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Original article

Assessment of ventricular wall motion with focused echocardiography during cardiac arrest to predict survival

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ABSTRACT

Objectives: Our primary goal is to investigate the hypothesis that in patients with a detectable ventricular wall motion (VWM) in cardiac ultrasonography (US) during cardiopulmonary resuscitation (CPR), survival rate is significantly more than in patients without VWM in US.

Material and methods: In our prospective, single center study, 129 adult cardiac arrest (CA) patients were enrolled. Cardiac US according to Focus Assessed Transthoracic Echo (FATE) protocol was performed before CPR. Presence of VWM was recorded on forms along with demographic data, initial rhythm, CA location, presence of return of spontaneous circulation (ROSC) and time until ROSC was obtained.

Results: 129 patients were included. ROSC was obtained in 56/77 (72.7%) patients with VWM and 3/52 (5.8%) patients without VWM which is statistically significant ($p > 0.001$). Presence of VWM is 95% (95% CI: 0.95–0.99) sensitive and 70% (95% CI: 0.58–0.80) specific for ROSC. 43/77 (55.8%) patients with VWM and 1 (1.9%) of 52 patients without VWM survived to hospital admission which was statistically significant ($p < 0.001$). Presence of VWM was 100% (95% CI: 0.87–1.00) sensitive and 54% (95% CI: 0.43–0.64) specific for survival to hospital admission.

Conclusion: No patient without VWM in US survived to hospital discharge. Only 3 had ROSC in emergency department and only 1 survived to hospital admission. This data suggests no patient without VWM before the onset of CPR survived to hospital discharge and this may be an indication to end resuscitative efforts early in these patients.

1. Introduction

Cardiopulmonary resuscitation (CPR) results either with the return of spontaneous circulation (ROSC) or with the decision of terminating resuscitative efforts. While achieving ROSC is the primary goal, a successful CPR must also result with good neurological outcome. Many factors such as initial cardiac rhythm, early defibrillation and early chest compressions, patient's age, comorbidity, prolonged CPR affect the outcome of resuscitation.[1,2] Termination of CPR is a more controversial subject. Guidelines and studies suggest terminating CPR efforts on normothermic, elderly patients with an initial rhythm of asystole, and whose brain stem reflexes are absent.[3–5] Clinical judgement of the rescuer is also a key factor.[4] Lately, considering more objective endpoints such as lower end tidal CO_2 values and absence of ventricular wall motion (VWM) on cardiac ultrasound (US) are recommended.[6]

US is a widely used, beneficial tool of emergency medicine practice. Many protocols are described for different patient groups. Focus Assessed Transthoracic Echo (FATE) is a commonly used and recognized protocol for bedside echocardiography. Since this protocol is performed faster than a regular transthoracic echocardiography, it is preferred in more acute settings such as management of critically ill patients and resuscitation. Many researchers investigated the use and advantages of US in CPR.[7–15] In many studies, absence of VWM in CPR implies a poor survival rate and it is discussed to use US as a predictor of outcome and as another key factor to consider when deciding to terminate CPR.

In our study, our primary goal was to investigate the hypothesis ROSC is obtained significantly more in patients with a detectable VWM during CPR. As a secondary goal, we aimed to study the correlation between presence or absence of VWM in cardiac US and survival until hospital admission and after hospital discharge.

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2. Material and methods

2.1. Study design and setting

This is a prospective, single-center, observational study held in [blinded] between January 2014 and July 2014. Our primary goal was to investigate the clinical predictive value and utility of VWM for the estimation of ROSC. Secondary goals were to investigate the utility of VWM for the estimation of survival-to-hospital admission and long-term survival (1-month).

2.2. Sample size estimation and selection of participants

In order to test our primary hypothesis, required sample size was estimated using the data from a study in 2005 by Salen et al.[11] According to this data, the sample size necessary to investigate the statistical significance with a 0.01 Type I error and 0.01 Type II error (with 99% power and $p < 0.01$) was calculated to include a sum of 57 patients, 9 with VWM and 48 without VWM in US. Considering missing data and patients, 3 folds of the necessary sample size was intended. Using consecutive sampling, all patients who presented with CA and had CA during their stay in emergency department (ED) and on whom a cardiac US was performed were enrolled until the planned sample size was achieved. Patients younger than 18 years of age, patients with thoracic deformities or injuries that prevents US examination and pregnant patients were excluded. During the planned time frame of the study, 177 patients received CPR, however, 30 patients were missed mainly due to rapid evaluation and transfer to operating room, missing personal data and high patient volume of the ED. A total of 147 patients were enrolled to the study. 18 of those 147 patients were then removed from the study due to incomplete data, lost to follow-up. Study and follow-up was completed with a final sample-size of 129 patients.

