



Clinical paper

A performance improvement-based resuscitation programme reduces arrest incidence and increases survival from in-hospital cardiac arrest[☆]



Daniel P. Davis^{a,*}, Patricia G. Graham^b, Ruchika D. Husa^{c,d}, Brenna Lawrence^e, Anushirvan Minokadeh^f, Katherine Altieri^g, Rebecca E. Sell^h

^a Department of Emergency Medicine, University of California at San Diego, United States

^b Department of Nursing Education, Development, Research, University of California at San Diego, United States

^c Division of Cardiology, University of California at San Diego, United States

^d Division of Cardiology, Ohio State University, United States

^e Department of Nursing, University of California at San Diego, United States

^f Department of Anesthesiology, University of California at San Diego, United States

^g School of Medicine, University of California at San Diego, United States

^h Division of Pulmonary and Critical Care Medicine, University of California at San Diego, United States

ARTICLE INFO

Article history:

Received 8 May 2014

Received in revised form 6 April 2015

Accepted 15 April 2015

Keywords:

Cardiac arrest

Resuscitation

CPR

Inpatient

Hospital

Training

ABSTRACT

Background: Traditional resuscitation training models are inadequate to achieving and maintaining resuscitation competency. This analysis evaluates the effectiveness of a novel, performance improvement-based inpatient resuscitation programme.

Methods: This was a prospective, before-and-after study conducted in an urban, university-affiliated hospital system. All inpatient adult cardiac arrest victims without an active Do Not Attempt Resuscitation order from July 2005 to June 2012 were included. The advanced resuscitation training (ART) programme was implemented in Spring 2007 and included a unique treatment algorithm constructed around the capabilities of our providers and resuscitation equipment, a training programme with flexible format and content including early recognition concepts, and a comprehensive approach to performance improvement feeding directly back into training. Our inpatient resuscitation registry and electronic patient care record were used to quantify arrest rates and survival-to-hospital discharge before and after ART programme implementation. Multiple logistic regression analysis was used to adjust for age, gender, location of arrest, initial rhythm, and time of day.

Results: A total of 556 cardiac arrest victims were included (182 pre- and 374 post-ART). Arrest incidence decreased from 2.7 to 1.2 per 1000 patient discharges in non-ICU inpatient units, with no change in ICU arrest rate. An increase in survival-to-hospital discharge from 21 to 45% ($p < 0.01$) was observed following ART programme implementation. Adjusted odds ratios for survival-to-discharge (OR 2.2, 95% CI 1.4–3.4) and good neurological outcomes (OR 3.0, 95% CI 1.7–5.3) reflected similar improvements. Arrest-related deaths decreased from 2.1 to 0.5 deaths per 1000 patient discharges in non-ICU areas and from 1.5 to 1.3 deaths per 1000 patient discharges in ICU areas, and overall hospital mortality decreased from 2.2% to 1.8%.

Conclusions: Implementation of a novel, performance improvement-based inpatient resuscitation programme was associated with a decrease in the incidence of cardiac arrest and improved clinical outcomes.

© 2015 Published by Elsevier Ireland Ltd

[☆] A Spanish translated version of the abstract of this article appears as Appendix in the final online version at <http://dx.doi.org/10.1016/j.resuscitation.2015.04.008>.

* Corresponding author at: UCSD Emergency Medicine, 200 West Arbor Drive, #8676, San Diego, CA 92103, United States.

E-mail address: danieldavismd@gmail.com (D.P. Davis).

1. Introduction

Sudden, unexpected cardiac arrest remains a leading cause of morbidity and mortality. Despite a renaissance in our understanding of the pathophysiology of arrest and potential therapies reported survival remains low from both inpatient and out-of-hospital arrest.^{1,2} The current cardiac arrest resuscitation paradigm

emphasizes optimal performance of basic skills, such as chest compressions and ventilations.^{3,4} However, the actual performance of these skills falls far short of expectations.⁵

Traditional resuscitation training models employ a generic course format based on a universal algorithm for all health care providers regardless of practice setting, equipment, experience, or level of training.⁶ This model emphasizes ventricular fibrillation, which is more important in the out-of-hospital environment.^{7,8} Traditional course content cannot be modified, exposures are infrequent – typically on a biennial basis, and a critical link to institution-specific performance improvement data does not exist. Providers assume multiple roles during training, which may result in confusion given the infrequency of resuscitation events.

In 2007, our institution implemented a novel resuscitation programme with the following core components: a unique treatment algorithm constructed around the specific capabilities of our providers and equipment, flexible training format and content emphasizing early recognition concepts, and a comprehensive approach to performance improvement with direct feedback to training. The main objective of this analysis was to document the impact of this resuscitation programme on clinical outcomes associated with inpatient cardiac arrest.

