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| Question |
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| **Population:** | Adults in any setting in cardiac arrest |
| **Intervention:** | A particular finding on point-of-care ultrasound during CPR |
| **Comparison:** | An external confirmatory test or process including some component other than point-of-care ultrasound |
| **Main outcomes:** | True positive, false positives, false negatives, true negatives |
| **Setting:** | 1. In hospital cardiac arrest (including operative setting)
2. Out of hospital cardiac arrest
 |

# ASSESsment

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| ProblemIs the problem a priority? |
| Judgement | Research evidence | Additional considerations |
| ○ No○ Probably no○ Probably yes● **Yes**○ Varies○ Don't know | One goal of cardiac arrest resuscitation is to identify reversible etiologies of circulatory collapse. Historical case details or physical exam findings may suggest certain etiologies and a limited number of bedside laboratory and radiographic tests are available for screening or to further inform the likelihood of a suspected etiology. Point-of-care ultrasound (POCUS) is a clinically-oriented sonographic assessment performed at the bedside by the treating clinician. POCUS is routinely used as a diagnostic screening tool in other acute care conditions such as trauma and undifferentiated shock and these paradigms have been adapted for use in cases of cardiac arrest with active cardiopulmonary resuscitation. There are at least seven proposed structured POCUS assessments during cardiac arrest (see below), which largely overlap and guide assessment for evidence of acute myocardial infarction, cardiac tamponade, massive pulmonary embolism, tension pneumothorax, aortic dissection, ruptured aortic aneurysm, and/or hypovolemia.The potential for misinterpretation during cardiac arrest may be under-recognized and the diagnostic test accuracy of POCUS used in this fashion is unknown. POCUS during cardiac arrest has become common in clinical practice without recognizing the potential pitfalls or potential for misinterpretation.Known frameworks to assess for etiologies of cardiac arrest:1. CAUSE (Hernandez 2008 198)
2. FEEL (Breitkreutz 2010 1527)
3. FEER (Breitkreutz 2007 S150)
4. PEA (Testa 2010 77)
5. SESAME (Lichtenstein 2015 471)
6. SHoC (Atkinson 2017 459)
7. CASA (Gardner 2018 729)
 | This topic was prioritized by the ALS Task Force based on the frequent use of point-of-care ultrasound (POCUS) during cardiac arrest despite the potential pitfalls for misinterpretation as a diagnostic tool. A comprehensive and rigorous summary of its intra-arrest diagnostic capabilities provides valuable information to both the resuscitation science community and bedside clinicians. |
| Desirable EffectsHow substantial are the desirable anticipated effects? |
| Judgement | Research evidence | Additional considerations |
| ○ Trivial○ Small○ Moderate○ Large● **Varies**○ Don't know | The primary desirable effect is to identify the underlying etiology of cardiac arrest with a high degree of sensitivity and/or specificity. In this manner, POCUS could serve as a screening tool (e.g. higher sensitivity) or as a confirmatory test for a suspected etiology (e.g. higher specificity). In either case, POCUS would ideally guide the use or withholding of specific therapies to target reversible etiologies of cardiac arrest.

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|  | Disease (+) (e.g. massive pulmonary embolism) | Disease (-)(e.g. No massive pulmonary embolism) |
| POCUS finding (+) (e.g. right ventricular enlargement present) | True Positive | False Positive |
| POCUS finding (-)(e.g. right ventricular enlargement absent) | False Negative | True Negative |

In one observational study of 48 subjects with high risk of bias (van der Wouw 1997 780), no sonographic finding had sufficiently narrow confidence intervals around point estimates of sensitivity to ‘rule out’ the etiology of cardiac arrest, but the certainty of this evidence is very low.In one observational study of 48 subjects with high risk of bias (van der Wouw 1997 780), sonographic findings tended to have higher point estimates of specificity or narrower confidence intervals around these point estimates to ‘rule in’ the etiology of cardiac arrest, but the certainty of this evidence is very low.

