

Improving In-Hospital Cardiac Arrest Process and Outcomes With Performance Debriefing

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Background: Recent investigations have documented poor cardiopulmonary resuscitation (CPR) performance in clinical practice. We hypothesized that a debriefing intervention using CPR quality data from actual in-hospital cardiac arrests (resuscitation with actual performance integrated debriefing [RAPID]) would improve CPR performance and initial patient survival.

Methods: Internal medicine residents at a university hospital attended weekly debriefing sessions of the prior week's resuscitations, between March 2006 and February 2007, reviewing CPR performance transcripts obtained from a CPR-sensing and feedback-enabled defibrillator. Objective metrics of CPR performance and initial return of spontaneous circulation were compared with a historical cohort in which a similar feedback-delivering defibrillator was used but without RAPID.

Results: Cardiopulmonary resuscitation quality and outcome data from 123 patients resuscitated during the intervention period were compared with 101 patients in the baseline cohort. Compared with the control period, the mean (SD) ventilation rate decreased (13 [7]/min vs

18 [8]/min; $P < .001$) and compression depth increased (50 [10] vs 44 [10] mm; $P = .001$), among other CPR improvements. These changes correlated with an increase in the rate of return of spontaneous circulation in the RAPID group (59.4% vs 44.6%; $P = .03$) but no change in survival to discharge (7.4% vs 8.9%; $P = .69$).


Conclusions: The combination of RAPID and real-time audiovisual feedback improved CPR quality compared with the use of feedback alone and was associated with an increased rate of return of spontaneous circulation. Cardiopulmonary resuscitation sensing and recording devices allow for methods of debriefing that were previously available only for simulation-based education; such methods have the potential to fundamentally alter resuscitation training and improve patient outcomes.

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CARDIOPULMONARY RESUSCITATION (CPR) is one of the few therapies known to improve survival from sudden cardiac arrest.^{1,2} While instruction in CPR is required for the majority of health care professionals, the optimal methods to teach and ensure correct perfor-

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mance of the complex, time-critical actions of CPR are unknown. The need for novel CPR training and quality improvement efforts is underscored by recent investigations that document poor CPR performance during actual cardiac arrests, despite rescuer training in advanced cardiovascular life support (ACLS) or basic life support (BLS).³⁻⁵

A number of studies have demonstrated that initial survival is often correlated with the quality of CPR that is delivered.^{6,7} Specifically, improved outcomes have been correlated with faster and deeper chest compressions, decreased pauses in chest compressions, and decreased ventilation rates.⁸⁻¹² These studies have prompted the International Liaison Committee on Resuscitation to call for renewed emphasis on CPR training and education in their 2005 revision of consensus resuscitation guidelines.²

Initial efforts to improve CPR performance, via the use of either mechanical devices to automate CPR delivery or feedback-enabled defibrillators, have yielded variable or modest results during actual resuscitation events.^{11,13-15} Our prior work with a real-time audiovisual CPR feedback defibrillator demonstrated improvements in CPR quality but did not yield im-

improvements in clinical outcomes.¹⁵ Postevent debriefing based on actual performance data represents an innovative educational technique that has the potential to improve CPR quality. This general method, which has been widely integrated into both military and aviation practices, has demonstrated great success in the evaluation of stressful and infrequent events for future performance improvement.^{16,17} Performance debriefing has been combined with mannequin simulation in a variety of medical education settings, including resuscitation.^{18,19} However, the impact of simulation training or debriefing techniques on actual resuscitation performance remains unknown.

Novel technology capable of collecting detailed transcripts of CPR quality from actual resuscitations has recently become available.^{3,4,20} Using this technology, we developed a unique debriefing program (resuscitation with actual performance integrated debriefing [RAPID]) for rescuers following in-hospital resuscitation attempts in an academic teaching hospital. We hypothesized that the RAPID educational intervention, using objective performance data from the rescuers' own recent resuscitation efforts, would improve CPR quality metrics as well as initial clinical outcomes from cardiac arrest.

