Simulation and education

Code blue pit crew model: A novel approach to in-hospital cardiac arrest resuscitation

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Abstract

Background: Mortality from in-hospital cardiac arrests remains a large problem world-wide. In an effort to improve in-hospital cardiac arrest mortality, there is a renewed focus on team training and operations. Here, we describe the implementation of a "pit crew" model to provide in-hospital resuscitation care.

Methods: In order to improve our institution's code team organization, we implemented a pit crew resuscitation model. The model was introduced through computer-based modules and lectures and was reemphasized at our institution-based ACLS training and mock code events. To assess the effect of our model, we reviewed pre- and post-pit crew implementation data from five sources: defibrillator downloads, a centralized hospital database, mock codes, expert-led debriefings, and confidential surveys. Data with continuous variables and normal distribution were analyzed using a standard two-sample t-test. For yes/no categorical data either a Z-test for difference between proportions or Chi-square test was used.

Results: There were statistically significant improvements in compression rates post-intervention (mean rate 133.5 pre vs. 127.9 post, two-tailed, $p = 0.02$) and in adequate team communication (33% pre vs. 100% post; $p = 0.05$). There were also trends toward a reduction in the number of shockable rhythms that were not defibrillated (32.7% pre vs. 18.4% post), average time to shock (mean 1.96 min pre vs. 1.69 min post), and overall survival to discharge (31% pre vs. 37% post), though these did not reach statistical significance.

Conclusion: Implementation of an in-hospital, pit crew resuscitation model is feasible and can improve both code team communication as well as key ACLS metrics.

Keywords: Resuscitation, Code blue, Pit crew, Team training, Simulation

Introduction

There are at least 200,000 in-hospital cardiac arrests (IHCA) each year in the United States,[1] and hospital survival following an IHCA is estimated to be 15–30%.[2–5] Though some degree of mortality reflects patients' underlying disease, inadequate resuscitation also likely contributes to decreased survival.[6–10] For example, in a study completed by Ornato et al., resuscitation errors were noted in 40% of cases presenting in ventricular fibrillation (VF)/pulseless ventricular tachycardia (pVT) and in 27% of cases with an alternative presenting rhythm.[10] Errors in resuscitation were associated with decreased rates of return of spontaneous circulation (ROSC) and survival to hospital discharge.

In an effort to minimize errors, a number of training techniques have been utilized to improve resuscitation practices. These include the implementation of ACLS training and the utilization of resuscitation simulation sessions.[11–16] However, knowledge of ACLS and adherence to established algorithms is not enough. The presence of leadership skills, prior leadership training, and utilization of more directive statements are associated with better cardiac arrest simulation performance,[17–19] while inadequate communication and lack of leadership behaviors have been associated with poorer outcomes during cardiac arrest scenarios.[20,21]

In addition to strong communication and leadership skills, team function and organization are also important when managing critical care scenarios. One way that many first responders deal with the inherent chaos of emergency situations is by utilizing a "pit crew" model when responding to cardiopulmonary arrests.[22–25] Recently, Hopkins et al. included a pit crew model and team training as part of their "best practices" protocol when responding to out-of-hospital cardiac arrests (OHCA).[25] In this study, patients treated in the post-intervention period had higher survival to hospital discharge and better neurologic outcomes in the form of higher cerebral perfusion category scores. Similarly, in an earlier retrospective cohort analysis of OHCA, team-focused CPR was associated with improved survival with good neurologic outcome compared to standard CPR.[26]

Team training and communication are also an area of focus for in-hospital cardiopulmonary resuscitation.[27,28] The American Heart Association (AHA) 2013 consensus statement recommended that providers utilize a coordinated team response with "specific role responsibilities".[29] Though the guideline did not detail exactly how many roles there should be or what the responsibilities should include, it did endorse utilizing a pit crew model in order to ensure high quality CPR and to minimize pauses in compressions.

Despite this recommendation, descriptions of in-hospital resuscitation teams with specific roles and responsibilities are lacking. The aim of this quality improvement initiative was to improve code team communication and organization through the development of a pit crew model for resuscitation. Here we describe our institution's development and roll-out of that model and a retrospective comparison of pre- and post-implementation metrics.

