The heart of the matter: Utility of ultrasound of cardiac activity during traumatic arrest

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BACKGROUND: The clinical utility of determining cardiac motion on ultrasound has been reported for patients presenting in pulseless medical cardiac arrest. However, the relationship between ultrasound-documented cardiac activity and the probability of surviving pulseless electrical activity has not been examined in populations with trauma. We hypothesized that cardiac activity on ultrasound predicts survival for patients presenting in pulseless traumatic arrest.

METHODS: We conducted a retrospective analysis at our university-based urban trauma center of adult patients with trauma, who were pulseless on hospital arrival. Results of cardiac ultrasound performed during trauma resuscitations were compared with the electrocardiogram (EKG) rhythm and survival.

RESULTS: Among 318 pulseless patients with trauma, 162 had both EKG tracings and a cardiac ultrasound, and 4.3% of these 162 patients survived to hospital admission. Survival was higher for those with cardiac motion than for those without it (23.5% vs. 1.9% for patients with EKG electrical activity, $p = 0.002$, and 66.7% vs. 0% for patients without EKG electrical activity, $p < 0.001$). The sensitivity of ultrasound cardiac motion to predict survival to hospital admission was 86% (specificity, 91%; positive predictive value, 30%; negative predictive value, 99%). When examined by mechanism, sensitivity was 100% for the 111 patients with penetrating trauma and 75% for the 50 patients with blunt trauma.

CONCLUSION: Survival in pulseless traumatic arrest is very low, but survival for patients with no cardiac motion on ultrasound is also exceedingly rare. Cardiac ultrasound had a negative predictive value approaching 100% for survival to hospital admission. For patients with prolonged prehospital cardiopulmonary resuscitation, ultrasound evaluation of cardiac motion in pulseless patients with trauma may be a rapid way to help determine which patients have no chance of survival in the setting of lethal injuries, so that futile resuscitations can be stopped. (*J Trauma Acute Care Surg*. 2012;73: 102–110. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Diagnostic study, level III.

KEY WORDS: Ultrasound; trauma; cardiac; FAST; pulseless.

Survival rates for victims of traumatic cardiac arrest range from 0% to 3.7%.[1] Current guidelines exist for resuscitation of patients with blunt trauma and patients with penetrating trauma in cardiac arrest. According to the National Association of EMS Physicians and the American College of Surgeons joint position statement, patients with blunt trauma and cardiac arrest at the scene, and patients with penetrating trauma who have no signs of life at the scene, (i.e., pulseless, apneic, and without pupillary reflexes, spontaneous movement or organized electrocardiogram [EKG] activity) should not be resuscitated.[2] However, the decision to stop futile resuscitations for patients with lethal injuries can be difficult considering the complexity of the situation and the desire to save a life.

Patients in traumatic arrest are evaluated by prehospital cardiopulmonary resuscitation (CPR) duration, an absent pulse on physical examination, and EKG rhythm morphology. Cardiac ultrasound is increasingly being used and can rapidly assess cardiac motion. In pulseless patients with trauma whose prehospital CPR times are prolonged, ultrasound evaluation of cardiac motion may provide essential information to guide resuscitations when injuries are lethal. Previous studies in pulseless patients in medical cardiac arrest indicate that survival to hospital admission was 67% and survival to hospital discharge was 3% when cardiac activity was demonstrated by ultrasound.[3] For patients whose medical cardiac arrest occurs out of the hospital and who present to the emergency department (ED), ultrasound activity has been proposed to distinguish between patients with electromechanical dissociation (EMD), and those with "pseudo-EMD," where the cause of pulseless electrical activity (PEA) is potentially reversible.[4] The American Heart Association describes echocardiography as being potentially useful for patients in PEA cardiac arrest (in-house or in the ED); cardiac contractions could be a possible indication for continued CPR.[5] According to a small study of cardiac ultrasound performed by medical house officers on patients having in-house medical PEA arrest, the house officers' readings largely agreed with the cardiologists' in ascertaining when patients had a normal study or had no cardiac motion.[6] One group has proposed that ultrasound be a part of an algorithm ("Cardiac Arrest Ultrasound Exam [C.A.U.S.E.]") for the resuscitation of patients in primary nonarrhythmogenic

Submitted: October 28, 2011; Revised: January 11, 2012; Accepted: January 19, 2012.
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DOI: 10.1097/TA.0b013e3182569ebc

cardiac arrest.[7] The same group emphasizes the use of ultrasound to identify potential causes of cardiac arrest, including cardiac tamponade, hypovolemia, and pulmonary embolism. Taken together, these studies support the use of ultrasound as a fast, noninvasive, and accurate way to decide whether continuing resuscitation of a patient in medical arrest is futile or helpful.

