Notable Grand Rounds

of the

Michael & Marian Ilitch
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Wayne State University
School of Medicine

Detroit, Michigan, USA

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UPDATES AND CONTROVERSIES IN CARDIOPULMONARY RESUSCITATION

January 28, 2026

About Notable Grand Rounds

These assembled papers are edited transcripts of didactic lectures given by mainly senior residents, but also some distinguished attending and guests, at the Grand Rounds of the Michael and Marian Ilitch Department of Surgery at the Wayne State University School of Medicine.

Every week, approximately 50 faculty attending surgeons and surgical residents meet to conduct postmortems on cases that did not go well. That "Mortality and Morbidity" conference is followed immediately by Grand Rounds.

This collection is not intended as a scholarly journal, but in a significant way it is a peer reviewed publication by virtue of the fact that every presentation is examined in great detail by those 50 or so surgeons.

It serves to honor the presenters for their effort, to potentially serve as first draft for an article for submission to a medical journal, to let residents and potential residents see the high standard achieved by their peers and expected of them, and by no means least, to contribute to better patient care.

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Updates and Controversies in Cardiopulmonary Resuscitation

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January 28, 2026

Editor's Note: This manuscript is derived from a Grand Rounds presentation delivered to general surgeons, residents, and students. The original lecture was designed to review emerging evidence, stimulate discussion, and highlight areas of uncertainty in contemporary cardiopulmonary resuscitation practice. In adapting the material for publication, the narrative has been reframed to emphasize evidentiary context, physiologic rationale, and guideline alignment, while preserving the clinically pragmatic orientation of the original presentation. The goal is not to propose definitive practice mandates, but to critically examine evolving data that challenge traditional heuristics and to support informed, system-aware decision-making during cardiac arrest..

1. Introduction

Cardiopulmonary resuscitation (CPR) has evolved through centuries of empirical observation, physiologic experimentation, and increasingly sophisticated technological augmentation. One of the earliest documented examples of electrical resuscitation dates to 1775, when the Danish physician Peter Christian Abildgaard observed that a hen rendered lifeless by electrical shock could be revived with a subsequent shock applied to the chest. Remarkably, the animal survived repeated iterations of this experiment and later resumed normal biological function, including egg-laying. While primitive by modern standards, this observation established a foundational principle that persists today: cardiac arrest is not necessarily synonymous with irreversibility, and timely intervention can restore life even after apparent cessation of vital signs.

Despite dramatic advances in defibrillation technology, pharmacologic therapy, and post–

cardiac arrest care, the core elements of CPR remain grounded in rapid recognition, uninterrupted chest compressions, and early treatment of reversible causes. Yet many aspects of resuscitation practice continue to rely on subjective assessments or heuristics that are increasingly challenged by empirical evidence. Among these, the manual pulse check—long regarded as a fundamental step in cardiac arrest evaluation—has come under particular scrutiny.

In parallel, point-of-care ultrasound (POCUS) has emerged as a potentially transformative tool during resuscitation, offering real-time physiologic information that may surpass traditional bedside assessments. Similarly, extracorporeal cardiopulmonary resuscitation (ECPR) has expanded the conceptual boundaries of what constitutes "refractory" cardiac arrest, while thrombolytic therapy for pulmonary embolism–associated arrest raises unresolved questions regarding the optimal duration of resuscitative efforts.

This review examines three contemporary areas of controversy in CPR practice: the role of ultrasound during resuscitation, the evidence supporting ECPR, and the appropriate duration of CPR following thrombolysis for presumed massive pulmonary embolism. These topics are contextualized within current guideline recommendations, including key updates from the 2025 American Heart Association (AHA) Advanced Cardiac Life Support (ACLS) guidelines (American Heart Association, 2025). Together, they illustrate a broader shift in resuscitation medicine—from reliance on tactile and temporal markers toward physiology-driven, technology-assisted decision-making.

2. Limitations of Manual Pulse Checks in Cardiac Arrest

Manual palpation of a central pulse has traditionally been used to determine the presence or absence of circulation during cardiac arrest. In practice, this assessment is intended to be rapid, reliable, and decisive, guiding the initiation or cessation of chest compressions. However, accumulating evidence demonstrates that manual pulse checks are neither consistently accurate nor efficiently performed, even by trained medical professionals.

