Clinical paper

Seizure-like activity at the onset of emergency medical service-witnessed out-of-hospital cardiac arrest: An observational study

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Abstract

Aims: Emergency medical service (EMS) may detect seizure-like activity in addition to agonal breathing in out-of-hospital cardiac arrest (OHCA). This study investigates the incidence and predictors of seizure-like activity in nontraumatic, EMS-witnessed OHCA and their association with clinical outcomes.

Methods: This prospective study explored EMS-recorded concomitant signs/symptoms that lead to the requirement of advanced life support in patients with nontraumatic, EMS-witnessed OHCA. Seizure-like activity includes abnormal/tonic movements and eyeball deviation. Sudden OHCA was defined by the absence of signs/symptoms of impending cardiac arrest at EMS contact or progressive circulatory/respiratory depressions after the EMS contact. Neurologically favorable outcomes were defined as the cerebral performance category score of 1 or 2 at discharge.

Results: From April 2012 to March 2020, 465 patients were studied. The incidence of seizure-like activity at cardiac arrest onset was 12.7% (59/465) in all patients with nontraumatic, EMS-witnessed OHCA. Seizure-like activity was common during shockable initial rhythm; in patients with "sudden" OHCA; and in patients who were younger, male, or had a presumed cardiac etiology. In a boosting tree, shockable initial rhythm, "sudden" OHCA, and presumed cardiac etiology were major factors that predicted the incidence of seizure-like activity. Multivariate logistic regression models including and excluding OHCA characteristics revealed that both seizure-like activity and agonal breathing recorded during EMS-witnessed OHCA were associated with favorable outcomes.

Conclusions: Seizure-like activity is a major sign/symptom of the onset of "sudden" cardiac arrest of presumed cardiac etiology, particularly in patients with shockable initial rhythms. Such activity were significantly associated with neurologically favorable outcomes.

Keywords: Seizure-like activity, Emergency medical service, Out-of-hospital cardiac arrest, Neurologically favorable outcome, Shockable initial rhythm

Introduction

Basic life support guidelines state that brief seizure-like activity or abnormal movements in addition to agonal breathing (gasping) may interfere with the recognition of cardiac arrest by bystanders and dispatchers [1–2]. The incidence of seizure-like activity in patients with out-of-hospital cardiac arrest (OHCA) has been investigated during 9–1-1 emergency calls [2].

It is well known that numerous cardiovascular disorders induce syncope accompanied by transient abnormal movements mimicking convulsions or seizures, which result from the acute onset of cerebral

hypoxia [3–8]. Several studies have confirmed this presentation based on the Tilt-table test [3,7,9]. These studies reported that fatal arrhythmias might be the true cause of epilepsy in patients [4]. Seizure-like activity was reported to be significantly associated with initial shockable rhythm and survival to hospital discharge [2] Very few studies have stated the exact incidence of seizure-like activity accompanying the onset of cardiac arrest and its association with patients with OHCA [10,11]

Emergency medical service (EMS) personnel are aware of the signs/symptoms associated with the onset of cardiac arrest, and they may witness OHCA after their arrival at the emergency scene by judging these signs/symptoms. Therefore, identifying and analyzing the signs/symptoms during the entire process of OHCA from the first point of EMS contact with the patient is a reliable method to assess the onset of signs/symptoms for this condition. This prospective observational study investigated the incidence and predictors of seizure-like activity and agonal breathing in patients with nontraumatic, EMS-witnessed OHCA and their association with outcomes.

Methods

Study design and setting

The database was designed based on Utstein recommendations [12] and included the following data: Glasgow Coma Scale (GCS) score, respiratory pattern, and radial pulse at EMS contact with the patient; all concomitant signs/symptoms that led to the detection/confirmation of cardiac arrest (carotid pulse checking) and start of cardiopulmonary resuscitation (CPR) and advanced life support (ALS); and abnormal movement and/or agonal breathing during CPR. The EMS personnel reported abnormal/tonic movements and eyeball deviations as the signs/symptoms of cardiac arrest onset. Abnormal/tonic movements included abnormal movements of the body and extremities, some of which mimicked tonic convulsion, clenching of the jaw or difficulty in opening the mouth, and face contracture. These signs and symptoms were categorized as seizure-like activity based on a previous study using the head-up tilt test [7]. The EMS personnel reported some cases of abnormal expiratory sounds immediately before collapse, some of which proceeded with seizure-like activity. Although abnormal expiratory sound is known as a prodromal sign of epileptic seizure [13] this sound alone was not included in seizure-like activity.

