Bystander cardiopulmonary resuscitation and cardiac rhythm change over time in patients with out-of-hospital cardiac arrest

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ABSTRACT

Background Whether and how bystander cardiopulmonary resuscitation (CPR) modifies the cardiac rhythm after out-of-hospital cardiac arrest (OHCA) over time remains unclear. We investigated the association between bystander CPR and the likelihood of ventricular fibrillation (VF) or ventricular tachycardia (VT) as the first documented cardiac rhythm.

Methods We identified individuals with witnessed OHCA of cardiac origin from a nationwide population-based OHCA registry in Japan between 1 January 2005 and 31 December 2019. The first documented cardiac rhythm was compared between patients who received bystander CPR and those who did not, using a 1:2 propensity score-matched analysis.

Results Of 309 900 patients with witnessed OHCA of cardiac origin, 71 887 (23.2%) received bystander CPR. Propensity score matching paired 71 882 patients who received bystander CPR with 143 764 who did not. The likelihood of detecting a VF/VT rhythm was significantly higher among patients who received bystander CPR than among those who did not (OR 1.66; 95% CI 1.63 to 1.69; p<0.001). Comparing the two groups at each time point, the difference in the proportions of patients with VF/VT rhythms peaked at 15–20 min but was insignificant at 30 min postcollapse (15 min after collapse; 20.9% vs 13.9%; p<0.001). The likelihood of a pulseless electrical activity rhythm was significantly lower in patients who received bystander CPR during the first 25 min postcollapse (15 min after collapse; 26.2% vs 31.5%; p<0.001). The two groups had no significant difference in the likelihood of asystole (15 min after collapse; 51.0% vs 53.3%; p=0.078).

Conclusion Bystander CPR was associated with a higher VF/VT likelihood and a lower likelihood of pulseless electrical activity at first documented rhythm analysis. Our results support early CPR for OHCA and highlight the need for further research to understand whether and how CPR modifies the cardiac rhythm after arrest.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The first documented cardiac rhythm of ventricular fibrillation (VF) or ventricular tachycardia (VT) is associated with better patient outcomes after out-of-hospital cardiac arrest (OHCA).
⇒ The presence of bystander cardiopulmonary resuscitation (CPR) is associated with better outcomes after arrest, although how it affects cardiac rhythm over time remains unclear.

WHAT THIS STUDY ADDS

⇒ In this study of victims of OHCA arrest in Japan, from 2005 to 2019, bystander CPR was found to be associated with a higher chance of VF/VT and a lower chance of pulseless electrical activity rhythm as the first documented cardiac rhythm.
⇒ These differences remained significant up to approximately 30 min after the collapse.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Early bystander CPR increases the likelihood of a patient with OHCA having a first documented rhythm that can be defibrillated (VF/VT), thereby increasing the probability of survival.
⇒ This study adds to the already robust evidence base supporting early CPR in OHCA.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is a global public health concern with an incidence of 30–110 per 100 000 person-years and a survival rate ranging from 3.1% to 20.4%.[1–3] ECG waveforms documented in patients with OHCA are classified into four categories: ventricular fibrillation (VF), ventricular tachycardia (VT), pulseless electrical activity (PEA) and asystole. VF/VT can be defibrillated (shockable), whereas PEA and asystole are non-shockable. The first documented cardiac rhythm is associated with outcomes, with survival reportedly being 3–10 times more likely in patients with initial VF/VT than in those with PEA or asystole.[4–7]

Previous studies have reported that the amplitude of VF declines with time,[5 8] and a longer duration between collapse and first rhythm detection is associated with a reduced likelihood of VF/VT rhythm.[5 7] However, early cardiopulmonary resuscitation (CPR) is associated with an increased likelihood of a first documented rhythm of VF/VT,[5 9] especially when the interval between collapse and CPR is short.[10] One potential mechanism explaining these results is that bystander CPR modifies the electrophysiological properties of the myocardium in a manner that delays the waveform conversion from VF/VT to non-shockable cardiac rhythms.

Previous studies that evaluated the association of VF with time or bystander CPR did not use time-to-rhythm analysis nor sufficiently adjust for potential confounders of age and sex;[7 11] therefore, the potential effect of bystander CPR on cardiac rhythm over time remains unclear. In this study, we aimed to investigate the association between bystander CPR and the first documented cardiac rhythm.

METHODS

This retrospective cohort study analysed data from the All-Japan Utstein Registry of the Fire and Disaster Management Agency and adhered to the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.[12] Analysis of the anonymised data was approved by the Fire and Disaster Management Agency. The requirement for informed consent was waived since the data set was anonymised before analysis.

Data source

The All-Japan Utstein Registry is a population-based database that includes all individuals who experienced OHCA and were transported by emergency medical service (EMS) in Japan. As reported previously, data were recorded using a common form based on the Utstein style.[13] The collected data included the patient's age and sex, presumed aetiology of the cardiac arrest, bystander witness status, whether and when bystander CPR commenced, whether defibrillation by a bystander was achieved, first documented cardiac rhythm, date and time of the collapse, time of emergency call, and time of EMS contact with the patient. Witnessed status, presence and duration of bystander CPR, and whether defibrillation occurred were determined by EMS personnel through observation and interviews with bystanders at the scene. In the registry, the aetiology of the arrest was determined clinically by the physician in charge in collaboration with the EMS personnel.[13] The arrest was presumed to be of cardiac origin unless presented with contrary evidence. The first documented cardiac rhythm was classified as VF/VT, PEA, asystole or other. Specific details for the 'other' category were not reported in the data set.

All patients were followed for up to 1 month after OHCA by the EMS providers in charge. At 1 month after the cardiac arrest, the neurological status was determined by means of the interview with the physician (in person or on the phone) responsible for the care of the patient using the Cerebral Performance Category Scale, which categorises outcomes as follows: Category 1 (good cerebral performance), Category 2 (moderate cerebral disability), Category 3 (severe cerebral disability), Category 4 (coma or vegetative state) and Category 5 (death).[13 14] EMS personnel collected the data using a consistent format and uploaded the information to the Fire and Disaster Management Agency database server for verification.

Study population

We included individuals who experienced witnessed OHCA of cardiac aetiology between 1 January 2005 and 31 December 2019, and were listed in the All-Japan Utstein Registry. The exclusion criteria were as follows: (1) Resuscitation was not attempted by EMS, (2) Whether bystander CPR occurred was uncertain, (3) The time from collapse to CPR was >60 min or else the record was considered invalid (ie, negative value of the time from collapse to CPR, and time records indicating bystander CPR initiation after the EMS personnel started the CPR), (4) Defibrillation was successfully performed by a bystander, and (5) The time from collapse to cardiac rhythm assessment was >60 min or missing. Patients for whom a bystander performed defibrillation were excluded because the time from collapse to cardiac rhythm assessment was undetermined. Because of the retrospective nature of this study, we did not perform formal sample size calculation and included as large a sample as possible. Therefore, the study period was determined by the registry period available at the time of study design.