One of the earliest systematic evaluations of pulse-check accuracy was published in *Critical Care Medicine* in 2000 (Dick et al., 2000). In this study, 206 emergency medical technicians and paramedics were asked to assess carotid pulses in 16 patients undergoing coronary artery bypass grafting who were alternately placed on pulsatile or nonpulsatile cardiopulmonary bypass. All patients had previously documented palpable carotid pulses. Despite this controlled setting, pulselessness was not recognized for an entire minute in over 10% of encounters, and fewer than 2% of pulseless patients were correctly identified within 10 seconds. Conversely, nearly half of patients with a pulse were incorrectly declared pulseless, potentially prompting unnecessary chest compressions or escalation of resuscitative efforts. The median time to a decision exceeded 24 seconds—well beyond the recommended duration for pulse assessment during CPR (see Table 1 on page. 3).

Concerns regarding the reliability of pulse checks are not limited to prehospital providers. A more recent prospective observational study published in *Resuscitation* in 2021 evaluated pulse assessment accuracy in a high-volume tertiary emergency department managing 450–500 cardiac arrests annually (Yilmaz et al., 2021). In this study, 10 medical assistants with at least two years of emergency department experience performed alternating carotid and femoral pulse checks during 1,289 pulse assessments in 102 patients. Their findings echoed earlier concerns. Femoral pulses were falsely identified as present in 11 encounters in which objective criteria for return of spontaneous circulation (ROSC) were absent. Similarly, carotid pulses were falsely perceived in 10 such encounters. In each case, CPR would have been inappropriately terminated based on manual assessment alone.

Importantly, these studies highlight “can’t-miss” scenarios—situations in which erroneous pulse detection leads to premature cessation of resuscitation in patients without effective circulation. Such errors carry profound clinical consequences, particularly in low-flow states where weak arterial pulsations, vasopressor-induced vascular tone, or operator expectation may confound tactile perception.

The limitations of manual pulse checks are further compounded by physiologic factors intrinsic to cardiac arrest. During CPR, forward flow is minimal, arterial pressures are low, and pulse pressure may be insufficient to generate a reliably palpable waveform. Environmental distractions, time pressure, and cognitive bias further degrade assessment accuracy. Collectively, these factors challenge the assumption that palpation is an adequate surrogate for true perfusion.

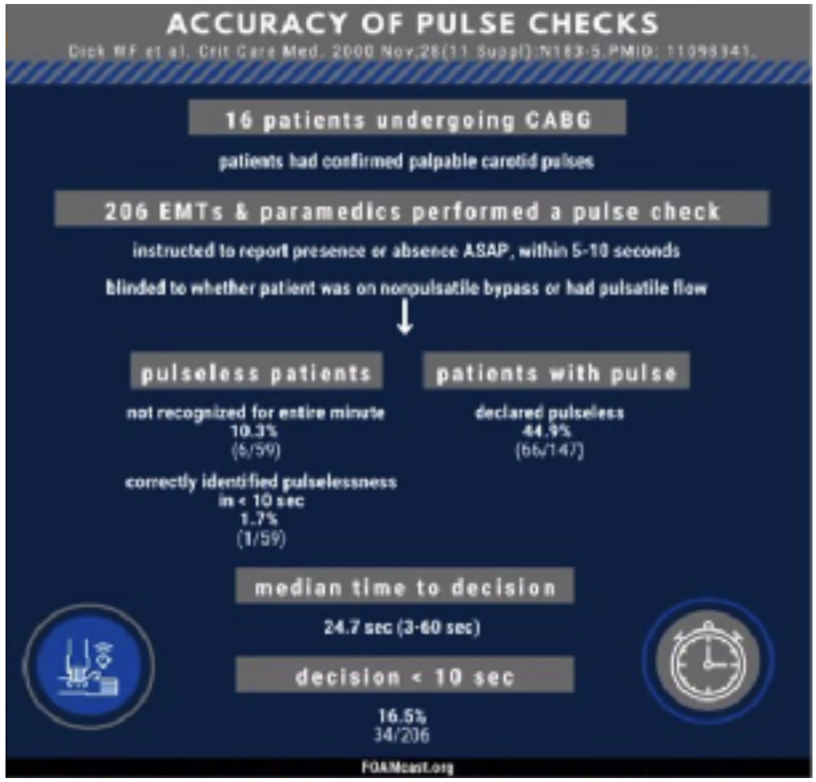

Table 1. Accuracy and timing of manual carotid pulse checks in controlled surgical patients. *Source*: Ref. 1.

