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Pulseless electrical activity following traumatic cardiac arrest: Sign of life or death?★

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ABSTRACT

Background: Generally considered a sign of life, PEA is the most common arrhythmia encountered following pre-hospital traumatic cardiac arrest. Some recommend cardiac ultrasound (CUS) to determine cardiac wall motion (CWM) prior to terminating resuscitation efforts. This purpose of this study was to evaluate the outcomes of patients with traumatic cardiac arrest presenting with PEA, with and without CWM.

Methods: Trauma patients who underwent pre-hospital CPR were identified from the registries of two level-1 trauma centers. Pre-hospital management by emergency medical transport services was guided by advanced life support protocols. The on-duty trauma surgeon directed the resuscitations and performed or supervised CUS and determined CWM.

Results: Among 277 patients who underwent pre-hospital CPR, 110 patients had PEA on arrival to ED. 69 (62.7%) were injured by blunt mechanisms. Median CPR duration was 20.0 and 8.0 min for pre-hospital and ED, respectively. Sixty-three patients (22.7%) underwent resuscitative thoracotomy. One hundred seventy-two patients (62.1%) received CUS and of these 32 (18.6%) had CWM. CWM was significantly associated with survival to hospital admission (21.9% *vs.* 1.4%; $P < 0.001$); however, no patient with CUS survived to hospital discharge. Overall, only one patient with PEA on arrival survived to discharge.

Conclusion: Following pre-hospital traumatic cardiac arrest, PEA on arrival portends death. Although CWM is associated with survival to admission, it is not associated with meaningful survival. Heroic resuscitative measures may be unwarranted for PEA following pre-hospital traumatic arrest, regardless of CWM.

Introduction

Despite a trend toward improved survival among hospitalized trauma patients, death following traumatic cardiac arrest (TCA) remains the expected outcome. A recent systematic review demonstrated a 96.7% mortality rate for adult patients with TCA [1]. Asystole and pulseless electrical activity (PEA) are the most commonly observed cardiac electrical rhythms associated with TCA, the latter being the most common and both associated with dismal prognosis [2,3]. Nonetheless, PEA is considered to be a sign of life, prompting ongoing resuscitation. As defined by American College of Surgeons Committee on Trauma in 2001, signs of life are considered present with any of the following: pupillary response, spontaneous ventilation, presence of carotid pulse, measureable or palpable blood pressure, extremity movement, or cardiac electrical activity [4]. In a review of 24 studies that included 4620 cases from institutions that reported emergency department resuscitative thoracotomy for both blunt and penetrating trauma during over 25 years, Rhee et al. observed the survival advantage to signs of life on arrival (11.5% *vs.* 2.6%) [5]. However, signs of life include a variety of findings, and their review did not distinguish between PEA and the other signs of life as described above. It has been our anecdotal observation that cardiac electrical activity (*i.e.* PEA) is often unaccompanied by any other sign of life. It has also been our observation that there is often attempted resuscitation in this scenario, even when the period of pre-hospital cardiopulmonary resuscitation (CPR) has been protracted.

We have also observed in our clinical practice increasing use of the pericardial view associated with the focused assessment with

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sonography for trauma (P-FAST) to guide resuscitative efforts predicated on the presence or absence of cardiac wall motion (CWM). Prior research has identified that survival is exceedingly unlikely for patients with P-FAST determination of the absence of CWM [6–8]. Nevertheless, the utilization of P-FAST to determine whether to terminate resuscitative efforts or not has yet to be incorporated into consensus guidelines regarding resuscitation for traumatic cardiac arrest.

The purpose of this study was to analyze our recent experience with TCA to determine if patients who presented with PEA unaccompanied by any other signs of life had a better prognosis when compared with those that presented with asystole, and to evaluate the utility of CWM by p-FAST to direct termination *vs.* continuation of resuscitation with respect to patient survival. We hypothesized that patients with PEA would have lower mortality than those in asystole, and that presence of CWM would be associated with survival.

