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Research

Diagnosis of out-of-hospital cardiac arrest by emergency medical dispatchers: a diagnostic accuracy study

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Abstract

Introduction
This study was conducted to assess the diagnostic accuracy of out-of-hospital cardiac arrest (OHCA) made by emergency medical dispatchers (EMDs) in Tehran, Iran.

Methods
Patients more than 18 years of age who were suspected of having an OHCA by EMDs or emergency medical service (EMS) technicians at the patient's bedside were eligible for inclusion in the study. The initial diagnosis, results of primary assessment and monitoring, and the final outcome of the mission (gold standard) were all recorded. Related archived audios were extracted from the system and listened to by the researcher (MM). Other required data were extracted from EMS mission forms and recorded in a pre-prepared checklist. After statistical analysis the accuracy was calculated.

Results
A total of 4732 patients were included (mean age 68.1 ± 19.7 years) of which 2830 (59.8%) were men. These cases reported by 173 EMDs that the EMDs mean age was 27.7±3.7 years, and they were all women. Cardiac arrest prevalence based on final diagnosis (gold standard) was 37.4% (95% CI: 36.0–38.8). Sensitivity and specificity of OHCA diagnosis by EMDs was 78.6% and 92.4%, respectively. Positive predictive value, negative predictive value and accuracy were 86.1% (95% CI: 84.5–87.6), 87.8% (95% CI: 86.8–88.8) and 87.3% (95% CI: 86.3–88.2), respectively. The sensitivity of diagnosis increased with increasing EMD's work experience and also increasing the number of reported OHCA cases.

Conclusion
Based on the results, accuracy of OHCA diagnosis by EMDs was almost 87%. It is likely that more experienced EMDs or those with more experience diagnosing OHCA are better at recognising OHCA.

Keywords:
emergency medical dispatcher; emergency medical services; diagnosis; out-of-hospital cardiac arrest

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Introduction

Out-of-hospital cardiac arrest (OHCA) is a major public health problem due to its high level of complications and low survival rate, and the global incidence of OHCA is high (1,2). In the United States and Canada alone, almost 65% of cardiac arrests occur outside the hospital, with more than 85% occurring in residential homes (usually the patient's own home) (3,4). The survival rate in these cases is usually less than 10%, with most patients dying before they reach hospital (5,6).

The survival of OHCA patients largely depends on an interconnected and co-ordinated chain. One of the rings that shape the survival chain is the initial diagnosis of cardiac arrest by a bystander, which could improve survival prospects. This step is crucial in early initiation of cardiopulmonary resuscitation (CPR), which is usually done during the phone conversation between the bystander and an emergency medical dispatcher (EMD). But there are barriers to the recognition of OHCA: it is not always possible due to inadequate caller information, lack of physical contact of a caller with the victim, and the non-diagnosis of abnormal or agonal breathing as a symptom of cardiac arrest (7-9).

The importance of detecting OHCA during an emergency call has been emphasised by the European Resuscitation Council Guidelines (10). Recognition of OHCA during an emergency call is a prerequisite for initiating CPR that could lead to long-term survival of the victim (11-14). Because 2 to 3% of emergency calls to the Tehran Emergency Medical Service (EMS) Centre report cardiorespiratory arrest, since 2008 the centre has been conducting a CPR training program for EMDs based on standard protocols to improve patient outcomes. EMDs (all of whom are women holding a Master Degree in nursing) completed 60 hours of training before they started working at the centre, followed by an average of 2 hours of monthly training thereafter. Until now there has been no study on the diagnostic accuracy of OHCA identification by EMDs in Iran; therefore this study was conducted to answer this question.

Methods

Study design

This diagnostic accuracy study was conducted over a 6-month period from March to September 2018 in Tehran, Iran. The study protocol was approved by the Ethical Committee of Tehran University of Medical Sciences. Data gathering was performed retrospectively using the Tehran EMS data registry. The EMS Center of Tehran, with its 185 headquarters, covers a population of just over 13 million people. Over 7000 calls are made each day to the centre, approximately 1750 cases lead to the dispatch of ambulances with almost 2 to 3% of these being for OHCA.