These observations have prompted renewed interest in alternative strategies for determining ROSC, including capnography, electrocardiographic patterns, and, increasingly, ultrasound-based assessments (Yilmaz et al., 2021). As resuscitation science advances, reliance on subjective tactile assessment alone appears increasingly misaligned with both physiologic reality and empirical evidence.

3. Ultrasound in Cardiopulmonary Resuscitation

3.1. Ultrasound-Assisted Pulse Checks

Given the documented unreliability of manual pulse checks, ultrasound has emerged as an appealing alternative for determining the presence of circulation during cardiac arrest. Rather than inferring perfusion through tactile sensation, ultrasound allows direct visualization of vascular flow or cardiac activity, offering a more objective assessment during pulse checks.

One practical application is the use of color Doppler ultrasound to assess femoral arterial flow during pulse checks. In this approach, the ultrasound probe is positioned over the femoral neurovascular bundle, allowing simultaneous visualization of the femoral artery and vein. Activation of color Doppler enables detection of pulsatile arterial flow, which may be present even when manual palpation fails. Technical considerations are important: when the Doppler beam is oriented at a near-perfect 90-degree angle to blood flow, opposing color signals may cancel each other, producing a falsely absent signal due to basic Doppler physics. Minor probe angulation adjustments typically resolve this issue.

Beyond its diagnostic utility, Doppler-based pulse assessment offers an important team-level advantage. Resuscitation is inherently collaborative, and ultrasound provides a shared visual reference that can be interpreted simultaneously by multiple team members. This visual confirmation may reduce ambiguity during pulse checks and help synchronize decision-making during high-stress moments of resuscitation (Gottlieb, 2023).

3.2 Identifying Return of Spontaneous Circulation Using Multimodal Criteria

Determining return of spontaneous circulation (ROSC) during CPR requires accurate, rapid, and reproducible criteria. Manual pulse detection alone fails to meet these standards, prompting evaluation of alternative physiologic markers. Three modalities have been studied most extensively: end-tidal carbon dioxide ($ETCO_2$), electrocardiographic rhythm analysis, and cardiac ultrasound.

Among these, $ETCO_2$ has the strongest evidentiary support. Numerous studies demonstrate that a sustained rise in $ETCO_2$—typically above 10–20 mmHg—is highly sensitive for ROSC, reflecting improved pulmonary blood flow and cardiac output (Yilmaz et al., 2021). Lower thresholds improve sensitivity but reduce specificity, while sustained values above 20 mmHg are strongly suggestive of effective circulation.

Electrocardiographic rhythm analysis offers additional information but is limited by the frequent presence of electrical activity without mechanical output. Organized rhythms containing consecutive QRS complexes, with or without visible P waves, may occur in the absence of meaningful perfusion and therefore lack sufficient reliability as sole indicators of ROSC.

Cardiac ultrasound provides a direct assessment of mechanical cardiac activity. When used for ROSC determination, specific criteria are critical. True ROSC on ultrasound requires coordinated myocardial wall motion accompanied by valve opening, indicating forward flow. Isolated fibrillatory myocardial movement—often seen after epinephrine administration—should not be interpreted as ROSC, as it lacks hemodynamic significance. Similarly, passive swirling of intracardiac blood without myocardial contraction does not meet criteria for effective circulation.

	Cardiac beat in CUS	Organised rhythm	$ETCO_2$ increase
	% (CI)	% (CI)	% (CI)
Sensitivity	100	100	100
Specificity	99.2 (98.4–99.6)	83.9 (81.7–86)	99.5 (98.9–99.8)
Positive predictive value 91.8 (85.8– 95.4	37.2 (34.2–40.3)	94.9 (83.4–97.7)	
Accuracy	99.2 (98.6–99.6)	85.3 (83.3–87.2)	99.5 (99–99.8)

Table 2. Sensitivity, specificity, positive predictive value, and accuracy of ROSC identification strategies. *Source*: Ref. 2.

In a prospective observational study comparing pulse checks with objective ROSC criteria, cardiac ultrasound demonstrated high accuracy and positive predictive value when these strict criteria were applied (Yilmaz et al., 2021; see Table 2 on p. 4).