The EMS system in Ishikawa Prefecture has previously been described in detail [14,15]. Paramedics can use several resuscitation procedures, including semi-automated external defibrillation, insertion of supra laryngeal airways, and infusion of Ringer lactate solution through a peripheral vein for OHCA. Authorized paramedics have been permitted to insert tracheal tubes and administer intravenous epinephrine in some patients with OHCA (aged $\geq$ 8 years) under online medical direction since 2004 and 2006, respectively. Since 2011, EMS personnel have been encouraged to initiate chest compressions when the carotid pulse is weak and/or <50 bpm in comatose adult patients with "respiratory arrest" (agonal breathing or apnea) and loss of the radial pulse. However, OHCA onset has been universally recorded as the time when the EMS personnel confirm the loss of carotid pulse [12]. Chest compression is also initiated immediately after confirming OHCA. When the EMS personnel witness shockable OHCA, they take shock-first action by delivering one immediate defibrillation with an automated external defibrillator after confirming the loss of the carotid pulse and consciousness. They can detect the seizure-like activity and agonal breathing associated with OHCA and investigate the incidence and predictors of seizure-like activity or their association with clinical outcomes.

Participants

In the present study, the EMS in Ishikawa Prefecture, Japan, prospectively recorded the concomitant signs/symptoms that led to carotid pulse check, the initiation of chest compressions, and ALS requirement in patients with EMS-witnessed OHCA between April 1, 2012, and March 31, 2020. Detailed databases were completed after additional interviews with the EMS personnel conducted by a supervisor in each fire department. The final repeated interview was conducted within a few months of the OHCA. The final anonymous data analysis was performed based on the National Guidelines for Ethics in Epidemiological Surveys [16]. Patients were not involved in the study design, data interpretation, or report writing.

Study procedures

First, the paper-based records of patients with OHCA were reviewed by the supervisors and EMS personnel in each fire department who managed the patients. Then, the patient records were reviewed by the emergency physician in Ishikawa Medical Control Council, followed by record correction and information addition. Finally, an anonymous database was created in each fire department and the collaborator and study members were compiled in each fire department. Afterward, the final databases were completed following repeated interviews of the EMS personnel.

Because seizure-like activity has been reported to accompany acute or sudden cardiovascular events, the present study defined the cases of "sudden" EMS-witnessed OHCA by excluding patients with impending cardiac arrest at EMS contact or those with progressive circulatory/respiratory depressions after the EMS contact. Impending cardiac arrest was defined when $\geq$1 of the following four criteria were satisfied: 1) deep coma, defined as a GCS score of 3; 2) very weak or absent radial pulse; 3) agonal breathing or apnea; and 4) antecedent bradycardia, defined as a heart rate of <50 bpm in the 2–10 min preceding OCHA: antecedent bradycardia occurred frequently up to 10 min before cardiac arrest and was associated with poor clinical outcome [17].

Analysis

All patients experienced EMS-witnessed OHCA. Exceptional cases included those patients who received ALS within 90 seconds of contact owing to an impending cardiac arrest and traumatic OHCA with extremely poor prognosis. First, we compared the demographics of patients with and without seizure-like activity. Second, the association of seizure-like activity and agonal breathing, other signs/symptoms, and characteristics of OHCA with neurologically favorable outcomes was studied. If there was no evident cause of noncardiac etiology, presumed cardiac etiology was considered as a type of exclusion diagnosis.

Outcome measures

The primary outcome of this study was a neurologically favorable outcome, defined as a cerebral performance category score of 1 (good recovery) or 2 (moderate disability) [18], which was determined by a physician at discharge from the last hospital. The secondary endpoints were other signs/symptoms recorded by the EMS personnel, shockable initial electrocardiogram rhythms, and a record of seizure-like activity.

Fire departments follow all OHCA survivors for up to 1 year from the event to the final hospital discharge.

Statistical analysis

Univariate analyses were performed using the chi-squared test or Fisher's exact probability test for nominal variables and the Mann–Whitney U test for continuous variables. Demographics of patients with EMS-witnessed OHCA included that seizure-like activity, patient age, patient sex, patient years, presumed cardiac etiology, shockable initial rhythm, sustained return of spontaneous circulation (ROSC) after the first defibrillation, "Sudden" OHCA (the absence of any signs/symptoms for an impending cardiac arrest at EMS contact or progressive circulatory/respiratory depression after the EMS contact), emesis/vomiting, and agonal breathing during EMS-performed CPR after the confirmation of a cardiac arrest. A boosting tree [19] was used to identify the major factors for predicting the incidence of seizure-like activity and agonal breathing. Multivariable logistic regression analysis was performed to identify major factors associated with neurologically favorable outcome. Multivariable logistic regression analysis for neurologically favorable outcomes was performed using two models. Model 1 included only signs/symptoms: seizure-like activity, "sudden" cardiac arrest, emesis/vomiting, and agonal breathing during EMS-performed CPR after the confirmation of a cardiac arrest. Model 2 included all factors (the signs/symptoms and characteristics of patients with OHCA: age, sex, presumed cardiac etiology, and shockable initial rhythm). All tests were 2-tailed, and a p-value of <0.05 was considered significant. All statistical analyses were performed using the JMP Pro 15 software (SAS Institute, Cary, NC, USA).