The clinical utility of determining cardiac motion on ultrasound has been suggested for patients in medical pulseless arrest.[3–7] However, the relationship between cardiac activity documented by ultrasound and the probability of surviving PEA has not yet been examined for patients presenting in pulseless traumatic arrest, in which causes of PEA may be treatable. We hypothesized that cardiac activity on ultrasound predicts survival for patients presenting in pulseless traumatic arrest.

PATIENTS AND METHODS

Institutional review board approval was obtained for this retrospective study. We analyzed our institutional trauma database and ED records of all trauma patients, presenting without a pulse at our university-based urban trauma center from January 2002 to September 2008, who were older than 18 years. The results of cardiac ultrasound performed during the trauma resuscitation were compared with EKG rhythm and survival. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated to ascertain whether cardiac motion on ultrasound predicted whether a patient survived long enough to be admitted from the trauma bay to the hospital.

Downtime and code duration were compared among subgroups of patients. Downtime was defined as the time interval in minutes between loss of pulse (or arrival of the emergency medical services [EMS]on scene if patient had no pulse when EMS arrived) and arrival in the trauma bay, all as recorded on the EMS prehospital records document. When the runsheet was unavailable, an estimated time was used if the downtime was reported verbally to a hospital staff and recorded in the medical record. Code duration was defined as the time interval in the ED in minutes between arrival in the trauma bay and the end of the code, that is, the time of death or, in the case of survivors, the documented time when a pulse returned. Survival was either defined as leaving the ED alive (i.e., survival to hospital admission) or survival to hospital discharge.

Focused assessment with sonography for trauma (FAST) is readily available at our institution in the ED and may be immediately performed at the request of the trauma team, trauma surgical attending staff, or emergency medicine attending staff. FAST is performed by a surgeon or emergency medicine physician member of the trauma team who has received ultrasound training under the direct supervision of a FAST credentialed emergency medicine attending or trauma surgeon. Because cardiac ultrasound is not a routine part of our institutional trauma resuscitation workup and FAST is done at the discretion of the trauma team and attending surgeons, not all patients received an ultrasound. For example, patients who arrived at our institution clearly deceased or those who had an obvious case of pulselessness that was immediately corrected, may not have undergone a cardiac ultrasound. As a general guideline for the use of ED resuscitative thoracotomy, at our institution, we refer to the series from Denver.[8] Typically patients will undergo resuscitative thoracotomy if the prehospital duration of CPR is less than 15 minutes for penetrating trauma and less than 5 minutes for blunt trauma. Cardiac ultrasound was typically used for patients with prehospital CPR times that were longer than these time periods.

All examinations were performed using a SonoSite MicroMaxx ultrasound scanner (SonoSite, Bothell, WA) with images recorded in DICOM format. Subxiphoid views were obtained using a 5-MHz curvilinear probe. In instances where there was obviously no cardiac movement, one view of the heart was obtained. If there was any question of movement or if the cardiac ultrasound was being conducted as part of a FAST examination, two views of the heart were obtained to evaluate for pericardial fluid. All ultrasound images are routinely reviewed by the fellowship-trained emergency medicine ultrasound director. Cardiac activity was defined as presence of any organized, nonfibrillating motion.

Data were analyzed statistically using Fisher's exact tests, χ^2 tests, or *t* tests as appropriate.

RESULTS

Overall Patient Characteristics and Survival Outcome

A flowchart depicting a total of all 318 patients with trauma who are presenting without pulses (Fig. 1) shows that, of the 135 patients with electrical activity on electrocardiography, 71 had an ultrasound completed, 17 of whom had cardiac motion. Of these 17 patients, 4 survived to hospital admission. Of the 54 patients with electrical activity on electrocardiography but no cardiac motion on ultrasound, only 1 survived to hospital admission. Of the 64 patients with electrical activity but no ultrasound performed, 4 (6%) survived to hospital admission after the operation, one of whom also survived to hospital discharge and was seen for follow-up visits in our clinic. This patient had a brachial artery injury from a cut by glass and arrived in PEA. Because of the obvious source of bleeding and recent loss of pulse, the patient was resuscitated, was transfused, immediately underwent successful arterial repair, and subsequently had a functionally normal outcome.

To calculate the clinical utility of cardiac ultrasound in pulseless patients with trauma, only patients who received an ultrasound were included in the analysis. Figure 2 shows the 162 pulseless patients with trauma who received both electrocardiography and a cardiac ultrasound. Of these, 71 patients had electrical activity, and 91 did not. Of the 71 patients who had electrical activity on electrocardiography, 17 patients also had cardiac motion on ultrasound, whereas 54 had no cardiac motion. Of the 91 patients who had no electrical activity on electrocardiography, 3 patients had cardiac motion on ultrasound, and 88 had no cardiac motion. Among all of the 162 pulseless patients with trauma who received both EKG tracing and cardiac ultrasound, 4.3% survived to hospital admission (23.5% of those with electrical activity and cardiac motion vs. 1.9% with electrical activity but no cardiac motion

