INTERNET SCIENTIFIC PUBLICATIONS

The Internet Journal of Rescue and Disaster Medicine 2004 : Volume 4 Number 1

Survival And Outcome From Prehospital Cardiac Arrest

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Citation: R. B. Vukmir : Survival And Outcome From Prehospital Cardiac Arrest . *The Internet Journal of Rescue and Disaster Medicine.* 2004 Volume 4 Number 1

Abstract

Early observational studies commented on the likelihood of survival associated with EMS sites and providers, while the efficacy of both EMTs and paramedics is still hotly debated. Demographic profiles of the prehospital arrest population find those who are younger, present with ventricular dysrhythmia or with shorter response times optimize the "prehospital chain of survival" have better outcome. Specific arrest outcome predictors that are standardized help to clarify outcome including arrest time, location of arrest, bystander CPR, and early defibrillation. Predictors

of long term survival focus on the presence of return of spontaneous circulation (ROSC), as well as intervals until resuscitation intervention that preclude functional recovery. Overall survival to hospital discharge was 3.8% (1.7-13%) of a 3,220 pooled patient group. Analysis of their functional recovery found good outcome in 86.7% (44-89%), moderate impairment in 10.2% (8.5-44%) and severe impairment in 3.1% (2-36%) of survivors from a cohort of 1679 pooled patients. Although, survival from prehospital arrest is diminished in geriatric groups, those who survive often have good functional recovery.

Introduction

A description of early ambulance systems that were utilized for evacuation of battlefield casualties were described by military surgeon, Dominque-Jean Larrey (1766-1842) during the Napoleonic Wars.[1] They were then adapted for clinic use in large American cities such as Cleveland and New York prior to 1865.[2] Skeptics questioned the necessity of an ambulance transport service suggesting "what difference would that make, the case must come to the hospital anyway."[3]

One of the earliest EMS outcome studies was reported by Pantridge in 1967 citing the Belfast experience.[4] The mobile intensive care unit was summoned in 338 cases with 312 admissions for myocardial infarction with a 50% "rule in" rate an exceptionally high acuity patient population. The prehospital arrest incidence was 3.4% (10) with 50% (5) of this group surviving to discharge, a surprising survival statistic in this critically ill population.

The US experience was reported by Crampton in 1975, noting a 26% decline in prehospital and 62% in-hospital mortality involving those who have undergone ambulance transport. These patients were younger than 70 years, and were found to have a 66% success rate in prehospital CPR, measured as long term survival.[5]

Iseri et al reported the early American experience with 26 patients and rapid response paramedic units defining the ventricular fibrillation group, which was amenable to successful countershock therapy in 86% (12), where they demonstrated survival in 43%.[6] They defined a brady-systolic cardiac arrest group, which was found to be associated with autopsy proven complete coronary artery occlusion in 50% (7) of patients, with a universally fatal result. Interestingly, they conclude that a more aggressive approach to prehospital management of brady-systolic arrests is warranted.

Eisenberg et al report the results of an evaluation of prehospital care by Emergency Medical Technicians (EMT) compared to that after the addition of paramedic skills such as defibrillation, endotracheal intubation and drug administration to the resuscitation armaterium.[7] They report an improved rate of survival (19 to 34%) to the coronary care unit (CCU) as well as rate of hospital discharge from 7 to 17%, which they related to a decrease in time to advanced care delivery that was shortened from 27.5 to 7.7 minutes.

In a separate report they analyzed 487 prehospital arrest patients cared for by EMTs or paramedics in specific regions where the annual arrest incidence was 5.6-6.0/10,000. Proportionally more lives were saved in paramedic than EMT provider areas with 8.4% and 1.3% mortality reduction respectively, a six fold improvement.[8]

EMS

The use of prehospital health care providers to intervene in acute cardiac emergencies has historically been a focus of emergency care. However, Dean reported on the outcome of 134 patients who received mobile paramedic unit care compared to control patients without paramedic intervention demonstrating no change in outcome by multiple logistic regression analysis.[9] Defibrillation was the only helpful intervention identified, but added a 29 minute delay to hospital arrival, possibly negating the benefits suggesting the need for more streamlined care.

