**DIAGNOSTIC PERFORMANCE OF POINT-OF-USE ULTRASOUND OF RESUSCITATION OUTCOMES: A SYSTEMATIC REVIEW AND META-*ANALYSIS OF 3,265 PATIENTS***

*Maciej Dudek, Lukasz Szarpak, Frank W. Peacock, Aleksandra Gasecka, Wladyslaw Gawel, Pawel Wroblewski, Halla Kaminska, Gabriela Borkowska, Ewa Skrzypek, Adam Smereka, Jaroslaw Meyer-Szary, Mariola Malecka*

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**Table S1.** Technical parameters of the included studies.

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| ***Study*** | ***Technical parameters*** | | | | | ***Operator characteristics*** | |
| ***Vendor*** | ***Model*** | ***Probe*** | ***Frequency (MHz)*** | ***Window*** | ***ECHO operator*** | ***Experience / training*** |
| Aichinger et al. 2012 | SonoSite | 180 Plus | Microconvex | 4–2-MHz | Subcostal | Physician-staffed EMS teams | Two-hour course |
| Atkinson et al. 2019 | NS | NS | NS | NS | Sub-xiphoid, parasternal long axis, or apical four chambers | Physician | Experience personel |
| Backett et al. 2019 | NS | NS | NS | NS | NS | Physician | NS |
| Blaivas et al. 2001 | Aloka | 200 | Curved-array and phased-array | 2.5-MHz | Subcostal | Emergency medicine residents | 8-hour basic ultrasound course |
| Breitkreutz et al. 2010 | SonoSite | i-Look 15 | Curved | 3.5–5 MHz | FEEL protocol | Specialist in cardiology, internal medicine, surgery, anaesthesiology or paediatrics with an additional subspecialisa- tion in pre-hospital emergency medicine. | Experience personel |
| Cebicci et al. 2014 | CHISON | 8500 | Curvlinear | 3,5 MHz | Subcostal | EP | Experience personel |
| Chardoli et al. 2012 | NS | NS | NS | NS | Subxiphoid | emergency resident | teaching course to achieve competence in performing and interpreting echocardiography through subxiphoid (subcostal) view in 10 seconds to detect some of PEA etiologies |
| Chua et al. 2017 | SonoSite | Edge II | NS | NS | Subcostal | Physician | Training programme. Exam: passed the test and performed 25 scans for each organ system (for example, cardiac, lung and aorta) |
| Cureton et al. 2012 | SonoSite | MicroMaxx | Curvilinear | 5-MHz | Subxiphoid  FAST | Surgeon or emergency medicine physician member of the trauma team | Ultrasound training under the direct supervision of a FAST credentialed emergency medicine attending or trauma surgeon. |
| Flato et al. 2015 | SonoSite | M Turbo | Sector | 3-MHz | FEEL protocol | Specialists in intensive care | Formal training and certification in echocardiography (levels 2 and 3) |
| Gaspari et al. 2016 | NS | NS | NS | NS | Subxyphoid or parasternal long axis | EP | NS |
| Hayhurst et al. 2011 | NS | NS | NS | NS | Subxiphoid, parasternal, apical, combined | EP or specialist trainees | Level 1 competency in emergency ultrasound |
| Kim et al. 2016 | GE Healthcare | LOGIQ S6 | Phased array | 3.5-MHz | Subcostal or parasternal | EP or emergency resident | ≥3 years’ experience in emergency echocardiography |
| Lien et al. 2018 | Toshiba | SSA-550A | Curvilinear | 2-5-MHz | Subxiphoid | EP | 4-h focused training curriculum |
| Ozen et al. 2016 | Hitachi | Aloka Prosound 6 | Convex abdominal | 3.5-MHz | FATE protocol | EP | NS |
| Salen et al. 2001 | Pie Medical Scanner | 200 | Curvilinear | 3.5-MHz | Subxiphoid | EP | NS |
| General Electric | RT3200 Advantage II |
| Salen et al. 2005 | NS | NS | Curvilinear | 3.5-MHz | Transthoracic, subxiphoid, or the parasternal long- axis B-mode–view | EP | NS |
| Schuster et al. 2009 | Philips | EnVisor | Curvilinear | 5-MHz | Subxiphoid,  E-FAST | Surgery and emergency department residents | Ultrasound training |
| Tayal et al. 2003 | Shimadzu | SDU-400 | Modal | 3.5MHz | Subcostal, four chamber apical and parasternal views | Paramedic | NS |
| Tomruk et al. 2012 | Chison | 600M | Curvilinear | 7-MHz | Subxiphoid | EP | NS |

