Available online at www.sciencedirect.com

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Association between shockable rhythm conversion and outcomes in patients with out-of-hospital cardiac arrest and initial non-shockable rhythm, according to the cause of cardiac arrest

Kap Su Han [1], *Sung Woo Lee* [1], *Eui Jung Lee, Moon Hwan Kwak, Su Jin Kim* *

Department of Emergency Medicine, College of Medicine, Korea University, Inchon-ro 73, Seongbuk-gu, Seoul, 02841, Republic of Korea

Abstract

Objective: Conversion to shockable rhythm from an initial non-shockable rhythm is associated with good neurologic prognoses in patients with out-of-hospital cardiac arrest (OHCA). We aimed to investigate whether conversion to shockable rhythm has an association with good neurologic outcomes, according to the etiology of cardiac arrest.

Methods: We conducted a nationwide, population-based, cohort study using the OHCA data from the Korea Centers for Disease Control and Prevention database in 2012–2016. We included patients with OHCA and an initial non-shockable rhythm. The primary outcome was good neurologic outcome at discharge, etiologies of arrest were categorized to medical, non-medical cause. We analyzed the effect of conversion to a shockable rhythm on outcome according to causes of cardiac arrest using multiple regression analysis.

Results: Of 114,628 patients with an initial non-shockable rhythm, 25,042 (21.8%) experienced conversion to a shockable rhythm; 83,437 (72.8%) had medical causes and 31,191(27.2%) had non-medical causes. In all patients with OHCA and initial non-shockable rhythm, adjusted odds ratio (OR) of conversion for good neurologic outcome was 2.051 (95% confidence interval [CI] 1.181–2.297). The medical cause group showed an adjusted OR 1.789 (95% CI 1.586–2.019) of conversion for good neurologic outcome. In non-medical cause group, the adjusted OR of conversion was 0.644 (95% CI 0.372–1.114).

Conclusion: Conversion to shockable rhythm had an association with good neurologic outcome in patients with OHCA with initial non-shockable rhythms, especially due to cardiac cause. However, rhythm conversion was not associated with better outcome in patients with non-medical causes.

Introduction

Patients with out-of-hospital cardiac arrest (OHCA) have poor outcomes when the initial rhythm is non-shockable compared with those with an initial shockable rhythm.[1,2] Chan et al. reported that patients with OHCA who have an initial shockable rhythm had a survival rate of 16.1–27.9% and those with an initial non-shockable rhythm had a survival rate of 2.1–4.4%.[3] The incidence of non-shockable rhythm have increased over the past few decades and showed a tendency of higher rate in Asian countries.[4–6] The probability of a favourable neurologic outcome in patients with non-shockable rhythm is very low despite the high incidence of initial non-shockable rhythm.[7]

Considering the good prognosis of patients with OHCA with an initial shockable rhythm, subsequent conversion to shockable rhythm in patients with OHCA who have an initial non-shockable rhythm may be related to a good prognosis. Several studies have reported that subsequent conversion to shockable rhythm from non-shockable rhythm in patients with OHCA with an initial non-shockable rhythm is associated with good survival outcomes[8–12] and good neurologic outcomes.[8,13–15]

* Corresponding author.
E-mail address: icarusksj@gmail.com (S.J. Kim).
[1] Contributed equally to this article as first authors.

https://doi.org/10.1016/j.resuscitation.2019.07.025
Received 23 December 2018; Received in revised form 29 June 2019; Accepted 22 July 2019

Previous studies of whether conversion to a shockable rhythm affects outcomes have all been performed in patients with OHCA or in those with a presumed cardiac cause. Although non-cardiac OHCA is known to have a worse prognosis than OHCA with cardiac causes [6,16–18], the initial rhythm shockable rhythm still showed good outcome in OHCA patients with non-cardiac etiology, similar to in OHCA patients with cardiac cause compared with non-shockable rhythm.[16,18,19] However, there was no study that analyzed the effect of shockable rhythm conversion from an initial non-shockable rhythm on the prognosis in patients with OHCA due to non-medical causes and medical causes including cardiac etiology. Therefore, we aimed to investigate whether conversion to a shockable rhythm is associated with good prognosis, according to the causes of cardiac arrest.

Methods

Study design and data source

This study was based on a nationwide population-based observational cohort in Korea, the Out-of-Hospital Cardiac Arrest Surveillance (OHCA Surveillance), which includes patients in whom resuscitation was attempted after OHCA.[20–22] We conducted a secondary analysis of the OHCA Surveillance database. This database was established in 2008 by the Korea Centers for Disease Control and Prevention (KCDC).

Korea has approximately 50 million residents. The Korean emergency medical services (EMS) is a single-tiered, government-based system. EMS personnel cannot declare death at the scene or terminate cardiopulmonary resuscitation (CPR) unless there is return of spontaneous circulation (ROSC). Therefore, all patients with OHCA are transported to the emergency department (ED). KCDC researchers subsequently visit the medical facilities to which patients are transferred, to review medical records and conduct surveys using a structured survey form. All patients with OHCA in Korea are included in this surveillance.