METHODS

STUDY SETTING AND POPULATION

The study hospital is an academic, tertiary care facility with approximately 600 in-patient beds. Cardiac arrests occurring in the hospital are treated by the cardiac arrest resuscitation team, which is led by the on-call cardiology resident physician and includes 1 to 2 intern physicians and 0 to 2 medical students. The team is joined by a critical care nurse, respiratory therapist, anesthesiologist, and pharmacist at the cardiac arrest location. While on the cardiology rotation, resident teams took calls every fourth night and participated in approximately 3 to 4 cardiac resuscitations per month. All physician rescuers were ACLS certified and received a 45-minute orientation to the study defibrillator and review of resuscitation protocols on or immediately before their first call day of the month.

Resuscitation attempts for consecutive hospitalized adult patients who had a cardiac arrest during the study periods (defined by the loss of a pulse, requiring the delivery of chest compressions) were included for analysis. Resuscitation attempts were excluded if the patient was younger than 18 years, the patient had a do-not-resuscitate order, or if the arrest took place in the emergency department or operating room environment. In addition, a small number of patients during the study periods did not receive treatment with a CPR-sensing defibrillator and were therefore excluded from analysis. If a patient had multiple cardiac arrests, only the initial event was included to minimize confounding of the results.

DESIGN

A prospective interventional trial using a historical control group was used to evaluate the combined effects of audiovisual feedback and performance debriefing on CPR quality and patient outcomes. Resuscitations in our RAPID cohort were included from March 2006 to February 2007. Arrest event, patient, and rescuer data were compared with that from a previously published cohort (collected between December 2004 and Decem-

ber 2005) that served as a control in the present study.¹⁵ In both the intervention and control groups, a CPR-sensing defibrillator provided real-time audiovisual feedback on CPR quality during resuscitation attempts. However, during the intervention period, rescuers participated in a debriefing intervention using data obtained from that defibrillator following the resuscitation attempt. Both cohorts received care under the same resuscitation team structure, and no notable changes to hospital resuscitation policy were made during either period. However, new international resuscitation guidelines were released just before the start of the intervention period.²

The study protocols, consents, and data collection mechanisms were approved by the institutional review board of the University of Chicago Medical Center, Chicago, Illinois. Waiver of consent provisions were used for patients (on the basis of minimal harm and general impracticability), while an oral consent process was used for rescuers. Collection of patient information was designed to comply with the Health Insurance Portability and Accountability Act of 1996 regulations.

CPR-SENSING MONITOR AND DEFIBRILLATOR

A commercially available monitor and defibrillator (MRx with Q-CPR; Philips Medical Systems, Andover, Massachusetts) with the capability to detect and record chest compressions and ventilations was used during resuscitation attempts in the RAPID cohort. This device relies on the same technology as the investigational device (US Investigational Device Exemption G020121) used in our baseline cohort. Chest compression measurements were obtained via a chest compression pad, outfitted with both an accelerometer and force detector, which was adhered to the patient's sternum. Ventilations were measured by changes in thoracic impedance obtained through standard defibrillation pads. Technical aspects of these measurements have been described and validated elsewhere.^{4,20-22} These data were then analyzed using customized software (Q-CPR Review; Philips Medical Systems). The technical specifications for CPR detection and algorithms for audiovisual feedback remained the same between the 2 defibrillator models used in the different cohorts.

EDUCATIONAL INTERVENTION

During the intervention period, members from all resuscitation teams attended weekly debriefing sessions, led by study investigators (D.P.E., T.L.V.H., L.B.B., and B.S.A.) and other attending physicians from the fields of cardiology, anesthesiology, and emergency medicine, in which transcripts from the prior week's cardiac arrest resuscitation events were reviewed. These transcripts included electrocardiography, ventilation, chest compression, and end-tidal carbon dioxide waveforms as well as notations for audio feedback received during the resuscitations. Approximately 2 to 4 cases were chosen by study personnel (D.P.E. and B.S.A.) for presentation. Key sections in the arrest transcript detailing aspects of CPR quality deficiency or therapeutic interventions, such as defibrillation, were routinely converted into presentation slides (PowerPoint; Microsoft Corp, Redmond, Washington) by study investigators (D.P.E., B.L., and S.K.) and served as the basis for discussion (**Figure 1**). Recent publications highlighting resuscitation techniques specific to each session were briefly reviewed as appropriate. These sessions were approximately 45 minutes in duration each week and included approximately 30 minutes for review of specific cases and 15 minutes for general discussion and brief didactic instruction. An internal medicine chief resident helped to facilitate discussion. Attendance was strongly encouraged, and approximately 6 to 10 trainees attended each week. Rescuers