Results

Overview of case selection

Of the 8,532 patients with OHCA transported to hospitals by the EMS personnel during the study period, the cases of 504 patients were initially identified as EMS-witnessed OHCA in which the EMS attempted to record the concomitant signs/symptoms. However, four of these 504 patients had no carotid pulse or respiration at EMS contact with the patient and received ALS within 90 seconds of contact. In addition, 35 of these 504 patients suffered traumatic OHCA. After excluding these 39 (4 + 35) patients from the 504 initial patients, the final analysis was performed with the data of 465 patients (Fig. 1). Among these 465 patients, only one patient had a history of epilepsy.

Incidence of seizure-like activity at cardiac arrest onset

As shown in Fig. 2A, the incidence of seizure-like activity was 12.7% (59 of 465 patients). Most patients with seizure-like activity had abnormal/tonic movements for a short duration ($\leq$2 min), some of which were accompanied by eyeball deviation. The details of seizure-like activity are shown in Fig. 2B. Abnormal/tonic movements alone were observed for > 70% patients with seizure-like activity.

Comparison of demographics between patients with and without seizure-like activity

As shown in Table 1, comparisons of demographics between patients with and without seizure-like activity revealed that seizure-like activity was more frequently observed in younger patients (median age: 67 vs. 79 years), male patients (74.6% vs. 59.4% female), patients with presumed cardiac etiology (with: 72.9% vs. without: 41.6%), patients with shockable initial rhythm (with: 49.2% vs. without: 9.4%), and "sudden" OHCA (with: 69.5% vs. without: 23.2%).

The EMS personnel performed immediate defibrillation in patients with a shockable initial rhythm. Responsiveness to defibrillation differed between patients with and without seizure-like activity (49.2% vs. 9.4%). Sustained ROSC was achieved after the first defibrillation in 15 of 29 patients with seizure-like activity (51.7%) and in 8 of 38 patients without seizure-like activity (21.1%). Abnormal expiratory sounds immediately before patient collapse were occasionally recorded in 8 of 59 patients (13.6%) with seizure-like activity and in 6 of 406 (1.5%) patients without seizure-like activity.

Boosting tree analysis revealed that shockable initial rhythm, "sudden" OHCA, and presumed cardiac etiology were the major factors for predicting the incidence of seizure-like activity. The incidence of seizure-like activity was 43.3% (29/67) in patients with OHCA with shockable initial rhythms; 59.1 % (26/44) in those with "sudden" OHCA with shockable initial rhythms; and 63.2% (24/38) in those with presumed cardiac, "sudden" OHCA with shockable initial rhythms (Supplemental Fig. 1).

Similar analyses were performed for agonal breathing during EMS-performed CPR after confirming a cardiac arrest. Boosting tree analysis revealed that shockable initial rhythm, "un-sudden" OHCA, and presumed cardiac etiology were the major factors for predicting the incidence of agonal breathing during EMS-performed CPR (Supplemental Fig. 2). Therefore, in contrast to seizure-like activity, agonal breathing was recorded more frequently in patients with "un-sudden" OHCA than in those with "sudden" OHCA (35.8% vs. 24.4%).

Association of seizure-like activity and other OHCA characteristics with neurologically favorable outcomes

As shown in Table 2, univariate analysis results showed that younger patients (70 vs. 79 years) and patients with seizure-like activity (40.7% vs. 10.6%), "sudden" OHCA (27.4% vs. 9.1%), agonal breathing during EMS-performed CPR after the confirmation of a cardiac arrest (19.9% vs. 11.8%), presumed cardiac etiology (22.2% vs. 7.9%), and shockable initial rhythm (49.3% vs. 8.5%) experienced neurologically favorable outcomes. Multivariable logistic regression analysis for neurologically favorable outcomes was performed using two models. In Model 1, seizure-like activity, "sudden" OHCA, and agonal breathing during EMS-performed CPR after the confirmation of a cardiac arrest were the factors associated with neurological favorable outcomes. In Model 2, seizure-like activity, shockable initial

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│ All OHCA patients transported to hospitals   │
│ by EMS during the period of 2012.4.1–2020.3.31│
│                  n = 8,532                    │
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                       │
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│ EMS-witnessed OHCA patients in which EMS     │
│ attempted to record the concomitant signs    │
│ that lead to ALS                             │
│                  n = 504                      │
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No carotid pulse or respiration on EMS contact with patients and received ALS within 90 sec of contact
n = 4