Study population and variables

Data from January 2012 to December 2016 were extracted from the database. We included adult patients with OHCA ($\geq$18 years) with an initial non-shockable rhythm, and for whom resuscitation was attempted by EMS personnel. Patients transferred from the ED to other facilities and those whose families refused further resuscitation were excluded. We also excluded patients whose cause of cardiac arrest was not recorded. The study population was classified according to cause of cardiac arrest, which was classified as medical or non-medical according to the Utstein-style international guidelines (revised in 2014). Based on this guidelines, the cause of cardiac arrest was divided into medical and non-medical origin such as trauma, overdose, drowning, electrocution, asphyxia, and "not recorded".[23] Cardiac arrest due to airway obstruction by external causes such as foreign-body airway obstruction or strangulation was defined as asphyxia. There were many hanging patients in this cohort and they were classified as 'hanging' separately. We further divided medical causes into cardiac and non-cardiac. Only patients with a definite non-cardiac medical cause were classified as having a medical non-cardiac cause like pulmonary embolism. The shockable rhythm or not was automatically analyzed by automatic external defibrillator on scene at prehospital phase and was analyzed through EKG monitoring by emergency physician. The conversion to a shockable rhythm in the patient with an initial non-shockable rhythm was defined that electrical shock was delivered by AED after analyzing rhythm at prehospital phase or by emergency physician at emergency department. The conversion group comprised patients who received electrical shock during CPR, and while the non-conversion group comprised who did not receive electrical shock during CPR.

The registry included data on patients' demographic characteristics, witnessed arrest status, presumed cause of arrest, incidence of suspected or confirmed trauma, bystander CPR, initial documentation of cardiac rhythm, presence of a do-not-attempt-resuscitation (DNAR) order or terminal illness, prehospital ROSC (defined as ROSC at ED admission), presence of therapeutic hypothermia or targeted temperature management or coronary angiography, and Glasgow–Pittsburgh cerebral performance category (CPC) score at discharge.

Outcomes

The primary outcome was good neurologic outcome at hospital discharge, defined as a CPC score of 1 or 2. The CPC score was determined by a medical record reviewer based on the discharge summary. The secondary outcome was survival at hospital discharge and rate of ROSC.

Statistical analysis

The demographics and characteristics of the study cohorts were summarized using descriptive statics. Continuous data were reported as mean $\pm$ standard deviation. Continuous variables were compared using unpaired Student *t*-tests whereas categorical variables were compared using a chi-square or Fisher's exact test. Multiple logistic regression analysis was used to assess the associations between conversion to a shockable rhythm and good neurologic outcomes after adjusting for selected covariates (age, sex, presence of a witness, and attempted bystander resuscitation). Multiple regression analysis was performed according to the cause of cardiac arrest. All statistical analyses were performed using IBM SPSS version 20.0 (IBM Corp., Armonk NY, USA). Two-tailed P-values $<$0.05 were considered significant.

Results

Overall, 142,095 patients with OHCA were included in the OHCA Surveillance registry. We included 114,628 patients with an initial non-shockable rhythm after excluding those who were transferred to other facilities, age $<$18 years, whose cause of cardiac arrest were not recorded, with DNAR status, and with a shockable initial rhythm (Fig. 1). 83,437 (72.8%) had cardiac arrest due to a medical cause and 31,191(27.2%) due to a non-medical cause. Among medical causes, 77,567 (92.9%) were of presumed cardiac origin. Among non-medical causes, 18,085 (57.9%) were due to trauma, 2,045 (6.5%) to drug overdose, 1,797 (5.7%) to drowning, 2,764(8.8%) to asphyxia, and 6,500 (20.8%) to hanging (Fig. 1).

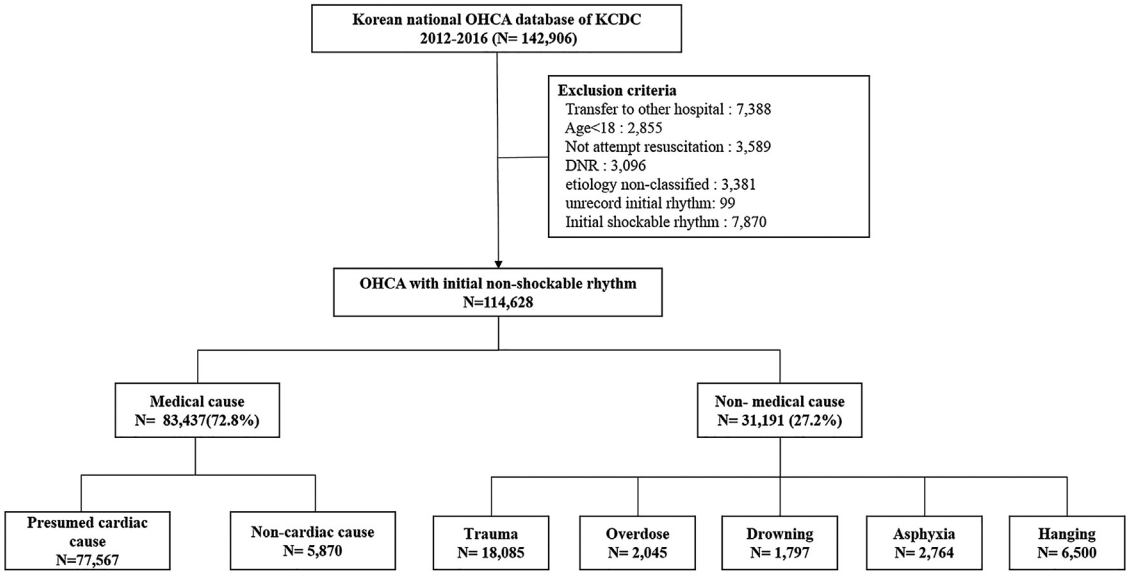

Fig. 1 – Flow chart of study population.