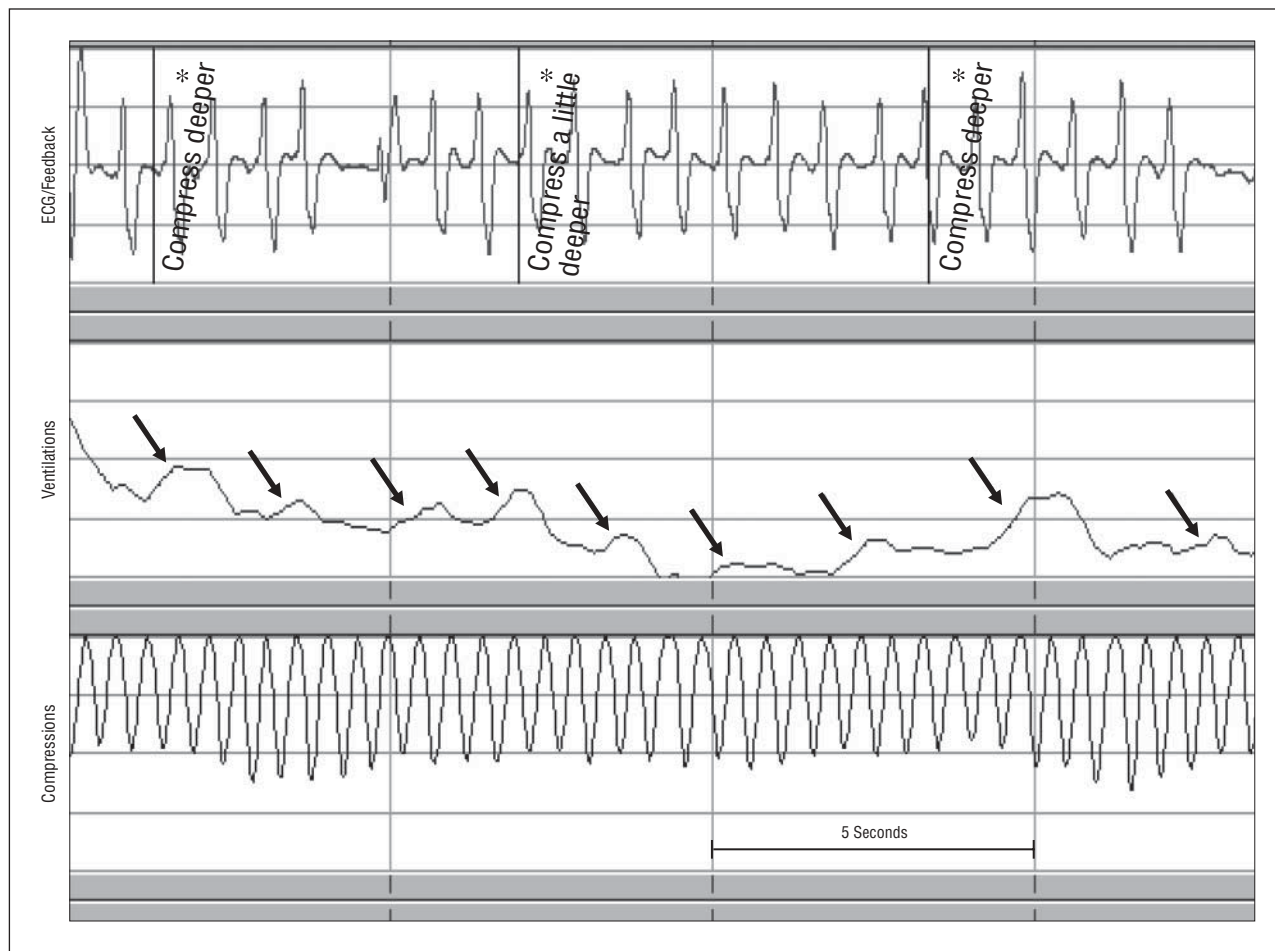


Figure 1. Sample performance debriefing presentation slide. A 20-second defibrillator tracing used in a postevent debriefing illustrates shallow chest compressions, failure to respond to audio prompts to “compress deeper,” and hyperventilation. Each ventilation is marked with an arrow, and each audio prompt is marked with an asterisk. ECG indicates electrocardiograph.

who delivered care during the control cohort period did not participate in debriefing sessions, but at the start of the monthly rotation they received a similar orientation to the defibrillator and protocols as used for the rescuers in the RAPID cohort. In both the baseline and RAPID cohorts, trainees received automated real-time audiovisual prompts regarding CPR quality during resuscitations and received the same training in the use of this feedback during monthly orientations.

During the second half of the intervention cohort period (between September 2006 and February 2007), trainees were surveyed at the start and conclusion of their month on the cardiology service regarding their knowledge of ACLS guidelines and confidence in their role as rescuer. Matched, written surveys composed of 24 preintervention and 30 postintervention open- and close-coded questions were administered by study personnel (B.L. and D.W.). Surveys were analyzed for answers to CPR guideline questions based on the 2005 ACLS target range of 100/min for compression rate, 8/min to 10/min for ventilation rate, and 1.5 to 2.0 inches (38-51 mm) for compression depth.²

DATA ANALYSIS

Objective CPR performance and electrocardiographic data were downloaded from the study defibrillators after resuscitation events. All arrest transcripts were manually annotated by study personnel for the start (defined as the first chest compression) and end (defined as 5 minutes after the start or at the return of spontaneous circulation [ROSC], if occurring within 5 min-

utes) of an episode. Preshock and postshock pauses, defined as the duration of time between chest compressions and defibrillation, were calculated manually. Cardiac rhythm at the start of the resuscitation, as well as before and after defibrillation, were noted. Patient demographic and outcome data were abstracted via subsequent review of medical records.