Study population

All patients over 18 years of age with suspected OHCA by EMDs of the Tehran EMS Centre or EMS technicians at the patient's bedside were eligible for inclusion in the study. Cases of post-traumatic cardiac arrest; absence of the caller at the patient's bedside or lack of their co-operation; or cardiac arrest in the presence of a healthcare provider were excluded from the study. Final diagnosis was confirmed by an EMS technician, who was managing the patients. Sampling was conducted as a census method. To identify false negative cases, all cardiorespiratory arrests detected by the EMS technician that were not diagnosed by EMDs were extracted from the mission forms; and for detecting the true negative cases, all cases detected by the dispatcher and agreed with by the EMS technician were considered.

Protocol

In the protocol used for diagnosis of OHCA, the in-charge EMD asks the bystander to shake the patient's shoulders and asks: 'Is there any response?' 'Does the patient moan or not?' In next step, the patient's breathing should be checked. So the bystander is asked to look at the patient's chest wall and confirm whether there is any chest rise during a 10 second observation, or describe the patient's breathing pattern. If the patient is unconsciousness and has no breathing, the patient's address is taken and the nearest ambulance is sent to the scene. After dispatching the ambulance, the dispatcher should ask the bystander to perform CPR according to their remote guide.

Data gathering

According to the rules, all calls between the caller and the dispatcher are recorded routinely. All ambulances are equipped with an automated external defibrillator. The initial diagnosis, results of primary assessment and monitoring, and the final outcome of the mission, are all recorded. Related archived audios were extracted from the system and listened to by one of the researchers (MM). Other required data were extracted from EMS mission forms and recorded on a pre-prepared checklist. The checklist consisted of three parts:

- the patients' demographic data and information related to their main complaint, accompanying symptoms and medical history;
- the dispatchers' baseline information including their education level, work experience, previous theoretical and practical training, work experience in an emergency department or intensive care unit; and
- the diagnosis made by the EMDs and final diagnosis on scene by EMS personnel.

Statistical analysis

Values were expressed as frequency (number and percentage), median (interquartile range with 75th to 25th percentiles), as appropriate. Chi-square tests were used for trend of true or false proportion diagnosis in levels of experience of the EMDs.

Logistic regression model was used to investigate correlated factors with OHCA. At this point, all independent variables were analysed using univariate analysis and then the variables that had a p-value less than 0.2 were put into multivariate logistic regression model. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) as well as disease prevalence are expressed as percentages. PPV and NPV were calculated based on final diagnosis. Confidence intervals for sensitivity and specificity are 'exact' Clopper-Pearson confidence intervals (15). Confidence intervals for the predictive values are standard logit confidence intervals (16). All analysis of the studied relationships was performed with a 95% confidence interval and statistical analyses were performed using the STATA software, version 12.

Results

Characteristics of the participants and correlated factor

A total of 4732 cases were approached, including 2830 (59.8%) men. The age of participants ranged from 18 to 106 years, and the mean standard deviation (SD) and median interquartile range (IQR) was 68.1 (19.7) and 73.0 (27.0), respectively. The mean age of females was significantly higher than males (71.3 vs. 65.9, respectively, p=0.001).

Of all the participants, 74.5% had a history of at least one disease: cardiovascular disease was the highest at 27.8%; gastrointestinal disorder was the lowest at 2.5% (Table 1). Of all the participants, 3507 (74.1%) had history of at least one cardiovascular disease, hypertension disorder, stroke, cancer and diabetes, of which 1.0% had a history of cardiovascular disease, hypertension disorder and cancer at the same time (Figure 1). Cardiac arrest prevalence based on final diagnosis was 37.4%. Multivariate regression analysis showed that history of hypertension disorder (OR=12.8) is the most important risk factor, and no history of disease (OR=0.13) a protective factor for cardiac arrest (Table 1).

Characteristics of the EMDs

This study assessed 4732 suspected OHCA cases reported by 173 EMDs with a mean age of 27.7 (SD=3.7). All of the EMDs were women with work experience in the dispatch system of between 1 week and 84 months: 22.0% had less than 1 month's experience; 15.1% had more than 31 months experience; and 18.5% had 13 to 18 months experience (Table 2). The number of cases reported by any EMD was between one and 92 cases. The range number of cases reported by any EMD was between one and 92 cases. The majority of EMDs (34.1%) had experience of reporting less than nine cases. A total of 564 cases (11.9%) were reported by seven EMDs (4.0%) and each one reported 70 cases or more (Table 2).