3.3 Prognostic Significance of Cardiac Activity on Ultrasound During CPR

Beyond pulse confirmation, cardiac ultrasound may offer prognostic insight during resuscitation. A large multicenter observational study published in *Resuscitation* in 2016 evaluated the association between ultrasound-detected cardiac activity and outcomes in patients with pulseless electrical activity or asystole (Resuscitation, 2016). This study included 793 patients across 20 emergency departments in the United States and Canada and specifically excluded patients who achieved ROSC within five minutes, focusing on prolonged resuscitation efforts.

Point-of-care ultrasound examinations were performed using a subxiphoid view immediately after intubation and during subsequent pulse checks. To prevent interruptions in chest compressions, image acquisition was performed by a designated ultrasound operator separate from the code leader, with strict time limits enforced. Ultrasound clips were obtained in approximately five seconds and reviewed during the subsequent compression cycle.

Cardiac activity in this study was defined broadly as any myocardial movement, excluding isolated blood swirling. Patients with ultrasound-detected cardiac activity had significantly higher odds of ROSC, survival to hospital admission, and survival to hospital discharge compared with those without detectable activity. Specifically, the odds ratio for ROSC was 2.8, with progressively higher odds observed for downstream outcomes. Importantly, patients with cardiac activity also underwent longer resuscitation attempts, suggesting that ultrasound findings influenced clinician decision-making regarding continuation of CPR.

Safety endpoints were also evaluated. Epinephrine dosing intervals remained within guideline-recommended ranges, and ultrasound image acquisition did not meaningfully prolong pauses in chest compressions. These findings suggest that when performed within a structured protocol, ultrasound can provide prognostic information without compromising CPR quality.

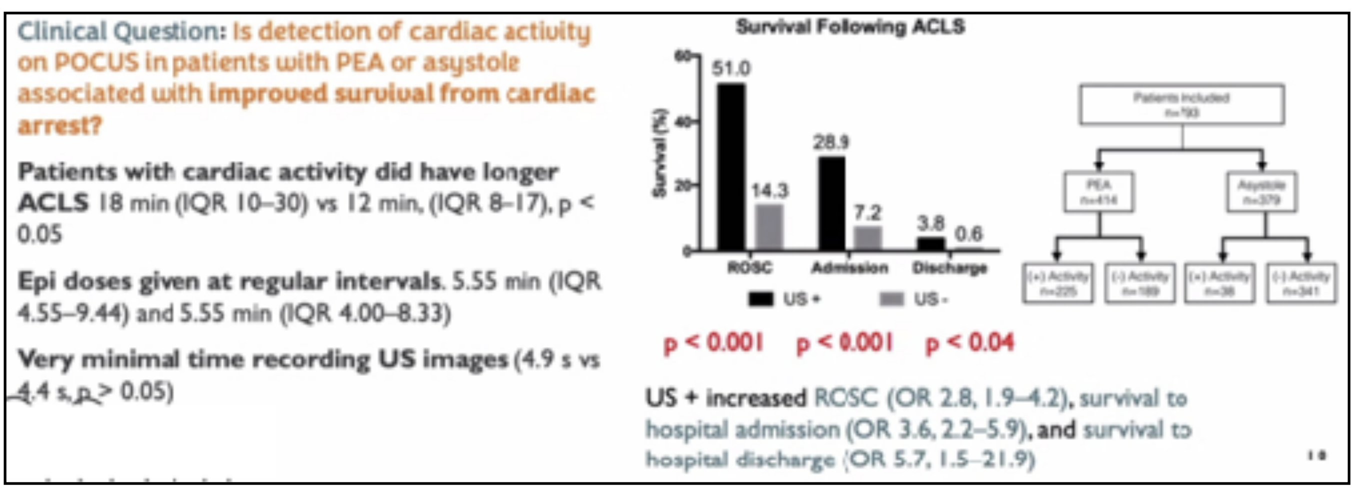

Fig. 1. Survival outcomes stratified by ultrasound-detected cardiac activity during CPR. *Source*: Ref 4.

3.4 Ultrasound-Guided Non-ACLS Interventions

Ultrasound during CPR may also facilitate identification of reversible causes of cardiac arrest and guide non-ACLS interventions. In the same multicenter cohort, 34 patients were found to have pericardial effusions during resuscitation. Pericardiocentesis was attempted in 13 of these patients, with a survival to hospital discharge rate of approximately 15%—substantially higher than the roughly 1% survival observed in the overall cohort (Resuscitation, 2016). Although absolute survival remained low, these findings underscore the potential impact of identifying tamponade during arrest.

