Interruptions of Chest Compressions During Emergency Medical Systems Resuscitation

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***Background*—**Survival after nontraumatic out-of-hospital (OOH) cardiac arrest in Tucson, Arizona, has been flat at 6% (121/2177) for the decade 1992 to 2001. We hypothesized that interruptions of chest compressions occur commonly and for substantial periods during treatment of OOH cardiac arrest and could be contributing to the lack of improvement in resuscitation outcome.

***Methods and Results*—**Sixty-one adult OOH cardiac arrest patients treated by automated external defibrillator (AED)–equipped Tucson Fire Department first responders from November 2001 through November 2002 were retrospectively reviewed. Reviews were performed according to the code arrest record and verified with the AED printout. Validation of the methodology for determining the performance of chest compressions was done post hoc. The median time from "9-1-1" call receipt to arrival at the patient's side was 6 minutes, 27 seconds (interquartile range [IQR, 25% to 75%], 5 minutes, 24 seconds, to 7 minutes, 34 seconds). An additional 54 seconds (IQR, 38 to 74 seconds) was noted between arrival and the first defibrillation attempt. Initial defibrillation shocks never restored a perfusing rhythm (0/21). Chest compressions were performed only 43% of the time during the resuscitation effort. Although attempting to follow the 2000 guidelines for cardiopulmonary resuscitation, chest compressions were delayed or interrupted repeatedly throughout the resuscitation effort. Survival to hospital discharge was 7%, not different from that of our historical control (4/61 versus 121/2177; $P=0.74$).

***Conclusions*—**Frequent interruption of chest compressions results in no circulatory support during more than half of resuscitation efforts. Such interruptions could be a major contributing factor to the continued poor outcome seen with OOH cardiac arrest. **(*Circulation*. 2005;112:1259-1265.)**

Key Words: cardiopulmonary resuscitation ■ circulation ■ resuscitation ■ heart arrest

Hundreds of thousands of cardiac arrest victims continue to die each year despite our best efforts.[1] Resuscitation with neurologically normal long-term survival remains an elusive goal, even though updated cardiopulmonary resuscitation (CPR) guidelines are published nearly every 6 years.[2–6] Advances in resuscitation, such as use of automated external defibrillators (AEDs), can improve survival in specific circumstances[7–9] but have failed to improve overall survival rates in some communities.[10]

Recent studies have established that many professional providers struggle to accomplish the resuscitation tasks outlined in the guidelines.[11,12] For example, Wik et al[11] found that out-of-hospital (OOH) cardiac arrest victims treated by paramedics or nurse anesthetists received chest compressions only 52% of the time. In addition, 62% of the chest compressions given were less than the recommended depth (<38 mm).[11] Abella et al[12] found that in-hospital cardiac arrest response teams, comprising an ample number of highly trained medical personnel, had very similar difficulties in providing CPR according to the guideline's recommendations. In their prospective observational series of 67 patients with in-hospital cardiac arrest, these authors found that chest compressions were not being provided during 24% of the resuscitation time and that 37% of all chest compressions according to the guidelines were too shallow (<38 mm). Such experiences suggest that the actual performance of CPR, even by professional rescuers, may vary greatly from the intended ideal.

In our community, OOH cardiac arrest survival rates are tracked by the Tucson Fire Department (TFD). Despite continued efforts at quality improvement and incorporation of all revised resuscitation guidelines into the emergency medical systems (EMS) response protocols during the last 10 years, there has been no improvement in survival (Table 1).

This lack of improvement in OOH cardiac arrest survival motivated us to more carefully examine what actually occurs

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TABLE 1. Annual OOH Cardiac Arrest Survival Rates in Tucson, Arizona, 1992–2001

	Survival to Hospital Discharge Rate, %	
Year	All Initial Rhythms	VF Initial Rhythm
1992	7	14
1993	9	13
1994	4	7
1995	4	9
1996	4	8
1997	5	8
1998	7	9
1999	8	10
2000	5	8
2001	5	10

