Incidence and Clinical Relevance of Echocardiographic Visualization of Occult Ventricular Fibrillation: A Multicenter Prospective Study of Patients Presenting to the Emergency Department After Out-of-Hospital Cardiac Arrest

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Study objectives: Ventricular fibrillation (VF) is traditionally identified on ECG but echocardiography can visualize myocardial fibrillation. The prevalence and importance of occult VF defined as a nonshockable ECG rhythm but VF by echocardiography is unknown.

Methods: In this multicenter, prospective study, emergency department patients presenting following out-of-hospital cardiac arrest were eligible for inclusion if echocardiography and ECG were performed simultaneously. Recorded echocardiography and ECG were interpreted separately by physicians blinded to all patient and resuscitation information. The primary outcome was percentage of occult VF. The secondary outcomes included survival to hospital discharge, termination of defibrillated VF, and return of spontaneous circulation (ROSC). Termination of VF is described as a postdefibrillation change in ECG rhythm to a nonshockable rhythm. Multivariate modeling accounted for confounding variables.

Results: Of 811 patients enrolled, 5.3% (95% confidence interval [CI] 3.9 to 7.1) demonstrated occult VF. An additional 24.9% (95% CI 22.1 to 28.0) demonstrated ECG VF. Of the patients with occult VF, 81.4% demonstrated ECG pulseless electrical activity (PEA) and 18.6% demonstrated ECG asystole. Occult VF was less likely to be defibrillated compared with ECG VF. Defibrillation was not significantly more likely to terminate occult VF (75.0% vs 55.6%; odds ratio [OR], 2.3; 95% CI 0.42 to 15.24). ROSC was not statistically different for occult VF compared with ECG VF (39.5% vs 24.8%; OR, 2.26; 95% CI 0.87 to 5.9). Survival to hospital discharge was no different for patients with occult VF compared with ECG VF (7.0% vs 5.4%; OR, 3.6; 95% CI 0.63 to 19.2) despite fewer defibrillation attempts for patients with occult VF.

Conclusion: Occult VF was seen in 5.3% of patients following out-of-hospital cardiac arrest. Recognizing and treating occult VF who otherwise would have been treated as PEA or asystole led to survival outcomes indistinguishable to traditionally recognized VF. [Ann Emerg Med. 2025;■:1-9.]

Please see page XX for the Editor's Capsule Summary of this article.

Keywords: Cardiac arrest, Ventricular fibrillation, Echocardiography, Electrocardiography, ECG.

0196-0644/$-see front matter

https://doi.org/10.1016/j.annemergmed.2025.04.014

SEE EDITORIAL, P. XXXX.

INTRODUCTION

Background

In the United States, more than 350,000 patients experience an out-of-hospital cardiac arrest annually, with ventricular fibrillation (VF) responsible for roughly 60,000 cardiac arrests.[1,2] Survival to hospital discharge for patients with a shockable ECG rhythm is significantly higher than survival for those with a nonshockable rhythm.[3-5]

Importance

The identification of VF during cardiac arrest currently relies exclusively on interpretation of the electrical rhythm of the heart using the ECG.[6] Despite the reliance on ECG

Editor's Capsule Summary

What is already known on this topic

Ventricular fibrillation is usually detected through an ECG.

What question this study addressed

What is the rate of occult (non-ECG detected) ventricular fibrillation identified via ultrasound?

What this study adds to our knowledge

In this multicenter, prospective study of 811 patients, 5.3% had occult ventricular fibrillation identified on ultrasound.

How this is relevant to clinical practice

Ultrasound can identify occult ventricular fibrillation in patients who may otherwise be treated as a nonshockable rhythm.

in cardiac arrest, the accuracy of ECG in detecting VF in the clinical environment remains unknown. Echocardiography (echo) can visualize fibrillation of the ventricular myocardium, and patients with echocardiographic VF demonstrating a nonshockable ECG rhythm (ie, occult VF) have been described.[7-9] The importance of identifying occult VF is unknown, but the limited available information suggests that defibrillating echo VF may produce a similar outcome to defibrillating ECG VF.[7]

Over the last 2 decades, point-of-care echo has been increasingly incorporated into resuscitation efforts during cardiac arrest but with limited research on its utility in the VF patient population. Rapid defibrillation remains the cornerstone of the treatment for VF, and point-of-care echo offers an alternative method of identifying VF that is being missed by ECG.

