Evaluation) APACHE IVa score, observed ICU mortality, and expected ICU mortality.

Data Collection. We collected descriptive data on ISMC participation and performance on a hospital level during calendar years 2016 and 2017. We abstracted survival data on a hospital level using our system medical records database (MedSeries4®, Siemens Healthcare, Malvern PA) to identify the discharge disposition of all patients with ICD-10 diagnosis of cardiac arrest or ICD-10 procedure code for CPR during calendar year 2017. Hospital-level potential confounding variables during 2017 were provided by the Banner Health Clinical Analytics department. Hospital expected mortality was calculated based on ICD-10 codes and demographic data using the CareScience® risk of mortality model (Premier Inc, Charlotte NC). ICU expected mortality was calculated using APACHE IVa® severity scoring system (Cerner Corp, Kansas City MO).

Analysis. Our analytic approach was designed to reduce confounding. We chose hospital expected mortality as our primary potential confounder because case-mix severity has previously been shown to be the most important determinant of variance in hospital IHCA survival rates (5). Analysis of our pilot data also showed that smaller hospitals (<25 beds) performed significantly more ISMCs per 100 hospital beds than larger hospitals in our healthcare system. Therefore, simply using ISMCs/100 beds/year as the exposure variable in our analysis would introduce confounding by hospital size, and direct comparison between large inner-city tertiary hospitals and rural critical access facilities was deemed to introduce a significant threat to internal validity. We therefore decided *a-priori* to incorporate stratification by hospital size into the definition of our exposure variable. More-active hospital ISMC participation was therefore defined as having conducted more than the median number of ISMCs/100 hospital beds/year *within* the appropriate hospital size stratum (≤25 beds, 26-200 beds, or >200 beds). All other study hospitals were designated as less-active ISMC participants. Univariate statistical analysis was performed to compare hospitals with more-active versus less-active ISMC participation for the outcomes of ISMC performance and IHCA survival to discharge and also for all potential confounders. Proportions were compared using Chi-squared tests with continuity correction, and medians using the Wilcoxon rank sum test. Multiple logistic regression was then used to compare hospitals with more-active versus less-active ISMC participation for the outcome IHCA survival with adjustment for hospital expected mortality. Logistic regression was limited to our exposure variable and this single potential confounder because our unit of analysis only provides an N of 26 (28). We used IBM SPSS Statistics for Mac, Version 24.0. Armonk, NY: IBM Corp.

Results.

A total of 572 standardized ISMCs were performed in study hospitals during 2016-2017. Aggregate ISMC performance metrics are enumerated in table 1. Hospitals that met our definition of more-active ISMC participation performed a median of 17.6 ISMCs/100 beds/year vs 3.2 ISMCs/100 beds/year in hospitals with less-active participation (p=0.0013). Hospitals with more-active ISMC participation achieved a higher percentage of simulated defibrillation in less than two minutes (35.0 vs 25.8% p=0.05), but did not demonstrate better composite CPR performance or teamwork (see table 2).

220,361 patients were admitted and 3,289 patients experienced IHCA in study hospitals in 2017. One hundred twenty-five of 3,289 IHCAs (3.8%) involved patients less than 18 years of age. The overall IHCA survival rate was 37.4% (36.8% in adult IHCA and 53.6% in pediatric IHCA, p=0.0001). Hospitals with more-active ISMC participation had an IHCA survival rate of 42.8% vs. 31.8% in hospitals with less-active ISMC participation (p<0.0001). The odds ratio for the association of more-active ISMC participation and IHCA hospital mortality was 0.62 (95% CI: 0.54-0.72; p<0.0001), and did not significantly change after adjustment by logistic regression for hospital expected mortality (adjusted OR: 0.62; 95% CI: 0.54-0.71; p<0.001). This survival benefit was not explainable by differences in hospital size, proportion of pediatric codes or other potential confounders listed in table 2. Hospitals with more-active ISMC participation had significantly lower proportion of admissions to the ICU, but slightly worse APACHE IVa scores (see table 2). More-active ISMC participation was associated with improved survival in strata of large (35.1% vs 28.9% - p=0.001) and medium-sized hospitals (63.7 vs. 39.8% - p<0.001), but not in small hospitals (51.3% vs 57.6% - p=0.38).