Traumatic OHCA
n = 35

Non-traumatic, EMS-witnessed OHCA patients confirmed by the study group
n = 465

Analyses for incidences of seizure-like activity and their association with outcomes
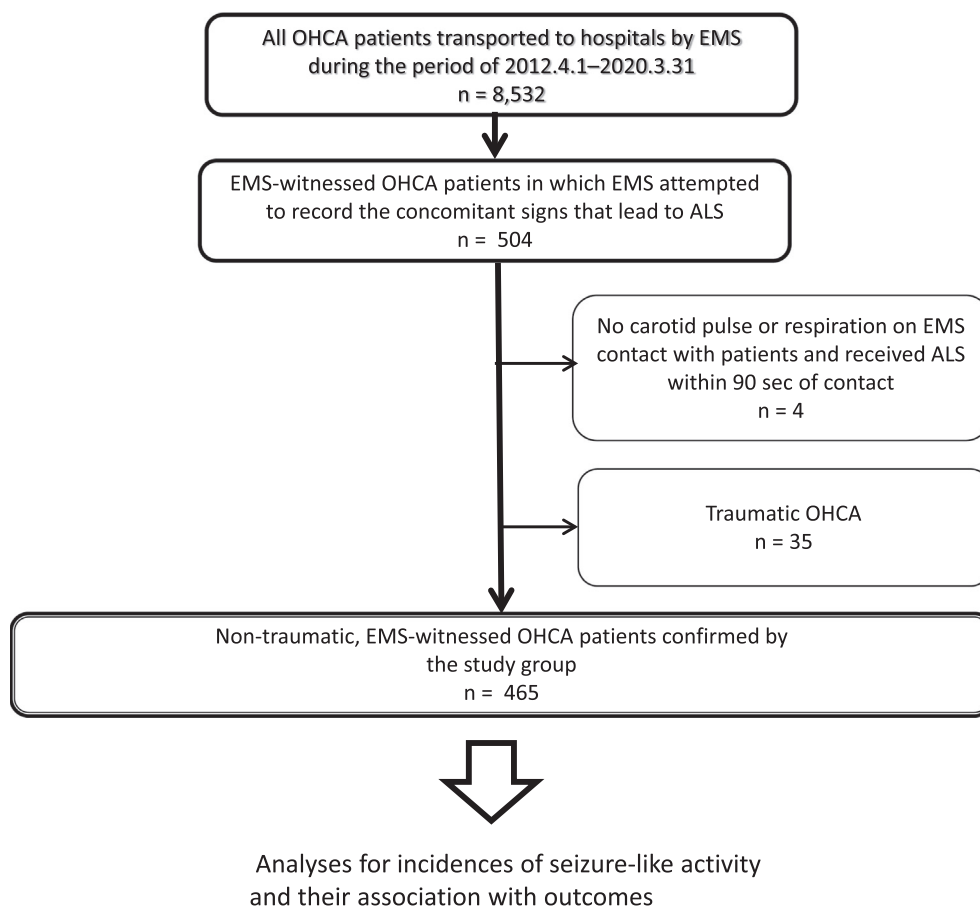
Fig. 1 – Data selection. OHCA: out-of-hospital cardiac arrest; EMS: emergency medical service; ALS: advanced life support.

rhythm, and agonal breathing during EMS-performed CPR after the confirmation of a cardiac arrest were the factors associated with better neurological outcomes.

Discussion

This study determined the incidence and characteristics of major signs/symptoms observed in patients with EMS-witnessed OHCA at OHCA onset and their association with neurologically favorable patient outcomes. Among all concomitant signs/symptoms that lead to the confirmation of a cardiac arrest (carotid pulse checking) and the initiation of CPR and ALS, seizure-like activity included abnormal/tonic movements of the body, extremities, and face and the eyeball deviation was considered a sign/symptom associated with tonic seizures [7]. The overall incidence of seizure-like activity in this study was 12.7% in all patients with nontraumatic, EMS-witnessed OHCA. Seizure-like activity was more frequently observed in younger, male patients and those with presumed cardiac etiology, shockable initial rhythm, and "sudden" OHCA. In addition, the incidence of seizure-like activity increased to 43.3% in patients with OHCA with shockable initial rhythm, 59.1% in those with "sudden" OHCA with shockable initial rhythm, and 63.2% in those with "sudden" OHCA of presumed cardiac etiology with shockable initial rhythm. Furthermore, the results of univariate analysis showed that younger patients and patients with seizure-like activity, "sudden" OHCA, agonal breathing during EMS-performed CPR after the confirmation of a cardiac arrest, presumed cardiac etiology, and shockable initial rhythm experienced neurologically favorable outcomes. In multivariable logistic regression analysis, Model 1 revealed that seizure-like activity, "sudden" OHCA, and agonal breathing during EMS-performed CPR after the confirmation of a cardiac arrest were neurologically favorable outcome factors. Model 2 revealed that seizure-like activity, shockable initial rhythm, and agonal breathing during EMS-performed CPR after the confirmation of a cardiac arrest were neurologically favorable outcome factors.

