A six-year prospective study of out-of-hospital cardiac arrest managed by a voluntary ambulance organisation

一個救護車志願機構處理院前心搏停止的六年期前瞻性研究

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Objective: To obtain a database on the epidemiology of prehospital cardiac arrest and its management by a voluntary ambulance service, with the view for developing future strategies and service improvement. *Design:* A 6-year prospective study from December 1998 to November 2004, using the Utstein-style template. *Setting:* A voluntary ambulance service in Hong Kong. *Subjects and methods:* Ambulance members had to complete and submit a specially designed data form after managing a cardiac arrest case, together with the ambulance run record and the automated external defibrillator (AED) computer printout, if appropriate. *Main outcome measures:* Survival to hospital discharge and return of spontaneous circulation after resuscitation. *Results:* A total of 72 cardiac arrests occurred during the period, with patients' age ranging from 29 to 106 years (mean 73.4). Most cardiac arrests occurred at home (46 or 63.9%). There were 58 witnessed cardiac arrests (80.5%), but bystander cardiopulmonary resuscitation (CPR) was started in only nine cases (15.5%) before the arrival of the ambulance crew. Six patients had evidence of rigor mortis or dependent lividity on ambulance arrival. For the 61 patients with electrocardiogram strips, the initial presenting rhythm on the AED was asystole in 45 (73.8%), pulseless electrical activity in 5 (8.2%), and ventricular fibrillation (VF) in 11 (18.0%). The median call-to-arrival time for VF cases (4.0 minutes) was significantly shorter than that of non-VF rhythms (8.5 minutes) [Mann-Whitney U test p=0.008]. Five patients had return of spontaneous circulation after resuscitation, but only one survived to hospital discharge. *Conclusions:* Bystander CPR and ambulance response time are two areas requiring urgent improvement in our locality. As the majority of cardiac arrests occurred at home, the cost-effectiveness of public access defibrillation for Hong Kong is unclear. However, strategic placement of AED at 'high incidence' locations should be seriously considered. (*Hong Kong j.emerg.med.* 2005;12:140-147)

目的：擁有一個志願救護車服務於院前心搏停止及其處理的流行病學資料庫，指望發展未來的策略及改善服務。**設計：**使用厄特斯泰因形式樣板從一九九八年十二月至二零零四年十一月的六年期間作前瞻性的研究。**設定背景：**一個香港志願的救護車服務。**研究對象及方法：**救護員處理心搏停止個案後需完成及提交一份特別設計的資料表格，並連同救護車出勤記錄及自動體外心臟去顫器的電腦打印輸出（如適用）。**主要結果量度：**經復甦後回復自發性血液循環及生存出院。**結果：**研究期間共有 72 名心搏停止個案，病者年齡介乎 29 至 106 歲（平均 73.4 歲）。大部份心搏停止在家中發生（46 名 /63.9%），58 宗為目擊的心搏停止個案（80.5%），但只有 9 宗（15.5%）在救護員抵達前有旁觀者動手施行心肺復甦法，6 名病者在救護車抵達時已出現屍僵或屍斑。61 名病者有心電圖紙帶記錄，在自動體外心臟去顫器

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最初呈現的心律，45 名（73.8%）為心搏靜止、5 名（8.2%）為無脈搏的心電活動、11 名（18.0%）為心室纖維性顫動。比較救護車從被傳召至抵達現場時間的中位數，心室纖維性顫動的病者（4.0 分鐘）比非心室纖維性顫動心律的病者（8.5 分鐘）顯著地較短（曼—惠特尼 U 檢驗 p=0.008）。有 5 名病者經復甦後回復自發性循環，但只得 1 名病者生存出院。**總結：**目前本地急需改善的兩個主要範疇為旁觀者施行心肺復甦法及救護車反應的時間。由於大部份心搏停止在家中發生，所以在香港實施普及公眾使用自動體外心臟去顫術的成本效益還未肯定。不過，應認真地考慮策略性地放置自動體外心臟去顫器於高發生率的地方。

Keywords: Ambulances, cardiopulmonary resuscitation, emergency medical services, heart arrest, ventricular fibrillation

