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Implementing the 2005 American Heart Association Guidelines, Including Use of the Impedance Threshold Device, Improves Hospital Discharge Rate After In-Hospital Cardiac Arrest

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OBJECTIVE: To determine the impact of the 2005 American Heart Association cardiopulmonary resuscitation (CPR) guidelines, including use of an impedance threshold device (ITD), on survival after in-hospital cardiac arrest. METHODS: Two community hospitals that tracked outcomes after in-hospital cardiac arrest pooled and compared their hospital discharge rate before and after implementing the 2005 American Heart Association CPR guidelines (including ITD) in standardized protocols. In CPR we used the proper ventilation rate, allowed full chest-wall recoil, conducted continuous CPR following intubation, and used an ITD. We compared historical control data from a 12-month period at St Cloud Hospital, St Cloud, Minnesota, to data from a subsequent 18-month intervention phase. We compared historical control data from a 12-month period at St Dominic Hospital, Jackson, Mississippi to a subsequent 12-month intervention phase. 507 patients received CPR during the study period. Patient age and sex were similar in the control and intervention groups. RESULTS: The combined hospital discharge rate for patients with an in-hospital cardiac arrest was 17.5% in the control group (n = 246 patients), which is similar to the national average, versus 28% in the intervention group (n = 261 patients) (P = .006, odds ratio 1.83, 95% CI 1.17–2.88). The greatest benefit of the intervention was in patients with an initial rhythm of pulseless electrical activity: 14.4% versus 29.7% (P = .014, odds ratio 2.50, 95% CI 1.15, 5.58). Neurological function (as measured with the Cerebral Performance Category scale) in survivors at hospital discharge was similar between the groups. CONCLUSIONS: Implementation of improved ways to increase circulation during CPR increased the in-hospital discharge rate by 60%, compared to historical controls in 2 community hospitals. These data demonstrate that immediate care with improved means to circulate blood during CPR significantly reduces hospital mortality from in-hospital sudden cardiac arrest. *Key words: cardiac arrest; sudden death; impedance threshold device; cardiopulmonary resuscitation; CPR; pulseless electrical activity; ventricular fibrillation.* [Respir Care 2010;55(8):1014–1019. © 2010 Daedalus Enterprises]

Introduction

Cardiac arrest remains a leading cause of death in the United States.[1-3] Although cardiac arrest is frequently considered an out-of-hospital event,[4] cardiac arrest inside the hospital is also a leading cause of morbidity and mortality.[5-7] Treatment with cardiopulmonary resuscitation (CPR) of this common and deadly process has been part of the standard of care for decades, but is often ineffective.[8-10] A poor survival rate for in-hospital cardiac arrest has been well documented by the National CPR Registry, and there

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has been no significant change in the in-hospital survival rate for decades.[5-7] At present the national survival rate for in-hospital cardiac arrest is only about 17%.[5]

While the cause of in-hospital cardiac arrest is often considered different from out-of-hospital cardiac arrest, the process in both settings requires immediate treatment.[4-10] In 2005, the American Heart Association (AHA) issued new evidence-based CPR guidelines that fundamentally changed the focus of initial resuscitation efforts to emphasize improved circulation.[11] The highly recommended new interventions included more compressions per minute, fewer interruptions in chest compressions, delivery of chest compressions before defibrillation, full chest-wall recoil to enhance refill of the heart with blood after each compression, reducing the tidal volume and inspiratory time of each breath, and use of an impedance threshold device (ITD) that significantly improves blood flow to the heart and brain during CPR.[11]

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To date, high-quality CPR and use of the ITD have been shown to improve hemodynamics and the short-term survival rate for patients with out-of-hospital cardiac arrest.[12-14] The impact of these changes in the guidelines for patients with in-hospital cardiac arrest is unknown. Thus, the purpose of this study was to determine the effect of implementing the 2005 AHA guidelines, including use of the ITD, on survival rate in patients with in-hospital cardiac arrest.