Schwarzkopf M [2] reviewed emergency calls to determine the incidence of seizure-like activity using key descriptor phrases such as "seizing," "shaking," or "convulsing." They compared patient demographics, OHCA characteristics, and outcomes (discharged alive) between patients with and without seizure-like activity. However, this study might have underestimated the incidence of seizure-like activity because the ability of lay bystanders to detect the signs is much lower than that of the EMS personnel who experience OHCA daily and are well aware of OHCA signs/symptoms. One study analyzing EMS dispatch records reported that the seizure reported by the caller indicated a risk for unexpected OHCA and knowledge regarding the history of previous seizures is clinically important [20]. The higher incidence of seizure-like activity in this study compared with that reported in previous studies may be because of improved cognition and observation skills of the EMS personnel.
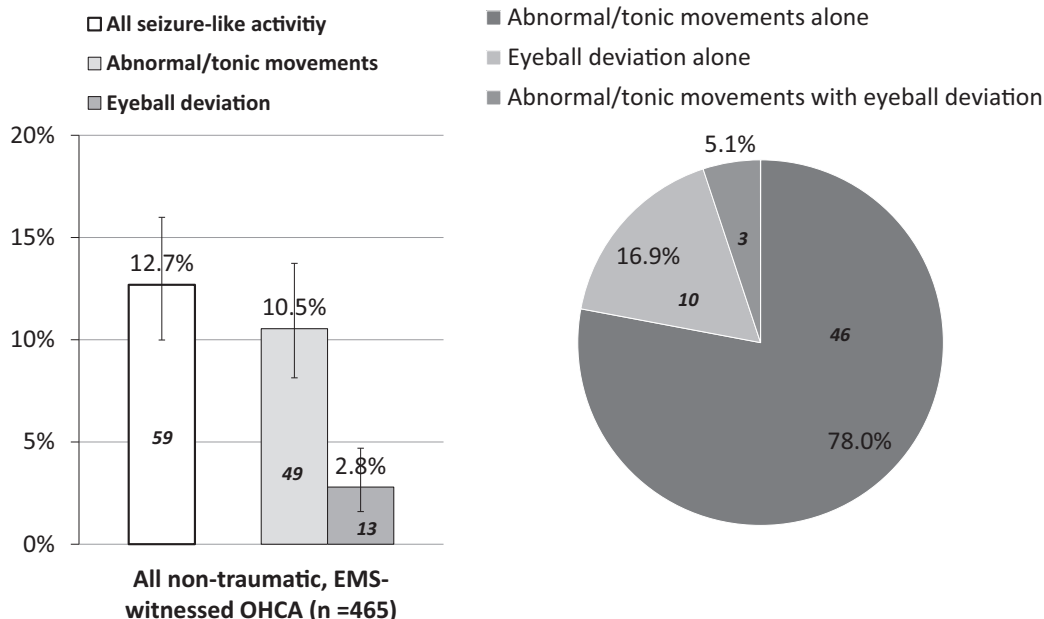
Fig. 2 – Seizure-like activity observed as signs/symptoms of the onset of cardiac arrest. A: Number (italics) of all seizure-like activity, including single or combinations of abnormal/tonic movements and eyeball deviation. B: Details of the composition of the seizure-like activity EMS: emergency medical service; OHCA: out-of-hospital cardiac arrest.

In OHCA, spontaneous gasping or agonal breathing has been examined more extensively than seizure-like activity [21–24]. The present study also confirmed that agonal breathing during CPR was associated with neurologically favorable outcomes. Agonal breathing in dying patients is the last pattern of breathing before terminal apnea [25]. The high incidence of sustained ROSC by immediate defibrillation in patients with "sudden" OHCA with seizure-like activity may reduce the appearance of agonal breathing. In boosting tree analyses of this study, "sudden" OHCA was a major factor for predicting the incidence of seizure-like activity, whereas "un-sudden" OHCA was a major factor for predicting the incidence of agonal breathing during EMS-performed CPR. These findings suggest that seizure-like activity, rather than agonal breathing, is an important sign of "sudden" OHCA .

Seizure-like activity accompanying patient collapse due to "sudden" cardiac arrest may lead to improper detection of cardiac arrest, as suggested by previous studies on emergency call handling [2,18,26] and convulsive syncope, excluding epilepsy [7,8]. When laypersons or untrained healthcare providers witness patients suffering OHCA with seizure-like activity, they may identify the patient's case as epileptic seizure. The dispatchers who receive emergency calls reporting seizure-like activity may fail to detect cardiac arrest. Furthermore, the higher incidence of seizure-like activity in patients with shockable initial rhythm suggests that this activity negatively affects the outcomes of patients with sudden cardiac arrest with shockable rhythm because of delayed defibrillation and wrong information provided to the EMS and rapid response teams. Patient outcomes can be improved by immediate defibrillation after confirming the cardiac arrest because sudden cardiac arrest with seizure-like activity can frequently cause shockable rhythm. In this study, sustained ROSC was attained after the first immediate defibrillation by the EMS personnel in >50% of the patients with EMS-witnessed OHCA with seizure-like activity and shockable initial rhythm. Responsiveness to defibrillation was significantly higher in patients with seizure-like activity than in those without seizure-like activity. Seizure-like activity may pertain to the more shocking nature of the OHCA given that favorable outcomes are expected as a result of recency and time to intervention (more short time as patients would be suffering EMS-witnessed OHCA). Information on whether seizure-like activity delays cardiac arrest detection and CPR initiation by the EMS personnel will be of interest to researchers exploring this domain.