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| POCUS Findings | Disease (Autopsy and/or Clinical Adjudication) |
| Myocardial Infarction | Cardiac Tamponade | Pulmonary Embolism |
| Sensitivity (95% CI) | Specificity (95% CI) | Sensitivity (95% CI) | Specificity (95% CI) | Sensitivity (95% CI) | Specificity (95% CI) |
| Reduced contractility in a region of myocardium | 0.86(0.57 - 0.98) | 0.94(0.71-0.99) |  |  |  |  |
| Pericardial effusion with collapse of at least one cardiac chamber |  |  | 1.00(0.29-1.00) | 1.00(0.88-1.00) |  |  |
| Dilated right ventricle and right atrium with poor filling of left atrium and left ventricle |  |  |  |  | 1.00(0.16-1.00) | 0.97(0.82-0.99) |

Eleven observational studies with high risk of bias report the prevalence of a given POCUS finding and a description of subsequent imaging, procedural success, or post-procedural clinical outcomes that suggest confirmation of this POCUS finding. (Chua 2018 310; Hilberath 2014 926; Jung 2020 31; Lien 2018 125; Lin 2006 167; Memtsoudis 2006 1653; Shillcutt 2012 362; Tayal 2003 315; Varriale 1997 1717; Zengin 2012 68; Zengin 2016 105) These estimates of positive predictive value are restricted to small subgroups of subjects among the total number enrolled in each study.

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| **Study** **(Author Year Population)** | **Total sample in study (n)** | **Reference Standard** | **POCUS finding** | **TP** | **FP** | **Positive Predictive Value (95% CI)** |
| **Myocardial Infarction** |
| Lien 2018 OHCA | 177 | Invasive coronary angiography | Anterior wall akinesis (LV) | 1 | 0 | 100%(3-100%)  |
| Lin 2006 OR | 10 | Elevated serum troponin T values and/or ST-segment changes on ECG and/or coronary angiography | Segmental wall motion abnormality (TEE)  | 5 | 0 | 100%(48-100%)  |
| Memtsoudis 2006 OR | 21 | Surgical revascularization | Regional wall motion abnormality (TEE)  | 3 | 3 | 50%(12-88%)  |
| Memtsoudis 2006 OR | 21 | IABP placement | Regional wall motion abnormality (TEE)  | 1 | 5 | 17%(1-64%)  |
| Memtsoudis 2006 OR | 21 | Post-operative medical management of myocardial infarction | Regional wall motion abnormality (TEE)  | 2 | 4 | 33%(4-78%)  |
| Shillcutt 2012 OR | 4 | Percutaneous coronary intervention | Severe LV systolic and diastolic dysfunction | 1 | 0 | 100%(3-100%)  |
| Cardiac Tamponade |
| Hilberath 2014 OR | 6 | Aspirate from pericardiocentesis and/or performance of pericardial window and primary surgical repair | Tamponade (no specifics provided) (TEE)  | 4 | 0 | 100%(40-100%)  |
| Jung 2020OHCA | 158 | ROSC after pericardiocentesis | Tamponade (no specifics provided) (TEE)  | 3 | 1 | 75%(19-99%) |
| Lien 2018OHCA | 177 | ROSC after pericardiocentesis | RV compression with pericardial effusion | 2 | 6 | 25%(3-65%) |
| Lien 2018OHCA | 177 | Aspirate from pericardiocentesis | RV compression with pericardial effusion | 4 | 4 | 50%(16-84%)  |
| Memtsoudis 2006 OR | 21 | Pericardiotomy | Tamponade (no specifics provided) (TEE)  | 2 | 0 | 100%(16-100%)  |
| Zengin 2012OHCA & ED | 73 | ROSC after pericardiocentesis | Tamponade (no specifics provided) | 2 | 2 | 50%(7-93%) |
| Zengin 2016ED | 173 | ROSC after pericardiocentesis | Tamponade (no specifics provided) | 4 | 6 | 40%(12-74%) |
| **Pericardial Effusion** |
| Tayal 2003OHCA | 20 | Separate formal TTE | Anechoic fluid collection in pericardial sac | 5 | 3 | 63%(24-91%) |
| Tayal 2003OHCA | 20 | CT thorax | Anechoic fluid collection in pericardial sac | 3 | 5 | 38%(9-76%) |
| **Pulmonary Embolism** |
| Chua 2017OHCA | 104 | Right femoral DVT + ROSC after systemic fibrinolysis | D sign (straightening of interventricular septum) with dilated RV | 1 | 0 | 100%(3-100%) |
| Lin 2006 OR | 10 | Pulmonary embolectomy | Thrombus in RV or pulmonary artery (TEE)  | 2 | 0 | 100%(16-100%)  |
| Memtsoudis 2006 OR | 21 | Pulmonary embolectomy | Central thrombus (pulmonary artery, RA, or SVC) (TEE)  | 4 | 1 | 80%(28-99%)  |
| Varriale 1997IHCA | 20 | VQ scan | Occluded right pulmonary artery | 1 | 0 | 100%(3-100%) |
| **Aortic Dissection** |
| Zengin 2016ED | 173 | Intention to perform operative intervention  | Aortic dissection (no specifics provided) | 2 | 0 | 100%(16-100%) |
| **Hypovolemia** |
| Lin 2006 OR | 10 | Absolute decrease in hemoglobin of 9.5 g/dL despite transfusion of 15 units of whole blood and packed red cells  | Empty LV with large hemothorax (TEE)  | 1 | 0 | 100%(3-100%)  |
| Shillcutt 2012 OR | 4 | ROSC after transfusion and fluid resuscitation | Low end-diastolic volume | 1 | 0 | 100%(3-100%)  |
| Varriale 1997IHCA | 20 | ROSC after intravenous volume replacement | Pseudo-PEA with hypercontractile LV | 1 | 0 | 100%(3-100%) |