Goals of This Investigation

The goal of our investigation was to identify the prevalence and survival impact of occult VF in out-of-hospital cardiac arrest.

METHODS

Study Design and Setting

We conducted a multicenter, prospective observational trial involving 28 emergency departments (EDs) in the United States and Canada from December 2021 through March 2024. The study protocol was approved by the UMass Chan Medical School institutional review board and member hospital institutional review boards with a waiver of consent. The study followed the Strengthening the Reporting of Observational studies in Epidemiology guidelines for cohort studies.

The principal investigator (RG) designed the trial, and local site principal investigators attested to the adherence to the study protocol and approved of the submission for publication. All local site principal investigators confirmed the accuracy of data gathering processes at their sites. The first draft of the manuscript was written by the principal investigator (RG), and all authors contributed to revisions. All authors attest to the accuracy and completeness of the manuscript data.

EDs (n=28) in the multicenter trial were in Canada in the Ottawa Province (1) and across the United States in New England (5), Middle Atlantic (7), South Atlantic (5), East South Central (1), West South Central (2), Midwest (3), Mountain, (2) and Pacific (2) regions based on United States census regions. The EDs involved in this study collectively treat 4,265 cardiac arrest patients annually and are located in large (18), midsize (6), and small (4) cities at predominantly academic centers.

There was no study-mandated protocol for the clinical care provided to patients presenting after out-of-hospital cardiac arrest that were enrolled in this study. Participating EDs had incorporated echo into the resuscitation of out-of-hospital cardiac arrest as a standard of care for their hospital prior to enrolling patients in this study. Hospital personnel, whether involved in the study or not, were aware of the purpose and design of the study.

Selection of Participants

Eligible patients were at least 18 years of age presenting to the ED after an atraumatic out-of-hospital cardiac arrest with resuscitation continuing in the ED. Eligible patients included at least one simultaneous echo and ECG during any of the initial 3 pauses in cardiopulmonary resuscitation (CPR). Patients were enrolled as a convenience sample, based on when ECGs and echos were recorded simultaneously. Exclusion criteria included loss or corruption of the recorded echo or ECG, missing secondary endpoint data, and termination of resuscitation efforts due to end-of-life decisions. In addition, patients with recorded echo and ECG from only later pauses in the resuscitation (ie, patients missing paired echo and ECGs from the first 3 pauses in CPR) were excluded. The rationale for excluding this cohort was to better understand the impact of interventions during earlier pauses in CPR.

Interventions

Patients with out-of-hospital cardiac arrest were screened for inclusion and exclusion criteria upon arrival at the ED.

Clinical care followed Advanced Cardiac Life Support protocols and was determined by the physician in charge of the resuscitation. Clinical staff caring for the patient were not blinded to ECG or echo information. Echo images included parasternal long or subxiphoid views of the heart for transthoracic echo and mid-position views for transesophageal echo. Echo images were obtained during pauses in CPR at the discretion of the clinical team caring for the patient, simultaneous with either 3-lead or defibrillator pad ECG acquisition. Patients enrolled in the study were followed to death or discharge from the hospital, whichever came first. Patients underwent follow-up through patient contact by research staff or chart review if patient contact did not occur.