Methods

Patients

All patients who had a true cardiopulmonary arrest (CPA) at the main campus of our tertiary care, academic medical center were included in this quality improvement project. Data were reviewed for all events pre-intervention (April 2013–December 2013) and post-intervention (October 2014–June 2015). The main goal was to improve team communication and function with a secondary goal to improve resuscitation metrics. Since all data obtained were de-identified and were collected under the auspices of quality improvement, a formal IRB was not required; permission for publication was obtained by our institution's Chief Quality and Patient Safety Officer.

Pit crew implementation

Our code team is comprised of internal medicine residents, nurses, pharmacists, respiratory therapists, anesthesia residents and attendings, and pulmonary/critical care or cardiology fellows. Due to the size of our institution, there are several people from each department on "code call" who respond to CPA events located near their geographic zone for that particular day. All CPA events are announced via overhead alert and members assemble based on their assigned call schedule and zone. However, due to the ad hoc nature of our code team and members' inability to pre-assign roles and responsibilities, inadequate communication and organization were frequently cited complaints.[30]

In order to improve role clarity and code team organization, we developed a new "pit crew" model for in-hospital cardiac arrest resuscitation (Fig. 1). In this model, there are between ten and twelve clearly defined code team roles – each with specific responsibilities (Table 1). These roles are positioned within two circles: an inner circle which is within one arm-length of the patient and an outer circle which is within one arm-length of the inner circle (or two arm-lengths from the patient). Roles within the inner circle involve direct patient care activities whereas outer circle roles include tasks such as charting, running, and supervising. We also highlighted key crew resource management (CRM) principles that were pertinent to code team function (i.e. closed loop communication, sterile communication, and debriefing).

This new resuscitation model was introduced throughout the hospital system in a step-wise fashion. First, individuals from each of the key departments were invited to participate in a "Code Blue Team Training Day." As part of this training, participants were educated about the new pit crew model and the importance of related CRM principles. These newly-trained participants then acted in a video which was designed to illustrate the new model. This video was incorporated into respiratory therapy, pharmacy and nursing orientations as well as computer-based learning modules. A separate lecture was given to all internal medicine residents and then the model was introduced to the entire department of internal medicine during a grand rounds presentation. Lastly, the new model was depicted on all screen-savers hospital-wide.

We also used mock codes and our expert-led debriefing process to reinforce the new model and relevant CRM principles. Mock codes were implemented at our institution approximately six months prior to the implementation of our pit crew model as a way to better quantify areas for improvement in code team function and to provide participants with real-time feedback on their resuscitation performance. Like true code events, mock codes were announced overhead without prior warning. Participants were the same personnel responding to true code blue events for that assigned day. The pit crew model was also reemphasized at expert-led debriefings. At our institution, an expert-led debriefing is triggered if a quality concern is identified during a code blue event. In this debriefing, a code blue committee leader will meet with responders from both the local unit and code team to identify areas of opportunity and implement any needed process improvement. A full description of our debriefing process has been published previously.[30] Data were collected for all mock codes and expert-led debriefings under the auspices of quality improvement.

