

Burden of out-of-hospital cardiac arrest in Karachi, Pakistan: Estimation through the capture-recapture method

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Abstract

Objective: To assess the application of capture-recapture method as a potential strategy to estimate the incidence of out-of-hospital cardiac arrest.

Methods: This cross-sectional study was carried out from January to April 2013 in Karachi and comprised three public general hospitals, one public cardiac hospital, one private general hospital and two ambulance services. Two-sample capture-recapture method was used: first capture was through cardiac arrest data from two major emergency medical services and second capture was from the five teaching hospitals. Records from the hospitals and ambulance services were compared on 7 variables; name, age, gender, date and time of arrest, cause of arrest and destination hospital. Matched and unmatched cases were used in the equation to estimate the incidence of out-of-hospital cardiac arrest.

Results: Of the 630 out-of-hospital cardiac arrest cases reported, 191(30.3%) related to the emergency medical services records and 439(69.7%) to hospital records. The capture-recapture identified only 9(1.4%) matched cases even with the least restrictive criteria and estimated the annual out-of-hospital cardiac arrest incidence as 166/100,000 population (95% confidence interval: 142.9 to 189.6).

Conclusion: Capture-recapture method could be a potential alternative for providing population level data in the absence of organised health information systems.

Keywords: Out-of-hospital cardiac arrest, Burden, Two source capture-recapture. (JPMA 68: 990; 2018)

Introduction

Sudden cardiac death contributes to about 15% of global mortality. The majority of these deaths occur in the low and middle income countries (LMICs).^{1,2} In high income countries, over 50% of all cardiac arrests occur outside of the hospitals and these out-of-hospital cardiac arrests (OHCA) are one of the primary drivers for the establishment of modern pre-hospital emergency medical services (EMS).³ Improvement in emergency care has led to significant improvements in survival rates from 0% to as high as 40% in some settings.^{4,5}

Recently published reviews report incidence and outcomes of OHCA from developed countries such as Europe, North America, Asia, Australia, Canada, Japan etc.⁶ and estimated the OHCA incidence from 24/100,000 per year to 186/100,000 per year, but there is limited data on OHCA from LMICs.⁷ There are several reasons for the poor data on OHCA. Some of the reasons are related to the limitations of health information system to capture emergency-related information. With regard to the OHCA,

many cases do not make it to the healthcare system which adds to difficulty in obtaining incidence information. Since incidence data on disease frequently drive public health and public policy, the focus on diseases such as cardiac arrest will remain limited unless local data is available from LMICs. Capture-recapture methodology has been used extensively in medicine and public health to study difficult-to-count populations. The current study was planned to explore the application of capture-recapture method for estimating the incidence of OHCA.

Materials and Method

This cross-sectional study was carried out from January to April 2013 in Karachi which has an estimated population of about 20 million.⁸ The city has three main public-sector referral hospitals providing general emergency care. There are also two public-sector hospitals focussing on cardiovascular diseases. In the private sector, there are three hospitals with well-organized general emergency care.^{9,10} For pre-hospital care, there are three main ambulance services, all of which are privately run and funded through local philanthropy and charity. Out of these three, two are primarily transport services with limited training and equipment/supplies for emergency care while one has capability to provide on-scene cardiopulmonary resuscitation (CPR), automatic external defibrillation and can initiate dispatch-assisted CPR.¹¹ The

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current study comprised three public general hospitals, one public cardiac hospital, one private general hospital and two ambulance services. The average daily emergency department headcount ranged from approximately 140 patients to as high as 1000 patients a day.^{12,13} Only one of the five hospitals had searchable data from their emergency department (ED). The other four kept medical records for patients who were admitted to the hospital and not all ED patients due to sheer volume. Similarly, variability in data collection and storage was found in ambulance services. One of the ambulance services kept detailed record of responses such as medications given, CPR performed etc. and non-clinical data as well such as response time, transport time etc. Other data included name, gender, date and time of event, age of the patient, place of the incident, destination hospital and type of emergency which for cardiac arrest was mentioned as sudden unresponsiveness leading to death or 'heart failure', a local term used for death presumed to be due to cardiac arrest.¹⁴

Data was obtained from EMS records through prospectively carried out round-the-clock surveillance of all patients presenting with presumed cardiac arrest to the selected hospitals for which 17 data collectors were hired who worked in 8-hour shifts across the five EDs and collected information using a data-collection form. Cases of OHCA from EMS were defined as cases in which ambulances were dispatched for patients with sudden cessation of breathing and responsiveness or suspected sudden death due to heart failure in patients with no history of trauma. OHCA from hospital EDs were defined as patient presenting to the ED with a history of unresponsiveness and sudden cessation of respiration and was diagnosed as cardiac arrest by the treating emergency physician.