Comparison of characteristics and resuscitation variables according to cause of cardiac arrest

The proportion of conversion was 18.3% in patients with medical causes and 10.4% in patients with non - medical causes ($P < 0.001$). Patients with medical cause were significantly older; more likely to be male; and to have a witnessed arrest, and received bystander CPR than those in those with non-medical causes (Table 1). In our study, the mean age of patients with non-medical causes was 55.36 years and that of patients with medical causes was 70.03 years.

Outcomes according to shockable rhythm conversion for each cause of cardiac arrest

In patients with OHCA and an initial non-shockable rhythm, the overall survival rate at hospital discharge was 3.4% and the rate of good neurologic outcome at hospital discharge was 1.2%. The survival rates and outcomes of those with OHCA due to medical causes were 3.6% and 1.5%, respectively, while those of patients with OHCA due to non-medical causes were 3.0% and 0.6%, respectively (Table 2). The rates of survival to discharge in patients with non-medical causes were 1.4% for trauma, 3.4% for overdose, 3.3% for drowning, 10.9% for asphyxia, and 3.5% for hanging ($P < 0.001$).

Comparing the outcomes of the study population according to conversion, the rates of ROSC, survival, and good neurologic outcome were higher in the conversion group than in the non-conversion group.

For medical causes, the rates of ROSC in the conversion group were higher than in the non-conversion group. The rates of survival to discharge in the conversion and non-conversion groups were 6.5% and 3.0%, respectively ($P < 0.001$) and the rates of good neurologic outcome at hospital discharge were 3.0% and 0.9%, respectively ($P < 0.001$). Among medical causes, in patients with a presumed cardiac cause, the conversion group had higher rates of good neurologic outcome than the non-conversion group. However, in patients with non-cardiac medical origin, there was no difference in good neurologic outcome between the two groups (Table 2).

For non-medical causes, the rates of ROSC in the conversion group were higher than those in the non-conversion group. For trauma, the rates of survival to discharge in the conversion group were higher than those in the non-conversion group, and there was no difference in rates of good neurologic between two groups. For overdose, drowning, and hanging, there was no significant difference in the rates of survival and the good neurological outcome between the two groups. For asphyxia, the conversion group had lower rates of survival and good neurologic outcome than the non-conversion group (Table 2).

Comparison of characteristics and resuscitation variables according to neurologic outcome in the groups with medical and non-medical cause

Table 3 displays the basic characteristics and resuscitation variables, stratified according to good neurologic outcome (CPC 1-2). For medical causes, patients with the CPC1-2 were significantly younger; more likely to be male; and to have a witnessed arrest, received bystander CPR, experienced OHCA in a public place, and have conversion to shockable rhythm than patients with CPC 3-5. For non-medical causes, patients with CPC1-2 were more likely to have witnessed arrest and received bystander CPR than those with CPC 3-5, but there was no significant difference in age, sex and rate of shockable rhythm conversion between the groups with CPC1-2 and the group with CPC 3-5.

Adjusted odds ratio of conversion to shockable rhythm for outcomes according to cause of cardiac arrest

After adjustment for age, sex, presence of a witness, attempted bystander resuscitation and conversion, in all patients with OHCA and initial non-shockable rhythm, multiple logistic regression revealed that younger age, male sex, presence of a witness, attempted bystander CPR, and conversion to shockable rhythm (odds ratio [OR] 2.051, 95% confidence interval [CI] 1.831-2.297) were independent predictors of good neurologic outcomes (Table 4).

Table 1 – Comparison of characteristics and resuscitation variables according to cause of cardiac arrest.

Variable	Medical cause (n = 83,437, 18.3%)	Non-medical cause (n = 31,191, 10.4%)	P-value
Age (y ± SD)	70.03 ± 15.05	55.36 ± 18.16	<0.001
Age group			<0.001
1844 y	5240 (6.3)	8943 (28.7)	
4564 y	21566 (25.8)	11742 (37.6)	
6574 y	18399 (22.1)	5038 (16.2)	
≥75 y	38232 (45.8)	5468 (17.5)	
Sex, male	51103(61.2)	21281 (68.2)	<0.001
Location(metropolitan)	33004 (39.6)	10689 (34.3)	<0.001
Witnessed arrest	34591 (41.5)	8733 (28.0)	<0.001
Witnessed by EMS	5597 (6.7)	1564 (5.0)	<0.001
Arrest in public location	9168(11.0)	12874 (41.3)	<0.001
Bystander CPR	10432(12.5)	2846 (9.1)	<0.001
Initial rhythm			<0.001
PEA	5444 (6.5)	1780 (5.7)	
Asystole	77993 (93.5)	29410 (94.3)	
Arrest aetiology			
Medical origin		-	
Presumed cardiac origin	77567 (93.0)	-	
Non-cardiac medical origin	5870 (7.0)	-	
Non-medical origin	-		
Trauma	-	18085 (58.0)	
Overdose	-	2045 (6.6)	
Drowning	-	1797 (5.8)	
Asphyxia	-	2764 (8.9)	
Hanging	-	6500 (20.8)	
Conversion to shockable rhythm	15235 (18.3)	3252 (10.4)	<0.001
Coronary reperfusion treatment	1117 (1.3)	21 (0.1)	<0.001
TTM	1598 (1.9)	718 (2.3)	<0.001
ECMO	410 (0.5)	49 (0.2)	<0.001
Pre-hospital ROSC	1928 (2.3)	529 (1.7)	<0.001
ROSC	19404 (23.3)	5638 (18.1)	<0.001
Survival to discharge	3006 (3.6)	923 (3.0)	<0.001
CPC 1-2	1217 (1.5)	181(0.6)	<0.001

