Cardiac Movement Identified on Prehospital Echocardiography Predicts Outcome in Cardiac Arrest Patients

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Abstract

Introduction. The prognostic value of emergency echocardiography (EE) in the management of cardiac arrest patients has previously been studied in an in-hospital setting. These studies mainly included patients who underwent cardiopulmonary resuscitation (CPR) by emergency medicine technicians at the scene and who arrived at the emergency department (ED) still in a state of cardiac arrest. In most European countries, cardiac arrest patients are normally treated by physician-staffed emergency medical services (EMS) teams on scene. Transportation to the ED while undergoing CPR is uncommon. **Objective.** To evaluate the ability of EE to predict outcome in cardiac arrest patients when it is performed by ultrasound-inexperienced emergency physicians on scene. **Methods.** We performed a prospective, observational study of nonconsecutive, nontrauma, adult cardiac arrest patients who were treated by physician-staffed urban EMS teams on scene. Participating emergency physicians (EPs) received a two-hour course in EE during CPR. After initial procedures were accomplished, EE was performed during a rhythm and pulse check. A single subxiphoid, four-chamber view was required for study enrollment. We defined sonographic evidence of cardiac kinetic activity as any detected motion of the myocardium, ranging from visible ventricular fibrillation to coordinated ventricular contractions. The CPR had to be continued for at least 15 minutes after the initial echocardiography. No clinical decisions were made based on the results of EE. **Results.** Forty-two patients were enrolled in the study. The heart could be visualized successfully in all patients. Five (11.9%) patients survived to hospital admission. Of the 32 patients who had cardiac standstill on initial EE, only one (3.1%) survived to hospital admission, whereas four out of 10 (40%) patients with cardiac movement on initial EE survived to hospital admission ($p = 0.008$). Neither asystole on initial electrocardiogram nor peak capnography value, age, bystander CPR, or downtime was a significant predictor of survival. Only cardiac movement was associated with survival, and cardiac standstill at any time during CPR resulted in a positive predictive value of 97.1% for death at the scene. **Conclusion.** Our results support the idea of focused echocardiography as an additional criterion in the evaluation of outcome in CPR patients and demonstrate its feasibility in the prehospital setting. **Key words:** ultrasound; emergency; resuscitation; prehospital; sonography

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Introduction

Cardiopulmonary resuscitation (CPR) is a frequent procedure in urban emergency medical systems (EMS), and patient outcomes are poor.[1] The prehospital treatment of cardiac arrest is normally managed according to standardized protocols. While some predictors of adverse outcome have been identified, no strong recommendations for when to stop or continue resuscitative efforts exist.

There are early descriptions of echocardiographic studies in patients in cardiac arrest.[2] With the advent of portable handheld battery-operated ultrasound systems, the use of prehospital ultrasound use is now a reality.[3–10] The prognostic value of emergency echocardiography (EE) in the management of cardiac arrest patients has been studied only in an in-hospital setting.[11–13] These studies included patients who underwent CPR by emergency medicine technicians at the scene and who arrived at the emergency department (ED) still in cardiac arrest. In most European countries, patients suffering from cardiac arrest are normally treated by physician-staffed EMS teams on scene. Transportation to the ED while undergoing CPR is uncommon. Breitkreutz and colleagues developed an advanced life support (ALS)-conform algorithm for the implementation of EE in CPR[7] and demonstrated its feasibility and its impact on patient management in the prehospital setting.[8] The aim of our study was to evaluate the ability of EE to predict outcome in cardiac arrest patients when it is performed by ultrasound-inexperienced emergency physicians on scene.

METHODS

We performed a prospective observational study of nonconsecutive cardiac arrest patients who were treated by physician-staffed EMS teams on scene. This study was approved by the institutional review board. Informed consent was obtained only after recovery of the patient.

The study was conducted in the city of Graz, Austria, and its suburban areas, comprising a total population of about 500,000 inhabitants. Four emergency vehicles (two emergency vehicles capable of patient transport that are comparable to mobile intensive care units [MICUs] and two physician-staffed cars) are on call 24 hours per day. Usually the MICU and the physician-staffed car are dispatched together.

We enrolled lifeless patients who were pulseless on initial evaluation on a convenience basis when a study physician was on shift. Each of the 24 participating emergency physicians (EPs) received a two-hour course in focused echocardiography, including video demonstrations, hands-on training, and an introduction into an ultrasound algorithm in accordance with recent ILCOR guidelines[14] based on the algorithm and its training described by Breitkreutz et al.[7]

All patients presenting with cardiac arrest and undergoing CPR were eligible for study enrollment. The CPR had to be performed in accordance with recent ILCOR guidelines.[14] We excluded patients younger than 18 years of age, and we excluded victims of trauma. After obtaining initial procedures such as defibrillation, endotracheal intubation, and vascular access, we performed EE during a rhythm and pulse check. To avoid artificial movement of the valvular structures of the heart, mechanical ventilation was held during EE. While a single subxiphoid, four-chamber view was required for study enrollment, physicians were allowed to perform multiple EE examinations. We defined sonographic evidence of cardiac kinetic activity as any detected motion of the myocardium, ranging from visible ventricular fibrillation to coordinated ventricular contractions. The CPR had to be continued for at least 15 minutes after the initial echocardiography. No clinical decisions were made based on the results of EE.