Methods

This was a retrospective, cohort study consisting of adult trauma patients (≥18 years of age) admitted to one of two American College of Surgeons verified level 1 trauma centers in Maricopa County, Arizona within the same hospital system (Dignity Health - St. Joseph's Hospital and Medical Center in Phoenix, Arizona and Dignity Health - Chandler Regional Medical Center in Chandler, Arizona) between February 2013–September 2017 and January 2015–December 2017, respectively. Both centers received approval from their Institutional Review Boards (IRB) for this study. Patient clinical and demographic characteristics were abstracted from the hospital trauma registries. All patients with TCA that received pre-hospital CPR were identified for study inclusion. Emergency medical services (EMS) and trauma bay records were reviewed for each patient from the medical record to determine presenting cardiac rhythm. Pre-hospital management by emergency medical transport services was guided by advanced life support protocols. Practice management guidelines at both hospitals for management of TCA mirrored the guidelines of the Western Trauma Association [8]. P-FAST was often performed during patient evaluation by the trauma surgeon. There was no practice guideline in place regarding the use of P-FAST to determine the presence or absence of cardiac motion. The decision to use P-FAST for this purpose (and/or evaluate for cardiac tamponade) was at the discretion of the individual trauma surgeon.

All adult trauma patients (≥18 years of age) treated at either hospital's emergency department (ED) following blunt or penetrating injury leading to TCA were identified. Patients that did not receive pre-hospital cardiopulmonary resuscitation from EMS and those patients with presumed medical causes of cardiac arrest (such as myocardial infarction) were excluded. The following variables were collected from each patient: age, gender, duration of pre-hospital CPR (as performed by the medical transport service), survival to admission *vs.* pronouncement of death in ED, and disposition at hospital discharge (alive *vs.* dead).

Means are reported with standard deviations and were compared using Student's t-tests. Medians are reported with the 25th and 75th interquartile ranges and were compared using the independent samples median test. Categorical variables are reported with counts and percentages with 95% confidence intervals and were compared using Pearson chi-square test with the Yates correction for continuity applied or Fisher's exact test if an expected cell count was less than 5. P values < 0.05 were considered statistically significant. IBM SPSS Statistics 25 (IBM Corporation, Armonk, NY) was used for data analysis.

Results

Collective cohort

277 trauma patients that underwent pre-hospital CPR for TCA were identified (181 managed at St. Joseph's Hospital and 96 managed at Chandler Regional). Mean patient age was 43.1 (17.5), 218 (78.7%) were male, and median Injury Severity Score was 24.1 (18.2). Mechanism of injury was penetrating in 99 patients (35.7%), the most common of which was due to ballistic injuries. Anatomic location of injury was head/neck in 25 patients, torso in 34 patients, and extremity in 4 patients, and multiple sites in the remaining patients. Among patients injured by blunt mechanism, the most common specific mechanism was pedestrian injury by motor vehicle. 144 patients (52.0%) were intubated prior to hospital arrival and 235 patients received epinephrine in route (84.8%).

Fig. 1 demonstrates patient outcomes as stratified by presenting cardiac rhythm in the emergency department. 20 patients were identified on arrival to have had return of spontaneous circulation. Eighteen of these patients survived to hospital admission and four of them were discharged alive from hospital. One-hundred and forty-seven patients were identified on arrival in asystole. Among these patients, five survived to admission [3.4% (1.1%–7.8%)], but

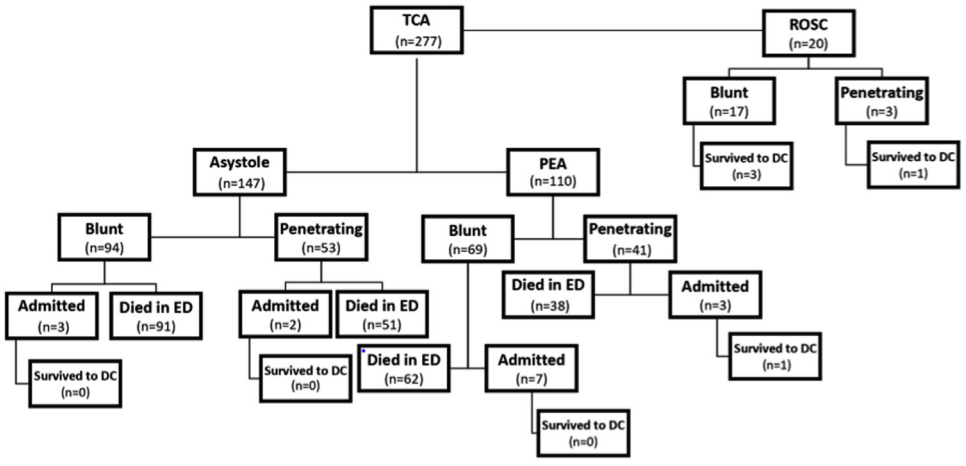

Fig. 1. Admission and discharge survival of all pulseless patients.
Legend: TCA = traumatic cardiac arrest, PEA = pulseless electrical activity, ROSC = return of spontaneous circulation, ED = Emergency Department, DC = discharge.