Ultrasound was also used to identify suspected massive pulmonary embolism. Fifteen patients met criteria based on either visualization of clot-in-transit or echocardiographic features consistent with acute right heart strain. Survival rates in this subgroup exceeded those of the broader cohort, particularly among patients who received thrombolytic therapy.

Clot-in-transit represents one of the most specific sonographic findings for pulmonary embolism and, when visualized, provides compelling justification for targeted intervention.

However, caution is warranted when interpreting right ventricular dilation during cardiac arrest. Experimental models demonstrate that right ventricular dilation can develop rapidly during CPR due to redistribution of blood into the venous system and right heart, independent of pulmonary embolism. Animal studies show that such dilation may occur within three cycles of CPR, limiting the specificity of this finding when used in isolation. Additional features—such as free wall thickness suggesting chronic remodeling, clot visualization, or corroborating clinical context—are necessary to strengthen diagnostic confidence.

3.5 Guideline Perspectives on Ultrasound Use During CPR

Guideline statements reflect both the promise and uncertainty surrounding ultrasound during resuscitation. The 2021 European Resuscitation Council guidelines emphasize that intra-arrest ultrasound should be performed only by skilled operators and must not cause additional or prolonged interruptions in chest compressions. The guidelines acknowledge its utility in diagnosing treatable causes of arrest, such as cardiac tamponade and pneumothorax, while explicitly cautioning against using right ventricular dilation alone to diagnose massive pulmonary embolism or using myocardial contractility as the sole criterion for terminating CPR (European Resuscitation Council, 2021).

American Heart Association guidelines similarly adopt a cautious stance. The 2015 AHA guidelines state that the use of point-of-care ultrasound during adult cardiac arrest to diagnose reversible causes or assess cardiac function is “not well established,” reflecting limited high-quality randomized data (American Heart Association, 2015). The 2025 update maintains this position, classifying ultrasound use during resuscitation as supported by low-to-moderate quality evidence, while recognizing its growing role in experienced hands (American Heart Association, 2025).

Together, these recommendations reinforce a central principle: ultrasound may enhance resuscitation when integrated thoughtfully into a structured workflow, but it must never compromise the primacy of uninterrupted, high-quality chest compressions.

4. Extracorporeal Cardiopulmonary Resuscitation

4.1 Early Single-Center Experience: The CHEER Trial

Extracorporeal cardiopulmonary resuscitation has emerged as a potential strategy for patients with refractory cardiac arrest, defined by failure to achieve ROSC despite prolonged conventional resuscitation. One of the earliest prospective evaluations of this approach was the CHEER trial, published in *Resuscitation* in 2015 (CHEER Trial Investigators, 2015).

The CHEER trial was a single-center prospective pilot study examining a bundled resuscitation strategy that combined mechanical CPR, therapeutic hypothermia, extracorporeal membrane oxygenation (ECMO), and early coronary reperfusion. Inclusion criteria were deliberately restrictive: patients were required to be between 18 and 65 years of age, have a presumed cardiac etiology of arrest, and demonstrate refractory cardiac arrest lasting longer than 30 minutes. Two enrolled patients achieved ROSC during cannulation and therefore never received ECMO.

Despite the prolonged duration of arrest prior to extracorporeal support, outcomes were notable. Among patients with out-of-hospital cardiac arrest, approximately one-third survived, while 60% of those with in-hospital cardiac arrest survived. The primary outcome—survival with good neurologic recovery, defined as a Cerebral Performance Category (CPC) score of 1 or 2—was achieved in 54% of patients. Secondary outcomes included ROSC in over 90% of cases and survival to hospital discharge in more than half of the cohort.

Importantly, all survivors demonstrated favorable neurologic outcomes, underscoring the potential of ECPR not merely to prolong life but to preserve meaningful neurologic function. Median time from collapse to initiation of ECMO was approximately 40 minutes, and the average duration of extracorporeal support was three days, emphasizing the importance of rapid cannulation and coordinated systems of care.