TP true positive. FP false positive. CI confidence interval. IHCA in-hospital cardiac arrest. OHCA out-of-hospital cardiac arrest. OR operating room. TEE transesophageal echocardiogram. RV right ventricle. RA right atrium. LA left atrium. LV left ventricle. TTE transthoracic echocardiogram. ED Emergency Department. CT computed tomography. ROSC return of spontaneous circulation. DVT deep vein thrombus. VQ ventilation perfusion. PEA pulseless electrical activity. | Preceding medical history, medication lists, recent interactions with the healthcare system, and case features of the cardiac arrest all inform the likelihood of different etiologies of cardiac arrest. Indirect observational evidence from the systematic review notes that POCUS “changed management” or “influenced care”, which suggests that POCUS yielded some diagnostic information. (Breitkreutz 2010 1527; Gaspari 2016 33; Gaspari 2017 103; Ketelaars 2018 406; Pyo 2021 62). However, it is not clear that these interventions improved clinical outcomes and the studies do not report data to estimate diagnostic test accuracy.Indirect observational evidence from a conference abstract estimated diagnostic test accuracy of POCUS against autopsy in 163 expired, adult, nontraumatic out-of-hospital cardiac arrest subjects with attempted resuscitation. POCUS identified cardiac tamponade (sensitivity 70% [95% CI 55-77%]; specificity 99% [95% CI 67-99%]), abdominal or thoracic aortic aneurysm (sensitivity 75% [95% CI 38-75%]; specificity 100% [95% CI 99-100%]), and pulmonary embolism (sensitivity 14% [95% CI 3-14%]; specificity 100% [95% CI 99-100%]) with higher specificity than sensitivity. (Matsuoka 2013 S91)Indirect evidence from other acute time-sensitivity conditions suggest that POCUS is more specific than sensitivity to identify the presence of pathology. A 2018 Cochrane review of the E-FAST (extended-focused assessment with sonography in trauma) exam estimated sensitivity 0.74 (95% CI 0.65-0.81) and specificity 0.96 (95% CI 0.94-0.98) to indicate thoracoabdominal injury after blunt trauma. A 2019 systematic review of POCUS estimated higher pooled specificity than sensitivity to indicate the type of shock (hypovolemic, cardiogenic, obstructive, distributive) among cases of undifferentiated shock. However, studies had high risks of bias and unclear descriptions of the index test and reference standard. |
| Undesirable EffectsHow substantial are the undesirable anticipated effects? |
| Judgement | Research evidence | Additional considerations |
| ○ Large○ Moderate○ Small○ Trivial● **Varies**○ Don't know | The primary undesirable effect is falsely interpreting sonographic findings or overestimating the diagnostic test accuracy of sonographic findings during resuscitation. This could either result in treating pathology that is not actually present (e.g. false positive) or not treating pathology that is actually present (e.g. false negative). Treating pathology that is not present may introduce additional morbidity or iatrogenic complications should subjects regain spontaneous circulation. However, post-cardiac arrest subjects are already highly complex patients that require a large burden of healthcare resources. The incremental amount of additional iatrogenic morbidity will vary based on the treatment administered. Not treating pathology that is present may inadvertently lead to declaration of futility or premature termination of resuscitation in patients that could have otherwise survived.We found wide variability in the confidence intervals around point estimates to diagnose etiologies of cardiac arrest. The prognostic implications of sonographic findings during cardiac arrest are at high risk of over-interpretation or providing false reassurance. Another undesirable effect is additional interruptions in otherwise continuous chest compressions (Huis In’t Veld 2017 95, Clattenburg 2018 65). Although there are several logistical strategies that may be used to mitigate this issue (Clattenburg 2018 69; Gaspari 2021 100094; Teran 2019 409). | Most clinicians perceive little additional ‘harm’ that can be conferred on subjects in active cardiac arrest and the ‘treatment threshold’ for a suspected etiology based on bedside assessment is typically low given the emergent and time-sensitive nature of the condition. |
| Certainty of evidenceWhat is the overall certainty of the evidence of effects? |
| Judgement | Research evidence | Additional considerations |
| ● **Very low**○ Low○ Moderate○ High○ No included studies | The certainty of evidence of the diagnostic test performance of POCUS during cardiac arrest was uniformly very low due to risk of bias, inconsistency, and imprecision.