Data in table are presented as mean ± SD or number (percentage).
Abbreviations: OHCA, out-of-hospital cardiac arrest; SD, standard deviation; EMS, emergency medical services; CPR, cardiopulmonary resuscitation; PEA, pulseless electrical rhythm; TTM, targeted temperature management; ECMO, extracorporeal membrane oxygenation; ROSC, return of spontaneous circulation; CPC, cerebral performance category.

For medical causes, multiple logistic regression revealed that younger age (OR for 1-year increment 0.954, 95% CI 0.951-0.958), male sex (OR 1.285, 95% CI 1.125-1.468), bystander-witnessed arrest (OR 5.260, 95% CI 4.545-6.088), bystander CPR (OR 1.862, 95% CI 1.634-2.123), and conversion to shockable rhythm (OR 1.789, 95% CI 1.586-2.019) were associated with good neurologic outcome. For non-medical causes, bystander-witnessed arrest (OR 2.772, 95% CI 2.061-3.728), and bystander CPR (OR 2.858, 95% CI 2.021-4.044) were associated with good neurologic outcome but age, male sex and conversion to shockable rhythm (OR 0.644, 95% CI 0.372-1.114) were not associated with outcome (Table 4).

Adjusted odds ratio of conversion to shockable rhythm for outcomes according to each subgroup by cause of cardiac arrest

Fig. 2 shows the ORs of conversion to shockable rhythm for good neurologic outcome, after adjustment for age, sex, presence of a witness, and attempted bystander resuscitation, according to detailed cause of cardiac arrest. For presumed cardiac causes, the ORs of conversion to a shockable rhythm for good neurologic outcome was 1.783 (95% CI 1.575-2.018). The conversion to a shockable rhythm was not associated with good neurologic outcome in patients who had OHCA due to other detailed causes such as non-cardiac medical cause (OR 0.836 95% CI 0.425-1.645), trauma (OR 1.125 95% CI 0.481-2.631), overdose (OR 0.501 95% CI 0.114-2.195), drowning (OR 0.416 95% CI 0.095-1.823), asphyxia (OR 0.345 95% CI 0.107-1.119) and hanging (OR 0.317 95% CI 0.043-2.351).

Discussion

In patients with OHCA who have an initial non-shockable rhythm, conversion to a shockable rhythm was associated with better survival and neurologic outcomes at discharge. In the analysis according to cause of cardiac arrest, conversion to a shockable rhythm was associated with good neurologic outcomes in patients with OHCA due to medical causes but not in those with OHCA due to non-medical causes. Conversion to shockable rhythm was associated with good neurological outcome only in patients with OHCA of a presumed cardiac causes among medical causes.

Table 2 – Outcomes by conversion to shockable rhythm for each cause of cardiac arrest in patients with initial non-shockable rhythm.

Cause of arrest	ROSC				Survival at hospital discharge				CPC 1 or 2 at hospital discharge			
	All	Conversion	No conversion	p-value	All	Conversion	No conversion	p-value	All	conversion	No conversion	p-value
All cohort (n = 114,628)	**25042 (21.8)**	**6984 (37.8)**	**18058 (18.8)**	**<0.001**	**3929 (3.4)**	**1086 (5.9)**	**2843 (3.0)**	**<0.001**	**1398 (1.2)**	**501 (2.7)**	**897 (0.9)**	**<0.001**
Medical cause (n = 83,437)	**19404 (23.3)**	**5863 (38.5)**	**13541 (19.9)**	**<0.001**	**3006 (3.6)**	**987 (6.5)**	**2022 (3.0)**	**<0.001**	**1217 (1.5)**	**487 (3.2)**	**730 (1.1)**	**<0.001**
Cardiac cause (n = 77,567)	16802 (21.7)	5352 (37.2)	11450 (18.1)	<0.001	2699 (3.4)	941 (6.5)	1758 (2.8)	<0.001	1146 (1.5)	477 (3.3)	669 (1.1)	<0.001
Non-cardiac medical cause (n = 5,870)	2602 (44.3)	511 (61.3)	2091 (41.5)	<0.001	307 (5.2)	43 (5.2)	264 (5.2)	0.503	71 (1.2)	10 (1.2)	61 (1.2)	0.573
Non-medical cause (n = 31,191)	**5638 (18.1)**	**1121 (34.5)**	**4517 (16.2)**	**<0.001**	**923 (3.0)**	**102 (3.1)**	**821 (2.9)**	**0.515**	**181 (0.6)**	**14 (0.4)**	**167 (0.6)**	**0.274**
Trauma (n = 18,085)	2284 (12.6)	439 (26.4)	1845 (11.2)	<0.001	259 (1.4)	36 (2.2)	223 (1.4)	0.006	57 (0.3)	6 (0.4)	51 (0.3)	0.429
Overdose (n = 2,045)	398 (19.5)	76 (35.5)	322 (17.6)	<0.001	71 (3.4)	8 (3.7)	63 (3.4)	0.469	26 (1.2)	2 (0.9)	24 (1.3)	0.478
Drowning (n = 1,797)	291 (16.2)	95 (33.1)	196 (13.0)	<0.001	60 (3.3)	11 (3.8)	49 (3.2)	0.359	22 (1.2)	2 (0.7)	20 (1.3)	0.293
Asphyxia (n = 2,764)	1377 (49.8)	223 (52.2)	1154 (49.4)	0.152	302 (10.9)	24 (5.6)	278 (11.9)	<0.001	50 (1.8)	3 (0.7)	47 (2.0)	0.037
Hanging (n = 6,500)	1288 (19.8)	288 (43.6)	1000 (17.1)	<0.001	231 (3.5)	23 (3.5)	208 (3.6)	0.515	26 (0.4)	1 (0.2)	25 (0.4)	0.243

