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EMS-WITNESSED CARDIAC ARREST

Descriptive epidemiology, predictors of survival, and survival comparison with bystander-witnessed cardiac arrest

by

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ABSTRACT

Statement of the Problem

Cardiac arrest is the leading cause of death in Canada, yet it remains a problem with extremely poor prognosis. The prehospital response to cardiac arrest is critical since the majority of these events occur in the community, prior to the patient being transported to hospital. The number of people affected and the overall economic impact make prehospital cardiac arrest a major national health care problem. Educating and training both health professionals and lay persons about how to manage this problem is of paramount importance. Hence, identifying and understanding the science of prehospital cardiac arrest to aid in the implementation of effective response regimens is necessary.

Cardiac arrests that occur after the arrival of trained emergency medical services (EMS) personnel (either ambulance or firefighters) may be a particularly homogeneous subgroup in which to assess not only mechanisms of cardiac arrest, but also the effectiveness of prehospital systems, and thereby contribute to our current understanding of the cardiac arrest condition.

Objectives

The objectives of this study are threefold: 1) to elucidate the epidemiology of EMS-witnessed cardiac arrest in Ontario in terms of demographics, EMS-system and clinical characteristics, and rates of incidence and survival; 2) to determine predictors of survival to hospital discharge in this group; and 3) to compare outcomes among EMS-witnessed and bystander-witnessed cardiac arrest.

Methods

This observational cohort included all adults suffering a witnessed cardiac arrest (by EMS or bystander) in the 21 urban/suburban communities of the large Ontario Prehospital Advanced Life Support (OPALS) Study. During the study period, the system provided a basic life support with defibrillation (BLS-D) level

of care, but no ALS. All case and survival definitions follow the Utstein style. Descriptive statistics were used to characterize EMS-witnessed cardiac arrest. Univariate procedures (Chi-square, t-test, Wilcoxon rank sum) were used to identify factors associated with survival to hospital discharge and these factors were further tested using multivariate logistic regression to determine independent and significant predictors of survival. Further univariate analyses were undertaken for certain clinically important subgroups. Comparisons were made between EMS and bystander-witnessed cases and were tested using univariate analyses. Logistic regression methods were used to adjust survival among EMS-witnessed and bystander-witnessed cases using those covariates found to be significant predictors of outcome. Finally, further subgroup comparisons were made between EMS-witnessed and bystander-witnessed cardiac arrest.

Results

From January 1, 1991 to December 31, 1996, there were 9,072 cardiac arrest cases. Of these, 610 (6.7%) were EMS-witnessed and 4043 (44.6%) were bystander-witnessed. EMS-witnessed patients were predominantly males (60%) having a mean age of 70 years. Of these cases, 82% had a relevant cardiac or respiratory medical history, and 91% were known to have experienced prodromal symptoms prior to calling EMS. As a result of initial symptoms (i.e., chest pain), 9% of patients had taken nitroglycerin prior to EMS arrival. Upon arresting, an initial rhythm of pulseless electrical activity (PEA) was present in 50% of the patients, ventricular fibrillation or ventricular tachycardia (VF/VT) in 34%, and asystole in 16%. EMS procedures indicated that 13% of patients received immediate precordial thump after becoming pulseless, and that 35% of cases received defibrillatory shocks. Overall survival to hospital discharge for EMS-witnessed arrest was 12.6%. Multivariate analysis indicated that the following factors were significantly and independently associated with survival (OR with 95% CI): initial rhythm of VF/VT 20.7 (9.8, 43.7), prodromal symptoms of chest pain 2.5 (1.4, 4.5) or shortness of breath 0.5 (0.3, 1.0), use of nitroglycerin prior to EMS arrival 2.3 (1.2, 4.5), and unconsciousness on EMS arrival 0.5 (0.2, 0.9). Survival subgroup analyses indicated that more patients survived VF/VT versus other rhythms (34.2% vs. 2.4%, $p<0.0001$), and patients experiencing chest pain were more likely to survive than those with shortness of breath (30.3% vs. 6.3%, $p<0.0001$). Further subgroup comparisons indicated that chest pain patients were more likely than shortness of breath patients to experience VF/VT (62% vs. 17%, $p<0.0001$), whereas, shortness of breath patients were more likely to suffer PEA (61% vs. 33%, $p<0.001$) or asystole (22% vs. 5%, $p<0.001$).

Compared to bystander-witnessed cardiac arrests, EMS cases were more likely to be female (40% vs. 30%, $p<0.001$) and older (70 vs. 68 years, $p<0.001$). The proportion of patients in VF/VT was much lower for EMS-witnessed cases (32% vs. 51%, $p<0.001$), which was offset by a much higher rate of PEA (47% vs. 22%, $p<0.001$). Consequently, fewer patients received defibrillatory shocks in the EMS-witnessed group (35% vs. 56%, $p<0.05$). The median response and on-scene time intervals were longer for EMS-witnessed cases (respectively, 6.2 vs. 6.0 minutes, $p<0.05$; and 13.0 vs. 10.0 minutes, $p<0.0001$). Survival to discharge was greater for EMS-witnessed, both overall (12.6% vs. 6.3%, $p<0.001$), and for VF/VT (34.2% vs. 11.2%, $p<0.001$). Upon adjusting for other independent predictors of survival, the EMS-witnessed patient was over two and a half times more likely to survive than a bystander-witnessed case (OR=2.6; 95% CI=1.9 to 3.4).

Conclusions

This constitutes the largest series of EMS-witnessed cardiac arrest cases yet studied and clearly indicates that EMS-witnessed cases are a unique cardiac arrest group with better survival outcomes than other prehospital cardiac arrest groups. These patients initially present to the EMS system with prodromal symptoms and many have a known history of cardiac or respiratory disease.

It is apparent that two very distinct groups exist within the EMS-witnessed cardiac arrest population: those patients who experience initial symptoms of chest pain and those with shortness of breath. Differentiating between these symptoms may be a simple way of determining underlying mechanisms prior to patient collapse. Chest pain patients are more likely to take nitroglycerin prior to EMS arrival, suffer an initial arrest rhythm of VF/VT, and have associated higher survival rates. These patients are likely experiencing myocardial ischemia or infarction, whereas shortness of breath patients likely suffer the more severe effects of acute pulmonary edema or heart failure. Although these underlying mechanisms of arrest can not be modified, more aggressive treatment of symptomatic patients in the prehospital setting with oxygen, nitrates and other medications, may lead to decreased cardiac arrest mortality.

EMS-witnessed cardiac arrests benefit from immediate CPR and defibrillation and have dramatically better survival rates than bystander-witnessed patients. Survival from cardiac arrest occurring in the presence of EMS providers does not depend on the first two links of the chain of survival (rapid EMS access, bystander CPR). Instead, survival is largely dependent on the third and fourth links, rapid defibrillation, and Advanced Cardiac Life Support (ACLS). Because of this, EMS-witnessed cases may simulate the highest possible survival rates, and may be a surrogate for the effectiveness of an EMS system in managing cardiac arrest.

To my Father,
who taught me to never approach an important
question in any way but to ask everything.

To my Mom,
who has been my greatest champion.

In memory of *the Vision.*

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1. INTRODUCTION

1.1. Statement of the Problem

Cardiac arrest, the sudden cessation of breathing and circulation, is the leading cause of death in Canada, yet it remains a problem with extremely poor prognosis. The prehospital response to cardiac arrest is critical since the majority of these events occur in the community, prior to the patient being transported to hospital. The number of people affected and the overall economic impact makes prehospital cardiac arrest a major national health care problem. Educating and training both health professionals and lay persons about how to manage this problem is of paramount importance. Hence, identifying and understanding the science of prehospital cardiac arrest to aid in the implementation of effective response regimens is necessary.

Authors have suggested that cardiac arrests that occur after arrival of trained **emergency medical services** (EMS) personnel (either ambulance or firefighters) may be a particularly homogeneous subgroup in which to assess mechanisms and thereby contribute to our current understanding of the cardiac arrest condition.[1,2,3] The objectives of this study are threefold: 1) to elucidate the epidemiology of **EMS-witnessed cardiac arrest** in terms of demographics, EMS system and clinical characteristics, and rates of incidence and survival; 2) to determine predictors of survival in this group; and 3) to compare outcomes among EMS-witnessed and **bystander-witnessed cardiac arrest**.

1.2. Background

For centuries, medicine had fashioned its theories about **sudden death** on little more than intuition and inferential thinking. One of the world's first civilizations, the ancient Egyptians (2000 BC), provided the earliest evidence of an association between sudden death and certain signs and symptoms (pain and dyspnea).[4] Yet, it wasn't until the early 18th century that the first epidemiological study of this malady was undertaken.[4] Pope Clement XI appointed his physician Lancisi to study the apparently high occurrence of sudden death in Rome. In his writings, *De Subtaneis Mortibus*,[5] Lancisi endeavored to match anatomical conditions with clinical observations, and documented the first connection between heart disease and sudden death. Lancisi was also the first to recognize the role of smoking as an important risk factor for heart disease.

With coronary heart disease and acute myocardial infarction becoming the major focus for cardiac research in the mid 1900's, the emphasis on sudden death almost disappeared. It wasn't until the late 1960's, when Kuller[6] reintroduced the important relationship between heart disease and sudden death, and Pantridge[7] introduced the concept of the mobile coronary care unit, that the importance of sudden death as a research focus reemerged. Since then, there has been substantial literature debating the cause and prevention of sudden death. As we approach the 21st century, it is remarkable that much of our current understanding of sudden death, validated through technical diagnostics and rigorous methodology, reiterates many of the early observations made by scientists centuries before our time.

Today, heart disease has become, and remains to be, the leading cause of death in North America and most other industrialized countries. In the 1990's the mortality from cardiac disease has fallen to just less than 200 per 100,000 Canadians from more than 280 per 100,000 in the 1950's.[8] Although mortality due to cardiovascular disease is decreasing, the number of cases of cardiac arrest is increasing as the population ages. Death due to heart disease often manifests itself as sudden collapse: approximately half of the 54,000 cardiac deaths that occur in Canada each year are sudden.[8]

1.2.1. Definitions of Cardiac Arrest

Cardiac arrest is characterized as the absence of pulse and respiration (including agonal, gasping respirations) in an unresponsive individual. The definition of **sudden** cardiac death has been somewhat more elusive. In 1991, the Utstein group proposed a set of guidelines for universal prehospital cardiac arrest definitions.[2] Since the term "sudden death" has yet to be standardized and has acquired many meanings and varied usage in the literature, the **Utstein Style** proposes that no comment on time or "suddenness" be used in describing a prehospital cardiac arrest population.

Cardiac arrest has become the vanguard of EMS research: the most widely studied, and consequently, the most heavily scrutinized area in prehospital medicine. This may be, in part, due to the relative abundance and availability of cardiac arrest data, the ease with which study populations can be defined, or perhaps, the ability to introduce interventions in a uniform manner within well-established and monitored treatment protocols. Prehospital investigators are especially interested in cardiac arrests of cardiac origin. The exact cause of death for all cases of cardiac arrest is not generally possible as it would require considerable time and expense to obtain autopsy data and hospital records for all cases. As a result, classification in the prehospital research setting is inferred, that is, cardiac arrest of **presumed cardiac etiology** is implied in the absence of any clearly identifiable **non-cardiac** cause (terminal illness, drug overdose, suicide, drowning, hypoxia, exsanguination, cerebrovascular accident, and trauma).[2]

1.2.2. Mechanisms of Cardiac Arrest

For many years authors have relied on two broad groupings to represent the underlying pathology of cardiac arrest: mechanical and electrical failure.[4,9,10,11,12,13] This simplistic division reduces cardiac arrest mechanisms to two representative processes: pump problems, brought about by residual ischemia, thromboses or ventricular failure; or, impulse problems, resulting from abnormal electrical initiation, conduction or repolarization, and which may also be brought on by ischemia. Cardiac arrest is characterized by four main rhythm disturbances all of which are associated with the absence of cardiac output: 1) ventricular tachycardia (VT), an abnormal rapid rhythm originating from the ventricle; 2) ventricular fibrillation (VF), a chaotic rhythm originating from the ventricle; 3) pulseless electrical activity (PEA), the presence of some type of electrical activity associated with the absence of a detectable pulse; and 4) asystole, the absence of any electrical activity whatsoever.

Although either mechanism may lead to a fatal dysrhythmia causing cardiac arrest, the clinical scenarios preceding the terminal event are quite different. In mechanical failure, inadequate ventricular function may result from insufficient blood flow to the heart muscle which diminishes cardiac output and leads to hypotension, eventually manifesting itself as cardiogenic shock. Symptoms may differ depending on whether the patient suffers coronary insufficiency associated with myocardial ischemia or infarction, or cardiogenic pulmonary edema. Whereas, in electrical failure, the primary event may be a rapid-onset rhythm disturbance such as ventricular fibrillation, or ventricular tachycardia caused by conducting system abnormalities and may not be associated with prior warning symptoms.

Apart from the underlying mechanism, the stressed myocardium is susceptible to rhythm disturbances initiated by a number of possible stimuli. Such factors are thought to include autonomic disturbances, acute coronary thromboses, coronary arterial spasm, electrolyte or metabolic imbalances, physical or mental stress, and drugs.[4] In the presence of pre-existing structural, hemodynamic, or neurohumoral instability, these precipitating factors markedly increase the risk of sudden cardiac death.

Victims of cardiac arrest may collapse without warning or perhaps with brief or more prolonged symptoms such as chest pain, shortness of breath, sweating, nausea and/or general fatigue. Once the heart stops pumping, blood no longer flows to the brain. Subsequently, the victim rapidly loses consciousness (if not already so), and seizures, agonal (gasping) respirations and incontinence may follow.

1.2.3. Prehospital Response

Effective management of the cardiac arrest victim outside of the hospital involves the coordination of several elements best illustrated by "the chain of survival" concept.[14] The "chain of survival" identifies 4 components as vital links in improving the outcome of cardiac arrest: 1) early access to EMS which includes early recognition of a medical emergency, prompt activation of EMS by dialing the emergency-access telephone number, "911", and the subsequent rapid deployment of emergency personnel; 2) early initiation of basic cardiopulmonary resuscitation **(CPR)**, a repeated series of mouth-to-mouth respirations and chest compressions, by trained citizens or first responders to sustain blood flow to support temporary cerebral and myocardial viability, 3) early **defibrillation** by electrical shock to interrupt the abnormal electrical activity of the arrested heart muscle and to reestablish a normal spontaneous heart rhythm, and 4) early advanced cardiac life support **(ACLS)** which includes advanced airway management such as endotracheal or nasal intubation, as well as the delivery of cardiac arrest drugs.

Optimizing care at each level of the chain is believed to improve survival from prehospital cardiac arrest. Many communities across North America have invested considerable effort and resources into improving the links in their chain of survival; a practice that has seen recognizable differences in survival outcomes.[16] Optimization strategies have included: the introduction of expanded 911 programs for earlier EMS access; the promotion of educational curricula to both improve public knowledge in the recognition of a medical emergency, and to train citizens in basic CPR techniques; the improvement in EMS response times to medical emergencies; the implementation of first responder defibrillation programs; and, the addition of paramedics with advanced skills to the EMS system.[14]

1.2.4. Emergency Medical Services

EMS has come to play a critical role in the response, initial management, and rapid transport of cardiac arrest patients. EMS personnel include both ambulance and fire personnel who are trained to provide one of three general levels of cardiac care: basic life support **(BLS)** in which EMS personnel are trained in basic airway management, oxygen administration and basic CPR; basic life support with defibrillation **(BLS-D)**; and, advanced life support **(ALS)**, which includes intubation, intravenous therapy and drug therapy. In an ALS system, paramedics are capable of managing victims of cardiac arrest according to the standard Advanced Cardiac Life Support **(ACLS)** protocols set out in the American Heart Association (AHA) guidelines. [15] Control and quality assurance of designated medical acts such as defibrillation and ACLS are overseen by a physician director operating from a base hospital program.

The response to a cardiac emergency may be multi-layered. Friends, family members or bystanders are often the first persons on the scene and often witness the cardiac event itself. These individuals are sometimes trained in basic CPR. **Citizen CPR** rates vary from community to community with the current figure at about 14% for Ontario. [16] Depending on the level of care available in a community, the EMS system may include either a single or multi-**tiered response**. In a one-tier design, a single agency is responsible to attend to all medical emergencies. This may be either BLS, BLS-D or ALS, depending on the level of training available locally. A two-tiered system involves the dispatch of the closest and first available unit, whether they be **first-responder** fire, police or BLS EMT's, followed by a higher level of response (BLS-D or ALS). In some centres a third tier exists. In these centres the first response is by fire or police, which is closely followed by BLS-D personnel, and then finally by the arrival of ALS paramedics. Currently, most centres in Ontario have a two-tiered system, with local fire departments providing first response to medical emergencies.

1.2.5. The Ontario Prehospital Advanced Life Support (OPALS) Study

The relative improvement in cardiac arrest survival that may be attributed to each of the components of the prehospital response is not clear. Specifically, the incremental benefits of rapid defibrillation and ALS have on cardiac arrest survival are not known. In order to address these questions, the Ontario Prehospital Advanced Life Support (OPALS) study was launched in 1994. This is a three phase, multicenter, before-after clinical trial currently being conducted in 21 communities across the province. The study aims to assess the benefit in cardiac arrest survival and morbidity resulting from the addition of 1) rapid defibrillation, and 2) a program of full advanced life support (ALS). This study will be the largest out-of-hospital cardiac arrest study ever conducted and will compile a dataset which will include over 20,000 cardiac arrest cases by study completion in the year 2002.

1.2.6. Survival in Prehospital Cardiac Arrest

Despite the magnitude of this problem, and widespread study, current treatment of prehospital cardiac arrest yields relatively few survivors. Reported survival to hospital discharge for prehospital cardiac arrest in Ontario is approximately 4%.[16] Other reported system survival rates vary widely, from less than 2%[17,18] to 44%.[19] The disparity in these rates may be attributed to regional variances in patient, system and population demographics including, population age, size, density, geographic layout and topography, and local differences in the various components of the "chain of survival": public awareness (hence access to medical care and citizen CPR rates), EMS response rates, and level of EMS care.

Further survival rate variance can be attributed to differences in cardiac arrest case definitions (i.e., inclusion and exclusion criteria) and survival definitions (i.e., immediate resuscitation vs. longer term outcomes). Since the Utstein Style[2] was proposed, investigators have attempted to follow the Utstein style generating results that are more easily compared across studies.

1.2.7. Survival Subgroups

While the overall survival rate for cardiac arrest in Ontario and elsewhere is poor, certain subgroups exist that may have more favourable outcomes. It is well documented that patients with an initial arrest rhythm of ventricular fibrillation or ventricular tachycardia **(VF/VT)** sustain better survival outcomes.[20,21] As well, extensive literature exists to support the idea that rapid response times, witnessed status and, to a lesser extent, bystander CPR may also positively impact on survival.[1,20,21,22,23,24,25] Sub-groups may provide important clues for establishing mechanisms, understanding disease progression, and determining appropriate treatment regimens.

A specific subgroup of patients exists who, upon experiencing certain acute symptoms, access the EMS system and subsequently arrest in front of EMS responders. There may be no better place to test hypotheses and clinical interventions than in this group since time delays, presence of bystanders, and performance of citizen CPR, do not factor into the resuscitation effort. These EMS-witnessed cardiac arrest patients are the subject of this thesis.

2. LITERATURE REVIEW

Prehospital EMS-witnessed cardiac arrest articles were identified through a comprehensive search of Medline using various key descriptors and the names of authors known to have published in the field. The search period was from 1966 through 1997 and included all human study, English-language literature under the exploded and combined key words "heart arrest" or "cardiac arrest" and "EMS". To test the completeness of this search strategy, the names of several key authors were searched to ensure that the initial search had identified all of their relevant articles. A secondary hand-search was done from the reference lists of retrieved citations to check for previously unidentified articles discussing prehospital cardiac arrest in any form.

Cardiac arrest articles were categorized as review articles, editorials, and original reports. Original reports were identified if they included EMS-witnessed cardiac arrest as the primary study group of interest. Other studies that reported incidence and survival rates for EMS-witnessed cardiac arrest separately from the overall cardiac arrest group were also identified. The following literature review examines the surrounding issues and provides a detailed critique of the small set of reports that have exclusively studied EMS-witnessed cardiac arrest.