Methods

This research was performed at St Cloud Hospital, St Cloud, Minnesota, and St Dominic Hospital, Jackson, Mississippi.[1]

Data were prospectively gathered following training and implementation of the 2005 AHA guidelines (including ITD use) in 2 medium-size community hospitals: St Cloud Hospital, St Cloud, Minnesota, and St Dominic Hospital, Jackson, Mississippi, which were early adopters of the new CPR methods and the ITD. Both hospitals have a Code Blue Committee, a code team staffed by physicians and nurses, respiratory therapists, a full complement of board-certified cardiology and intensive care unit staff, educators dedicated to training and retraining hospital staff on proper CPR technique, and a comprehensive data-collection process incorporated into their standard quality-assurance program that provided accurate intervention and historical control data. Both hospitals have family practice residents or hospitalists at times on the wards, but the code team is directed by board-certified internists or emergency physicians.

Publication of these conglomerate quality-assurance data was approved by the institutional review boards of both St Cloud Hospital and St Dominic Hospital.

St Cloud Hospital is a 489-bed hospital with approximately 13 in-hospital cardiac arrests per month. The historical control data were obtained from the 12 months (2005) prior to the intervention, and the intervention group data were obtained over 18 months (July 2006 through December 2007) immediately following a 6-month period of training, in-services, and implementation of the 2005 AHA guidelines (with ITD use). St Cloud Hospital participates in the National CPR Registry program. Data related to the incidence rate and outcomes after cardiac arrest were gathered from those report forms.

St Dominic Hospital is a 570-bed hospital with approximately 12 in-hospital cardiac arrests month. The historical control data were obtained from the 12 months (June 2005 to June 2006) prior to the intervention, and the intervention-group data were obtained from the subsequent 12 months following implementation of the 2005 AHA guidelines (with ITD use). St Dominic Hospital began to track the incidence rate and clinical outcomes after cardiac arrest in 2004, using a quality-assurance data-collection process and recording system similar to the National CPR Registry.

In both hospitals, family practice residents or hospitalists rotate through the wards, but the medical management of all codes is directed by board-certified internists or emergency physicians. Patients who had a cardiac arrest after admission to the hospital, including those in intensive care, in a step-down unit, in the emergency department, and on the wards, were included. Patients who had a do-not-resuscitate order and those who had out-of-hospital cardiac arrest admitted to the emergency department with ongoing CPR were excluded from analysis.

Following publication of the AHA guidelines in 2005,[11] efforts were independently undertaken at both hospitals to develop a training and implementation process. To this end, the new guidelines ranked the new recommendations based on evidence levels of 1, 2a, 2b, 3, and indeterminate. A level-3 recommendation is reserved for interventions thought to be dangerous, and the indeterminate category indicates interventions that require more science before adopting. The Code Committee in both hospitals decided to adopt the guideline recommendations that had evidence

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levels of 2b or higher, and those recommendations constituted the hospital training curriculum, including:

- A change in the Basic Life Support compressions-to-ventilations ratio, to 30:2 (evidence level 2a)
- Continuous chest compressions, with asynchronous ventilations at 10 breaths/min, with a duration of no more than one second per breath for Advanced Life Support CPR (evidence level 2a)
- Reduction of the tidal volume to approximately 500 mL/breath (evidence level 2a)
- Minimizing pauses for pulse check (evidence level 2a)
- Allowing full chest-wall recoil after each compression (evidence level 2b)
- Chest compression before and after defibrillation if CPR was started greater than 4 min after the cardiac arrest (evidence level 2b)
- Use of the ITD (evidence level 2a)