Data review and analysis

We reviewed pre- and post-pit crew implementation data from five sources: defibrillator downloads, the Information Warehouse
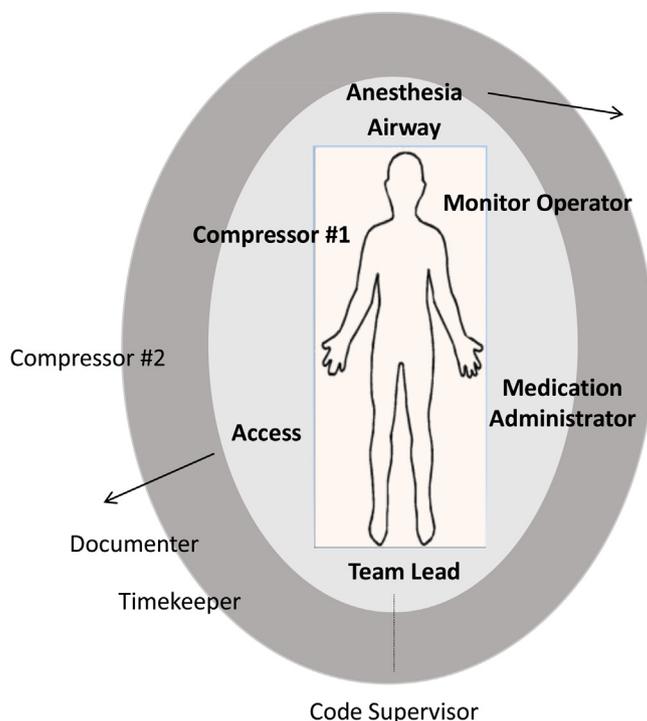
Fig. 1 – Code blue pit crew model. The inner circle (light grey) includes roles that require providers to be within one arm length of the patient. The outer circle (dark grey) includes roles that are important for overall team function but do not require direct contact with the patient.

(a centralized, clinical, hospital database), supervised mock codes, expert-led code blue debriefings, and random confidential surveys. Defibrillator downloads, the Information Warehouse queries, and mock code reviews provided ACLS metrics. CPR rate was obtained via transthoracic impedance captured by the Physio-control Lifepak 20 s, and Codestat 9 software was utilized for data analysis. Compression rates over the entire event were analyzed. More subjective data about code team communication and function were obtained from the mock codes, expert-led debriefings, and the confidential surveys. In an effort to minimize bias from the more subjective sources, data were analyzed and coded by two independent reviewers. The reviewers then met and reviewed their data analysis. If there was disagreement about how they had coded the data, they went back to the original data for re-review and discussed their reasons for scoring the event in a particular way until a consensus was reached. Not all

Table 1 – Pit crew roles and responsibilities.

Role	Responsibility
Inner circle	
Team lead	Lead code team as per ACLS algorithm; assess "Hs &Ts" regarding cause for code event
Airway/anesthesia	Establish advanced airway; bag patient at appropriate rate depending on if advanced airway is present or not
Medication administrator	Administer medications, read-back all medications
Monitor/defibrillator operator	Operate defibrillator including charging/shocking as appropriate, aid with rhythm interpretation
Compressor #1	Complete chest compressions
*Access	Obtain IV access if needed
Outer circle	
Pharmacy (crash cart operator)	Draw up medications as requested by team lead
Timekeeper	Announce every 2 min interval
Documenter	Document code events in the EMR
Code supervisor	Serve as "back-up" for the code lead; manage outer circle
Compressor #2	Switch off/on with compressor #1 every 2 min cycle
Runner	Obtain additional equipment/resources as needed

areas of communication were commented upon in the expert-led debriefings or confidential surveys. When no comment was made, the reviewers marked the category as "I" (indeterminate). Proportions were based on the number of yes/no designations only.

We compiled both our baseline (pre) and post-intervention metrics but only metrics that were anticipated to change with the intervention were analyzed for statistical significance (Table 2). Readers should determine if statistically non-significant changes would be clinically relevant/meaningful in their setting. Compression rate compliance was based on a rate of 100–120 starting April 2013 (early AHA guideline update).

Data with continuous variables and normal distribution was analyzed using a standard two-sample t-test test. If data were not normally distributed, a Mann–Whitney U test was performed. For yes/no categorical data either a Z-test for difference between proportions or Chi-square test were used. Two-tailed analysis was used unless otherwise noted.

Results

There were exactly 159 cardiopulmonary arrest events at our medical center in both the pre-intervention (April 2013–December 2013) and post-intervention (October 2014–June 2015) time periods. Each time frame included three quarters of code events with a nine month gap during the intervention period. The automatically recorded data elements from the Information Warehouse were the most complete, but there were still omissions due to incomplete charting of the bedside staff during some events. Additionally, due to the fact that data were gathered retrospectively, some defibrillator data could not be recovered. By design, confidential surveys and expert-led debriefings occurred for only a subset of cardiopulmonary arrests (CPA) (Table 2). In addition to the true CPA data, we also completed and analyzed 10 mock code events (Table 2).