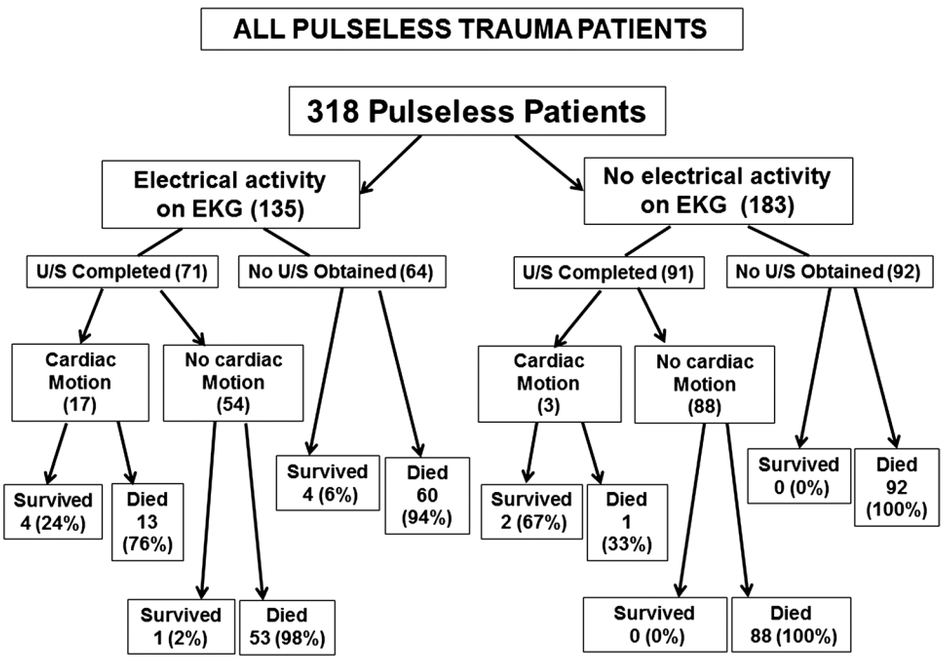

Figure 1. The 318 patients with pulseless traumatic arrest were categorized according to presence or absence of electrical activity and whether ultrasound was performed and showed cardiac motion. Survival was defined as survival to hospital admission.

[$p = 0.002$] and 66.7% of those with no electrical activity but with cardiac motion vs. 0% with neither electrical activity nor cardiac motion [$p < 0.001$]; Table 1). The sensitivity of ultrasound cardiac motion to predict survival to hospital admission was 86%, with a specificity of 91%, PPV of 30%, and NPV of 99%. All survivors had either electrical activity, or cardiac motion, or both; while 100% of patients without cardiac motion and electrical activity died.

Survival in Patients With Penetrating Trauma

A flowchart depicting the 111 patients with penetrating trauma who received both EKG tracing and cardiac ultrasound

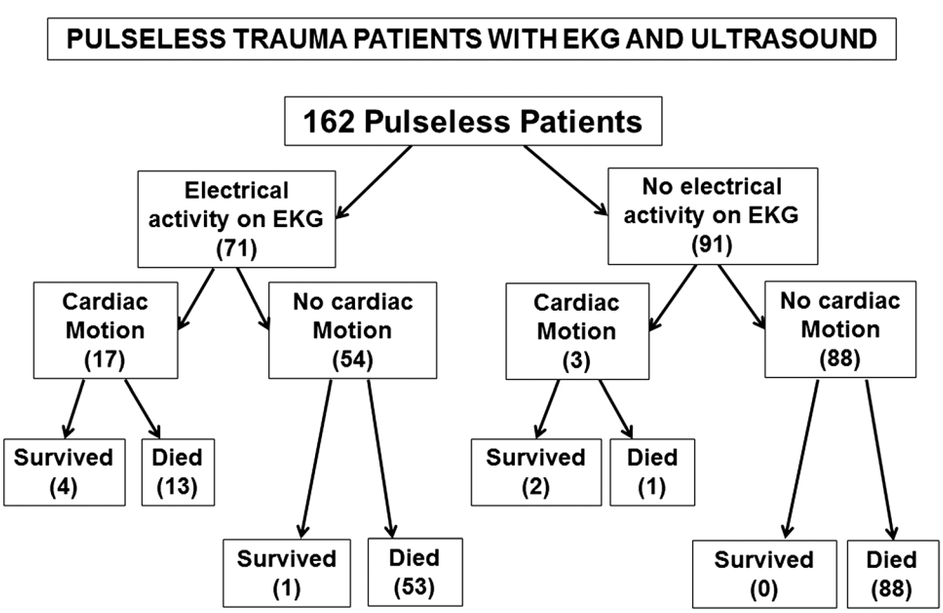

Figure 2. There were 162 patients with pulseless arrest who underwent both electrocardiography and ultrasound. These patients were categorized according to presence or absence of electrical activity and whether ultrasound showed cardiac motion. Survival was defined as survival to hospital admission.