Echocardiographic video loops and ECG images were digitally recorded and stored in a centralized study database under a random number name. The reviewers included one emergency physician with experience reviewing more than 10,000 echos, and 2 fellowship-trained cardiologists blinded to all patient information and prior image interpretation. ECG interpretations by research staff categorized the identification of the cardiac rhythm as either pulseless electrical activity (PEA), asystole, VF, ventricular tachycardia, paced, or undetermined. Echo interpretation by research staff categorized the cardiac activity as no cardiac activity, organized cardiac activity (ie, contractions), disorganized cardiac activity (ie, twitching), VF, ventricular tachycardia, or undetermined. Cardiac activity was determined based on previously published definitions, with the exception of echo VF and ventricular tachycardia where definitions are less established.[10,11] Echocardiographic VF was predefined as visible myocardial fibrillatory activity. For an example of echo VF, see the Video E1 (available at http://www.annemergmed.com). Echo and ECG interpretations that did not agree were adjudicated by a third cardiologist blinded to the prior 2 interpretations and all patient information. Each ECG and echo image set was performed independently (not at the same time), blinded to all patient and provider information, and separately by each expert reviewer.

Outcomes

The primary outcome was the prevalence of VF visualized by echo and not identified by ECG. The secondary outcomes included survival to hospital discharge, defibrillation resulting in termination of VF, and return of spontaneous circulation (ROSC). Termination of VF is described as a postdefibrillation change in ECG rhythm to a nonshockable rhythm. ROSC was defined as the detection of a palpable pulse or a measurable blood pressure for greater than a minute.

Not every pause in CPR included recorded ECG and/or echo as performance of both was determined by the clinician in charge of the resuscitation. Analyses are provided for the cohort of patients with ECG and/or echo performed and recorded during the initial 3 pauses in CPR. Identification of the pause and timing of ECG and echo was accomplished using time stamps for both the ECG and the echo. Timing of ECG and echo were compared to timestamp for initiation of resuscitation efforts. The rationale for analyzing this cohort was to better understand the impact of interventions (or lack thereof) during earlier pauses in CPR. Early identification and defibrillation of VF is known to be associated with improved outcomes and including later pauses could result in obscuring findings from the initial pauses in CPR.[12]

Data recorded for this study followed the Utstein nomenclature and included recommended data points except for neurologic outcomes.[13] Out-of-hospital data were collected by clinical emergency medical services personnel present at the scene who obtain the information from family or bystanders and communicate this information to clinical staff or research staff in the ED. Patient data were recorded by research staff at the time of patient enrollment, manually abstracted from the medical record when not recorded by research staff or obtained by personal communication with clinical staff involved in the resuscitation. Data manually abstracted from the medical record were performed by research staff at each site to identify or clarify data points required for the study database. Conflicts between data sources were identified by research staff at each site and clarified by communication with clinical staff present at the resuscitation prior to entering data into REDCap. Data were entered into a centralized electronic database as the study progressed.[14]

Missing data or suspect data were identified once entered into the centralized database and reviewed by the study primary investigator. Clarifications, questions, and requests for additional data were communicated by the study primary investigator to the site primary investigator. The site primary investigator clarified, corrected, or submitted initially missing data after direct communication with research staff involved in the study, clinical staff present during the resuscitation, and out-of-hospital personnel who transported the patient when needed.

Analysis

The analysis for prevalence of occult VF was performed without adjustment for covariates giving the proportion with Clopper-Pearson 95% confidence interval (CI). Categorical data are summarized as numbers and percentages with 95% CI using the modified Wald technique. Continuous variables with a normal distribution were summarized as means and 95% CI, and non-normal distributions were summarized using median and interquartile ranges. Descriptive tables compare groups using chi-squared or Wilcoxon rank sum tests. Agreement between reviewers (interrater reliability) was measured using Cohen's κ coefficient.[15]

The analysis for our secondary outcomes of survival was performed adjusted for potential confounders. Secondary outcomes (survival and results of defibrillation) are reported as adjusted odds ratios (OR) with 95% CI, with VF as the reference group using multivariable logistic regression. Sites with less than 10 patients enrolled were combined when site was considered as a fixed effect covariate.

No a priori sample size calculation was performed as our primary outcome focused on proportion estimation and CIs. A post hoc sample size estimate of statistical power for comparisons based on observed results shows that there was 46% power to detect the difference between groups' ROSC and 31% power to detect the difference between groups' termination of VF. The required sample size to estimate the proportion of occult VF among VF patients with a CI width of 0.03 is 880.