關鍵詞：救護車、心肺復甦法、緊急醫療服務、心搏停止、心室纖維性顫動

Introduction

St John is the oldest order of chivalry in the world, having had its beginning in Jerusalem in 1023. In Hong Kong, St John was established in 1884.[1] It is a non-profit non-political organisation committed to promoting and encouraging all work of humanity and charity for the relief of sickness, distress, suffering or danger irrespective of race, colour, creed and circumstances. It is better known for its first aid and ambulance services in Hong Kong. There are ten ambulances stationed at three depots in Hong Kong Island, Kowloon and the New Territories respectively, providing free on-call emergency ambulance service to the public 24 hours daily throughout the year. In line with the concept of the "chain of survival", the skill of automated external defibrillation (AED) was first introduced to St John ambulance members in 1993. Ambulances were equipped with automated external defibrillators in 1995.[1] Formal structured training and monitoring programs were started in 1998. The objective of this study was to obtain a database on the epidemiology of cardiac arrest and its management by St John members, with a view for developing future strategies on voluntary ambulance service and public access defibrillation.

Subjects and methods

This was a six-year prospective study from December 1998 to November 2004. St John ambulance members had to complete and submit a specially designed data form after managing a cardiac arrest case, together with the ambulance run record and the AED computer printout, if appropriate. The following data were collected following the Utstein-style template:[2] date, district, site, sex, age, time when call received, time of arrival at scene, time of departure from scene, time of arrival at hospital, chief complaint, history of cardiac disease, witness, time of collapse, bystander cardiopulmonary resuscitation (CPR), time when CPR was initiated, time when CPR ended, initial electrocardiographic rhythm, time of 1st shock, total number of shocks, return of spontaneous circulation (ROSC), AED model used, patient outcome, and additional remarks. As all ambulance cases would be sent to Hospital Authority hospitals, the latter's territory-wide patient database was accessed to check for hospital admission and survival.

Before March 2001, the AED model used was Laerdal Heartstart 3000, which could generate a monophasic truncated exponential waveform and escalating energy levels. This was replaced in the second quarter of 2001 by the Laerdal Heartstart FR/FR2 models, which used a biphasic truncated exponential waveform and a fixed energy level considered to be safer and more efficacious.[3,4]

The data were entered into the computer software SPSS 10.0 for Windows (SPSS Inc., Chicago, USA), and subjected to statistical analysis. Mann-Whitney U test was used for analysis of continuous variables, with $p<0.05$ taken as statistically significant.

Results

A total of 72 cardiac arrests occurred during the period. There were 38 males (58.2%) and 34 females (47.2%). Only 69 patients' age was known, ranging from 29 to 106 years (mean 73.4, SD 18.5), and 50 (72.5%) were above 65. All were Chinese except one Italian, one Indian and one Filipino. The sites of cardiac arrest occurrence are shown in Table 1. The majority of the complaints were collapse, while there were 4 shortness of breath, 3 "injuries" and 1 "drunk". The overall call-to-arrival interval (call to ambulance stop time) ranged from 1-21 minutes (median 8.0), and 10 runs were over 12 minutes (13.9%) (Table 2). For the 34 cases with the interval between ambulance stop time and time of arrival at patient's side recorded, the range was 0-6 minutes (median 2.0). The scene time (time ambulance stopped to time ambulance departed) ranged from 5-62 minutes (n=45, median 12.0). The outlier was a case with rigor mortis. The transport time from scene to arrival at emergency department ranged from 2-25 minutes (n=40, mean 8.5). There were 58 witnessed cardiac arrests (80.5%), including those occurring during transport. However, bystander CPR was started in only nine cases (15.5%) before the arrival of the ambulance crew, two of which were performed by doctors. Six patients had evidence of rigor mortis or dependent lividity on ambulance arrival, four at home and two in hotel. Ten patients were suffering from advanced malignancy. Only 16 had definite history of cardiac disease but 20 had chronic diseases such as diabetes, hypertension, stroke or chronic obstructive pulmonary disease.