TABLE 1. Patient Characteristics, Resource Use, and Survival to Hospital Admission for All Patients Who Underwent Electrocardiography and US

	All Patients With Trauma Who Underwent Electrocardiography and US	With EKG Electrical Activity			Without EKG Electrical Activity		
		With US Cardiac Motion	Without US Cardiac Motion	*p*	With US Cardiac Motion	Without US Cardiac Motion	*p*
n	162	17	54		3	88	
Downtime, mean (SEM), min	15.8 (0.8)	13.1 (2.6)	14.6 (1.2)	0.6	0	18.9 (1.0)	0.008
Code duration mean (SEM), min	6.0 (0.4)	13.1 (2.6)	6.7 (0.7)	0.003	6.0 (0)	4.1 (0.3)	0.2
Underwent EDT, n (%)	8 (5)	3 (18)	4 (7)	0.2	0	1 (1)	0.9
Transfused, n (%)	14 (9)	6 (35)	4 (7)	0.004	1 (33)	1 (1)	<0.001
Underwent operation, n (%)	3 (2)	3 (18)	0 (0)	0.002	0 (0)	0 (0)	NA
Survived to hospital admission, n (%)	7 (4)	4 (24)	1 (2)	0.002	2 (67)	0 (0)	<0.001

Downtime is the time between loss of pulse and arrival in the trauma bay per emergency medical providers' records. Code duration is the time between arrival and time of end of code (i.e., time of death if patient died). *p* values are for the comparisons between patients with US cardiac motion versus no US cardiac motion.
NA, not applicable; US, ultrasound.

(Fig. 3) shows that 45 patients had electrical activity on electrocardiography, with 14 patients showing cardiac motion. Of these 14 patients, 3 survived to hospital admission. Of the 66 patients who had no electrical activity on electrocardiography and an ultrasound completed, only 1 patient showed cardiac motion; this patient did not survive. The sensitivity of ultrasound cardiac motion to predict survival to hospital admission in pulseless patients with penetrating trauma was 100%, with a specificity of 89%, PPV of 20%, and NPV of 100%.

Survival in Patients With Blunt Trauma

A flowchart depicting the 50 patients with blunt trauma who received both EKG tracing and cardiac ultrasound (Fig. 4) shows that 26 patients (52%) had electrical activity on electrocardiography, with 3 patients having cardiac motion. One of these patients survived to hospital admission. Interestingly, of the 23 patients with electrical activity but no cardiac motion, 1 survived to hospital admission, and the remaining 22 died. Of the 24 patients who had no electrical activity on electrocardiography and an ultrasound completed, 2 patients showed cardiac motion and survived. The remaining 22 patients who had neither electrical activity nor cardiac motion did not survive. The sensitivity of ultrasound cardiac motion to predict survival to hospital admission in pulseless patients with blunt trauma was 75%, with a specificity of 96%, PPV of 60%, and NPV of 98%. One patient in the database had missing

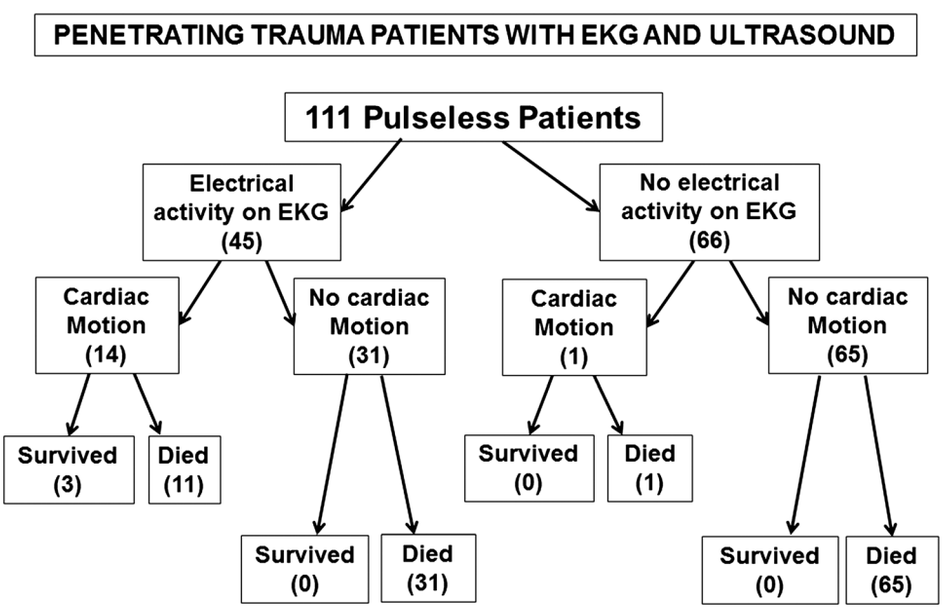

Figure 3. There were 111 patients with pulseless arrest from penetrating trauma who had both electrocardiography and ultrasound performed. They were categorized according to presence or absence of electrical activity, and whether ultrasound showed cardiac motion. Survival was defined as survival to hospital admission.