Defibrillator download data revealed a statistically significant improvement in compression rate post-intervention (mean rate 133.5

Table 2 – ACLS and communications data by source.

Information warehouse

	Pre	Post	p-Value
Total N	159	159	–
Pulseless at code start (#Yes)	124	138	–
Adrenaline (Epinephrine) ≤5 min[a]	96 (83%)	101 (92%)	–
Survival to discharge (%)	31	37	0.26
Presented pVT/VF (#)	49	38	–
Shockable rhythms not identified (%)	32.7	18.4	0.13
Mean time to shock (min)[b]	1.96	1.69	0.41
pVT/VF Shocked ≤2 min (%)[b]	20 (74%)	23 (79%)	0.32
Life pack			
Total N	86	109	–
Mean compression rate over entire event	133.5	127.9	0.02
Mock codes			
Total N	6	4	–
pVT/VF shocked ≤2 min from defibrillator placement (%)	0	75	0.02
Closed loop communication adequate (%)	33.3	75	–
Team lead self-identified (%)	66.7	100	0.22
Sterile communication utilized (%)	16.7	75	0.08
Team communication adequate (%)	33.3	100	0.05
Confidential survey[c]			
Total N	11	25	–
Communication problems (%)	73	44	0.913
Expert-led debriefings[c]			
Total N	17	19	–
Problems with communication (%)	57.10	47.4	0.291
Problems with team function (%)	93.30	52.6	0.89
Communication problems noted in CS (%)	81.3	61.1	0.945
All roles filled (%)	17	25	–
Closed loop communication adequate (%)	0	66.7	–
Sterile communication (%)	11.1	50	–

pVT = pulseless ventricular tachycardia; VF = ventricular fibrillation; CS = confidential survey.

[a] Time of pulselessness or time to first adrenaline was not known or documented in all cases; data was available for 115 cases pre-intervention and 110 post.

[b] Time to defibrillation was not documented in all cases; data was available for 27 case pre-intervention and 29 post.

[c] Not all areas of communication were commented upon in the confidential surveys or expert-led debriefings. When no comment was made, the category was marked as "I" (indeterminate) and the proportions were based on the number of yes/no designations only.

pre vs. 127.9 post, two-tailed p = 0.02). Forty-nine patients pre-intervention and 38 patients post-intervention had an initial presenting rhythm of pulseless ventricular tachycardia (pVT) or ventricular fibrillation (VF). There was a trend toward a reduction in the number of shockable rhythms that were not defibrillated post-intervention (33% pre vs. 18% post) and a trend toward improvement in average time to shock post-intervention (mean 1.96 min pre vs. 1.69 min post) though these did not reach statistical significance. There was also a trend toward overall improved survival to discharge post-intervention (31% pre vs. 37% post).

When data from the supervised mock codes were analyzed, there were statistically significant improvements in the number of patients who were shocked appropriately in less than two minutes (0% pre and 75% post, p = 0.02, chi squared) and the events with "adequate team communication" (33% pre vs. 100% post, p = 0.05). There were also improvements in some of the specific crew resource management principles that were reinforced as part of the new resuscitation model including the presence of closed loop communication (33% pre vs. 75% post), self-identification of the team members (67% pre vs. 100% post), and presence of sterile communication (17% pre vs. 75% post), but these did not meet statistical significance.

Confidential survey data revealed a reduction in "problems noted with code team communication/function" post-intervention (73% pre and 44% post) and expert-led debriefings cited less "problems with team function" post-intervention (93% pre vs. 53% post) but neither were statistically significant given the small sample size. In addition, there was a trend toward improvement in "all [code team] roles filled" (17% pre and 25% post), "closed loop communication" (0% pre vs. 67% post), and "sterile communication" (11% pre vs. 50% post) but these also were not statistically significant secondary to small sample size.