*Legend: EMS, Emergency Medical Service; EP, emergency physician; FATE, Focus Assessed Transthoracic Echo; NS, not specified;*

## **Table S2.** Methodology characteristics of the included studies.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Study*** | ***Inclusion criteria*** | ***Exclusion criteria*** | ***Outcome(s)*** | ***Finding(s)*** |
| Aichinger et al. 2012 | patients who were pulseless on initial evaluation on a convenience basis when a study physician was on shift | Patients younger than 18 years of age or victims of trauma | Return of spontaneous circulation (ROSC);  Arrival in the ED with spontaneous circulation (SHA);  Survival to hospital discharge (SHD) | 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. |
| Atkinson et al. 2019 | All adult cardiac arrest patients brought to the emergency department. | Patients under the age of 19 years, resuscitation was halted due to end-of-life decisions, or for the initiation of cardiac arrest as an inpatient. | Resuscitative effort as evidenced by length-of- resuscitation and frequency-of-interventions such as rates of administration of epinephrine and endotracheal intubation; ROSC; SHD. | Emergency department cardiac arrest patients with cardiac activity on PoCUS received longer resuscitation with higher rates of intervention as compared to those with negative findings or when no PoCUS was performed. Patients with cardiac activity on PoCUS had improved clinical outcomes as compared with patients not receiving PoCUS, and patients with no activity on PoCUS. |
| Backett et al. 2019 | All adult non-trauma cardiac arrest patients. | Patients under age 19 years, if their initial cardiac rhythm was shockable, if resuscitation was halted due to end-of-life decisions, or if no cardiac PoCUS was performed. | Assess whether the combined use of POCUS and ECG rhythm improves out- come prediction during ED cardiac arrest | The absence of cardiac activity on POCUS, or on both ECG and POCUS together, better predicts negative out- comes in cardiac arrest than ECG alone. No test reliably pre-dicted survival. |
| Blaivas et al. 2001 | All patients presenting in cardiac arrest, with ongoing CPR | Patients younger than 18 years of age. atients in arrest from trauma or obvious noncardiac causes | SHA | Patients presenting with cardiac standstill on bedside echocardiogram do not survive to leave the ED regardless of their electrical rhythms. This finding was uniform regardless of downtime. |
| Breitkreutz et al. 2010 | Patients with symptoms either of profound hypotension and/or severe dyspnoea/tachypnoea where judged by the EP to be in a peri- resuscitation state, and patients undergoing CP | Patients refused echocardiography. | To evaluate the feasibility of FEEL in pre-hospital resuscitation, the incidence of potentially treatable conditions detected, and the influence on patient management. | Application of ALS-compliant echocardiography in pre-hospital care is feasible and alters diagnosis and management in a significant number of patients. Further research into its effect on patient outcomes is warranted. |
| Cebicci et al. 2014 | 1) age over 18;  2) presence of arrival electrocardiogram of the patient;  3) cardiac USG performed at patient’s arrival. | Patients whose cardiac rhythm was not recorded, or a cardiac USG was not performed at arrival. | SHA | Usage of USG during CPR in order to evaluate cardiac contractility, increases the success rate of accomplished CPR |
| Chardoli et al. 2012 | Patients with PEA cardiac arrest (absence of pulse despite electrical activity in ECG) | NS | Death versus the return of spontaneous circulation (ROSC). | Bedside echocardiography can identify some reversible causes of PEA. However, there are no significant changes in survival outcome between the echo group and those with traditional CPR. |
| Chua et al. 2017 | Patients aged at least 21 years who arrived in the ED in cardiac arrest regardless of initial electrocardiographic rhythm. | Pregnant women and terminally ill patients where resuscitation efforts were deemed to be inappropriate or futile by the attending physician. | SHD | Bedside ultrasonography can be safely incorporated into the ACLS protocol. Detection of any reversible causes may alter management and improve survival in selected patients. |
| Cureton et al. 2012 | Trauma database and ED records of all trauma patients, presenting without a pulse, who were older than 18 years. | NS | SHA | 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 pulse- less 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. |
| Flato et al. 2015 | Patients who exhibited cardiac arrest in the ICU with initial asystole or PEA rhythm, aged older than 18 years and whose relatives signed an informed consent form | Lack of availability of one of the trained professionals to perform transthoracic echocardiography or the existence of a do not resuscitate recommendation. | ROSC, SHD | Transthoracic echocardiography conducted during cardiopulmonary resuscitation in ICU patients can be performed with- out interfering with care protocols and can contribute to the differential diagnosis of cardiac arrest and to the identification of a subgroup of patients with better prognosis. |