Outcomes and variable definitions

The primary outcome was the first documented cardiac rhythm analysed by the EMS personnel. The secondary outcomes were survival and favourable neurological outcomes at 1 month after OHCA that was defined as a Cerebral Performance Category Score of 1 or 2 points. The time of the emergency call was categorised as 03:00–06:59, 07:00–10:59, 11:00–14:59, 15:00–18:59, 19:00–22:59 and 23:00–02:59.[15] Age was categorised as 0–17 years, 18–34 years, 35–49 years, 50–64 years, 65–79 years and ≥80 years.[16]

Statistical analysis

We compared the first documented cardiac rhythm between patients who received bystander CPR and those who did not using propensity score matching analysis. The propensity score matching framework was selected because it balances confounding factors between the groups and has advantages over ordinal regression analysis.[17] We estimated propensity scores using a multivariate logistic regression model that included age, sex and the time of the cardiac arrest. Patients who received bystander CPR were matched to those who did not, using 1:2 nearest-neighbour matching without replacement. A calliper width of <20% of the pooled SD of the logit of the propensity score was allowed for matching. Match balance was evaluated using the standardised mean difference, and a meaningful imbalance was defined as an absolute standardised mean difference ≥0.1.

After matching, we first tested the association between the collapse-to-rhythm detection interval and the study's end point in the two groups using logistic regression analysis; ORs and their 95% CIs were calculated. Then, we compared the likelihood of observing a VF/VT rhythm between the two groups using multivariate logistic regression analysis that included bystander CPR, time from collapse to rhythm analysis (difference from mean time, 9.6 min) and the interaction term of these two variables as explanatory variables. We also estimated the risk differences and 95% CIs for study end points between the two groups at each minute using linear regression analysis. The estimated risk differences and 95% CIs were plotted using a locally estimated scatterplot smoothing curve. We compared the proportions of patients who survived and achieved favourable neurological outcomes at 1 month after arrest in the matched cohort using the χ^2 test.

All statistical analyses were performed using R V.4.1.1 (R Foundation for Statistical Computing, Vienna, Austria). Given the low proportion of such incidences, we handled missing values using the complete case method.[18] All statistical tests were two-tailed, and results were considered statistically significant based on a value of $p<0.05$ or 95% CI.

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting, or dissemination plans of our research.

RESULTS

A total of 1804345 individuals experienced OHCA and were transported to hospitals by the EMS in Japan during the dates of interest. Of these, 1051416 had OHCA of cardiac aetiology

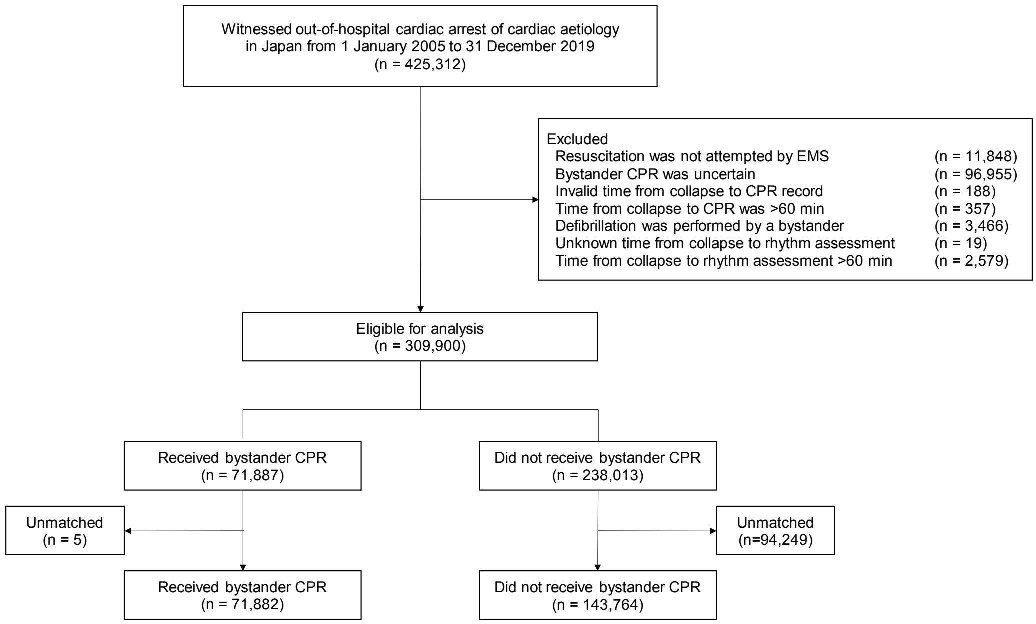


Figure 1 Study flow chart. CPR, cardiopulmonary resuscitation; EMS, emergency medicine service.

and 425 312 experienced witnessed OHCA of cardiac aetiology. Of these, 11 848 individuals for whom resuscitation was not attempted, 96 955 for whom bystander CPR was uncertain, 545 for whom >60 min elapsed between collapse and bystander CPR (or had an invalid record), and 6064 for whom the interval between collapse to rhythm analysis was >60 min or unknown, were excluded. A total of 309 900 patients (119 717 women (38.6%); median age, 78 years (IQR, 67–86 years)) were eligible for analysis (figure 1). The ages of 12 patients (<0.01%) were unknown; none of the other variables of interest were missing.

Of the 309 900 patients who were eligible for analysis, 71 887 (23.2%) received bystander CPR. Table 1 shows the baseline characteristics of the patients who received bystander CPR and those who did not before and after propensity score matching. Before matching, there were significant imbalances in terms of the time of arrest, age and sex. One-to-two propensity score matching identified 71 882 patients who received bystander CPR and 143 764 balanced counterparts who did not. Figure 2 shows the distributions of the intervals between collapse and bystander CPR in the matched cohort. The median time from collapse to CPR was 1 min (IQR, 0–4 min).