Data in table are presented as number (percentage).

Abbreviations: OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation; CPC, cerebral performance category.

Table 3 – Characteristics of resuscitation variables according to neurologic outcome in the group with medical cause and non-medical cause.

Variable	Medical cause (N = 83,437)			Non-medical cause (N = 31,191)		
	CPC 1-2 (1,217, 1.5%)	CPC 3-5 (82,220, 98.5%)	P-value	CPC 1-2 (181, 0.6%)	CPC 3-5 (31,010, 99.4%)	P-value
Age (y ± SD)	56.71 ± 14.04	70.23 ± 14.97	<0.001	54.36 ± 19.00	55.37 ± 18.15	0.459
Age group			<0.001			0.571
18–44 y	196 (16.1)	5044 (6.1)		8886 (28.7)	57 (31.5)	
45–64 y	673 (55.3)	20893 (25.4)		11681 (37.7)	61 (33.7)	
65–74 y	215 (17.7)	18184 (22.1)		5011 (16.2)	27 (14.9)	
≥75 y	133 (10.9)	38099 (46.3)		5432 (17.5)	36 (19.9)	
Sex, male	906(74.4)	50197(61.1)	<0.001	113 (62.4)	21168 (68.3)	0.092
Location(metropolitan)	622 (51.1)	32382 (39.4)	<0.001	71 (39.2)	10618 (34.2)	0.157
Witnessed arrest	983 (80.8)	33608 (40.9)	<0.001	94 (51.9)	8639 (27.9)	<0.001
Witnessed by EMS	293 (24.1)	5304(6.5)	<0.001	22(12.2)	1542(5.0)	<0.001
Arrest in public location	299(24.6)	8869(10.8)	<0.001	57 (31.5)	12817 (41.3)	0.008
Bystander CPR	340 (27.9)	10092 (12.3)	<0.001	43 (23.8)	2803 (9.0)	<0.001
Initial rhythm			<0.001			0.154
PEA	170 (14.0)	5274 (6.4)		14 (7.7)	1767 (5.7)	
Asystole	1047(86.0)	76946(93.6)		167(92.3)	29243(94.3)	
Arrest etiology						
Medical cause			0.104			
Presumed cardiac cause	1146(94.2)	76421(92.9)				
Non-cardiac medical cause	71(5.8)	5799(7.1)				
Non-medical cause	-	-				<0.001
Trauma				57 (31.5)	18028(58.1)	
Overdose				26 (14.4)	2019(6.5)	
Drowning				22 (12.2)	1775(5.7)	
Asphyxia				50 (27.6)	2714(8.8)	
Hanging	-	-		26 (14.4)	6474(20.9)	
Conversion to shockable rhythm	487 (40.0)	14748 (17.9)	<0.001	14 (7.7)	3238 (10.4)	0.274
Coronary reperfusion treatment	365 (30.0)	752 (0.9)	<0.001	2 (1.1)	19 (0.1)	0.007
TTM	219 (18.0)	1370 (1.7)	<0.001	23 (12.7)	695 (2.2)	<0.001
ECMO	20 (1.6)	390 (0.5)	<0.001	2 (1.1)	47 (0.2)	0.033
Pre-hospital ROSC	722 (59.3)	1206 (1.5)	<0.001	125 (69.1)	404 (1.3)	<0.001
ROSC	1217 (100)	18187 (22.1)	-	181 (100)	5457 (17.6)	-

Data in table are presented as mean ± SD or number (percentage).

Abbreviations: OHCA, out-of-hospital cardiac arrest; SD, standard deviation; EMS, emergency medical services; CPR, cardiopulmonary resuscitation; PEA, pulseless electrical rhythm; TTM, targeted temperature management; ECMO, extracorporeal membrane oxygenation; ROSC, return of spontaneous circulation; CPC, cerebral performance category.