Later, Shuster went on to evaluate 15 prehospital studies over the early years of emergency medical care suggesting no benefit of prehospital administration of any of a number of commonly administered prehospital medications.[10] However, there were no studies that examined such widely utilized agents as albuterol, bicarbonate, bronchodilator agents, diazepam, dobutamine, dopamine, glucose, isoproterenol, naloxone, or nitrous oxide for prehospital efficacy.[11]

Paramedic effectiveness has been evaluated using Advanced Cardiac Life Support (ACLS) intervention as a benchmark with a 91% success rate for obtaining intravenous access, or endotracheal intubation. However, drug administration was only consistent in 43% of standardized recommendations by intravenous route and 37% by endotracheal route.[12] Stricter compliance with national ACLS guidelines and facilitated extended refresher training may improve effectiveness on prehospital cardiac life support. Four factors are related to the ability to successfully resuscitate prehospital arrest patients, which include time to starting rescue procedures, use of electrical defibrillation, accuracy of BLS technique and ventilatory efficacy with greatest emphasis placed upon time until resuscitation.

The "early defibrillation" controversy has once again raised interest in utilization of first responders or Emergency Medical Technicians (EMT) in a two tier response system to maximize efficiency. Wilson evaluated 126 patients whose care was limited to basic life support including mask oxygen, IV fluids, closed chest massage, and artificial respiration.[13] The survival rate was 22% (28) to hospital admission and 9% (11) to hospital discharge, with a favorable prognosis group identified to include those with initial rhythm of ventricular fibrillation or tachycardia in 14% (7 of 50), initial blood pressure > 90mmHg systolic and pulse rate >50 bpm in 50% (3 of 6). However, a crucial point of distinction was that if patient was in cardiac arrest, than no intervention including CPR could change outcome.

Prehospital Clinical Predictors

Since well designed prehospital outcome studies are few, prehospital predictors of outcome may potentially be inferred by the analysis of animal experimental data. Angelos evaluated a ten minute ventricular fibrillation (VF) accompanied by a five minute Basic Life Support (BLS) resuscitation model to identify improved coronary perfusion as a factor in the normal neurologic outcome group, and CPP appeared to be an independent predictor of favorable outcome.[14] The author has performed a similar trial in brief (five minute), moderate (ten minute), and prolonged (15 minute) canine VF model to also identify improved coronary (CPP) and systemic (MAP) perfusion pressure as favorable outcome predictors found to be associated with improved survival and neurologic outcome.[15]

Paradis performed in a study where the coronary perfusion pressure (CPP), which was quantified as the aortic to right atrial pressure gradient during the relaxation phase correlated to the return of spontaneous circulation (ROSC).[16] In those patients with ROSC, the initial CPP was increased (13.4 vs. 1.6 mmHg), as was the maximal CPP obtained (25.6 vs. 8.4 mmHg). They found that only those with a CPP > 15 mmHg had ROSC, although not all 75% (18 of 24) of those with adequate coronary perfusion were successfully resuscitated.

Brison's demographic analysis included the cardiac resuscitation experience of 1510 cardiac arrest patients where 92% of patients were 50 years of age, 68% were male and 79% of arrests occurred at home.[17] The average ambulance response time in witnessed events was 7.8 minutes correlated to an overall survival rate of 2.5%. Factors predicting survival include age, ambulance response time, whether CPR started before ambulance arrival, but interestingly was not related to early defibrillation.

Tresch evaluated a population of 381 cardiac arrest patients comparing older and younger (< 20 years) cohorts, who have undergone paramedic witnessed cardiac arrest.[18] The elderly patient cohort more commonly had a past history of heart failure (25 vs. 10%), was commonly taking digoxin (40 vs. 20%), diuretics (35 vs. 25%), and was more likely to complain of dyspnea (53 vs. 40%). Younger patients were more likely to complain of chest pain (27 vs. 13%) and more often presented in ventricular fibrillation (42 vs. 22%). Interestingly, the patients' chief complaint often correlated with initial rhythm, where 68% of those with chest pain demonstrated a ventricular fibrillation event compared to 21% of those with dyspnea. Although, there were equivalent initial resuscitation rates in the elderly, their survival to discharge was decreased comparatively (24 to 10%).

Survey data offered by Ng concerning 105 younger arrest patients from 1 to 39 years found a male predominance (62%), event secondary to cardiac disease (38%), due to artherosclerotic heart disease in 50% and secondary to toxic exposure in 21%.[19] The most common presenting rhythm was ventricular fibrillation in 45% associated with a 48% resuscitation rate with over one quarter of the post resuscitation patients progressing to long term survival. Favorable outcome was predicted by the arrest being witnessed, or associated with primary cardiac dysrhythmia; while asystole was a negative prognostic indicator and age, sex, race, bystander CPR, and paramedic response time were not significant prognostic factors affecting long term survival.