The proportions of the first documented VF/VT and PEA rhythms as a function of the time from collapse to rhythm analysis are depicted in figure 3. Patients who received bystander CPR consistently displayed a higher proportion of VF/VT within the first 30 min after collapse; in contrast, they had a lower

Table 1 Baseline patient characteristics before and after propensity score matching

	Before matching			After matching		
	With bystander CPR (n=71 887)	Without bystander CPR (n=238 013)	ASD	With bystander CPR (n=71 882)	Without bystander CPR (n=143 764)	ASD
Time of arrest, hours, n (%)			0.106			0.001
3–6	7815 (10.9)	30 133 (12.7)		7814 (10.9)	15 628 (10.9)	
7–10	17 266 (24.0)	54 777 (23.0)		17 265 (24.0)	34 530 (24.0)	
11–14	14 200 (19.8)	41 824 (17.6)		14 199 (19.8)	28 454 (19.8)	
15–18	14 468 (20.1)	44 248 (18.6)		14 466 (20.1)	28 940 (20.1)	
19–22	11 386 (15.8)	40 004 (16.8)		11 386 (15.8)	22 756 (15.8)	
23–02	6752 (9.4)	27 027 (11.4)		6752 (9.4)	13 456 (9.4)	
Age in years, n (%)			0.160			0.003
0–17	516 (0.7)	1160 (0.5)		516 (0.7)	941 (0.7)	
18–34	1056 (1.5)	2545 (1.1)		1056 (1.5)	2090 (1.5)	
35–49	3469 (4.8)	11 241 (4.7)		3469 (4.8)	6982 (4.9)	
50–64	9625 (13.4)	35 386 (14.9)		9625 (13.4)	19 074 (13.3)	
65–79	21 192 (29.5)	84 823 (35.6)		21 192 (29.5)	42 672 (29.7)	
80–114	36 024 (50.1)	102 851 (43.2)		36 024 (50.1)	72 005 (50.1)	
Men, n (%)	41 422 (57.6)	148 761 (62.5)	0.100	41 419 (57.6)	82 782 (57.6)	0.001

ASD, absolute standardised mean difference; CPR, cardiopulmonary resuscitation.

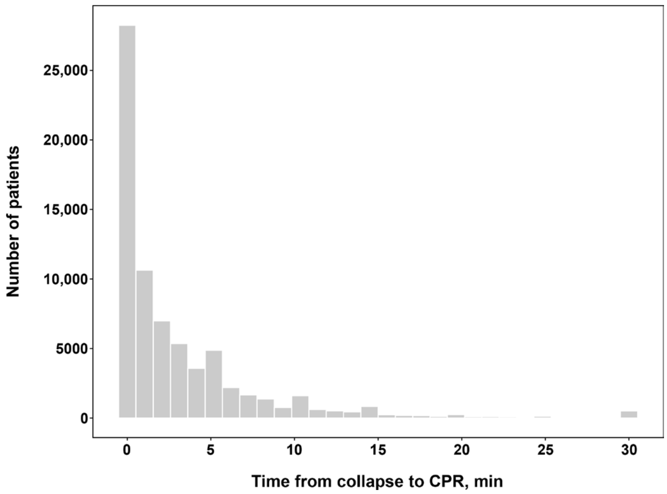


Figure 2 Distribution of time from collapse to CPR among patients who received bystander CPR. The maximum time (30 min) indicates ≥30 min. CPR, cardiopulmonary resuscitation.

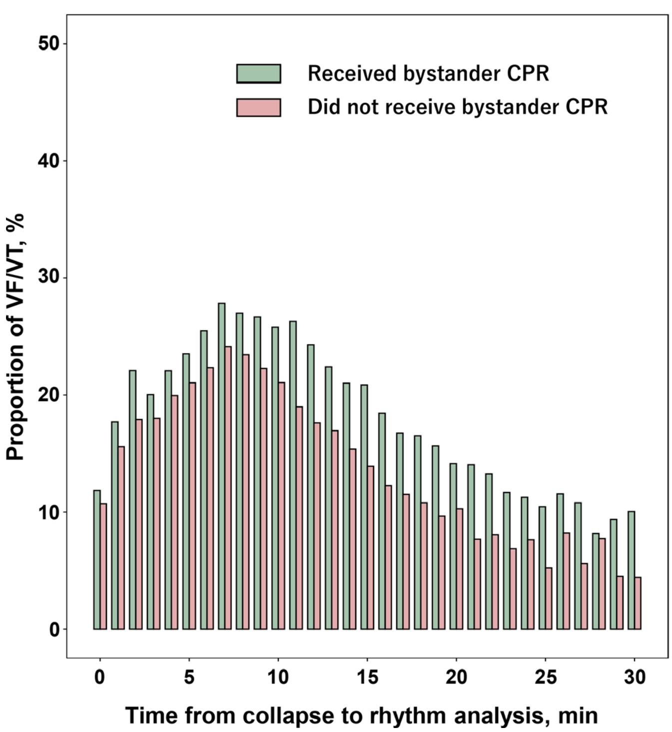
proportion of PEA as the first documented cardiac rhythm (details are shown in online supplemental table 1). Table 2 shows the results of multivariate logistic regression analysis. The likelihoods of VF/VT (OR 0.99 per 1-incremental minute; 95% CI 0.99 to 0.99; p<0.001) and PEA (OR 0.97 per 1-incremental minute; 95% CI 0.97 to 0.97; p<0.001) rhythms decreased significantly as the time from collapse to rhythm analysis increased, whereas the risk of asystole increased significantly (OR 1.09 per 1-incremental minute; 95% CI 1.09 to 1.09; p<0.001). The likelihood of a first documented rhythm of VF/VT was significantly higher in patients who received bystander CPR than in those who did not (OR 1.66; 95% CI 1.63 to 1.69; p<0.001).

Table 2 Likelihood of first documented rhythm according to whether bystander CPR was given, and the time from collapse to rhythm analysis

	Adjusted OR (95% CI)	*P* value
VF/VT as the first documented rhythm		
Bystander CPR	1.66 (1.63 to 1.69)	<0.001
Collapse to rhythm analysis, per 1-incremental min	0.99 (0.99 to 0.99)	<0.001
Interaction term	0.97 (0.97 to 0.97)	<0.001
PEA as the first documented rhythm		
Bystander CPR	0.82 (0.81 to 0.84)	<0.001
Collapse to rhythm analysis, per 1-incremental min	0.97 (0.97 to 0.97)	<0.001
Interaction term	0.99 (0.99 to 0.99)	<0.001
Asystole as the first documented rhythm		
Bystander CPR	1.13 (1.12 to 1.15)	<0.001
Collapse to rhythm analysis, per 1-incremental min	1.09 (1.09 to 1.09)	<0.001
Interaction term	0.97 (0.97 to 0.97)	<0.001

CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

Figure 4 shows the differences in the risk of VF/VT between the two groups as a function of the time from collapse to rhythm analysis (details are shown in online supplemental table 2). The likelihood of VF/VT was significantly higher in patients who received bystander CPR; the difference peaked at 15–20 min and became insignificant at 30 min after the collapse (15 min