Potential confounders include data that have been identified as impacting survival outcomes following cardiac arrest.[16-20] To avoid overfitting the regression models, the most important predictors were selected using lasso regression. Additional important predictors identified by random forest were included if they significantly improved the fit of the model. The following factors were considered: age, sex, witnessed arrest, bystander CPR, downtime prior to CPR, the pause number where VF was assessed, if VF was defibrillated, participating site, and initial cardiac rhythm.

Regression analysis of termination of VF was adjusted for initial cardiac rhythm, bystander CPR, and site. Regression analysis of ROSC was adjusted for initial cardiac rhythm, out-of-hospital ROSC, downtime prior to CPR, pause number, if VF was defibrillated and site. Regression analysis of survival was adjusted for initial cardiac rhythm and if VF was defibrillated.

No imputation was performed for missing data. (See Table E1, available at http://www.annemergmed.com, for missing data for each data point.) Statistical analysis was performed using (R Foundation for Statistical Computing), version 4.4.0.

RESULTS

Characterization of Study Subjects

A total of 977 patients were enrolled in the study at 28 hospital sites across the United States and Canada, with 166 patients excluded (Figure). Forty-four patients were excluded because the ECG and echo were not recorded simultaneously and 12 were excluded because the ECG and echo were recorded after the resuscitation had ended. Twenty-seven patients were excluded because of corrupted images (unable to be viewed after recorded) and one patient was lost to follow-up. Finally, 102 patients only had echo and ECG data from later pauses in the resuscitation, defined as the fourth pause during CPR in the ED or later, thus were excluded from the analysis. A total of 811 patients were included in the patient cohort with simultaneous ECG and echo during the first 3 pauses of CPR in the ED.

Patient characteristics are shown in Table 1. Overall, patient characteristics were similar between cohorts, except for interventions by ED physicians. Clinicians were more likely to defibrillate ECG VF compared with occult VF (54.5% vs 30.2%) and patients with ECG VF were less likely to be imaged using transesophageal echo (2.5% vs 11.6%).

Main Results

Forty-three of 811 or 5.3% (95% CI 3.9 to 7.1) of patients presenting to the ED after an out-of-hospital cardiac arrest demonstrated occult VF during the first 3 pauses in CPR. This is compared with 202 of 811 or 24.9% (95% CI 22.1 to 28.0) of patients in cardiac arrest with ECG VF. ECG VF was identified earlier in the arrest with 48% (97 of 202) identified during the first pause compared with 33% (14 of 43) for occult VF (Table E2, available at http://www.annemergmed.com). Of the nonshockable ECG rhythms seen in occult VF, 35 or 81.4% of patients with occult VF demonstrated ECG PEA and 8 or 18.6% demonstrated ECG asystole. Of the 202 patients with ECG VF, 47 patients (23.3%) demonstrated echo VF and 124 (61.4%) demonstrated no echo VF. Agreement between reviewers was substantial for both echo VF (κ=0.65; 95% CI 0.60 to 0.70) and ECG VF (κ=0.76; 95% CI 0.72 to 0.78).[9]

Overall survival to hospital discharge for all patients enrolled in the study was 3.1% (25 of 811). Patients with ECG VF were more likely to be defibrillated compared to occult VF (54.0% vs 30.2%). The subset of patients with both ECG VF with echo VF was most likely to be defibrillated (43 of 52, 82.7%). Defibrillation was more likely to terminate occult VF compared with ECG VF (75.0% vs 55.6%; OR, 2.3; 95% CI 0.42 to 15.24). ROSC was more likely for occult VF (39.5% vs 24.8%; OR, 2.26; 95% CI 0.87 to 5.9). See Table 2 for outcomes adjusted for patient variables.