The effect of an extended EMS training program on cardiac arrest survival was evaluated in 1196 patients by Wright, where the majority of cases 62% (740) presented in EMD or asystole, while 38% (456) presented in ventricular fibrillation.[20] As expected the survival rate in those who presented with asystole was dismal 0.1% (1 of 740). Factors associated with the likelihood of presenting in ventricular fibrillation include age < 71 years, witnessed arrest, bystander resuscitation, public arrest, and ambulance response time <6 minutes. While improved outcome was associated with shorter response time, but not bystander CPR, the newly acquired skills provided by EMS training were used in 78% of patients.

Outcome of Prehospital Cardiac Arrest

Clearly, there are widely discrepant rates of survival in hospital compared to prehospital cardiac arrest events. Rosenberg evaluated 300 hospitalized patients demonstrating a 54% initial post-CPR survival followed by 23% survival to hospital discharge.[21] Predictors of good resuscitation outcome include an initial ventricular tachycardia or fibrillation rhythm, and brief duration of CPR<30 minutes.

Prehospital survival was suboptimal compared to in-hospital events due to inherent logistic considerations. Roth reported on 187 cases of out-of-hospital arrest where an improved outcome was noted based on initial rhythm—VF/VT (15%) compared to other rhythms-including asystole, idioventricular (IVR), atrioventricular block (AVB), and electromechanical dissociation (EMD) (3%), as well as with bystander CPR improving survival to 24% in VF/VT and 0% in other rhythms.[22]

Secondly, response times of less than four minutes resulted in improved survival to discharge in 7 increased to 23% of VF/VT events, and 7 increased to 30% of other arrhythmic events.(13) Likewise, the use of bystander CPR improved outcome from 23 to 42% in VF/VT and 7 to 15% survival when ACLS providers arrived within four minutes. [20]

Similar survey data from Valenzuela's 372 prehospital patient study demonstrates a 20% survival rate to hospital admission and 6% survival to discharge.[23] This rate was improved to 26% for hospital admission and 10% for hospital discharge in witnessed events for all arrhythmic events; and 38% and 15% respectively for witnessed ventricular fibrillation.

Bonnin evaluated a 181 patient group where only 6% (10) who failed prehospital resuscitation survived to hospitalization, but only 0.6% (1) were discharged neurologically intact; with gender as the only predictive correlate.[24]

Van der Hoeven conducted a retrospective chart review of 309 adult patients where 13% survived to hospital discharge with favorable prognosis associated with the event being witnessed at time of arrest, short call response interval, initial cardiac rhythm of VF or VT and the provision of appropriate ACLS care.[25] The crucial point is that improvement of all aspects of the "prehospital chain of survival" is likely to result in better outcome if directed toward earlier intervention.

Arrest Outcome Prediction Variables

Standardization

It has been recommended that standardized case and survival definitions be adopted to improve the external validity of cardiac arrest trial comparison. [23] The Utstein II recommendation on data recording dictate using the template approach to record time points and intervals, individual clinical data and description of EMS systems and is the most widely recognized technique.[26] However, these recommendations are largely ignored as the complexity of analysis and recording preclude implementation by field medics.

Arrest Time

An important consideration in outcome prediction in adult prehospital cardiac arrest is the time until definitive resuscitation intervention is begun. One such measure is scene time (ST) evaluated by Spaite in 298 patients.[27] Here, only a minority (27%) of patients had ST<12 minutes, but they were more likely to have return of spontaneous circulation (ROSC) 26% vs. 15%; and were more likely to survive 13 vs. 6% compared to those on scene for more prolonged periods of time.

However, demographic analysis of prehospital arrests found deficiencies in documentation with reports filed on 89% of patients with VF as the first recorded rhythm in 52% progressing to asystole or EMD in 86%, yielding a 2% survival to hospital discharge. [12] They reported a median time to Basic Life Support (BLS) of six minutes, call to response time of eight minutes, call to Advanced Life Support (ALS) time of ten minutes, and scene time of 15 minutes for emergency medical technicians and 31 minutes for paramedics. The obvious question is the cost to benefit ratio of a two fold increase in paramedic to EMT scene time.