Approval was obtained from the ethics review committee (ERC) of Aga Khan University Hospital, Karachi, as well as from the participating institutions. Capture-recapture method was used to estimate the burden of OHCA utilising information from two sources. It comprised comparing two data sources for identifying cases with common information present in both the lists; also called 'matches'.¹⁵ The first capture was all patients above 18 years with OHCA of cardiac aetiology from the records of the two major ambulance services. The recapture was the similar sample from our hospital-based surveillance system.

The information on the following variables was recorded: patient's name, age, gender, date and time of arrest, cause of arrest and name of destination hospital from

both the data sources. These data sources were then compared case-by-case for identifying matched cases. The degree of matching was defined based on three standards (Table-1). Standard A was the strictest criteria where it was required to have all seven variables match in cases from both the data sources. For each subsequent standard, the criteria were progressively made less strict. However, it was compulsory for all standards to have the similar date, time and gender. In order to consider patient's names as matched, it was required that both first and last names should be similar in both the sources. Time of arrest was considered to be matched if it was within one hour. Age was considered to be matched if it was within 10 year difference. As it is observed that in cases where patient's age cannot be verified at the time of incident through authentic sources such as national identification card, then the estimated age is mentioned. Date, gender, cause and hospital name were required to be exactly the same in both data sources in order to be considered as matched.

The number of cardiac arrest patients with 95% confidence intervals (CI) was calculated using the following formulae:

Estimated Value of

$$n = \frac{(C1+1)(C2+1) - 1}{m+1}$$

95% CI = Estimated value of $n \pm (Z_{\alpha/2}) \text{ SE (est. value of } n)$

Variance of estimated value of

$$n = \frac{(C1+1)(C2+1)(C1-m)(C2-m)}{(m+1)^2(m+2)}$$

Where C1= number of people in the first capture i.e. EMS data; C2= number of people in second capture i.e. hospital data and m= number of people in both sample (match).

Using Karachi's population from last census in 1998 (9.8 million)¹⁶ and a growth rate of 5%, the denominator was calculated to be 20.6 million. The incidence proportion of cardiac arrest patients in Karachi was obtained by dividing the estimated number of cardiac arrest patients by the estimated population of Karachi ($P^{\wedge} = n/N$).

Results

Of the 630 out-of-hospital cardiac arrest cases reported, 191 (30.3%) related to the emergency medical services records and 439 (69.7%) to hospital records. The mean age of the hospital group was significantly higher compared to the EMS population ($p < 0.001$). More male patients presented through the EMS compared to the hospital

Table-1: Degree of matching defined by three criteria below.

Criteria	Required features	Hospital, cause of death, name and age of patient
A	Date, time and gender	All four of above matched
B	Date, time and gender	Any three matched
C	Date, time and gender	Any two matched

Table-2: Annual incidence of cardiac arrest with 95% confidence intervals on three levels of matching criteria.

Matching of criteria	Estimated annual incidence per 100,000 population	95% CI for rate
A (Complete match)	554	421-686.
B (Three out of four match)	277	227-326
C (Two out of four match)	166	142-189

CI: confidence interval.

group ($p=0.002$). In terms of age, 66(34.6%) patients in EMS group were between the ages of 18 and 44 years followed by 61(31.9%) aged 45-64 years and 45(23.6%) >65 years. In the hospital group, 187(42.4%) patients were aged 45-64 years, followed by 166(37.8%) >65 and 87(19.8%) aged 18-44 years. ($p<0.001$)

Using the least restrictive criteria, only 9(1.4%) cases matched in both the samples. The burden of OHCA was calculated to be 93.8 per day. This figure was extrapolated 365 times to calculate annual incidence, which came out to be 34257.2 per year. This figure was divided by Karachi's projected population for the year 2013, which was calculated to be 20.6 million. The annual incidence was estimated to be 166.2/100,000 population (95% CI: 142.9 to 189.6). More restrictive criteria resulted in higher estimates (Table-2). Calculation from individual sources of either hospitals or EMS underestimated the actual burden. The burden calculated only from hospital data would have estimated the OHCA incidence to be 8.6/100,000 population, whereas that calculated only from two EMS sources would have been 3.7/100,000 population.