2.1. EMS-Witnessed Cardiac Arrest

Several authors have suggested that patients who arrest in the presence of EMS personnel represent a different group than those who arrest in front of lay-bystanders.[1,2,3] In general, EMS-witnessed cases are a group of patients who have manifested certain signs and symptoms (e.g., chest pain or dyspnea) which have lead to the activation of the EMS system. Albeit limited, research suggests that this group differs in their survival rates, initial rhythms, and likely the mechanism by which the arrests occurred.[3,26,27,28,29,30]

Due to the unique circumstances surrounding the EMS-witnessed cardiac arrest, the Utstein guidelines recommend that this group be separated from unwitnessed arrests and bystander-witnessed arrests.[2] They argue that the inclusion of these patients would diminish true citizen CPR rates, and distort the calculation of EMS response times since these factors are not applicable in the EMS-witnessed cardiac arrest situation. Moreover, it is believed that this group provides important information that may help to further explain cardiac arrest pathophysiology.

EMS-witnessed arrests represent about 10% of the prehospital cardiac arrest population (Table 2.1). Reported incidence rates vary between 3%[31] and 31%[32] of total arrests. Survival in this group also varies, between 7%[17] and 52%,[33] with all studies indicating better outcomes in this particular subgroup than for the overall arrest population. Wide variation in incidence and survival rates for EMS-witnessed cardiac arrest may be dependent on the type of EMS system studied and its corresponding response characteristics, or perhaps on the differences in underlying disease of the populations studied. Further study is warranted in this group as these patients represent a sufficiently large proportion of the prehospital cardiac arrest population and because the increased survival rates for this subgroup may be the best outcome measures with which to judge the performance of an EMS system.[2,26]

Table 2.1 Studies Reporting EMS-Witnessed Cardiac Arrest Statistics

Author, Date	Ref No.	Location of Study	System Type	Overall N	Overall Survival (%)	Bystander Witnessed N (%)	Bystander Witnessed Survival (%)	EMS-Witnessed N (%)	EMS-Witnessed Survival (%)	EMS-Witnessed VF/VT (%)	EMS-Witnessed Survival VF/VT (%
Principal Studies*											
Iseri, 1977	26	Orange County, US	ALS	260	---	---	---	26 (10%)	6 (23%)	14 (54%)	6 (43%)
Eisenberg, 1986	3	King County, US	ALS	2873	---	1696 (59%)	---	265 (9%)	96 (36%)	169 (64%)	82 (49%)
Tresch, 1990	27	Milwaukee, US	ALS	---	---	---	---	381 (---)	65 (17%)	123 (32%)	49 (40%)
Sedgwick, 1994	28	Scotland, GBR	ALS	3489	---	---	---	258† (7%)	40 (38%)	72 (68%)	39 (54%)
Gallagher, 1995**	29	New York, US	ALS	2329	46 (2%)	1237 (54%)	26 (2%)	258 (11%)	22 (9%)	63 (24%)	16 (25%)
Swor, 1995	30	Oakland County, US	ALS	2152	---	---	---	64†† (3%)	7 (11%)	28 (44%)	---
Additional Studies											
Diamond, 1977	34	Los Angeles, US	ALS	112	16 (14%)	---	---	12 (11%)	1 (8%)	9 (75%)	1 (11%)
Vertesi, 1978	35	New Westminster, Canada	ALS	227	58 (26%)	---	---	16 (9%)	---	---	---
Goldstein, 1981	10	Ohio/Michigan, US	ALS	2171	173 (8%)	---	---	258 (12%)	45 (17%)	---	---
Guzy, 1983	36	Los Angeles, US	ALS	368	---	122 (33%)	---	22 (6%)	---	---	---
Roth, 1984	20	Pittsburgh, US	ALS	187	18 (10%)	---	---	25 (13%)	6 (25%)	14 (58%)	5 (36%)
Wilson, 1984	37	Durham, US	BLS-IV	126	11 (9%)	36 (29%)	4 (11%)	24 (19%)	3 (13%)	11 (46%)	0 (0%)
Ritter, 1985	38	Lucas/Kent/Southfield, US	ALS	2142	173 (8%)	---	---	304 (14%)	53 (17%)	---	---
Crawford, 1986	33	Auckland, NZ	ALS	405	72 (18%)	---	---	61 (15%)	32 (52%)	---	---
Rowley, 1987	39	Nottinghamshire, GBR	BLS/BLS-D	403	44 (11%)	---	---	45 (11%)	14 (31%)	22 (49%)	11 (50%)
Stueven, 1989	21	Wisconsin, US	ALS	4216	533 (13%)	1500 (36%)	219 (15%)	405 (10%)	84 (21%)	---	---
Hargarten, 1990	40	Milwaukee, US	ALS	7371	372 (5%)	---	---	---	---	199 (---)	58 (29%)
Becker, 1991	17	Chicago, US	ALS	3221	55 (2%)	1112 (39%)	32 (3%)	272 (8%)	18 (7%)	75 (28%)	10 (13%)
Brison, 1992	41	Ontario, Canada	BLS-D	1510	38 (3%)	648 (43%)	25 (4%)	120 (8%)	9 (8%)	---	---
Shuster, 1993	31	Hamilton, Canada	BLS-D/ALS	297	13 (4%)	143 (48%)	11 (8%)	10 (3%)	1 (10%)	---	---
Lombardi, 1994	18	New York, US	ALS	2329	46 (2%)	1237 (54%)	26 (2%)	258 (11%)	22 (9%)	63 (24%)	16 (25%)
Killien, 1996	32	San Juan Isl., US	BLS-D	78	17 (2%)	35 (45%)	6 (17%)	24 (31%)	11 (46%)	18 (75%)	11 (61%)
Westfal, 1996	42	New York, US	ALS	406	11 (3%)	246 (61%)	7 (3%)	24 (6%)	3 (13%)	---	---

* Principal studies are those studies in which EMS-witnessed cardiac arrest patients were the primary study population
** This study population was a subgroup of Lombardi's[18] study
† *Included were patients conscious on ambulance arrival. Due to missing information, only 106 cases were included for analysis.*
†† *Patients were witnessed to arrest by first responders **without defib** (i.e. BLS).*

Iseri and colleagues[26] were the first to assess information on EMS-witnessed cardiac arrest patients. In a retrospective review of 260 cardiac arrest cases encountered in a paramedic system, their objective was to assess prehospital cardiac rhythms just prior to cardiac arrest in order to gain better insight into the mechanism and prevention of this condition. They found a 10% incidence of EMS-witnessed cardiac arrest in their prehospital population. An initial cardiac arrest rhythm of VF/VT was found in 54% of patients. Overall survival was 23% and survival in the EMS-witnessed VF/VT subgroup was 43%. There were no survivors in the brady-asystolic group.

Iseri provided useful information regarding the timing of cardiac events. It is reasonable that patients would require some time to self-assess their symptoms prior to recognizing a medical emergency and activating EMS. Patients who ultimately sustained a cardiac arrest rhythm of VF experienced an average of about 10 minutes of acute symptoms before accessing medical care, whereas brady-asystolic arrest patients endured a longer period of symptoms (31 minutes). The mean paramedic response time interval was about 5 minutes from the time of 911 access to the time at which the paramedic vehicle arrived on scene. VF was encountered about 15 minutes post-arrival, whereas brady-asystolic arrests occurred 19.5 minutes after EMS arrival.

The analysis of the time intervals provides a frame of reference for the rapidity with which cardiac arrest develops after initial symptoms, with VF/VT developing much more quickly than brady-asystolic arrest. Iseri attributed this to previous work which indicates that early arrhythmias may arise from the immediate effects of ischemia on the ventricle, whereas the later arrhythmias may result from the delayed effects of ischemia on the Purkinje System.[43]

The most frequent symptoms preceding cardiac arrest were chest pain (52%) and shortness of breath (40%), with chest pain being more common preceding the development of VF (70%). The authors felt that the large proportion of patients experiencing chest pain in the VF group, was an indication that coronary artery disease was the most likely cause of this arrhythmia.

Due to the small sample size, Iseri's study suffered from inadequate power to draw any solid conclusions. As well, since the study was carried out in a paramedic system, patients were apt to receive prophylactic therapy in the way of intravenous drug support, thus altering the otherwise natural course of events and perhaps contributing to an improved prognosis for these patients. It is also possible that some symptomatic patients in the overall prehospital population may have been prevented from developing a cardiac arrest altogether as a result of ALS interventions. Consequently, the study results may not be generalizeable to a system without ALS paramedics.

In 1986, **Eisenberg et al.**[3] published work on the significance of these symptoms in witnessed cardiac arrest patients both before (bystander-witnessed) and after arrival (EMS-witnessed) of paramedics. Their primary objective was to determine whether the presence of prodromal symptoms affects the likelihood of survival from cardiac arrest. Incidence and survival rates were similar to that of Iseri et al.,[26] except that the sample size was much larger in this study (265 EMS-witnessed arrests). EMS-witnessed and bystander-witnessed cardiac arrest accounted for 9% and 59% of their total cardiac arrest population respectively. Overall survival for EMS-witnessed arrest was 36%, and survival in the VF/VT subgroup was 49%.

The presence or absence of symptoms appeared strongly associated with the type of rhythm causing the cardiac arrest, regardless of the type of symptom reported. Although rhythms were similar in the EMS-witnessed patients and in those bystander-witnessed patients who had reported symptoms, they were very different from the rhythms found in the bystander-witnessed group who were without symptoms. Hence, Eisenberg further grouped together all those patients who had symptoms prior to cardiac arrest (which included all EMS-witnessed patients in their study, and 25% of the bystander-witnessed group). Significantly fewer patients with symptoms were found in the initial cardiac arrest rhythm of VF/VT compared to those without symptoms (61% vs. 93%). Furthermore, patients with symptoms had only half the likelihood of discharge when compared to those without symptoms (32% vs. 57%). This, however, may be fully explained by the difference in survival from VF/VT between patients with symptoms and those without (40% vs. 60%), as survival for other rhythms was equivalent in the two groups (10%).

The authors considered possible etiologic factors that might explain these differences. They suggest that the presence or absence of symptoms can help distinguish the type of cardiac arrest into one of the two major categories of mechanism of cardiac arrest: ischemic/thrombotic or electrical failure. They further indicate that in general, ischemic events are preceded by a prodrome, if only for a few moments, whereas electrical failure most often is not, and is usually instantaneous or "sudden". The rhythm associated with these sudden electrical events is predominantly VF, the rhythm which is most responsive to defibrillatory shock and which demonstrates the best outcomes in terms of survival.

It would seem likely that EMS-witnessed arrests would receive the most rapid delivery of care, and thus result in the highest survival rates. However, survival rates were not different between this group and the group that arrested prior to EMS arrival. The authors suggest that the presence or absence of symptoms, and thus the mechanism behind the arrest, may explain this. Significantly fewer patients were found in VF in the EMS-witnessed group than in the group without symptoms (hence, "electrical failure" group). Thus, although the arrest occurred after ambulance arrival, which would result in minimal time intervals to definitive care, this group had a poorer survival rate, as they were less likely to present in a viable arrest rhythm to the EMT's upon initial monitoring, and more likely to have suffered the effects of a longer duration of symptoms.

There are certain limitations in the design employed by Eisenberg that perhaps could not have been avoided due to the retrospective nature of this study. Information regarding the symptomatic history of patients came directly from the ambulance run report. This information may have been incomplete or even selectively recorded. There may also be differences in the availability of this type of data between the two study groups; for EMS-witnessed arrests this information may have been ascertained directly from the patient during the history taking, however in cases where the individual arrested prior to ambulance arrival, EMT's would have had to rely on the recount of bystanders who may not have been aware of the specific nature of the patient's complaint. Further questions must be raised regarding the apparent lack of a particular subgroup of patients that were not identified within the EMS-witnessed population. The authors indicated that all EMS-witnessed patients suffered prodromal symptoms prior to collapsing (e.g., chest pain, shortness of breath, epigastric pain, nausea, and other miscellaneous pain). However there was no mention of those patients who would have presented unconscious but with a pulse and respirations upon EMS arrival. This is an important group of patients who are not only difficult to ascertain medical histories from, but who may also have a differing prognosis from those patients who are conscious when the ambulance arrives. Since this study was carried out in an ALS system, it too furnishes the same generalizeability issues outlined previously.

Further support of the "symptom-mechanism" model was presented in **Tresch et al.**.[27] Tresch studied outcomes of EMS-witnessed cardiac arrest to obtain further information regarding the mechanism of prehospital cardiac arrest between elderly and younger adult patients. Tresch retrospectively examined EMS-witnessed cardiac arrest in an ALS system. Patients were divided into two age groups and compared: younger patients were less than 70 years of age and elderly patients were greater than 70. A much lower rate of VF/VT was found in the overall EMS-witnessed population (32%), with a commensurate lower rate of discharge (17%), compared to those rates previously described.[3,26] However, survival in the VF/VT subgroup was similar (40%).

Like Eisenberg, Tresch also concluded that the variance in survival outcomes was perhaps due to different mechanisms of arrest. When compared to elderly patients, younger patients were more likely to suffer from chest pain prior to arrest (35% vs. 19%), have an initial arrest rhythm of VF (42%, vs. 22%), and have a higher survival rate (24% vs. 10%). Elderly patients, compared to younger patients, were more likely to have shortness of breath as a chief complaint (60% vs. 47%), and to be in PEA on arrest (48% vs. 34%). Supported by evidence that patients in heart failure most frequently are found to have bradyarrhythmias upon cardiac arrest,[44] Tresch concluded that the high rate of dyspnea and the prevalence of bradyarrhythmias in his elderly group was consistent with the observation that the elder group more frequently had reported conditions of heart failure or pulmonary disease. Goldstein,[4] Iseri[26] and Myerburg[45] have also noted the importance of bradyarrhythmias in producing sudden cardiac arrest, the prevalence of advanced heart disease in these patients, and the associated poor survival.

Conversely, Tresch argued that younger patients reporting chest pain were more likely to have experienced an underlying acute myocardial ischemic event with resulting VF. This is supported by current literature which indicates that thombosis or acute ischemia are triggering mechanisms in most episodes of sudden death due to ventricular arrhythmias.[4]

One methodological concern was in the way that Tresch dealt with cases that were missing data. A total of 22 (5%) patients were entirely excluded from analyses because of incomplete data or an inability to accurately interpret electrocardiographic tracings due to faulty recordings. Under usual circumstances all available patient data is used to the greatest extent. Missing information is not normally an indication for case removal from the overall study population as this can lead to an underestimation of incidence rates and perhaps, a directional bias in outcome rates.

To further define the group with the maximum likelihood of benefit from defibrillation, **Sedgwick et al.**[28] retrospectively examined initial arrest rhythms in EMS-witnessed arrests in a BLS-D system. Included were cardiac arrest patients who were known to be conscious on arrival of EMS, and who also had a recorded rhythm within two minutes of the time of arrest.

One noteworthy observation was made and echoes that of the previous authors. Although both types of initiating dysrhythmia occurred in the study group, when compared to bradycardic arrests, a substantially larger proportion of patients who developed VF/VT were noted to have had chest pain as a warning signal (79% vs. 37%). This further supports the argument that differing mechanisms exist even within the EMS-witnessed cardiac arrest sub-group.

However, the selection criteria utilized for this study may have been biased in the inclusion of only patients who were conscious upon EMS arrival. This population of patients were more likely to be in better condition upon EMS arrival, hence have more viable arrest rhythms, and thus better prognoses. Most other studies were inclusive of all EMS-witnessed cardiac arrests, regardless of patient status upon EMS arrival. For this reason, Sedgwick found an extremely high rate of VF/VT (68%), with comparably better rates of survival. These results cannot be considered generalizeable.

The most recent study comparing bystander and EMS-witnessed cardiac arrests was conducted by **Swor et al.** in 1995.[30] In an attempt to determine whether first monitored rhythm and outcome were associated with who initiated CPR, patients were divided into two groups: those receiving bystander CPR and those receiving first responder CPR (that is, BLS EMT's without defibrillators).

Swor was able to contribute further information toward differentiating between mechanisms of cardiac arrest. Patients receiving bystander CPR more often had an initial rhythm of VF/VT than the first responder CPR patients even though both groups received CPR within moments of the collapse (81% vs. 44%). As patients found in VF/VT are considered to be more viable, and a greater proportion of these cases were found in the bystander CPR group, overall survival was better for the bystander group (18% vs. 11%).

Once again, these findings suggest differing reasons for calling EMS corresponding to different cardiac arrest mechanisms. The first responder CPR group undoubtedly had warning signs which led to the activation of the EMS system, whereas the bystander CPR group may have experienced sudden collapse prompting 911 access. In which case, the natures of arrest may in fact be quite different in the two scenarios, with more "pump failure" in the first responder CPR group, and more "electrical failure" (primary VF/VT) in the bystander CPR group.

Two important distinctions need to be made about this study. First, these first responder EMS-witnessed arrests do not represent "true" EMS-witnessed cardiac arrest events: first responders were capable of providing little more patient care than that of a citizen trained in basic CPR; first responders were not permitted to transport patients, creating time delays not normally seen in the EMS-witnessed arrest scenario; and furthermore, patients arresting after arrival of paramedics were not included for study. Secondly, because these first responders did not have defibrillation capabilities, reported statistics underestimate overall EMS-witnessed survival rates. Moreover, there was insufficient power to confirm the differences found between first responder and bystander CPR groups for overall survival and survival in the VF/VT subgroup.

In a 20 year period between 1977 and 1996 there were a further 17 prehospital cardiac arrest studies which reported occurrence and survival rates for the EMS-witnessed cardiac arrest sub-group (Table 2.1). Together, these studies represent an additional 1880 EMS-witnessed cardiac arrest patients for review. These studies were primarily set in ALS systems and many had very small sample sizes. EMS-witnessed cardiac arrest accounted for between 3%[31] and 31%[32] of overall cardiac arrests. Reported survival rates varied from 7%[17] to 52%.[33]

2.2. Summary

The literature maintains that the underlying mechanisms of cardiac arrest fall into one of two general categories: mechanical or electrical failure. However, it is possible that EMS-witnessed cardiac arrest cases are a more homogeneous population, and more often represent those patients suffering the more prolonged symptoms of mechanical, or "pump", failure secondary to myocardial ischemia, infarction or ventricular insufficiency.

Although somewhat simplistic, the idea that symptoms can differentiate the mechanism of cardiac arrest has clinical importance. At a population level, gaining an understanding of the characteristics of cardiac arrest will lead to improvements in overall patient care practices and influence the direction of EMS resources. At the individual level, knowing the mechanism of arrest may be useful to determine appropriate management for specific patients. As there has been little work in the literature relating symptoms to cardiac arrest characteristics and prognosis, the following questions necessitate further exploration: "What is the likely mechanism of arrest for EMS-witnessed cardiac arrest?" And, "Can symptoms help to differentiate the mechanism of cardiac arrest in this population?"

In addition, there seems to be a discrepancy regarding the overall prognosis for EMS-witnessed cardiac arrests. In an editorial comment, Cummins[1] citing evidence from Eisenberg[3] and Swor,[30] argues that these patients "obviously do not benefit from early defibrillation and may not benefit significantly from early CPR...if these patients lose their pulse and experience cardiac arrest in the out-of-hospital setting, their chances of survival are virtually non-existent...patients in this category cannot be treated effectively in the out-of-hospital setting and have a dismally low survival rate." However, numerous other authors have found significantly better survival rates in this group. Perhaps the discrepancies are a result of a methodologic problem in the inconsistent classification of patients between studies. Perhaps also, differing population characteristics, and mechanisms of arrest may be contributing to this disparity in survival outcomes. The question remains: "Do EMS-witnessed cardiac arrest patients, on the whole, have higher survival rates when compared to bystander-witnessed arrests?" And furthermore, "Why?"

In an attempt to better understand this group of patients, and cardiac arrest on the whole, the ensuing study will describe EMS-witnessed cardiac arrest in a large population, identify possible predictors of survival, and compare outcomes among EMS-witnessed and bystander-witnessed cardiac arrest.