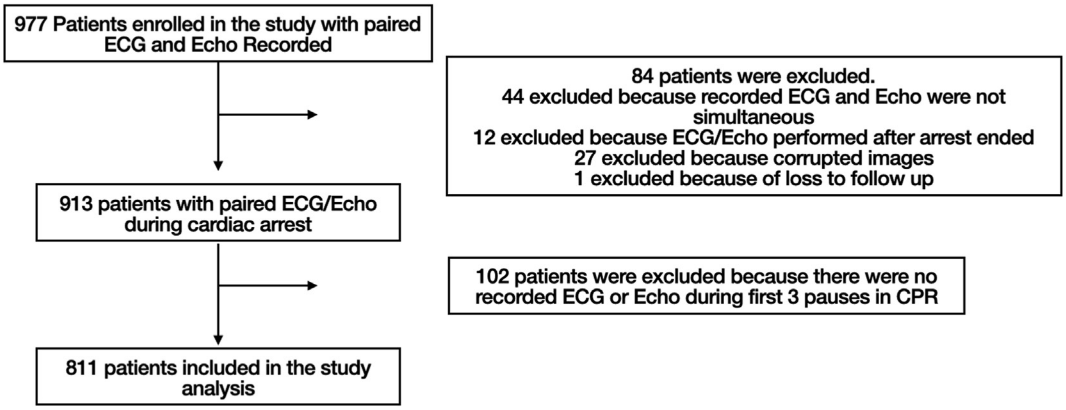

Figure. Patient flow diagram. *CPR*, cardiopulmonary resuscitation.

There was no statistical difference in survival to hospital discharge for patients presenting to the ED following out-of-hospital cardiac arrest with occult VF versus VF (7.0% vs 5.4%; OR, 3.6; 95% CI 0.63 to 19.2) (Table 2). Although not statistically significant, patients with both ECG VF and echo VF trended toward greater survival to hospital discharge (11.6%) compared with patients with only ECG VF (3.3%) or echo VF (8.9%). Patients with neither ECG nor echo VF had the lowest survival to hospital discharge (1.9%). For

Table 1. Patient characteristics by cardiac rhythm in the emergency department.

Patient Characteristic	ECG Ventricular Fibrillation (n=202)	Occult Ventricular Fibrillation (n=43)	Other Cardiac Rhythms (n=566)
Age (y), mean (SD)	61.5 (17.0)	62.9 (16.7)	61.9 (17.8)
Sex—male, % (95% CI)	70.1 (63.1-75.7)	69.8 (54.8-81.5)	68.2 (64.2-71.9)
Initial EMS cardiac rhythm, % (95% CI)			
Pulseless electrical activity	20.9 (15.7-26.9)	30.2 (18.5-45.2)	31.0 (27.3-34.9)
Asystole	36.8 (30.3-43.5)	5.6 (14.8-40.4)	41.9 (37.9-46.0)
Sinus	13.4 (9.3-18.8)	13.9 (6.2-27.6)	12.1 (9.6-15.0)
Ventricular fibrillation	21.9 (16.6-28.0)	25.6 (14.8-40.4)	12.6 (10.1-15.5)
Ventricular tachycardia	5.0 (2.6-9.0)	4.7 (0.4-16.3)	1.8 (0.9-3.3)
Witnessed arrest—yes, % (95% CI)	64.4 (57.5-70.6)	74.4 (59.5-85.2)	60.6 (56.5-64.5)
Bystander CPR—yes, % (95% CI)	54.0 (47.1-60.7)	52.4 (36.8-65.4)	47.5 (42.9-51.1)
EMS defibrillation—yes, % (95% CI)	43.1 (36.4-50.0)	46.5 (32.5-61.1)	34.2 (30.1-37.9)
Multiple defibrillations—yes, % (95% CI)	29.4 (23.4-45.8)	34.9 (22.4-49.9)	7.1 (5.2-9.5)
Downtime (min), median (IQR)	5 (0, 11.75)	5 (0, 15.0)	7 (0, 20)
Total CPR time in ED, mean (SD)	17.8 (12.6)	24.9 (19.4)	17.9 (16.0)
Echocardiographic imaging, % (95% CI)			
Transthoracic echo	97.5 (94.2-99.1)	88.4 (75.1-95.4)	94.7 (92.5-96.3)
Transesophageal echo	2.5 (0.9-5.8)	11.6 (4.6-24.9)	5.3 (3.7-7.5)
Defibrillation in ED—yes, % (95% CI)	54.5 (47.6-61.2)	30.2 (18.5-45.2)	6.8 (4.9-9.1)
Treatments in ED—yes, % (95% CI)			
Epinephrine	90.1 (84.6-93.2)	97.6 (86.8-100.0)	92.2 (89.7-94.2)
Amiodarone	43.8 (36.9-50.5)	39.5 (26.3-54.5)	14.5 (11.8-17.6)
Lidocaine	12.9 (8.9-18.2)	14.0 (6.2-27.6)	3.2 (2.0-5.0)
Calcium	55.2 (48.1-61.7)	60.5 (32.5-61.1)	49.5 (45.4-53.6)
Atropine	4.0 (1.9-7.8)	9.3 (3.1-22.2)	4.2 (2.8-6.3)