Data collected included patient downtime prior to CPR by paramedic or EP, CPR duration to first EE, medications used, shocks administered, initial electrocardiogram, initial end-tidal carbon dioxide ($ETCO_2$) value, and EE findings. The primary study endpoint was return of spontaneous circulation (ROSC) in the field and arrival in the ED with spontaneous circulation. The secondary study endpoint was survival to hospital discharge.

We used standardized data sheets to collect patient data, and entered these data into Excel (Microsoft Corp., Redmond, WA). The EE was performed using a 4–2-MHz microconvex transducer on a SonoSite 180 Plus portable handheld ultrasound system (SonoSite, Bothell, WA).

Data were analyzed using a commercially available statistical software package. Descriptive statistics, positive and negative predictive values, and likelihood ratios were calculated.

Because of the small cell sizes, Fisher's exact test rather than chi-square was used to compare survival rates in groups with and without sonographically detected cardiac activity. The Kruskal-Wallis one-way analysis of variance was used to compare the differences in medians between initial $ETCO_2$ value, age, and downtime prior to CPR for survivors and nonsurvivors.

RESULTS

We enrolled 42 patients in the study from March 1, 2009, to April 1, 2010. The attending physicians successfully implemented EE in the CPR algorithm and visualized the heart in all 42 study patients. Only one echocardiography was performed in 20 patients, whereas 22 patients had multiple examinations. The mean time of CPR to the first echocardiography was 17.4 minutes (standard error [SE] = 1.8). The mean patient age was 70.3 years (SE = 2.4). The mean age for the survivors was 66.3 years (SE = 8.2). The mean age for the nonsurvivors was 70.9 years (SE = 2.5, $p = 0.63$) (Table 1). The mean downtime prior to CPR was 11.8 minutes (SE = 1.7). The mean downtime prior to CPR was 9.8 minutes for the survivors (SE = 3.4) versus 12.1 minutes (SE = 1.9) for the nonsurvivors ($p = 0.9$). The mean initial $ETCO_2$ value was 31.2 mmHg (= 4.2 kPa, SE = 3.5). The mean initial $ETCO_2$ value was 32.2 mmHg (= 4.3 kPa) (SE = 9.7) for the survivors versus 31.0 mmHg (= 4.1 kPa) (SE = 3.8) for the nonsurvivors ($p = 0.68$).

Of the 42 study patients, five (11.9%) survived to hospital admission. Ten patients (23.8%) had cardiac

TABLE 1. Demographics of the Patients

	All Patients	Survivors	Nonsurvivors
Age–mean	70.3 (SE = 2.4)	66.3 (SE = 8.2)	70.9 (SE = 2.5)
Gender			
Male	30	2	28
Female	12	3	9

Survivors = patients who survived to hospital admission; nonsurvivors = patients with no return of spontaneous circulation in the field.
SE = standard error.

TABLE 2. Survival Rates in the Movement and No-Movement Groups Including Only the First Echocardiography

	No Movement			Movement		
	Asystole	PEA	VF/VT	Asystole	PEA	VF/VT
Survived	1	0	0	1	1	2
	1			4		
Died	18	7	6	0	3	3
	31			6		

Movement = myocardial motion in the first echocardiography; no movement = cardiac standstill in the first echocardiography.
ECG = electrocardiogram; PEA = pulseless electrical activity; VF/VT = ventricular fibrillation/ventricular tachycardia.

movement on the first EE and seven patients (16.7%) had cardiac movement on every EE.

Of the 32 patients who had cardiac standstill on the initial EE, only one (3.1%) survived to hospital admission, whereas four out of 10 (40%) patients with cardiac movement on the initial EE survived to hospital admission (p = 0.008) (Table 2). Of the five patients who survived to hospital admission, one patient survived to hospital discharge with full neurologic recovery. This single patient showed cardiac movement on the initial EE. All four other patients who survived to hospital admission died within the next two days. Cardiac standstill on initial EE resulted in a positive predictive value of 96.9% for death at the scene and a negative predictive value of 40%. The positive likelihood ratio was 4.2, and the negative likelihood ratio was 0.2.

Four out of seven patients (57.1%) with cardiac movement on every EE versus one out of 35 patients (2.9%) with cardiac standstill on any EE survived to hospital admission (p = 0.001) (Table 3). Cardiac standstill at any time during CPR resulted in a positive predictive value of 97.1% for death at the scene and a negative predictive value of 57.1%. The positive likelihood ratio was 4.6 and the negative likelihood ratio was 0.1.