none were discharged alive from hospital [0% (0%–2.5%)]. The remaining 110 patients presented with PEA unaccompanied by any other signs of life. Ten patients survived to admission [9.1% (4.4%–16.1%)], but only one [0.9% (0%–2.7%)] was discharged from alive from hospital. This patient sustained alleged self-inflicted injuries to bilateral forearms, had PEA on EMS arrival at the scene, and PEA was the presenting rhythm documented in the ED as well. Return of spontaneous circulation occurred following transfusion and ongoing closed-chest CPR.

Comparison of patient demographics, treatment characteristics and survival for PEA versus asystole are shown in Table 1. Proportionately there were fewer males with PEA in comparison to asystole (70.9% *vs.* 83.8%, $P = .015$). There were not statistically significant differences in patient age, code or downtime duration, injury severity, or survival.

PEA as the presenting rhythm in ED

Among the 110 patients with PEA as the presenting rhythm in the ED, the overall mortality was 99.1%. Twenty-five of these patients (22.7%) underwent resuscitative thoracotomy in the ED of which none survived to admission. Median CPR duration was 20.0 and 8.0 min for pre-hospital and ED, respectively. Duration of pre-hospital CPR was not associated with survival to admission for PEA patients (14.5 min *vs.* 20.0 min, $P = 0.213$).

P-FAST was performed in 79 of the 110 patients with PEA (71.8%). Survival as stratified by presence or absence of CWM is demonstrated in Table 2. Presence of CWM was significantly associated with survival to hospital admission (22.7% *vs.* 3.5%; $P = 0.032$), but not to hospital discharge (zero with or without CWM). Among the 31 patients that did not undergo P-FAST, 3 survived to admission and one was discharged alive from hospital. Among the ten patients with PEA that survived to admission, 1 became an organ donor.

Table 2
Survival to hospital admission and discharge for patients with PEA that received P-FAST.

	CWM (n = 22)	No CWM (n = 57)	P-value
Survival to admission	5(22.7%)	2(3.5%)	.032
Survival to discharge	0	0	—

Discussion

In this study, we observed that overall survival was dismal for patients found to be pulseless on arrival to the ED following TCA, irrespective of whether or not cardiac electrical activity (specifically PEA) was present. Twenty percent of patients with TCA that had return of spontaneous circulation by the time they arrived to the ED were discharged alive from hospital. In contrast, only one patient (0.4%) among the remaining 257 pulseless TCA patients (147 in asystole and 110 with PEA) was discharged alive.

The extreme mortality associated with PEA as observed in the present study is consistent with other relatively recent reports. Schuster et al. observed 100% mortality in a cohort of 28 patients that suffered TCA and either presented with PEA or developed PEA in the ED [6]. Martin et al. reviewed 110 TCA patients with PEA observed in the pre-hospital setting [10]. Only one patient in their study was discharged alive from hospital, and this patient had in fact arrived at the trauma center with return of spontaneous circulation. It is therefore uncertain as to why PEA in and of itself should be thought of as a sign of life akin to a palpable pulse, spontaneous extremity movement, or respiratory effort. In actuality, PEA comprises a range of severe circulatory shock states from "pseudo-cardiac arrest" to true electro-mechanical dissociation with cardiac standstill. "Pseudo-cardiac arrest" or "pseudo PEA," whereby the heart is actually still beating with cardiac output insufficient to produce a palpable pulse, could certainly be considered consistent with a sign of life, given that the heart is still functioning, although weakly. Electro-mechanical dissociation with cardiac standstill may, in fact, represent a harbinger of death rather than a sign of life. It is consequently compelling to use P-FAST to distinguish cardiac standstill from pseudo-arrest.