Discussion

Lack of clear code team organization and communication is a frequently cited problem within true code and mock code events.[30,31] In order to improve this aspect of code blue resuscitation, more emphasis should be placed on educating code team members about specific roles and responsibilities.

Though utilization of a pit crew model was suggested in the 2013 AHA consensus statement on CPR quality, there are few examples of how this can be implemented in the literature. Most of these examples are from EMS or first responder settings and so are not necessarily generalizable to the treatment of inpatient cardiac arrests. Recently, Colquitt et al. described the utilization of a pit crew resuscitation model for inpatient CPA events, but the model was only utilized for simulated mock codes and was not rolled out for true CPA events.[31] To the best of our knowledge, our initiative represents one of the first large-scale implementations of a pit crew resuscitation model utilized by an ad hoc code team. Similar to previously described out-of-hospital resuscitation models, our pit crew model includes specific roles for airway management, CPR delivery, medication administration, defibrillator operation, and documentation. However, given the medical complexity of an in-hospital cardiac arrest and the need to consider and treat underlying pathologies (i.e. "H"s and "T"s), we also added several other named roles. These additional roles include a code leader, timekeeper, pharmacist, and code supervisor. The ad hoc nature of our code team underscores the importance of well-structured, clearly defined code team roles. When responders arrive on the scene, team members must quickly assess the situation, self-identify, and fulfill a role that they are competent to perform.

Though the primary goal of this quality improvement initiative was to improve code team organization through the utilization of a model with clearly defined roles and responsibilities, we were also able to demonstrate quantifiable improvements in our resuscitation metrics with the implementation of this pit crew model. First, we noted an improvement in compression rates post-pit crew implementation. Though, depending on the rate, an average difference of five compressions per minute may or may not be clinically relevant, there is little debate regarding the importance of the appropriate depth and rate of chest compressions in general. Therefore, because both our pre- and post-implementation rates were above the upper limit recommended by the AHA, a decrease in five compressions per minute may be meaningful as it likely represents greater chest recoil and ultimately more effective CPR. However, we cannot state that the improvement in CPR rate was solely secondary to the implementation of the pit crew model since there was an increased focus on resuscitation education in general as we worked to educate code blue team members about the new framework. However, no other specific interventions were implemented during the time that we introduced the pit crew model.

We also noted improvements in subjective code team measurements including the presence of adequate code team communication. The importance of a strong code team communication was recently highlighted by Brahmajee et al.[32] In their qualitative study designed to identify what top-performing hospitals are doing to improve their resuscitation outcomes, they cited four factors that they believed to be associated with higher rates of in-hospital cardiac survival. These four factors include: team design, team composition and roles, communication and leadership, and ongoing training and educational efforts. Therefore, though we did not find a statistically significant increase in survival to discharge in our study, our development of a clear resuscitation model, clearly defined roles, a renewed emphasis on CRM principles (including communication metrics), and ongoing education in the form of debriefings and mock codes may ultimately be associated with improved mortality with a larger sample size.

The implementation of a pit crew resuscitation model to improve code team function was well-received at our institution. Inadequate communication and frequent overcrowding with lack of clarity regarding role fulfillment had been commonly cited problems at our medical center. The development and roll-out of the pit crew model directly addressed these weaknesses.[30] However, the implementation of a more standardized resuscitation model across our hospitals required significant time and resources. In addition to the education provided in the initial computer-based learning modules and lectures, we provided continuing education regarding the new pit crew model during mock codes, expert-led debriefings, ACLS recertification classes, and simulation sessions. Though this took institutional support and a dedicated work-group, we believe that providing continued education to different disciplines was ultimately what helped to ensure that this model was adopted.

Limitations

As alluded to previously, one of the largest limitations of this quality improvement project is its small sample size. We attempted to address this by including data from five different sources. However, the number of CPA events at our institution remains relatively small with an even smaller number of mock codes or cases identified as appropriate for

expert-led debriefing. Similarly, though we collected objective data from the defibrillators as well as from our institution's clinical database, these data were not complete for every CPA event due to incomplete charting and the retrospective nature of our quality project. Though our small sample size limited the robustness of our data, we believe that describing our model and the feasibility of its implementation remains valuable.