2.3. Observations, measurements and data collection

Cardiac US is a routine examination performed without intervening CPR in all CA patients in our clinic. US was performed by senior emergency medicine residents (EMRs) with at least 2 years of clinical experience. Senior EMRs are required to complete Basic and Advanced US Training Courses certified by the Emergency Medicine Association of Turkey (EMAT). In this study, a senior EMR performed cardiac US with FATE protocol and evaluated the presence or absence of VWM from subxiphoid window. FATE protocol suggests checking for more obvious conditions such as pericardial effusion and tamponade, first. Measurements of ventricular wall thickness and volumes, evaluating ventricular functions, pleural imaging and interpreting these findings with patient's clinical state are other suggested steps.[16] During acute settings such as CPR, checking for obvious conditions and VWM would be sufficient for clinical evaluation.[16] In a study on echocardiographies performed by emergency physicians (EPs), Bustam et al[17] reported interrater correlation of EPs as 0.79 (95% CI 0.77–0.84). This kappa value was compatible with previous studies of EPs performing echocardiography.[18,19] According to this and previous researches, FATE evaluations by different EPs with required training is accepted as highly correlated with each other. Therefore, we assumed that all senior EMRs with EMAT US certification would be highly correlated with each other and data gathered by different EMRs are collected together for the primary aim of the study.

CPR was performed according to AHA 2010 guidelines in patients with CA. Cardiac US was only performed during the hands-off periods of pulse checks. If it was not technically possible to perform US due to extensive thoracic injury, thickness, obesity or rapid evaluation and transfer to operating room, those patients were excluded from the study.

A data collection form was prepared and US examination findings (according to FATE protocol), absence or presence of VWM, age, sex, location of CA (in-hospital or out-of-hospital), and initial rhythm (VT/VF or PEA/asystole) were recorded. If ROSC was achieved, duration until ROSC was also recorded. Follow-up of the patients were performed using the Hospital Information System (HIS) and survival to hospital admission and survival at 1-month was recorded, as well.

Hitachi Aloka Prosound 6 Ultrasound was used in all examinations with an UST-9123 3.5 Mhz convex abdominal probe.

2.4. Power of the study

In our study, ROSC was achieved in 72.7% and 5.8% of the patients with and without VWM, respectively. The post-hoc achieved power of our study for the primary aim is calculated as 100%. Similarly, for our secondary goals, the post-hoc achieved power of our study is also 100%.

2.5. Statistical analysis

Categorical variables are reported as numbers and percentages with ranges. Fisher's Exact test was used to compare categorical variables. Continuous variables are reported as means with standard deviations and 95% confidence intervals (CI). Normality analysis of the continuous measures was performed using the Kolmogorov–Smirnov and Shapiro–Wilks tests and Q–Q plots. For normally distributed variables, Student's t-test was used. If the variables were not normally distributed, the data were transformed (if applicable) or nonparametric tests were performed. The sensitivity, specificity, positive (PPV) and negative predictive values (NPV), positive likelihood ratio (+LR), and negative likelihood ratio (−LR) of the VWM to estimate ROSC, short-term (admission) and long-term (1-month) survivals were calculated using MedCalc and an online calculator (Richard Lowry, Vassarstat.Net). In this study, MedCalc Software version 15.4 (MedCalc Software bvba, Mariakerke, Belgium), SPSS v20 (SPSS Inc., IBM, Chicago, IL), and G*Power statistical software package version 3.1.2 (Franz Faul, Universitat Kiel, Kiel, Germany) were used for analyses. This research is conducted after the approval by [blinded] University Ethics Committee.