Table 1. Sites where cardiac arrest occurred

Site	Number	Percent
Home	46	63.9
Old age home	3	4.2
Hotel	9	12.5
Race course	4	5.6
Club house	2	2.8
Outdoor	2	2.8
Ambulance in transport	3	4.2
Helicopter in transport	1	1.4
Clinic	1	1.4
Workplace	1	1.4
Total	72	100

As the six patients with rigor mortis or dependent lividity were non-resuscitable, they were excluded from further analysis. Electrocardiogram strips were missing from four patients, and AED was not available in one patient with collapse. For the remaining 61 patients, the initial presenting rhythm on the AED was asystole in 45 (73.8%), pulseless electrical activity (PEA) in 5 (8.2%), and ventricular fibrillation (VF) in 11 (18.0%). Fourteen patients were shocked by AED, as change to VF was detected in three patients by the continuous rhythm monitoring at some stage during the subsequent process of resuscitation or transport. The median call-to-arrival time for VF cases (4.0 minutes) was significantly shorter than that of non-VF rhythms (8.5 minutes) [Mann-Whitney U test p=0.008]. The time from arrival or witnessed arrest to first shock ranged from 1-13 minutes (median 3.0). The number of shocks ranged from 1-10 (median 2.0). The majority of patients were certified dead at the emergency departments but five patients had ROSC after resuscitation (Table 3). Only one survived and was discharged neurologically intact.

The story of the survivor began on a sunny day in February 2004, while the Community Chest was

Table 2. Ambulance response particulars by region

Region	No. of call (%)	Call-to-arrival time (minutes)				
		Median	Mean	Minimum	Maximum	</=12 min
Hong Kong Island	55 (76.4%)	7	8.2	1	21	85.5%
Kowloon	10 (13.9%)	10	9.8	5	15	80.0%
New Territories	7 (9.7%)	5	5.8	1	12	100.0%
Overall	72 (100%)	8	8.2	1	21	86.1%

Table 3. Particulars of patients with return of spontaneous circulation on arrival at hospital

Year	Sex	Age	Witnessed arrest	Bystander CPR	Initial rhythm	No. of shocks	Outcome	Remark
2000	M	61	Yes	No	Asystole	0	Died the same day	Lung cancer
2001	F	82	Yes	No	Asystole	0	Unknown, ID N/A	Diabetic
2001	F	33	Yes	No	Asystole	0	Died after three weeks	Psychiatric, drug overdose
2003	M	78	Yes	No	Asystole	1	Died the next day	Old stroke
2004	M	44	Yes	By doctor	VF	1	Survived neuro-intact	Healthy, runner

ID N/A=identity card number not available, VF=ventricular fibrillation

holding a Half Marathon Event at a country park. A 44-year-old Chinese male runner became confused and collapsed on returning to the finishing point. Cardiac arrest was diagnosed and CPR was started immediately by doctors at the scene. An AED was immediately brought in by St John members on duty there. Ventricular fibrillation was confirmed from the AED monitor and one electric shock was delivered. Sinus rhythm resumed afterwards (Figure 1). Pulse was detected and CPR was stopped. He regained consciousness in the ambulance on its way to hospital. He had no history of heart disease. He was discharged neurologically intact.

Discussion

In Hong Kong, access for emergency assistance is unified through the telephone number of 999. Free emergency ambulance service is mainly provided by the Fire Services Department. The small fleet of St John ambulances serves as a backup for the Fire Services Department in case of high demand, or as a direct alternative for the public. The Fire Services Department's performance pledge of emergency ambulance response time was 12 minutes from the time of call to the arrival of an ambulance at the street address. In 2004, the target was to meet this response time in 92.5% of all emergency calls.[5] Only 86.1% of our responses met the target of the Fire Services Department, but judging from our small fleet of ambulances, this should be regarded as quite good already. However, the response time should be the time of call to the arrival at the patient's side, instead of at street address only. This is clinically more appropriate as it may take some time to locate and access the flat in a high-rise building (in our cases, it was about two additional minutes).