A systematic review and meta-analysis revealed that conversion to shockable rhythm in patients with OHCA and initial non-shockable rhythm was associated with better outcomes of ROSC, 1-month survival, and 1-month good neurological function.[24] In previous studies, study populations comprised all patients with OHCA or those with presumed cardiac cause. Three previous studies including OHCA patients with presumed cardiac causes showed that rhythm conversion was associated with a good prognosis.[11,13,25] However, no studies to date have assessed the effect of shockable rhythm conversion on prognosis in patients who experienced cardiac arrest due to non-cardiac causes. Because cardiac arrest due to non-medical causes accounts for 21%-35%, it is also necessary to investigate the effect of conversion to shockable rhythm on outcomes in patients with this type of cardiac arrest.[6,16–18] In our study, the rate of ROSC was higher in patients with OHCA and shockable rhythm conversion regardless of the cause of cardiac arrest, except asphyxia. Conversion was not associated with good neurologic outcome in patients with non-cardiac causes. This could be attributed to the fact that cardiac arrests of non-cardiac origin may be caused by poor perfusion and hypoxia rather than electrical changes. According to the three-phase model, cardiac arrest can be divided into electrical, circulatory, and metabolic phases.[26,27] Cardiac arrest with a non-cardiac cause corresponds to the circulatory or metabolic phases rather than the initial electrical phase as compared with cardiac arrest due to a cardiac cause. Therefore in OHCA due to non-cardiac cause, rate of conversion to shockable rhythm and effect of conversion on outcome may be low. In this study, conversion in patients with cardiac arrest due to asphyxia, which is induced by hypoxia, had a negative impact on survival and did not affect neurologic outcome. In patients with cardiac arrest due to hypoxic injury, conversion was not related to good neurologic outcomes.

In our study, witnessed arrest and bystander CPR were associated with improved survival to discharge and good neurologic outcomes in patients with OHCA due to medical and non-medical causes. However age, sex and initial rhythm were not associated with good neurologic outcomes in OHCA of non-medical causes. Factors related to the prognosis of cardiovascular disease, such as sex and age, affect the prognosis of patients with cardiac arrest due to medical causes.

Table 4 – Multiple logistic regression analysis for good neurologic outcome according to cause of cardiac arrest

Variable	Total (N = 114,628) CPC 1 or 2 at discharge Adjusted OR (95% CI)	Medical cause (N = 83,437) CPC 1 or 2 at discharge Adjusted OR (95% CI)	Non-medical cause (N = 31,191) CPC 1 or 2 at discharge Adjusted OR (95% CI)
Age(y)	0.968(0.965-0.971)	0.954(0.951-0.958)	0.993(0.985-1.001)
Sex, male	1.208(1.070-1.364)	1.285(1.125-1.468)	0.770(0.568-1.045)
Witnessed arrest	5.263(4.631-5.980)	5.260(4.545-6.088)	2.772(2.061-3.728)
Bystander CPR	2.171(1.923-2.452)	1.862(1.634-2.123)	2.858(2.021-4.044)
Conversion to shockable rhythm	2.051(1.831-2.297)	1.789(1.586-2.019)	0.644(0.372-1.114)

Abbreviations: OHCA, out-of-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; CPC, cerebral performance category; OR, odds ratio; CI, confidence interval.

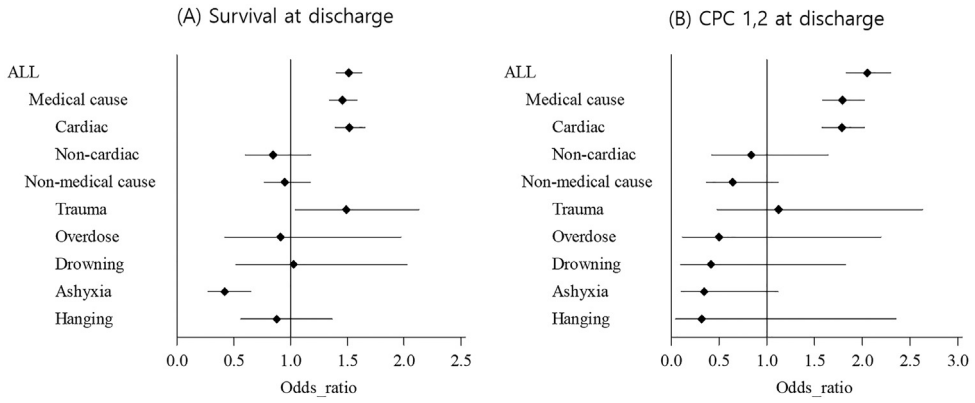

Fig. 2 – Forest plot of adjusted odds ratios of conversion to shockable rhythm for outcome at discharge according to each cause of arrest after adjusting for age, sex, presence of a witness and attempted bystander resuscitation. (A) Survival at discharg. (B) good neurologic outcome.

However, for non-medical causes, such as trauma, asphyxia, drug overdose, and drowning, prognosis is not related to age or sex. Cardiac arrest due to external factors, such as trauma, drowning, etc., occurs more frequently in young ages; therefore, patients with non-medical causes were usually younger than those with cardiac arrest due to medical causes. Claesson et al. reported that patients with non-medical causes were younger.[28] We performed a multiple logistic regression analysis for good neurologic outcome according to age group by quartile (Q) (Q1, 18–54 years; Q2, 55–70 years; Q3, 71–79 years; and Q4, over 80 years). In Q1-3 group, conversion to shockable rhythm was associated with good neurologic outcome. In over 80years old patients, conversion was not associated with good neurologic outcome. Multiple regression analysis was adjusted for age (Table 4) and conversion was not associated with prognosis in older age group. Therefore, the effect of conversion on prognosis was not influenced by age difference of arrest cause.