Return of spontaneous circulation was defined as the onset of an organized rhythm with a palpable pulse and measurable blood pressure for at least 20 minutes. Cardiopulmonary resuscitation quality parameters such as chest compression rate and depth, ventilation rate, and no-flow fraction, which represents the fraction of time, within a given period, that a pulseless patient went without chest compressions, were calculated in 30-second segments of CPR and as aggregate mean values over the first 5 minutes of resuscitation. Criteria for the calculation of these parameters have been previously published.^{4,10,15} Cardiopulmonary resuscitation quality was deemed within the target range for each 30-second segment if the compression rate was between 90/min and 120/min, compression depth was 38 mm or greater, and the ventilation rate was 15/min or less, as recommended by expert consensus for the measuring and reporting of CPR quality.²³ The duration for CPR quality assessment was chosen to be consistent with our prior work evaluating CPR quality in 30-second segments.^{3,4,8,10} The first 5 minutes of CPR was used for consistency in both cohorts, as well as to minimize the potential confounding associated with CPR provided near the end of a cardiac arrest (which may have been deemed futile by rescuers).

Table 1. Patient Demographics and Resuscitation Characteristics by Cohort^a

Variable	Baseline (n=101)	RAPID (n=123)	P Value
Sex			
Female	51 (51)	63 (52) ^b	.87
Male	50 (50)	59 (48) ^b	
Age, mean (SD), y	62.3 (17)	60.7 (16)	.48
Initial rhythm			
VF or VT	18 (18)	19 (16)	.63
PEA or asystole	83 (82)	104 (85)	
Location			
ICU	56 (56)	77 (63)	.53
Hospital ward	40 (40)	40 (33)	
Other	5 (5)	6 (5)	
Daytime event ^c	44 (44)	60 (49)	.44
Academic quarter			
July-September	18 (18)	47 (38)	.001
October-December	25 (25)	25 (20)	
January-March	26 (26)	13 (11)	
April-June	32 (32)	38 (31)	

Abbreviations: ICU, intensive care unit; PEA, pulseless electrical activity; RAPID, resuscitation with actual performance integrated debriefing; VF, ventricular fibrillation; VT, ventricular tachycardia.