3. Results

Of the 129 patients, 46 (35.6%) were female and 83 (64.4%) were male. Mean age of female patients was 68.96 ± 16.44 (95% CI: 64.07–73.84), male patients was 63.08 ± 15.94 (95% CI: 59.60–66.56) and mean difference was 5.87 ± 2.96 (95% CI: 0.01–11.74) which was statistically insignificant (t-test, $p = 0.053$). Only 4 (3.1%) of 129 patients had CA due to trauma. Flowchart of the patients is presented in Fig. 1.

When we compared the outcomes and results according to sex, no significant difference was observed for the presence of VWM (Female: 29 (63.0%); Male: 48 (57.8%); $p = 0.580$), rate of ROSC (Table 1), rate of initial rhythms (VT/VF: Female: 7 (15.2%); Male: 23 (27.7%); $p = 0.130$), survival rate to hospital admission (Female: 14 (30.4%); Male: 30 (36.1%); $p = 0.565$), and long-term survival at 1-month (Female: 2 (4.3%); Male: 6 (7.2%):$p = 0.711$). Sex was not found to be a confounding factor for any of the outcomes.

Comparison of demographic data of the patients according to the primary aim (VWM for ROSC) and secondary aim (VWM for short term survival) of the study was presented in Tables 1 and 2. In patients with VWM, ROSC was obtained in 72.7% ($n = 56$; $p < 0.001$) but VWM was present in 97.7% ($n = 43/44$) patients who had ROSC

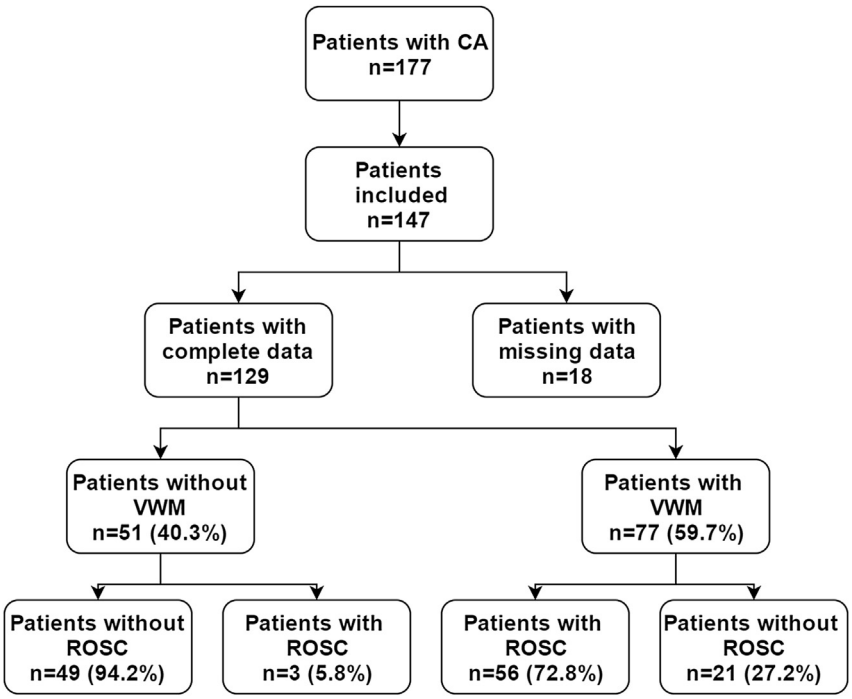

Fig. 1. Patient flowchart. CA = Cardiac arrest, VWM = Ventricular wall motion, ROSC = return of spontaneous circulation.

Table 1
Demographic data of the patients according to primary goal (VWM for ROSC).

		ROSC present N (%)	ROSC absent N (%)	Total N (%100)	P
Sex	Female	20 (43.5)	26 (56.5)	46	0.717
	Male	39 (47.0)	44 (53.0)	83	
Location of CA	In-hospital	31 (51.7)	29 (48.3)	60	0.220
	Out-of-hospital	28 (40.6)	41 (59.4)	69	
Initial rhythm	VT/VF	21 (70.0)	9 (30.0)	30	**0.003**[a]
	NEA/Asystole	38 (38.4)	61 (61.6)	99	
VWM	Present	56 (72.7)	21 (27.3)	77	**<0.001**[a]
Short term survival	Present	44 (100.0)	0 (0.0)	44	**<0.001**[a]
1 month survival	Present	8 (100.0)	0(0.0)	8	–

[a] Statistically significant. Fisher's exact test.

and, in 93.1% (n = 41/44) patients who survived to hospital admission and in all of the patients who survived at 1-month (n = 8; 100%). Although there were 52 patients whose VMW were absent at CPR, 3 patients had ROSC and 1 of them survived until hospital admission. At all, none of them survived at the end of 1 month.