Previous studies have reported sudden unexpected death in epilepsy (SUDEP) [27,28]. Most of these deaths reportedly resulted from external causes such as drowning and suffocation [28]; however, SUDEP is complex and is still under investigation. In the present study, only one patient had a history of epilepsy. Furthermore, in most patients, seizure-like activity was observed immediately before the EMS personnel confirmed the sudden loss of consciousness and carotid pulse. Thus, the proportion of SUDEP cases in this study was small.

Limitations

Although this study covered a 9-year period in the community population, the number of patients with EMS-witnessed OHCA analyzed in this study was small. The database was created after a 3-step review and additional interviews with EMS personnel; however, the

Table 1 – Background and characteristics of EMS-witnessed out-of-hospital cardiac arrest patients with and without seizure-like activity recorded as signs/symptoms of the onset of cardiac arrest.

Background and characteristics	Seizure-like activity as signs/symptoms for the onset of OHCA		p-value by univariate analysis [a]
	Recorded (n = 59)	Not recorded (n = 406)	
Patient			
Age, years, median (IQR)	67 (58–77)	79 (68–86)	<0.01
Male, % (n)	74.6 (44)	59.4 (241)	0.02
Characteristic of OHCA			
Presumed cardiac, % (n)	72.9 (43)	41.6 (169)	<0.01
Shockable initial rhythm (VF/VT), % (n)	49.2 (29)	9.4 (38)	<0.01
Sustained ROSC after 1st defibrillation,% (n)	51.7 (16/29)	21.1 (8/38)	<0.01
Time interval			
Between EMS contact with the patient and start of CPR by EMS, min, median (IQR)	7.8 (3.4–14.8)	8.3 (4.8–14.3)	0.67
"Sudden" OHCA, % (n) [b]	69.5 (41)	23.2 (94)	<0.01
Impending cardiac arrest upon EMS contact with the patient	23.7 (14)	62.3 (253)	<0.01
Deep coma (GCS = 3), % (n)	22.0 (13)	54.2 (220)	-
Radial pulse very weak or absent, % (n)	10.2 (6)	27.6 (112)	-
Agonal breathing, % (n)	8.5 (5)	29.8 (121)	-
Apnea, % (n)	1.7 (1)	7.4 (30)	-
Progressive respiratory and/or circulatory depression between EMS contact with the patient and confirmation of cardiac arrest), % (n)	10.2 (6)	35.2 (143)	<0.01
Agonal breathing, % (n)	3.4 (2)	18.5 (75)	-
Apneic, % (n)	3.4 (2)	6.9 (28)	-
Antecedent bradycardia (<50/min), % (n) [c]	3.4 (2)	9.4 (38)	-
Weak radial pulse, % (n)	0 (0)	10.1 (41)	-
Abnormal expiratory sounds immediately before collapse, % (n)	13.6 (8)	1.5 (6)	<0.01
Emesis/vomiting between EMS contact with the patient and confirmation of cardiac arrest, % (n)	6.8 (4)	3.5 (14)	0.27
Agonal breathing during EMS-performed CPR after confirmation of cardiac arrest, % (n)	23.7 (14)	33.7 (137)	0.12

Calculated by the chi-squared test or Fisher exact probability test for nominal variables and Wilcoxon rank sum test for continuous variables.

"Sudden" EMS-witnessed OHCA patients by excluding those with impending cardiac arrest between EMS contact with patients and progressive respiratory and/or circulatory depression between EMS contact with the patient and confirmation of cardiac arrest.

Findings suggested circulatory depression in 2–10 minutes preceding OHCA.,

OHCA, out-of-hospital cardiac arrest; OR, odds ratio; CI, confidence interval; IQR, interquartile range; ECG, electrocardiogram; VF/VT, ventricular fibrillation and pulseless ventricular tachycardia; EMS, emergency medical service; ROSC, return of spontaneous circulation; CPR, cardiopulmonary resuscitation.

Table 2 – Associations of seizure-like activity, other signs/symptoms, and characteristics of OHCA with neurologically favorable outcomes in all OHCA groups.