In previous studies, most studies report that conversion is associated with a good prognosis.[11,12,25,29] By contrast, some studies, that conversion to shockable rhythm has no or a negative effect on prognoses.[30,31] The different outcomes in some studies may be due to differences in the target patient group and in the EMS protocol in different regions and the differences in the percentage of patients who converted to a shockable rhythm and the composition ratio of patients with pulseless electrical rhythm (PEA) /asystole patients. Another difference in study populations may be that between cardiac and non-cardiac causes. Thomas et al. showed that the conversion to shockable rhythm was not related to survival, and the study included all adult patients with OHCA. If the proportion of patients with non-cardiac causes of is high, the conversion may not be associated with prognosis. Therefore, it is necessary to consider the distribution of the causes of cardiac arrest.[31] In addition, there are opinions that the cardiac causes, which account for the largest portion of the cardiac arrest, should be further subdivided.[32] It is necessary to analyze the prognosis and treatment according to the cause of the cardiac arrest.

This study has several limitations. First, as the conversion was presumed to be caused by the delivery of an electrical shock, some of the patients were possibly included in the conversion group even though the conversion to shockable rhythm was not due to the misinterpretation of the rhythm. Second, we classified patients based only according to their initial rhythm and did not analyze rhythm just before the conversion to a shockable rhythm. For accurate analysis, the rhythm before it converts into a shockable rhythm should be analyzed; however, we examined the effect of conversion to a shockable rhythm according to the initial rhythm. Third, conversion was more effective when it occurred early.[8,15] However, we did not consider the period from occurrence of cardiac arrest to conversion.

There may be differences according to the time to conversion depending on each cause, so the fact that this was not considered in this study is a disadvantage. Fourth, post-cardiac arrest care, such as TTM, was not controlled. The frequency of TTM was higher in patients with good neurologic prognosis than in patients with poor prognosis. However, in multiple regression analysis including TTM, the odds ratio of conversion were the same pattern as those of multiple regression without TTM according to cause of cardiac arrest.

Conclusion

In the present nationwide OHCA database cohort, shockable rhythm conversion had an association with good neurologic outcome in patients with OHCA with initial non-shockable rhythms, especially due to cardiac cause. However, rhythm conversion was not associated with better outcome in patients with non-medical causes.

Authors' contributions

All authors have made substantial contributions to the conception of the study and data collection and have approved the final version of the manuscript. KSH and EJL managed and analyzed the data, including quality control. SJK, KSH, and SWL conceived and designed the study, and wrote the manuscript. KSH, SJK, and SWL managed and analyzed the data. All authors contributed substantially to the revision of the manuscript.

Ethical consideration

The Institutional Review Board (IRB) of the Korea University Medical Center approved this retrospective analysis (IRB no. 2017ANO338)

Conflicts of interest

The authors have no relevant conflicts of interest regarding this research. Neither the entire paper nor any part of its content has been published or has been accepted by another journal. The paper is not being submitted in its entirety or in part to any other journal.

Data statement

The data used were obtained from Out-of-Hospital Cardiac Arrest Surveillance, 2012 of the Korea Centers for Disease Control and Prevention.

ACKNOWLEDGEMENTS

The study was funded by the National Research Foundation of Korea, grant no. 2017RIA2B1005037. This work was also supported by the grant funded by Korea University (#K1625501, #K1813011). Su Jin Kim received funding from the National Research Foundation of Korea and from Korea University. The funding sources had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