Overall survival to hospital discharge rate for the decade 1992–2001 was 6±2%. The survival to discharge rate of those with VF as the initial rhythm for the same period was 10±2%. Table includes all presenting rhythms of cardiac arrest. All EMS vehicles were equipped with AEDs by December 1997. Trauma arrests were not included.

during our guidelines-based TFD EMS resuscitations. Of note, all TFD personnel involved in EMS activities receive extensive retraining and skill refreshment on a regular basis (monthly). Quality improvement is performed through regular review of all resuscitation field records. We hypothesized that interruptions of chest compressions occur commonly and for substantial periods during treatment of OOH cardiac arrest. We therefore conducted a retrospective review of the TFD cardiac arrest resuscitation efforts during the 12-month period between November 2001 and November 2002 to determine the proportion of time spent doing chest compressions during each resuscitation attempt.

Methods

The TFD provides a 2-tiered, single EMS system for the City of Tucson (population 487 000; area 505 km^2). All TFD EMS first responders use a bag-mask device and work in at least pairs and sometimes a foursome, hence providing multirescuer CPR.

The database is part of a TFD quality improvement program for its treatment of OOH cardiac arrest. The TFD has statutory authority to collect and analyze cardiac arrest data as part of its public health quality assurance responsibilities. The local institutional review board has determined that consent to compile such data is unnecessary. If information is needed from the patient's hospital medical record, consent is obtained.

Case and Survival Definitions

All included subjects were at least 16 years old and had suffered a nontraumatic cardiac arrest. Whether or not a case was "witnessed" was determined by review of the dispatch and paramedic records. Performance of "bystander CPR" was visually determined by the EMS provider on arrival. Time from "collapse to 9-1-1 call" was not reliably available for all patients and therefore, was not reported. The "9-1-1 call to arrival at the patient's side" interval included the time needed to find the patient and begin assessment. "Arrival-to-diagnosis" interval included the time at the patient's side needed to make a rhythm diagnosis, and the "diagnosis-to-treatment" time interval encompassed the time from rhythm diagnosis to either defibrillation or chest compressions. "Total time on the scene" interval was from arrival at the patient until decision to transport the patient and did not include the time of transport to the hospital. "Survival to hospital admission" was defined as spontaneous circulation allowing admission to the intensive care unit. "Survival to hospital discharge" included discharge to home or another care facility.

Study Data

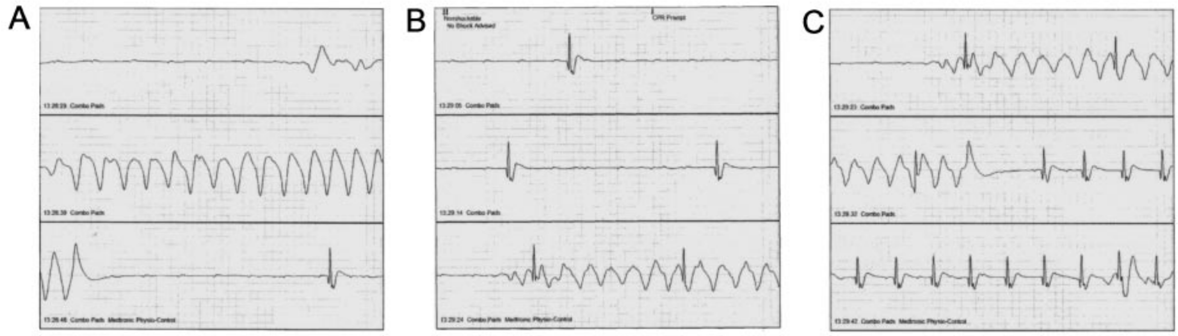
Cardiac arrest incidence and survival rates in Tucson, Arizona, were obtained from the TFD cardiac arrest database for a 10-year period (1992 to 2001) for historical comparison. The data reported in this study are from the 12-month period of November 2001 through November 2002. During this period, the TFD was using the 2000 guidelines algorithms for cardiac arrest resuscitation efforts. An ongoing, expanded Utstein-style[13] survey of prehospital cardiac arrest undertaken jointly by the TFD and the University of Arizona College of Medicine identified 61 cases of OOH cardiac arrest treated by TFD EMS first responders equipped with voice-recording AEDs during the designated 12-month study period. A total of 413 cardiac arrests occurred during this period, but most were not included in this analysis because the full AED data set (both voice and ECG) were unavailable. Most of these nonincluded cases were treated by paramedic first responders using either a manual defibrillator or a non–voice-recording AED. Resuscitation was not attempted in patients found with rigor mortis or other obvious evidence of irreversible death. Cases of cardiac arrest resulting from trauma, drowning, electrocution, known terminal illness, or sudden infant death syndrome were excluded. Details on the collection of data within the TFD cardiac arrest database have been previously reported.[14,15]