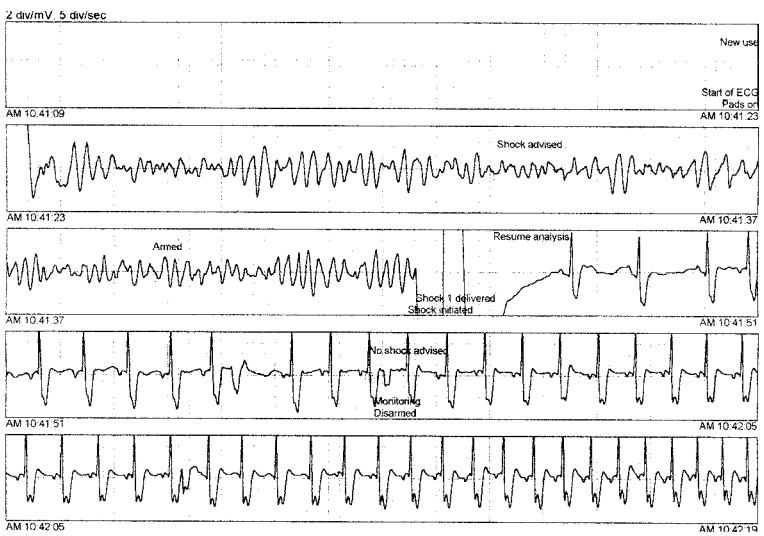

Figure 1. AED electrocardiogram of the survivor of sudden cardiac arrest.

The time to initiation of resuscitation is the most important factor affecting survival from out-of-hospital cardiac arrest - the "chain of survival": early access, early CPR, early defibrillation and early advanced care. Survival rate declined with increasing time intervals to CPR, defibrillation and advanced care.[6] Predictors of survival in out-of-hospital cardiac arrest (OHCA) include the initial rhythm (strongly related to VF when the emergency responders arrive at the scene), witness, interval between collapse to ambulance arrival, bystander CPR (claimed to maintain circulation and VF), time to defibrillation, patient age, location and comorbidity (e.g. heart failure, diabetes, hypertension, chronic pulmonary disease, cancer, gastrointestinal disease, obesity).[7-13] Some of these factors may be inter-related.

Fredriksson et al systematically reviewed 14 studies on out-of-hospital cardiac arrest published according to the Utstein guidelines and found that bystander-witnessed arrest varied between 38-89%, bystander CPR was performed in 21-56%, and hospital discharge rate of those with cardiac aetiology varied between 2-49%.[14] Current knowledge indicates that middle-sized urban cities (population approximately 0.5 million) are optimal for survival from OHCA. Survival rates have been reported to be lower in both rural small cities and in large cities.[15] The overall survival of OHCA in USA was less than 5%.[7,16] In a review on Canada, Vaillancourt et al obtained the following figures: witnessed arrest 35.2-55.0%, bystander CPR 14.7-46.0%, asystole 35.7-51.3%, and survival to hospital discharge 4.3-9.0%.[17] Sekimoto et al reported that the survival rates of OHCA in Japan were 1.0% in 1989 and 0.9% in 1996. They attributed their low incidence of VF-related OHCA to low incidence of bystander CPR.[12] Asian cities have similar poor survival rates: Taipei city 1.4% (population 2.6 millions),[18] Hong Kong 1.3-3.0% (population 6.8 millions),[19-24] Singapore 0.5-3.4% (population 4.1 millions),[25-29] and Osaka 5.1% (population 8.8 millions).[30]

Our findings concurred with previous local studies and those of Singapore, and perhaps other large Asian cities as well (Table 4). Our overall survival-to-hospital discharge rate (1/66 or 1.5%) was dismal. Although more than 80% of the cardiac arrests were claimed to be witnessed, our bystander CPR rate was only 15.5% (9/58). Only 12% of the Hong Kong population had received CPR training, as compared with the recommendation from the American Heart Association that at least 20% of adults need to be trained in CPR before morbidity and mortality from OHCA can be reduced substantially.[31] Similarly, only 18.0% of our patients were in VF on arrival, while the rest had asystole