Likewise, survival to hospital discharge has been clearly related to time until therapeutic intervention. Both the periods from collapse until initiation of BLS (3.6 vs. 6.1 minutes) and time until delivery of first defibrillation (4.3 vs. 7.3 minutes) were shorter in survivors, as well as a trend to improved projected survival using an early defibrillation linear regression model (3% to 28%).[28]

Urban vs. Suburban Location

The scope of the urban paramedics practice has been well described noting differences in practice of airway management, defibrillation, volume administration, medications, and medical command utilization.[29] Efficiency analysis finds that a limiting factor in resource utilization of a rural EMS is the availability and efficacy of emergency departments, as opposed to critical care bed availability as the rate limiting step in more urban environments.[30]

Educational issues need be specifically defined for rural sites. Birnbaum evaluated the educational needs of 461 health care providers in rural sites and only 39% or nurses and 64% of physicians correctly identified third degree block; while one third of nurses and 22% of physicians did not identify coarse ventricular fibrillation suggesting the need for additional definitive ACLS training programs in rural sites.[31]

There may also be a trend in survival based on locale of arrest; as a densely populated urban environment has been suggested to be associated with worsened outcome compared to smaller communities. One possible explanation may be the paradoxical increase in response and scene time noted in cities with the shorter distances offset by greater traffic congestion, resulting in increased transport time in cities.

Becker reported the results of cardiac events in Chicago with over three million inhabitants, where 91% of patients were pronounced dead in the ED and 7% died in hospital, leaving only 2%, who survived to hospital discharge.[32] The PHASE (PreHospital Arrest Survival Evaluation) study evaluated 3,243 consecutive cardiac arrest patients with an overall survival of 1.4% (99% CI, 0.9-2.3%) improving to 5.3% (99% CI, 2.9-8.8%)with witnessed cases.[33] However, this rate of survival was significantly lower than reported in mid-sized suburban/urban areas (33%, 99%CI 3.4-35.6%, $p<0.0001$) and suburban/rural areas (12.6%, 99% CI 8.9-16.3%, $p<0.001$). More moderate sized sites (>100,000 + population) that were analyzed suggest from a 279 patient group that a 4.0%overall and 5.8% witnessed arrest hospital discharge rate was observed.[34]

Therefore, there is wide ranging variability in reported prehospital arrest survival rate suggesting the need for standardization of the arrest model, the population and intervention provided to allow valid comparison between studies.

Our own experience with EMS response classified according to population density found that our overall emergency department survival in 372 patients was 15% and survival was improved for urban (23%), compared to suburban (14%), and rural (9%) sites.[35] These findings appeared to be independent of response time with the most rapid response measured as ACLS time in suburban locales (6.9 ± 5.2 min.), compared to urban (8.7 ± 5.6 min.) and rural locations (10.6 ± 7.3 min.). Additional explanation of this finding may be offered by examination of patient groups for severity, as well as the provider education and expertise in different locations.

Bystander CPR

It is commonly assumed that patients who have bystander CPR (ByCPR) provided early in arrest have improved outcome. However, Troiano in a retrospective analysis of 138 prehospital cardiac arrest survivors found no difference in outcome with 55-58% of patients who recovered in the minimal disability category demonstrating no positive correlation to provision of bystander CPR.[36]

Education is a prominent component of any prehospital care plan. Dracup prospectively evaluated instruction in ByCPR in 83 families of high risk cardiac patients and found an 81% rate of successful instruction of these family participants.[37]

Bystander vs. EMS First Responder CPR has also been a point of comparison to evaluate efficacy resuscitation. Swor performed a retrospective cohort analysis of 217 cardiac arrest victims where 71% (153) received bystander CPR and 29% (64) received First Responder CPR where the actual incidence of bystander CPR performed may be lower than expected, found to be provided in only 11% in a series of 100 patients.[38]

The impact of the interval between cardiac arrest and ByCPR has not been established. Martens evaluated 1195 patients where good outcome and prolonged survival (9.7%) was associated with the occurrence of ROSC (22.7%).[39] The mean time between emergency call and layperson CPR was 2.5 ± 0.1 minutes with delay until intervention is a crucial factor associated with worsened outcome.

The prevalence of bystander CPR in Bossaert's analysis of 3053 arrest patients was 33% (998) and was performed by lay persons in 41% (406), 18% (178) by family members, 23% (228) by other lay people, and healthcare professionals in 59% (592), as well as being performed predominantly by physicians in 86% (506) and nurses in 19% (86).[40] Interestingly, ByCPR is nearly as often performed by health care professionals as laypersons.