2. Methods

The University of California at San Diego Healthcare System includes two urban hospitals with a combined total of approximately 600 beds. Both receive ambulance admissions and have the capability for emergency percutaneous coronary intervention and targeted temperature management. A designated “Code Blue” team includes: physician leader (senior medicine resident or critical care fellow), nurse leader (critical care nurse), airway physician (emergency medicine attending or anesthesiology senior resident), respiratory therapist, and pharmacist. Additional staff from the activating unit and intensive care unit (ICU) may also respond. The nurse leader and respiratory therapist also respond to rapid response team (RRT) activations, with the physician leader available for consultation as needed.

2.1. Data collection and definitions

All adult (age ≥ 16 years) inpatient cardiac arrests from July 2005 through June 2012 were included. For the purposes of this analysis, a cardiac arrest was defined by the absence of a palpable pulse, the performance of chest compressions, or a defibrillation attempt. Code Blue team activation was not required for inclusion, as certain ICU-level units manage patients using available internal resources and do not request a formal “Code Blue” response. Cardiac arrest occurring in non-admitted patients, the operating room or emergency department, or in patients with active “Do Not Attempt Resuscitation” (DNAR) orders at the time of Code Blue activation were excluded. Eligible patients were identified using an electronic resuscitation database into which all resuscitation events are entered, with or without a formal “Code Blue” activation. The telecommunications log, which records all calls for emergency assistance throughout the hospital, and the resuscitation documentation field of the electronic patient care record (PCR) were cross-referenced to assure complete capture. Data were abstracted from the resuscitation database and the electronic PCR. Discharge rates and overall hospital mortality were available from hospital census data starting in July 2006. Waiver of informed consent was granted for this study by our Investigational Review Board.

2.2. Intervention

Until Spring 2007, all inpatient providers were required to maintain basic life support (BLS) certification; critical care providers were also required to maintain advanced cardiac life support (ACLS) certification. Institutional policies and procedures as well as the content of ACLS/BLS courses were modified in January 2006 to reflect updated American Heart Association (AHA)/International Liaison Committee on Resuscitation (ILCOR) guidelines and specific didactic sessions held for all providers as part of the implementation plan. In Spring 2007, the advanced resuscitation training (ART) programme for resuscitation management was introduced as a flexible, adaptive strategy for resuscitation oversight. The specific programme elements will be described below.

2.2.1. RRT

An institutional RRT was introduced as part of the ART programme to provide critical diagnostic and therapeutic assistance to decompensating patients. The RRT response includes a critical care nurse, respiratory therapist, and the charge nurse from the activating inpatient care unit. Emphasis on early recognition of the signs and symptoms of deterioration was integrated into ART and basic resuscitation training (BART) courses to assure timely and appropriate RRT activations.

2.2.2. Performance improvement

Performance improvement efforts document overall programme effectiveness, inform the training curriculum, and identify opportunity areas for additional intervention. The ART performance improvement team consists of a physician and a nurse, who provide data abstraction and clinical interpretation, as well as a data analyst. Clinical and demographic data are abstracted from the PCR and the institutional incident reporting system, while cardiopulmonary resuscitation (CPR) process data are exported from defibrillators. The ART performance improvement physician or nurse accesses the data card within 48 h of each arrest and analyzes CPR process data using defibrillator-specific software (RescueNet, ZOLL Medical, Chelmsford, MA). Documentation from the PCR is used as a reference to identify periods of spontaneous perfusion to accurately calculate chest compression fraction (CCF) values. All resuscitation events are reviewed by a multi-disciplinary committee to assure data accuracy and identify performance improvement issues.

All resuscitation events are categorized into a unique taxonomy based on four basic pathophysiological processes: circulatory, dysrhythmic, respiratory, and neurologic. Subcategories within each of these stimulate additional performance improvement-related data collection targeting preventability. In addition, the subcategories form the basis for case-specific feedback provided to code team members, which includes commentary regarding preventability, clinical arrest resuscitation performance, and CPR metrics. This feedback is compiled into a brief (2–3 pages) report by a critical care faculty member and disseminated to the participating Code Blue team members within 1 week of the event (see online supplement). In addition, summary data are presented to institutional committees and used to identify opportunity areas for institutional initiatives, guide changes to the institutional algorithms, and direct content of training sessions.

2.3. Treatment algorithms

Institutional treatment algorithms address both cardiac arrest as well as arrest prevention and are updated annually based on scientific evidence, performance improvement data, and available technologies. The algorithm is “hierarchical” and defines five therapeutic considerations: initial assessment, CPR, defibrillation, return of spontaneous circulation (ROSC), and post-arrest care (Fig. 1).