^aData are shown as number (percentage) unless otherwise specified.

^bDemographic data were missing from 1 patient in the RAPID phase.

^cDaytime is defined as 7:00 AM to 6:59 PM.

Table 2. Trainee Level by Cohort

Level of Training	Baseline, No. (%) (n=142)	RAPID, No. (%) (n=112)	P Value
PGY3-4	19 (13)	12 (11)	.88
PGY2	23 (16)	21 (19)	
PGY1	84 (59)	65 (58)	
MS4	16 (11)	14 (13)	

Abbreviations: PGY, postgraduate year; MS4, fourth-year medical student (subintern); RAPID, resuscitation with actual performance integrated debriefing.

All calculations were performed using a statistical software application (Stata version 9.0; StataCorp, College Station, Texas). Skewed data, such as time intervals, were reported as medians with interquartile ranges and compared using a Wilcoxon rank sum test. Means were compared using a 2-sided *t* test, and binary variables were compared using the χ^2 test. A logistic regression analysis was undertaken to adjust for the effects of patient age, sex, initial rhythm, and time and location of arrest on ROSC. *P* < .05 was considered statistically significant.

RESULTS

During the RAPID period, 112 trainees attempted resuscitation on 123 distinct patients. These events were compared with resuscitations from 101 patients, performed by 142 trainees, in the baseline period (**Table 1** and **Table 2**). There were no significant differences between the groups in age, sex, presence of a shockable initial rhythm, or location or timing of cardiac arrest. In addition, there was no significant difference in rescuer level of training be-

Table 3. Rescuer Knowledge and Attitudes Before and After RAPID

Variable	Before RAPID, No. (%) (n=48)	After RAPID, No. (%) (n=40)	P Value
Knowledge of 2005 ACLS recommendations			
Compression depth	19 (40)	21 (53)	.23
Compression rate	36 (75)	36 (90)	.07
Ventilation rate	17 (35)	23 (58)	.04
Defibrillation algorithm	18 (38)	37 (93)	<.001
Attitudes regarding role of intervention			
Improved guideline understanding	NA	33 (83)	
Improved comfort level	NA	33 (83)	
Improved leadership skills	NA	28 (70)	
Was a valuable addition to curriculum	NA	33 (83)	
Missing		1 (3)	
Level of training			
PGY3-4	7 (15)	10 (25)	.96
PGY2	11 (23)	7 (18)	
PGY1	25 (52)	19 (48)	
MS4	4 (8)	4 (10)	
Missing	1 (2)	0	
ACLS certification before intervention, mo			
≤6	20 (42)	NA	
7-12	13 (27)	NA	
13-24	10 (21)	NA	
>24	5 (10)	NA	
Debriefing sessions attended			
1	NA	12 (30)	
2-3	NA	24 (60)	
4-5	NA	4 (10)	

Abbreviations: ACLS, Advanced Cardiovascular Life Support; NA, not applicable; MS4, fourth-year medical student (subintern); PGY, postgraduate year; RAPID, resuscitation with actual performance integrated debriefing.

tween the 2 groups. There was, however, a significant difference between the 2 groups in terms of when during the academic cycle the arrests occurred, with the baseline arrests less likely to occur in July, August, or September and more likely to occur in January, February, and March.