3. METHODS

3.1. Objectives

1. To describe the epidemiology of EMS-witnessed cardiac arrest in a BLS-D system.
    1.1. To describe demographic, EMS system and clinical characteristics of this group.
    1.2. To determine the incidence rate of EMS-witnessed arrest.
    1.3. To determine the rate of survival to hospital discharge of EMS-witnessed arrest cases.
2. To determine predictors of survival to hospital discharge of EMS-witnessed cardiac arrest in a BLS-D system. **(Primary Objective)**
3. To compare EMS-witnessed cases to bystander witnessed cases in terms of outcome, and prognostic factors.

3.2. General Study Design

The current investigation is considered a sub-study of the ongoing OPALS study. The principal OPALS study is a clinical trial utilizing a before-after design. The OPALS study commenced prospective data collection in January 1994. Centres also provided three years of baseline data starting from January 1991 **(Phase I)**. The OPALS study is assessing the sequential introduction of two specific interventions: rapid defibrillation **(Phase II)**, and ALS

(Phase III). The data collection phases within each community are separated by intervening and overlapping training and run-in periods: **Phase IIR** and **Phase IIIR** (between Phases I and II and Phases II and III respectively). Within this framework it was possible to carry out a retrospective cohort study to examine EMS-witnessed cardiac arrest.

Patients were identified from the OPALS database, the original source of data for this study. The dataset is extensive and already includes many of the variables which may help elucidate the epidemiology of EMS-witnessed cardiac arrest and predict survival for this particular subgroup. Further variables were abstracted from original case reports and entered into an ancillary database. The two databases were combined to create a comprehensive EMS-witnessed dataset. The analysis involved the combination of Phase I, Phase IIR (run-in data to Phase II) and Phase II data so as not to infringe upon the results of the main OPALS study. This data covers the period in time prior to the implementation of full ALS (Phase III) in the OPALS study. The overall thesis design is outlined in Figure 3.1.

Figure 3.1 Thesis Outline

OBJECTIVE	DATA SOURCES	KEY DATA ELEMENTS	OUTCOME MEASURES	DATA ANALYSIS
1. To describe the **epidemiology** of EMS-witnessed cardiac arrest.	OPALS database; EMS-witnessed chart review	age; sex; study centre; date; pick-up/arrest location; relevant medical history; medications; prodromal symptoms; nitro use; chief complaint; clinical status/vital signs on arrival; pre-/initial arrest rhythms; fire first on scene; defib; precordial thump; time intervals: 1) onset of symptoms to EMS access, 2) onset of symptoms to collapse, 3) call received to vehicle stops, 4) vehicle stops to depart scene, and 5) depart scene to arrive ED; survival: ROSC, admission, survival.		Descriptive: Frequencies (%), Means (±SD).
2. To determine **predictors of survival** for EMS-witnessed cardiac arrest.	OPALS database; EMS-witnessed chart review	age; sex; study centre; date; pick-up/arrest location; relevant medical history; medications; prodromal symptoms; activity prior to symptoms; nitro use; chief complaint; clinical status/vital signs on arrival; pre-/initial arrest rhythms; fire first; defib; precordial thump; time intervals: 1) onset of symptoms to EMS access, 2) onset of symptoms to collapse, 3) call received to vehicle stops, 4) vehicle stops to depart scene, and 5) depart scene to arrive ED;	Survival to hospital discharge	1) Univariate: Chi square, T-test, Wilcoxon rank sum 2) Multivariate: Logistic regression, OR with 95% CI.
3. To **compare EMS-witnessed** arrest to **bystander-witnessed** arrest.	OPALS database; EMS-witnessed chart review	age; sex; study centre; date; initial arrest rhythm; defib; fire first on scene; time intervals: 1) call received to vehicle stops, 2) vehicle stops to depart scene, and 3) depart scene to arrive ED.	Survival to discharge; survival to admission; ROSC	1) Univariate: Chi-square, T-test, Wilcoxon rank sum 2) Multivariate: Logistic regression, OR with 95% CI.

3.3. Setting

The OPALS study is being conducted in 21 urban/suburban study communities across Ontario which have been identified within the response areas of 11 base hospital programs (Appendix B). According to 1991 census data the combined population served in these 21 centres is 2,840,400. Communities had a population range that varied from 16,000 to 750,000. Ambulance services responding in these centres respond to over 120,000 dispatched code 4 (highest priority) calls each year. Each year in the study sites, approximately 1,650 cardiac arrest patients are either transported to hospital or pronounced in the field after EMS resuscitation attempts have failed. This represents an incidence of about 58 prehospital cardiac arrest patients per 100,000 persons each year.

EMT's providing a BLS-D level of care and having over 1000 hours of clinical training responded to all medical emergencies within the study area. Firefighters were often dispatched under local tiered-response agreements to assist the EMT's at the scene of the prehospital emergency. In Phase I of the OPALS study fire fighter support consisted of basic CPR and oxygen administration. By Phase II, fire fighters in all centres except one (Fort Erie) were also trained to provide defibrillation with automatic defibrillators. All centres have had 911 emergency service since at least January 1991.

3.4. Study Population

Case definitions follow the Utstein Style[2] for reporting cardiac arrest data (Figure 3.2). All cases were carefully reviewed and classified according to inclusion criteria by the primary author of this study. Questionable cases were reviewed by two other members of the OPALS study group and classified according to consensus. Reviewers were not be blinded to outcome as this information was readily available from ambulance documents. Those Phase I (baseline phase) and Phase II (rapid defibrillation phase) patients identified in the OPALS cardiac arrest database who met the following eligibility requirements were considered for the present study. The prehospital cardiac arrest study population is presented in a schematic diagram in Figure 3.3.

3.4.1. Inclusion Criteria

The primary study population consisted of all patients treated for cardiac arrest outside the hospital in one of 21 study communities who:

1) arrested after the arrival of emergency medical service (EMS) personnel capable of providing a level of care recognized as basic life support with defibrillation (BLS-D).
2) were greater than or equal to 16 years of age.

In addition, the study population for Objective 3 was expanded to also include those patients who were witnessed to arrest in the presence of a bystander prior to EMS arrival.

3.4.2. Exclusion Criteria

Exclusion of patients was determined from inclusion/exclusion codes found in the OPALS database. Patients were excluded from the study if any of the following criteria were present:

1) traumatic arrests and cases clearly of non-cardiac etiology (including hypothermia, electrocution, drowning, drug overdose, carbon monoxide poisoning, exsanguination, cerebrovascular accident, or primary respiratory arrest due to upper airway obstruction, or asphyxia).
2) patients who had clear signs of irreversible cardiac arrest and were classified as an "obvious death" as defined by the Ambulance Act of Ontario (decapitation, transection, visible decomposition, putrefaction or otherwise).

Figure 3.2 Utstein Style[2] Template for Reporting Data from Cardiac Arrest

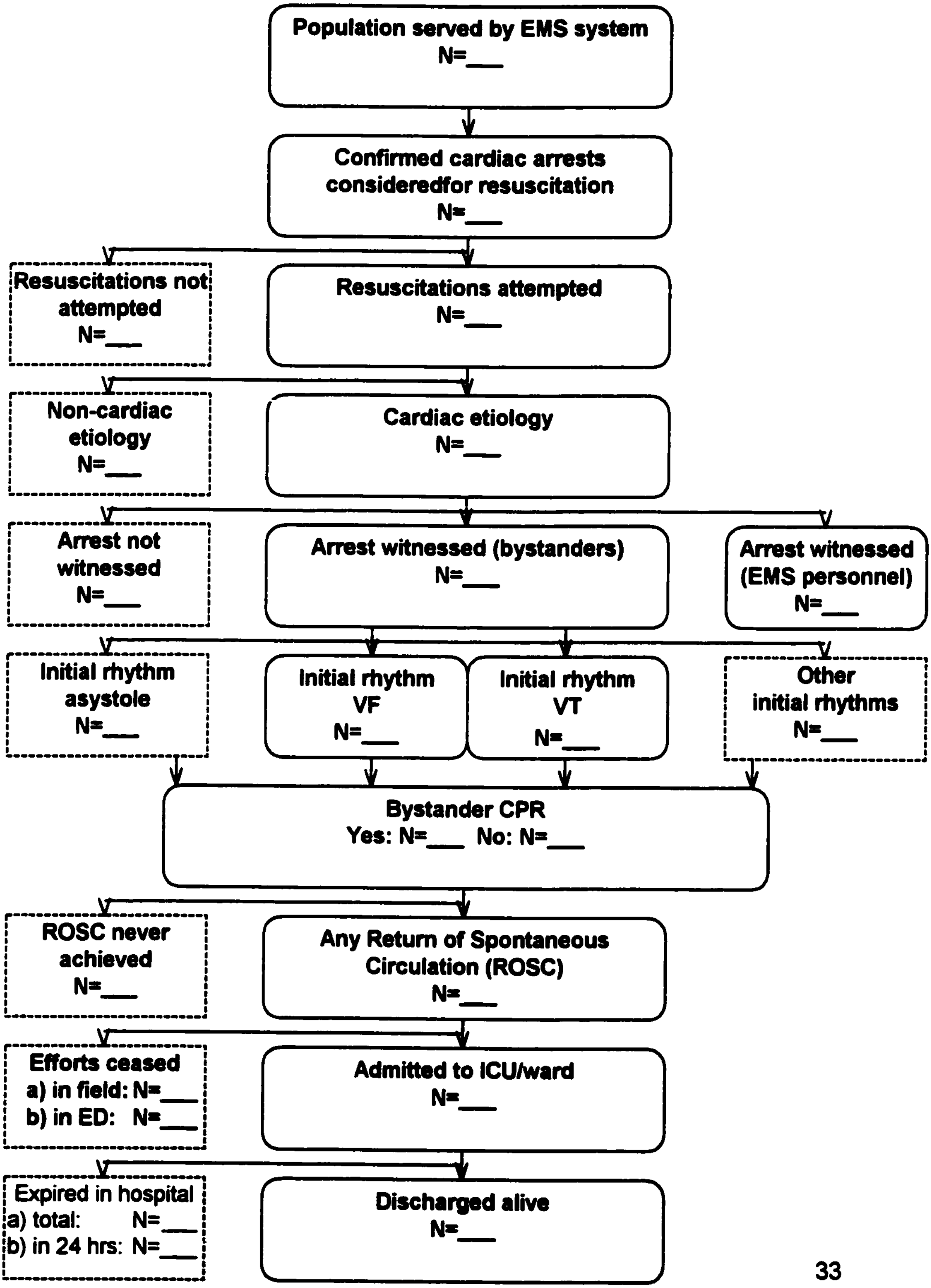
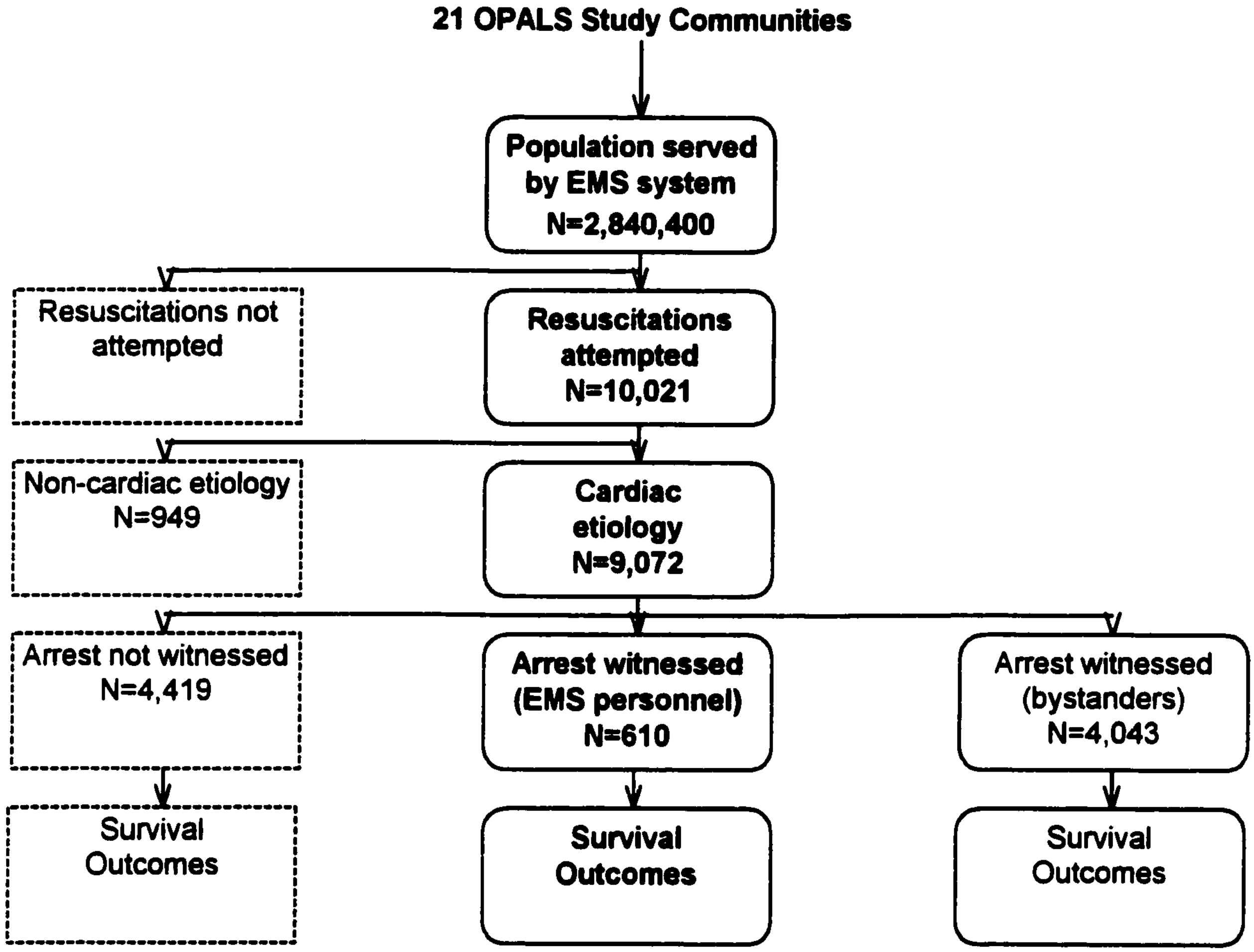


Figure 3.3 Flow Chart of Prehospital Cardiac Arrest Study Population



3.5. Hypotheses

3.5.1. Primary Hypothesis (Objective 2)

That an association exists between one or more specific covariates (Section 3.6.3) and survival to hospital discharge for EMS-witnessed cardiac arrest. That is, that one or more of the resulting adjusted regression coefficients of covariates are different from zero (i.e., H_1: $\beta_1, \beta_2, \ldots, \beta_k \neq 0$).

3.5.2. Secondary Hypotheses (Objective 3)

a) That there is a difference in survival to hospital discharge between EMS-witnessed and bystander-witnessed cardiac arrest.
b) That there is a difference in ROSC and survival to hospital admission between EMS-witnessed and bystander-witnessed cardiac arrest.

3.6. Data Management

3.6.1. Data Collection

The OPALS cardiac arrest dataset consists of data which has been collected both on a retrospective (January 1, 1991 to December 31, 1993) and prospective basis (January 1, 1994 to present). Field personnel are required to complete an ambulance call report (ACR) during or soon after each completed call. All return priority "code 3" (prompt) and "code 4" (urgent) forms are submitted by the ambulance services to the regional base hospital program for quality assurance review and storage. As a part of their mandate to assure the quality of the ambulance defibrillation program, base hospital personnel review all cardiac arrest calls, determine initial cardiac arrest rhythms from medical control modules (MCM) or data tapes, and are responsible for ascertaining patient survival outcomes. Computerized dispatch information for response time data is obtained from local dispatch centres and matched to individual cardiac arrest case files. All data is then submitted on a monthly basis to the OPALS Data Coordinating Centre at the Clinical Epidemiology Unit (CEU) at the Ottawa Civic Hospital.

3.6.2. Database Development

The OPALS database was created in SAS version 6.11. Screens are interactive, and several logic and range checks have been employed to minimize data entry error. The ancillary database designed specifically for this study, was created in Microsoft Access version 7.0 (by VDM). This database employs several drop down lists, as well as logic and range checks similar to the OPALS database. It is believed that the design of this database was such that data entry efficiency was optimized and data entry error was minimized.

3.6.3. Measurements

A number of specific patient, system, and survival variables were used to describe this population. Many of these variables were already available in the OPALS database, however others were gathered through an organized review of case files (VDM). All variables in the comprehensive EMS-witnessed dataset (Figure 3.4) conformed to the standards set at the Uniform Prehospital EMS Data Elements Conference.[46]

Figure 3.4 Data Template for Thesis Study

CASE IDENTIFIERS	DATABASE
Base hospital study centre	Both
Date	Both
Ambulance run number (unique ID)	Both
OPALS count	Both
PATIENT FACTORS	
Age	OPALS
Sex	OPALS
Relevant cardiac/respiratory medical history	THESIS
Specific medical history (10 variables)	THESIS
Relevant cardiac/respiratory drug use	THESIS
Specific patient medications (14 variables)	THESIS
Prodromal symptoms	THESIS
Specific patient complaint (16 variables)	THESIS
Activity prior to symptom onset	THESIS
Nitroglycerin use prior to EMS arrival	THESIS
Chief complaint on EMS arrival	THESIS
Clinical status on EMS arrival	THESIS
Vital signs on EMS arrival (7 variables)	THESIS
Glasgow Coma Scale on EMS arrival (3 variables)	THESIS
Pre-arrest rhythm	THESIS
Pick-up location	THESIS
Arrest location	THESIS
Initial arrest rhythm	Both
Time: symptom onset	THESIS
Time: patient collapse (VSA)	THESIS
Return of spontaneous circulation	Both
Admitted to hospital	Both
Discharged alive from hospital	Both
EMS SYSTEM FACTORS	
Ambulance service number	OPALS
Fire department first on scene	THESIS
Fire department witnessed	THESIS
Who initiated CPR	OPALS
First responder defibrillation	Both
Precordial thump	THESIS
Defibrillatory shock	OPALS
Time: symptom onset	THESIS
Time: call received (EMS access)	THESIS
Time: vehicle stopped (EMS on scene)	THESIS
Time: first analysis	THESIS
Time: first shock	THESIS
Time: depart scene	Both
Time: arrive emergency department	Both

3.6.3.1. Measurements for Objective 1

An attempt was made to gather information on the pre-arrest situation. Current data collection practice in the prehospital research setting seldom considers information about the patient's medical history or even about the period just before the arrest. Here, information was collected on a number of pre- and post-arrest variables (Figure 3.4).

Initial arrest rhythms as interpreted by base hospital personnel upon review of the defibrillator tape or medical control module (MCM) report and subsequently entered into the OPALS database were used in the data analysis. However, for all cases with an available rhythm strip, an independent review was performed in order to verify the arrest rhythm, and further to determine the pre-arrest rhythm where possible. Rhythm information was entered into the ancillary dataset, and initial cardiac arrest rhythms were later cross-referenced with the main OPALS dataset. Any discrepancies were reconciled by further review and adjusted appropriately in the respective dataset.

Although EMS access and response times are available from dispatch reports, many of these times are not ordinarily considered relevant in the EMS-witnessed circumstance due to the occurrence of the arrest subsequent to the arrival of ambulance personnel. For this reason, the main OPALS dataset does not include response time information. However, for this study, it was decided that EMS response along with patient event time information may be useful for descriptive purposes to account for the timing of events in an EMS-witnessed cardiac arrest. Consequently, event time information was entered from dispatch data into the ancillary dataset. As well, run reports and defibrillator summary data were used to estimate the two patient event time points: onset of symptoms, and time of arrest.

A set of criteria were used to determine the acceptability of the estimation of patient event times (i.e., symptom onset, time of arrest) on an individual case basis. In the absence of a method to confirm the timing of the onset of symptoms other than the narrative report of the ambulance officer it was, in some cases, determined that the available data was too vague to estimate the time and the corresponding data fields were left blank.

3.6.3.2. Measurements for Objective 2

To address the second objective, all patient history, pre- and post-arrest variables described above were considered for univariate and multivariate testing with survival. The primary measures were those variables determined to be predictors of survival to hospital discharge.