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| --- | --- |
| US Findings | Disease (Autopsy and/or Clinical Adjudication) |
| Myocardial Infarction | Cardiac Tamponade | Pulmonary Embolism |
| Sensitivity  | Specificity | Sensitivity  | Specificity | Sensitivity  | Specificity |
| Reduced contractility in a region of myocardium | VERY LOW | VERY LOW |  |  |  |  |
| Pericardial effusion with collapse of at least one cardiac chamber |  |  | VERY LOW | VERY LOW |  |  |
| Dilated right ventricle and right atrium with poor filling of left atrium and left ventricle |  |  |  |  | VERY LOW | VERY LOW |

 | The certainty of evidence of the prognostic ability of point-of-care echocardiography is also uniformly very low due to risk of bias, inconsistency, and imprecision. (Reynolds 2020 56) |
| ValuesIs there important uncertainty about or variability in how much people value the main outcomes? |
| Judgement | Research evidence | Additional considerations |
| ○ Important uncertainty or variability○ Possibly important uncertainty or variability● **Probably no important uncertainty or variability**○ No important uncertainty or variability | None of the identified studies specifically address this question. | Clinicians tend to value diagnostic tests with sufficiently high sensitivity and/or specificity to be clinically useful. |
| Balance of effectsDoes the balance between desirable and undesirable effects favor the intervention or the comparison? |
| Judgement | Research evidence | Additional considerations |
| ○ Favors the comparison○ Probably favors the comparison○ Does not favor either the intervention or the comparison○ Probably favors the intervention○ Favors the intervention○ Varies● **Don't know** | No POCUS finding had sufficiently high and/or certain sensitivity or specificity to support its use as a sole diagnostic test to ‘rule out’ or ‘rule in’ the cause of cardiac arrest during resuscitation. POCUS findings tended to have higher point estimates of specificity or narrower confidence intervals around these point estimates. This pattern is also present in indirect evidence from other acute care conditions such as thoracoabdominal trauma and undifferentiated shock. In this manner, POCUS may ultimately be better utilized as a confirmatory test to prompt treatment aimed at specific reversible causes of cardiac arrest, but the wide variability in confidence intervals around point estimates and the very low certainty of evidence render these data difficult to interpret. Conversely, POCUS cannot exclude the presence of the same pathology with a sufficient degree of certainty. Thus, paradoxically, the presence of certain POCUS findings might encourage treatment directed at specific reversible causes of cardiac arrest, but absence of the same does not rule them out. Given the current available evidence, if POCUS is used in a diagnostic capacity during cardiac arrest, it should be considered an adjunct to inform the likelihood of a given cause of cardiac arrest based on clinical suspicion and other available information while acknowledging its limitations and potential for misinterpretation. POCUS should not be the sole criterion used to ‘rule out’ or ‘rule in’ a given cause of cardiac arrest. | These same considerations apply to POCUS as a prognostic tool during cardiac arrest. No sonographic finding had sufficiently or consistently high sensitivity to support its use as a sole criterion to terminate resuscitation. Some sonographic findings tended to have higher ranges of specificity than others for clinical outcomes. In this manner, point-of-care echocardiography might be useful to identify sonographic findings that support continuation of resuscitation. However, the presence or absence of any particular finding had insufficient sensitivity to use a sole criterion for termination of resuscitation. Thus, paradoxically, the presence of certain sonographic findings might encourage the continuation of resuscitative efforts, but absence of the same is not sufficient justification (in isolation) to cease resuscitative efforts.   |
| Resources requiredHow large are the resource requirements (costs)? |
| Judgement | Research evidence | Additional considerations |