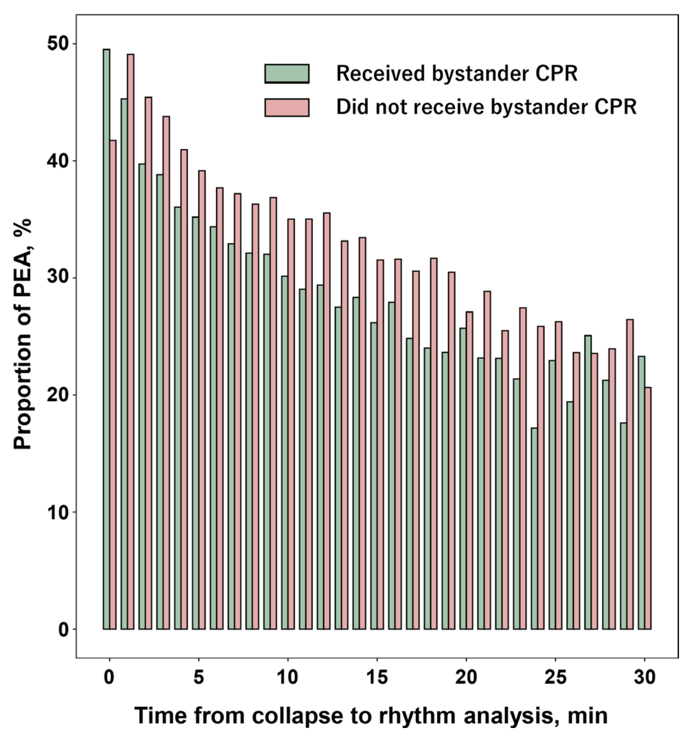


Figure 3 Proportions of VF/VT and PEA in the first documented cardiac rhythms in each minute after the collapse. Grouped bar graphs show the data of patients who received bystander CPR and those who did not. The left panel shows the proportion of VF/VT, and the right panel shows the proportion of the PEA rhythm. CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

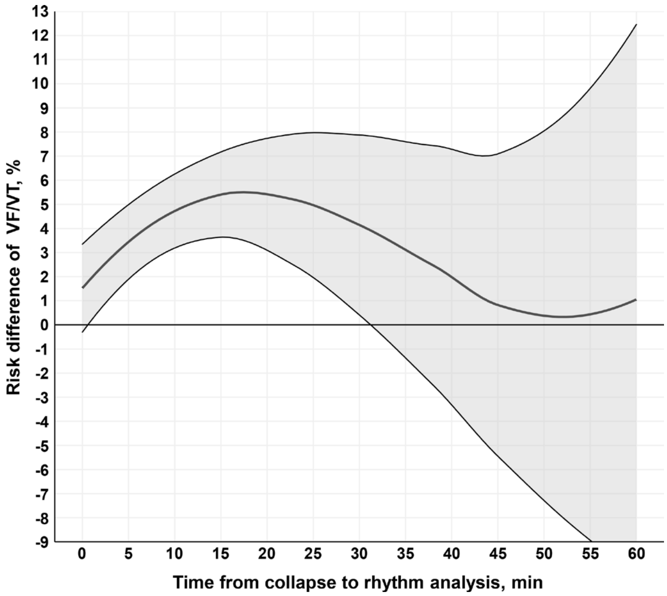


Figure 4 Difference in the risk of VF/VT between patients who received bystander cardiopulmonary resuscitation and those who did not. The solid line represents the estimated risk differences in observing VF/VT, whereas the shaded bands represent the 95% CIs for the estimated points. Positive risk difference values indicate that the likelihood of VF/VT is higher in patients who received bystander cardiopulmonary resuscitation. VF, ventricular fibrillation; VT, ventricular tachycardia.

after the collapse, 20.9% vs 13.9%, p<0.001). In contrast, the likelihood of a PEA rhythm was significantly lower in patients who received bystander CPR for up to 25 min (15 min after the collapse, 26.2% vs 31.5%, p<0.001, figure 5). There was no significant difference in the likelihood of asystole between the two groups (15 min after the collapse, 51.0% vs 53.3%, p=0.078, online supplemental figure 1). Patients who received bystander CPR had significantly higher rates of survival (11.0% (95% CI 10.8% to 11.2%) vs 10.8% (95% CI 10.6% to 10.9%), p=0.03) and favourable neurological outcomes (7.0% (95% CI 6.8% to 7.2%) vs 6.6% (95% CI 6.5% to 6.7%), p<0.001) at 1 month after the event than those who did not receive CPR.

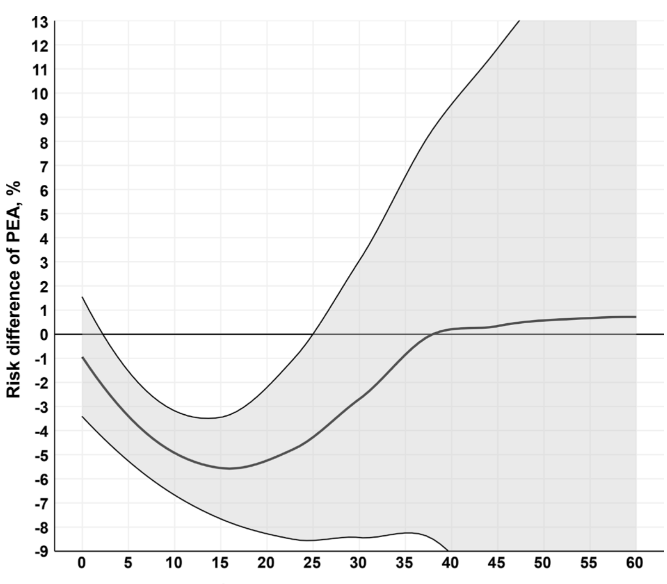


Figure 5 Difference in the risk of PEA between patients who received bystander cardiopulmonary resuscitation and those who did not. PEA, pulseless electrical activity.

DISCUSSION

Our analysis revealed that bystander CPR was associated with a higher likelihood of observing VF/VT rhythm; this association was statistically significant up to 30 min postcollapse. Our use of a large data set and propensity score matching framework enabled accurate estimation of the differences in the proportions of patients with VF/VT rhythms every minute, as well as the comparison of these proportions between patients who received bystander CPR and those who did not.

The difference in the proportions of VF/VT rhythms between the two groups was greatest at 15–20 min, which was also the case in a previous study.[5] This difference subsequently declined over time and became insignificant at 30 min postcollapse. These results indicate that the difference between those who receive bystander CPR and those who do not widens over time in the early phase but that waveform degeneration apparently begins to outweigh the modifying effect of resuscitation at 15–20 min, with the proportion of VF/VT rhythms between the two groups being no longer different after 30 min.