Common clinical scenarios encountered suggest that family members and laypersons more often applied CPR to younger victims, those found at public places, roadside, and in the work place, where SIDS and drowning figured predominantly as clinical scenarios; while health care professionals performed CPR on older patients and in public places. However, those whose arrests were caused by trauma/hemorrhage and intoxication were less likely to receive this intervention. There appears to be a late survival benefit conferred by ByCPR, where these events are more frequently witnessed and have shorter access time to EMS, also associated with decreased BLS and ACLS time. Likewise, in those with unwitnessed arrests early and late survival are significantly improved in those receiving ByCPR. This was a glowing endorsement of ByCPR with effects most significant in those cases with prolonged (ALS > 8 minutes) response time, while furthermore no effects of suboptimal CPR were noted.

However, Troiano evaluated 138 ByCPR patients and found no difference in any functional level measured as the cerebral performance category scale (CPC) with most patients in the minimal disability group (Grade 1) 55-58%, followed by moderate (Grade 2) 24-18%, severe (Grade 3) 16-16%, vegetative (Grade 4), brain dead (Grade 5) 3-8% groups with and without bystander CPR, respectively.[41] Clearly, the results were underwhelming regarding the benefits of byCPR with little beneficial difference in outcome or in some cases actual worsening was noted in the ByCPR group.

Our group has evaluated the effect of bystander CPR in prehospital survival in 488 patients with an overall survival rate of 16%.[42] Improved survival was noted in witnessed arrest (58%) with a three fold increase (23%) increase in survival. However the presence of bystander CPR (36%) did not correlate with improved survival raising questions of efficacy. Perhaps, this lack of improvement is related to the quality of CPR provided.

Early Defibrillation

The use of early defibrillation has been assumed to improve outcome. White's data on 44 patients in VF with 14 (32%) initially treated by police, where 7 (50%) were resuscitated and 10 (71%) were subsequently discharged home, suggests a significant beneficial effects.[43] There was also a significant difference in timing of intervention with 911 call-shock time interval of 4.9 ± 1.3 minutes for those with ROSC compared to 6.1 ± 0.7 minutes for those without response, which supported this assertion.

The demographics of urban First Responder defibrillation have been reported by Callaham for 265 patients, where 65% converted from VF and 42% of all stable conversions were defibrillated only once.[44] Most defibrillation occurred by six minutes in 70% and ten minutes in 23% with the proportion of stable arrhythmia conversions decreasing from 30% on first conversion attempt to 2% on fourth attempt. In addition, the development of adequate pulse and blood pressure less likely in refractory cases. However, patients are likely to refibrillate even after successive conversion, warranting additional therapy.

Cobbe performed a comparison to monitor controls after implementation of an AED program where 1,111 cardiac arrests were encountered and defibrillation was undertaken in 54% (602) with ROSC in 30% (180) and a 12% (75) survival to discharge.[45] As expected, survival was inversely related to delay from onset of cardiac arrest to time of first shock and greater in the case of witnessed arrest. Witnessed VF in presence of EMS personnel offered the best outcome with 33% survival.

Analysis of early defibrillation data suggests that those who present without a pulse, lack of respiration with arrival of ambulance personnel, no bystander CPR, more than 15 minutes from time of arrest and who presented with an unshockable rhythm were found to have no chance of survival (0%) in Marsden's series of 414 patients.[46]

Our experience with 294 cardiac arrest patient suggests survival was improved with decreased time to ACLS intervention (7.2 vs. 9.6 minutes), or transport time (37.3 vs. 41.9 minutes), and in fact there were no survivors associated with ACLS time was over 25 minutes.[47]

Long Term Outcome

Ongoing resuscitative efforts after failed prehospital attempts have largely been unsuccessful in achieving long term recovery. Kellerman reported on 281 consecutive patients following failed prehospital ACLS attempts presenting predominantly in asystole (51%) and VF/VT (29%) with a 13.3% rate of ED survival and 1.7% rate of hospital discharge with two prehospital survivors re-arresting while two hospital survivors left the hospital with severe neurologic deficits.[48] Lewis similarly reported on a group of 243 patients, where 13% (32) arrived with ROSC and 21% (7) were discharged neurologically intact; compared to 87% (211) of patients who were pulseless where only 0.4% (1) were discharged without neurological dysfunction.[49]

The presence of ROSC is a significant outcome predictor in this setting. Kellerman reported their experience with 1,068 patients where only 29% had ROSC, but when it occurred they were more likely to be admitted (69 vs. 7%) and to be subsequently discharged alive (26.5 vs. 0.4%).[50] However, there was a poor outcome cohort where 0.3% (3 of 758) patients who survived to hospital discharge had moderate to severe disability.