CI, Confidence interval; *echo*, echocardiography; *ED*, emergency department; *EMS*, emergency medical services; *IQR*, interquartile range.

Table 2. Adjusted defibrillator and survival outcomes.

Outcome	ECG Ventricular Fibrillation (n=202) Number of Patients (%) (95% CI)	Occult Ventricular Fibrillation (n=43) Number of Patients (%) (95% CI)	Adjusted Odds Ratio (95% CI)
Survival to hospital discharge*	11 (5.4%) (3.0-8.8)	3 (7.0%) (1.7-19.3)	3.6 (0.63-19.19)
ROSC†	50 (24.8%) (19.3-31.2)	17 (39.5%) (26.3-58.9)	2.26 (0.87-5.9)
Termination of ventricular fibrillation after defibrillation‡,$	60 (55.6%) (46.2-64.6)	9 (75.0%) (46.2-91.7)	2.31 (0.42-15.24)

ROSC, return of spontaneous circulation.
*Diagnostics for survival regression: R^2=0.19, c-statistic=0.90.
†Diagnostics for ROSC regression: R^2=0.29, c-statistic=0.84.
‡Denominators for term ventricular fibrillation are defibrillated with known status: 108 and 12.
$Diagnostics for termination of ventricular fibrillation regression: R^2=0.21, c-statistic=0.76.

unadjusted outcomes related to all ECG/echo cohorts, see Table 3.

A small percentage of patients (n=40, 4.9%) included in the study were imaged using transesophageal echo instead of transthoracic echo. In this study, a higher percentage of patients with occult VF were identified using transesophageal echo compared with transthoracic echo (12.5% vs 4.9%). There was no difference in survival for patients imaged using transthoracic echo compared with transthoracic echo. Removing transesophageal echo studies from our analysis does not change either our primary or secondary outcomes (Table E3, available at http://www.annemergmed.com).

Limitations

This study has several limitations. First, recorded echo and ECG were not available every pause in CPR. ECGs were performed in all pauses but recorded in 76.4% of pauses because of difficulty with recording ECG data at the precise time the echo was being performed. Echo was recorded in 57.3% of the pauses, because clinicians did not perform the echo, remember to record images, or images were recorded but data files were corrupted. We included data from the first 3 pauses to better capture all patients in VF but did not include later pauses to limit potential bias in our secondary outcomes. VF survival requires rapid defibrillation and including later pauses could inappropriately bias our outcomes.[21] In addition, only enrolling patients with both ECG and echo introduced an element of selection bias as those patients where echo and ECG were not recorded occurred commonly in patients with ECG VF that were immediately defibrillated.

Another limitation involves how echos were reviewed. Echo images were reviewed by experienced sonographers who had the ability to review recordings multiple times and without a time constraint. It is unclear if clinicians managing an arrest would identify all cases of occult VF given inherent time constraints and the distraction of

Table 3. Unadjusted defibrillator and survival outcomes by echo/ECG findings.