Quality Assurance

The TFD provides regular training about the EMS aspects of their professional responsibilities. Required, quarterly, all-day educational training sessions occur, during which resuscitation education and skill refreshment are included. A mandatory skills laboratory is required every 6 months as well. Quality assurance is performed through careful review of each and every resuscitation call and attempt. Indeed, the mandated purpose for the TFD resuscitation database was for quality improvement.

Data Collection and Call-to-Event Time Intervals

Collapse-to-event intervals were calculated through the use of monitor-defibrillator units (Lifepak 500 AED and Lifepak 12, Medtronic Emergency Response Systems) equipped with event documentation capacity. These units record the cardiac rhythm during each arrest. Within 24 hours of a cardiac arrest event, TFD personnel transmit by telephone line the recorded continuous waveform to 1 of 3 dedicated computers. The continuous ECG waveform begins when the device is powered on and ends when the device is powered off. The computer automatically synchronizes the time in the device and on the waveform with the atomic clock. Each event is reviewed in its entirety, and the waveform is examined with the Code Stat Suite Reviewer (Code Stat Suite version 4.1.1, Medtronic Emergency Response Systems). The Figure illustrates such AED ECG recordings. The cursor is placed at the beginning point of the first compression, and the time is documented in hours, minutes, and seconds. The cursor is then placed at the end point of the last compression before a delay for any reason, and the time is documented. This process continues throughout the resuscitation effort until transport begins, the prospectively identified termination point of the study, because previous experience with this system has shown that motion artifact markedly increases during transport and limits reliability. No assumptions or estimates are made in analyzing the recordings. The Lifepak 500 AEDs are also equipped with voice recording, which allows annotation of other interventions at the appropriate times (ie, intubation, etc). All annotations and time documentation become part of the event log. The event log was then reviewed by 2 of the authors, and the study time intervals were calculated.



An AED ECG record from a representative patient. A, The ECG record from the AED after a shock for prolonged VF resulting in asystole. Chest compressions were begun (15 delivered) followed by a pause of 2 ventilations. The ventilations are not well seen, but an isolated intrinsic QRS complex is noted. B, The slow intrinsic QRS complexes without assistance from chest compressions, followed by the resumption of chest compressions. C, The continued intrinsic QRS complexes during chest compressions, followed by a sustainable intrinsic and faster QRS rhythm. Abbreviations are as defined in text.

Statistical Methods

Descriptive statistics, such as proportions and percentiles, were used to highlight when chest compressions were and were not performed. Such data are reported as mean±SD. χ^2 or Fisher's exact test was used to compare such proportions with earlier reports from this database. The time interval data are reported as the median, with 25% to 75% interquartile range (IQR) because of the nonnormal distribution of these data. Other nonparametric testing was performed with a Mann-Whitney *U* test, and an unpaired, 2-tailed Student *t* test was performed on parametric data. A value of $P \leq 0.05$ was considered significant. All analyses were performed with either StatView 5.0 (SAS Institute) or InStat for Macintosh, version 3 (Graphpad Software) software.

Post Hoc Validation Study

A post hoc validation study was done in swine to confirm the accuracy of our methodology for determining the performance of chest compressions using the LifePak 12 AED continuous ECG record. All animal experiments were conducted with the approval of the University of Arizona Institutional Animal Care and Use Committee.

Four healthy, domestic swine (25±1 kg) were studied. Each was anesthetized and instrumented as previously reported from our laboratory.[16] The animal was shaved over the entire thorax, and an AED (Lifepak 12) was placed with the pads over the right anterior chest and the left lateral chest.