4.2 Randomized Evidence: The ARREST Trial

Following encouraging early data, the ARREST trial sought to evaluate ECPR within a randomized framework. Published in *The Lancet* in 2020, this phase 2, single-center, open-label randomized controlled trial compared ECMO-assisted CPR with standard ACLS in patients with refractory ventricular fibrillation or pulseless ventricular tachycardia (ARREST Investigators, 2020).

Eligible patients were between 18 and 75 years of age, had a presumed cardiac etiology of arrest, and failed to achieve ROSC after three defibrillation attempts. Thirty patients were randomized equally to receive either ECPR or continued conventional ACLS. Survival to hospital discharge—the primary outcome—occurred in 43% of patients in the ECPR group compared with 7% in the standard ACLS group. This corresponded to an absolute risk reduction of 36% and a number needed to treat of three.

Neurologic outcomes further strengthened the case for ECPR. All survivors in the ECPR group demonstrated favorable neurologic status at follow-up, with CPC scores of 1 or 2 at three and six months. In contrast, neurologic recovery in the conventional ACLS group was limited. Mean duration of CPR in the standard group exceeded 80 minutes, reflecting aggressive conventional efforts prior to termination.

The magnitude of benefit observed in the ARREST trial is striking when contextualized against established therapies. For comparison, the number needed to treat for aspirin in acute myocardial infarction is substantially higher. These findings positioned ECPR as one of the most potent interventions yet studied for refractory cardiac arrest—at least within highly controlled, experienced systems.

4.3 Multicenter Experience: Early ECPR Trial

To address questions of generalizability and system-level feasibility, a larger multicenter randomized trial was conducted across ten centers in the Netherlands and published in *The New England Journal of Medicine* in 2023 (Suurveen et al., 2023). This trial enrolled 134 patients with refractory out-of-hospital cardiac arrest and compared early ECPR with conventional CPR.

Unlike prior single-center studies, participating hospitals varied substantially in ECMO experience. Notably, half of the centers had cannulated fewer than two patients for ECPR in the year preceding the trial. The primary outcome—survival with favorable neurologic outcome at 30 days—did not differ significantly between groups. Similarly, no statistically significant differences were observed in overall survival or long-term neurologic function.

Several limitations likely contributed to these findings. Duration of low-flow time prior to ECMO initiation was longer and more variable than in earlier trials, reflecting transport delays and logistical challenges inherent to a multicenter design. Additionally, while the ECPR group underwent significantly more percutaneous coronary interventions, this did not translate into improved survival, suggesting that delayed initiation of extracorporeal support may blunt its potential benefit.

These results highlight a critical distinction: ECPR appears highly effective in experienced, tightly coordinated systems but may lose efficacy when implemented across heterogeneous centers without sufficient procedural volume or streamlined workflows.

4.4 Guideline Recommendations and Patient Selection

Current guideline statements reflect both optimism and caution regarding ECPR. The American Heart Association recommends consideration of ECPR "in select patients when provided within an appropriately trained and equipped system of care" (American Heart Association, 2025). However, no universally accepted selection criteria are endorsed.

Patient characteristics consistently associated with improved outcomes include receipt of bystander CPR, shockable initial rhythm, intermittent ROSC or signs of life during resuscitation, and shorter low-flow times. Systems-level factors—including operator experience, rapid cannulation capability, and regionalized referral networks—are emphasized as essential components of successful ECPR programs.

The AHA further recommends that centers offering ECPR develop and regularly reassess patient selection criteria to maximize benefit, ensure equitable access, and limit futile intervention. A regionalized approach to ECPR delivery is considered reasonable to optimize outcomes and resource utilization, while rapid intra-arrest transport for the purpose of ECPR may be considered for a limited subset of highly selected patients (American Heart Association, 2025).

Collectively, available evidence suggests that ECPR represents a powerful but fragile intervention: one whose effectiveness is inseparable from system design, timing, and expertise. As such, its future impact will depend as much on organizational discipline as on technological capability.

5. Thrombolysis in Pulmonary Embolism–Associated Cardiac Arrest

5.1 Clinical Question: Optimal Duration of CPR After Thrombolysis

Pulmonary embolism (PE) remains a potentially reversible cause of cardiac arrest, yet management decisions during resuscitation are often made under conditions of diagnostic uncertainty. When thrombolytic therapy is administered for presumed massive PE during cardiac arrest, clinicians face a critical and unresolved question: how long should CPR be continued to allow the therapy a meaningful opportunity to take effect?