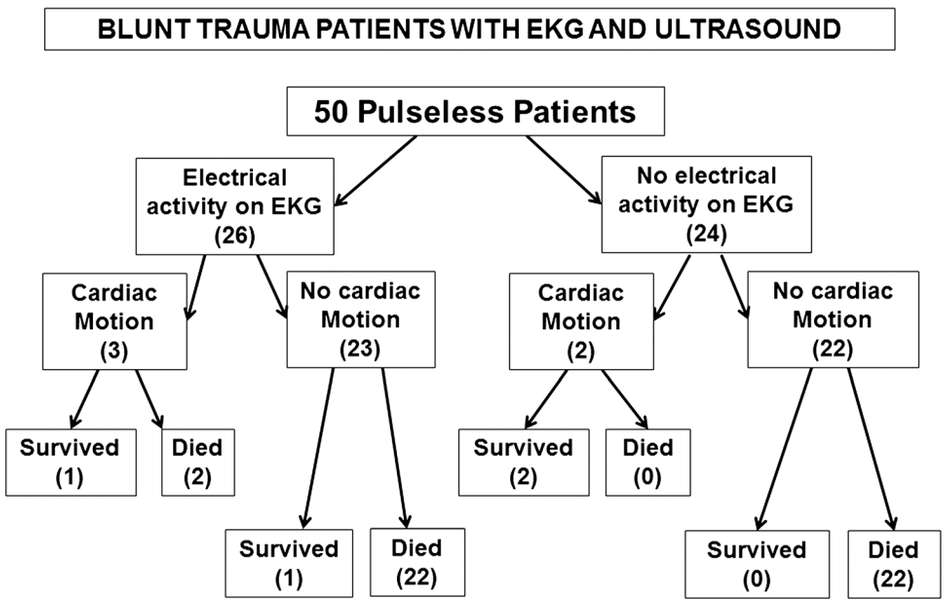

Figure 4. There were 50 patients with pulseless arrest from blunt trauma who underwent both electrocardiography and ultrasound. They were categorized according to presence or absence of electrical activity and whether ultrasound showed cardiac motion. Survival was defined as survival to hospital admission.

information on the mechanism of injury and thus was omitted from analysis.

Downtime, Code Duration, and Resource Use

Table 1 shows that, for all pulseless patients with both EKG tracings and cardiac ultrasound, resource use was generally higher in those patients who exhibited cardiac motion. Mean code duration was longer for patients with both EKG activity and cardiac motion on ultrasound compared to those with only EKG activity and no cardiac motion (mean [SEM], 13.1 [2.6] minutes vs. 6.7 [0.7] minutes; $p = 0.003$). Although approximately equal numbers of patients underwent ED thoracotomy (EDT) regardless of cardiac motion, more patients with cardiac motion on ultrasound received blood transfusions (six patients vs. four patients, $p = 0.004$), underwent operation (three patients vs. no patient, $p = 0.002$) and ultimately survived to hospital admission (six patients vs. one patient, $p = 0.002$).

EDT was performed in 5% (8 of 162) patients who received both EKG tracings and a cardiac ultrasound. This represented 15% (8 of 55) of the total number of EDT s done for all trauma activations at our institution during the study period. Fifty-three percent (29 of 55) of EDTs were done on patients who did not have either EKG tracings or ultrasounds

TABLE 2. Patient Characteristics, Resource Use, and Survival to Hospital Admission for Patients With Penetrating Trauma Who Underwent Electrocardiography and US

	Patients With Penetrating Trauma With EKG and US	With EKG Electrical Activity			Without EKG Electrical Activity		
		With US Cardiac Motion	Without US Cardiac Motion	*p*	With US Cardiac Motion	Without US Cardiac Motion	*p*
n	111	14	31		1	65	
Downtime, mean (SEM), min	16.7 (0.9)	9.7 (2.6)	15.0 (1.5)	0.1	0	18.8 (1.2)	NA
Code duration mean (SEM), min	5.7 (0.5)	12.8 (2.8)	6.5 (0.9)	0.01	6.0 (0)	4.0 (0.3)	NA
Underwent EDT, n (%)	8 (7)	3 (21)	4 (13)	0.5	0	1 (2)	0.9
Transfused, n (%)	10 (9)	6 (43)	3 (10)	0.01	0 (0)	1 (2)	0.9
Underwent operation, n (%)	3 (3)	3 (21)	0 (0)	0.008	0 (0)	0 (0)	NA
Survived to hospital admission, n (%)	3 (3)	3 (21)	0 (0)	0.008	0 (0)	0 (0)	NA

Downtime is the time between loss of pulse and arrival in the trauma bay per emergency medical providers' records. Code duration is the time between arrival and time of end of code (i.e., time of death if patient died). *p* values are for the comparisons between patients with US cardiac motion versus no US cardiac motion.