REFERENCES

1. Nadkarni VM, Larkin GL, Peberdy MA, et al. First documented rhythm and clinical outcome from in-hospital cardiac arrest among children and adults. Jama 2006;295:50–7.
2. Daya MR, Schmicker RH, Zive DM, et al. Out-of-hospital cardiac arrest survival improving over time: Results from the Resuscitation Outcomes Consortium (ROC). Resuscitation 2015;91:108–15.
3. Chan PS, McNally B, Tang F, Kellermann A. Recent trends in survival from out-of-hospital cardiac arrest in the United States. Circulation 2014;130:1876–82.
4. Cobb LA, Fahrenbruch CE, Olsufka M, Copass MK. Changing incidence of out-of-hospital ventricular fibrillation, 1980-2000. Jama 2002;288:3008–13.
5. 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.
6. Kuisma M, Repo J, Alaspaa A. The incidence of out-of-hospital ventricular fibrillation in Helsinki, Finland, from 1994 to 1999. Lancet 2001;358:473–4.
7. Reynolds JC, Grunau BE, Rittenberger JC, Sawyer KN, Kurz MC, Callaway CW. Association Between Duration of Resuscitation and Favorable Outcome After Out-of-Hospital Cardiac Arrest: Implications for Prolonging or Terminating Resuscitation. Circulation 2016;134:2084–94.
8. Goto Y, Maeda T, Nakatsu-Goto Y. Prognostic implications of conversion from nonshockable to shockable rhythms in out-of-hospital cardiac arrest. Crit Care 2014;18:528.
9. Olasveengen TM, Samdal M, Steen PA, Wik L, Sunde K. Progressing from initial non-shockable rhythms to a shockable rhythm is associated with improved outcome after out-of-hospital cardiac arrest. Resuscitation 2009;80:24–9.
10. Herlitz J, Svensson L, Engdahl J, Silfverstolpe J. Characteristics and outcome in out-of-hospital cardiac arrest when patients are found in a non-shockable rhythm. Resuscitation 2008;76:31–6.
11. Wah W, Wai KL, Pek PP, et al. Conversion to shockable rhythms during resuscitation and survival for out-of hospital cardiac arrest. Am J Emerg Med 2017;35:206–13.
12. Zheng R, Luo S, Liao J, et al. Conversion to shockable rhythms is associated with better outcomes in out-of-hospital cardiac arrest patients with initial asystole but not in those with pulseless electrical activity. Resuscitation 2016;107:88–93.
13. Kajino K, Iwami T, Daya M, et al. Subsequent ventricular fibrillation and survival in out-of-hospital cardiac arrests presenting with PEA or asystole. Resuscitation 2008;79:34–40.
14. Funada A, Goto Y, Tada H, et al. Age-specific differences in prognostic significance of rhythm conversion from initial non-shockable to shockable rhythm and subsequent shock delivery in out-of-hospital cardiac arrest. Resuscitation 2016;108:61–7.
15. Kitamura N, Nakada TA, Shinozaki K, et al. Subsequent shock deliveries are associated with increased favorable neurological outcomes in cardiac arrest patients who had initially non-shockable rhythms. Crit Care 2015;19:322.
16. Engdahl J, Bang A, Karlson BW, Lindqvist J, Herlitz J. Characteristics and outcome among patients suffering from out of hospital cardiac arrest of non-cardiac aetiology. Resuscitation 2003;57:33–41.
17. Hess EP, Campbell RL, White RD. Epidemiology, trends, and outcome of out-of-hospital cardiac arrest of non-cardiac origin. Resuscitation 2007;72:200–6.
18. Kitamura T, Kiyohara K, Sakai T, et al. Epidemiology and outcome of adult out-of-hospital cardiac arrest of non-cardiac origin in Osaka: a population-based study. BMJ Open 2014;4:e006462.
19. Orban JC, Truc M, Kerever S, et al. Comparison of presumed cardiac and respiratory causes of out-of-hospital cardiac arrest. Resuscitation 2018;129:24–8.
20. Ro YS, Song KJ, Shin SD, et al. Association between county-level cardiopulmonary resuscitation training and changes in Survival

Outcomes after out-of-hospital cardiac arrest over 5 years: A multilevel analysis. Resuscitation 2019;139:291–8.
21. Ko SY, Shin SD, Ro YS, et al. Effect of detection time interval for out-of-hospital cardiac arrest on outcomes in dispatcher-assisted cardiopulmonary resuscitation: A nationwide observational study. Resuscitation 2018;129:61–9.
22. Cho EJ, Shin SD, Jeong S, Kwak YH, Suh GJ. The effect of atmosphere temperature on out-of-hospital cardiac arrest outcomes. Resuscitation 2016;109:64–70.
23. Perkins GD, Jacobs IG, Nadkarni VM, et al. Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: A Statement for Healthcare Professionals From a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Resuscitation 2015;96:328–40.
24. Luo S, Zhang Y, Zhang W, Zheng R, Tao J, Xiong Y. Prognostic significance of spontaneous shockable rhythm conversion in adult out-of-hospital cardiac arrest patients with initial non-shockable heart rhythms: A systematic review and meta-analysis. Resuscitation 2017;121:1–8.
25. Rajan S, Folke F, Hansen SM, et al. Incidence and survival outcome according to heart rhythm during resuscitation attempt in out-of-hospital cardiac arrest patients with presumed cardiac etiology. Resuscitation 2017;114:157–63.
26. Gilmore CM, Rea TD, Becker LJ, Eisenberg MS. Three-phase model of cardiac arrest: time-dependent benefit of bystander cardiopulmonary resuscitation. Am J Cardiol 2006;98:497–9.
27. Campbell RL, Hess EP, Atkinson EJ, White RD. Assessment of a three-phase model of out-of-hospital cardiac arrest in patients with ventricular fibrillation. Resuscitation 2007;73:229–35.
28. Claesson A, Djarv T, Nordberg P, et al. Medical versus non medical etiology in out-of-hospital cardiac arrest-Changes in outcome in relation to the revised Utstein template. Resuscitation 2017;110:48–55.
29. Fukuda T, Matsubara T, Doi K, Fukuda-Ohashi N, Yahagi N. Predictors of favorable and poor prognosis in unwitnessed out-of-hospital cardiac arrest with a non-shockable initial rhythm. Int J Cardiol 2014;176:910–5.
30. Hallstrom A, Rea TD, Mosesso Jr. VN, et al. The relationship between shocks and survival in out-of-hospital cardiac arrest patients initially found in PEA or asystole. Resuscitation 2007;74:418–26.
31. Thomas AJ, Newgard CD, Fu R, Zive DM, Daya MR. Survival in out-of-hospital cardiac arrests with initial asystole or pulseless electrical activity and subsequent shockable rhythms. Resuscitation 2013;84:1261–6.
32. Chen N, Callaway CW, Guyette FX, et al. Arrest etiology among patients resuscitated from cardiac arrest. Resuscitation 2018;130:33–40.