Another limitation is the subjective nature of some of the data collected. Survey data are subject to individual's own biases and may vary depending on the participant. Additionally, the events that were reviewed in expert-led debriefings likely represent "worst case" scenarios and may not be indicative of all true code blue events. Though we were able to attain data from a variety of different sources, the measurement of code team communication and organization remains inherently subjective. In order to combat this, we had two independent reviewers evaluate all purely subjective measures. We also collected data regarding objective ACLS metrics including those that require adequate code team function.

Lastly, though the implementation of a pit crew model for resuscitation was well-received at our institution, our findings or practices may not be generalizable across other institutions.

Conclusions

This study represents one of the first adoptions of the pit crew model as part of the coordinated response to in-hospital cardio-pulmonary arrests. By better defining code team roles and responsibilities, we have laid the foundation for ongoing improvement of our code team's organization and communication and, ultimately, patient outcomes.

Conflicts of interest

None.

Acknowledgments

REFERENCES

1. Merchant RM, Yang L, Becker LB, et al. American Heart Association Get With The Guidelines-Resuscitation Investigators. Incidence of treated cardiac arrest in hospitalized patients in the United States. Crit Care Med 2011;39:2401–6.
2. Peberdy MA, Kaye W, Ornato JP, et al. Cardiopulmonary resuscitation of adults in the hospital: a report of 14720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. Resuscitation 2003;58:297–308.
3. Sandroni C, Nolan J, Cavallaro F, Antonelli M. In-hospital cardiac arrest: incidence, prognosis and possible measures to improve survival. Intensive Care Med 2007;33:237–45.
4. Kazaure HS, Roman SA, Sosa JA. Epidemiology and outcomes of the in-hospital cardiopulmonary resuscitation in the United States, 2000-2009. Resuscitation 2013;84:1255–60.
5. Mallikethi-Reddy S, Akintoye E, Rubenfire M, Briasoulis A, Grines CL, Afonso L. Nationwise survival after inhospital cardiac arrest before and after 2010 cardiopulmonary resuscitation guidelines: 2007-2014. Int J Cardiol 2017;249:231–3.
6. Abella BS, Sandbo N, Vassilatos P. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation 2005;111:428–34.
7. Panesar SS, Ignatowicz AM, Donaldson LJ. Errors in the management of cardiac arrests: an observational study of patient safety incidents in England. Resuscitation 2014;85:1759–63.
8. Donnino MW, Salcicioli JD, Howell MD, et al. Time to administration of epinephrine and outcome after in-hospital cardiac arrest with non-shockable rhythms: retrospective analysis of large in-hospital data registry. BMJ 2014;348:g3028.
9. McEvoy MD, Field LC, Smalley JC, Nietaert PJ, Scarbrough SH. The effect of adherence to ACLS protocols on survival of even in the setting of in-hospital cardiac arrest. Resuscitation 2014;85:82–7.
10. Ornato JP, Peberdy MA, Reid RD, Feeser R, Dhindsa HS, NRCPR Investigators. Impact of resuscitation system errors on survival from in-hospital cardiac arrest. Resuscitation 2012;83:63–9.
11. Dane FC, Russell-Lindgren K, Parish DC, Durham MD, Brown TD. In-hospital resuscitation: association between ACLS training and survival to discharge. Resusctiation 2000;47:83–7.
12. Moretti MA, Machado Cesar LA, Nusbacher A, Kern KB, Timerman S, Franchini Ramires JA. Advanced cardiac life support training improves long-term survival from in-hospital cardiac arrest. Resuscitation 2007;72:458–65.
13. Wayne DB, Didwania A, Feinglass J, Fudala MJ, Barsuk JH, McGaghie WC. Simulation-based education improved quality of care during cardiac arrest team responses at an academic teaching hospital: a case control study. Chest 2008;133:56–61.
14. Roberts NK, Williams RG, Schwind CJ. The impact of brief team communication, leadership and team behavior training on ad hoc team performance in trauma care settings. Am J Surg 2014;207:170–8.
15. Jnah AJ, Newberry DM, Trembach AM, et al. Neonatal Resuscitation Training: implications of course construct and discipline compartmentalization on role confusion and role ambiguity. Adv Neonatal Care 2016;16:201–10.
16. Lockey A, Lin Y, Cheng A. Impact of adult cardiac life support course participation on patient outcomes — a systematic review and meta-analysis. Resuscitation 2018;129:48–54.
17. Yeung JHY, Ong GJ, Davies RP, Gao F, Perkins GD. Factors affecting team leadership skills and their relationship with quality of cardiopulmonary resuscitation. Crit Care Med 2012;40:2617–21.
18. Hunziker S, Buhlmann C, Tschan F, et al. Brief leadership instructions improve cardiopulmonary resuscitation in a high-fidelity simulation: a randomized controlled trial. Crit Care Med 2010;38:1086–91.
19. Robinson PS, Shall E, Rakhit R. Cardiac arrest leadership: in need of resuscitation? Postgrad Med J 2016;92:715–20.
20. Taylor KL, Ferri S, Yavorska T, Everett T, Parchuram C. A description of communication patterns during CPR in ICU. Resuscitation 2014;85:1342–7.
21. Marsch SCU, Muller C, Marquardt K, Conrad G, Tschan F, Hunziker PR. Human factors affect the quality of cardiopulmonary resuscitation in simulated cardiac arrests. Resuscitation 2004;60:51–6.
22. Gonzales L, Oyler BK, Hayes JL, et al. Out-of-hospital cardiac arrest outcomes with "pit crew" resuscitation and scripted initiation of mechanical CPR. Am J Emerg Med 2018;37(5):913–20.
23. Glendenning D. Putting the pit crew approach into practice. EMS World 2012;41:41–7.
24. Ong MEH, Quah JLJ, Annathurai A, et al. Improving the quality of cardiopulmonary resuscitation by training dedicated cardiac arrest teams incorporating a mechanical load-distributing device at the emergency department. Resuscitation 2013;84:508–14.
25. Hopkins CL, Burk C, Moser S, Meersman J, Baldwin C, Youngquist ST. Implementation of pit crew approach and cardiopulmonary resuscitation metrics for out-of-hospital cardiac arrest improves patient survival and neurological outcome. J Am Heart Assoc 2016;5:e002892.