TABLE 3. Patient Characteristics, Resource Use, and Survival to Hospital Admission for Patients With Blunt Trauma Who Underwent Electrocardiography and US

	Patients With Blunt Trauma Who Underwent Electrocardiography and US	With EKG Electrical Activity			Without EKG Electrical Activity		
		With US Cardiac Motion	Without US Cardiac Motion	*p*	With US Cardiac Motion	Without US Cardiac Motion	*p*
n	50	3	23		2	22	
Downtime, mean (SEM), min	16.3 (1.5)	25 (3.5)	14.2 (2.0)	0.1	0	20.5 (2.0)	0.01
Code duration mean (SEM), min	6.2 (0.8)	14.5 (10.4)	7.1 (1.1)	0.1	Unknown	4.4 (0.9)	NA
Underwent EDT, n (%)	0 (0)	0 (0)	0 (0)	NA	0 (0)	0 (0)	NA
Transfused, n (%)	3 (6)	1 (33)	1 (4)	0.08	1 (50)	0 (0)	<0.001
Underwent operation, n (%)	0 (0)	0 (0)	0 (0)	NA	0 (0)	0 (0)	NA
Survived to hospital admission, n (%)	4 (8)	1 (33)	1 (4)	0.08	2 (100)	0 (0)	<0.001

Downtime is the time between loss of pulse and arrival in the trauma bay per emergency medical providers' records. Code duration is the time between arrival and time of end of code (i.e., time of death if patient died). *p* values are for the comparisons between patients with US cardiac motion versus no US cardiac motion.

obtained and, so these patients were not included in the analysis. Of the remaining 26 patients, 18 patients had only EKG tracings monitored and did not receive a cardiac ultrasound before undergoing EDT. The mean downtime in our study for patients undergoing EDT was 11 minutes, whereas the overall mean downtime for all patients in the study was 16 minutes. However, among those who underwent EDT and survived, the mean downtime was 2 minutes.

Subgroup analysis of patients with only penetrating injuries (Table 2) continued to show that, for patients with EKG activity, those who also exhibited cardiac motion had a longer mean code duration (mean [SEM], 12.8 [2.8] minutes vs. 6.5 [0.9] minutes, $p = 0.01$), were more likely to receive blood transfusions (six patients vs. three patients, $p = 0.01$), were more likely to undergo operation (three patients vs. no patient, $p = 0.008$), and were more likely to survive to hospital admission (three patients vs. no patient, $p = 0.008$). Those patients with blunt injuries still had poor outcomes overall, but those found to still have cardiac motion on ultrasound were more likely to receive blood transfusions and survive to hospital admission (Table 3).

To see if isolated patient injuries may impact outcomes, we analyzed the patients who sustained isolated head injuries separately. None of these patients received an EDT. Only 21% of these patients survived to hospital admission, and unfortunately none survived to hospital discharge.

TABLE 4. All Pulseless Patients With Trauma Who Underwent Both Electrocardiography and Cardiac US and Survived to Hospital Admission

Mechanism	Downtime, min	Electrical Activity at Admission	Cardiac Motion on US	Clinical Course
GSW to abdomen	4	Yes (PEA, rate 112)	Yes	Return of pulse after EDT; aortic, IVC, colon, and liver injuries repaired; died in ICU 4 h 4 min after arrival
GSW to abdomen	3	Yes (PEA, rate 52)	Yes	EDT, then to OR. Aortic, IVC, liver, spleen injuries repaired; died in OR 1 h 2 min after arrival
GSW to chest	4	Yes (PEA, bradycardia)	Yes	EDT; subclavian artery injury repaired in OR; died in OR 52 min after arrival
Bicycle accident	0 (lost pulse on arrival)	Yes (PEA, rate 30)	No motion	Found asystolic in field; then sinus rhythm en route. Pulse returned 1 min after US completed. Anoxic brain injury; C2 fracture, cervical spinal cord disruption. Died in ICU 2 d after arrival
Crush injury/fall	0 (lost pulse on arrival)	No	Yes	Asystole then ventricular tachycardia; pulse returned; lived for 52 min in ICU. Pelvic fracture, IVC tear.
Blunt head injury	Unknown	No	Yes	Found asystolic outside hospital. Pulse returned 6 min after arrival, anoxic brain injury, lived 2 d in ICU; qualified to be organ donor
Blunt head injury	10	Yes (PEA, rate 84)	Yes	Initially ventricular fibrillation, then asystolic in field. Lived 32 h in ICU; organ donor

GSW, gunshot wound; ICU, intensive care unit; IVC, inferior vena cava; OR, operating room.

Table 4 lists the mechanism, downtime, electrical activity, and cardiac motion at admission, and clinical course of all pulseless patients with both electrocardiography and cardiac ultrasound who survived to hospital admission.