Criterion validity of OHCA diagnosis by EMDs and correlated factors

Cardiac arrest prevalence based on EMD diagnosis was 34.1%. Sensitivity and specificity of OHCA diagnosis by EMDs was 78.6% and 92.4%, respectively. Cardiac arrest prevalence based on final diagnosis was 37.4% (95% CI: 36.0–38.8) and based on this prevalence, PPV, NPV and accuracy was 86.1% (95% CI: 84.5–87.6), 87.8% (95% CI: 86.8–88.8) and 87.3% (95%CI: 86.3–88.2), respectively. Sensitivity of EMD accuracy in diagnosis increased from 75.0% to 80.9% with increasing work experience (months), from less than 1 month to more than 30 months. Sensitivity of EMD accuracy in diagnosis increased from 59.0% to 77.8% with increasing frequency of cases reported, from one to nine, and more than 70 cases.

With increased work experience, the proportion of false diagnosis decreased from 14% to 12%, false negative to negative decreased from 16% to 12%, but false-positive to positive had no decreasing trend (Table 2). The proportion of false negative and false positive was significantly negatively correlated with work experience (months) (r=-0.251; p=0.004 and r=-0.205; p=0.049, respectively). The proportion of false

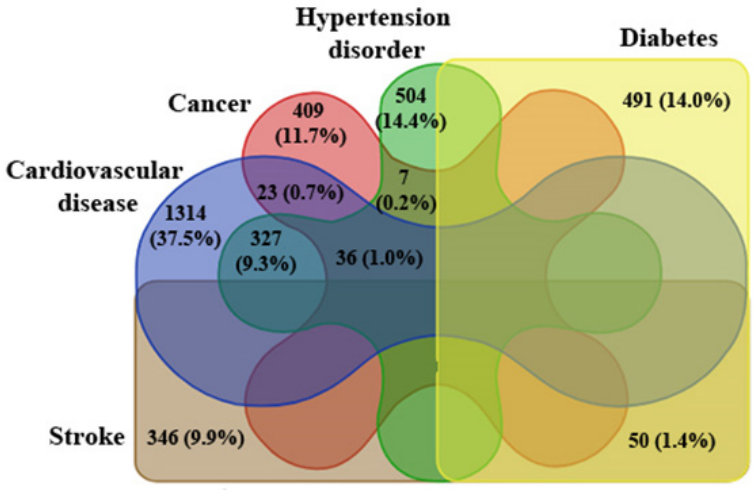

Figure 1. Veen diagram of history of prevalent disease in suspected OHCA cases

negative to negative was significantly negatively correlated with work experience (months) (r=-0.250, p=0.005), but proportion of false positive to positive was not significant correlated (r=-0.121, p=0.254).

The sensitivity of diagnosis made by each EMD increased with the number of reported OHCA cases. So, the proportion of true diagnosis was 85% for those EMDs who reported less than nine cases, while the proportion was 90% for those EMDs who reported more than 70 cases; this trend was statistically significant (p=0.003). The proportion of false negative to negative was significantly reverse trend (17% to 8%) with case report experience (p<0.001), but the proportion of false positive to positive was not significantly trend with case report experience (p=0.134) (Table 2). Age of the EMDs had no significant correlation with true OHCA diagnosis.

Discussion

Based on the results, accuracy of OHCA diagnosis by EMDs is almost 87%. Increasing the work experience and increasing the number of cases the EMDs reported, has been associated with increased sensitivity and also has a greater impact on the correct diagnosis of healthy people in terms of cardiac arrest. In other words, EMDs who have more experience or more reporting experience can better recognise OHCA.

There are similar articles on this topic. For example, Garza et al conducted a survey on 506 cases and reported overall sensitivity of 68.3% and PPV of 65.0% for diagnosis of OHCA by EMDs (17); others have reported various values, less or more (18,19). Vaillancourt et al conducted a systematic review reporting on which symptoms would help EMDs improve their accuracy regarding OHCA diagnosis. They reported that a combination of 'unconsciousness' and 'absence of breathing' or 'presence of abnormal breathing' are the most common clinical features that lead to a diagnosis of OHCA over the telephone. They also stated that sensitivity and specificity for the recognition of OHCA in previous studies has a range 38–97% and 95–99% respectively, and is dependent on the protocol used (20). A systematic review performed by Veireck et al for the recognition of OHCA by EMDs during emergency calls found a median sensitivity for OHCA recognition of 73.9%, with a range of 14.1 to 96.9%. They concluded that this wide range results from significant heterogeneity between study populations and the definition of recognised OHCA (10).