3.6.3.3. Measurements for Objective 3

The primary outcome measure for Objective 3 was survival to hospital discharge. ROSC and survival to hospital admission were considered secondary outcome measures. All patient, system and event variables available for both EMS-witnessed and bystander-witnessed cardiac arrest were utilized. No attempt was made to collect pre-arrest information on the over 4000 bystander-witnessed cardiac arrest cases as this would have created tremendous time and resource implications.

3.6.4. Data Abstraction

Decisions were made regarding the coding of certain variables abstracted from those narrative sections of the ambulance call report **(ACR)** forms: history of current condition, prior medical history, patient medications and allergies, treatment prior to EMS arrival, patient assessment, vital signs, and treatment (Appendix C). Abstracted variables for the EMS-witnessed study included: activity prior to symptom onset, arrest location, cardiac or respiratory history, use of cardiac or respiratory drugs, prodromal symptoms, and chief complaint. Abstracted variables were treated in a similar fashion to those pre-coded or numeric fields on the ambulance chart; if the EMT did not include the information, then the relevant variable was considered "unknown" and was set to missing. However, in some cases where data fields were incomplete on the run reports, values for certain variables could be imputed with confidence. For example, when the patient was unconscious upon EMS arrival and the Glasgow Coma Scale was not completed, the component response variables, *eye opening*, *verbal response*, and *motor response* each defaulted to "1", the appropriate scoring for an unresponsive individual. As well, if angina was not indicated in the chart, yet it was indicated in the patient medication section that the patient was using anti-anginal medications (specifically nitroglycerin), the variable *angina* would be coded "1" (Yes).

One particular variable requires further explanation: *prodrome*. In the case where patients were witnessed to suddenly collapse or fall, the absence of a prodrome prior to collapse was not always assured since the patient may have suddenly collapsed in front of a bystander who only just arrived at the patient. When it could be determined from the information provided by the bystander that the patient clearly collapsed without prior warning, these cases contributed to the denominator for data regarding prodromal symptoms. These cases would be coded "0" (No) for *prodrome*. When it was uncertain whether the patient had suffered symptoms prior to the collapse, *prodrome* was considered "unknown" and therefore "missing" and did not contribute to either the numerator or denominator for this variable. Despite this, the patient complaint, "sudden collapse/fall" was still coded "1" (Yes).

3.6.5. Data Entry

Ambulance, dispatch and rhythm information for the OPALS study was entered by OPALS study personnel (including VDM) into the main OPALS database in SAS. Double data entry was completed (by VDM) for key data elements (run number, study community, inclusion status, survival status). The OPALS data was sub-setted to include only those EMS-witnessed cases and bystander-witnessed cases that were eligible. Each record consisted of 16 relevant variables identified in the principal dataset for the EMS-witnessed study. This dataset was then converted to a SAS transport file so that it could be converted through DBMS Copy (version 2.0) to an SPSS (version 6.1.3) dataset. A further 81 variables were entered (by VDM) into the ancillary EMS-witnessed database in Microsoft Access (version 7.0). Data was exported to a Microsoft Excel (version 4.0) data file and then opened directly into SPSS. The two datasets were then merged in SPSS based on four identification variables: base hospital number, date, ambulance run number, and OPALS count number. This was to ensure that all case identifiers were identical in both datasets. Only a few cases did not merge directly, which was the result of original data entry error. These cases were corrected, and the datasets re-merged. Bystander-witnessed cases were simply appended to the SPSS dataset as no further variables were collected for those cases.

Missing variables were requested from study sites by the OPALS data coordinating centre. For this study, every attempt was made to secure all missing data but in very rare occasions key data elements were not available.

3.6.6. Data Editing, Logic Checks and Cleaning Procedures

Once all data was entered, and missing information had been acquired, data cleaning reports were programmed and generated from both SAS and SPSS for the OPALS and EMS-witnessed ancillary datasets respectively (VDM). Range checks were made on individual variables where appropriate to identify extreme values and determine whether these were true outliers, or if they had resulted from errors in measurement, data recording or data entry. Logic checks were also performed to ensure associated data elements corresponded and that data screen skip patterns had been followed. For example, if a patient's medical history was unknown (*missing*), then all subsequent cardiac and respiratory history fields in this category should have also remained missing. Conversely, if a relevant cardiac or respiratory medical history was expressly indicated as either present or absent (i.e., *yes* or *no*), then each of the corresponding specific medical history fields should have contained valid values (i.e., "1" for *yes* or "0" for *no*). Finally, any further missing values were identified and manually checked. All problems identified in the data cleaning stage were manually reviewed and corrected.

3.6.7. Derived Variables

A series of derived variables were created for the purpose of the analysis (Figure 3.5). There were five reasons for making such data transformations: 1) to calculate time intervals by finding the difference between individual event time variables; 2) to create useful aggregate variables by adding values of component sources; 3) to collapse and re-code certain variables when related classification levels could be reasonably grouped together; 4) to transform specific continuous and nominal variables to a categorical format based on fixed cut-points for use in univariate and logistic regression analysis; individual cutpoints were determined based on clinical relevance and prior use in the literature; and, 5) to further convert specific nominal and continuous variables into dichotomous indicator variables for logistic regression analysis. When computing derived variables, source variables with missing data, were not imputed, and the derived variable was set to missing. (Complete formulae for calculation of the derived variables is found in Appendix D.)

Figure 3.5 Derived Variables for Thesis Study

1) TIME INTERVAL VARIABLES
Symptom onset to 911 access
Symptom onset to Cardiac arrest
Vehicle stopped to Cardiac arrest
Cardiac arrest to Arrived ED
Call received to Vehicle stopped
Vehicle stopped to Departed scene
Departed scene to Arrived ED

2) AGGREGATE VARIABLES
Glasgow coma scale - total

3) COLLAPSED VARIABLES
Pick-up location
Patient complaint: dyspnea and/or chest pain
Patient complaint
Chief complaint
Pre-arrest rhythm
Precordial thump

4) CATEGORICAL VARIABLES
Age (10 year groups)
Month of year
Period of day patient arrested
Population size (persons)
To scene interval (min)
Symptom onset to collapse interval (min)

5) DICHOTOMIZED VARIABLES
Winter season
Morning VSA (12PM-8AM)
Evening VSA (4PM-12AM)
Coronary artery disease
Patient complaint: G.I. symptoms
Patient complaint: SOB
Patient complaint: chest pain
Patient complaint: SOB/CP
Patient complaint: Other
Chief complaint: Dyspnea
Chief complaint: Chest pain
Chief complaint: G.I. symptom
Chief complaint: Semi/Unconscious
Chief complaint: Respiratory arrest
Chief complaint: Seizure
Chief complaint: Other
Unconscious on EMS arrival
Pre-arrest: Normal sinus rhythm
Pre-arrest: Bradycardic rhythm
Pre-arrest: Tachycardic rhythm
Pulse rate < 50 / min
Pulse rate > 100 / min
Respiratory rate <10 / min
Respiratory rate > 30 / min
Systolic BP < 90 mmHg
Initial arrest rhythm: VF/VT
Initial arrest rhythm: Asystole
Initial arrest rhythm: Pea
Symptoms to collapse > 4 hrs

3.7. Sample Size

The primary hypothesis in this study was to assess predictors of survival for EMS-witnessed cardiac arrest by means of logistic regression analysis (Objective 2). Sample size tables by Hsieh[47] for logistic regression were consulted in order to establish the feasibility of conducting the analyses within a determined sample size. The sample size was fixed according to the number of patients accrued in Phases I and II of the OPALS study. The following table illustrates the approximate upper bounds of sample size that were needed to detect the specified association at different levels of power.

Table 3.1 Sample Size Requirements

Assumptions:*

P = 0.09
OR = 0.60
$\rho = 0.4$

Power:	**Sample Size**: $\alpha_{1\text{-tailed}} = 0.05$	**Sample Size**: $\alpha_{1\text{-tailed}} = 0.01$
.70	291	---
.80	378	---
.90	516	---
.95	646	952

*Assuming the variable, "prodromal symptoms" was the covariate of interest; the odds ratio 0.6 of survival corresponds to an increase in one standard deviation from the mean value of covariate of interest, given the mean values of the remaining covariates. The multiple correlation coefficient ρ relates the specific covariate of interest to the remaining covariates. Note that only 1-tailed α values are provided in the Hsieh tables and that sample sizes at α values of 0.01 are only provided at the 0.95 power level.

3.8. Statistical Analysis

The analyses included simple descriptive statistics to address the first objective, followed by univariate comparisons, as well as more advanced multivariate techniques to meet the final two objectives. Statistical analyses for Objectives 1, 2 and 3 were carried out on the comprehensive EMS-witnessed dataset in SPSS version 6.1.3. Many comparisons between EMS-witnessed and bystander-witnessed cardiac arrest were carried out in SAS version 6.11 where the original dataset resided so that data for unwitnessed cardiac arrest cases could be generated along with the main study groups for reference purposes.

All data is displayed in tables in the results section. Tables have been constructed to present denominators and to indicate missing values where applicable. P-values for univariate comparisons are also presented.

3.8.1. Analysis for Objective 1

Descriptive analysis was carried out on all categorical and dichotomous variables. Nominal data is displayed descriptively as absolute numbers and proportions. Univariate procedures were used for all continuous variables providing means, medians, minimum and maximum values, and frequency distributions. All time interval data are presented as medians due to the skewness of the data for these variables. As well, the inter-quartile range (IQR) was also computed where appropriate and when extreme outliers caused the absolute range to be an inadequate reflection of the tendency of the data.

3.8.2. Analysis for Objective 2

Univariate comparisons were made between several patient, system and treatment characteristics with survival to hospital discharge using chi-square, student t-test, and Wilcoxon rank sum test where appropriate. The full contingency tables for several variables were collapsed to 2 x 2 tables or sometimes greater using the derived dichotomous and categorical variables and two levels of survival (dead or alive).

Independent predictors of survival were determined using multivariate logistic regression analysis. Predictors of survival were displayed as odds ratios with 95% confidence intervals. Variables were considered for the model if they achieved moderate significance at the univariate level. As well, the nature of logistic regression is such that any observation with missing values for the response or explanatory variables is excluded from the analysis. Since this results in a listwise reduction of cases when different observations are missing data in different variables, care must be taken in adding variables with less than complete response rates. In order ensure a sufficient sample size to maintain the statistical power of the logistic regression analysis, only those variables with a 85% completion rate or greater were considered for the model. Interaction terms were considered for inclusion when there was significant statistical evidence and the interaction had clinical rationale. Covariates were added to the logistic model in a forward step-wise procedure. Entry and removal to and from the model was set at a significance level of 0.10 and was based on the probabilities of the likelihood ratio statistic and the maximum partial likelihood estimate.

3.8.3. Analysis for Objective 3

Patient and system characteristics for both EMS-witnessed and bystander-witnessed cardiac arrest groups were compared using univariate statistics. The principal analysis, to test the hypothesis of a difference in rates of survival to discharge between EMS-witnessed and bystander-witnessed cardiac arrest was carried out using unadjusted chi-square analyses (two-tailed P values). Ninety-five percent confidence intervals were calculated for the absolute difference in survival between the two groups. Potential confounders: study centre, age, sex, initial rhythm, citizen CPR, first responder CPR (fire or police), and time intervals were tested for an univariate association with outcome by chi-square and student t-test as appropriate. Logistic regression methods as outlined above were used to adjust raw survival proportions using those covariates found to be significant predictors of outcome. Secondary outcome measures, ROSC and survival to hospital admission, were tested using unadjusted chi-square analysis.

3.8.4. Subgroup Analysis for Objectives 2 and 3

Further univariate analyses, as described above, were undertaken for certain clinically important subgroups. A priori subgroups included: 1) initial rhythm of VF/VT; and 2) presence or absence of prodromal symptoms. Prodromal symptoms were not assessed for bystander-witnessed cardiac arrest cases, and thus this subgroup was omitted from the secondary analyses of the third objective. Further post-hoc sub-group analyses were performed for Objective 2 for three variables: 1) patient age younger or older than 70 years; 2) patients unconscious on EMS arrival; and 3) patient complaint of shortness of breath or chest pain.

3.9. Ethics

The OPALS study protocol was accepted by the institutional review boards of each of the participating base hospitals. Informed consent was not required prior to including patients in the OPALS study. Patient identifiers were deleted from ambulance and dispatch charts by base hospital personnel prior to submitting data to the OPALS DCC in Ottawa. Patient confidentiality was maintained at all times throughout this study.

4. RESULTS

4.1. Organization

The results section begins with a brief report on missing values which is followed by a detailed account of the findings of this study.

The first part of the main results section focuses on Objectives 1 and 2: a description of the epidemiology of EMS-witnessed cardiac arrest. Demographic data, as well as system and clinical characteristics including rates of occurrence and survival characteristics are presented first (Objective 1). Predictors of survival (Objective 2) and subgroup analyses follow this.

The second part addresses Objective 3 and presents a comparison between EMS-witnessed and bystander-witnessed cardiac arrest in terms of demographics, system and clinical characteristics, outcomes, and prognostic factors. Finally, survival comparisons are presented for specific subgroups.

4.2. Missing Values

The frequency of missing values in the completed dataset ranged from zero for many of the variables to 513 (84%) missing values for diastolic blood pressure. There were no missing values for the demographic variables for age, sex, date of arrest, pick-up location, location of arrest and study site.

Information on the pre-arrest situation varied. Activity prior to symptom onset was available for only 41% of the cases, whereas information regarding prodromal symptoms was obtained for 86% of the patients. Patient medical history and medications were documented in 87% and 67% of cases respectively. Nitroglycerin administration prior to EMS arrival was considered to be complete with any indication of prior nitroglycerin being coded "1" (Yes) and by default all others were coded "0" (No). This variable represents an important treatment consideration for these patients and it was felt that EMS providers were particularly reliable for ascertaining this specific type of information and completing the "treatment prior to ambulance arrival" section of the ACR.

Initial assessment variables varied in their completion rates. Patient chief complaint on EMS arrival was present for all but just less than 2% of cases. Patient condition and vital signs were the most poorly reported variables in the dataset with skin color having the best completion rate (93%) for this type of information. Patient responsiveness on initial assessment was very well documented with only 2% of cases missing this information.

EMS event times data was reasonably complete (less than 2% missing) which was expected as this information originated from central dispatch computerized sources. Conversely, patient event times were less reliably recorded (38% missing for time of symptom onset). This information is based on patient, bystander or EMT's estimates and is considered subjective. EMS treatment characteristics variables (precordial thump, defibrillation) were completed in all cases. Patient outcome was obtained for all cases (i.e., return of spontaneous circulation, hospital admission, survival to discharge).

4.3. Epidemiology of EMS-Witnessed Cardiac Arrest

There were 10,021 total cardiac arrest resuscitation attempts identified in the OPALS study communities between January 1, 1991 and December 31, 1996. In total there were 949 (10%) cardiac arrests that were not considered because they were either pediatric cases, non-cardiac, or traumatic in origin. The remaining 9,072 cardiac arrests were of presumed cardiac etiology. The collapse was witnessed by bystanders or EMS in 4,653 (51%) cases. The study cohort consisted of 610 (7%) consecutive EMS-witnessed cardiac arrest cases identified during the six year period.

4.3.1. Patient Characteristics

Table 4.1 displays the patient characteristics and survival rates for the EMS-witnessed cardiac arrest patients who made up this study. Patients were predominantly male (60%). The mean age was 69.8 and ranged from 19 to 104. There was no difference from expected in the proportion of arrests occurring in the winter season; 25% of patients arrested in the period from December to February. The pick-up location for most patients was at the place of residence with 77% of the 911 calls initiated from a personal residence and 10% from a nursing home. A further 7% experienced their initial symptoms in a public place. The majority of patients arrested at the scene of the medical emergency; 75% of patients became pulseless and apneic at the pick-up location prior to transport to hospital. This included 15% which occurred upon transferring the patient to the ambulance stretcher, and a further 25% which happened upon loading the patient into the vehicle before the vehicle became mobile. The least likely time of arrest was in the early morning hours between midnight and 8AM with 23% of patients arresting during this time period. Only 6 (2.4%) patients were involved in vigorous physical activity prior to the onset of symptoms.

Of the 529 cases with documentation of presence or absence of a previous medical history, patients or family members indicated a relevant cardiac or respiratory medical history in 82% of cases. There were 410 cases with information regarding medication use or non-use and 75% of these patients were currently being treated with cardiac or respiratory medications. Information about prodromal symptoms leading to the activation of the EMS system was provided for 86% of the patients. Of these, 91% of patients were known to have experienced symptoms prior to the call, whereas 9% were reported to have collapsed suddenly, and without warning. As a result of initial symptoms (i.e., chest pain), a total of 56 (9%) patients were reported to have taken nitroglycerin prior to the arrival of EMS. The predominant initial cardiac arrest rhythm was PEA in 50% of the patients. The proportion of patients with an arrest rhythm of VF/VT was 34%.

4.3.2. Survival

Survival rates for EMS-witnessed cardiac arrest were greater than expected for prehospital cardiac arrest on the whole. Resuscitation efforts resulted in a return of spontaneous circulation (ROSC) in 23.9% of patients and 16.7% of patients survived to hospital admission. Overall survival to hospital discharge for EMS-witnessed cardiac arrest was 12.6% (Table 4.1).

Table 4.1 EMS-Witnessed Cardiac Arrest Patient Characteristics

Patient Characteristics	N=610
Age (n=605; SD)	69.8 (12.9)
[range]	[19-104]
Male sex (%)	367 (60.2)
Winter season* (%)	154 (25.2)
Activity prior to symptom onset (n=251; %)	
Sleeping or reclining	113 (45.0)
Sitting activity	68 (27.1)
Light activity	40 (15.9)
Moderate activity	24 (9.6)
Vigorous activity	6 (2.4)
Nitroglycerin prior to EMS arrival (%)	56 (9.2)
Pick-up location (%)	
Residence	470 (77.0)
Nursing home	59 (9.7)
Public place	44 (7.2)
Other	37 (6.1)
Arrest location (%)	
At scene (pick-up location)	220 (36.1)
Moving to stretcher	90 (14.8)
Loading to ambulance	150 (24.6)
En route	125 (20.5)
Upon arrival at hospital	25 (4.1)
Period of day patient arrested (n=580; %)	
Early morning (midnight to 8AM)	132 (22.8)
Day (8AM to 4PM)	219 (37.8)
Evening (4PM to midnight)	229 (39.5)
Cardiac or respiratory history (n=529; %)	431 (81.5)
Use of cardiac or respiratory drugs (n=410; %)	306 (74.6)
Prodromal symptoms (n=525; %)	480 (91.4)
Initial cardiac arrest rhythm (n=573; %)	
VF	159 (27.7)
VT	37 (6.5)
Asystole	90 (15.7)
PEA	287 (50.1)
Return of spontaneous circulation (%)	146 (23.9)
Admitted to hospital (%)	102 (16.7)
Discharged alive from hospital (%)	77 (12.6)

* Winter season is December through to February.

4.3.3. Patient Medical History and Medication Use

Of patients for whom information about their medical history was available, 41% of patients reported previous coronary artery disease, and a further 21% indicated a cardiac history but did not indicate the specific condition (Table 4.2). Other reported conditions were: diabetes (20%), hypertension (20%), congestive heart failure (11%), and prior cerebrovascular accident (8%). A relevant respiratory history (e.g., asthma, emphysema) was indicated for 15% of patients.

Table 4.2 Previous Cardiac or Respiratory History for 529 EMS-Witnessed Cardiac Arrest Patients with Information for whom Information about Medical History was Available†

Previous Cardiac / Respiratory History	N=529 (%)*
Coronary artery disease	214 (40.5)
Cardiac history (unspecified)	111 (21.0)
Diabetes	105 (19.8)
Hypertension	104 (19.7)
Respiratory history	79 (14.9)
Congestive heart failure	56 (10.6)
Cerebrovascular accident	40 (7.6)
Hypercholesterolemia	3 (0.6)

† Information about medical history was available in 86.7% of cases.
* Percentages do not add to 100% as some patients may have had more than one medical condition reported.