DISCUSSION

Cardiac ultrasound is used as an extension of the FAST examination to evaluate patients with trauma in extremis. It has a 100% sensitivity, 97% specificity, and 97% accuracy for identifying hemopericardium after penetrating injury to the trunk.[9] Cardiac ultrasound has been used in many studies of patients with medical cardiac arrest,[3,4,6,7,10,11] and is increasingly being used in our center and elsewhere to examine pulseless trauma patients for the presence of cardiac motion. However, the significance of what this cardiac motion means in pulseless patients with trauma remains unknown. In our retrospective study of more than 300 patients (the largest to date), we found that absence of cardiac motion in pulseless patients with trauma predicted death with NPV of 99%.

Although we found that cardiac ultrasound has a high negative predicative value, it is still critically important to maintain management priorities when treating pulseless patients with trauma. ED resuscitative thoracotomy has been recommended in patients with trauma who are pulseless on hospital arrival and have a prehospital CPR time of less than 5 minutes in blunt trauma or less than 15 minutes in penetrating trauma.[8] These are the guidelines that we use at our institution. New guidelines from the Western Trauma Association recommend expanding the indications for resuscitative thoracotomy in patients with blunt trauma with a prehospital CPR time of less than 10 minutes.[12] It is essential to adhere to these potentially life-saving guidelines instead of obtaining a cardiac ultrasound. As such, of the 55 ED resuscitative thoracotomies that were performed during the study period, only 8 had ultrasound assessment of cardiac motion before initiation of the thoracotomy. This means that 85% (47 of 55) of ED resuscitative thoracotomies were completed without cardiac ultrasound and speaks to the importance of moving immediately to the resuscitative thoracotomy without spending time on ultrasound assessment.

Considering that the absence of cardiac motion on ultrasound in pulseless patients with trauma predicted death with an NPV of 99%, the increased utility of cardiac ultrasound may be in those patients who fall outside the guidelines for ED resuscitative thoracotomy. Therefore, we use cardiac ultrasound for pulseless patients with trauma with longer prehospital CPR times, to help confirm death, with the goal of preventing prolonged and unnecessary resuscitative efforts. Because trauma teams are programmed to do everything possible to save lives, it is often emotionally difficult to declare the patient dead and stop the resuscitation. Prolonged resuscitation efforts often result in the unnecessary use of resources. Cardiac ultrasound may be used during these circumstances to provide additional evidence that the patient is dead, to convince the trauma team that nothing else can be done, and thereby confirming that it is reasonable to stop the resuscitation.

Our overall rate of survival to hospital discharge was 0.003%, which is on the lower range of previously published reports on pulseless patients with trauma, which cite hospital discharge rates of 0% to 2.6% for pulseless patients with trauma.[13–16] This may be caused by patient selection because our study included patients with longer prehospital CPR times. In one study of patients arriving in the ED in cardiac arrest that was not specified as medical or surgical, 27% of those with cardiac motion on ultrasound versus 3% of those with no motion survived to hospital admission.[11] Another study of pulseless medical patients arriving in the ED in cardiac arrest had a 100% PPV for death if no cardiac motion was seen on parasternal cardiac ultrasound, with a 58% NPV for death if cardiac motion was present.[3]

In a study that examined cardiac ultrasound in 28 patients with trauma who either presented in PEA on arrival or developed PEA after arrival, 12 patients had organized cardiac motion on ultrasound.[15] Three of those patients survived to hospital admission; all three had organized motion on ultrasound, and two had narrow complex rhythms. The presence of cardiac activity was not a statistically significant predictor of survival; the absence of cardiac activity was 69% sensitive and 100% specific for lack of return of pulse, and the negative likelihood ratio was 0.3 for not regaining a pulse without activity on ultrasound. The inability of cardiac motion on ultrasound to predict survival may be caused by a lack of power in this small study. This study also differed from ours in that we focused only on patients who arrived without a pulse, often with unknown downtime, and for whom the presence of any type of cardiac motion raises questions of possible viability.

The differences in downtime between patients with cardiac motion versus those without it, or between patients with electrical activity and those without it, could imply that these subgroups of patients are merely at different points along a common continuum of decline. Prolonged downtime itself is a predictor of death,[17] and asystole as the initial rhythm portends extremely poor prognosis in patients with traumatic arrest, whereas 2% to 6% of patients who survive traumatic arrest arrived at the hospital in some other rhythm (e.g., PEA and ventricular fibrillation)[13,17] or with a heart rate of more than 40 beats per minute.[13] Although it may be argued that patients who were found pulseless by EMS have an unknown accurate downtime, EMS records are the earliest consistent recorded time available.

Special consideration should be given to patients in whom pericardial tamponade is suspected because the pericardial fluid may affect the interpretation of the cardiac ultrasound. Although studies of echocardiography in medical patients with pericardial effusion and clinical tamponade generally show that wall and valve motion occur despite the sonographic signs of tamponade,[18] there is variability in cardiac motion that can range from limited heart-wall movement to increased cardiac motion.[19] In such cases, treatment of the cardiac tamponade should be completed first before any attempts to categorize the patient as having lack of cardiac motion are undertaken.