Table 4. Comparison of non-traumatic OHCA in Hong Kong and Singapore

	This study	Previous Hong Kong studies[19-24]	Singapore studies[25-29]
Population	6.8 millions	6.8 millions	4.1 millions
Mean age (yr)	73.4	68.7 - 71.5	62.2 - 64.3
Male	58.2%	56.3 - 61.5%	65.6 - 71.8%
Arrest at home	63.9%	68.5 - 84.0%	59.8 - 67.6%
Witness present	80.5%	42.5 - 57.5%	64.7%
Bystander CPR	15.5%	8.9 - 15.6%	15 - 21.8%
Response time	8.0 min	6.4 - 6.5 min	9.2 - 10.2 min
Initial rhythm			
Asystole	73.8%	67.3 - 75.6%	39.8 - 54.5%
VF/VT	18.0%	14.1 - 22.5%	20.0 - 42.5%
PEA	8.2%	7.5 - 11.6%	17.7 - 22.9%
ROSC	7.6%	12.0 - 14.1%	17.4 - 22.5%
Discharged alive	1.5%	1.3 - 3.0%	0.4 - 3.5%

OHCA=out-of-hospital cardiac arrest; CPR=cardiopulmonary resuscitation; VF/VT=ventricular fibrillation/pulseless ventricular tachycardia; PEA=pulseless electrical activity; ROSC=return of spontaneous circulation.

or PEA which are often considered as 'fatal rhythms'.[32] As mentioned previously, the outcome of OHCA strongly relates to VF when the ambulance arrives at the scene. Bystander CPR increases the occurrence of VF or pulseless ventricular tachycardia (VT). Herlitz et al showed that when the emergency responders arrived within 4 minutes of collapse, 53% of the patients were in VF/VT. This successively declined with time. When the interval was above 20 minutes, only 27% was in VF/VT.[9] The median call-to-arrival time for our VF cases (4.0 minutes) was significantly shorter than that of non-VF rhythms (8.5 minutes), implying that patients might be in a more salvageable state with earlier arrival. A call-to-arrival time of 12 minutes is definitely too long if the prognosis of cardiac arrest is to be improved.

On the other hand, as six patients were biologically dead on arrival, three had evidence of trauma, one had drug overdose, and as a high percentage was suffering from poor premorbid states, malignancy and/or chronic debilitating illness, a low success rate with resuscitation is to be expected. In addition, unlike overseas data, the majority of our patients were elderly, with the mean age of 73.4 years and 72.5% above the age of 65. More than 60% of our cardiac arrests occurred at home. It has been shown that cardiac arrests outside the home were more often witnessed, more likely to have bystander CPR, less often preceded by symptoms, the rhythm more frequently VF, and survival rate higher.[33]

Early defibrillation provides a higher incidence of ROSC in patients with out-of-hospital ventricular fibrillation.[34-36] Collectively, the effectiveness of early defibrillation is well established, resulting in survival rates approaching 50%.[37] The rate of successful defibrillation was also low in our series (1/11 or 9.1%). Conversion to a pulse-generating rhythm is directly related to the interval between collapse and first defibrillation.[35,38,39] Valenzuela et al reported a 74% rate of survival-to-hospital discharge with rapid defibrillation within 3 minutes after cardiac arrest in casinos by on-site security officers.[16] Caffrey et al reported a survival rate of 67% with defibrillation of victims in VF/VT arrest within 3 minutes at the Chicago airports.[7]

Four patients with initial presenting rhythm of asystole had ROSC on arrival at hospital. The precipitating cause of arrest for some of them might be respiratory in origin. As expected, none of them survived to hospital discharge. It has been claimed that advanced care only increased hospital admission but failed to improve discharge survival with defibrillation delays.[13] Our survivor was an illustrative case of the importance of strengthening every step in our "chain of survival" as it was a witnessed arrest, with early bystander CPR started by doctors at scene, the rhythm was ventricular fibrillation and early defibrillation was performed promptly. It was similar to the Greek soldier Pheidippedes' collapse and instant death after running 26.2 miles all the way from Marathon to Athens to announce the Greek victory over the Persians in 490 BC - perhaps Pheidippedes could have been saved if an AED was available at that time.[40]