26. Pearson DA, Nelson RD, Monk L, et al. Comparison of team-focused CPR vs. standard CPR in resuscitation from out-of-hospital cardiac arrest: results from a statewide quality improvement initiative. Resuscitation 2016;105:165–72.

27. Knight LJ, Gabhart JM, Earnest KS, Leong KM, Anglemyer A, Franzon D. Improving code team performance and survival outcomes: implementation of pediatric resuscitation team training. Crit Care Med 2014;42:243–51.

28. Stewart C, Shoemaker J, Keller-Smith R, Edmunds K, Davis A, Tegtmeyer K. Code team training: demonstrating adherence to AHA guidelines during pediatric code blue activations. Pediatr Emerg Care 2017, doi:http://dx.doi.org/10.1097/PEC.0000000000001307 [Epub ahead of print].

29. Meaney PA, Bobrow BJ, Mancini ME, et al. Cardiopulmonary resuscitation quality: improving cardiac resuscitation outcomes both inside and outside the hospital. Circulation 2013;128: 417–35.

30. Risaliti C, Evans K, Buehler J, Besecker B, Ali N. Decoding code blue: a process to assess and improve code team function. Resuscitation 2018;122:e15–16.

31. Colquitt JD, Walker AB, Haney NS. Applying the pit crew resuscitation model to the inpatient care setting. J Nurses Prof Dev 2019;35: E1–7.

32. Brahmajee NK, Guetterman TC, Harrod M, et al. How do resuscitation teams at top-performing hospitals for in-hospital cardiac arrest succeed? A qualitative study. Circulation 2018;138:154–63.