It is assumed that a protocol-based behaviour would be more helpful to increase the accuracy of OHCA diagnosis. Nurmi et al conducted a study to assess the compliance to the protocol and reported that a high identification rate of OHCA was achieved despite poor protocol compliance by EMDs (21). On the other hand, Roppolo et al evaluated the efficacy of a new protocol that assesses the presence of agonal respirations, and they claimed that establishment of this protocol can significantly increase the detection of OHCA by EMDs over the telephone (22). Although implementation of a valid unique protocol may be helpful, a higher level of medical training could improve EMDs' accuracy of OHCA diagnosis. EMDs should consider the focussed questions regarding consciousness and breathing pattern assessment when a bystander calls and describe the victim's condition. Further studies are needed for evaluation of the effect of commonly used protocols (21,23,24).

Limitations

In some cases, at the time of contact, the patient may not be suffering from cardiopulmonary arrest, but may have a cardiopulmonary arrest during the time period from ambulance dispatch to when the ambulance crew arrives. There is no way to distinguish this issue.

Conclusion

Based on the results, accuracy of OHCA diagnosis by assessed EMDs was almost 87%. It is likely that, increasing the work experience and increasing the number of cases EMDs reported is associated with increased sensitivity and a greater impact on the correct diagnosis of, in particular, cardiac arrest in otherwise healthy people. In other words, EMDs who have more experience or more experience reporting OHCA can better recognise OHCA.

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Conflict of interest

The authors declare they have no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

Author contribution

Authors met the standard writing criteria based on the recommendations of the International Committee of Publishers of Medical Journals.

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Table 1. Univariate and multivariate analysis of correlated factors of OHCA

	With cardiac arrest (%)	Univariate			Multivariate		
		OR	95% CI	p-value	OR	95% CI	p-value
Age		reference	0.99 to 1.0	0.274			
Gender							
Female (n=1902, 40.2%)	642 (33.8)	reference			reference		
Male (n=2830, 59.8%)	1129 (39.9)	1.30	1.15 to 1.47	<0.001*	1.13	1.14-1.52	<0.001*
History of cardiovascular disease							
No (n=3418, 72.2%)	1054 (30.8)	reference			reference		
Yes (n=1314, 27.8%)	717 (54.6)	2.69	2.36 to 3.07	<0.001*	6.26	4.97-7.90	<0.001*
History of hypertension disorder							
No (n=4228, 89.3%)	1562 (36.1)	reference			reference		
Yes (n=504, 10.7%)	209 (51.1)	15.86	12.04 to 20.89	<0.001*	12.84	9.26-17.79	<0.001*
History of cancer							
No (n=4323, 91.4%)	1328 (31.4)	reference			reference		
Yes (n=409, 8.6%)	443 (87.9)	1.85	1.51-2.26	<0.001*	9.02	6.64-12.26	<0.001*
History of diabetes							
No (n=4241, 89.6%)	1463 (34.5)	reference			reference		
Yes (n=491, 10.4%)	308 (62.7)	3.20	2.63-3.88	<0.001*	6.44	4.77-8.69	<0.001*
History of stroke							
No (n=4386, 92.7%)	1584 (36.1)	reference			reference		
Yes (n=346, 7.3%)	187 (54.0)	2.08	1.67-2.59	<0.001*	5.26	3.75-7.37	<0.001*
History of psychological disorder							
No (n=4335, 91.6%)	1576 (36.4)	reference					
Yes (n=397, 8.4%)	195 (49.1)	1.69	1.37-2.08	<0.001*	10.48	7.70-14.28	<0.001*
History of gastrointestinal disorder							
No (n=4615, 97.5%)	1701 (36.9)	reference			reference		
Yes (n=117, 2.5%)	70 (59.8)	2.55	1.75-3.71	<0.001*	2.55	1.43-4.54	0.001
History of pulmonary disease							
No (n=4392, 92.8%)	1537 (35.0)	reference			reference		
Yes (n=340, 7.2%)	234 (68.8)	4.10	3.23-5.20	<0.001*	8.41	6.05-11.70	<0.001*
Other disease							
No (n=3854, 81.4%)	1294 (33.6)	reference			reference		
Yes (n=878, 18.6)	477 (54.3)	2.35	2.03-2.73	<0.001*	7.32	5.72-9.36	<0.001*
No history of disease or unspecified							
No (n=3523, 74.5%)	1421 (40.3)	reference			reference		
Yes (n=1209, 25.5%)	350 (28.9)	0.60	052-0.69	<0.001*	0.13	0.10-0.16	<0.001*