| ○ Large costs○ Moderate costs○ Negligible costs and savings○ Moderate savings○ Large savings● **Varies**○ Don't know | None of the identified studies directly addressed this question, however, they do describe the prior training of the sonographers that collected data in each study. These range from more general descriptions (e.g. ‘structured training program – lectures with hands-on practice on simulated and real patients’) to specific details (e.g. 150 ultrasound exams, 20-hour didactic course, 10 proctored ultrasound exams on live patients, etc.). Some studies note that all sonographers were cardiologists or anesthesiologists with formal echocardiogram training. Additionally, some studies specify the presence of a continuous quality assurance process on all ultrasound exams. If an institution has an existing POCUS program, the incremental resource requirements will be small. If an institution does not have an existing POCUS program, we expect the incremental resource requirements to start a new program and implement it in the setting of cardiac arrest will be at least moderate. | Point-of-care ultrasound is available in many Emergency Departments although there may be some global disparities. We expect additional fixed and/or recurring equipment and training costs to be low. Introducing point-of-care ultrasound to new inpatient or prehospital settings carries new fixed and recurring equipment and training costs. |
| Certainty of evidence of required resourcesWhat is the certainty of the evidence of resource requirements (costs)? |
| Judgement | Research evidence | Additional considerations |
| ○ Very low○ Low○ Moderate○ High● **No included studies** | None of the identified studies specifically address this question. | Unknown |
| Cost effectivenessDoes the cost-effectiveness of the intervention favor the intervention or the comparison? |
| Judgement | Research evidence | Additional considerations |
| ○ Favors the comparison○ Probably favors the comparison○ Does not favor either the intervention or the comparison○ Probably favors the intervention○ Favors the intervention○ Varies● **No included studies** | None of the identified studies specifically address this question. | Considerations of cost are noted above under “Resources required”. The effectiveness of diagnosing the etiology of cardiac arrest with point-of-care ultrasound during cardiac arrest is currently uncertain.  |
| EquityWhat would be the impact on health equity? |
| Judgement | Research evidence | Additional considerations |
| ○ Reduced○ Probably reduced○ Probably no impact○ Probably increased○ Increased○ Varies● **Don't know** | None of the identified studies specifically address this question. | Due to fixed and recurring equipment costs, there may be global or regional discrepancies in the availability of point-of-care ultrasound during cardiac arrest. |
| AcceptabilityIs the intervention acceptable to key stakeholders? |
| Judgement | Research evidence | Additional considerations |
| ○ No○ Probably no○ Probably yes○ Yes○ Varies● **Don't know** | None of the identified studies specifically address this question. | POCUS is commonly used in the Emergency Department in many regions to guide prognostic decisions during cardiac arrest. It is difficult to estimate the prevalence of use among cases of cardiac arrest treated in the Emergency Department, but the existence of multiple professional society statements and proposed sonographic protocols support its wide acceptance.Introducing POCUS to new inpatient or prehospital settings may generate new challenges to acceptability in those clinical settings. |
| FeasibilityIs the intervention feasible to implement? |
| Judgement | Research evidence | Additional considerations |
| ○ No○ Probably no○ Probably yes○ Yes○ Varies● **Don't know** | None of the identified studies specifically address this question.A central component to the operational feasibility of diagnosing etiologies of cardiac arrest with POCUS is a sufficient reference standard. An acceptable reference standard likely varies by target condition. Another key issue is sufficient inter-rater reliability of POCUS. No study reported inter-rater reliability of the POCUS index test in the context of diagnosis. | POCUS is already commonly used in the Emergency Department in many regions to guide treatment decisions during cardiac arrest. It is difficult to estimate the prevalence of use among cases of cardiac arrest treated in the Emergency Department, but the existence of multiple professional society statements and proposed sonographic protocols support its wide acceptance.Introducing POCUS to new inpatient or prehospital settings may generate new challenges to feasibility in those clinical settings.Indirect evidence from two observational studies of POCUS as a prognostic tool during cardiac arrest estimate the inter-rater reliability to classify cardiac motion with Kappa 0.63 and 0.93. (Flato 2015 1; Gaspari 2016 33) |