2013 UCSD ART/PART ARREST ALGORITHM

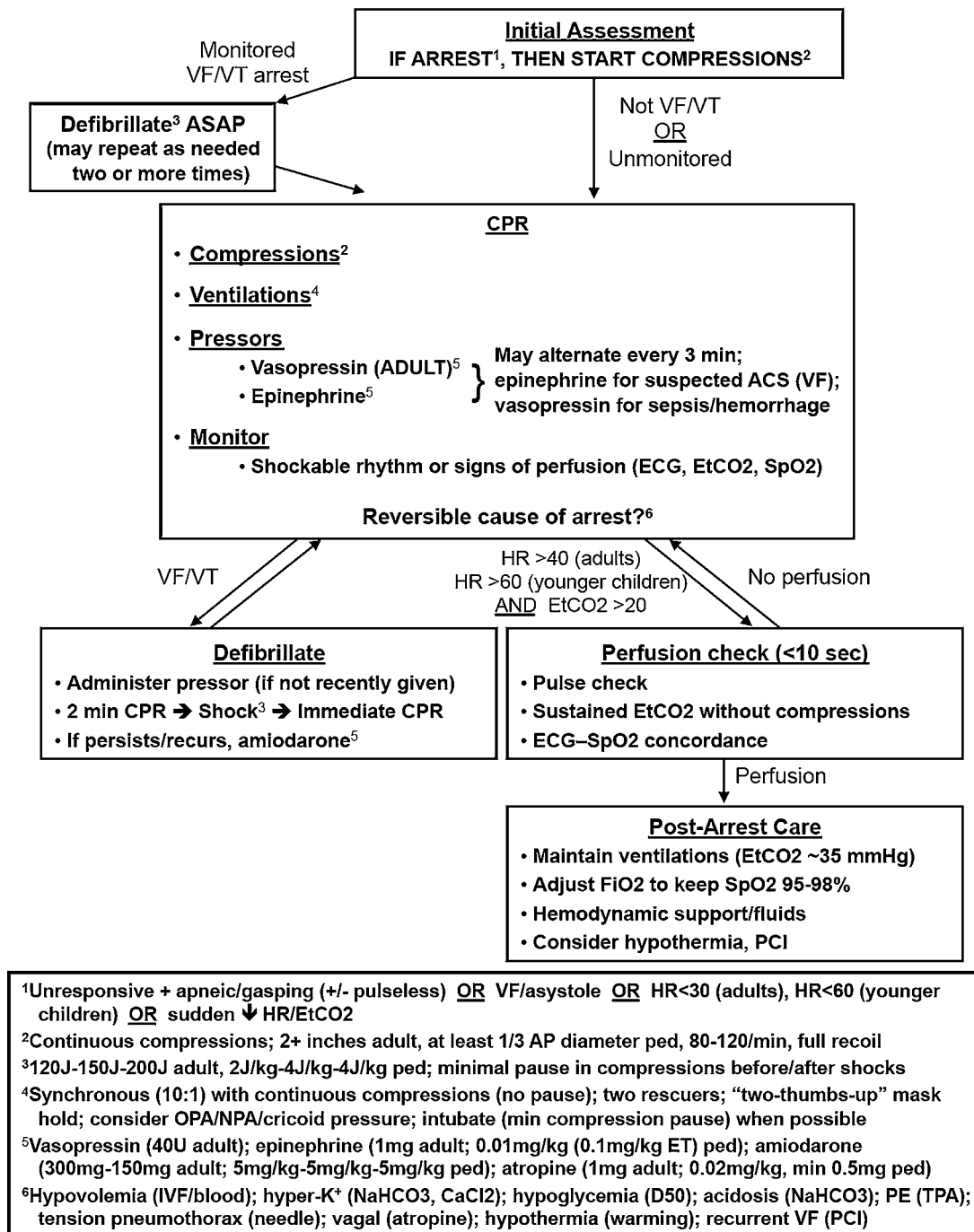


Fig. 1. Advanced resuscitation training (ART) programme algorithm for cardiac arrest.

The algorithm also reflects the availability of real-time CPR feedback, ECG filtration, hands-free defibrillation pads, and quantitative capnography available on new defibrillators (E Series, ZOLL Medical, Chelmsford, MA). Continuous, high-quality compressions are emphasized, with ventilations interposed on the upstroke of every 10th compression without a pause, ensuring controlled ventilation rates. Monitored ventricular fibrillation/tachycardia arrests are approached with expedited, stacked (up to three consecutive) defibrillation attempts. Arginine vasopressin (aVP) and adrenaline are alternated every 3 min. Quantitative capnography is used to guide CPR and identify ROSC. Filtered ECG technology increases CCF values by eliminating unnecessary compression pauses.