Discussion.

Our ecological study is the first to demonstrate a beneficial association between increased ISMC training and patient survival in a multi-hospital healthcare system. It should be noted that our control group was relatively "strong". Study hospitals with less-active ISMC participation conducted 3.2 ISMCs/100 beds/year and achieved an IHCA survival rate of 32%, comparing favorably to previously reported IHCA survival rates (2-7). Overall, IHCA survival in our 26 participating hospitals was 37%, *exceeding* the AHA Emergency Cardiovascular Care Committee goal of improving the IHCA survival rate to 35% by 2020 (13).

The magnitude of benefit observed in our study represents 151 potential lives saved at study hospitals with more-active ISMC participation, at a "cost" of conducting a mean of 14 additional ISMCs/100 beds/year. This equates to performing an additional 1.1 ISMCs/100 beds/year *per life saved*, likely a reasonable return on investment for most hospital systems. It is possible that improvement we observed in delivering defibrillation in less than two minutes during ISMCs could be related to the survival benefit observed in our study (8,10) although we did not measure defibrillation performance during actual IHCA.

Kirkpatrick defined four levels of outcome measures widely-used to evaluate the impact of educational interventions: reaction, learning, behavior and results (29). Previous studies of ISMC interventions have demonstrated positive changes in learners' reactions (30-31), learning (15,32) and behavior (30,33-34). But only two previous studies have shown an association between ISMCs and improved clinical outcomes (14,16). Both were observational, located in single tertiary academic hospitals, conducted ISMCs under the auspices of a residency and/or fellowship training program, limited analysis to pediatric IHCAs (in which survival is known to be significantly higher than in adults (2,13)) and used historical controls. Andreatta and colleagues showed that a program of regularly conducted ISMCs (15 ISMCs/100beds/year) was associated with a sustained improvement of pediatric IHCA survival rate from 33% to 53% ($p<0.001$) (14). Knight and colleagues showed that a program of monthly ISMCs (4 ISMCs/100 beds/year) was associated with an improvement in pediatric IHCA survival rate from 40.3% to 60.9% (16). Our study has several important distinctions. We did not rely on historical controls. Implementation of standardized ISMC training was not dependent on an academic clinical setting. We included patients from *all* services (adult and pediatric) in 26 hospitals and the number of IHCAs included in our analysis is more than 15 times greater than the sum included in both previous studies. Our study is unique in that we describe a standard ISMC program that can potentially be implemented in a broad range of institutions with widely differing resources.

We think several factors were essential to the observed results of our ISMC program. Standardization of training methodology allows a diverse group of interprofessional learners to focus on a common set of evidence-based learning objectives with efficient use of educational resources. Our ISMC evaluation checklist and debriefing forms provided a uniform method of recording dependable and pertinent data, including an accurate timeline of critical actions, to inform debriefing sessions. The importance of sustained and frequent ISMC training is supported by the observation that ample potential for improved BLS/CPR performance persists in our system despite more than five years of effort. Knowledge gained without subsequent reinforcement begins to decay almost immediately and may be essentially lost within three months (35). The value of reinforcement by repetitive training is well documented in the clinical literature on CPR (36,37) and is the basis of the AHA's current Resuscitation Quality Improvement Program (38). In fact, the historical requirement for CPR recertification every two years has been recently challenged, and more frequent learning sessions are currently being assessed and employed (39). The search for the optimal interval between training sessions required to maintain a consistent proficiency level represents an active area of on-going research (33,34).