# Summary of judgements

|  | **Judgement** |
| --- | --- |
| **Problem** | No | Probably no | Probably yes | **Yes** |  | Varies | Don't know |
| **Desirable Effects** | Trivial | Small | Moderate | Large |  | **Varies** | **Don't know** |
| **Undesirable Effects** | Large | **Moderate** | Small | Trivial |  | **Varies** | **Don't know** |
| **Certainty of evidence** | **Very low** | Low | Moderate | High |  |  | No included studies |
| **Values** | Important uncertainty or variability | Possibly important uncertainty or variability | **Probably no important uncertainty or variability** | No important uncertainty or variability |  |  |  |
| **Balance of effects** | Favors the comparison | Probably favors the comparison | Does not favor either the intervention or the comparison | Probably favors the intervention | Favors the intervention | Varies | **Don't know** |
| **Resources required** | Large costs | Moderate costs | Negligible costs and savings | Moderate savings | Large savings | **Varies** | Don't know |
| **Certainty of evidence of required resources** | Very low | Low | Moderate | High |  |  | **No included studies** |
| **Cost effectiveness** | Favors the comparison | Probably favors the comparison | Does not favor either the intervention or the comparison | Probably favors the intervention | Favors the intervention | Varies | **No included studies** |
| **Equity** | Reduced | Probably reduced | Probably no impact | Probably increased | Increased | Varies | **Don't know** |
| **Acceptability** | No | Probably no | **Probably yes** | Yes |  | Varies | **Don't know** |
| **Feasibility** | No | Probably no | **Probably yes** | Yes |  | Varies | **Don't know** |