A similar analysis was performed by Bonnin in an attempt to determine criteria for advanced life support termination, such as pulselessness. Bonnin found a 25% rate of resuscitation all patients achieved within 25 minutes in 1,491 consecutive cardiac arrests, but only 0.6% (6) of 95% without pulses survived after persistent VF.[51] They concluded that excluding persistent VF in those who undergo normothermic unmonitored out of hospital primary cardiac arrest without resuscitation success within 25 minutes of effort may have resuscitation attempts safely curtailed, as the likelihood of acceptable neurologic outcome becomes nonexistent.

The long term survival after prehospital cardiac arrest was related by Myerburg in an eight year study of 61 patients with overall survival of 39% (61).[52] Subsequent deaths were a result of recurrent arrest in 66% (16 of 24) cases occurring at average 27.5 ± 19.7 months from the time of study entry with life table analysis demonstrating a 10% rate of recurrence of cardiac arrest in first year followed by 5% rate per year for the next three years. However, the left ventricular ejection at entry was not significantly different between survivors (45.3 ± 13.6%) and non-survivors (37.5 ± 12.6%), but the ejection fraction was significantly lower in patients who died from causes other than recurrent cardiac arrest (24.5 vs. 42.7%).

Cumulative survival was 3.8% from pooled data from a group of 3,083 prehospital cardiac arrest patients (Table 1) [48,49,50,51]

Survival

Study	Patients	Pulses	ED	Hospital	Overall
Kellerman	281		13.3%	1.7%	1.7%
					(5)
Lewis	243				
ROSC		13%(32)		21.7%(7)	3.2%
Absent		87%(211)		0.4%(1)	(3)
Kellerman	1068				
ROSC		29%(309)	69%(213)	26.5%(82)	7.9%
Absent		81%(759)	7%(53)	0.4%(3)	(85)
Bonnin	1491				
ROSC		5%(74)		25%(18)	1.7%
Absent		95%(1417)		0.6%(8)	(26)
Schoenenberger	141		35%(49)	13%(18)	13%
Witnessed					(18)
Cumulative	3220				137
					4.2%

Table 1: Survival From Prehospital Cardiac Arrest

Neurologic Recovery

However, others have found slightly more optimistic long term outcome statistics. Schoenenberger retrospectively evaluated the case histories of 141 witnessed arrest patients, where 65% died in the ED, while 35% were resuscitated and admitted.[53] However, 13% (18) survived until discharge where the majority (16) demonstrated no or mild neurologic impairment and most (17) were alive one year later. Good prognosis was found to be associated with bystander CPR, short interval to onset of resuscitation and ventricular fibrillation as the presenting rhythm at emergency department entry.

Abramson as part of the Brain Resuscitation Cerebral Time study group defined outcome based on time of arrest (AT) and time of CPR (CPRT).[54] In 262 comatose patients, they found that the combination of brief arrest time (<6 minutes) accompanied by short CPR time (<30 minutes) found the rate of recovery to normal or moderate disability was 50% compared to 3%, if the CPR was prolonged (>30 minutes). In patients, with prolonged arrest time (AT>6 minutes) and very brief CPR time (<5 minutes), a similar reasonable recovery is noted in 50% of patients. However, if CPR persists over 15 minutes, there is no (0%) chance of good recovery. Therefore, if patients have both a prolonged arrest time (>6 minutes) and CPR time (>15 minutes) all patients went on to have a poor outcome.

An early prediction model was developed by Longstreth from 389 patients to help forecast neurologic recovery.[55] The best model determined by discriminant analysis contained four admission variables: motor response, pupillary light response, spontaneous eye movements and blood glucose level over 300mg/dl upon awakening. The model's prediction of awakening had sensitivity of 92%, and specificity of 65% and may reliably predict outcome in some specific circumstances.

Cobbe evaluated 1,476 patients suffering prehospital cardiac arrest where 46% (680) were discharged alive.[56] The median hospital stay for survivors was 10 days compared to nonsurvivors of one day stay with normal or mild impairment on discharge status in 89% (605), moderate impairment in 8.5% (58) and severe impairment in 2% (13), with one comatose patient. Overall, there was four year survival after hospital discharge of 68%. Therefore, 40% of initial cardiac arrest survivors are discharged without significant disability, but are at risk for sudden cardiac death in 46% of cases (81 of 176).