Discussion

The results of the current study show that estimation of OHCA incidence based on the individual sources of either hospitals or EMS would have counted only 5% and 2.2% of the total cardiac arrests respectively. This level of underestimation is consistent with weak health information and disease surveillance systems, especially for conditions presenting in acute care settings. Deaths occurring outside of hospitals add further complexity as they are difficult to track and document.¹⁷

The burden estimated through capture-recapture method from Karachi, Pakistan, was relatively higher compared to the estimates from high-income countries (HICs). A prospective observational study done across 10 sites in North America reported the incidence of non-traumatic, EMS-assessed OHCA as ranging from 71.8/100,000 in Ottawa to as high as 159/100,000 in Dallas.¹⁸ Another systematic review estimated EMS attended OHCA ranging from 24/100,000 person years in Bohemian to 186/100,000 person years in New York. Whereas, among the HICs of East-Asia the OHCA rates were reported to be lower than other high-income settings (52.5/100,000 person years).⁶

EMS systems in LMICs are at different developmental phases and maturity. In Pakistan, for example, EMS is still in the development phase.¹¹ Most ambulance services do not provide interventions, such as CPR or external defibrillation, and are primarily patient transport services and often have lack of clinical oversight. In Karachi, the three main ambulance services have their own call numbers which make it difficult for users. Hospital-based emergency care is also variable as there are only two hospitals with emergency care providers available for majority of the time. Counting cardiac arrests based only on ambulance transportation would have missed a large number of cardiac arrests transported by other modes of transportation.

We used the capture-recapture method to estimate the incidence of OHCA. The methodology has been used for estimating mortality and burden of diseases from causes such as human immunodeficiency virus, drug abuse, sudden cardiac deaths, injuries and cancers etc.^{14,19-22} To our knowledge, this is the first use of capture-recapture methodology for OHCA.

In terms of limitations, there are four major assumptions for the method of capture-recapture to produce consistent results.¹⁴ First, the population should be closed and that the time period between capture and recapture should not be so long that the population changes and it should be long enough to allow for all marked individuals to be dispersed. In this study, the capture-recapture sampling took place at the same time, so this assumption was fulfilled. Secondly, the chances for each individual in the population to be caught should be equal and constant during both capture and recapture periods. All the areas of the city had access to the five hospitals, which could be observed from the fact that our sample had a representation from all 18 towns of Karachi city. At the same time, none of the areas were uncovered from the networks of EMSs from which we obtained the data as these ambulances are two major services of Karachi with access to all city areas. One of the limitations of this process

was that we were not able to obtain permission from all the selected hospitals and EMS sites as planned, which would have given us a more representative sample. Thirdly, the capture sources should be independent. This assumption is difficult to fulfil in most studies and we faced the same situation. Some of the cardiac arrest cases do not present to hospitals and are declared dead at home by the nearest available healthcare provider and, hence, these cases can neither be captured by EMS sample nor by hospital samples. It would have been the sample of patients who presented to EMS and, hence, transported to major hospitals either for treatment or obtaining death certificates. Due to potential dependency, our estimates are likely to underestimate the actual numbers. Finally, individual cases do not lose their mark, in other words the capture information is correct. The data collected on patients by the ambulance services and hospitals is part of the administrative information obtained by hospitals and EMSs. The information is often linked to billing and includes basic information such as name, age and gender and is less likely to be incorrect.

Conclusion

Capture-recapture was found to be a useful alternative to estimate population level incidence where data systems are weak.

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Conflict of Interest: None.