Experimental Measurements

Hemodynamics, including aortic systolic and diastolic pressures, right atrial systolic and diastolic pressures, and calculated coronary perfusion pressure (aortic diastolic pressure−simultaneous right atrial diastolic pressure), were measured throughout the CPR period. ECG monitoring was done both by standard limb leads and separately by the AED.

Experimental Protocol

After 7 minutes of untreated ventricular fibrillation (VF), each animal underwent attempted defibrillation, and then CPR (chest compressions and ventilations) was performed. According to the 2000 guidelines, chest compressions were periodically interrupted to reassess the animal and attempt further defibrillation, if indicated (eg, presence of VF). The time period during which chest compressions were performed was determined by 2 different techniques. The hemodynamic record was played back at real-time speed and reviewed by one investigator (R.W.H.). The cumulative time period during which chest compressions were actually performed was recorded with a stopwatch. A second investigator (L.L.C.) calculated the time during which chest compressions were performed using the AED continuous ECG waveform, as was done in the clinical portion of this study. The total time during which chest compressions were performed was calculated for each animal by the 2 different techniques. The total chest compression time was then compared between the 2 techniques with a simple regression analysis (Statview 5.0 statistical software, SAS Institute).

Results

The methodology of using the AED continuous-waveform data to determine when chest compressions were and were not performed was validated with the post hoc animal study. No difference in the proportion of time with and without chest compressions was found, whether such were calculated from the actual hemodynamic record during CPR or the AED ECG waveform data obtained during CPR. Assessing for chest compressions from the intra-aortic pressure waveform showed that the percentage of resuscitation effort with chest compressions for the 4 animals averaged 34.9±15.9%, whereas the AED ECG record revealed that chest compressions were performed 35.3±16.7% of the time. A comparison of the 2 techniques produced a correlation coefficient (r^2) of 0.997 ($P=0.0014$).

The demographics of the study population are shown in Table 2. No data are presented on time of collapse to 9-1-1 call. Such data are difficult to accurately collect and more so to verify.[17] The median time interval from 9-1-1 call to arrival at the patient's side was 6 minutes, 27 seconds (25% to 75% IQR, 5 minutes, 24 seconds, to 7 minutes, 34 seconds). Another 30 seconds (IQR, 13 to 57 seconds) was needed from arrival at the patient's side until a rhythm diagnosis was made. The time interval from making a diagnosis until rhythm-specific therapy was begun, ie, defibrillation for VF or chest compressions for non-VF, was 20 seconds (IQR, 12 to 25 seconds). The total time interval from 9-1-1 call to institution of definitive treatment (defibrillation or chest compressions) was 7 minutes, 33 seconds (IQR, 6 minutes, 28 seconds, to 8 minutes, 45 seconds).

The time interval from arrival at the patient in VF to delivering the first shock was 54 seconds (IQR, 38 to 74 seconds). The interval between the first and second shocks was 27 seconds (IQR, 25 to 63 seconds), with an additional 30 seconds (IQR, 22 to 70 seconds) between the second and third shocks. Overall, the time interval to deliver the 3 recommended shocks for refractory VF was 1 minute, 44

TABLE 2. Study Population Demographics

No.	61
Age, y (mean±SD)	63±18
Gender, n (%)	
Male	36 (59)
Female	25 (41)
Witnessed, n (%)	31 (51)
Not witnessed, n (%)	30 (49)
Bystander CPR,* n (%)	32 (52)
No bystander CPR, n (%)	29 (48)
Witnessed and bystander CPR, n/N (%)	18/31 (58)
Witnessed but no bystander CPR, n/N (%)	13/31 (42)
Initially detected rhythm, n (%)	
VF	20 (33)
Non-VF	41 (67)
Survival to hospital admission, n (%)	10 (16)
Survival to hospital discharge, n (%)	4 (7)

*Bystander CPR includes all who received CPR before arrival of EMS. Nineteen of these 32 (59%) had bystander CPR by medical personnel with a duty to respond (nursing home staff, registered nurses at dialysis units, physician at office, etc). Only 15 of the total 61 cases (25%) had bystander CPR by nonprofessionals without a "duty" to respond.

seconds (IQR, 1 minute, 34 seconds, to 1 minute, 54 seconds). Interestingly, it was uncommon that 3 shocks were needed to terminate VF (only 5 times in 21 cases of VF). The total time from 9-1-1 call to transport was 22 minutes, 43 seconds (IQR, 15 minutes, 50 seconds, to 27 minutes, 41 seconds).