Limitations

Our study is ecological in design, and should be interpreted as hypothesis-generating. This study design was chosen for pragmatic reasons, but the use of hospital-level data limited our multivariate statistical analysis and potentially subjected our results to ecological bias. This was mitigated to some degree by our use of stratification by hospital size, adjustment for case-mix severity (expected hospital mortality) by logistic regression, and our analysis of other potential confounders. Our main potential confounder, expected hospital mortality, was calculated using a commercial hospital mortality prediction model inherently limited by its dependence on administrative data. Some potentially important confounders were not measured in our study; it's possible that hospitals with more-active ISMC participation might also have more-active participation in other, *unmeasured,* quality-improvement activities that relate to improved patient survival. However, our finding that the *overall* mortality rate was no different between hospitals with more-active vs. less-active ISMC participation is an argument in favor of the hypothesis that improved survival post IHCA was a specific effect of ISMC training. We do not have a good explanation for why a survival benefit was not demonstrable in the stratum representing smaller hospitals in our healthcare system – it's possible that our study was simply underpowered in this stratum, which had the lowest number of IHCA events (n=208).

Despite the inherent potential weaknesses of ecological studies, our study meets a proposed set of quality guidelines for conducting and reporting ecological studies (28). It has been recently proposed that ecological studies are not necessarily methodologically inferior for *all* research applications, since important insights can be derived from group-level data when the research question relates to group-level interventions and effects (40). Ultimately, a prospective randomized controlled trial will be required to circumvent the inherent limitations of our ecological study.

Conclusions.

Our ecological study extends the current state of related literature, suggesting that more-active hospital participation in a standardized ISMC program can improve hospital IHCA survival rates across a large and diverse healthcare system. We believe essential features of a successful ISMC training program include a standardized simulation intervention incorporating electronic capture of pertinent quantitative data, implemented in a sustained and frequent fashion to inter-professional teams of bedside caregivers. More work is needed, but increasing implementation of ISMC training programs could help narrow the existing gap in clinical care for all IHCA patients identified in the 2013 AHA Consensus Statement and address the IOM/AHA call to action (11,12).

Conflicts of interest: None.

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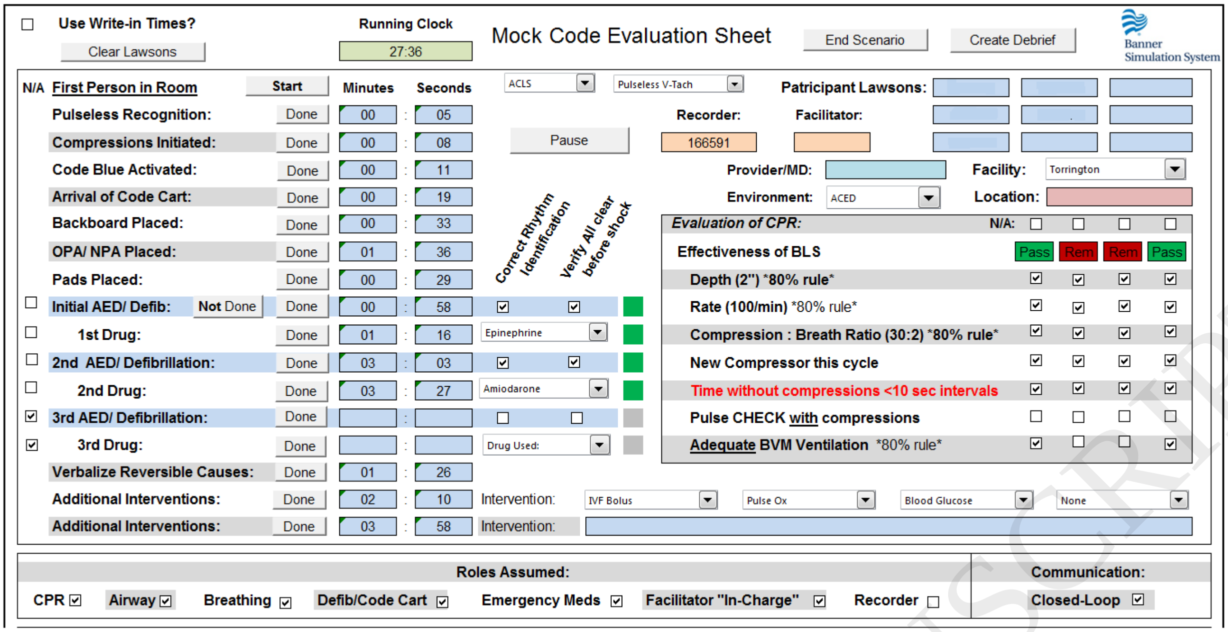
Figure legends:

Figure 1: An example of an actual in-situ mock code evaluation checklist.