Overall almost 30% of EMS-witnessed patients were using nitrates (Table 4.3). Other drugs reported included: antihypertensives (20%), diuretics (19%), cardiac glycosides (12%), analgesics (11%), calcium channel blockers (10%), and bronchodilators (9%). Home oxygen was used by 10% of patients. Additional medications are listed in Table 4.3.

Table 4.3 Cardiac or Respiratory Drugs for 410 EMS-Witnessed Cardiac Arrest Patients with Information Indicating Either Use or Non-use of Medications†

Use of Cardiac / Respiratory Drugs	N=410 (%)*
Nitrates	120 (29.3)
Antihypertensives	82 (20.0)
Diuretics	77 (18.8)
Cardiac glycosides	51 (12.4)
Analgesics	46 (11.2)
Calcium channel blockers	40 (9.8)
Bronchodilators	36 (8.8)
Antidiabetics (oral hypoglycemics)	27 (6.6)
Antidiabetics (insulin)	23 (5.6)
Anticoagulants	22 (5.4)
Beta blockers	18 (4.4)
Antiarrhythmics	12 (2.9)
Antihypercholesterolemics	1 (0.2)

† Patient medication use/non-use was available for 67.2% of cases.
* Percentages do not add to 100% as some patients may have been taking more than one drug.

4.3.4. Prodromal Symptoms

Overall, 39% of cases were suffering from a decreased level of consciousness or were unconscious at the time of EMS activation (Table 4.4). As well, 20% of all patients were witnessed to suddenly collapse or fall. In these cases the absence of a prodrome prior to collapse was not always assured as the collapse may have been unwitnessed, or the patient may have suddenly collapsed in front of a bystander who only just arrived at the patient. Thus, depending on the availability of information, these cases may or may not have contributed to the data regarding prodromal symptoms.

Individual patients sometimes experienced multiple symptoms. The greatest patient complaint was dyspnea in 56% of patients. Chest pain was also a frequent complaint occurring in 37% of patients. Other prevalent prodromal symptoms included: gastrointestinal symptoms, other pain, general weakness, diaphoresis, and seizure. Further reported symptoms are listed in Table 4.5.

Table 4.4 Patient Condition Prompting 911 Call for EMS-Witnessed Cardiac Arrest Patients

Patient Condition (prompting 911 call)	**N=610 (%)***
Sudden collapse / fall	123 (20.2)
Decreased level of consciousness / unconscious (n=603)	236 (39.1)
Respiratory arrest	5 (0.8)

Table 4.5 Patient Complaint Prompting 911 Call for 525 EMS-Witnessed Cardiac Arrest Patients with Available Information†

Patient Complaint (prompting 911 call)	N=525 (%)*
Shortness of breath	292 (55.6)
Chest pain	195 (37.1)
Gastrointestinal symptoms	95 (18.1)
Other pain	55 (10.5)
Weakness	47 (9.0)
Other	38 (7.2)
Diaphoresis	36 (6.9)
Seizure	27 (5.1)
Syncope	23 (4.4)

† Patient complaint was indicated for 86.1% of cases.
* Percentages do not add to 100% as some patients may have experienced more than one complaint.

4.3.5. Patient Assessment Characteristics

Table 4.6 lists the chief complaint as identified by the EMT upon initial assessment of the patient. Altogether, 49% of patients were either semi-conscious or unconscious upon EMS arrival. Other conditions frequently cited for chief complaint were dyspnea (22%), chest pain (14%), and respiratory arrest (7%).

Table 4.6 Chief Complaint on Initial Assessment for EMS-Witnessed Cardiac Arrest Patients[†]

Chief Complaint (on initial assessment)	N=601 (%)
Decreased level of consciousness / unconscious	296 (49.3)
Shortness of breath	133 (22.1)
Chest pain	85 (14.1)
Respiratory arrest	41 (6.8)
Other	24 (4.0)
Gastrointestinal symptoms	13 (2.2)
Seizure	9 (1.5)

[†] Chief complaint was indicated for 98.5% of cases.

Patient condition and vital signs are presented in Table 4.7. Mean vital signs appeared within the normal ranges for these measures, although patients were more likely to be pale (61%) and diaphoretic (60%) upon assessment by EMT's. Of the 177 cases that were monitored prior to arresting, 48% presented with a bradycardic rhythm (sinus bradycardia or bradyarrhythmia with a rate less than 60), 24% with a tachycardic rhythm (sinus tachycardia or tachyarrhythmia with a rate greater than 100), and 23% with normal sinus rhythm. The remaining 5% of patients monitored were in atrial fibrillation. Patient responsiveness, measured from 3 (lowest possible score) to 15 (highest possible score) on the Glasgow Coma Scale, showed a bimodal distribution with the majority of patients falling at the two extremes (Table 4.8). A total of 41% of patients were at the bottom of the scale with a GCS of 3 and a further 34% were found to be at the high score of 15.

Table 4.7 EMS-Witnessed Cardiac Arrest Initial Patient Assessment

Patient Condition and Vital Signs	N=610
Pulse rate (n=407; SD)	73.7 (32.6)
[range]	[6-200]
Respiratory rate (n=481; SD)	16.9 (11.0)
[range]	[0-48]
Systolic blood pressure (n=134; SD)	123.0 (43.8)
[range]	[40-255]
Diastolic blood pressure (n=96; SD)	76.9 (22.8)
[range]	[0-130]
Skin color (n=569; %)	
Normal	35 (6.2)
Pale	348 (61.2)
Cyanotic	132 (23.2)
Ashen	41 (7.2)
Jaundice	6 (1.1)
Flushed	7 (1.2)
Skin temperature (n=460; %)	
Warm (normal)	216 (47.0)
Cool	240 (52.2)
Hot	4 (0.9)
Skin condition (n=520; %)	
Dry	207 (39.8)
Diaphoretic	313 (60.2)
Pre-arrest rhythm (n=177; %)	
Normal sinus rhythm	41 (23.2)
Bradycardic rhythm	84 (47.5)
Tachycardic rhythm	43 (24.3)
Atrial fibrillation	9 (5.1)

Table 4.8 EMS-Witnessed Cardiac Arrest Patient Responsiveness on Initial Assessment

Patient Response	N=610
Unconscious on EMS arrival (%)	231 (37.9)
Glasgow Coma Scale - eye opening (n=597; %)	
None (1)	269 (45.1)
To pain (2)	21 (3.5)
To voice (3)	27 (4.5)
Spontaneous (4)	280 (46.9)
Glasgow Coma Scale - verbal response (n=597; %)	
None (1)	314 (52.6)
Incomprehensible sounds (2)	31 (5.2)
Inappropriate words (3)	14 (2.3)
Confused (4)	29 (4.9)
Oriented (5)	209 (35.0)
Glasgow Coma Scale - motor response (n=596; %)	
None (1)	291 (48.8)
Extension to pain (2)	11 (1.8)
Flexion to pain (3)	13 (2.2)
Withdraws from pain (4)	25 (4.2)
Localizes pain (5)	22 (3.7)
Obeys command (6)	234 (39.3)
Glasgow Coma Scale - total (n=596) median [range]	6 [3-15]

4.3.6. EMS System and Treatment Characteristics

Fire responded first to the scene of the medical emergency in only 14% of cases. Median patient and EMS response time intervals with the absolute range are displayed in Table 4.9. The median time interval from symptom onset to 911 access was 8.6 minutes with an inter-quartile range (IQR) from 2.6 minutes to 1.8 hours. The median accumulated time interval from symptom onset to the time of EMS-witnessed cardiac arrest was 28.0 minutes with an IQR from 16.0

minutes to 1.8 hours. Altogether, the majority of patients arrested within 2 hours of initial symptoms (77%). The EMS "response time" interval from call received to vehicle stopped was 6.2 minutes; "on-scene time" from vehicle stopped to departed scene was 13.0 minutes; and total "transport time" from departed scene to arrival at the hospital was 4.1 minutes.

EMS procedures information indicated that a precordial thump was applied immediately after the patient became pulseless in 13% of the cases. Electrical countershock was delivered by a defibrillator in 35% of the cases, all of which were administered by ambulance personnel.

Table 4.9 EMS-Witnessed Cardiac Arrest EMS System and Treatment Characteristics

EMS System Characteristics	N=610	
Fire first on scene (%)	87 (14.3)	
Precordial thump (%)	80 (13.1)	
Defibrillated (%)	212 (34.8)	
Median patient event time intervals - min [range]		
Symptom onset - 911 access (n=381)	8.6 [0.02-1435]	
Symptom onset - cardiac arrest (n=377)	28.0 [1.0-1373]	
≤10 min. (%)		32 (8.5)
≤1 hour (%)		17 (57.6)
1 to 2 hours (%)		37 (9.8)
2 to 4 hours (%)		60 (15.9)
>4 hours (%)		31 (8.2)
Vehicle stopped - cardiac arrest (n=574)	8.4 [0.1-29.5]	
Cardiac arrest - arrived ED (n=579)	8.7 [0.0-31.6]	
Median EMS response time intervals - min [range]		
Call received - vehicle stopped (n=594)	6.2 [0.3-69.0]	
≤4 min. (%)		15 (19.4)
4 to 6 min. (%)		70 (28.6)
6 to 8 min. (%)		66 (27.9)
8 to 10 min. (%)		95 (16.0)
>10 min. (%)		48 (8.1)
Vehicle stopped - departed scene (n=602)	13.0 [1.9-39.9]	
Departed scene - arrived ED (n=606)	4.1 [0.1-37.6]	

4.3.7. Incidence

EMS-witnessed cardiac arrest represents 6.7% of the overall adult primary cardiac etiology cardiac arrest population. As a percent of the total number of arrests in each community, EMS-witnessed cardiac arrest accounted for between 2% of all arrests in Grimsby to 9% in Welland (Table 4.10).

Table 4.10 EMS-Witnessed Cardiac Arrest by Study Community

Study Community	Total Arrests N=9072 (%)	EMS-Witnessed N=610 (%)	EMS-Witnessed to Total Arrests* (%)
Burlington	353 (3.9)	23 (3.8)	(6.5)
Cambridge	365 (4.0)	16 (2.6)	(4.4)
Fort Erie	92 (1.0)	6 (1.0)	(6.5)
Grimsby	50 (0.6)	1 (0.2)	(2.0)
Kingston	336 (3.7)	26 (4.3)	(7.7)
Kitchener-Waterloo	655 (7.2)	34 (5.6)	(5.2)
Lindsay	99 (1.1)	8 (1.3)	(8.1)
London	972 (10.7)	83 (13.6)	(8.5)
Mississauga	813 (9.0)	57 (9.3)	(7.0)
Niagara Falls	333 (3.7)	26 (4.3)	(7.8)
Oakville	276 (3.0)	15 (2.5)	(5.4)
Ottawa-Nepean-Gloucester	1362 (15.0)	87 (14.3)	(6.4)
Peterborough	297 (3.3)	17 (2.8)	(5.7)
Port Colborne	83 (0.9)	5 (0.8)	(6.0)
Port Hope-Cobourg	149 (1.6)	12 (2.0)	(8.1)
Sarnia	310 (3.4)	17 (2.8)	(5.5)
St. Catharines	599 (6.6)	50 (8.2)	(8.4)
Sudbury	464 (5.1)	30 (4.9)	(6.5)
Thunder Bay	418 (4.6)	28 (4.6)	(6.7)
Welland	201 (2.2)	18 (3.0)	(9.0)
Windsor	845 (9.3)	51 (8.4)	(6.0)

* Represents EMS-witnessed cardiac arrest as a percentage of total cardiac arrests in community.

The proportion of cases occurring by month ranged from a low of 6.4% in June to 10.3% in May (Table 4.11). A seasonal pattern in the number of cardiac arrests occurring by month did not exist. Chi-square analysis showed that there was no significant difference in the proportion of arrests occurring by month.

Table 4.11 EMS-Witnessed Cardiac Arrest by Month

Month	N=610 (%)
January	60 (9.8)
February	41 (6.7)
March	55 (9.0)
April	41 (6.7)
May	63 (10.3)
June	39 (6.4)
July	45 (7.4)
August	41 (6.7)
September	49 (8.0)
October	62 (10.2)
November	61 (10.0)
December	53 (8.7)

4.3.8. Predictors of Survival

Of the 610 EMS-witnessed patients, 77 (13%) survived to hospital discharge. Several variables were found to have an univariate association with survival of EMS-witnessed cardiac arrest patients (Table 4.12 to Table 4.20). Survivors were more likely: to have taken nitroglycerin prior to EMS arrival (Table 4.12); to have an initial cardiac arrest rhythm of VF/VT (Table 4.12); to be using calcium channel blockers (Table 4.15); and, to complain of chest pain and/or other pain (i.e., referred pain - usually indicated as neck, shoulder, back, or arm pain), or to be experiencing syncopal episodes as reasons for calling 911 (Table 4.17). Upon EMS arrival, survivors more frequently experienced chest pain as a chief complaint (Table 4.19), and more often received defibrillatory shocks (Table 4.20). Time intervals from symptom onset to EMS access, and from time of collapse to arrival at the emergency department were longer for survivors (Table 4.20).

Conversely, non-survivors were more likely to be in a non-shockable arrest rhythm (asystole or PEA) (Table 4.12), have low GCS scores (Table 4.13), have bradycardic rhythms and depressed respiratory rates on first assessment (Table 4.13), have a lower systolic blood pressure (Table 4.13), and to complain of decreased levels of consciousness, sudden collapse (Table 4.16), or shortness of breath (Table 4.17), as reasons for calling 911. Non-survivors also more frequently were unconscious on EMS arrival (Table 4.19), and had a chief complaint of shortness of breath (Table 4.19).

Table 4.12 Univariate Comparison of EMS-Witnessed Cardiac Arrest Patient Characteristics with Survival

Patient Characteristics	Non-Survivors N=533	Survivors N=77	
Age (SD)	70.0 (13.1)	68.8 (12.1)	
Male sex (%)	317 (59.5)	50 (64.9)	
Winter season (%)	133 (25.0)	21 (27.3)	
Activity prior to symptom onset (n=210:41; %)			
Sleeping or reclining	96 (45.7)	17 (41.5)	
Sitting activity	57 (27.1)	11 (26.8)	
Light activity	35 (16.7)	5 (12.2)	
Moderate activity	19 (9.0)	5 (12.2)	
Vigorous activity	3 (1.4)	3 (7.3)	
Nitroglycerin prior to EMS arrival (%)	38 (7.1)	18 (23.4)	****
Pick-up location (%)			
Residence	412 (77.3)	58 (75.3)	
Nursing home	54 (10.1)	5 (6.5)	
Public place	36 (6.8)	8 (10.4)	
Other	31 (5.8)	6 (7.8)	
Arrest location (%)			
At scene (pick-up location)	183 (34.3)	37 (48.1)	
Moving to stretcher	82 (15.4)	8 (10.4)	
Loading to ambulance	135 (25.3)	15 (19.5)	
En route	112 (21.0)	13 (16.9)	
Upon arrival at hospital	21 (3.9)	4 (5.2)	
Period of day patient arrested (n=505:75; %)			
Early Morning (midnight to 8AM)	119 (23.6)	13 (17.3)	
Day (8AM to 4PM)	194 (38.4)	25 (33.3)	
Evening (4PM to midnight)	192 (38.0)	37 (49.3)	
Cardiac or respiratory history (n=457:72; %)	375 (82.1)	56 (77.8)	
Use of cardiac or respiratory drugs (n=351:59; %)	263 (74.9)	43 (72.9)	
Prodromal symptoms (n=452:73; %)	410 (90.7)	70 (95.9)	
Initial cardiac arrest rhythm (n=497:76; %)			
VF/VT	129 (25.9)	67 (88.2)	****
Asystole	89 (17.9)	1 (1.3)	***
PEA	279 (56.1)	8 (10.5)	****

Testing procedures: Chi-square for proportions
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Table 4.13 Univariate Comparison of EMS-Witnessed Cardiac Arrest Initial Patient Assessment with Survival

Patient Characteristics	Non-Survivors N=533	Survivors N=77	
Unconscious on EMS arrival (%)	217 (40.8)	14 (18.2)	***
Glasgow Coma Scale - total (n=521:75)			
median [range]	6.0 [3-15]	15.0 [3-15]	****
Pulse rate (n=371:63) mean (SD)	71.3 (33.6)	86.7 (22.0)	***
Pulse rate < 50 / min	144 (38.8)	4 (6.3)	****
Pulse rate > 100 / min	69 (18.6)	15 (23.8)	
Respiratory rate (n=416:65) mean (SD)	16.5 (11.3)	19.3 (8.5)	*
Respiratory rate < 10 / min	122 (29.3)	6 (9.2)	***
Respiratory rate > 30 / min	43 (10.3)	6 (9.2)	
Systolic blood pressure (n=93:41) mean (SD)	119.2 (47.1)	131.7 (34.0)	
Systolic blood pressure < 90 mmHg	22 (23.7)	2 (4.9)	**
Pre-arrest rhythm (n=153:24; %)			
Normal sinus rhythm	29 (19.0)	12 (50.0)	***
Bradycardic rhythm	81 (52.9)	3 (12.5)	***
Tachycardic rhythm	37 (24.2)	6 (25.0)	

Testing procedures: Chi-square for proportions; Wilcoxon Rank Sum for medians; T-test for means
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Table 4.14 Univariate Comparison of EMS-Witnessed Cardiac Arrest Previous Cardiac or Respiratory History with Survival†

Previous Cardiac / Respiratory History	Non-Survivors N=457 (%)	Survivors N=72 (%)
Coronary artery disease	178 (38.9)	36 (50.0)
Cardiac history (unspecified)	98 (21.4)	13 (18.1)
Diabetes	91 (19.9)	14 (19.4)
Hypertension	86 (18.8)	18 (25.0)
Respiratory history	72 (15.8)	7 (9.7)
Congestive heart failure	45 (9.8)	11 (15.3)
Cerebrovascular accident	36 (7.9)	4 (5.6)
Hypercholesterolemia	2 (0.4)	1 (1.4)

Testing procedures: Chi-square for proportions
† Presence or absence of previous medical history was available for 529 (86.7%) cases.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Table 4.15 Univariate Comparison of Cardiac or Respiratory Drugs with Survival for 410 EMS-Witnessed Cardiac Arrest Patients with Information Indicating Either Use or Non-Use of Medications †

Use of Cardiac / Respiratory Drugs	Non-Survivors N=351 (%)	Survivors N=59 (%)	
Nitrates	102 (29.1)	18 (30.5)	
Antihypertensives	70 (19.9)	12 (20.3)	
Diuretics	64 (18.2)	13 (22.0)	
Cardiac glycosides	45 (12.8)	6 (10.2)	
Analgesics	42 (12.0)	4 (6.8)	
Calcium channel blockers	28 (8.0)	12 (20.3)	**
Bronchodilators	31 (8.8)	5 (8.5)	
Antidiabetics (oral hypoglycemics)	22 (6.3)	5 (8.5)	
Antidiabetics (insulin)	22 (6.3)	1 (1.7)	
Anticoagulants	19 (5.4)	3 (5.1)	
Beta blockers	15 (4.3)	3 (5.1)	
Antiarrhythmics	12 (3.4)	0 (0)	
Antihypercholesterolemics	1 (0.3)	0 (0)	

Testing procedures: Chi-square for proportions

† Patient medication use/non-use was available for 410 (67.3%) cases.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Table 4.16 Univariate Comparison of Patient Condition Prompting 911 Call with Survival for EMS-Witnessed Cardiac Arrest Patients

Patient Complaint (prompting 911 call)	Non-Survivors N=533 (%)	Survivors N=77 (%)	
Sudden collapse / fall	114 (21.4)	9 (11.7)	*
Decreased consciousness/unconscious (n=527:76)	222 (42.1)	14 (18.4)	****
Respiratory arrest	5 (0.9)	0 (0)	

Testing procedures: Chi-square for proportions

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Table 4.17 Univariate Comparison of Patient Complaint Prompting 911 Call with Survival for 525 EMS-Witnessed Cardiac Arrest Patients with Available Information †