| Gaspari et al. 2016 | Patients in non-traumatic cardiac arrest with no pulse. | Patients with isolated ventricular fibrillation as their cardiac rhythm at the time of presentation;  Traumatic cardiopulmonary arrest;  Ultrasound system or physician experienced in bedside cardiac ultrasound not available  Resuscitative efforts halted due to end of life decisions or designations;  Attending physician of record declines enrollment of patient. | The percentage of patients that survive to hospital admission. The percentage of patients that survive to hospital discharge and ROSC. | The presence of cardiac activity at the initiation of ACLS in the ED was the variable most associated with survival following cardiac arrest. Point-of-care ultrasound during cardiac arrest can identify patients with higher likelihood of survival to hospital discharge, and can identify interventions outside of the standard ACLS algorithm. Point-of-care ultrasound should be integrated into ACLS algorithms. |
| Hayhurst et al. 2011 | Adult patients in cardiac arrest | NS | ROSC | It is concluded that echo in life support is feasible and that the scan findings may guide further interventions. |
| Kim et al. 2016 | All adult participants had OHCA. | Patients were excluded if they were <18 years old, arrested by trauma or drug intoxication, or could not receive echocardiography because of the absence of a well-trained senior emergency medicine resident or emergency medicine specialist who could perform periresuscitation echocardiography. | ROSC | In all patients with serial echocardiographic cardiac standstill ≥10 min, no patients had ROSC. These results displayed compelling test performance and discrimination ability for subjects with and without ROSC. Our study is suggestive, and it warrants further study. |
| Lien et al. 2018 | Adult non-traumatic, out-of-hospital cardiac arrest (OHCA) patients admitted to the ED were eligible for this study. | Patients with pregnancy, tracheostomy, neck tumors, neck operation, or do-not-resuscitate order. | ROSC | PoCUS confers diagnostic value and prognostic implications which potentially impact the efficacy and outcomes of CPR. |
| Ozen et al. 2016 | Cardiac arrest patients in pulseless electrical activity (PEA) and asystole. | Patients younger than 18 years of age, patients with thoracic deformities or injuries that prevents PoCUS examination and pregnant patients. | ROSC, SHD | No patient without ventricular wall motion in US survived to hospital discharge. Only 3 had ROSC in emergency department and only 1 survived to hospital admission. This data suggests no patient without ventricular wall motion before the onset of CPR survived to hospital discharge and this may be an indication to end resuscitative efforts early in these patients. |
| Salen et al. 2001 | Pulseless ED patients were enrolled in a prospective and nonconsecutive fashion. | NS | SHD | Both the sonographic detection of cardiac activity and ETCO2 levels higher than 16 torr were significantly associated with survival from ED resuscitation; how- ever, logistic regression analysis demonstrated that prediction of survival using capnography was not enhanced by the addition of cardiac sonography. |
| Salen et al. 2005 | Cardiac arrest patients in pulseless electrical activity (PEA) and asystole. | NS | ROSC | Results support the idea that transthoracic B-mode cardiac sonography can provide physicians involved in the resuscitation of pulseless patients with asystole and PEA with information that may help in making pertinent management decisions regarding cardiopulmonary resuscitation. |
| Schuster et al. 2009 | All patients presenting with or progressing to PEA during initial trauma resuscitation. | NS | SHD | The presence of PEA at any time during initial resuscitation is a grave prognostic indicator. FAST is a useful test to identify contractile cardiac activity. FAST may identify those patients with potential for survival. |
| Tayal et al. 2003 | Patients with pulseless electric activity or PEA-like states. | NS | SHA | Emergency echocardiography performed by emergency physicians in patients in PEA or near PEA states can detect pericardial effusions with correctable etiologies versus true PEA with ventricular standstill. |
| Tomruk et al. 2012 | Consecutive adults (aged ≥ 18 years) who presented in cardiac arrest | Terminal illness, drowning, hanging and severe hypothermia (< 30 °C). | ROSC | Ultrasonographic detection of cardiac activity may be useful in determining prognosis during cardiac arrest. Further studies are needed to elucidate the predictive value of ultrasonography in cardiac arrest patients. |