Oxygen therapy is titrated, end-tidal CO₂ monitored closely, and TTM is encouraged following ROSC. Pediatric advanced resuscitation training (PART) was integrated into the algorithm in 2010.

2.3.1. Resuscitation training

Training is provided annually for all critical care providers (physicians, nurses, respiratory therapists, and pharmacists) and semi-annually or quarterly for those responding routinely to cardiac arrest victims. Non-critical care providers receive biennial or annual basic resuscitation training (BART). The format is flexible and integrated with existing unit-specific training sessions and competency assessments. Content is determined by the

institutional ART steering committee based on the institutional training algorithm as well as performance improvement data. Training is “contextual” and adapted to each unit and provider type based on anticipated patient needs and performance improvement data. Providers rehearse roles and utilize equipment that would be employed during actual resuscitation events. Training modalities include lectures, psychomotor skills stations, self-directed online content, case reviews, and multi-disciplinary simulation sessions. ART courses are generally taught by critical care physicians, with BART courses provided to non-critical care providers by code nurses. All instructors receive specialized training in both the content of ART/BART courses as well as optimal resuscitation training strategies. Clinical nurse specialists attend critical care nurse ART sessions to perform competency assessments and identify providers requiring remediation.

2.3.1.1. Before and after analysis. The primary analysis compared the pre-intervention period (July 2005–June 2007) to the post-intervention period (July 2007–June 2012). Outcome measures included survival-to-hospital discharge as well as neurological status at discharge using cerebral performance category (CPC) scores.⁹ A CPC score of 1 or 2 was defined as a good neurological outcome. Hospital discharge and mortality data were available after July 2006. In addition, the case-mix index was used as a measure of overall hospital acuity during the study period. The case-mix index is a relative value for individual diagnosis-related groups to indicate resource intensity and acuity (cms.gov).

The impact of the RRT programme was determined by calculating the incidence of non-ICU arrests per 1000 patient discharges from July 2006 through June 2012. The incidence of ICU arrests was also determined to assess the RRT impact on the ICU. Finally, the broad impact of the programme was quantified by calculating the rate of arrest-related deaths per 1000 patient discharges as well as overall hospital mortality from July 2006 through June 2012. An arrest-related death was defined as a cardiac arrest victim who did not survive to hospital discharge, which considers both the incidence and outcome of cardiac arrests. Patient acuity over the study period was quantified using case-mix data.

2.3.1.2. Resuscitation performance measures. The frequency of compressions initiated prior to code team arrival and the use of adrenaline and aVP were determined before and after ART implementation. Descriptive analysis was performed using CPR process data exported from defibrillators in the post-ART period. These data were not available from the pre-ART period. The aggressiveness by which end-of-life issues were addressed before and after ART programme implementation was quantified by comparing the rate at which non-survivors with initial ROSC were made DNAR prior to death.

2.4. Statistical analyses

Chi-square was used to compare survival rates in the pre- and post-intervention periods. In addition, logistic regression was used to calculate odds ratios of survival-to-discharge and good neurological outcome before and after ART implementation after adjusting for the following covariates: age, gender, time of day, shockable rhythm, and ICU status. Time of day was selected as a surrogate for the presence of an ICU attending in the hospital at the time of the arrest. Hosmer–Lemeshow test was used to determine goodness-of-fit.

Chi-square test for trend was used to determine statistical significance of any change in arrest incidence over time and the rate of arrest-related deaths for both ICU and non-ICU patients. With regard to the resuscitation performance measures, chi-square was used to compare incidence variables, Student’s *t*-test was used to

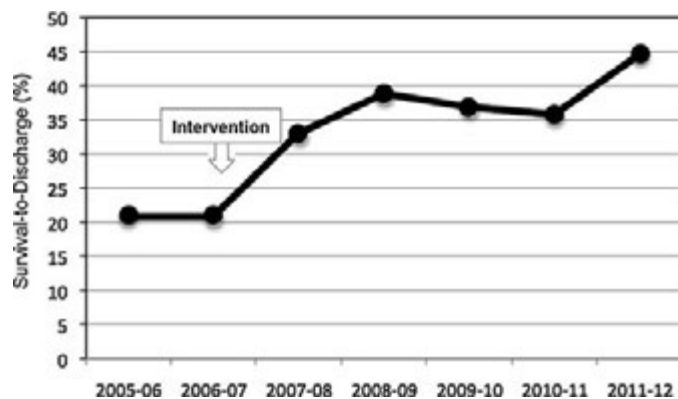


Fig. 2. Survival-to-discharge for all patients for each study year.

compare parametric variables, and Mann–Whitney *U* was used to for non-parametric variables. StatsDirect (StatsDirect Software Inc., Ashwell, UK) statistical software was used for all comparisons. *p*-values less than 0.05 were considered statistically significant.