The initial rhythms of VT/VF or PEA/asystole were compared according to the outcome rates. 24 of 30 VT/VF patients (80.0%) vs 53 of 99 PEA/asystole patients (53.5%) had VWM. 21 of 30 VT/VF patients (70.0%) vs 38 of 99 PEA/asystole patients (38.3%) had ROSC. The rates of both outcomes in VT/VF patients was statistically higher (p = 0.011 and p = 0.003).

In patients with an initial rhythm of VT/VF, survival to hospital admission and survival at 1-month was significantly higher than the patients with PEA/Asystole (Survival to admission: 16/30 (58.3%) vs 28/99 (28.3%) p = 0.016; Survival at 1-month: 5/30 (16.7%) vs 3/99 (3.0%); p = 0.017).

Clinical utility metrics of VWM and an initial rhythm of VT/VF as diagnostic tools for the estimation of ROSC is presented in Table 3.

Table 2
Categorical variables according to short term survival.

		Short term survival present N (%)	Short term survival absent N (%)	Total N (%100)	P
Sex	Female	14 (30.4)	32 (69.6)	46	0.565
	Male	30 (36.1)	53 (63.9)	83	
Arrest location	In-hospital	23 (38.3)	37 (61.7)	60	0.359
	Out-of-hospital	21 (30.4)	48 (69.6)	69	
Initial rhythm	VT/VF	16 (53.3)	14 (46.7)	30	**0.016**[a]
	PEA/Asystole	28 (28.3)	71 (71.7)	99	
VWM	Present	43 (55.8)	34 (44.2)	77	**<0.001**[a]
	Absent	1 (1.9)	51 (98.1)	52	
1 month survival	Present	8 (100.0)	0 (0.0)	8	**<0.001**[a]
	Absent	36 (29.8)	85 (70.2)	121	

[a] Statistically significant, Fisher's exact test.

Table 3
Clinical utility metrics of VWM and initial rhythm of VT/VF as a diagnostic tool for the estimation of ROSC and Survival to hospital admission.

	VT/VF as initial rhythm		VWM	
	ROSC	Survival to admission	ROSC	Survival to admission
	Value (95% CI)	Value (95% CI)	Value (95% CI)	Value (95% CI)
Sensitivity	0.36 (0.24–0.49)	0.36 (0.23–0.52)	**0.95 (0.95–0.99)**	**1.00 (0.87–1.00)**
Specificity	**0.87 (0.77–0.94)**	**0.84 (0.74–0.90)**	**0.70 (0.58–0.80)**	0.54 (0.43–0.64)
PPV	0.70 (0.51–0.85)	0.53 (0.35–0.71)	**0.73 (0.62–0.82)**	0.41 (0.31–0.53)
NPV	0.62 (0.51–0.71)	0.72 (0.62–0.80)	**0.94 (0.83–0.98)**	**1.00 (0.91–1.00)**
+LR	2.77 (1.38–5.57)	2.21 (1.19–4.10)	3.16 (2.20–4.55)	2.16 (1.74–2.67)
−LR	0.74 (0.61–0.90)	0.76 (0.61–0.96)	0.07 (0.02–0.22)	**0 (0-NaN)**

PPV: positive predictive value, NPV: negative predictive value, LR: likelihood ratio, NaN: not a number.

This data shows that absence of VWM negates the possibility of ROSC with 95% sensitivity and excludes the possibility of survival to hospital discharge for certain. On the other hand an initial rhythm other than VT/VF has only 36% sensitivity for ruling-out the possibility of ROSC and survival to hospital admission. Presence of VWM (specificity: 70% and 54%, respectively) or an initial rhythm of VT/VF (specificity: 87% and 84%, respectively) has only moderate value to estimate the possibility of ROSC or survival to hospital admission (rule-in). 8/77 (10.4%) patients with VWM and 5/30 (16.5%) patient with an initial rhythm of VT/VF has survival at 1-month. Among all those parameters, absence of VWM is the only valuable parameter for both ruling-out the possibility of ROSC and survival to hospital admission. Presence or absence of VT/VF as an initial rhythm or presence of VWM are found to be poor parameters for all outcomes.