Despite our best efforts to maintain consistency and objectivity with training and supervision by an ultrasound certified attending physician, one difficulty in our study was

standardizing how cardiac motion was quantified. None of the pulseless patients who had cardiac motion on ultrasound had brisk cardiac contractions. Possibly, the same degree of very minimal motion could be described as "no motion" by one clinician, and "positive motion" or "a twitch of motion" by another. Moreover, this subjective description of motion could be described as positive or negative according to whether the clinician thought the motion had an appearance associated with survivability, thereby potentially influencing whether a code was continued. In addition, although it has been our practice to use cardiac ultrasound to help confirm death during prolonged downtimes, owing to the retrospective nature of the study, it is difficult to prove that the EKG and FAST findings altered clinical management.

The subjective categorization among patients "with" and "without" cardiac activity may also be an imprecise view of what is actually occurring in the heart electrically. For example, there is likely to be a continuum of patients considered to have a barely perceptible electrical signal, which some clinicians may call *asystole*. A lack of agreement may exist regarding the term *agonal*, and even the terms pulseless electrical activity or *electromechanical dissociation*. PEA can be defined as the presence of organized electrical activity but no pulse.[20] In a previous study, cardiac ultrasound motion has been documented in 86% of patients in EMD who have electrical activity but no pulse.[21] EMD is conventionally thought of as organized electrical activity in the absence of simultaneous muscular activity, and it can be distinguished from pseudo-EMD where there is contractile activity, but not enough of it to generate a pulse.[22] The American Heart Association refers to PEA as including multiple types of rhythms, including pseudo-EMD, idioventricular rhythms, and others, which demonstrate mechanical contractions too weak to generate a pulse.[23]

Patients who are brain dead after devastating traumatic injuries have the potential to be organ donors, and cardiac ultrasound may help identify those who have physiologic potential for survival under intensive care until organ donation is possible. In our study, of the 11 survivors, 2 became organ donors and another qualified for organ donation, but the family declined. All three patients had head injuries. Although the potential for organ donation exists for patients who survive to hospital admission, most die quickly, and in our study, all but one patient who survived to hospital admission died in the hospital. That only one patient survived to hospital discharge reinforces how lethal the condition of these patients is and how important it is to limit futile resuscitations. In a resource-limited environment where maximum efficiency is required, we should strive to save our resources to ensure they are available to be used for patients who will benefit from them as well as limit futile procedures that may worsen patient conditions or present unnecessary risks to health care staff. In a busy trauma center or ED, there are often multiple codes or trauma activations that can occur simultaneously. Knowing which patients can benefit from our efforts assists us in managing finite numbers of staff and limited resources at any one time.

The data collected in our study allows us to propose an algorithm that could be applied to patients in pulseless traumatic arrest who have more than 15 minutes of prehospital CPR for penetrating trauma and more than 5 minutes for blunt trauma. These patients should have an initial evaluation of their cardiac function by electrical rhythm and cardiac ultrasound. Those found to be asystolic with no motion on cardiac ultrasound should be declared dead. Those with a rhythm other than asystole and with no motion on cardiac ultrasound should be declared dead because lack of cardiac motion is highly predictive of death. Continued resuscitation of patients with cardiac motion on ultrasound can be justified, acknowledging the small rate of survival to hospital admission and the even smaller rate of survival to hospital discharge. However, the finding of no cardiac motion, especially for patients without electrical activity, can reliably predict death.

CONCLUSIONS

The rate of ultimate survival for patients in pulseless traumatic arrest is quite low, but survival for patients with no cardiac motion on ultrasound is exceedingly rare. Our study showed that the absence of cardiac motion and especially the absence of both cardiac motion and electrical activity were highly predictive of death. Cardiac ultrasound had an NPV approaching 100% for survival to hospital admission. Ultrasound evaluation of cardiac motion in pulseless patients with trauma with prolonged prehospital CPR may be a rapid way to help determine which patients have no chance of survival in the setting of lethal injuries, so that futile resuscitations can be stopped.

AUTHORSHIP

All authors participated in designing this study. E.L.C. and L.Y.Y. conducted the literature searches. E.L.C., R.O.K., and E.J.M. collected the data, which all authors assisted in interpreting. E.L.C. and L.Y.Y. performed statistical analyses. D.P.P. provided ultrasound interpretation. E.L.C., L.Y.Y., and G.P.V. prepared the manuscript, which R.O.K., E.J.M., D.P.P., and G.P.V. reviewed. G.P.V. provided oversight of the study.

DISCLOSURE

Dr. Price has been a consultant with SonoSite and Philips and was involved in but not a direct recipient of grant funding by SonoSite and Philips for an unrelated study. For the remaining authors, no conflicts were declared.

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