3. Results

3.1. Before and after analysis

A total of 556 inpatients suffered cardiac arrest during the study period, including 182 patients in the pre-intervention period and 374 patients in the postintervention period (Table 1). Improvements in overall survival-to-hospital discharge and good neurological outcome were observed following ART programme implementation (Table 2) ($p < 0.001$ for both). These improvements persisted after adjustment for multiple covariates. The Hosmer–Lemeshow test indicated appropriate model goodness-of-fit for both survival-to-hospital discharge ($p = 0.980$) and good neurological outcome ($p = 0.881$). Pre-ART arrest survival was stable but increased throughout the post-intervention years in both ICU and non-ICU patients (Table 3 and Fig. 2), while the incidence of non-ICU arrests decreased without an increase in ICU arrests. This resulted in a decrease in arrest-related deaths (Table 3). Overall CPC scores improved following ART programme implementation (Fig. 3). In addition, a decline in overall hospital mortality from 2.2% to 1.8% ($p < 0.001$) was observed, predominantly due to the decrease in arrest-related deaths. This was not explainable by patient acuity,

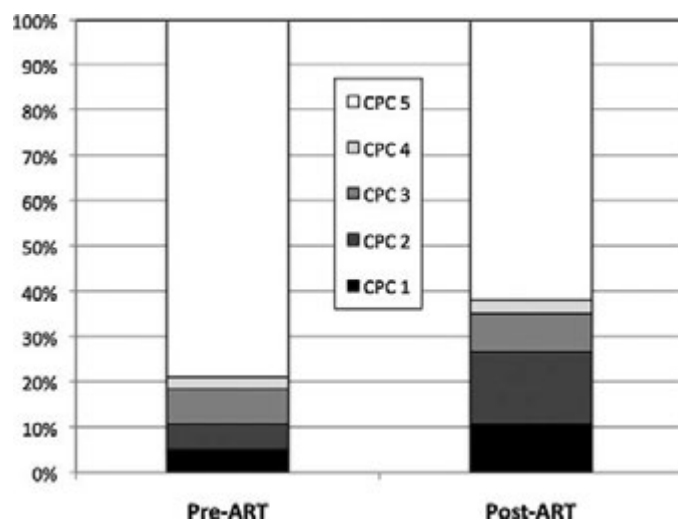


Fig. 3. Cerebral performance category for arrest victims before and after ART programme implementation.

Table 1Clinical and demographic data regarding study population for pre-intervention ($n = 182$) and post-intervention ($n = 374$) cohorts.

| Parameter | Pre-intervention ($n = 182$) | Post-intervention ($n = 374$) | p -Value |
|----------------------------|--------------------------------|---------------------------------|------------|
| Mean age (years) | 58 (51–65) | 57 (52–62) | 0.366 |
| Male gender – n (%) | 122 (67) (60–73) | 221 (59) (54–64) | 0.086 |
| Initial VF/VT – n (%) | 24 (13) (9–19) | 64 (17) (14–21) | 0.286 |
| Non-ICU location – n (%) | 100 (55) (48–62) | 146 (39) (34–44) | <0.001 |
| Peak hours – n (%) | 80 (44) (37–51) | 172 (46) (41–51) | 0.718 |

VF, ventricular fibrillation; VT, ventricular tachycardia; ICU, intensive care unit; peak hours, 7 a.m. to 5 p.m.

Table 2

Primary outcomes of survival-to-hospital discharge and good neurological outcome at discharge comparing the pre- and post-intervention cohorts.

| Outcomes | Pre-intervention (%) | Post-intervention (%) | Unadjusted odds ratio (95% CI) | Adjusted ^a odds ratio (95% CI) | Adjusted p -value |
|--------------------------------------|----------------------|-----------------------|--------------------------------|---|---------------------|
| Survival to discharge | 38/182 (20.9) | 142/374 (38.0) | 2.3 (1.6, 3.7) | 2.2 (1.4, 3.4) | <0.001 |
| Good neurologic outcome ^b | 19/182 (10.4) | 99/374 (26.5) | 2.7 (1.9, 5.2) | 3.0 (1.7, 5.3) | <0.001 |

^a Adjusted for age, gender, occurrence during peak hours (7 a.m. to 5 p.m.), initial shockable rhythm, location of arrest (ICU versus non-ICU).^b Cerebral performance category 1 or 2**Table 3**

Survival-to-hospital discharge, cardiac arrest incidence, arrest-related deaths, and overall hospital mortality during the study period.