Fedoruk et al demonstrated the effectiveness of rapid on-site defibrillation in Casino Windsor, Canada, where 100% of cardiac arrests were witnessed, with presenting rhythm of VF/VT in 91% and a survival rate 65%. In comparison, the community figures were: 54.6% witnessed, VF/VT 34.3%, discharged alive 5.5%.[41] It has been estimated that a system designed for Kuala Lumpur (population 1.4 millions), Malaysia to deliver a defibrillator to 85% of cardiac arrests within 6 minutes would cost approximately US$2.5 millions per year for saving seven lives (6% survival rate), probably three of which would have significant neurological damage.[42] As most cardiac arrests occur at home,[16] public access defibrillation is still a controversial issue in Hong Kong.[37] The challenges are where defibrillators should be placed and who should be trained to use them. As saving a life is invaluable, AED should be strategically placed in "high volume" or "high risk" public locations such as airports, ferry terminals, train terminals and mass gatherings.[16,43]

Clinical audit and quality assurance by a medical director are necessary to ensure the standard of our prehospital service. Care in interpreting the electrocardiograms is necessary as artefacts may be introduced by movements of the ambulance or chest compressions (Figure 2). As AED is now a standard equipment in all ambulances, practising doctors should familiarise themselves with its operations and

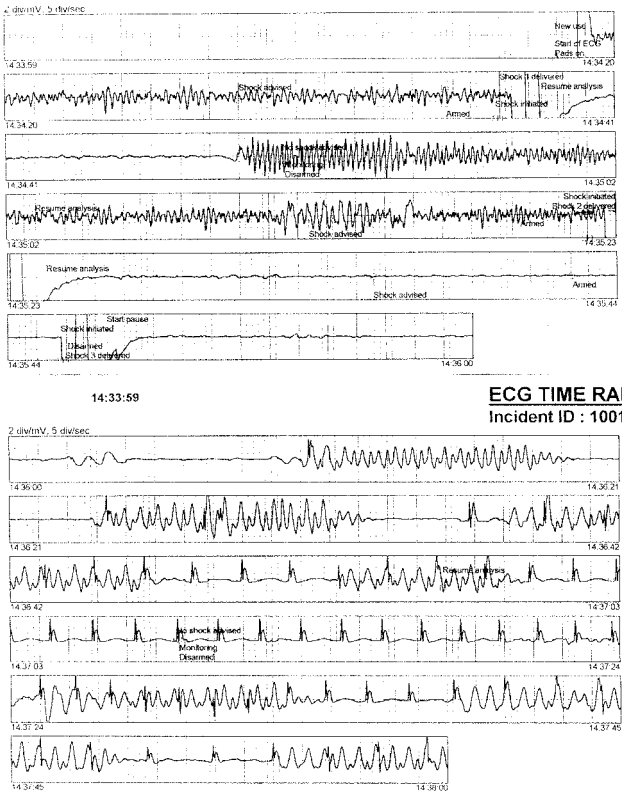

Figure 2. AED electrocardiogram of a patient with VF, defibrillation, and pulseless electrical activity superimposed by CPR artefacts.

protocols, in order to provide a "seamless" prehospital and in-hospital care.

This study suffered from the limitation of the small number of cases as the Fire Services Department was the main provider of emergency ambulance service in Hong Kong. In addition, manual entry of some data might result in missing or inaccurate information.

Conclusion

There is little doubt that strengthening the "chain of survival" will improve survival after cardiac arrest, especially early defibrillation. Of many predictors, factors such as witness of collapse, age and comorbidity are uncontrollable, but bystander CPR and ambulance response time are two modifiable areas requiring urgent improvement in our locality. As the majority of cardiac arrest occurred at home, the cost-effectiveness of public access defibrillation for Hong Kong is still controversial. However, the strategic placement of AED at 'high incidence' locations should be seriously considered. A territory-wide audit by the Fire Services Department would give a much better epidemiological picture of OHCA in Hong Kong.

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