The ITD (ResQPOD, Advanced Circulatory Systems, Minneapolis, Minnesota) shown in Figure 1 was initially used on a face mask and then transferred to an advanced airway device as needed. When the ITD was used on a face mask, a 2-handed technique was implemented to maintain a continuous tight seal between the face and the mask during compressions and ventilations. Once intubated, the ITD was transferred to the advanced airway, and the timing lights were activated to guide ventilation frequency and compression rate. These changes were emphasized in handouts to medical personnel, and in refresher courses offered every 6 months. Training for and implementation of the ITD began through the respiratory therapy departments at both hospitals and was subsequently extended to the intensive care unit staff, emergency department staff, and medical staff in the hospital responsible for cardiac arrest response. Training focused on didactic and psychomotor skills, using a manikin. In St Dominic Hospital, respiratory care personnel carried the ITD in a small pack attached to their belt. The device was stocked together with the resuscitator bag and masks on the crash carts in both hospitals. To increase compliance with the protocols, use of the ITD was added to the check-off list on the code sheets in both hospitals.

Data were collected prospectively at both hospitals and pooled together with the intent to publish the conglomerate data. At the time the study was proposed, the data from the 2 hospitals represented the largest controlled clinical experience with the new CPR techniques and ITD use. The primary end point was hospital discharge rate. Hospital-discharge data from the historical control phase and the intervention phase were analyzed separately for each hospital, and together. Data were compared using Fisher's exact test (2-sided). A P value of $< .05$ was considered evidence of statistical significance.

Fig. 1. Demonstration of the 2-handed technique in initial use of the impedance threshold device (ITD) with a face mask, maintaining a continuously tight seal during compressions and ventilations. (Courtesy of Advanced Circulatory Systems, Minneapolis, Minnesota.)

Results

Both hospitals implemented a rapid-response team during the study, in an attempt to reduce the incidence of cardiac arrest. Despite this, the incidence of cardiac arrest remained fairly constant through the control, training/implementation, and intervention phases at both hospitals: 12 arrests per month at St Cloud Hospital, and 13 arrests per month at St Dominic Hospital.

In the 2 hospitals, 246 patients suffered cardiac arrest and received CPR in the historical phase, and 261 patients in the intervention phase. The average age and male:female ratio were similar in both phases. In the historical phase the mean age was 69 ± 15 years, and in the intervention phase it was 68 ± 14 y (difference not significant). During the historical phase 63% of the patients were male, versus 70% during the intervention phase (difference not significant).

Combining data from both hospitals, survival to hospital discharge was 17.5% in the control phase, versus 28%

Table 1. Survival to Hospital Discharge*

Hospital	Control (*n*/*N*, %)	Intervention (*n*/*N*, %)	*P*†	Odds Ratio	95% CI
St Cloud	16/89 (18.0)	35/125 (28.0)	.105	1.77	0.87–3.71
St Dominic	27/157 (17.2)	38/136 (27.9)	.034	1.87	1.03–3.41
Combined‡	43/246 (17.5)	73/261 (28.0)	.006	1.83	1.17–2.88

* $N = 507$.
† Via Fisher's exact test (2-sided).
‡ Combined St Cloud and St Dominic Hospitals data.

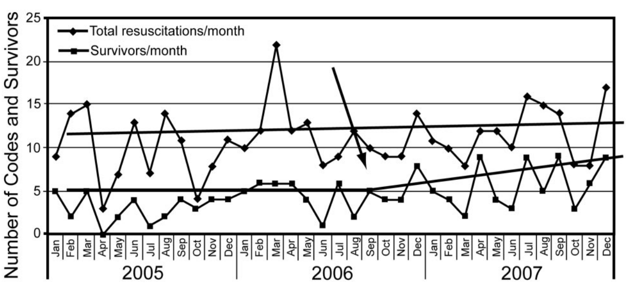

Fig. 2. The number of cardiac arrests and survivors per month in St Cloud Hospital. The 2005 AHA guidelines were implemented in September 2006.

during the intervention phase ($P = .006$, odds ratio 1.83, 95% CI 1.17–2.88) (Table 1). The study had 79.2% power to detect a difference in combined survival rate as large as that observed (17.5% vs 28.0%), with a 2-sided alpha of .05.