| Parameter | Pre-intervention | | Post-intervention | | | | | Chi-square test-for-trend p -value |
|--|------------------|------------|-------------------|------------|------------|------------|------------|--------------------------------------|
| | 5–6 | 6–7 | 7–8 | 8–9 | 9–10 | 10–11 | 11–12 | |
| <i>Survival to discharge (%)</i> | | | | | | | | |
| All* | 18/87 (21) | 20/95 (21) | 25/76 (33) | 29/75 (39) | 25/68 (35) | 25/70 (36) | 38/85 (45) | <0.001 |
| ICU* | 9/43 (21) | 9/40 (23) | 12/42 (29) | 16/48 (33) | 10/40 (25) | 13/43 (30) | 21/54 (39) | 0.024 |
| Non-ICU* | 9/44 (20) | 11/55 (20) | 13/34 (38) | 13/27 (48) | 15/28 (54) | 12/27 (44) | 17/31 (55) | <0.001 |
| <i>Arrest incidence (per 1000 patient discharges)</i> | | | | | | | | |
| All | N/A | 4.6 | 3.4 | 3.3 | 2.8 | 2.8 | 3.3 | <0.001 |
| ICU | N/A | 1.9 | 1.9 | 2.1 | 2.0 | 1.7 | 2.1 | 0.886 |
| Non-ICU | N/A | 2.7 | 1.5 | 1.2 | 0.8 | 1.1 | 1.2 | <0.001 |
| <i>Arrest-related deaths (per 1000 patient discharges)</i> | | | | | | | | |
| All | N/A | 3.6 | 2.3 | 2.0 | 1.9 | 1.8 | 1.8 | <0.001 |
| ICU | N/A | 1.5 | 1.3 | 1.4 | 1.3 | 1.2 | 1.3 | 0.468 |
| Non-ICU | N/A | 2.1 | 0.9 | 0.6 | 0.6 | 0.6 | 0.5 | <0.001 |

with mean lower case-mix coefficient values observed pre- versus post-ART (1.50 versus 1.63, $p < 0.001$), indicating higher acuity in the post-intervention period.

3.2. Resuscitation performance measures

The frequency of compressions initiated prior to code team arrival increased following ART implementation (74–97%, $p < 0.01$). The administration of aVP increased following ART implementation (34–53%, $p = 0.011$), while the use of adrenaline remained high (99% for both periods, $p = 0.841$). The quality of CPR was excellent following ART implementation (Table 4). No difference was observed in the pre- and post-ART periods with regard to the likelihood of DNAR status among non-survivors with initial ROSC (76% versus 75%, $p = 0.841$).

Table 4

Cardiopulmonary resuscitation (CPR) parameters in the post-intervention period.

| CPR parameter | Mean value (95% CI) |
|-------------------------------------|---------------------|
| Chest compression fraction (%) | 91 (88–93) |
| Compression rate (compressions/min) | 123 (117–129) |
| Compression depth (cm) | 6.6 (5.8–7.1) |
| Pre-shock pause (s) | 2.6 (1.6–3.5) |
| Post-shock pause (s) | 3.6 (2.8–4.5) |
| Perfusion check (s) | 4.3 (1.9–6.8) |
| Ventilation rate (breaths/min) | 9.7 (8.0–11.4) |

4. Discussion

Sudden cardiac arrest remains an important public health disease with little improvement in outcomes over the past several decades.^{10,11} Important objectives have been identified with regard to cardiac arrest resuscitation, particularly the provision of high-quality compressions with minimal interruptions.¹² However, published data suggest that these targets are infrequently achieved, which may explain the somewhat stagnant survival rates.⁵ This may reflect limitations in current resuscitation training models, which employ a generic curriculum that may not be relevant to in-hospital resuscitation.

Here we present data documenting improved outcomes following implementation of an institution-specific, performance improvement-driven resuscitation programme. The ART programme consists of a resuscitation “bundle” that includes a novel treatment algorithm as the foundation for adaptive, flexible, multi-disciplinary training that is directly influenced by performance improvement data. Early detection concepts are integrated into training for all staff, resulting in a decrease in the rate of non-ICU cardiac arrests by more than 50%. This was also reflected by the decreasing proportion of non-ICU arrests in the post-intervention period (Table 1). Furthermore, survival-to-hospital discharge and good neurological outcomes doubled following ART implementation. Together, the decreased incidence of sudden, unexpected arrests and increased arrest survival resulted in a substantial decline in arrest-related deaths and a decrease in overall hospital mortality.

Reducing preventable deaths should be a primary goal for hospitals but incorporates a broad spectrum of efforts designed to reduce arrest incidence and improve arrest survival. The ART programme provides a scaffolding that links “afferents” and “efferents” to reduce preventable deaths in the hospital and out-of-hospital settings. Afferents (inputs) include guidelines and expert opinion, scientific publications, institutional characteristics, and performance improvement data. Efferents (outputs) include treatment algorithms, adaptive/contextual training, technology and equipment, and initiatives targeting specific opportunities for improvement. This linkage appears to be critically important in reducing preventable deaths in focusing attention on specific opportunities that are most likely to produce measurable results.