Legend: ACLS, advanced cardiovascular life support; CPR, cardiopulmonary resuscitation; ED, emergency department; FAST, focused abdominal sonography for trauma; ICU, Intensive care unit; PEA, pulseless electrical activity; PoCUS, point-of-care ultrasonography; ROSC, return of spontaneous circulation; SHA, survival to hospital admission; SHD, survival to hospital discharge;

## **Table S3.** Subgroup analyses of echocardiography for resuscitation outcomes prediction.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Subgroup** | **Sensitivity (95%CI)** | **Specificity (95%CI)** | **LR + (95%CI)** | **LR- (95%CI)** |
| ***Survival to hospital discharge*** | | | | |
| OHCA | 0.041 (0.018, 0.080) | 0.024 (0.001, 0.129) | 0.054 (0.004, 0.797) | 23.934 (4.989, 114.818) |
| IHCA | - | - | - | - |
| OHCA or IHCA | 0.062 (0.047, 0.078) | 0.021 (0.008, 0.042) | 0.047 (0.003, 0.798) | 20.442 (5.873, 71.153) |
| ***Return of spontaneous circulation*** | | | | |
| OHCA | 0.194 (0.139, 0.260) | 0.735 (0.589, 0.851) | 0.843 (0.532, 1.337) | 1.038 (0.902, 1.195) |
| IHCA | 0.166 (0.118, 0.223) | 0.554 (0.425, 0.677) | 0.443 (0.115, 1.696) | 1.498 (1.203, 1.864) |
| OHCA or IHCA | 0.238 (0.214, 0.264) | 0.507 (0.458, 0.557) | 0.096 (0.005, 1.932) | 105.678 (12.522, 891.896) |
| ***Survival to hospital admission*** | | | | |
| OHCA | 0.121 (0.093, 0.154) | 0.261 (0.173, 0.366) | 0.147 (0.048, 0.445) | 2.829 (1.756, 4.560) |
| IHCA | 0.04 (0.02, 0.08) | 0.34 (0.19, 0.53) | - | - |
| OHCA or IHCA | 0.138 (0.122, 0.155) | 0.201 (0.162, 0.243) | 0.167 (0.101, 0.275) | 3.494 (2.365, 5.161) |

Legend: CI, confidence interval; LR+, positive likelihood ratio; LR-, negative likelihood ratio.



## **Figure S1.** A summary table of review authors' judgements for each risk of bias item for each study.



## **Figure S2.** A plot of the distribution of review authors' judgements across studies for each risk of bias item.