P-FAST is being increasingly used in the setting of TCA to determine whether or not the heart is beating, in addition to assessment for pericardial effusion causing tamponade. In a recent prospective study of the utility of P-FAST in this manner, Inaba et al. identified from 187 patients with TCA that presence of CWM was 100% sensitive and 73.7% specific for the identification of survivors and organ donors [7]. The likelihood of survival if pericardial fluid and CWM were both absent was zero. Cureton et al. similarly conducted an analysis of the utility of P-FAST for TCA and observed that, among 162 patients with P-FAST performed for TCA, the presence of CWM was associated with survival to hospital admission (23.5% of those with electrical activity and CWM vs. 1.9% with electrical activity but no CWM, p = 0.002) [8]. We contend that it is rational to use P-FAST to assess for CWM with the goal of distinguishing the cardiac standstill of true electro-mechanical dissociation from pseudo-PEA, as a heart that is still beating demands ongoing attempts at patient resuscitation. Schuster et al. noted in their cohort of TCA patients with PEA that the three patients among 28 that survived beyond initial resuscitation all had presence of CWM, although none were discharged alive from hospital [6]. Similarly, our experience reported herein suggests that presence of CWM is associated with survival to admission, but meaningful survival is unlikely. Nonetheless, it seems appropriate to strongly consider termination of resuscitative efforts in the absence of CWM and continue efforts should CWM be present, given the consistent reported experience as described above.

Table 1
Characteristics of 257 trauma patients presenting with TCA.

	PEA (n = 110)	Asystole (n = 147)	P-value
Male, n (%)	78 (70.9%)	140 (83.8%)	.010
Age, years	44.2 (17.0)	42.4 (17.8)	.412
ED resuscitation duration, minutes[a]	10.0 (4.0 – 19.8)	7.0 (4.0 – 14.0)	.063
Pre-hospital resuscitation duration, minutes[a]	20.0 (15.0 – 25.0)	20.0 (13.0 – 27.0)	.505
Epinephrine prior to hospital, n [% (95% CI)]	96 [87.3% (79.6% - 92.9%)]	139 [83.7% (77.2% - 89.0%)][b]	.418
Intubation prior to hospital, n [% (95% CI)]	57 [51.8% (42.1% - 61.4%)]	87 [52.4% (44.5% - 60.2%)][b]	.923
Injury severity score	23.8 (18.0)	24.2 (18.4)	.857
Survive to admission, n [% (95% CI)]	10 [9.1% (4.4% - 16.1%)]	23 [13.8% (8.9% - 19.9%)]	.239
Survive to discharge, n [% (95% CI)]	1 [0.9% (0% - 5%)]	4 [2.4% (0.7% - 6.0%)]	.363

[a] median with interquartile range.
[b] n = 166.

There are several limitations of our study that are worthy of discussion. As a result of the retrospective study design, the determination of whether or not a patient's cardiac rhythm was PEA was based on the charting contained in the medical record. It is plausible that what was named "PEA" in the record may have in fact been a relatively disorganized electrical rhythm and would not necessarily have been labeled PEA by objective observers. With respect to the records, this study also collected temporal data regarding the duration of CPR from pre-hospital records, and the accuracy of such charting may not have been precise. The duration of CPR performed at the scene of injury prior to emergency medical services arrival was not available and therefore not included in the calculation of the duration of CPR. Similarly, the presence or absence of CWM was determined by chart review, without access to the actual sonographic images, and there was no uniform definition of what was to be deemed positive vs. negative CWM shared among the trauma surgeons. Additionally, this study was not designed to truly determine whether or not CWM was associated with survival, as the clinical practice was to, in general, terminate resuscitation for absence of CWM and continue resuscitative efforts when CWM was present. We can, however, glean from our results that positive CWM did not translate to meaningful survival for any of our patients. Lastly, it is notable that the cohort described comprised exclusively adult patients. It is known that pediatric patients have relatively more favorable outcomes following TCA [1], and our findings may not be applicable to the resuscitation of children.

Conclusion

Following TCA in the pre-hospital setting, PEA on arrival is associated with dismal prognosis. Resuscitative efforts are unlikely to reverse the course of this pathophysiology, warranting sound clinical judgement from the treating physician concerning the decision to continue or desist, relative to mechanism of injury and clinical presentation. CWM (signifying a beating heart and thereby pseudo PEA) was not associated with meaningful survival. Nonetheless, we conclude that P-FAST is a useful tool for distinguishing PEA with cardiac standstill, which is in all likelihood terminal (and continued resuscitation would become an attempt at reanimation), versus pseudo PEA, whereby the heart is actually still beating, representative of a veritable sign of life, and ongoing resuscitative attempts may be considered appropriate despite the unfavorable prognosis.

Disclaimers

None of the authors have any financial disclosures.

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