Full compliance with the new protocol continued to improve with additional retraining, as did hospital discharge rate. Prior to implementation of the new CPR interventions in St Cloud Hospital, it was uncommon to have more than 5 patients discharged alive each month. Using the National CPR Registry format, the incidence rate of cardiac arrest and the number of patients discharged each month are shown for St Cloud Hospital in Figure 2. The number of survivors per month began to increase once the 2005 AHA guideline implementation process was initiated.

Survival data from both hospitals combined, based on a subgroup analysis of presenting cardiac arrest rhythm, are shown in Table 2. Patients in the intervention group who presented with ventricular fibrillation, pulseless electrical activity, and asystole demonstrated better survival than the control population. However, the benefits of the new intervention were statistically significant in this subgroup analysis only for patients with an initial rhythm of pulseless electrical activity. For patients with an initial rhythm of pulseless electrical activity there was a greater than 2-fold increase in survival to hospital discharge ($P = .014$). No other subgroups based upon initial rhythm had a statistically significant difference in outcome. There were 5 patients in the historical control phase and 12 patients in the intervention phase for whom the initial rhythm could not be identified or was missing from the chart.

Conglomerate data from both hospitals demonstrated that the overall percentages of patients discharged with good neurological function were high and not statistically different between the control and intervention groups. A total of 70.7% (29/41) of the patients in the control phase in the combined hospital-discharge data had a Cerebral Performance Category score of 1 (normal) or 2 (mild cognitive impairment), compared to 79.6% (43/54) in the intervention group ($P = .343$).

The results of the study were summarized in odds ratios. The group differences can also be summarized by relative risk estimates (ratios of survival rates) or estimates of differences in survival rate to determine the absolute risk reduction. For example, based upon the data in Table 1:

St Cloud:
Relative risk ratio 1.56, 95% CI (0.93–2.77)
Difference: 10.02%, 95% CI (−1.65 to 21.13%)

St Dominic:
Relative Risk ratio 1.62, 95% CI (1.05–2.56)
Difference: 10.74%, 95% CI (0.97–20.50%)

Combined:
Relative risk ratio 1.60, 95% CI (1.15–2.25)
Difference: 10.49%, 95% CI (3.19–17.76%)

The direction of the comparisons (better results for the intervention having higher relative risks or positive differences) was chosen to be consistent with the original direction used for odds ratios. By inverting these ratios the emphasis is focused on risk reduction and not improvement. The results between the 2 sites are remarkably close on all measures of risk. Based upon these analyses, the relative risk ratio of 1.60 for the combined data can be used to conclude that one would expect 10 more survivors for every 100 patients treated with the new intervention over that expected otherwise (the odds ratio is 1.83). In order words, on average, one more life is saved per ten uses of the new intervention.

There were no known complications reported with use of the new CPR interventions, compared to the historical

Table 2. Hospital Discharge Rate by Initial Heart Rhythm*

Initial Heart Rhythm	Control (*n*/*N*, %)	Intervention (*n*/*N*, %)	*P*†	Odds Ratio	95% CI
Ventricular fibrillation	18/57 (31.6)	21/48 (43.8)	.228	1.68	0.70–4.04
Pulseless electrical activity	14/97 (14.4)	27/91 (29.7)	.014	2.50	1.15–5.58
Asystole	10/87 (11.5)	23/110 (20.9)	.087	2.04	0.86–5.09

* $N = 490$.
† Via Fisher's exact test (2-sided).
‡ Combined St Cloud and St Dominic Hospitals data.

controls, and there were no reported ITD malfunctions with the patients treated with ITD during the intervention phase. The incidence of gastric inflation was not reported to be higher during the intervention phase. Although therapeutic hypothermia was used routinely in St Cloud hospital for patients with out-of-hospital cardiac arrest, it was rarely used for patients with in-hospital cardiac arrest. Only one survivor to hospital discharge from St Cloud Hospital during the intervention phase was treated with therapeutic hypothermia, and no patients were treated with hypothermia in St Dominic Hospital.