VanHoeyweghen performed a retrospective evaluation of 2,713 arrest patients discharged with poor outcome patient profiles.[57] Those with EMD or asystole 14% (405 of 2,713) on paramedic arrival, with absent pupillary response and inefficient cardiac massage have 0% (0 of 405) chance of survival, compared to those 50% (1,373 of 2,713) with efficient CPR with 1.9% (27 of 1,373) survival. Those asystole patients with a pupillary light response 8.7% (236 of 2,713) have a 17.8% (42 of 236) survival rate. Cardiac arrests presenting with VF 25.7% (699 of 2,713) have a 17.0% (119 of 699) long term survival, with gasping noted as an additional positive prognostic factor. The recommend a 30 minute resuscitation in asystole and 45 minute in VF, after which further intervention is no warranted due to lack of meaningful survival.

More subtle signs of cognitive impairment have also been investigated. Sauve completed longitudinal neuropsychologic testing in 25 patients between 3 and 25 weeks post arrest event demonstrating 72% of patients are left with mild to severe cognitive impairment.[58] Even six months after the event 29% had impairment specifically including delayed recall, deficits in retention and recall. Good outcome was also inversely proportional to the time until awakening.

Similar results were also reported by Earnest who analyzed a survivor cohort of 32% (38 of 117) out of hospital arrest patients three and one half years after the event.[59] There were 53% (20 of 38) patients still living with 53% resuming independent social activities, but only 32% who returned to work, although 57% (8 of 14) tested normally in limited psychiatric testing. Satisfactory long term outcome was associated with the patient being awake on admission, and able to follow simple commands at two days being associated good neurologic status at time of hospital discharge. However, no patients with poor neurologic function at discharge were found to have successfully resumed working or independent living. Overall good outcome is found in 86% (44-89%) of patients, mild impairment in 10% (8-44%) and severe impairment in 3% (2-36%) of a survivor cohort pooled from 1679 arrest patients. (Table II) [52, 56,58,59]

			Improvement:		
Study	Patients	Discharge	Normal	Mild	Severe
Schoenenberger	141	13%	44.4%	44.4%	
Witnessed		(18)	8	8	
Cobbe	1475	46%			
		(680)	89%	8.5%	2%
			(605)	(58)	(13)
Sauve		(25)		36%	36%
				(9)	(9)
Earnest		(38)	57.1%		
			(22)		
Cumulative	1679	761	86.7% (635)	10.2% (75)	3.1% (22)

Table 2: Neurologic Recovery After Prehospital Cardiac Arrest

Testing

Attempts have been made to further quantify and predict the likelihood of survival after prehospital arrest utilizing noninvasive testing. The best results were obtained by demonstration of brain lactate in magnetic resonance imaging, and absent N2O waves in short latency somatosensory evoked potentials, which correlated with the duration of anoxia, as well as being associated with worsened prognosis.[60] Electroencephalography (EEG) has also been utilized to delineate outcome and recovery profiles. Rothstein evaluated 40 patients with hypoxic-ischemic coma, where the bilateral absence of control evoked potentials (SSEP) and/or malignant EEG change reliably predicted unfavorable outcome in 81% (21 of 26) patients.[61] Most patients did not recover with only 35% (14) who awakened, where 13% recovered completely and 23% had varying cognitive improvement, but SSEP and EEG findings did not distinguish between these outcomes.

A multidiagnostic panel protocol was implemented for use after hypoxic ischemic come in 32 patients by Edgren.[62] Good outcome, defined as resuming an independent life style within six months were correlated with CSF lactate (78%) at 24 hours and modified Coma Score (96%) the Glasgow-Pittsburgh Coma Score (94%) , and EEG (77%) at 48 hours. The absence of motor withdrawal to noxious stimuli was specific with a 100% association with adverse outcome, although not sensitive with absence of movement not necessarily precluding good prognosis.

Therapeutic Intervention Strategies

Additional outcome information is gathered from evaluations of the efficacy of various therapeutic intervention strategies. Roine reported the results of a double blind trial of nimodipine in 155 (23%) patients successfully resuscitated from 677 attempts.[63] Three months post cardiac arrest 60% (41 of 68) were found to have moderate to severe cognitive deficits with 48% not improved by 12 months and the presence of depression in 45% (22) and severe depression noted in 24% (12) of patients.