Most notably, chest compressions were performed only 43±18% of the time during the resuscitation effort. Hence, no chest compressions were performed during the majority of the active resuscitation effort. Chest compressions were often not begun when EMS providers initially arrived at the patient in cardiac arrest and, once begun, were frequently interrupted for other resuscitation tasks. The time interval from arrival at the patient's side until the first chest compression recorded by the AED was a median of 78 seconds (IQR, 56 to 129 seconds). The longest continuous period of chest compressions was 122 seconds (IQR, 68 to 206 seconds), whereas the shortest continuous period was 11 seconds (IQR, 7 to 20 seconds). Similarly, the median time for the longest period without chest compressions was 172 seconds (IQR, 109 to 246 seconds). The shortest period of no chest compressions was 11 seconds (IQR, 8 to 18 seconds). The median time with continuous chest compressions was 55 seconds (IQR, 43 to 74 seconds), whereas the median time period when no compressions were performed was 57 seconds (IQR, 40 to 78 seconds).

The first 5 minutes of resuscitation effort for OOH cardiac arrest are crucial, because many of these individuals will have already been in cardiac arrest for 6 to 12 minutes before the arrival of professional EMS personnel. In reviewing our database specifically for what is actually done in the first 5 minutes on arrival at the patient's side, we found that chest compressions were being performed only 40±21% of the time during this crucial period. When we compared the first 5 minutes and the entire data set, no significant differences in the proportion of time with and without chest compressions, or in the average period of time when chest compressions were and were not performed, were found (Table 3).

Twenty-one patients (34%) had VF during the resuscitation requiring defibrillation. After the first shock, 17 of 21 were successfully defibrillated, but all converted to asystole (12/17) or pulseless electrical activity (5/17). Four patients remained in VF after the initial shock. Of note, no initial defibrillation shock resulted in a perfusing rhythm.

In 10 of the 61 patients, spontaneous circulation was restored and they were admitted alive. Eight of these 10 had an initial rhythm of VF. Nine of the 10 had a witnessed cardiac arrest, 8 received bystander CPR, and 8 were both witnessed and received bystander CPR. Those successfully resuscitated had significantly greater rates of each of these parameters compared with those who could not be resuscitated (Table 4). Four of 61 (7%) patients survived to hospital discharge.

Discussion

Weisfeldt and Becker[17] described 3 phases of VF cardiac arrest. In the first few minutes, the electrical phase, immediate defibrillation is crucial for optimal survival. After the first few minutes, the circulatory phase begins, wherein providing some circulation before defibrillation improves outcome.[18] This study shows that experienced, professional EMS responders perform chest compressions <50% of the time in their resuscitation efforts for OOH cardiac arrests. This is especially distressing, because almost all of these patients are in the circulatory phase of cardiac arrest on arrival of EMS providers. The current 2000 guidelines for CPR and emergency cardiovascular care emphasize the importance of rapid

TABLE 3. Comparison of First 5 Minutes vs the Entire Resuscitation Effort

	First 5 Minutes	Entire Effort	*P*
Time with CCs, %	40±21	43±18	NS
Time without CCs, %	60±21	57±18	NS
Longest period with CCs, seconds	65 (46, 84)	122 (68, 206)	0.0001
Average period with CCs, seconds	46 (30, 67)	55 (43, 74)	NS
Longest period without CCs, seconds	95 (70, 147)	172 (109, 246)	0.0001
Average period without CCs, seconds	56 (41, 87)	57 (40, 78)	NS

CC indicates chest compression. Time interval data are reported as median and (25%, 75% interquartile range).