Discussion

This is the first report of the impact on survival of the 2005 AHA guidelines (including ITD use) for patients with in-hospital cardiac arrest. Results from this study demonstrate that implementation of the 2005 AHA guidelines (including ITD use) increased the hospital discharge rate by 60% for patients with in-hospital cardiac arrest ($P = .006$). The control rate of 17.5% is similar to the rate reported by the National CPR Registry in data from nearly 15,000 patients.[5] These data support the hypothesis that increasing circulation during CPR improves the overall survival rate. Based upon the calculated relative risk ratios, implementation of the 2005 AHA guidelines (including ITD use) for patients with in-hospital cardiac arrest resulted in one additional patient surviving to hospital discharge for every ten patients treated.

In this study, proper implementation of the new CPR approach was the focus of training and retraining efforts by hospital personnel. Respiratory therapists played a central role in implementing many aspects of the new guidelines, including proper ventilation technique and use of the ITD. CPR is performed by various hospital personnel, whereas airway management is typically performed predominantly by respiratory therapy staff. While the ITD enhances circulation to the heart and brain, it is attached to the airway. Accordingly, respiratory care personnel were taught ITD use and the importance of proper 2-handed face mask technique (see Fig. 1). Furthermore, all personnel were encouraged to correct colleagues when CPR was not performed according to the AHA guidelines. The implementation process was an intense and coordinated process by personnel from respiratory care, the intensive care unit, and the emergency department. To maintain high-quality CPR, retraining efforts were organized every 6 months, especially as most personnel had to relearn a new approach to CPR. This included lifting the palm of the compressing hand off the chest during each decompression phase to assure full chest-wall recoil.

Rather than study the impact of a single intervention for patients in cardiac arrest, it was the expressed intent of this study to combine multiple interventions known to improve survival rate in both patients and animals in a unified protocol to maximize circulation during CPR. This approach is similar to new protocols designed to treat other disease states associated with severe hypotension, such as the bundled therapies for treatment of sepsis.[15] In addition to enhancing forward blood flow, recent data show that allowing full chest-wall recoil,[16,17] limiting the ventilation rate,[18-20] and use of the ITD[18,21-24] all decrease intracranial pressure during the decompression phase of CPR. This mechanism, together with the increase in forward blood flow to the heart and brain during the compression phase (as a result of improved cardiac refilling), may also have contributed to the positive results.

The greatest benefit of these synergistic therapies was in patients with pulseless electrical activity. This survival improvement in patients with pulseless electrical activity was higher than that reported when a similar series of changes were made in the out-of-hospital setting.[24] The time from arrest to start of CPR is typically much shorter for patients with in-hospital cardiac arrest.[25] Accordingly, the data from this study generate the hypothesis that the faster adequate circulation is achieved during CPR, the greater the likelihood of survival.

Limitations

This investigation used the only appropriate clinical control groups possible when evaluating the impact of the AHA recommendations, and, as such, is subject to the limitations and potential confounders of historical controls. The study was not blinded, as blinding is not possible with use of these CPR techniques. Second, it is not possible to determine which aspects of the new intervention had the most impact on overall survival rate, since each intervention that enhances circulation affects the next. However, as noted above, we believe that no single therapy alone is primarily responsible for improved outcome for this complex disease state. Third, initial rhythm strips were not captured by the quality-assurance programs used in this study for 5 patients in the historical control group and 12 patients in the intervention group, introducing limited but potential bias in patient subgroup analysis. Finally, the lack of significance at St Cloud (a subgroup analysis) relative to St Dominic is almost entirely a factor of the smaller sample size. Similar issues with small sample sizes affect whether statistical significance was demonstrated in the subgroup analyses by heart rhythm.

Conclusions

Implementation of improved ways to increase circulation during CPR resulted in a 60% increase in in-hospital discharge rates, compared to historical controls in 2 community hospitals. These data demonstrate that immediate care with improved means to circulate blood during CPR can significantly reduce hospital mortality rates after in-hospital sudden cardiac arrest.

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