The survival-to-discharge rates reported here are substantially higher than have been previously reported for inpatient institutions.^{2,8,10,13–17} Multiple potential explanations exist to explain these improved outcomes. The model effectiveness may be related to the adaptive, contextual nature of the training based on practice location, provider type, prescribed role in hospital resuscitation events, and patient type as well as the link to performance improvement. The unique approach to data analysis and the ability to address opportunities through training and other interventions appear to be effective strategies to improve outcomes. The ART programme also appears to have achieved an institutional “culture of resuscitation,” including a sense of personal ownership by providers as well as individual and unit accountability for resuscitation events.

The addition of arrest prevention to the life-support training curriculum was an important element in reducing preventable deaths. While RRT programmes are not unique to ART, the integration with other resuscitation training and unique taxonomy that allows providers to employ pattern recognition as a primary strategy for arrest prevention appear to be more affective than traditional approaches. In addition, we used a variety of strategies to underscore the importance of chest compression quality during arrest resuscitation. This included a unique cognitive approach to didactics, integration of new technology (CPR feedback, PetCO₂) into training and clinical practice, and aggressive feedback of compression performance to providers. These efforts manifested in an increase in early CPR as well as high quality compressions. Furthermore, the performance of continuous chest compressions with interposed ventilations may optimize the balance between perfusion and ventilation for the inpatient setting.⁷ Compression depth was greater than in previous studies, although we did not attempt to correct for mattress compression. In simulation studies, a hospital mattress appears to add approximately 0.5 inches to the measured compression depth, even with use of a compression board. It is unclear whether the increased use of aVP contributed to the improved outcomes. Although aVP may be more potent with profound acidosis, this has not translated to higher survival rates.¹⁸

The potential impact of the RRT programme on the incidence of cardiac arrest in non-ICU patients is an important consideration.^{8,14,19–22} A decrease in non-ICU relative to ICU arrests might be anticipated to result in a decrease in arrest survival given the poor prognosis of ICU arrest victims. Thus, it is notable that a decrease in non-ICU arrest incidence and an increase in overall arrest survival was observed, which resulted in a dramatic reduction in arrest-related deaths and overall mortality. Although previous studies have associated RRT programmes with an increase in the aggressiveness by which end-of-life issues are addressed, this does not appear to explain the results observed here.²⁰

There are several limitations that must be considered when interpreting these data. Multiple interventions were implemented simultaneously as part of a resuscitation “bundle,” and the importance of any single component could not be determined. We believe that improved CPR performance was the primary motivator of the

improved survival rates observed here. This included an increase in immediate performance of chest compressions as well as a cultural shift toward emphasis on adequate compression depth and recoil, controlled compression rates, minimal interruptions, and avoidance of hyperventilation. The implementation of a rapid response programme reflected an emphasis on prevention of arrest, which also appears to have been successful. We believe the integration of rapid response surveillance concepts with cardiac arrest resuscitation is an important component of inpatient resuscitation training.

A before-and-after analysis was employed, which could have introduced a bias related to secular trends. We used case-mix coefficients to explore the possibility of a decrease in patient acuity during the study. Instead, the increasing case-mix coefficient values suggested higher patient acuity, which would predict increased mortality rather than the decrease observed here.

The first year of the study also overlapped with the release of the 2005 guidelines.²³ However, we did not observe any measurable change in outcomes despite aggressive implementation of these guidelines. This is consistent with other reports from emergency medical services agencies and inpatient facilities.^{11,24} The final study years also overlapped with the release of the 2010 guidelines, although no specific efforts were undertaken in our institution to address any specific elements. In addition, we did not have CPR process data prior to ART implementation. Nevertheless, the high quality of compressions following the study intervention compared to published data suggests that this was one of the more important factors in explaining the improved outcomes.¹²

The implementation of a RRT programme undoubtedly modified arrest etiologies. A decrease in overall survival was anticipated as a result of the relative increase ICU versus non-ICU arrests. The decrease in arrest incidence and increase in survival suggest a synergistic rather than competing effect of RRT implementation. Finally, the incidence of VF was lower than anticipated.² This underscores the importance of considering the unique blend of patients within each institution.