Patient Complaint (prompting 911 call)	Non-Survivors N=452 (%)	Survivors N=73 (%)	
Shortness of breath	263 (58.2)	29 (39.7)	**
Chest pain	146 (32.3)	49 (67.1)	****
Other pain	39 (8.6)	16 (21.9)	***
Gastrointestinal symptoms	82 (18.1)	13 (17.8)	
Weakness	37 (8.2)	10 (13.7)	
Other	36 (8.0)	2 (2.7)	
Diaphoresis	34 (7.5)	1 (1.4)	
Seizure	24 (5.3)	3 (4.1)	
Syncope	16 (3.5)	7 (9.6)	*

Testing procedures: Chi-square for proportions
† Patient complaint was indicated for 525 (86.1%) cases.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Table 4.18 Univariate Comparison of Prodromal Symptoms of Chest Pain and/or Shortness of Breath with Survival for 525 EMS-Witnessed Cardiac Arrest Patients with Available Information †

Patient Complaint (prompting 911 call)	Non-Survivors N=452 (%)	Survivors N=73 (%)	
No Prodrome	42 (9.3)	3 (4.1)	
Shortness of breath	192 (42.5)	13 (17.8)	****
Chest pain	75 (16.6)	33 (45.2)	****
Both (shortness of breath and chest pain)	71 (15.7)	16 (21.9)	
Other	72 (15.9)	8 (11.0)	

Testing procedures: Chi-square for proportions
† Patient complaint was indicated for 525 (86.1%) cases.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Table 4.19 Univariate Comparison of Chief Complaint on Initial Assessment with Survival for EMS-Witnessed Cardiac Arrest Patients †

Chief Complaint (on patient contact)	Non-Survivors N=525 (%)	Survivors N=76 (%)	
Decreased level of consciousness / unconscious	282 (53.7)	14 (18.4)	****
Shortness of breath	122 (23.2)	11 (14.5)	
Chest pain	44 (8.4)	41 (53.9)	****
Respiratory arrest	39 (7.4)	2 (2.6)	
Other	18 (3.4)	6 (7.9)	
Gastrointestinal symptoms	12 (2.3)	1 (1.3)	
Seizure	8 (1.5)	1 (1.3)	

Testing procedures: Chi-square for proportions
† Chief complaint was only indicated for 601 (98.5%) cases.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Table 4.20 Univariate Comparison of EMS-Witnessed Cardiac Arrest System Characteristics with Survival

EMS System Characteristics	Non-Survivors N=533	Survivors N=77	
EMS response in 8 min or less (n=600; %)	398 (76.7)	53 (70.7)	
Fire first on scene (%)	78 (14.6)	9 (11.7)	
Precordial thump (%)	67 (12.6)	13 (16.9)	
Defibrillated (%)	145 (27.2)	67 (87.0)	****
Median patient event time intervals - min			
Symptom onset - 911 access (n=381)	7.0	25.6	*
Symptom onset - cardiac arrest (n=378)	25.0	40.0	
Vehicle stopped - cardiac arrest (n=574)	8.5	7.7	
Cardiac arrest - arrived ED (n=579)	8.5	10.5	
Median EMS response time intervals - min			
Call received - vehicle stopped (n=600)	6.2	6.3	
Vehicle stopped - departed scene (n=602)	13.0	13.7	
Departed scene - arrived ED (n=606)	4.1	4.1	

Testing procedures: Chi-square for proportions; Wilcoxon Rank Sum for medians
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Multivariate logistic regression was used to adjust survival for multiple covariates. Table 4.21 shows the results of applying forward stepwise variable selection using the -2 Log L statistic to assess the relative improvement in model fit for each successive variable entered.

Table 4.21 Likelihood Ratio Statistics (-2 Log L) for the Model at Each Step, and Degrees of Freedom and p-Values for Selecting Variables for the Final Model (Includes VF/VT)

Step	Variable Entered	-2 Log L	df	*p*-value
0	Intercept	404.539	1	<.0001
1	VF/VT	296.162	1	<.0001
2	Nitroglycerin	283.009	1	<.0001

The initial model identified VF/VT and nitroglycerin use as independent and significant predictors of survival (Table 4.22). VF/VT was associated with a very large point estimate and wide confidence intervals. Other variables that were significant at the univariate level were not fitted in this model: sex, age by decade, sudden collapse or fall, chest pain, shortness of breath, patient complaint other than chest pain or shortness of breath, response time interval from call received to vehicle stops, and on-scene interval from vehicle stops to depart scene.

Table 4.22 Logistic Regression Analysis: Factors Contributing to Survival Including VF/VT†

Covariate	Coefficient	OR	95% CI	
Intercept	-3.770			
VF/VT	3.028	20.7	(9.76, 43.69)	****
Nitroglycerin prior to EMS arrival	1.474	4.4	(1.96, 9.73)	***

† Due to listwise reduction of cases with missing data only 481 (78.9%) cases were included in the analysis.
$p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Further univariate (Table 4.23) and multivariate analyses indicated that VF/VT was highly associated with several of the other variables considered. A logistic regression was analyzed with VF/VT as a dependent variable. The resulting model indicated that several variables considered for the original model were independently associated with VF/VT: chest pain was a positive predictor whereas, unconsciousness on EMS arrival and shortness of breath were negative predictors.

Table 4.23 Measures of Association Between the Initial Rhythm VF/VT and Other Covariates for EMS-Witnessed Cardiac Arrest

Covariate of Interest	Non-VF/VT N=377	VF/VT N=196	
Nitroglycerin (n=52; %)	28 (7.4)	24 (12.2)	
Unconscious on EMS arrival (n=217; %)	159 (42.3)	58 (29.6)	**
Chest pain (n=103; %)	39 (12.0)	64 (38.3)	****
Shortness of breath (n=188; %)	156 (48.1)	32 (19.2)	****
EMS response in 8 minutes or less (n=425; %)	278 (74.5)	147 (77.0)	

Testing procedures: Chi-square for proportions
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

A final logistic regression analysis was carried out for EMS-witnessed patients excluding VF/VT as a covariate (Table 4.24 to Table 4.25). Due to listwise reduction of cases with missing data only 514 (84.3%) cases were included in the analysis. This multivariate analysis indicated that having initial symptoms which involved chest pain, and use of nitroglycerin prior to EMS arrival were factors that had an independent and significant association with improved survival. Factors found to be related to poorer survival were shortness of breath as a prodromal symptom, and unconsciousness on ambulance arrival.

Variables that were considered for the model but did not maintain their independent significance with survival when adjusted for were sex, age by decade, sudden collapse or fall, patient complaint other than chest pain or shortness of breath, response time interval from call received to vehicle stops, and on-scene interval from vehicle stops to depart scene. Removal of these variables from the model did not change the point estimates of the main effects and thus none of these variables were considered to be confounding.

After determination of the main effects model, interaction among main effects variables was assessed by forming a series of combined terms and introducing them each to the logistic regression model. Interactions considered to have clinical rational and/or prior reference in the literature were considered. Only first-order interactions were examined. No interaction terms entered the model.

Goodness of fit was based on the significance level of the -2 Log Likelihood statistic (-2 Log L) and on minimization of the Akaike Information

Criterion (AIC) statistic. The -2 Log L score for the final main effects model was highly significant (p<.00001). The AIC value of 383.9 was also the lowest score attributed to any of the models tested. The predictive accuracy of the model was determined from the c statistic, a measure of the area under the receiver operating characteristic (ROC) curve. The value of the c statistic for this model was 0.86 which indicates that the model has relatively high predictive accuracy.

Table 4.24 Likelihood Ratio Statistics (-2 Log L) for the Model at Each Step, and Degrees of Freedom and p-Values for improvement for Selecting Variables for the Final Model

Step	Variable Entered	-2 Log L	df	*p*-value
0	Intercept	412.802	1	<.0001
1	Chest pain	389.853	1	<.0001
2	Nitroglycerin	380.410	1	<.0001
3	Unconscious on EMS arrival	375.506	1	<.0001
4	Shortness of breath	371.893	1	<.0001

Table 4.25 Logistic Regression Analysis: Factors Contributing to Survival†

Covariate	Coefficient	OR	95% CI	
Intercept	-1.84			
Nitroglycerin prior to EMS arrival	0.83	2.30	(1.17, 4.54)	*
Unconscious on EMS arrival	-0.79	0.45	(0.23, 0.91)	*
Shortness of breath	-0.68	0.51	(0.25, 1.04)	
Chest pain	0.90	2.47	(1.36, 4.48)	**

† Due to listwise reduction of cases with missing data only 514 (84.3%) cases were included in the analysis.

p < 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001

4.3.9. Subgroup Comparisons

4.3.9.1.Survival Subgroups

Survival for patients in VF/VT was 34.2%, whereas survival rates for all other patients was only 2.4% (Table 4.26). Patients who had initial symptoms which included chest pain had a greater survival rate when compared to patients who indicated shortness of breath as a prodrome (30.3% vs. 6.3%). Not surprising was the lower survival for patients who were unconscious on ambulance arrival compared to those patients that were conscious (6.1% vs. 16.7%). Finally, patients under 70 years of age had a trend towards improved survival when compared to those greater than 70 years (14.1% vs. 11.7%; p=0.39).

Table 4.26 Survival in EMS-Witnessed Cardiac Arrest Clinically Important Subgroups

Subgroup	Total Patients N	Survivors (%)	
Age			
<70 years	263	37 (14.1)	
>70 years	342	40 (11.7)	
Prodromal symptoms			
No prodrome	45	3 (6.7)	
Shortness of breath	205	13 (6.3)	****
Chest pain	108	33 (30.6)	****
Both (shortness of breath and chest pain)	87	16 (18.6)	
Other	80	8 (10.0)	
Unconscious on EMS arrival			
Yes	231	14 (6.1)	****
No	378	63 (16.7)	
Initial arrest rhythm			
VF/VT	196	67 (34.2)	****
Other (asystole, PEA)	377	9 (2.4)	

Testing procedures: Chi-square for proportions
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

4.3.9.2. Younger vs. Older Patients

Compared to elderly patients greater than 70 years of age, younger patients were more likely to be male (69% vs. 53%), and to have a prodromal symptom of chest pain (Table 4.27). There was an increased trend for younger patients to have an initial arrest rhythm of VF/VT (39% vs. 31%; p=0.058). Although there was no difference in the numbers of younger and older patients who had a return of spontaneous circulation (24.7% vs. 23.7%), a trend was found toward a greater proportion of younger patients surviving to hospital discharge (14.1% vs. 11.7%; p=0.39), perhaps indicating that elderly patients were less able to survive once a pulse had been re-established.

Table 4.27 Subgroup Analysis: Comparison of EMS-Witnessed Cardiac Arrest Patients Less Than and Greater Than 70 Years

Patient Characteristics	<70 Years N=263 (%)	≥70 Years N=342 (%)	
Male sex	182 (69.2)	180 (52.9)	****
Nitroglycerin prior to EMS arrival	24 (9.1)	32 (9.4)	
Cardiac or respiratory history (n=226:300)	170 (75.2)	259 (86.3)	***
Use of cardiac or respiratory drugs (n=170:237)	109 (64.1)	195 (82.3)	****
Prodromal symptoms (n=227:295)	203 (89.4)	274 (92.9)	
No prodrome	24 (10.6)	21 (7.1)	
Shortness of breath	78 (34.4)	125 (42.4)	
Chest pain	51 (22.5)	57 (19.3)	
Both shortness of breath/chest pain	40 (17.6)	47 (15.9)	
Other	34 (15.0)	45 (15.3)	
Initial arrest rhythm (n=247:321)			
VF/VT	95 (38.5)	99 (30.8)	
Asystole	39 (15.8)	50 (15.6)	
PEA	113 (45.7)	172 (53.6)	
Return of spontaneous circulation	65 (24.7)	81 (23.7)	
Admitted to hospital	49 (18.6)	53 (15.5)	
Discharged alive from hospital	37 (14.1)	40 (11.7)	

Testing procedures: Chi-square for proportions
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

4.3.9.3. Initial Arrest Rhythm of VF/VT

Patients in VF/VT, compared to those with other arrest rhythms, were generally younger in age and male (Table 4.28). These patients were more likely to have had chest pain and to have taken nitroglycerin prior to EMS arrival. As indicated earlier, patients in VF/VT had a much higher rate of discharge.

Table 4.28 Subgroup Analysis: Comparison of EMS-Witnessed Cardiac Arrest Patients With and Without an Initial Rhythm of VF/VT

VF/VT Patient and System Characteristics	Non-VF/VT N=377		VF/VT N=196		
Age (n=374:194; SD)	70.7	(12.7)	68.1	(13.1)	*
Male sex (%)	216	(57.3)	125	(63.8)	
Nitroglycerin prior to EMS arrival (%)	28	(7.4)	24	(12.2)	
Cardiac or respiratory history (n=328:168; %)	268	(81.7)	137	(81.5)	
Use of cardiac or respiratory drugs (n=252:140; %)	190	(75.4)	105	(75.0)	
Prodromal symptoms (n=324:167; %)	294	(90.7)	154	(92.2)	
No prodrome	30	(9.3)	13	(7.8)	
Shortness of breath	156	(48.1)	32	(19.2)	
Chest pain	39	(12.0)	64	(38.3)	
Both shortness of breath/chest pain	49	(15.1)	32	(19.2)	****
Other	50	(15.4)	26	(15.6)	****
Symptom onset to arrest > 4 hrs (n=227:134; %)	23	(10.1)	6	(4.5)	*
Return of spontaneous circulation (%)	43	(11.4)	95	(48.5)	****
Admitted to hospital (%)	19	(5.0)	79	(40.3)	****
Discharged alive from hospital (%)	9	(2.4)	67	(34.2)	****

Testing procedures: Chi-square for proportions
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

4.3.9.4. Presence or Absence of Prodromal Symptoms

There were no age or sex differences for patients with and without prodromal symptoms (Table 4.29). As expected, nitroglycerin use prior to ambulance arrival was limited to that group of patients who experienced a prodrome. There was a much greater use of cardiac and respiratory drugs in the group who experienced a prodrome. There were no significant differences between groups in terms of initial cardiac arrest rhythm. A trend was seen toward improved survival rate for the group with prodromal symptoms, however, this could be due, in part, to the small sample of patients observed to have no prodromal symptoms.

Table 4.29 Subgroup Analysis: Comparison of EMS-Witnessed Cardiac Arrest Patients With and Without Prodromal Symptoms

Patient and System Characteristics	No Prodrome N=45	Prodrome N=480	
Age (n=45:477; SD)	68.3 (12.2)	69.9 (13.2)	
Male sex (%)	27 (60.0)	284 (59.2)	
Nitroglycerin prior to EMS arrival (%)	0 (0.0)	54 (11.3)	*
Cardiac or respiratory history (n=33:435; %)	24 (72.7)	352 (80.9)	
Use of cardiac or respiratory drugs (n=18:357; %)	8 (44.4)	269 (75.4)	**
Initial arrest rhythm (n=43:448; %)			
VF/VT	13 (30.2)	154 (34.4)	
Asystole	7 (16.3)	68 (15.2)	
PEA	23 (53.5)	226 (50.4)	
Return of spontaneous circulation (%)	12 (26.7)	123 (25.6)	
Admitted tc hospital (%)	8 (17.8)	89 (18.5)	
Discharged alive from hospital (%)	3 (6.7)	70 (14.6)	

Testing procedures: Chi-square for proportions
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

4.3.9.5.Shortness of Breath and Chest Pain

Comparisons were made between patients who experienced prodromal symptoms which included dyspnea with those who were reported to have had chest pain (Table 4.30). The chest pain patients were slightly younger (non-significant) and more often male. Not surprisingly, chest pain patients had more frequent use of nitroglycerin. Chest pain patients were also more likely to be found in VF/VT, whereas dyspneic patients more frequently were in aystole or PEA. There was a wide difference in survival rates between these two groups with more survivors in the chest pain group (30.6% vs. 6.3). On the whole, patients experiencing both chest pain and shortness of breath had intermediate values between those experiencing either of these conditions exclusive of the other. However, the combined group had a higher rate of nitroglycerin use, more often reported a relevant medical history, and had more frequently reported use of cardiac or respiratory medications.

Table 4.30 Subgroup Analysis: Comparison of EMS-Witnessed Cardiac Arrest Patients With Shortness of Breath and Chest Pain

Patient and System Characteristics	SOB N=205	Chest Pain N=108	Both N=87	
Age (n=203:108:87; SD)	70.9 (13.3)	69.4 (12.2)	69.2 (12.3)	
Male sex (%)	112 (54.6)	74 (68.5)	53 (60.9)	*
Nitroglycerin prior to EMS arrival (%)	3 (1.5)	23 (21.3)	26 (29.9)	****
Cardiac/respiratory history (n=183:103:81; %)	151 (82.5)	83 (80.6)	70 (86.4)	
Use of cardiac or respiratory drugs (%) (n=183:103:81)	119 (78.3)	59 (72.0)	57 (83.8)	
Symptom onset to arrest > 4 hrs (%) (n=117:78:72)	14 (12.0)	6 (7.7)	6 (8.3)	
Initial arrest rhythm (n=188:103:81; %)				
VF/VT	32 (17.0)	64 (62.1)	32 (39.5)	****
Asystole	41 (21.8)	5 (4.9)	9 (11.1)	***
PEA	115 (61.2)	34 (33.0)	40 (49.4)	***
Return of spontaneous circulation (%)	34 (16.6)	45 (41.7)	26 (29.9)	****
Admitted to hospital (%)	22 (10.7)	37 (34.3)	17 (19.5)	****
Discharged alive from hospital (%)	13 (6.3)	33 (30.6)	16 (18.4)	****

Testing procedures: Chi-square for proportions
p < 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001

4.4. EMS-Witnessed Compared to Bystander-Witnessed Cardiac Arrest

The 610 patients who were witnessed to arrest by EMS personnel represented 6.7% of the total number of primary cardiac etiology cardiac arrests. A much larger group of patients were witnessed to collapse by bystanders. Overall there were 4,043 bystander-witnessed cardiac arrests which accounted for 44.5% of all arrests.

4.4.1. Demographic, System and Clinical Characteristics

Compared to bystander-witnessed cardiac arrest patients, EMS-witnessed cases were significantly more likely to be female (40% vs. 30%), and older (70 vs. 68 years) (Table 4.31). The proportion of patients in VF/VT was significantly lower for EMS-witnessed cases (28% vs. 52%), which was offset by a much higher rate of PEA (47% vs. 22%). Survival to discharge was significantly greater for EMS-witnessed, both overall (12.5% vs. 6.2%), and for VF/VT (35.6% vs. 11.2%).

Table 4.31 Univariate Comparison of EMS-Witnessed and Bystander-Witnessed Cardiac Arrest Patient Characteristics

Patient Characteristics	Witnessed Status† Unwitnessed (n=4419)	Bystander (n=4043)	EMS (n=610)	
Age (SD)	68.7 (13.6)	67.9 (13.8)	69.8 (12.9)	***
Male sex (%)	2898 (65.6)	2850 (70.5)	367 (60.1)	***
Winter season (%)	1200 (27.2)	1070 (26.5)	154 (25.3)	
Population size (%)				
Under 30,000	261 (5.9)	180 (4.5)	32 (5.3)	
30,000 to 100,000	1005 (22.7)	841 (20.8)	124 (20.3)	
100,000 to 200,000	987 (21.1)	853 (21.1)	142 (23.3)	
200,000 to 500,000	1547 (35.0)	1513 (37.4)	225 (36.9)	
Over 500,000	619 (14.0)	656 (16.2)	87 (14.3)	
Initial cardiac arrest rhythm (%)				
VF/VT	1061 (24.0)	2079 (51.4)	196 (32.1)	***
Asystole	2533 (57.3)	955 (23.6)	90 (14.8)	***
PEA	647 (14.6)	880 (21.8)	287 (47.1)	***
Return of spontaneous circulation (%)	228 (5.2)	592 (14.6)	146 (23.9)	***
Admitted to hospital (%)	171 (3.9)	459 (11.4)	102 (16.7)	***
Discharged alive from hospital (%)	65 (1.5)	256 (6.3)	77 (12.6)	***

Testing procedures: Chi-square for proportions
† Unwitnessed cardiac arrest data is presented for descriptive purposes only and was not considered for univariate testing.
$p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

An interesting difference between EMS-witnessed and bystander-witnessed cardiac arrest is in the proportion of patients that are ultimately defibrillated (Table 4.32). Bystander-witnessed arrests are shocked much more often that EMS-witnessed arrest patients. Fire response and EMS time intervals did not appear to differ between the two groups.