Twenty patients (47.6%) were found to have asystole on the initial electrocardiogram. Ten percent of the patients with asystole on the initial electrocardiogram ($n = 20$) versus 13.6% of the patients with ventricular fibrillation ($n = 11$) or pulseless electrical activity (PEA) ($n = 11$) survived to hospital admission (p = 1.0).

All 18 patients who underwent bystander CPR died at the scene, whereas five of 19 patients (20.8%) without bystander CPR survived to hospital admission (p = 0.06).

TABLE 3. Survival Rates in the Movement and No-Movement Groups Including All Performed Echocardiographies

	No Movement			Movement		
	Asystole	PEA	VF/VT	Asystole	PEA	VF/VT
Survived	1	0	0	1	1	2
	1			4		
Died	18	8	8	0	2	1
	34			3		

Movement = myocardial motion in every echocardiography; no movement = cardiac standstill in at least one echocardiography.
ECG = electrocardiogram; PEA = pulseless electrical activity; VF/VT = ventricular fibrillation/ventricular tachycardia.

DISCUSSION

There are precise guidelines on how to give advanced life support, but only vague recommendations exist for the grave decision on whether to initiate and when to stop resuscitative efforts.[14,15] Downtime, bystander CPR, duration of resuscitative efforts, initial electric rhythm, and age are widely accepted prognostic parameters.[15,16] However, these criteria are not fully reliable, and the decision is usually made subjectively, affected by individual biases.[17] Especially in the case of persistent PEA, the decision to stop CPR in spite of remaining electrical activity can be difficult. Consequently, there is a significant need for a reproducible and accurate prognostic parameter.

Previous studies found that cardiac sonography has a high prognostic value in predicting outcome in in-hospital CPR patients. In a study by Blaivas and Fox, 169 patients had a focused ultrasound examination of the heart during CPR.[11] Patients with cardiac standstill on ultrasonography uniformly did not survive to leave the ED regardless of their initial electrical rhythm. Our study appears to confirm those results, although one patient with cardiac standstill on the initial scan survived to hospital admission. Moreover, Salen et al. also report six out of 86 patients with cardiac standstill on at least one ultrasound scan who survived to hospital admission from the ED.[12] Based on these two studies, there consistently appears to be a small group of surviving patients following a scan showing cardiac standstill. This suggests that cessation of CPR should not be based on one initial single scan showing cardiac standstill.

Our results suggest that neither asystole on initial electrocardiogram nor initial capnography value, age, bystander CPR, or downtime is a sufficiently significant predictor of survival. Only cardiac movement was associated with survival, and cardiac standstill at any time during CPR resulted in a positive predictive value of 97.1% for death at the scene. Some results of our study such as mean time to CPR or survival rates are not representative of an average CPR-patient population. Patients who regained spontaneous circulation within a short time did not receive an ultrasound scan and were therefore not enrolled in our study. This selection bias might explain the counterintuitive results relating to the prognostic value of bystander CPR in our study. However, the lack of association with traditional predictors of outcome might also simply reflect the relatively small sample size.

Using ultrasound to identify potentially reversible causes of cardiac arrest has previously been discussed.[8,18–23] It may appear plausible that diagnosing pneumothorax, hypovolemia, pericardial tamponade, and even pulmonary embolism during resuscitation could be promising diagnostic methods in the future. However, this would require greater experience with ultrasound and additional training for implementation in the Advanced Cardiac Life Support (ACLS) algorithm. This was not feasible in the context of our study. While we did not aim to identify reversible causes, our study found that the identification of cardiac movement was feasible for inexperienced EPs after a two-hour introduction and training session.

LIMITATIONS

A limitation of our study is the relatively small sample size. Furthermore, for technical reasons, it was not possible to videotape the ultrasound scan for documentation and review by another interpreter. While not focusing on the method itself, our study aims to evaluate whether an EP can predict the outcome of a CPR patient with ultrasound after a two-hour course. Although the participating physicians had previously not used ultrasound, acceptance was high and feasibility was 100%. Performing the focused ultrasound examination was not a problem for the EP after intubation and establishing intravenous access (being supported by up to one paramedic and three emergency technicians). The emergency teams reported that the EE did not disturb resuscitative efforts adhering to the latest guidelines, as also shown in a study by Breitkreutz et al.[7]

CONCLUSIONS

Employing an easy-to-use device as a highly reproducible predictor of survival in cardiac arrest patients would be of high value for the EP deciding whether to continue resuscitative efforts. Our results support the idea of focused echocardiography as an additional criterion in the evaluation of outcome in CPR patients and demonstrate its feasibility in the prehospital setting. Because of the severe consequences of the decision to abandon further resuscitation efforts, larger studies with highly significant results are needed to support the routine use of a focused ultrasound examination in the initial phase of CPR as a predictor for outcome.

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