5. Conclusions

An inpatient resuscitation programme was associated with decreased incidence and mortality from cardiac arrest. This programme included a “bundle” that employed institution-specific algorithms targeting an inpatient demographic, emerging science, and advanced technology, as well as adaptive, contextual training. In addition, the programme included a comprehensive approach to performance improvement with direct linkage to training. The improvements in outcome may have resulted from early, high-quality CPR. Finally, the dramatic reduction in arrest incidence underscores the importance of early detection and prevention for inpatient resuscitation programmes.

Disclosures

The University of California at San Diego owns intellectual property surrounding the Advanced Resuscitation Training programme.

Conflict of interest statement

None of the authors had a conflict of interest regarding the topic of this manuscript during the period of work described.

Acknowledgements

The authors would like to thank the UC San Diego Code Blue and Critical Care Committees for their support and guidance.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.resuscitation.2015.04.008>

References

- Nichol G, Thomas E, Callaway CW, et al. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA* 2008;300:1423–31.
- 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.
- Neumar RW, Otto CW, Link MS, et al. Adult advanced cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 2010;122:S729–67.
- Sayre MR, Koster RW, Botha M, et al. Adult basic life support: 2010 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. *Circulation* 2010;122:S298–324.
- Abella BS, Sando N, Vassilatos P, et al. Chest compression rates during cardiopulmonary resuscitation are suboptimal. *Circulation* 2005;111:428–34.
- Advanced cardiac life support instructors manual. Dallas, TX: American Heart Association; 2006.
- Wang HE, Abella BS, Callaway CW, Investigators AN. Risk of cardiopulmonary arrest after acute respiratory compromise in hospitalized patients. *Resuscitation* 2008;79:234–40.
- Ebell MH, Kruse JA, Smith M, Novak J, Drader-Wilcox J. Failure of three decision rules to predict the outcome of in-hospital cardiopulmonary resuscitation. *Med Decis Mak* 1997;17:171–7.
- Safar P, Tisherman SA, Behringer W, et al. Suspended animation for delayed resuscitation from prolonged cardiac arrest that is unresuscitable by standard cardiopulmonary–cerebral resuscitation. *Crit Care Med* 2000;28:N214–8.
- Dans PE, Nevin KL, Seidman CE, McArthur JC, Kariya ST. Inhospital CPR 25 years later: why has survival decreased? *South Med J* 1985;78:1174–8.
- Sasson C, Rogers MAM, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes* 2010;3:63–81.
- Christenson J, Andrusiek D, Everson-Stewart S, et al. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. *Circulation* 2009;120:1241–7.
- Brady WJ, DeBehnke DJ, Laundrie D. Prevalence, therapeutic response and outcome of ventricular tachycardia in the out-of-hospital setting: a comparison of monomorphic ventricular tachycardia, polymorphic ventricular tachycardia, and torsades de pointes. *Acad Emerg Med* 1999;6:609–17.
- Brindley PG, Markland DM, Mayers I, Kutsogiannis DJ. Predictors of survival following in-hospital adult cardiopulmonary resuscitation. *CMAJ* 2002;167:343–8.
- Khalafi K, Ravakhah K, West BC. Avoiding the futility of resuscitation. *Resuscitation* 2001;50:161–6.
- Larkin GL, Copes WS, Nathanson BH, Kaye W. Pre-resuscitation factors associated with mortality in 49,130 cases of in-hospital cardiac arrest: a report from the National Registry for Cardiopulmonary Resuscitation. *Resuscitation* 2010;81:302–11.
- Ravakhah K, Khalafi K, Bathory T, Wang HC. Advanced cardiac life support events in a community hospital and their outcome: evaluation of actual arrests. *Resuscitation* 1998;36:95–9.
- Ornato JP. Optimal vasopressor drug therapy during resuscitation. *Crit Care* 2008;12:1–3.
- Bader MK, Neal B, Johnson L, et al. Rescue me: saving the vulnerable non-ICU patient population. *Jt Comm J Qual Patient Saf* 2009;35:199–205.
- Chen J, Bellomo R, Flabouris A, Hillman K, Finfer S, Investigators MS. The relationship between early emergency team calls and serious adverse events. *Crit Care Med* 2009;37:148–53.
- Devita MA, Braithwaite RS, Mahidhara R, et al. Use of medical emergency team responses to reduce hospital cardiac arrests. *Qual Saf Health Care* 2004;13:251–4.
- Ranji SR, Auerbach AD, Hurd CJ, O'Rourke K, Shojania KG. Effects of rapid response systems on clinical outcomes: systematic review and meta-analysis. *Hosp Med* 2007;2:422–32.
- Resuscitation AHA/ILCo. 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 2005;112:1–203.
- Bigham BL, Koprowicz K, Rea T, et al. Cardiac arrest survival did not increase in the Resuscitation Outcomes Consortium after implementation of the 2005 AHA/ILCo CPR and ECC guidelines. *Resuscitation* 2011;82:979–83.