It should be noted that we observed an increase in VF/VT proportion that peaked at approximately 5–10 min after the collapse, even in patients who did not receive bystander CPR. These results imply that cardiac rhythms other than VF/VT convert to VF/VT at the early phase after the collapse in their natural history; however, we could not comment on the mechanism of these findings because of our study design and lack of related evidence.

We found that bystander CPR was associated with higher rates of survival and favourable neurological outcomes after OHCA. These results are congruent with those of previous studies, although the differences between the two groups in the current study were notably smaller than those in previous studies.[19–21] Owing to the unknown time from collapse to rhythm analysis, we excluded patients who received successful defibrillation by a bystander and were likely to experience favourable outcomes.[9 13] This may have resulted in diminished survival and favourable neurological outcomes, thereby contributing to the small differences in patient outcomes between the two groups.

Our results have several implications for both clinical practice and future research. First, CPR increases the likelihood that the first documented rhythm is shockable (VF/VT), thereby increasing the probability of survival.[19–21] Second, a lower proportion of PEA during the period was observed, corresponding to a higher likelihood of VF/VT rhythms. Although some previous studies assumed that bystander CPR prevents waveform conversion from VF/VT to asystole,[5 22] waveform conversion from VF/VT to PEA was more likely to be delayed. Third, despite our finding of an increased probability of VF/VT associated with CPR, most patients (77.9%) still presented with a non-shockable rhythm. Future studies need to focus on improving the outcomes of patients with non-shockable cardiac rhythms following OHCA.[23 24] Fourth, the proportion of patients receiving defibrillation by a bystander was quite low (1.1% of witnessed OHCA of cardiogenic aetiology). As public-access defibrillation programmes have been shown to improve outcomes after OHCA through the facilitation of prompt defibrillation,[13] it is advisable to undertake further initiatives to raise awareness of bystander CPR using public-access defibrillators.

Finally, the benefit of CPR was lost relatively quickly (30 min) after the collapse. Although bystander CPR plays an important role in the 'chain of survival' for patients with cardiac arrest, an early EMS response that enables advanced life support and deterministic therapies is critical for improving the outcomes in patients with OHCA.

Limitations

This study had several limitations. First, this retrospective investigation attempted to adjust for baseline characteristics using propensity score matching; however, other confounding factors may still have biased the results. For example, the data set lacked information regarding the cardiac arrest victim's socioeconomic status, comorbidities and location, which might be associated with bystander CPR occurrence and outcome.[25–27] Second, patients who had achieved return of spontaneous circulation owing to a bystander's defibrillation were excluded because the rhythm analysis time was unavailable. Considering that these patients are presumed to have had a VF/VT rhythm, this may have resulted in an underestimation of the difference between the two groups. Third, the data set did not include information on the quality of bystander CPR. Although patients whose receipt of bystander CPR was uncertain were excluded, the quality of the CPR performed may have differed between individuals. Fourth, the time of rhythm analysis was determined to be that of EMS contact with the patient. While EMS personnel typically evaluated cardiac rhythms as soon as a cardiac arrest was recognised, any potential delays in the time from EMS contact to rhythm analysis were not reflected in the data set.

Conclusions

Bystander CPR was associated with a higher likelihood of VF/VT and a lower likelihood of PEA at first documented rhythm analysis. These differences remained significant up to approximately 30 min after the collapse. Our results support early CPR for OHCA and highlight the need to conduct further studies to understand whether and how CPR modifies the cardiac rhythm after the arrest.

Contributors KSh: conceptualisation, methodology, formal analysis, writing—original draft preparation, guarantor. TK, MH and KSu: methodology, writing—reviewing and editing.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the ethics committee of Metropolitan Bokutoh Hospital (approval number: 03-145). The requirement for informed consent was waived given that our study design was retrospective and the data set was anonymised prior to analysis.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available. Not applicable.

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Supplemental Table 1. First documented cardiac rhythm according to bystander CPR status and the time from collapse to rhythm analysis

	Patients who received bystander CPR					Patients who did not receive bystander CPR				
Time interval, min	No. of analyses	First documented cardiac rhythm				No. of analyses	First documented cardiac rhythm			
		VF/VT	PEA	Asystole	Other		VF/VT	PEA	Asystole	Other
0	1672	198 (11.8)	828 (49.5)	332 (19.9)	314 (18.8)	47,429	5083 (10.7)	19,798 (41.7)	7464 (15.7)	15,084 (31.8)
1	565	100 (17.7)	256 (45.3)	180 (31.9)	29 (5.1)	2311	360 (15.6)	1135 (49.1)	756 (32.7)	60 (2.6)
2	1168	258 (22.1)	464 (39.7)	412 (35.3)	34 (2.9)	3720	666 (17.9)	1690 (45.4)	1299 (34.9)	65 (1.7)
3	1777	356 (20.0)	690 (38.8)	676 (38.0)	55 (3.1)	4143	746 (18.0)	1814 (43.8)	1522 (36.7)	61 (1.5)
4	2161	477 (22.1)	779 (36.0)	835 (38.6)	70 (3.2)	4035	805 (20.0)	1653 (41.0)	1513 (37.5)	64 (1.6)
5	2790	656 (23.5)	982 (35.2)	1074 (38.5)	78 (2.8)	4843	1019 (21.0)	1897 (39.2)	1840 (38.0)	87 (1.8)
6	3866	985 (25.5)	1329 (34.4)	1446 (37.4)	106 (2.7)	5901	1318 (22.3)	2224 (37.7)	2273 (38.5)	86 (1.5)
7	4898	1363 (27.8)	1613 (32.9)	1816 (37.1)	106 (2.2)	6597	1592 (24.1)	2454 (37.2)	2450 (37.1)	101 (1.5)
8	5781	1561 (27.0)	1857 (32.1)	2225 (38.5)	138 (2.4)	7382	1730 (23.4)	2680 (36.3)	2870 (38.9)	102 (1.4)
9	6058	1616 (26.7)	1940 (32.0)	2345 (38.7)	157 (2.6)	7485	1667 (22.3)	2760 (36.9)	2960 (39.5)	98 (1.3)
10	5987	1544 (25.8)	1805 (30.1)	2514 (42.0)	124 (2.1)	7275	1532 (21.1)	2549 (35.0)	3098 (42.6)	96 (1.3)
11	5488	1443 (26.3)	1594 (29.0)	2350 (42.8)	101 (1.8)	6589	1251 (19.0)	2309 (35.0)	2944 (44.7)	85 (1.3)
12	4751	1154 (24.3)	1396 (29.4)	2107 (44.3)	94 (2.0)	5751	1013 (17.6)	2044 (35.5)	2630 (45.7)	64 (1.1)
13	3950	885 (22.4)	1086 (27.5)	1912 (48.4)	67 (1.7)	4826	818 (16.9)	1600 (33.2)	2352 (48.7)	56 (1.2)
14	3232	679 (21.0)	916 (28.3)	1584 (49.0)	53 (1.6)	3825	588 (15.4)	1279 (33.4)	1921 (50.2)	37 (1.0)
15	2766	577 (20.9)	724 (26.2)	1411 (51.0)	54 (2.0)	3299	459 (13.9)	1040 (31.5)	1759 (53.3)	41 (1.2)
16	2271	419 (18.5)	634 (27.9)	1177 (51.8)	41 (1.8)	2602	319 (12.3)	822 (31.6)	1430 (55.0)	31 (1.2)
17	1940	325 (16.8)	482 (24.8)	1099 (56.6)	34 (1.8)	2138	246 (11.5)	654 (30.6)	1210 (56.6)	28 (1.3)