Outcome	ECG Vfib/ Echo No Vfib (n=117)	ECG Vfib/ Echo Unknown (n=33)	ECG Vfib/ Echo Vfib (n=52)	ECG No Vfib/ Echo Vfib (n=43)	ECG No Vfib/ Echo No Vfib (n=566)
	Number of Patients of Total Number, % (95% CI)				
Survival to hospital discharge	4 of 117 3.4% (1.1-8.8)	1 of 33 3.0% (0.5-15.3)	6 of 52 11.5% (5.0-23.3)	3 of 43 7.0% (1.7-19.3)	11 of 566 1.9% (1.1-3.5)
ROSC	18 of 117 15.4% (9.9-23.1)	6 of 33 18.2% (8.6-34.4)	26 of 52 50.0% (36.9-63.1)	17 of 43 39.5% (26.3-54.4)	162 of 566 28.6% (25.1-32.5)
Termination of ventricular fibrillation after defibrillation	26 of 47 55.3% (41.2-68.6)	13 of 19 68.4% (45.8-84.8)	18 of 43 41.9% (28.4-56.7)	9 of 13 69.2% (42.0-87.7)	-

Vfib, ventricular fibrillation.

making clinical decisions in a high-pressure situation. However, it is also possible that expert review of the recorded echo may have been more challenging and/or possibly less accurate than the initial clinical interpretation. In many cases, the 3- to 6-second echo recordings represent a fraction of the echo images visible to clinicians during the arrest. The additional information from "visualized but not recorded echo images" prior to starting the recording process could potentially assist clinical staff in improved recognition of occult VF.

In addition, the numbers of patients in subcategories like ECG VF but no echo VF or occult VF with specific nonshockable rhythms are small, so conclusions related to these populations should be limited. Finally, like all cardiac arrest trials, it is possible that unadjusted confounding could have biased results.

DISCUSSION

In the current study, a total of 5.3% of patients presenting to the ED demonstrated occult VF, VF not recognized by ECG but visible on echo. ECG VF was more likely to be defibrillated, as is expected, but the number of VF patients who were defibrillated was low for both ECG VF (54%) and occult VF (32%). The accuracy of ECG in diagnosing VF is unknown as there had been no clinically relevant alternatives. Interpreting VF during cardiac arrest is inherently challenging due to artifacts, compressed time to interpret the ECG, and the chaotic nature of the resuscitation. Agreement for emergency medicine residents interpreting the ECG for VF is known to be poor.[22] The contribution of ECG artifacts in accurately interpreting the cardiac arrest ECG may help explain why most patients with occult VF in this study presented with PEA and not asystole. The misidentification of VF as PEA has not been explored previously in the literature as prior studies have focused on VF masquerading as asystole.[23]

Survival outcomes for occult VF were no different than ECG VF even though occult VF was less likely to be defibrillated. We speculate that there was similar survival because successful termination of VF was greater for defibrillated occult VF compared with ECG VF. Alternatively, the degree of echocardiographic activity during VF may be associated with greater survival, and occult VF patients had greater echocardiographic activity compared with ECG VF. Although not statistically significant, survival to hospital discharge trended higher when VF was identified by both ECG and echo (11.5%) over ECG VF without echo VF (3.4%). Patients with nonshockable rhythms demonstrate a similar finding of increased cardiac activity correlating with increased survival. PEA with organized myocardial contractions have higher survival rates compared with those with disorganized twitching or no activity at all.[10]

Although the agreement for interpreting echo VF in this study is considered substantial, a κ of 0.67 is low enough to raise some concerns. However, this agreement is in the range of agreement for other echo findings such as left ventricular function.[24,25] It is not clear if agreement between clinicians is impacted by a number of factors. Echo image quality during cardiac arrest can be relatively poor as images are obtained in a few seconds, and machine settings are generally not optimized to visualize VF. Lower agreement for echo VF may also be a result of its novelty and scarcity in patients traditionally undergoing echocardiography. Identification of VF by echo has not previously been suggested for cardiac arrest and neither cardiology nor emergency medicine training focuses on identifying VF by echo. Training is required to help develop the skills needed to rapidly and accurately identify VF by echo.