# Type of recommendation

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| --- | --- | --- | --- | --- |
| **Strong recommendation against the intervention** | **Conditional recommendation against the intervention** | **Conditional recommendation for either the intervention or the comparison** | **Conditional recommendation for the intervention** | **Strong recommendation for the intervention** |
| ○  | ●  | ○  | ○  | ○  |

# Conclusions

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| Recommendation |
| We suggest against routine use of point of care ultrasound during CPR to assessfor reversible causes of cardiac arrest (weak recommendation, very low-certainty evidence).We suggest that if point of care ultrasound can be performed by experiencedpersonnel without interrupting CPR, it may be considered as an additional diagnostictool when clinical suspicion for a specific reversible cause is present (weak recommendation, very low-certainty evidence).Any deployment of diagnostic point of care ultrasound during CPR should be carefully considered and weighed against the risks of interrupting chest compressions and misinterpreting the sonographic findings (good practice statement). |
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| Justification |
| This topic was prioritized by the ALS Task Force based on the frequent utilization of point-of-care ultrasound during cardiac arrest without recognizing the potential pitfalls for misinterpretation as a diagnostic tool. A comprehensive and rigorous summary of its intra-arrest diagnostic capabilities provides valuable information to both the resuscitation science community and bedside clinicians.In making these recommendations, the ALS Task Force considered the following: * The inconsistent definitions and terminology used for sonographic evidence of specific causes of cardiac arrest was the primary source of clinical heterogeneity. We strongly encourage the establishment of uniform definitions and terminology to describe sonographic findings of reversible causes of cardiac arrest.
* The identified studies suffer from high risk of bias related to selection bias and ascertainment bias. Additionally, the logistics of cardiac arrest resuscitation introduce potential for spectrum bias (when diagnostic test accuracy is influenced by the case mix of subjects and/or prevalence of the target condition) and verification bias (when availability or use of the reference standard is influenced by ‘test positive’ or ‘test negative’ status). Verification bias was present in all but one of the included studies, largely restricting contingency tables to positive predictive value. The evidence supporting use of POCUS as a diagnostic tool is uniformly of very low certainty. Clinicians should cautiously interpret sonographic findings during cardiac arrest in light of these limitations. We strongly encourage subsequent investigations of POCUS during cardiac arrest to employ methodology that mitigates these risks of bias. This includes enrolling a consecutive, prospective sample; utilizing clear definitions of the index test, credentials of the sonographer, and testing interval; selecting an objective, uniform reference standard; and blinding appropriately.
* No included studies reported estimates of inter-rater reliability. The influence of acoustic window, sonographer training/experience, and particular pathology in question on inter-rater reliability is also unknown. As POCUS matures as a field, there are now validated image quality rating scales to promote standardization of assessment. (Gaspari 2021 100097).
* No POCUS finding had sufficient sensitivity to be used as sole criterion to ‘rule out’ the cause of cardiac arrest, but the certainty of this evidence is very low.
* POCUS findings had higher point estimates and/or narrower confidence intervals of specificity to ‘rule in’ certain causes of cardiac arrest, but this evidence is from a single study and of very low certainty.
* The diagnostic utility of POCUS is affected by the clinical context. For example, a post-operative cardiac surgery patient with acute cardiac arrest has given pre-test probabilities for specific causes such as cardiac tamponade, pulmonary embolism, or acute hemorrhage. Conversely, the diagnostic utility of POCUS may be more limited in the context of undifferentiated cardiac arrest in the out-of-hospital setting.
* Clinicians should be cautious about introducing additional interruptions in chest compressions with a transthoracic approach to point-of-care echocardiography during cardiac arrest. (Huis In’t Veld 2017 95, Clattenburg 2018 65) Several logistical strategies mitigate these concerns, including use of transesophageal echocardiography. (Clattenburg 2018 69; Gaspari 2021 100094; Teran 2019 409).
* The task force noted several pitfalls and logistical questions around the feasibility of diagnosing a myocardial infarction in the context of pulseless electrical activity or similar low-flow states. In this context, wall motion abnormalities may result from the ischemia of a low-flow state or a pre-existing infarct, as opposed to a *de novo* myocardial infarction.
* Not treating a reversible cause of cardiac arrest risks failure of resuscitation or more severe post-cardiac arrest injury. Treating an incorrect diagnosis suggested by POCUS risks iatrogenic injury or delayed identification of the true underlying cause.
* POCUS is subject to the availability of equipment and skilled operators. Starting a new POCUS program requires material fixed and recurring costs and resources to obtain equipment and train clinicians. An existing POCUS program requires fewer incremental resources to be used in the context of cardiac arrest. In either case, the development and maintenance of the requisite skill sets both obtain and interpret images under the compromised conditions of cardiac arrest presents an additional burden for a POCUS program. The task force expects that most diagnostic applications of POCUS will occur in a hospital-based setting as opposed to the prehospital setting.
* Given the items listed, many task force members advocated for restriction of diagnostic applications of POCUS to circumstances in which the clinical suspicion for a readily treatable abnormality is high and justifies interruption of CPR. In such instances, the time allotted for imaging should be as brief as possible.
* The prognostic utility of POCUS to predict clinical outcomes is covered in a separate PICOST (https://costr.ilcor.org/document/prognostication-with-point-of-care-echocardiography-during-cardiac-arrest-task-force-systematic-review-costr).
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| Subgroup considerations |
| We planned *a priori* subgroup analysis of shockable and nonshockable initial cardiac rhythm. However, risk of bias and other confounding precluded the ability to pool data or conduct meaningful analyses of these subgroups. |