18	1562	258 (16.5)	375 (24.0)	908 (58.1)	21 (1.3)	1863	201 (10.8)	590 (31.7)	1054 (56.6)	18 (1.0)
19	1227	192 (15.6)	290 (23.6)	725 (59.1)	20 (1.6)	1502	145 (9.7)	458 (30.5)	887 (59.1)	12 (0.8)
20	1082	153 (14.1)	278 (25.7)	635 (58.7)	16 (1.5)	1255	129 (10.3)	340 (27.1)	778 (62.0)	8 (0.6)
21	890	125 (14.0)	206 (23.1)	548 (61.6)	11 (1.2)	1081	83 (7.7)	312 (28.9)	678 (62.7)	8 (0.7)
22	770	102 (13.2)	178 (23.1)	479 (62.2)	11 (1.4)	930	75 (8.1)	237 (25.5)	604 (64.9)	14 (1.5)
23	660	77 (11.7)	141 (21.4)	428 (64.8)	14 (2.1)	729	50 (6.9)	200 (27.4)	467 (64.1)	12 (1.6)
24	542	61 (11.3)	93 (17.2)	380 (70.1)	8 (1.5)	642	49 (7.6)	166 (25.9)	416 (64.8)	11 (1.7)
25	440	46 (10.5)	101 (23.0)	287 (65.2)	6 (1.4)	594	31 (5.2)	156 (26.3)	400 (67.3)	7 (1.2)
26	407	47 (11.5)	79 (19.4)	280 (68.8)	1 (0.2)	487	40 (8.2)	115 (23.6)	329 (67.6)	3 (0.6)
27	343	37 (10.8)	86 (25.1)	214 (62.4)	6 (1.7)	429	24 (5.6)	101 (23.5)	298 (69.5)	6 (1.4)
28	306	25 (8.2)	65 (21.2)	209 (68.3)	7 (2.3)	401	31 (7.7)	96 (23.9)	271 (67.6)	3 (0.7)
29	267	25 (9.4)	47 (17.6)	190 (71.2)	5 (1.9)	310	14 (4.5)	82 (26.5)	207 (66.8)	7 (2.3)
30	219	22 (10.0)	51 (23.3)	142 (64.8)	4 (1.8)	339	15 (4.4)	70 (20.6)	250 (73.7)	4 (1.2)
31	199	22 (11.1)	25 (12.6)	147 (73.9)	5 (2.5)	284	12 (4.2)	70 (24.6)	199 (70.1)	3 (1.1)
32	222	23 (10.4)	39 (17.6)	157 (70.7)	3 (1.4)	249	13 (5.2)	46 (18.5)	186 (74.7)	4 (1.6)
33	178	18 (10.1)	35 (19.7)	120 (67.4)	5 (2.8)	216	13 (6.0)	46 (21.3)	153 (70.8)	4 (1.9)
34	137	11 (8.0)	31 (22.6)	94 (68.6)	1 (0.7)	187	6 (3.2)	42 (22.5)	138 (73.8)	1 (0.5)
35	147	9 (6.1)	28 (19.0)	106 (72.1)	4 (2.7)	182	7 (3.8)	35 (19.2)	140 (76.9)	0 (0.0)
36	114	5 (4.4)	25 (21.9)	81 (71.1)	3 (2.6)	155	5 (3.2)	26 (16.8)	121 (78.1)	3 (1.9)
37	106	7 (6.6)	17 (16.0)	81 (76.4)	1 (0.9)	142	4 (2.8)	27 (19.0)	111 (78.2)	0 (0.0)
38	100	6 (6.0)	24 (24.0)	69 (69.0)	1 (1.0)	158	10 (6.3)	31 (19.6)	114 (72.2)	3 (1.9)
39	87	9 (10.3)	10 (11.5)	67 (77.0)	1 (1.1)	122	2 (1.6)	14 (11.5)	106 (86.9)	0 (0.0)
40	74	2 (2.7)	10 (13.5)	59 (79.7)	3 (4.1)	129	8 (6.2)	26 (20.2)	92 (71.3)	3 (2.3)

41	73	4 (5.5)	12 (16.4)	56 (76.7)	1 (1.4)	126	3 (2.4)	22 (17.5)	100 (79.4)	1 (0.8)
42	59	3 (5.1)	16 (27.1)	39 (66.1)	1 (1.7)	114	5 (4.4)	24 (21.1)	85 (74.6)	0 (0.0)
43	57	2 (3.5)	12 (21.1)	43 (75.4)	0 (0.0)	96	4 (4.2)	18 (18.8)	72 (75.0)	2 (2.1)
44	57	3 (5.3)	9 (15.8)	44 (77.2)	1 (1.8)	84	6 (7.1)	15 (17.9)	60 (71.4)	3 (3.6)
45	48	3 (6.2)	11 (22.9)	34 (70.8)	0 (0.0)	76	7 (9.2)	17 (22.4)	52 (68.4)	0 (0.0)
46	53	4 (7.5)	11 (20.8)	35 (66.0)	3 (5.7)	75	3 (4.0)	8 (10.7)	63 (84.0)	1 (1.3)
47	42	4 (9.5)	9 (21.4)	29 (69.0)	0 (0.0)	59	1 (1.7)	9 (15.3)	44 (74.6)	5 (8.5)
48	32	1 (3.1)	6 (18.8)	24 (75.0)	1 (3.1)	56	3 (5.4)	11 (19.6)	40 (71.4)	2 (3.6)
49	32	1 (3.1)	2 (6.2)	29 (90.6)	0 (0.0)	51	2 (3.9)	14 (27.5)	32 (62.7)	3 (5.9)
50	29	0 (0.0)	6 (20.7)	23 (79.3)	0 (0.0)	59	0 (0.0)	14 (23.7)	45 (76.3)	0 (0.0)
51	24	2 (8.3)	4 (16.7)	17 (70.8)	1 (4.2)	50	2 (4.0)	8 (16.0)	39 (78.0)	1 (2.0)
52	26	0 (0.0)	4 (15.4)	21 (80.8)	1 (3.8)	45	4 (8.9)	3 (6.7)	36 (80.0)	2 (4.4)
53	26	5 (19.2)	4 (15.4)	17 (65.4)	0 (0.0)	49	2 (4.1)	9 (18.4)	32 (65.3)	6 (12.2)
54	30	0 (0.0)	3 (10.0)	27 (90.0)	0 (0.0)	40	3 (7.5)	9 (22.5)	28 (70.0)	0 (0.0)
55	20	0 (0.0)	6 (30.0)	14 (70.0)	0 (0.0)	36	4 (11.1)	3 (8.3)	29 (80.6)	0 (0.0)
56	6	0 (0.0)	1 (16.7)	5 (83.3)	0 (0.0)	50	1 (2.0)	7 (14.0)	37 (74.0)	5 (10.0)
57	21	1 (4.8)	1 (4.8)	19 (90.5)	0 (0.0)	40	3 (7.5)	7 (17.5)	30 (75.0)	0 (0.0)
58	19	3 (15.8)	3 (15.8)	12 (63.2)	1 (5.3)	41	3 (7.3)	8 (19.5)	29 (70.7)	1 (2.4)
59	14	2 (14.3)	2 (14.3)	10 (71.4)	0 (0.0)	34	0 (0.0)	3 (8.8)	31 (91.2)	0 (0.0)
60	14	0 (0.0)	3 (21.4)	11 (78.6)	0 (0.0)	46	3 (6.5)	7 (15.2)	35 (76.1)	1 (2.2)