Table 4.32 Univariate Comparison of EMS-Witnessed and Bystander-Witnessed Cardiac Arrest EMS System Characteristics

EMS System Characteristics	Witnessed Status† Unwitnessed (n=4419)	Bystander (n=4043)	EMS (n=610)	
EMS response in 8 min or less (%) (n=4348:3970:600)	3546 (81.6)	3190 (80.4)	454 (75.7)	*
Fire first at scene (%) (n=4348:3998:610)	457 (11.5)	451 (11.3)	87 (14.3)	*
Defibrillated (%) (n=4408:4041:610)	1416 (32.1)	2263 (56.0)	212 (34.8)	****
Median EMS response time intervals - min				
Call received - vehicle stopped (n=4348:3970:600)	6.0	6.0	6.2	*
Vehicle stopped - departed scene (n=4293:3953:602)	10.1	10.0	13.0	****
Departed scene - arrived ED (n=4309:3944:606)	4.0	4.0	4.1	****

Testing procedures: Chi-square for proportions
† Unwitnessed cardiac arrest data is presented for descriptive purposes only and was not considered for univariate testing.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

Multivariate logistic regression was used to adjust overall unadjusted survival proportions for EMS-witnessed and bystander-witnessed patients. As before, VF/VT was first included in the model, but then removed from the final logistic regression due to its relationship with several of the other variables (Table 4.33 to Table 4.34).

Table 4.33 Likelihood Ratio Statistics (-2 Log L) for the Cardiac Arrest Survival Model at Each Step, and Degrees of Freedom and p-Values for Selecting Variables for the Final Model: VF/VT Included

Step	Variable Entered	-2 Log L	df	*p*-value
0	Intercept	2210.609	1	<.0001
1	VF/VT	1954.680	1	<.0001
2	EMS-witnessed	1890.378	1	<.0001
3	Call received to vehicle stops - min	1874.217	1	<.0001
4	Vehicle stops to depart scene - min	1864.787	1	<.0001
5	Age / 10 years	1861.191	1	<.0001

Table 4.34 Logistic Regression Analysis for Bystander and EMS-Witnessed Cardiac Arrest factors contributing to Survival: VF/VT Included

Covariate	Coefficient	OR	95% CI	
Intercept	-3.05			
Age / 10 years	-0.09	0.92	(0.84, 1.00)	
EMS-witnessed	1.52	4.57	(3.31, 6.31)	****
Call received to vehicle stops - min	-0.11	0.90	(0.85, 0.95)	***
Vehicle stops to depart scene - min	-0.05	0.95	(0.92, 0.98)	**
VF/VT	2.63	13.90	(9.13, 21.14)	****

† Due to listwise reduction of cases with missing data only 4255 (91.4%) cases were included in the analysis.
* p < 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001

The final logistic regression model is outlined in Table 4.35 and Table 4.36. Due to listwise reduction of cases with missing data only 4598 (83.3%) cases were included in the analysis. As expected, increasing age was associated with poorer survival. As well, longer response time intervals (from call received to vehicle stops), and longer on-scene intervals (from vehicle stops to depart scene) were also associated with decreased survival. However, when controlling for all of these independent covariates, EMS-witnessed cardiac arrests had an odds of survival which was nearly 3 times more likely than for bystander-witnessed arrests.

Variables that were considered for the model but did not maintain their independent significance with survival when adjusted for were fire fighter arriving first to scene, sex, population size by quartile, winter season and time from depart scene to arrival at the emergency department. Removal of these variables from the model did not affect the point estimates of the main effects and so none of these variables were considered tc be confounding.

After determination of the main effects model, interaction between variables was assessed by offering a series of combined terms separately to the logistic regression. Only first-order interactions were examined. No interaction terms entered the model.

Goodness of fit was again based on the significance level of the -2 Log L score and on minimization of the AIC statistic. The -2 Log L score for the final main effects model was highly significant ($p<.0001$). The AIC value of 2177.3 was also the lowest score attributed to any of the models tested. The value of the c statistic for this model was 0.93 which indicates that the model has high predictive accuracy.

Table 4.35 Likelihood Ratio Statistics (-2 Log L) for the Cardiac Arrest Survival Model at Each Step, and Degrees of Freedom and p-Values for Selecting Variables for the Final Model

Step	Variable Entered	-2 Log L	df	*p*-value
0	Intercept	2249.268	1	<.0001
1	EMS-witnessed	2222.493	1	<.0001
2	Call received to vehicle stops – min	2191.333	1	<.0001
3	Age / 10 years	2171.960	1	<.0001
4	Vehicle stops to depart scene – min	2165.328	1	<.0001

Table 4.36 Logistic Regression Analysis for Bystander and EMS-Witnessed Cardiac Arrest factors contributing to Survival

Covariate	Coefficient	OR	95% CI	
Intercept	-0.34			
Age / 10 years	-0.18	0.84	(0.77, 0.90)	****
EMS-witnessed	0.94	2.57	(1.93, 3.43)	****
Call received to vehicle stops - min	-0.14	0.87	(0.82, 0.91)	****
Vehicle stops to depart scene - min	-0.04	0.96	(0.93, 0.99)	*

† Due to listwise reduction of cases with missing data only 4412 (94.8%) cases were included in the analysis.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

4.4.2. Subgroup Comparisons

Although VF/VT accounts for a smaller proportion of EMS-witnessed versus bystander-witnessed cardiac arrest, there is a significantly higher proportion of survivors for this rhythm subgroup in EMS-witnessed cases (34.2% vs. 11.2%). As well, there is improved survival for EMS-witnessed cases in both patients older and younger than 70 years of age (Table 4.37).

Table 4.37 Survival Comparison Between EMS-Witnessed and Bystander-Witnessed Cardiac Arrest in Clinically Important Subgroups

Subgroup	N	N	Survivors Bystander (%)	Survivors EMS (%)	
Age					
<70 years	2046	268	168 (8.2)	37 (13.8)	**
≥70 years	1997	342	88 (4.4)	40 (11.7)	***
Initial arrest rhythm					
VF/VT	2079	196	233 (11.2)	67 (34.2)	***
Asystole	955	90	5 (0.5)	1 (1.1)	
PEA	880	287	16 (1.8)	8 (2.8)	

Testing procedures: Chi-square for proportions
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$

5. DISCUSSION

These data consitute the largest sample of consecutive EMS-witnessed cardiac arrest cases yet studied. The results provide a detailed overview of the patient who suffers cardiac arrest in the presence of EMS personnel and have the potential to influence both EMS care and future research initiatives. Based on information gathered about prodromal symptoms and other patient characteristics, it is apparent that two very distinct groups exist within the EMS-witnessed cardiac arrest population: those patients who experience symptoms of chest pain prior to collapse, and those with shortness of breath. These characteristics are also predictors of survival with chest pain patients much more frequently experiencing favorable outcomes. Further, it was found that survival from EMS-witnessed cardiac arrest is twice that of bystander-witnessed cardiac arrest. Survival for EMS-witnessed cardiac arrest is not affected by rapid EMS response times, or by citizen witnesses or bystander CPR, but rather by the effectiveness of EMS care. This group may represent the highest potential for successful resuscitation in a BLS-D EMS system.

5.1. EMS-Witnessed Cardiac Arrest Profile

The present data suggest that this may be a distinct group of prehospital cardiac arrest patients. A large proportion of these patients have a known history of cardiac or respiratory disease and the vast majority of this group are symptomatic prior to collapsing. The typical profile of the patient who arrests in the presence of EMS personnel is a 70 year old male, with a history of cardiac or respiratory disease and related medication use, who experiences initial warning symptoms of shortness of breath or chest pain at home one or two hours prior to collapsing.

An interesting finding was that the EMS-witnessed arrest patient was more likely to have an initial arrest rhythm of PEA rather than VF/VT. Similarly, low rates of VF/VT were found for EMS-witnessed arrests in Chicago and New York.[17,18] In contrast, authors in King County reported that almost two thirds of their EMS-witnessed patients had an initial rhythm of VF/VT with correspondingly high rates of survival for this group.[3] A number of other centres have had findings comparable to King County.[26,28,34] Authors have suggested that the disparity in the rates of VF/VT and survival for EMS-witnessed cardiac arrest may reflect differences in underlying disease, or other sociodemographic features of a given population. It is also possible that differing selection criteria have been utilized between studies. In this study population, higher rates of PEA may reflect greater co-morbid illness. However, without further investigation, no clear explanation can be given to explain the lower rates of VF/VT found in this study group.

Previous studies based on information from vital statistics and prehospital records have demonstrated circadian variation in the occurrence of sudden cardiac death[48,49] A recent study examining witnessed cardiac arrest in an ALS system demonstrated that the lowest rates occur between midnight and 6 AM.[49] Similar findings were noted in this study group with fewer patients arresting in the period between midnight and 8 AM. After this, the rate increased and remained elevated throughout the remainder of the day and into the early evening. Despite this, circadian variation did not show an association with the outcome of resuscitation. Researchers have also associated cardiac arrest with increased physical activity, [50,51] however, similar trends were not found within this study group. Typically, patients were either resting or performing light activity. Very few patients were found to be engaging in vigorous physical activity which is consistent with other authors' findings regarding those patients experiencing prodromal symptoms prior to cardiac arrest.[3]

5.2. Mechanisms of arrest

The high frequency of symptoms and documented evidence of existing cardio-respiratory disease and medication use suggest that the majority of patients in this group have pre-existing heart disease. Authors suggest that these patients may experience one of two different mechanisms of cardiac arrest with differing prognoses: electrical and mechanical failure.[3,26,27,28,29,30] Since most cardiac arrest patients do not undergo electrophysiological testing or autopsy, it is difficult to verify the exact mechanism of arrest. Despite this, the nature of the presenting rhythm upon collapse may differentiate between these types of arrest with VF/VT representing patients experiencing electrical failure and brady-asystolic rhythms identifying those patients with mechanical arrest or "pump" failure.

Moreover, the data suggest that this distinction between the mechanism of arrest is apparent even in the period prior to collapse. Patients may be classified according to the prodromal symptoms of chest pain and shortness of breath. Patients experiencing chest pain may be suffering from ischemia or acute myocardial infarction, whereas patients complaining of dyspnea may have acute pulmonary edema or congestive heart failure (CHF). Evidence for these assumptions exists in the differences identified between these two groups for several characteristics including differing survival rates, initial arrest rhythms, and onset times of symptoms and collapse. We found a significant difference in the survival rates for these two groups, with a much better outlook for the chest pain group. If our assumption is correct and symptoms do in fact differentiate the mechanism of arrest, the high rates of survival associated with chest pain compared to the low survival for dyspneic patients coincides with literature that suggests that cardiac arrest patients who have sustained a myocardial infarction have a far better survival outlook than patients experiencing heart failure.[4,10,26,27,45]

As a few smaller studies have also found, the type of symptom is strongly associated with the type of rhythm causing the cardiac arrest.[26,27,28] That is, higher rates of VF/VT were observed in those patients experiencing chest pain and higher rates of brady-asystolic arrest were found in those patients with dyspnea. The greater proportion of patients with VF/VT in those experiencing chest pain, is consistent with the electrical events that may result from myocardial ischemia or infarction.[43] As well, evidence suggesting that patients in heart failure generally develop bradycardic rhythms as ventricular function declines is consistent with the greater rates of PEA and asystole found in the dyspneic group.[4,45]

Furthermore, a trend was seen in the time interval between symptom onset and arrest. A greater percentage of dyspneic patients were found to have prolonged intervals (>4 hours from initial symptoms) to collapse. This may follow from others' findings who have observed prolonged times to arrest for patients experiencing brady-asystolic arrests when compared to those experiencing VF/VT.[26,43]

Results of the logistic regression analysis also seem to indicate that two different groups may exist. An independent and significant survival benefit was seen for those patients experiencing chest pain and who had taken nitroglycerin prior to arresting. Whereas non-survival was predicted for patients who had symptoms of shortness of breath with no chest pain involvement. Goldstein[10] also found disparity in the types of prodromal symptoms occurring in survivors of cardiac arrest attributable to differing mechanisms of arrest, and suggested that the presence of prodromal symptoms may also be a factor in patient survival.

5.3. Identifying Prehospital Patients at Risk of Cardiac Arrest

Although there is considerable variability in the clinical manifestation of the events leading to cardiac arrest, it may be possible to identify potential victims of cardiac arrest in the prodromal stages.[52,53] This study, as well as others,[3,10,13,27,54,55] has shown that cardiac arrest patients have high rates of underlying cardiac disease (particularly prior MI, angina, and hypertension), and high rates of prodromata (which were also noted to increase in frequency of occurrence in the days leading up to the cardiac event). As well, many of these patients had a decreased level of consciousness or were unconscious at the time of EMS access, and even more were in a moribund state upon arrival of EMS personnel. Although it was not possible to detect specific precipitating factors to accurately identify potential cardiac arrest patients, this study has identified certain conditions under which EMS personnel should be aware of impending risk: patients presenting with prodromal symptoms (i.e., shortness of breath or chest pain) associated with decreased levels of consciousness and evidence of prior cardio-respiratory illness. Patients with a previous cardiac or respiratory history may be helped by educational programs to recognize immediate risk and to seek early access to medical care. The benefit to EMS personnel in identifying these patients is that there may then be potential to aggressively treat these symptomatic patients in the prehospital setting with oxygen, nitrates, and other medications, and possibly prevent sudden cardiac death.

5.4. Survival of EMS-Witnessed Cardiac Arrest Patients

Survival rates for EMS-witnessed patients were much higher than those rates published for the general cardiac arrest population in Ontario.[16,31,41] This is not surprising given that most studies have made similar observations with the EMS-witnessed cardiac arrest sub-group. In almost one quarter of the patients, a return or spontaneous circulation was achieved at some point during the resuscitation attempt and about half of these patients were eventually discharged alive from hospital. Even better were survival rates for patients experiencing an initial arrest rhythm of VF/VT, who were three times more likely to survive until discharge than the overall EMS-witnessed population. Although this rhythm group represented only a small proportion of all EMS-witnessed cardiac arrests, it accounted for almost all of the survivors.

Aside from being in a favorable arrest rhythm, certain other factors were found to have an independent and significant association with survival in this group. Prodromal symptoms of chest pain and use of nitroglycerin prior to EMS arrival corresponded with positive outcomes, whereas, shortness of breath and unconsciousness on EMS arrival were related to decreased survival. Although an association was found between chest pain and nitroglycerin use, the strength of association was not great enough to assume colinearity between these factors. Consequently, both chest pain and nitroglycerin use prior to EMS arrival are considered independent predictors of survival.

Although symptoms cannot be modified, knowledge of these indicators does have implications for both patients and providers. Earlier recognition of these symptoms may result in more rapid access to EMS and may mean that the patient is in better condition upon EMS arrival. By improving the first link of the "chain of survival", symptomatic patients move through the system faster which may improve the chance of a successful resuscitation or even provide an opportunity to circumvent the arrest altogether.

Further implications regard the use of nitroglycerin. Patients suffering myocardial infarction who took nitroglycerin probably gained a survival advantage by limiting the extent of myocardial damage through improved coronary perfusion. Anecdotal accounts illustrate that patients are often apprehensive about taking their nitroglycerin when they experience anginal symptoms, especially the first time they find themselves faced with making this decision. Properly educating the patient and family members regarding the appropriate use of this drug is of import; had more of the symptomatic patients taken nitroglycerin, we may have seen a greater survival rate. This finding also lends support to program initiatives for the administration of symptom relief drugs such as nitroglycerin by BLS-D personnel.

5.5. EMS-Witnessed Versus Bystander-Witnessed Cardiac Arrest

We observed that the survival rate for patients experiencing an EMS-witnessed arrest was much higher than that for patients experiencing arrests witnessed by bystanders. In fact, the likelihood of survival for EMS-witnessed patients was over two and a half times greater than for bystander-witnessed arrest when controlled for other independent predictors by logistic regression. This appears to be consistent with the fact that these patients are receiving immediate resuscitation attempts at the moment they arrest.

However, the literature is not entirely in agreement regarding the likely outcomes for these patients.[1,3,30] Authors like Cummins and Eisenberg assert that EMS-witnessed cardiac arrest is characterized by a group with an extremely poor prognosis, while other authors such as Goldstein[10] indicate that in terms of resuscitation success, EMS-witnessed arrests were the most effective part of their program. Once again, the characterization of the type of arrest by mechanism is an important consideration. Cummins indicates that EMS-witnessed patients are a group who primarily experience the effects of mechanical arrest, whereas more primary sudden electrical failure occurs in the bystander-witnessed group. However, failure to further sub-divide arrests into those caused by myocardial ischemia/infarction versus those resulting from the effects of acute pulmonary edema, may have resulted in an over-generalization of the characteristics of the EMS-witnessed patient. Eisenberg suggests that these patients represent rapid cardiac failure due to mechanical dysfunction, most commonly following acute coronary thrombosis. The EMS-witnessed arrest, as described, begins with chest pain, cardiac dysfunction, hypoperfusion, and pulmonary edema and ends in a loss of pulse. Cummins argues that these patients represent the most severe form of cardiogenic shock and that prehospital treatment of this group is essentially futile. Although the mechanism described exists, it is the most severe form and likely represents only a fraction of EMS-witnessed cardiac arrests. This study found that the prognosis for EMS-witnessed cardiac arrest patients as a whole is quite good, and that individual patient prognoses may be based, in part, on which mechanism the patient experiences. The poorer prognoses are restricted to those patients suffering the more severe effects of heart failure or pulmonary edema.

We know that VF/VT is the arrest rhythm associated with the highest survival rates. It would then follow that the higher incidence of this rhythm in the bystander-witnessed group would equate to higher survival rates for this group. However, the opposite was observed in this study. In fact, subgroup analysis indicated that EMS-witnessed arrests had triple the survival rate when compared to bystander-witnessed arrest for patients in VF/VT. It is likely that the more rapid delivery of electrical shock in the EMS-witnessed case leads to improved survival in a smaller group of patients who experience this rhythm. Numerous studies have indicated that successful resuscitation is largely a question of the time between onset of ventricular fibrillation and the administration of defibrillatory shock.[22, 56,57,58,59,60,61]

The lower overall rate of VF/VT observed in the EMS-witnessed group might be explained by the fact that a larger fraction of this group is experiencing cardiac arrest as a result of heart failure or pulmonary disease which is associated with brady-asystolic rhythms.[4] Conversely, the bystander-witnessed group may experience more primary arrhythmic events, or ischemic/infarction events with associated higher rates of VF/VT. Studies indicate that patients who sustain a cardiac arrest due to VF/VT have a much higher probability of surviving, especially when the arrest is witnessed and bystanders initiate CPR immediately.[3,30]

5.6. Methodological Issues

Although certain limitations exist, there are several reasons for using a cohort design to meet the current objectives. First, the general nature of the study is descriptive, and not interventional. A traditional epidemiological design is most appropriate for identifying the characteristics of a particular population, upon which future controlled studies can be designed. Second, assessing factors related to survival within a group, the primary objective of this study, may be better ascertained through a case-control study. However, the type of predictors that we are assessing are event-related (e.g., symptoms, cardiac arrest characteristics, EMS system characteristics, and event times), and not true environmental or lifestyle exposures which are those factors best suited to controlled studies. Moreover, it would be difficult to identify a suitable control group in order to assess potential exposures in a proper fashion.

The design is not exclusively retrospective in nature. The OPALS study commenced in April 1994, and all data from that time forward is considered prospective. In order to obtain a sufficient sample size, OPALS required centers to provide three years of retrospective data. There was some concern about the complete identification of all cardiac arrest event and outcome data in the retrospective period. However base hospital programs have been required by the Ministry of Health to maintain complete files on all cardiac arrest patients since the beginning of their base hospital defibrillation programs (prior to 1991 for all of the involved sites). Furthermore, the OPALS study has performed exhaustive reviews of case reports and maintains extensive oversight of site reporting to ensure the completeness of the dataset.