4. Discussion

In our study, 72.7% of patients with VWM had ROSC and this finding was consistent with the previous studies.[10–14] Also, 43 (55.8%) of patients with VWM had survival to hospital admission while same rate was only 1.9% for patients without VWM. We found that pooled results for sensitivity and specificity of VWM as a predictor of ROSC is 95.0% (95% CI: 86.0–99%) and 70.0% (95% CI: 58–80), which was similar to previous research.[15] Only 3 patients without VWM had ROSC, only 1 patient survived to hospital admission, but none had survived at 1-month. Therefore, presence of VWM in predicting ROSC being the primary aim of our study, our findings support that, absence of VWM confirmed by FATE at CPR is highly correlated with the demise of those patients and early termination of CPR efforts may be considered.

In a study by Blavias with non-traumatic CAs, all the patients with ROSC (n = 20/169, 11.8%) had VWM and no patients without VWM had ROSC.[8] In Salen et al's 2001 study in patients with VWM (n = 41/102, 40.2%) short term survival (11/41, 26.8%) was showed to be significantly higher ($p < 0.001$).[6] Aichinger et al reported that among non-traumatic CAs, only 1/32 (3.1%) patients without VWM (n = 32/42, 76.2%) and 4/10 (40.0%) patients with VWM (n = 10/42, 23.8%) had short term survival which was statistically significant ($p = 0.008$).[7] In Salen et al's 2005 study, none of the 59 patients without VWM (n = 59/70, 84.3%) but 8/11 patients (n = 8/11, 72.7%) with VWM (n = 11/70, 15.7%) had ROSC and short term survival was also statistically higher for VWM patients ($p < 0.001$).[11] In a subgroup analysis of a study by Breitkreutz et al among 35/88 patients (40%) who had short term survival, 30/35 (85.7%) had VWM and 5/35 patients (14.3%) did not.[9] In this study, authors report that in some of the patients without VWM, underlying etiologies included some treatable conditions such as pericardial effusion, right ventricular dilatation and left ventricular dysfunction but they didn't specify in which of the conditions those patients without VWM survived.[9] In a study of Hayhurst et al, among 20/50 patients (40%) who had VWM, 11 (55%) had ROSC, and 4 (20%) had short term survival.[10] In a study by Schuster et al, 12/28 patients (42.9%) had VWM, 5/12 (41.7%) had ROSC, and 3/12 (25%) had short term survival.[12] In a study by Tomruk et al, with high rate of traumatic CAs (27.5%), ROSC was obtained in 19/27 (70.4%) of patients with VWM (n = 27/149, 18.1%).[13] In a study by Cebecci et al, which has a similar rate of traumatic CAs (4.4%) with our study, 81/410 patients (19.7%) had VWM but ROSC and short term survival rates were not reported.[14] In Salen's and Tomruk's studies who had larger patient populations, ROSC rates in patients with VWM is similar.[11,13]

In our study, 72.7% of patients with VWM had ROSC. Same data was reported as 72.7%,[11] 55%,[10] 41.2%,[12] and 70.4%[13] in previous studies. Although Hayhurst's study[10] had half the number of our patient population and Schuster's study[12] only included traumatic CAs, we report similar ROSC rates.