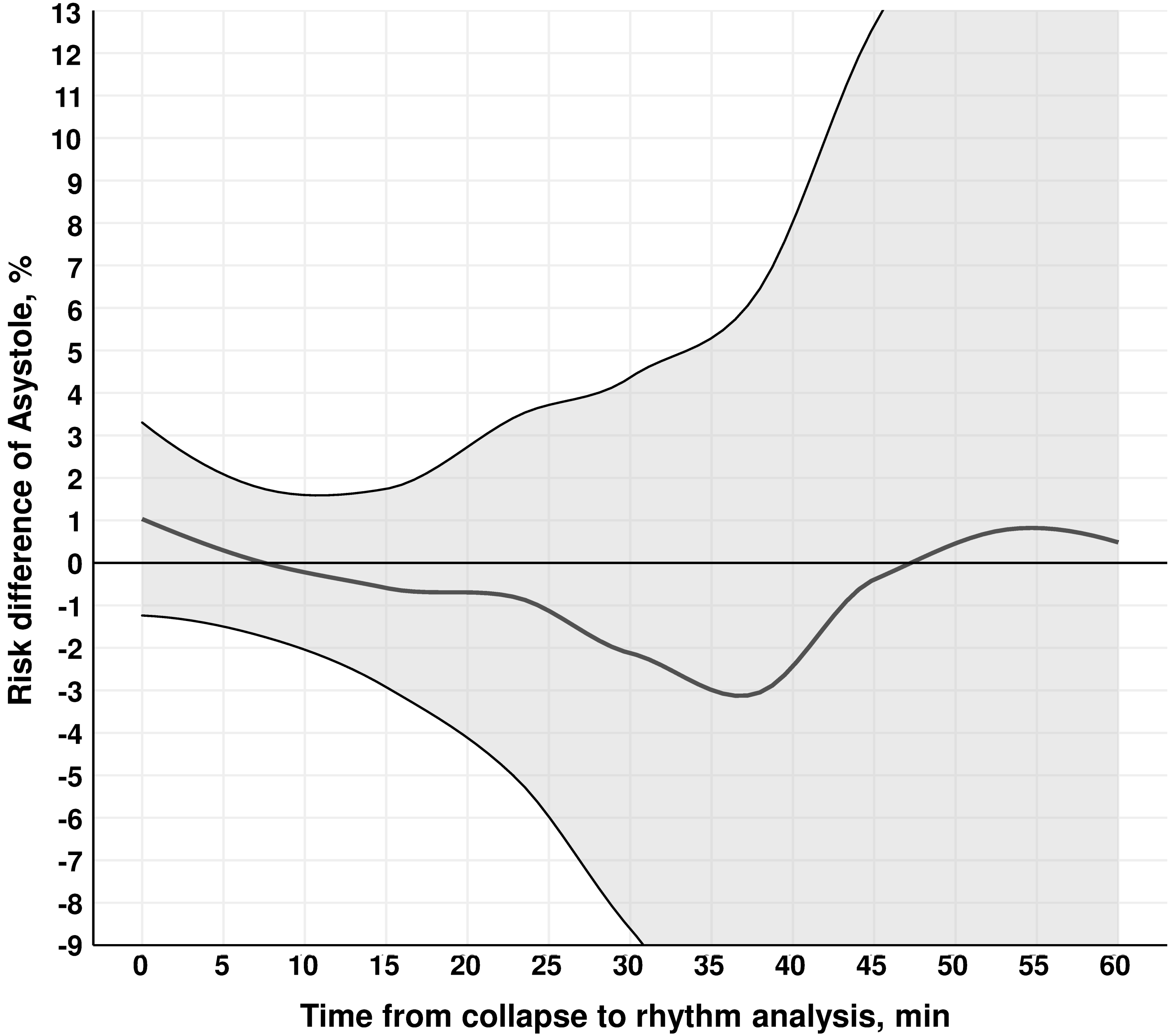
CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activity; VF/VT, ventricular fibrillation/ventricular tachycardia

Supplemental Table 2. Risk differences of first documented cardiac rhythms according to the time from collapse to rhythm analysis between patients who received bystander CPR and those who did not