CI = confidence interval; OR = odds ratio

Table 2. Contingency table and criterion values of OHCA diagnosis by EMDs by experience and number of cases reported by any dispatch

	No. of dispatch (%)	True positive (% of total)	False positive (% of total)	False negative (% of total)	True negative (% of total)	Total case (%)	Proportion of false positive to positive	Proportion of false negative to negative	Proportion False to total	Sensitivity	Specificity
Experience (in months)											
<1	38 (22.0)	105 (30.4)	15 (4.3)	35 (10.1)	190 (55.1)	345 (7.3)	0.13	0.16	0.14	75.0 (67.0-81.9)	92.7 (88.2-95.8)
1-6	29 (16.8)	182 (29.5)	32 (5.2)	50 (8.1)	353 (57.2)	617 (13.0)	0.15	0.12	0.13	78.4 (72.6-83.6)	91.7 (88.5-94.2)
7-12	17 (9.8)	224 (29.8)	32 (4.3)	66 (8.8)	429 (57.1)	751 (15.9)	0.13	0.13	0.13	77.2 (72.0-81.9)	93.1 (90.3-95.2)
13-18	32 (18.5)	371 (30.7)	56 (4.6)	87 (7.2)	695 (57.5)	1209 (25.5)	0.13	0.11	0.12	81.0 (77.1-84.5)	92.5 (90.43-94.3)
19-24	16 (9.2)	165 (30.1)	23 (4.2)	39 (7.1)	322 (58.7)	549 (11.6)	0.12	0.11	0.11	80.9 (74.8-86.0)	93.3 (90.2-95.7)
25-30	15 (8.7)	65 (28.4)	12 (5.2)	16 (7.0)	136 (59.4)	229 (4.8)	0.16	0.11	0.12	80.2 (69.9-88.3)	91.9 (86.3-95.7)
>30	26 (15.1)	280 (27.7)	54 (5.3)	66 (6.5)	612 (60.5)	1012 (21.4)	0.16	0.10	0.12	80.9 (76.4-84.9)	91.9 (89.6-93.8)
Number of cases reported by any dispatch											
1-9	59 (34.1)	69 (27.1)	8 (3.1)	31 (12.2)	147 (57.6)	255 (5.4)	0.10	0.17	0.15	69.0 (59.0-77.9)	94.8 (90.1-97.8)
10-19	19 (11.0)	75 (28.2)	10 (3.8)	23 (8.6)	158 (59.4)	266 (5.6)	0.12	0.13	0.12	76.5 (66.9-84.5)	94.1 (89.3-97.1)
20-29	28 (16.2)	214 (31.2)	35 (5.1)	77 (11.2)	360 (52.5)	686 (14.5)	0.14	0.18	0.16	73.5 (68.1-78.5)	91.1 (87.9-93.8)
30-39	21 (12.1)	229 (30.6)	27 (3.6)	73 (9.8)	419 (56.0)	748 (15.8)	0.11	0.15	0.13	75.8 (70.6-80.6)	93.9 (91.3-96.0)
40-49	10 (5.8)	125 (27.4)	21 (4.6)	26 (5.7)	284 (62.3)	456 (9.6)	0.14	0.08	0.10	82.8 (75.8-88.4)	93.1 (89.7-95.7)
50-59	16 (9.2)	264 (30.3)	51 (5.8)	60 (6.9)	497 (57.0)	872 (18.4)	0.16	0.11	0.13	81.5 (76.8-85.6)	90.7 (87.9-93.0)
60-69	13 (7.5)	256 (28.9)	44 (5.0)	58 (6.6)	527 (59.5)	885 (18.7)	0.15	0.10	0.12	81.5 (76.8-85.7)	92.3 (89.8-94.4)
≥70	7 (4.0)	160 (28.4)	28 (5.0)	31 (5.5)	345 (61.2)	564 (11.9)	0.15	0.08	0.10	83.8 (77.8-88.7)	92.5 (89.3-95.0)
Total	**173 (100)**	**1392 (29.4)**	**224 (4.7)**	**379 (8.0)**	**2737 (57.8)**	**4732 (100)**	**0.14**	**0.12**	**0.13**	**78.6 (76.6-80.5)**	**92.4 (91.4-93.4)**

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