Figure 2: An example of an actual in-situ mock code debriefing form.

Figr-1



☐ Use Write-in Times? | Clear Lawsons | Running Clock 27:36 | Mock Code Evaluation Sheet | End Scenario | Create Debrief | Banner Simulation System

N/A			Minutes	Seconds		
	First Person in Room	Start				
	Pulseless Recognition:	Done	00	05		
	Compressions Initiated:	Done	00	08		
	Code Blue Activated:	Done	00	11		
	Arrival of Code Cart:	Done	00	19		
	Backboard Placed:	Done	00	33		
	OPA/ NPA Placed:	Done	01	36		
	Pads Placed:	Done	00	29		
☐	Initial AED/ Defib: Not Done	Done	00	58	☑	☑
☐	1st Drug:	Done	01	16	Epinephrine	
☐	2nd AED/ Defibrillation:	Done	03	03	☑	☑
☐	2nd Drug:	Done	03	27	Amiodarone	
☑	3rd AED/ Defibrillation:	Done			☐	☐
☑	3rd Drug:	Done			Drug Used:	
	Verbalize Reversible Causes:	Done	01	26		
	Additional Interventions:	Done	02	10	Intervention: IVF Bolus, Pulse Ox, Blood Glucose, None	
	Additional Interventions:	Done	03	58	Intervention:	

Correct Rhythm Identification | Verify All clear before shock

ACLS | Pulseless V-Tach | Pause

Patricipant Lawsons: | Recorder: 166591 | Facilitator:

Provider/MD: | Facility: Torrington | Environment: ACED | Location:

Evaluation of CPR: N/A:	☐	☐	☐	☐
Effectiveness of BLS	Pass	Rem	Rem	Pass
Depth (2") *80% rule*	☑	☑	☑	☑
Rate (100/min) *80% rule*	☑	☑	☑	☑
Compression : Breath Ratio (30:2) *80% rule*	☑	☑	☑	☑
New Compressor this cycle	☑	☑	☑	☑
Time without compressions <10 sec intervals	☑	☑	☑	☑
Pulse CHECK with compressions	☐	☐	☐	☐
Adequate BVM Ventilation *80% rule*	☑	☐	☐	☑

Roles Assumed: CPR ☑ Airway ☑ Breathing ☑ Defib/Code Cart ☑ Emergency Meds ☑ Facilitator "In-Charge" ☑ Recorder ☐