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References

- Kudenchuk PJ, Redshaw JD, Stubbs BA, Fahrenbruch CE, Dumas F, Phelps R, et al. Impact of changes in resuscitation practice on survival and neurological outcome after out-of-hospital cardiac arrest resulting from nonshockable arrhythmias. *Circulation*. 2012; 125:1787-94.
- WHO. Global status report on noncommunicable diseases, 2010.
- Vaillancourt C, Charette ML, Bohm K, Dunford J, Castrén M. In out-of-hospital cardiac arrest patients, does the description of any specific symptoms to the emergency medical dispatcher improve the accuracy of the diagnosis of cardiac arrest: a systematic review of the literature. *Resuscitation*. 2011; 82:1483-9.
- Hiltunen P, Kuisma M, Silfvast T, Rutanen J, Vaahersalo J, Kurola J. Regional variation and outcome of out-of-hospital cardiac arrest (ohca) in Finland - the Finnresusci study. *Scand J Trauma Resusc Emerg Med*. 2012; 20:80.
- Nakanishi N, Nishizawa S, Kitamura Y, Nakamura T, Matsumuro A, Sawada T, et al. The increased mortality from witnessed out-of-hospital cardiac arrest in the home. *Prehosp Emerg Care*. 2011; 15:271-7.
- Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. *Resuscitation*. 2010; 81:1479-87.
- Ishtiaq O, M Iqbal, M Zubair, R Qayyum, M Adil. Outcome of cardiopulmonary resuscitation-predictors of survival. *J Coll Physicians Surg Pak*. 2008; 18:3-7.
- Amer K. Population explosion: Put an embargo on industrialisation in Karachi, in *The Express Tribune*, 2013.
- PMDC. Approved Hospitals for House Job. [Online] 2006 [Cited 2015 April 16]. Available from URL: <http://www.pmdc.org.pk/AboutUs/ListofHospitals/tabid/111/Default.aspx>.
- CPSP. FCPS Accredited Institutions. 2015; [Online] [Cited 2015 Nov 12]. Available from URL: <http://www.cpsp.edu.pk/index.php?code=YWNjcmVkaXRIZHxhY2NyZWZlZGF0aW9uLnBocHwweZDUFN8MA==>.
- Baqir M, Ejaz K. Role of pre-hospital care and ambulance services in Karachi. *J Pak Med Assoc*. 2011; 61:1167-9.
- Handing over charge: JPMC appoints new executive director. [Online] [Cited 2015 Aug 10]. Available from: URL: <http://pakistannewstoday.4com.co/tag/jpmc>.
- AKUH. Overview. [Online] [Cited 2015 September 14]. Available from URL: <http://hospitals.aku.edu/karachi/aboutus/HospitalOverview/Pages/Home.aspx>.
- Razzak JA, Luby SP. Estimating deaths and injuries due to road traffic accidents in Karachi, Pakistan, through the capture-recapture method. *Int J Epidemiol*. 1998; 27:866-70.
- Lange JH, YF Chang, RE LaPorte. Use of the capture-recapture method for epidemiological studies in determining prevalence. *Acta Neurolog Scand*. 2004; 109:79-80.
- Luby S, R Khanani, M Zia, Z Vellani, M Ali, AH Qureshi, et al., Evaluation of blood bank practices in Karachi, Pakistan, and the government's response. *J Pak Med Assoc*. 2006; 56: S25-30.
- Arts DG, De Keizer NF, Scheffer GJ. Defining and improving data quality in medical registries: a literature review, case study, and generic framework. *J Am Med Inform Assoc*. 2002; 9:600-11.
- Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, et al. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA*. 2008; 300:1423-31.
- Maron BJ, Murphy CJ, Haas TS, Ahluwalia A, Garberich RF. Strategies for assessing the prevalence of cardiovascular sudden deaths in young competitive athletes. *Int J Cardiol*. 2014; 173:369-72.
- Ghojzadeh M, Mohammadi M, Azami-Aghdash S, Sadighi A, Piri R, Naghavi-Behzad M. Estimation of cancer cases using capture-recapture method in Northwest Iran. *Asian Pac J Cancer Prev*. 2013; 14:3237-41.
- Lievre L, Deveau C, Gerbe J, Enel P, Tran L, De Castro N, et al. Yearly number of patients diagnosed with primary HIV-1 infection in France estimated by a capture-recapture approach. *AIDS*. 2006; 20:2392-5.
- Chiang SC, Chen CY, Chang YY, Sun HJ, Chen WJ. Prevalence of heroin and methamphetamine male users in the northern Taiwan, 1999-2002: capture-recapture estimates. *BMC Public Health*. 2007; 7:292.