During the second half of the debriefing intervention period, 48 of 67 eligible trainees completed baseline surveys before starting their month-long rotation as resuscitation team members. Of those trainees, 40 (83%) completed final surveys at the conclusion of the month (**Table 3**). The training level distribution in respondents was similar to that in the entire intervention cohort. Of the 48 respondents, 20 (42%) had been certified in ACLS within 6 months of baseline survey administration; 33 (69%), within 1 year; and 43 (90%), within 2 years. Before RAPID, only 36 (75%) knew the correct ACLS recommended rate of chest compressions; 19 (40%) knew the recommended compression depth; 17 (35%) knew the recommended ventilation rate, and 18 (38%) knew that stacked shocks of escalating energy were no longer indicated. Following the intervention, there was a nonsignificant increase in the percentage of rescuers answering correctly for compression rate (*P* = .07) and depth (*P* = .23) as well as a significant improvement in those answering correctly for ventilation (*P* = .04) and defibrillation (*P* < .001). Most respondents

Table 4. Cardiopulmonary Resuscitation Quality by Cohort

Quality Metric	Baseline	RAPID	P Value
5-Minute mean (SD)	(n=101)	(n=123)	
Compression depth, mm	44 (10)	50 (10)	<.001
Compression rate, No./min	100 (13)	105 (10)	.003
Ventilation rate, No./min	18 (8)	13 (7)	<.001
No-flow fraction	0.20 (0.13)	0.13 (0.10)	<.001
Preshock pause, median (IQR), seconds	16.0 (8.5-24.1) (n=108)	7.5 (2.8-13.1) (n=108)	<.001
Postshock pause, median (IQR), seconds	7.1 (2.7-14.8) (n=124)	2.4 (1.9-3.6) (n=106)	<.001
Appropriate shocks, No./total No. (%)	110/151 (73) (n=151)	104/117 (89) (n=117)	.001

Abbreviations: IQR, interquartile range; RAPID, resuscitation with actual performance integrated debriefing.

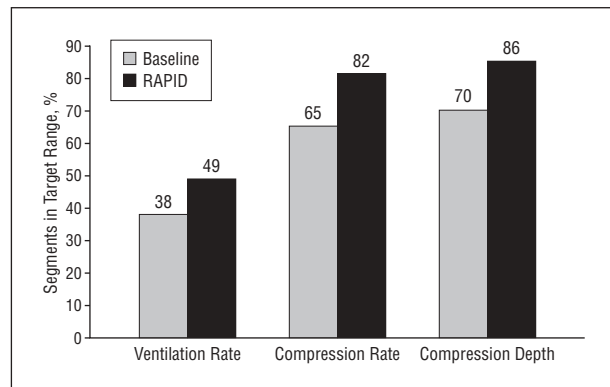


Figure 2. Cardiopulmonary resuscitation (CPR) quality as a percentage of time within target range. Data are given as percentage of 30-second segments during the first 5 minutes of CPR that are 15/min or less for ventilations, 38 mm or greater for compression depth, and 90/min to 120/min for compression rate. $P < .001$ for each parameter. RAPID indicates resuscitation with actual performance integrated debriefing.

believed that the debriefing sessions improved their understanding of the guidelines, comfort level with resuscitations, and leadership skills. In addition, a majority believed that the RAPID program was a valuable addition to their curriculum.

A number of CPR quality metrics improved in the RAPID cohort (**Table 4**). With the implementation of RAPID, mean (SD) compression depth increased (50 [10] vs 44 [10] mm; $P < .001$), mean (SD) compression rate increased (105 [10]/min vs 100 [13]/min; $P = .003$), mean (SD) ventilation rate decreased (13 [7] vs 18 [8]/min; $P < .001$), and mean (SD) no-flow fraction decreased (0.13 [0.10] vs 0.20 [0.13]; $P < .001$). These were associated with a significant decrease in the percentage of 30-second segments during the first 5 minutes that were outside of target range for compression rate and depth as well as ventilation rate ($P < .001$ for each parameter) (**Figure 2**). In addition, preshock and postshock pause times decreased significantly ($P < .001$ for each), and the proportion of appropriate shocks (shocks for ventricular fibrillation and ventricular tachycardia, as opposed to pulseless electrical activity and asystole) increased in the RAPID cohort (Table 4).