In this study, the survival to hospital discharge for the entire cohort (3.1%) was lower than what has been reported in the literature (9.9%).[26] It is important to note that the current study excluded patients who were successfully resuscitated out-of-hospital as well as patients successfully defibrillated immediately upon arrival to the ED prior to echo. Removal of these 2 populations could explain the lower overall survival. Prior studies reporting survival to hospital discharge for out-of-hospital cardiac arrest in patients without out-of-hospital ROSC are similar to this study (3.4%).[27]

Early defibrillation is critical for patients presenting in VF. The survival rate for VF defibrillated out-of-hospital is as high as 33%, but with lower survival for delayed defibrillation.[2,26,28,29] Forty-six percent of ECG VF in this study was not defibrillated, as it was not recognized by the clinical team. Echo identified patients with VF who were missed by ECG, and we speculate that echo may have contributed to increased recognition of ECG VF by the clinical team. In this study, patients with both ECG VF and echo VF were more likely to be defibrillated compared with ECG VF without echo VF. A recent Lancet Commission on sudden cardiac death advocates for the personalization of resuscitation over simplification.[30] Using echo during cardiac arrest to determine interventions has the potential to fundamentally change the paradigm of resuscitation following cardiac arrest. Echo introduces an element of individualization that is currently lacking in the treatment of out-of-hospital cardiac arrest.

In summary, this study is the first to describe the prevalence and importance of occult VF not identified by ECG. Our findings demonstrate that survival for occult VF is similar to

ECG VF, emphasizing the importance of identifying and accurately treating VF even if not evident by ECG. The introduction of echo to assist in detecting VF has the potential to improve overall survival following out-of-hospital cardiac arrest. We recommend that physicians consider interpreting bedside echo during cardiac arrest for the presence of VF and defibrillate VF rapidly upon identification.

We would like to thank Dr. Brian Allen at Louisiana State University, Dr. Gavin Budrham at Baystate Medical Center, Dr. Josh Greenstein at Staten Island Hospital, Dr. Petra Duran-Gehring at University of Florida Jacksonville, Dr. Mary Beth Phalen at Medical College of Wisconsin, Dr. Marek Radomski at University of Pittsburgh Medical Center, Maxwell Thompson at University of Alabama Birmingham, and Dr. Paul Pageau at Ottawa University for their contributions to this project. We would also like to thank Richard Caplan for statistical help.

Supervising editor: Michael Gottlieb, MD. Specific detailed information about possible conflicts of interest for individual editors is available at https://www.annemergmed.com/editors.

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Author contributions: RG conceived the study and designed the trial. RG, TG, PG, and RL supervised the conduct of the trial and data collection. All authors undertook recruitment of participating centers and patients and managed the data, including quality control. RG and RJC provided statistical advice on study design and analyzed the data; PG chaired the data oversight committee. RG drafted the manuscript, and all authors contributed substantially to its revision. RG takes responsibility for the paper as a whole.

Data sharing statement: Partial datasets and data dictionary are available from January 1, 2026, upon request to Dr. Gaspari at email Romolo.Gaspari@umassmemorial.org.

All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding and support: By *Annals'* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The study was conducted without funding, but statistical support during the final revisions of the manuscript was provided by an Institutional Development Award (IDeA) from the National Institute of General Medical Sciences of the National Institutes of Health under grant number U54-GM104941 (PI: Hicks) and the state of Delaware. Tobias Kumar reports consulting fees from GE HealthCare and research funding from Philips. Jason Nomura reports consulting fees from Philips and Caption AI and research funding from Bayer. Nikolai Schnittke reports research funding from Phillips. Zachary Soucy reports consulting fees from Creare Inc and is on the Advisory Board for Sonosite/Fujifilm. All other authors report no conflicts of interests.

Publication dates: Received for publication December 16, 2024. Revision received April 2, 2025. Accepted for publication April 10, 2025.

Trial registration number: 04906252

Presentation information: Data of this article were presented at the following meetings: Society for Academic Emergency Medicine National Conference, Phoenix, Arizona, May 2024; American College of Emergency Physicians *Research Forum* (ACEP24), Las Vegas, Nevada, October 2024; and American Heart Association Resuscitation Science Symposium Conference, Chicago, Illinois, November 2024.

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