In our study 43 (55.8%) of patients with VWM had survival to hospital admission while same rate was only 1.9% for patients without VWM. Blavias et al reported that all 20 patients who had short time survival also had VWM and no patient without VWM survived to hospital admission.[8] In Salen's 2001 study, 26.8% of patients with VWM had short term survival.[6] Same outcome was reported as 72.7% in Salen's 2005 study,[11] 20% in Hayhurst's study,[10] and 25% in Schuster's study.[12] Breitkreutz reported short term survival in patients without VWM as 14.3%.[9] Short term survival rate of patients without VWM in our study is similar to Breitkreutz's and Blavias' findings.[8,9] This data was not present in other studies. In our study, short term survival rate of patients with VWM is similar to Salen's 2005 study while other studies reported much lower rates.[11] Hayhurst reported only 20% short term survival in patients with VWM but also added that their clinic had insufficient experience in handling CAs.[10] This data should not be interpreted as inadequacy of VWM in predicting survival as a diagnostic tool. The main reason behind this low survival rate may be a result of different approaches in handling trauma patients in different clinics. Schuster's study included just trauma patients in a small population and they claim that the lower rates of short term survival may be due to other mechanisms and secondary factors.[12] In Schuster's 2001 study, similar limitations may apply since in their 2005 study survival rates were similar with our study.[6,11] As we stated in limitations of our study, the high short term survival rates may be affected from fast evaluation and quick transfer of patients to operation room since these patients are generally high risk patients and may have lowered our survival rates if included. Since our hypothesis was that the absence of VWM is a predictor of poor CPR outcome, we believe that inclusion of those missed patients who are quickly transferred to an operating room or morgue due to their morbid injuries and are most likely to be lost, may alter our success rates in CPR but may not affect the value of absence of VWM for predicting ROSC, short-term and long-term survival.

In our literature search, we managed to find 3 other researches reporting long-term survival similar to 1-month survival rates that

we have reported. In those and above studies, survival to hospital discharge in VWM patients was dramatically low.[7,10,11] The only different report among all studies belongs to Hayhurst et al, which reported 1 patient without VWM survived to hospital admission but passed before discharge.[10] While 43 of 56 patients with ROSC survived to hospital admission, only 8 survived after 1 month, and this 10.4% survival rate is the highest reported rate.[10] This high rate may be due to exclusion of patients in whom resuscitative efforts were terminated immediately after first evaluation before performing US examinations. Since our department is the referral center for critical care patients in Eastern Istanbul, serving more than 7 million people, we have the highest standards of patient care and fast evaluation of patients in critical conditions, which may be the main reason of our high success rates.

Study with the strongest level of evidence on the diagnostic utility of bedside echocardiography for predicting ROSC is a meta-analysis by Blyth et al, which included all the studies above except Tomruk's and Cebicci's.[15] In this meta-analysis, pooled results for sensitivity and specificity of VWM as a predictor of ROSC were reported as 91.6% (95% CI: 84.6–96.1) and 80.0% (95% CI: 76.1–83.6). In our study, we found the same clinical utility metrics as 95.0% (95% CI: 86.0–99%) and 70.0% (95% CI: 58–80), which was similar to pooled results.

In our study, Only 3 patients without VWM had ROSC and only 1 survived to hospital admission, but none had survived at 1-month. This result is compatible with other studies in literature.

5. Limitations

Firstly, we did not compare the interrater reliability of EMRs who performed US. The main reason for this was the evidence from previous studies that knowledge and skill levels of EMRs with similar US training and similar experience (seniority) levels had high interrater reliabilities. Therefore we assume that our EMRs also have high interrater reliability for FATE in CPR. However, skills, training and interrater reliability of our EMRs may not be the same.

Secondly, even though AHA guidelines report no difference between survival rates of different sexes after CA, results in a population with equal amount of patients from each sex may differ from our male dominant study population. However, we did not find any significant difference between the success rates at outcomes among sexes in our study population.

Our center is the largest Level III Trauma and Critical Care Center in its area and our patient population mainly consist of elderly patients with many comorbidities and high mortality rates. Therefore, CPR results may have been affected by this population. However, our outcome rates were similar with previous studies.

We could not manage to enroll all patients who had CA in our study due to fast patient evaluation process and overcrowding of our ED. Also duration of CPR and other patient information may not be accurately recorded due to high patient volume.

Number of patients with CAs due to traumatic events in our study is only 4. Results may differ in a more homogenous patient group. However, most of the previous studies also report similar rates, and the outcome rates of our study is comparable with those studies.

Duration of transfer to ED in out-of-hospital CA patients and whether CPR was performed or not is unknown. We assumed that prehospital and in-hospital CA patients have the same standard of care. This may have mislead us to a wrong conclusion that even though standard of care is not the same, survival after out-of-hospital CA is higher. However, since the primary aim of our study is the correlation of VWM with ROSC, we don't think this factor may have affected our conclusions.

6. Conclusion

Absence of VWM confirmed by FATE at CPR is highly correlated with the demise of those patients and early termination of CPR efforts may be considered. Further randomized control studies are needed in order to have a higher level of evidence for future guidelines.

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