These improvements were associated with a significant improvement in the rate of ROSC between the groups

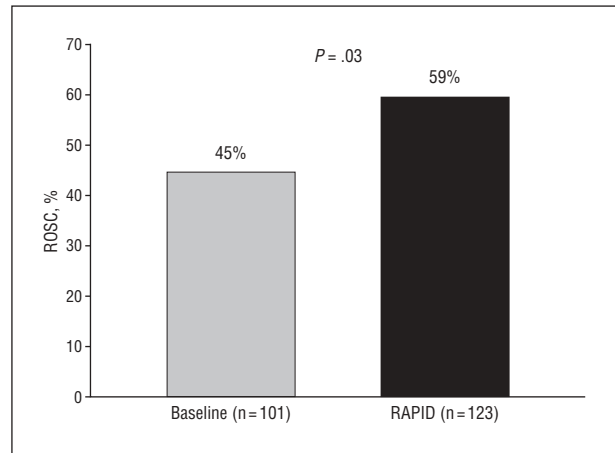


Figure 3. Return of spontaneous circulation (ROSC) by cohort. RAPID indicates resuscitation with actual performance integrated debriefing.

(59% vs 45%; $P = .03$) (**Figure 3**). Survival to discharge was indistinguishable between the groups (7% vs 9%; $P = .69$). After adjusting for shockable vs nonshockable initial rhythm, time and location of arrest, and patient demographics, RAPID was associated with a significant increase in the odds of ROSC (median [interquartile range] OR, 1.83 [1.06-3.16]; $P = .03$). To account for the potential bias introduced by including resuscitations during the intervention that occurred before the first debriefing of each month, all the analyses were repeated without including the 31 resuscitations meeting that criteria, and the results were not significantly altered (data not shown).

COMMENT

We have demonstrated that an integrated debriefing program based on actual resuscitation performance (RAPID) is effective in improving objective measurements of CPR quality and initial patient survival from in-hospital cardiac arrest. Specifically, we have shown that detailed “playback” of actual resuscitation events with targeted discussion is both feasible and effective in improving rescuer knowledge and performance of cardiac resuscitation as well as patient outcomes. This work has broad applicability for improving resuscitation training in both in-hospital and out-of-hospital settings.

Cardiac resuscitation in clinical practice requires a complex set of actions to be carried out by multiple rescuers under considerable stress. Given this reality, it is perhaps not surprising that conventional resuscitation education and training has had limited success.²⁴ Simulation training has been used in an attempt to address some of these issues by mimicking the complexities found in actual events.²⁵ In a randomized, crossover design study of internal medicine residents, Wayne et al²⁶ demonstrated that simulator training sessions significantly improved ACLS skills, while trainee experience alone had no significant effect. Another simulation-based study combined high-fidelity simulation with team training and intensive debriefing and demonstrated an improvement in simulated survival from 0% to 90% over the course of 1 day of training.¹⁹

However, simulation training has practical limitations and requires infrastructure that may not be accessible to

all institutions. In addition, the applicability of simulated scenarios to actual clinical events remains poorly understood. For example, the effects of audiovisual feedback in a simulated study of resuscitation were considerably more promising than during actual cardiac arrest.^{11,15,27} Therefore, the possibility of combining the educational strategies of feedback and debriefing with actual clinical events is both appealing and potentially accessible to a wider audience. Historically, this has not been feasible, given the lack of objective data available during and following cardiac arrest resuscitation attempts. However, new technology, capable of accurately measuring and potentially recording CPR quality in real time, is now available in both defibrillators and free-standing lower cost devices, allowing rescuers to learn from their actual performance by applying these educational techniques.

The differential effect of real-time audiovisual feedback between simulated and clinical scenarios suggests that human factors during actual resuscitation (such as noise at the scene, stress, and competing clinical priorities for the attention of team members) may have prevented the real-time feedback from having maximal benefit. We postulate that one of the ways RAPID worked was through sensitizing rescuers to the real-time audiovisual prompts they received during subsequent resuscitations.