	Risk difference (95% confidence interval), %		
Time interval, min	VF/VT	PEA	Asystole
0	1.1 (0.0–2.2)	7.8 (6.0–9.5)	4.1 (2.8–5.4)
1	2.1 (-0.5–4.7)	-3.8 (-7.4–-0.3)	-0.9 (-4.2–2.5)
2	4.2 (2.1–6.2)	-5.7 (-8.3–-3.1)	0.4 (-2.1–2.8)
3	2.0 (0.3–3.8)	-5.0 (-7.2–-2.7)	1.3 (-0.9–3.5)
4	2.1 (0.4–3.9)	-4.9 (-7.0–-2.8)	1.1 (-0.9–3.2)
5	2.5 (0.9–4.1)	-4.0 (-5.8–-2.1)	0.5 (-1.4–2.4)
6	3.1 (1.7–4.6)	-3.3 (-4.9–-1.7)	-1.1 (-2.8–0.5)
7	3.7 (2.3–5.1)	-4.3 (-5.8–-2.8)	-0.1 (-1.6–1.4)
8	3.6 (2.3–4.8)	-4.2 (-5.6–-2.8)	-0.4 (-1.8–1.0)
9	4.4 (3.2–5.7)	-4.8 (-6.2–-3.5)	-0.8 (-2.2–0.6)
10	4.7 (3.5–6.0)	-4.9 (-6.2–-3.5)	-0.6 (-2.0–0.8)
11	7.3 (6.0–8.6)	-6.0 (-7.4–-4.6)	-1.9 (-3.4–-0.3)
12	6.7 (5.3–8.0)	-6.2 (-7.7–-4.6)	-1.4 (-3.0–0.2)
13	5.5 (4.0–6.9)	-5.7 (-7.3–-4.0)	-0.3 (-2.1–1.5)
14	5.6 (4.1–7.2)	-5.1 (-6.9–-3.3)	-1.2 (-3.2–0.8)
15	6.9 (5.3–8.6)	-5.3 (-7.3–-3.4)	-2.3 (-4.5–-0.2)
16	6.2 (4.4–8.0)	-3.7 (-5.9–-1.5)	-3.1 (-5.5–-0.7)
17	5.2 (3.4–7.1)	-5.7 (-8.1–-3.4)	0.1 (-2.6–2.7)
18	5.7 (3.7–7.7)	-7.7 (-10.2–-5.1)	1.6 (-1.3–4.4)
19	6.0 (3.8–8.2)	-6.9 (-9.7–-4.0)	0.0 (-3.1–3.2)
20	3.9 (1.5–6.2)	-1.4 (-4.5–1.7)	-3.3 (-6.7–0.1)
21	6.4 (4.0–8.8)	-5.7 (-9.0–-2.4)	-1.1 (-4.8–2.5)
22	5.2 (2.6–7.8)	-2.4 (-5.8–1.1)	-2.7 (-6.7–1.2)
23	4.8 (2.1–7.5)	-6.1 (-9.9–-2.2)	0.8 (-3.5–5.1)
24	3.6 (0.7–6.5)	-8.7 (-12.6–-4.8)	5.3 (0.8–9.9)
25	5.2 (2.4–8.1)	-3.3 (-7.8–1.2)	-2.1 (-7.0–2.8)
26	3.3 (-0.1–6.7)	-4.2 (-8.8–0.4)	1.2 (-4.0–6.5)
27	5.2 (1.8–8.6)	1.5 (-3.7–6.7)	-7.1 (-12.8–-1.3)
28	0.4 (-3.0–3.9)	-2.7 (-7.9–2.5)	0.7 (-5.2–6.6)
29	4.8 (1.2–8.5)	-8.8 (-14.5–-3.2)	4.4 (-2.1–10.8)
30	5.6 (1.9–9.4)	2.6 (-3.3–8.5)	-8.9 (-15.5–-2.4)

31	6.8 (2.7–11.0)	-12.1 (-17.8–-6.4)	3.8 (-3.0–10.6)
32	5.1 (0.8–9.5)	-0.9 (-6.9–5.0)	-4.0 (-10.9–3.0)
33	4.1 (-0.6–8.8)	-1.6 (-8.4–5.2)	-3.4 (-11.3–4.4)
34	4.8 (0.4–9.2)	0.2 (-7.6–8.0)	-5.2 (-13.6–3.3)
35	2.3 (-1.9–6.4)	-0.2 (-7.5–7.1)	-4.8 (-12.9–3.3)
36	1.2 (-2.8–5.1)	5.2 (-3.0–13.3)	-7.0 (-16.0–1.9)
37	3.8 (-0.9–8.5)	-3.0 (-11.0–5.1)	-1.8 (-10.7–7.2)
38	-0.3 (-5.4–4.7)	4.4 (-4.3–13.0)	-3.2 (-12.7–6.4)
39	8.7 (3.0–14.4)	0.0 (-7.4–7.4)	-9.9 (-18.9–-0.8)
40	-3.5 (-8.3–1.3)	-6.6 (-15.4–2.1)	8.4 (-1.7–18.5)
41	3.1 (-1.6–7.8)	-1.0 (-10.0–7.9)	-2.7 (-12.6–7.3)
42	0.7 (-4.8–6.2)	6.1 (-5.0–17.1)	-8.5 (-20.2–3.3)
43	-0.7 (-5.9–4.6)	2.3 (-8.6–13.2)	0.4 (-11.3–12.2)
44	-1.9 (-8.6–4.9)	-2.1 (-12.6–8.5)	5.8 (-6.5–18.0)
45	-3.0 (-10.9–5.0)	0.5 (-12.1–13.2)	2.4 (-11.5–16.3)
46	3.5 (-3.5–10.6)	10.1 (-0.9–21.0)	-18.0 (-30.8–-5.1)
47	7.8 (-0.2–15.9)	6.2 (-6.9–19.3)	-5.5 (-20.7–9.6)
48	-2.2 (-9.4–5.0)	-0.9 (-15.1–13.3)	3.6 (-12.4–19.6)
49	-0.8 (-7.6–6.0)	-21.2 (-34.1–-8.3)	27.9 (13.5–42.3)
50	0.0 (0.0–0.0)	-3.0 (-18.2–12.1)	3.0 (-12.1–18.2)
51	4.3 (-5.2–13.9)	0.7 (-14.1–15.5)	-7.2 (-24.6–10.2)
52	-8.9 (-16.7–-1.1)	8.7 (-3.9–21.4)	0.8 (-15.2–16.8)
53	15.1 (2.7–27.5)	-3.0 (-17.7–11.8)	0.1 (-18.7–18.8)
54	-7.5 (-14.2–-0.8)	-12.5 (-26.7–1.7)	20.0 (5.0–35.0)
55	-11.1 (-21.0–-1.2)	21.7 (4.2–39.1)	-10.6 (-30.2–9.1)
56	-2.0 (-10.1–6.1)	2.7 (-19.9–25.2)	9.3 (-18.0–36.7)
57	-2.7 (-13.2–7.7)	-12.7 (-26.2–0.7)	15.5 (-0.7–31.6)
58	8.5 (-5.6–22.5)	-3.7 (-20.8–13.3)	-7.6 (-28.5–13.4)
59	14.3 (2.3–26.2)	5.5 (-10.6–21.5)	-19.7 (-38.5–-1.0)
60	-6.5 (-15.8–2.8)	6.2 (-11.9–24.3)	2.5 (-17.5–22.5)

PEA, pulseless electrical activity; VF/VT, ventricular fibrillation/ventricular tachycardia


Risk difference of Asystole, %
13
12
11
10
9
8
7
6
5
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2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
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20
25
30
35
40
45
50
55
60
Time from collapse to rhythm analysis, min