Signs/symptoms recorded by EMS and characteristics of OHCA known as prehospital confounders for outcomes of OHCA	Neurologically favorable outcome at 1-M, % (N) or median value for continuous variable	P by univariate analysis	Adjusted OR (95 %CI) in Model 1	Adjusted OR (95 %CI) in Model 2
Seizure-like activity				
Observed, n = 59	40.7% (24)	P < 0.01	4.36 (2.22–8.56)	2.39 (1.10–5.16)
Not observed, n = 406	10.6% (43)		Reference	Reference
Sudden OHCA				
"Sudden" OHCA, n = 135	27.4% (37)	P < 0.01	2.90 (1.58–5.32)	1.61 (0.81–3.22)
"Un-sudden" OHCA, n = 330	9.1% (30)		Reference	Reference
Emesis/vomiting*				
Observed, n = 18	27.8% (5)	P = 0.16	1.54 (0.47–5.07)	2.35 (0.69–8.02)
Not observed, n = 447	13.9% (62)		Reference	Reference
Agonal breathing during EMS-performed CPR after confirmation of cardiac arrest				
Observed, n = 151	19.9% (30)	P = 0.02	2.66 (1.48–4.78)	2.26 (1.21–4.22)
Not observed, n = 314	11.8% (37)		Reference	Reference
Patient Age, years, median (IQR)				
Favorable outcome, n = 67	70 (59–80)	P < 0.01	Excluded	Unit OR (/year)
Unfavorable outcome, n = 398	79 (67–86)			0.99 (0.97 –1.01)
Patient sex				
Male, n = 285	16.1% (46)	P = 0.18	Excluded	0.96 (0.51–1.83)
Female, n = 180	11.7% (21)			Reference
Etiology, % (n)				
Presumed cardiac, n = 212	22.2% (47)	P < 0.01	Excluded	1.76 (0.91–3.38)
Non-cardiac, n = 253	7.9% (20)			Reference
Initial rhythm, % (n)				
Shockable, n = 67	49.3% (33)	P < 0.01	Excluded	5.24(2.60–10.55)
Non-shockable, n = 398	8.5% (34)			Reference

* Between EMS contact with the patient and confirmation of cardiac arrest.

Model 1 included only signs/symptoms: seizure-like activity, "sudden" cardiac arrest (absence of signs/symptoms for impending cardiac arrest at EMS contact with patients or progressive circulatory/respiratory depression after EMS contact), emesis/vomiting, and agonal breathing during EMS-performed CPR after confirmation of cardiac arrest.

Model 2 included all factors (signs/symptoms and characteristics of OHCA: patient age, patient sex, presumed cardiac etiology, shockable initial rhythm).

OHCA, out-of-hospital cardiac arrest; OR, odds ratio; CI, confidence interval; IQR, interquartile range; EMS, emergency medical service; CPR, cardiopulmonary resuscitation.

quality of records for signs/symptoms depended on the observation ability of the EMS personnel, although they are aware of the signs/symptoms associated with cardiac arrest onset. The EMS personnel observe the patients during close contact. Therefore, the signs/symptoms analyzed in this study are more reliable than those obtained from callers and bystanders in bystander-witnessed OHCA cases.

Conclusions

Seizure-like activity, including abnormal/tonic movements of the body, extremities, and face and eyeball deviation, is a major sign/symptom of the "sudden" onset cardiac arrest, particularly ventricular fibrillation and tachycardia. Patient outcomes can be improved by immediate defibrillation after the confirmation of a cardiac arrest, considering that sudden cardiac arrest with seizure-like activity is frequently accompanied by shockable initial rhythm. However, both seizure-like activity and agonal breathing may interfere with the detection of cardiac arrest when witnessed by laypersons or untrained healthcare providers. Dispatchers should be aware that seizure-like activity in patients without a previous history of epileptic seizure is an important sign for sudden ventricular fibrillation or tachycardia.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2021.100168.

R E F E R E N C E S

1. Kleinman ME, Brennan EE, Goldberger ZD, Swor RA, Terry M, Bobrow BJ, Gazmuri RJ, Travers AH, Rea T. Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2015;132(18 suppl 2):S414–35. https://doi.org/10.1161/CIR.0000000000000259.

2. Schwarzkoph M, Yin L, Hergert L, Drucker C, Counts CR, Eisenberg M. Seizure-like presentation in OHCA creates barriers to dispatch recognition of cardiac arrest. Resuscitation. 2020 Nov;156:230–6. https://doi.org/10.1016/j.resuscitation.2020.06.036. Epub 2020 Jul 13.

3. Zaidi A, Clough P, Cooper P, Scheepers B, Fitzpatrick AP. Misdiagnosis of epilepsy: many seizure-like attacks have a cardiovascular cause. J Am Coll Cardiol 2000;36(1):181–4.

4. Schott GD, McLeod AA, Jewitt DE. Cardiac arrhythmias that masquerade as epilepsy. Br Med J 1977;1(6074):1454–7.

5. Bergfeldt L. Differential diagnosis of cardiogenic syncope and seizure disorders. Heart 2003;89:353–8.

6. Sabu J, Regeti K, Mallappallil M, Kassotis J, Islam H, Zafar S, Khan R, Ibrahim H, Kanta R, Sen S, Yousif A, Nai Q. Convulsive Syncope Induced by Ventricular Arrhythmia Masquerading as Epileptic Seizures: Case Report and Literature Review. J Clin Med Res 2016;8 (8):610–5. https://doi.org/10.14740/jocmr2583w.

7. Joo BE, Koo DL, Yim HR, et al. Seizure-like activities in patients with head-up tilt test-induced syncope. Medicine (Baltimore) 2018; 97: e13602. doi: 10.1097/MD.0000000000013602.

8. Shen WK, Sheldon RS, Benditt DG, et al. 2017 ACC/AHA/HRS Guideline for the Evaluation and Management of Patients With Syncope: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society. Circulation 2017; 136: e60-e122. doi: 10.1161/CIR.0000000000000499.