The primary data source for this study was information gathered from a review of ambulance call reports. Unfortunately, on occasion, the recording of information on these forms may be somewhat incomplete. The retrospective nature of this study requires the availability of adequate records. The validity of the results may be affected by cases that are missing key data elements or outcome measures. Hence, every effort was made to ensure that the data was as complete as possible. Outcome data was ascertained for all patients in this study. Nevertheless, not all patient information (such as, relevant medical history, warning signs and symptoms, and timing of events) was available in all cases.

A common concern with record and survey completion is recall bias. As all event information was extracted from documents completed by ambulance officers at the time of the event, there is limited potential for recall bias on the part of the EMT. Nevertheless, in recording patient medical histories from patients themselves and family members, the information provided to the EMT may have been selective, a problem that could not be avoided.

Madsen[53] noted that the recorded incidence of symptoms before cardiac arrest depends on the method of investigation. He suggests that documentation would consist only of those prodromes considered so severe that they were reported at the time. In this study, 91% of patients were reported to have had symptoms prior to arrest, according to information made available from patients or family members at the time of the incident and recorded on ambulance reports. Review of the documentation available for this study indicated that the recording of the presence or absence of prodromes was satisfactory and complete. However, it is possible that in some cases, specific symptoms may have been ignored or downgraded by patients or bystanders when more significant symptoms were experienced.

As well, due to the retrospective nature of this study, the potential for interviewer bias increases as all relevant events and outcomes have already occurred. For example, when reviewing cases for the presence and on-set of symptoms, as well as other factors, it was not possible to blind the author to outcome.

We were unable to definitively determine the precise mechanism for cardiac arrest in this group as autopsy data was not gathered, and other clinical test results (e.g., ECG, enzyme tests, and measures of ejection fraction) were not readily available for survivors. More complete information on the pre-arrest rhythm would also have been useful in identifying rhythm changes leading up to the arrest. Due to these limitations we are only at best able to speculate about the etiologic events underlying cardiac arrest in these patients.

Finally, it was not possible, due to economic and time constraints, to collect pre-arrest data on the over 4000 bystander-witnessed patients. This may have enabled a more thorough comparison of EMS-witnessed and bystander-witnessed cardiac arrest and would likely have provided further information regarding cardiac arrest mechanisms and precipitating events.

5.7. Clinical and EMS Implications

These findings have implications for prehospital clinical care, and for the direction of EMS resources and quality assurance programs: 1) the high survival rates for EMS-witnessed cases re-emphasize the value of early BLS-D care (oxygen, CPR and defibrillation); 2) the identification of high risk patients and predictors of survival supports more aggressive treatment and transport of symptomatic patients (e.g., shortness of breath, chest pain and unconsciousness); 3) improved survival of EMS-witnessed over bystander-witnessed cases highlights the benefit of early recognition of acute symptoms by patients and rapid EMS access; 4) as other bystander and response characteristics do not factor in these arrests, outcomes for EMS-witnessed cardiac arrest may be used to judge provider performance within a BLS-D system; and 5) comparisons of EMS-witnessed rates and survival may be a way of assessing not only ALS provider performance, but also the effectiveness of new interventions in an ALS system.

5.8. Future Research

It is hoped that knowledge of the basic epidemiology (incidence, survival rates and other characteristics) of this group will provide necessary background information for future observational or interventional designs. Further initiatives should consider: 1) ascertaining more extensive data concerning the pre-arrest and arrest situation for both EMS-witnessed and bystander-witnessed cardiac arrest cases through interviews with EMS personnel, bystanders and family members, and inclusion of in-hospital laboratory and ECG data and post-mortem findings; 2) identifying factors that may help to explain the disparity in VF/VT incidence and survival rates reported among various EMS systems, which may in turn have implications for more uniform reporting; 3) focus on identification of high risk patients and developing educational strategies for patients and EMS personnel that may assist in early recognition and prevention of cardiac arrest in symptomatic patients; and 4) investigating new treatment modalities for cardiac patients (such as early nitroglycerin or early thrombolytic therapy by ambulance personnel) that may lead to improvements in survival not only for the EMS-witnessed patient but also for the overall cardiac arrest population.

The opportunity exists to carry out a further study comparing incidence and survival rates for EMS-witnessed patients after the implementation of a full ALS system in the OPALS sites. It has been proposed that the rate of EMS-witnessed cardiac arrest may drop with the availability of more advanced care for those symptomatic cardiac patients who may have otherwise arrested in a BLS system. It can also be further hypothesized that the survival rate for those patients who do arrest in the presence of EMS personnel will further improve with the addition of paramedics.

6. CONCLUSIONS

Few studies have attempted to assess EMS-witnessed cardiac arrest in terms of survival and other characteristics. Our data represents the largest sample of EMS-witnessed cardiac arrest cases yet studied. This large sample size has given us the power to adequately describe EMS-witnessed cardiac arrest and to detect differences in survival rates and other key factors between EMS-witnessed and bystander-witnessed cardiac arrest.

EMS-witnessed cases are a unique group of cardiac patients who initially present to the EMS system with warning signals and who, unlike the general prehospital cardiac arrest population, benefit from immediate resuscitative efforts upon collapsing. Survival for this group does not depend, for the most part, on the first two links of the chain of survival (rapid EMS access, bystander CPR). Survival is more dependent on the third and fourth links, rapid defibrillation, and ACLS. Because of this, EMS-witnessed arrests may simulate the highest possible survival rates, and may be a surrogate for the effectiveness of the providers in an EMS system in managing cardiac arrest. Assuming immediate defibrillation, the outcome of VF/VT patients in this study may represent the best possible survival attainable within a BLS-D system. For ALS systems, EMS-witnessed cardiac arrest may act as a benchmark with which communities can compare the strength and competence of their system and providers, to other similar systems and centers.

While ultimately, the extent of left ventricular dysfunction is the major determinant of survival, we believe that certain factors such as prodromal symptoms, level of consciousness, patient administration of nitroglycerin prior to collapse, and initial arrest rhythms may have some predictive importance for the EMS-witnessed cardiac arrest patient. A clear distinction was found between patients suffering chest pain, and those patients suffering shortness of breath. Chest pain patients were more likely to suffer VF/VT, undoubtedly due to myocardial ischemia or infarction, and had a much higher survival rate. Differentiating between symptoms may be a simple way of distinguishing the type of prehospital cardiac arrest. Although the underlying mechanisms of arrest can not be modified in these patients, more aggressive treatment of symptomatic patients in the prehospital setting may lead to decreased cardiac arrest mortality.

We believe that knowledge of underlying mechanisms and the identification of risk factors for EMS-witnessed cardiac arrest have both methodological implications for future research as well as direct implications for the prevention of cardiac arrest and the appropriate management of individual patients. Continued study may lead to more aggressive prehospital treatment strategies and further educational imperatives.

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8. APPENDICES

APPENDIX A: Terminology

ACLS
Advanced Cardiac Life Support. Resuscitation protocols for cardiac arrest which include defibrillation, intravenous therapy and drug therapy.
ACR
Ambulance Call Report. Prehospital data form filled out for all patients transported by ambulance. Includes patient demographic, medical history, assessment and treatment information.
ALS
Advanced Life Support. Advanced level of EMS care that includes ACLS skills.
BLS
Basic Life Support. Basic level of EMS care which includes oxygen administration and cardiopulmonary resuscitation.
BLS-D
Basic Life Support with defibrillation. BLS care with the added skill of defibrillation.
Bystander-witnessed cardiac arrest
Collapse witnessed by any citizen other than on-duty EMS personnel.
Cardiac arrest
Cessation of spontaneous pulse and respiration.
Citizen CPR
CPR initiated by bystanders.
CPR
Cardiopulmonary resuscitation. The application of chest compressions and artificial ventilation to maintain blood and oxygen flow to vital organs in victims of cardiac arrest.
Defibrillation
Electrical counter-shock applied to cardiac arrest patients presenting in VF/VT to restore an organized heart rhythm.
EMS
Emergency Medical Services. Includes fire, ambulance, and police response to medical emergencies.
EMT
Emergency Medical Technician. EMS personnel trained to manage acute and critically ill patients in the prehospital environment.
EMS-witnessed cardiac arrest
Cardiac arrest witnessed by EMS personnel.
First-responder
EMS provider (EMT, firefighter or police) trained to provide immediate BLS or BLS-D care but who does not transport the patient.
Non-cardiac etiology
Documented evidence that the primary cause of cardiac arrest was other than cardiac in origin.

OPALS
Ontario Prehospital Advanced Life Support Study. Ongoing cardiac arrest study in 21 communities across Ontario.
Paramedic
EMT trained to provide an ALS level of care.
PEA
Pulseless electrical activity. A cardiac arrest rhythm.
Phase I
Baseline data collection phase for OPALS study.
Phase II
Rapid defibrillation intervention phase for OPALS study.
Phase IIR
Run-in phase prior to full implementation of rapid defibrillation intervention (Phase II) for OPALS study.
Phase III
ALS intervention phase for OPALS study.
Phase IIIR
Run-in phase prior to full implementation of ALS intervention (Phase III) for OPALS study.
Prehospital
The out-of-hospital environment.
Presumed cardiac etiology
The primary cause of a cardiac arrest is presumed to be of cardiac origin in the absence of clearly documented evidence to suggest the contrary.
Prodrome
Warning signs or symptoms signaling an impending medical emergency.
ROSC
Return of spontaneous circulation.
Sudden death
An poorly defined term for sudden-onset (without prior warning, or within minutes/hours of symptoms) cardiac arrest.
Tiered response
Multiple EMS services (ambulance, fire, paramedics) responding to a medical emergency.
Utstein Style[2]
Consensus guidelines for standardized cardiac arrest case and survival definitions.
VF/VT
Combined term for the two cardiac arrest rhythms of ventricular fibrillation and ventricular tachycardia.

APPENDIX B: Participating Study Centers

Base Hospital Program	Study Community
Cambridge	Cambridge
	Kitchener-Waterloo
Halton Mississauga	Burlington
	Mississauga
	Oakville
Kingston	Kingston
London	London
Niagara	Fort Erie
	Grimsby
	Niagara Falls
	Port Colborne
	St. Catharines
	Welland
Ottawa-Carleton	Ottawa-Nepean-Gloucester
Peterborough	Lindsay
	Peterborough
	Port Hope - Cobourg
Sarnia	Sarnia
Sudbury	Sudbury
Thunder Bay	Thunder Bay
Windsor	Windsor-Tecumseh

APPENDIX C: Ambulance Call Report (ACR) Form

Ministry of Health
Ontario

Ambulance Call Report

Emergency Health Services

Confidential when completed

screened areas must be completed for all patient carrying calls

[redacted]

None | Lights only | Lights & Siren

Ambulance Administration

CACC [redacted]

[redacted] Station [redacted] Special codes | Geo. code/UTM

[redacted]

Patient Identification

Surname [redacted] Birth Date (ymd)

[redacted] Same as P/U ☐ [redacted]

Clinical Information

[redacted] Time of occurence

[redacted]

[redacted] 1 ☐ Angina 2 ☐ MI 3 ☐ CHF 4 ☐ Asthma 5 ☐ Emphysema 6 ☐ Bronchitis 7 ☐ CVA/TIA 8 ☐ Diabetes 9 ☐ Convulsions 10 ☐ Other

[redacted] [redacted]

Treatment prior to ambulance arrival ☐ Police ☐ Fire ☐ Citizen ☐ Other

1 ☐ Arrest witnessed 2 ☐ Arrest unwitnessed 3 ☐ Arrest during call

CPR started by: ☐ Citizen ☐ Police/Fire ☐ BLS crew ☐ Other

Duration of CPR Minutes

[redacted] Age: | Gender: ☐ M ☐ F | Weight(kg) | Case severity | Head/neck | Chest (air entry) | Abdomen | Back | Pelvis | Extremities

General Appearance

Hospital Administration

Health No | Ver. | DND/RCMP Social Ins No | Registration No | Hospital code | Billed by: hospital/clinic ☐ Operator ☐ Other ☐

Charge

☐ Patient ☐ D.N.D.
☐ Employer ☐ Coroner
☐ W.C.B. ☐ Chargeable welfare
☐ D.V.A. ☐ Other

No charge

☐ Inter-hospital transfer ☐ Home for aged
☐ Home care ☐ Recipient general welfare assistance
☐ Homes for special care ☐ Other
☐ Nursing home patient

Billing evaluation

In my professional medical opinion ambulance use was:

☐ *Essential: a medical / other necessity*

☐ *Non essential:* not a medical necessity/other transport suitable

Signature *(medical practitioner/approved authority)*

Basic fee

Patient's portion

Charge for km over 40

Other charge

Amount billed

Payment received: Initials ☐

Disposition in Hospital *Emergency Dept.*

Refused treatment & released ☐
Treated (observed) & released ☐
Transfered to Adm. Dept. ☐
Transfered to another hospital ☐
Morgue ☐

Out Patient

☐ O.P. Clinic ☐ Ca. Clinic
☐ X-Ray ☐ Other
☐ In-patient returning ☐ In-patient discharged

1881-45 (92/11)

Clinical Information (continued)

Time			1	2	3
Vital Signs		rate			
	[redacted]	rhythm			
		vol.			
	[redacted]	rate			
		volume			
		colour			
	[redacted]	condition			
		temp.			
	[redacted]				
	+ reacts – no reaction c eyes closed	R size			
		R react			
		L size			
		L react			
Coma Scale	Eye opening	4 SPONTANEOUS			
		3 TO VOICE			
		2 TO PAIN			
		1 NONE			
	Verbal response	5 ORIENTED			
		4 CONFUSED			
		3 INAPPROPRIATE WORDS			
		2 INCOMPREHEN. SOUNDS			
		1 NONE			
	Motor response	6 OBEYS COMMAND			
		5 LOCALIZE (PAIN)			
		4 WITHDRAW (PAIN)			
		3 FLEXION (PAIN)			
		2 EXTENSION (PAIN)			
		1 NONE			
	Total				

Time	Medicine or Procedure	Code	Result	Initials	No.

Remarks (procedures continued)

If Physician at scene – name:

Final Assessment By Crew

[redacted]

Secondary problem

Problem Location (if trauma)

Patient transport

Other

General Administration

Time of Call Events	Call received	Crew notified	Crew mobile	Arrived scene	Arrived patient	Departed scene	Arrived destination	T.A.T. response

Base hospital

Base hospital No.

Base hospital physician name (if patch)

Notification time (if patch)

[redacted]

Hospital No.

White–Patient chart Buff–Billing office Canary–Base hospital Pink–Ambulance service

1881–45 (92/11)

APPENDIX D: Formulae for Derived Variables

Appx D.1 Time Interval Variables

Time Interval variables	Description	Formula for valid values of the source variable only	Source variables
tsocr	Symptom onset to 911 access	*var2-var1*	symonset callrecv
tsoca	Symptom onset to Cardiac arrest	*var2-var1*	symonset collapse
tvsca	Vehicle stopped to Cardiac arrest	*var2-var1*	arrivscn collapse
tcaae	Cardiac arrest to Arrived ED	*var2-var1*	collapse arrivdes
tcrvs	Call received to Vehicle stopped	*var2-var1*	callrecv arrivscn
tvsds	Vehicle stopped to Departed scene	*var2-var1*	arrivsn depscn
tdsae	Departed scene to Arrived ED	*var2-var1*	depscn arrivdes

Appx D.2 Aggregate Variables

Derived variable	Description	Formula for valid values of the source variable only	Source variables
gcstotal	Glasgow coma scale - total	= *(var1+var2+var3)*	gcseye gcsverb gcsmotor

Appx D.3 Collapsed Variables

Collapsed variables	Description	Formula for valid values of the source variable only	Source variables
locpu2	Pick-up location	(1=1) (5=2) (3=3) (2,4,6to12=4)	locpu
sob_cp	Patient complaint: shortness of breath and/or chest pain	if *var1*=0: (0=".") if *var2*=1: (1=1) if *var3*=1: (1=2) if *var2*=1 and *var3*=1 (1=3) if *var2* and *var3*=0 (0=".")	prodrome sob chpain
ptcomp	Patient complaint	if *var1*=0: (0=0) *var2*: (1=1) (2=2) (3=3) if *var1*=1 and *var2*=".": ("."=4)	prodrome sob_cp
chief2	Chief complaint	(1=1) (2=2) (5,6,17=3) (12,13=4) (14=5) (15=6) (3,11=7) (7,8,16=7)	chief
rhythpr2	Pre-arrest rhythm	(2=1) (3to6=2) (7to10=3) (11=4)	rhythpre
thump	Precordial thump	(2=1)	thump

Appx D.4 Categorical Variables

Categorical variables	Description	Formula for valid values of the source variable only	Source variables
agedec	Age (10 year groups)	fixed cutpoints: (<20,30,40,50,etc...)	age
month	Month of year	month(*var*)	date
timeoday	Period of day patient arrested	hour(*var*) in (1to7=1) (8to15=2) (16to23=3)	collapse
popgrp	Population size (persons)	fixed cutpoints: (<30,000; 100,000;200,000;>200,000)	commcode
tscene	To scene intervals (minutes)	fixed cutpoints: (4,6,8,10,>10)	tcrvs
tvsa	Symptom onset to collapse intervals (minutes)	fixed cutpoints: (10,60,120,480,>480)	tsoca

Appx D.5 Dichotomized Variables

Dichotomized variables	Description	Formula for valid values of the source variable only	Source variables
season	Winter season	(12,1,2=1) (else=0)	month
early	Morning VSA (12PM-8AM)	(1=1) (else=0)	timeoday
late	Evening VSA (4PM-12AM)	(3=1) (else=0)	timeoday
cad	Coronary artery disease	if (*var1 or var2 or var3*)=1: (1=1) (else=0)	angina cardsurg priormi
pcgi	Patient complaint: G.I. symptoms	if (*var1 or var2 or var3*)=1: (1=1) (else=0)	abpain nausea indigest
pcothr	Patient complaint: Other	if (*var1 or var2*)=1: (1=1) (else=0)	paresth othersx
pcun	Patient complaint: Semi/Unconsciousness	if (*var1 or var2 or var3*)=1: (1=1) (else=0)	decloc uncon resparr
pc_sob	Patient complaint: SOB	(1=1) (else=0)	ptcomp
pc_cp	Patient complaint: chest pain	(2=1) (else=0)	ptcomp
pc_both	Patient complaint: SOB/CP	(3=1) (else=0)	ptcomp
pc_other	Patient complaint: Other	(4=1) (else=0)	ptcomp
ccsob	Chief complaint: Dyspnea	(1=1) (else=0)	chief2
cccp	Chief complaint: Chest pain	(2=1) (else=0)	chief2
ccgi	Chief complaint: G.I. symptom	(3=1) (else=0)	chief2
ccun	Chief complaint: Semi/Uncons	(4=1) (else=0)	chief2
ccra	Chief complaint: Resp. arrest	(5=1) (else=0)	chief2
ccsz	Chief complaint: Seizure	(6=1) (else=0)	chief2
ccothr	Chief complaint: Other	(7=1) (else=0)	chief2
uncon2	Unconscious on EMS arrival	if (*var1 or var2*)=1: (1=1) (else=0)	ccun ccra
nsr	Pre-arrest: Normal sinus rhythm	(1=1) (else=0)	rhythpr2
brady	Pre-arrest: Bradycardic rhythm	(2=1) (else=0)	rhythpr2
tachy	Pre-arrest: Tachycardic rhythm	(3=1) (else=0)	rhythpr2
hr50	Pulse rate < 50 / min	(< 50=1) (else=0)	pulse
hr100	Pulse rate > 100 / min	(> 100=1) (else=0)	pulse
rr10	Respiratory rate <10 / min	(< 10=1) (else=0)	resp
rr30	Respiratory rate > 30 / min	(> 30=1) (else=0)	resp
sbp90	Systolic BP < 90 mmHg	(< 90=1) (else=0)	sbp
vf	Initial arrest rhythm: VF/VT	(1,2=1) (else=0)	rhytharr
as	Initial arrest rhythm: Asystole	(3=1) (else=0)	rhytharr
pea	Initial arrest rhythm: Pea	(4=1) (else=0)	rhytharr
tvsa4	Symptoms to collapse > 4 hrs	(1,2,3,4=0) (5=1)	tvsa