Another potential mechanism that may have accounted for the improved resuscitation performance by the house staff was the knowledge that their performance was going to be reviewed in an open forum with faculty and colleagues. In both study groups, the trainees consented to have their CPR quality measured. However, in the intervention period, the trainees knew that their performance was going to be analyzed openly. This heightened awareness may have motivated increased attention to detail during resuscitation care. This is supported by the lack of a difference in results when the resuscitations preceding the first debriefing of the month were omitted from analysis.

This study has several limitations. First and foremost, we cannot exclude improvements in CPR quality due to secular trend, particularly in light of the release of the 2005 ACLS guidelines in November 2005,² which decreased the recommended ventilation rate and increased the “quantity” of CPR to be delivered between pulse checks. However, we also observed improvements in compression rate and depth, which were not the subject of any changes in the CPR guidelines. In addition, the poor baseline knowledge the house staff had of these changes and the significant improvement in that knowledge following the intervention suggests that part of the benefit of RAPID was an increase in rescuer awareness of the 2005 ACLS guidelines. Finally, our prior published work, comparing audiovisual feedback with an earlier historical control cohort, which showed only modest improvements in CPR quality and no change in outcomes,¹⁵ argues against a significant effect of time and experience or Hawthorne effect.²⁸ Nonetheless, since both cohorts in the present study received audiovisual feedback, the baseline CPR quality in this study is possibly better than in other institutions. This study design therefore tests only the added effect of the debriefing intervention to audiovisual feedback. However, this effect would have been slightly larger had we used

our original historical control group that received no feedback. Another limitation of this study is that it was conducted at a single institution; the applicability of our findings to other institutions with different resuscitation team structures or paramedics remains unknown. In addition, to protect the confidentiality of the trainees, we did not maintain identifying data to link them with specific patients and therefore only have aggregate monthly data. It is therefore not possible to test the effects of the intervention on specific residents over time.

In the aggregate analysis of rescuer level of training, we found no difference between the 2 groups. However, there was a significant difference between the 2 groups in terms of when the arrests took place during the academic cycle, with the baseline arrests less likely to occur in July, August, or September and more likely to occur in January, February, and March. We postulate that this discrepancy would be more likely to bias toward the null, since trainees are less experienced in the late summer and early fall and gain experience throughout the year. However, when ROSC was assessed as a function of the time of year and quarter was included in the regression analysis, no significant differences were found (data not shown).

It is interesting to note that while we achieved a 33% improvement in the rate of ROSC, there was no significant difference in survival to discharge. One possibility for this discrepancy is that while ROSC is necessary for survival to discharge, many postresuscitation factors play a notable role as well, such as therapeutic hypothermia, tight glycemic control, and early revascularization, which are likely underused in clinical practice.²⁹⁻³¹ Return of spontaneous circulation was chosen as the main patient outcome variable because of power considerations and because it is most affected by resuscitation performance, the process variable targeted by our intervention.

In conclusion, an educational intervention of postresuscitation team debriefing using new CPR-sensing technology during actual cardiac arrest may improve objective measures of rescuer performance of CPR as well as initial patient outcomes from cardiac arrest. This relatively simple intervention could be implemented using a variety of CPR-sensing tools currently available or using recordings of electrocardiographic data from most defibrillators, since chest compression rate and pause times can often be inferred from an electrocardiographic artifact caused by the compressions. The recording of CPR data provides a number of opportunities for further improvement and optimization of both education and actual care, and future work will be required to identify the most effective methods of using these new tools in a wider variety of settings to improve resuscitation clinical skills and patient survival.

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Vanden Hoek, Becker, and Abella. *Analysis and interpretation of data*: Edelson, Litzinger, Arora, Lauderdale, and Abella. *Drafting of the manuscript*: Edelson, Litzinger, Kim, and Abella. *Critical revision of the manuscript for important intellectual content*: Edelson, Arora, Walsh, Lauderdale, Vanden Hoek, Becker, and Abella. *Statistical analysis*: Edelson, Litzinger, and Lauderdale. *Obtained funding*: Edelson, Becker, and Abella. *Administrative, technical, and material support*: Kim, Vanden Hoek, and Becker. *Study supervision*: Becker and Abella.

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