Few studies have examined the role of sodium bicarbonate on outcome from cardiac arrest. Delooz noted an inverse relationship at constant CPR time between amount of sodium bicarbonate infused and regaining consciousness at 14 days post CPR.[64] Although low versus high bicarbonate dosage has no influence on immediate success on resuscitation. Use of lower doses of bicarbonate (<1 mEq/kg) are associated with improved cerebral function compared to excessive doses.

Summary

There are numerous prehospital factors that are associated with cardiac arrest survival (Table 3). However there are a few well designed controlled evaluations of the effect of one variable on outcome. Generally speaking, it appears that favorable EMS factors include response time, bystander CPR, paramedic effectiveness, the presence of witnessed arrest, interventions such as early defibrillation; brief duration of arrest; and brief scene time.

	Outcome Favorable	No Correlation	Adverse
EMS			
	Paramedic Response Time [7, 12, 17, 47, 53]	19	
	Bystander CPR [7, 20, 46, 53]	19, 36, 41, 42	
	Paramedic Effectiveness [8, 12]	9	
	Witnessed Arrest [19, 23, 42, 45]		
	Intervention		
	Defibrillation [7, 43, 44]		
	Prehospital Medications [37]	10	
	Duration Brief [12]	21	
	Scene Time [27]		
	Location: Urban [35]		Urban 32
Cardiovascular Parameters			
	Rhythm		
	Ventricular Fibrillation/Tachycardia [12, 21, 22, 53]		Brady-Systolic [12]
	Primary Arrhythmia [19]		Asystole [20, 57]
	Cardiovascular parameters		
	SBP > 90mmHg [13]		No Pulse [46]
	HR > 50bpm		No Respirations [46]
	ROSC [50]		
	Coronary Perfusion		
	Coronary Perfusion Pressure (CPP) [16]		
	Initial > 15.mmHg		
	Maximal > 25.6mmHg		
Patient Profile			
	Patient Demographics		
	Younger Age 17	Age 19	
	Gender 24	Race 19	
		Sex 19	
Arrest Time			
	Arrest Time < 6 minutes [54]		
	CPR Time < 15 minutes [54]		
	Resuscitation		
	Asystole < 30 minutes [57]		
	VF/VT < 45 minutes [57]		
Physical Exam			
	Motor Response [55, 62]		
	Pupillary Light Response [55, 57]		
	Spontaneous Eye Movement [55]		
	Gasping Respirations [57]		
Testing			
	Glasgow Coma Score (GCS) [62]		

Table 3: Prehospital Factors Associated with Cardiac Arrest Survival

Elevation CSF Lactate [60]	SSEP
Short Latency (N_2O)[60]	
Malignant EEG [61]	

Cardiovascular parameters that are correlated to improved outcome include ventricular fibrillation; tachycardia or a primary arrhythmia; a systolic blood pressure greater than 90mmHg and a heart rate of greater than

50bpm, as well as ROSC associated with a CPP greater than 15mmHg.

Physical exam factors associated with improved outcome include motor response after arrest; some pupillary light response; spontaneous eye movement; and gasping respirations. These can be quantified as the Glasgow Coma Score.

Likewise, adverse prognostic factors include a brady systolic or asystolic arrest, absence of pulses, as well as absence of respirations on caregiver arrival. Sophisticated testing may be used to clarify adverse prognosis based on elevated CSF lactate, somatosensory evoked potentials (SSEP) of short latency, and an abnormal EEG pattern.

Perhaps most importantly, arrest time can be used to predict the outcome with an arrest time less than six minutes, CPR time less than 15 minutes, and resuscitation time for asystole of less than 30 minutes and VF/VT less than 45 minutes associated with some chance of good outcome. Arrests that persists much past these parameters are often associated with an unfavorable neurologic outcome or moderate disability, if indeed recovery occurs.

Conclusion

The emergency medicine literature is replete with studies evaluating specific resuscitation interventions, such as drug therapy, CPR technique, early defibrillation, or hypothermia in the prehospital cardiac arrest setting targeted to a survivorship endpoint.

However, due to sample size limitations, evaluation of functional outcome has not proven to be a prominent primary study end point. Additional limitations include the fact that it is difficult to control study environment to a single variable manipulated throughout the prehospital, emergency department, and intensive care unit areas or in the post resuscitation phase with multiple care providers and interventions involved in care.

Therefore, most analysis are limited to conclusions drawn from observations concerning outcome as secondary endpoints, or posthoc survival analysis with multiple therapeutic interventions, across diverse treatment environments vastly diluting their validity. Currently, prospective single variable trials are contemplated controlling the resuscitation milieu from field to ED to ICU.

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