TABLE 4. Outcome Data for OOH Cardiac Arrest

	Successfully Resuscitated	Not Resuscitated	*P*
n	10	51	
Age, y	66±19	62±18	0.51
Gender, %			
Male	30	65	0.08
Female	70	35	
Initial rhythm, %			
VF	80	33	0.02
Non-VF	20	67	
Witnessed, %	90	41	0.002
Bystander CPR, %	90	47	0.02
Witnessed and bystander CPR, %	80	24	0.002
9-1-1 call to arrival, seconds	333	391	0.11
Arrival to CCs, seconds	99	70	0.21
Total time at scene, seconds	549	1040	0.005
Time with CCs, %	34	49	0.09

CC indicates chest compression.

defibrillation because most survivors of OOH cardiac arrest are those with VF. The importance of rapid defibrillation for those with VF cannot be denied. However, statements such as "Give shocks as soon as a defibrillator is available"[19] have led to the relegation of all other efforts in favor of making a rhythm diagnosis (to detect VF), with immediate shock of all cases of VF, regardless of duration. In the current era of AED-equipped EMSs, this approach may result in significant periods during the initial resuscitation effort when no chest compressions are performed.[20,21] AEDs currently in use in many communities require substantial time to analyze, charge, shock, and then reanalyze, during which time the AED continually warns "Do not touch the patient." Newer versions of AEDs require considerably less time to perform these functions, during which chest compressions must be halted.

Other resuscitation tasks can also interrupt the performance of chest compressions. Reassessing the patient for pulses or rhythm changes, placement of intravenous lines, and intubation of the trachea can all interrupt chest compressions. Without careful attention, a substantial percentage of the resuscitation time can elapse without chest compressions (ie, without perfusion).

Recent data from Wik et al[18] show that with prolonged OOH cardiac arrest due to VF ("prolonged" defined as EMS arrival >5 minutes from emergency call), long-term survival rates were greater when chest compressions were provided before defibrillation. Such data highlight the importance of chest compressions for OOH VF cardiac arrest, unless defibrillation is available within 4 or 5 minutes of onset. The TFD data show that in a medium-size urban environment, it is uncommon for EMS personnel to reach OOH victims of cardiac arrest within this time period. Our average time interval from 9-1-1 call to arrival at the patient was >6½ minutes, and another 1 to 2 minutes were required from arrival at the patient's side to delivery of specific therapy. Even before including the interval from collapse to 9-1-1 call, the average duration of VF before EMS arrival is clearly within the time frame of the circulatory phase of VF cardiac arrest, when chest compressions and a period of hemodynamic support provided by professional EMS providers appear beneficial before attempts at defibrillation.[10,18]

Our initial defibrillation results illustrate what happens when prolonged VF is shocked before CPR is provided. None of the 21 initial shocks for VF resulted in a perfusing rhythm, similar to a recent report of the treatment of OOH cardiac arrest from the Netherlands, wherein only 4% (5/120) of initial shocks resulted in a return of spontaneous circulation without additional advanced cardiac life support therapy.[22] The majority of our Tucson OOH VF episodes were terminated with the initial shock (17/21), but always to a nonperfusing rhythm. Schneider et al[23] demonstrated similar results in the ORCA study, wherein they found that the first shock successfully terminated VF 77% (88/115) of the time. However, after prolonged VF, nearly all patients convert to a pulseless rhythm and fail to return to spontaneous circulation unless chest compressions are provided both before and after defibrillation.

The first few minutes of EMS therapy are probably the most important for successful resuscitation. Because almost all EMS resuscitation therapy will begin in the circulatory phase, simply because of the elapsed time from notification to arrival and treatment, providing circulation must be deemed the crucial early step. In the OOH scenario, chest compressions should occupy the majority of the first few minutes of EMS therapy. Unfortunately, comparing the first 5 minutes of treatment with the entire period of EMS-provided resuscitation effort revealed no differences in the percentage of time that chest compressions were performed (Table 3). In this crucial first 5 minutes of EMS resuscitation, chest compression–generated circulation was provided only 40% of the time! Animal studies have established that such interruptions of chest compressions are lethal in models of prolonged VF[24–26]; likewise, interruptions in either breathing or compressions can be harmful in asphyxial arrest.[27,28] It seems unreasonable to expect good outcomes after cardiac arrest when circulatory support is nonexistent for more than half of the resuscitation effort.