9. Grubb BP, Gerard G, Roush K, et al. Differentiation of convulsive syncope and epilepsy with head-up tilt testing. Ann Intern Med 1991;115:871–6.

10. De Maio VJ, Stiell IG, Wells GA, et al. Cardiac arrest witnessed by emergency medical services personnel: descriptive epidemiology, prodromal symptoms, and predictors survival. OPALS study group. Ann Emerg Med. Feb 2000;35(2):138–46.

11. Nehme Z, Andrew E, Bray JE, et al. The significance of pre-arrest factors in out-of-hospital cardiac arrests witnessed by emergency medical services: a report from the Victorian Ambulance Cardiac Arrest Registry. Resuscitation. Mar 2015;88:35–42.

12. Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L, Bossaert L, Delooz HH, Dick WF, Eisenberg MS. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. Circulation 1991;84(2):960–75.

13. British Epilepsy Association. Epilepsy Action: Focal seizures. [Accessed 1 January 2020, at https://www.epilepsy.org.uk/info/seizures/focal-seizures]

14. Maeda T, Yamashita A, Myojo Y, Wato Y, Inaba H. Augmented survival of out-of-hospital cardiac arrest victims with the use of mobile phones for emergency communication under the DA-CPR protocol getting information from callers beside the victim. Resuscitation 2016;107:80–7. https://doi.org/10.1016/j.resuscitation.2016.08.010.

15. Kurosaki H, Ohta K, Wato Y, Yamashita A, Inaba H. Assessing the efficacy of the new protocol for chest compressions before definitive cardiac arrest in emergency medical service-witnessed adult out-of-hospital cardiac arrests. Resuscitation 2018;130:92–8. https://doi.org/10.1016/j.resuscitation.2018.07.011.

16. Ministry of Education, Culture, Sports, Science and Technology, Ministry of Health, Labour and Welfare (Japan). Ethical guidelines for epidemiological research, http://www.niph.go.jp/wadai/ekigakurinri/guidelines.pdf (2002, accessed 28 January 2019).

17. US Bhalala, CP Bonafide, CM Coletti, et al. Antecedent bradycardia and in-hospital cardiopulmonary arrest mortality in telemetry-monitored patients outside the ICU. Resuscitation, 83(9), 1110-10.

18. Jennett B, Bond M. Assessment of outcome after severe brain damage. Lancet 1976;1:480–4.

19. J Hastie, T. J., Tibshirani, R. J., Friedman, J. H. The Elements of Statistical Learning: Data Mining, Inference, and Prediction 2009. 2nd ed. New York: Springer-Verlag.

20. Clawson J, Olola C, Heward A, Patterson B. Cardiac arrest predictability in seizure patients based on emergency medical dispatcher identification of previous seizure or epilepsy history. Resuscitation 2007;75(2):298–304.

21. Clark JJ, Larsen MP, Culley LL, Graves JR, Eisenberg MS. Incidence of agonal respirations in sudden cardiac arrest. Ann Emerg Med 1992;21(12):1464–7.

22. Zhao L, Li C, Liu Bo, Wang M, Shao R, Fang Y. The association of gasping and outcome, in out of hospital cardiac arrest: A systematic review and meta-analysis. Resuscitation 2015;97:7–12. https://doi.org/10.1016/j.resuscitation.2015.09.377.

23. Dabary G, Labarere J, Frascone RJ, et al. Long-Term Prognostic Value of Gasping During Out-of-Hospital Cardiac Arrest. J Am Coll Cardiol 2017;70:1467–76. https://doi.org/10.1016/j.jacc.2017.07.782.R.

24. Zhang Q, Liu Bo, Qi Z, Li C. Prognostic value of gasping for short and long outcomes during out-of-hospital cardiac arrest: an updated systematic review and meta-analysis. Scand J Trauma Resusc Emerg Med 2018;26(1). https://doi.org/10.1186/s13049-018-0575-1.

25. Perkin DR. The agony of agonal respitation: is the last gasp necessary? J Med Ethics. 2002;28:164–9. https://doi.org/10.1136/jme.28.3.164.

26. Clawson J, Olola C, Scott G, Heward A, Patterson B. Effect of a Medical Priority Dispatch System key question addition in the seizure/convulsion/fitting protocol to improve recognition of ineffective (agonal) breathing. Resuscitation 2008;79(2):257–64. https://doi.org/10.1016/j.resuscitation.2008.06.006.

27. Devinsky O. Sudden, unexpected death in epilepsy. N Engl J Med 2011;365(19):1801–11. https://doi.org/10.1056/NEJMra1010481.

28. Kei M, Satoko O, Rei E, et al. Etiology of Sudden Cardiac Arrest in Patients with Epilepsy: Experience of Tertiary Referral Hospital in Sappro City, Japan. Neurol Med Chir. 2016;56(5): 249-56. PMID: 26948699. doi: 10.2176/nmc. oa.2015-0285