Communication: Closed-Loop ☑

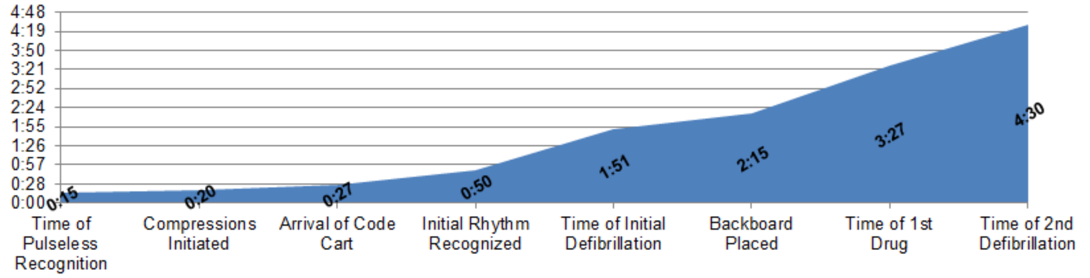
Figr-2

Pulseless V-Fib

Mock Code Debriefing Sheet

SUBMIT TO SHAREPOINT

Banner Simulation System



Intervention Timeline	Time from start	Time Success Criteria Met or Missed?
Time of Pulseless Recognition	00:15	Completed Successfully
Compressions Initiated	00:20	Completed Successfully
Arrival of Code Cart	00:27	Completed Successfully
Initial Rhythm Recognized	00:50	Completed Successfully
Time of Initial Defibrillation	01:51	Late: More than 15 seconds from rhythm recognition
Backboard Placed	02:15	Completed Successfully
Time of 1st Drug	03:27	Late: More than 120 seconds from rhythm recognition
Time of 2nd Defibrillation	04:30	Late: More than 135 seconds from first defib

Team Roles Filled:

Defib/Code Cart	Breathing	CPR	Facilitator "In Charge"
Emergency Meds	Recorder	Airway	Closed-Loop Communication

CPR by Cycle

Effective Compressions	Cycle One	Cycle Two
Depth (2") *80% rule*	red	green
Rate (100/min) *80% rule*	green	red
Compression : Breath Ratio (30:2) *80% rule*	red	red
New Compressor this cycle	green	green
Time without compressions <10 sec intervals	red	red
Pulse CHECK with compressions	red	green
Adequate BVM Ventilation *80% rule*	red	red

Interventions:

Pulse Ox

Critical Errors:

On the first Defib did not identify rhythm correctly

Debriefing Notes:

Remediation Methods used: Return Demonstr | Discussion

Commonly remediated items:

Compression Depth	☑	OPA insertion	☐	AED/Defib equipment usage	☐
Compression Technique	☑	BVM technique	☐	Hands free pads	☐
Hand position	☐	2 people on airway	☐	Connection problems	☐
30:2 Ratio	☑	"E" or "C" technique	☐	Pads versus 3-5 lead	☐
Counting aloud	☐	Each breath over 1 second	☐	ALS algorithm	☐
2 full minutes on chest	☐	Just enough to make chest rise	☐		
Off chest time < than 10 sec	☐	Correct Backboard usage	☐		
Pulse check with compressions	☐				

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Table 1: Performance metrics in 572 ISMCs.

Performance metrics	% ISMCs with successful performance.
Composite CPR quality	70.7%
Delay of ≤20 seconds before CPR initiated	43.2%
Depth of compressions ≥5 cm for more than 80% of any 2-min CPR cycle	74.4%
Compression rate ≥100 cpm for more than 80% of any 2-min CPR cycle	81.1%
Respirations given at 30:2 compression/respiration ratio or at a rate 8-10 bpm for more than 80% of any 2-min CPR cycle	82.6%
No episode of discontinuation of CPR for >10 seconds	72.1%
Defibrillation ≤2 minutes (if patient in VF or VT)	33.0%
Composite teamwork	35.6%
Effective leadership role demonstrated	39.9%
Closed-loop communication used	31.3%

Table 2: Comparison of hospitals with more-active versus less-active ISMC participation: ISMC performance, survival to discharge and possible confounders.

	Hospitals with more-active ISMC participation (n=12)	**Hospitals with less-active ISMC participation (n=14)**	**P value**
Median ISMCs/100 beds/year	17.6	3.2	0.001
ISMC Defibrillation within 2 minutes	35.0%	25.9%	0.05
ISMC CPR quality composite score	70.8%	70.8%	0.99
ISMC Teamwork composite score	39.5%	36.2%	0.50
Survival to discharge s/p IHCA.	42.8%	31.8%	0.0001
Potential confounders:			
Median number of licensed beds	93	70	0.92
Median number of admissions/year	3709	2675	0.86
Median number of IHCAs per year	92	55	0.86

Proportion of pediatric IHCAs	3.9%	3.7%	0.77
Hospital observed mortality	1.80%	1.78%	0.78
Hospital expected mortality	1.89%	1.79%	0.07
Proportion of admissions to ICU	12.4%	19.5%	<0.0001
Mean APACHE score	54.3	52.4	0.001
ICU observed mortality	6.5%	6.2%	0.23
ICU expected mortality	6.90%	6.41%	0.08