Wik et al[11] recently published similar data showing significant periods of no chest compressions during professional first-responder treatment of OOH cardiac arrest. These authors found that no chest compressions were performed during 48% of the time when the patient was without spontaneous circulation. We found a similar percentage (57%). Likewise, during the first 5 minutes of professional resuscitation, chest compressions were performed only 51% of the time in their series (vs 40% in ours). These results are strikingly similar and verify that in OOH resuscitation efforts by professional first responders, a significant amount of time elapses with no hemodynamic support in the absence of spontaneous circulation. Wik et al note that if their study is applicable to how CPR is delivered in other communities, then there is a great opportunity to improve current outcomes. Our study shows that similar challenges with interrupting chest compressions during the performance of CPR exist among professional rescuers in the United States.

Stiell et al[29] recently reemphasized the importance of bystander CPR in improving resuscitation outcomes for OOH cardiac arrest. Our data also suggest that many patients who were successfully resuscitated in Tucson were those whose cardiac arrest was witnessed and who receive bystander CPR (Table 4). Bystander CPR did not result in a successful outcome in unwitnessed cardiac arrest (1/14 resuscitated, 0/14 survived). Unfortunately, more than one third of witnessed cardiac arrest victims in our study did not receive bystander CPR (11/31, 35%). We hypothesize that if bystander CPR were simpler and thereby easier to remember and perform, then more of these witnessed cardiac arrest victims would receive this important early step in the chain of survival.

A trend toward more time with chest compressions during the resuscitation effort in nonsurvivors is also noted in Table 4. This apparent contradiction can be explained by the observation that those resuscitated typically responded quickly (to early defibrillation in a bystander-witnessed arrest), whereas those still requiring resuscitation efforts after 10 minutes generally were in non-VF rhythms, and by that time, there was very little else to do but compress the chest; hence, minimal interruption of chest compressions occurred until transport or declaration of death.

On the basis of these data, we are now embarking on a joint project with the TFD, the City of Tucson, and the Sarver Heart Center at the University of Arizona to limit EMS chest compression interruptions and to increase the rate of bystander CPR in witnessed, adult cardiac arrest.

Limitations

This study is a selective, subgroup, retrospective analysis of the TFD quality assurance cardiac arrest database. The potential pitfalls of such analyses are well documented and acknowledged. The methodology of determining when chest compressions were and were not performed from the AED continuous waveform was validated in a post hoc animal experiment. Excellent correlation between the hemodynamic record and the AED record of chest compressions was found. Using our described methodology allowed such data to be collected without any additional equipment, as required in the 2 previous reports of Wik et al[11] and Abella et al.[12] Alternative approaches, such as direct observation of EMS-provided resuscitation care, introduces the potential for observed performance bias. Although EMS providers know that the AED records their resuscitation efforts, such devices have become so commonplace that the chance of enhanced performance while under observation is greatly decreased.

An alternative explanation for the flat survival rate during the last 10 years is that although AEDs and early defibrillation have improved outcome in sudden, witnessed VF arrest, the decreased incidence of initial VF in OOH cardiac arrest has made the impact of this improvement less noticeable. A number of studies have documented this decrease in VF as the initial rhythm detected in OOH cardiac arrest.[11,29–31] In the rising number of non-VF cardiac arrest cases, for whom the most effective treatment is perfusion of the myocardium and central nervous system, avoiding interruptions of chest compressions may be even more important.

Conclusion

Professional EMS providers give chest compressions less than half of the time during their resuscitation efforts. There are many causes for such interruptions, but certainly the lack of hemodynamic support during the majority of the resuscitation effort could be contributing to the poor long-term outcomes. More attention should be paid to eliminating such chest compression interruptions during treatment of cardiac arrest victims by EMS personnel. Prospective studies are needed to determine the impact on outcome of decreasing such interruptions.

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