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| Implementation considerations |
| The lack of uniform definitions and terminology to describe sonographic findings during cardiac arrest, the high risks of bias and confounding in the existing literature, the uncertainty of inter-rater reliability, and the material risks of interrupting CPR all represent implementation challenges for POCUS assessment for reversible causes during cardiac arrest. We distinguish between clinical contexts of undifferentiated cardiac arrest when POCUS is employed to screen for reversible causes, and clinical contexts of cardiac arrest in which there is material pre-test suspicion for a specific reversible cause that could be confirmed by POCUS. POCUS findings tended to have higher point estimates of specificity or narrower confidence intervals around these point estimates. This pattern is also present in indirect evidence from other acute care conditions such as thoracoabdominal trauma and undifferentiated shock. In this manner, POCUS may ultimately be better utilized as a confirmatory test to prompt treatment aimed at reversible causes of cardiac arrest, but the wide variability in confidence intervals around point estimates and the very low certainty of evidence render these data difficult to interpret.Otherwise, POCUS is already commonly used in the Emergency Department to guide treatment decisions during cardiac arrest. It is difficult to estimate the prevalence of use among cases of cardiac arrest treated in the Emergency Department, but the existence of multiple professional society statements and proposed sonographic protocols support its wide acceptance.Introducing POCUS to new inpatient or prehospital settings may generate new implementation challenges. |

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| Monitoring and evaluation |
| We encourage the use of robust quality assurance programs with expert oversight to ensure valid and reliable interpretation of sonographic findings, and to measure the contributions of POCUS to interruptions in CPR. |

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| Research priorities |

There are no studies of the diagnostic accuracy of point-of-care ultrasound during cardiac arrest with methodology that sufficiently minimizes risk of bias, especially selection bias, ascertainment bias, and verification bias.

There are no uniform definitions and terminology to describe sonographic findings of reversible causes of cardiac arrest or the associated reference standards.

The inter-rater reliability of POCUS diagnostic findings during cardiac arrest is unknown.

No identified studies provided data on resource requirements, cost-effectiveness, equity, acceptability, or feasibility.

Some studies reported a ‘change in management’ driven by the diagnostic use of POCUS, but these assertions are not well characterized or quantified. Furthermore, it is unknown whether these ‘changes in management’ led to improved clinical outcomes.

**References**

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