Clinical practice varies widely. Intuitive thresholds for CPR duration following thrombolysis range from minutes to over an hour, reflecting uncertainty rather than evidence-based consensus. This variability is particularly pronounced when PE is presumed rather than definitively diagnosed, as diagnostic confidence substantially influences clinician willingness to prolong resuscitative efforts.

5.2 Pharmacokinetics of Alteplase in Low-Flow States

Understanding the pharmacokinetics of tissue plasminogen activator (tPA) in the setting of cardiac arrest is essential to addressing this question. CPR represents the lowest-flow state encountered in clinical medicine. In the absence of spontaneous circulation, delivery of intravenously administered medications to target thrombus is markedly delayed, rendering immediate therapeutic effects physiologically implausible.

An extracorporeal circuit study published in the *Journal of Vascular Surgery* in 2001 evaluated the pharmacokinetics of tPA and demonstrated that plasma concentrations rise gradually following administration, reaching peak therapeutic levels approximately 60 minutes after infusion (Journal of Vascular Surgery, 2001). Measurements at 15 and 30 minutes revealed subtherapeutic concentrations, underscoring the necessity of sustained circulation—even at low flow—for thrombolytic efficacy.

These findings reinforce a fundamental principle: thrombolytics cannot be expected to reverse obstruction instantaneously, particularly during CPR. Time, combined with ongoing circulation via chest compressions, is a prerequisite for meaningful clot lysis.

5.3 Case-Based Evidence Supporting Prolonged CPR

A widely cited case report illustrates the potential consequences of allowing thrombolysis sufficient time to act. This report describes a 63-year-old woman with a confirmed massive saddle pulmonary embolism and right heart strain who suffered cardiac arrest in the emergency department. Alteplase was administered promptly, and CPR was continued for 90 minutes. Following ROSC, the patient was awake and following commands. Although she later developed right heart failure requiring advanced support, she ultimately recovered, underwent rehabilitation, and was discharged home with preserved neurologic function (Annual CHEST Meeting, 2021).

While anecdotal, this case is physiologically coherent and highlights the disconnect between traditional CPR duration thresholds and the pharmacodynamics of fibrinolytic therapy.

5.4 Cohort Evidence: Confirmed PE and Thrombolysis During Arrest

More systematic evidence comes from the PEAPETT study, published in the *American Journal of Emergency Medicine* in 2016 (Shafi et al., 2016). This single-center retrospective study evaluated 23 patients with confirmed pulmonary embolism and pulseless electrical activity (PEA) arrest. Diagnosis was established via computed tomography pulmonary angiography in 20 patients and via ultrasound identification of clot-in-transit in three patients.

All patients received low-dose alteplase (50 mg administered as a bolus), followed by continuous CPR. The mean time from initiation of CPR to thrombolytic administration was approximately six minutes. ROSC was achieved in all but one patient, typically within 2–15 minutes after alteplase administration. Importantly, 20 of 23 patients ultimately returned to their pre-arrest functional status, corresponding to a CPC score of 1. Of the three deaths, one occurred 10 hours after arrest, one eight days later due to multiorgan failure, and one 15 months later from malignancy.

No major or minor bleeding events were reported. These outcomes are particularly notable given the advanced age and comorbidity burden of the cohort, which closely resembled typical clinical populations rather than highly selected younger patients.

5.5 Registry Evidence: Thrombolysis and Survival in Out-of-Hospital Arrest

Additional support for thrombolysis during PE-associated cardiac arrest comes from a retrospective multicenter analysis of the French National Cardiac Arrest Registry, published in *CHEST* in 2019 (CHEST Registry Investigators, 2019). This study included 248 patients with out-of-hospital cardiac arrest ultimately attributed to pulmonary embolism confirmed by CT imaging after ROSC.

Among these patients, 58 received fibrinolytic therapy during resuscitation, while 188 did not. Median duration of CPR was significantly longer in the thrombolysis group. Despite this, 30-day survival was markedly higher among patients who received fibrinolytics (16% vs 6%), with no significant difference in rates of fatal or intracranial hemorrhage between groups.

These findings suggest that prolonged CPR following thrombolysis does not incur excess bleeding risk and may confer a survival advantage in carefully selected patients with high likelihood of PE.

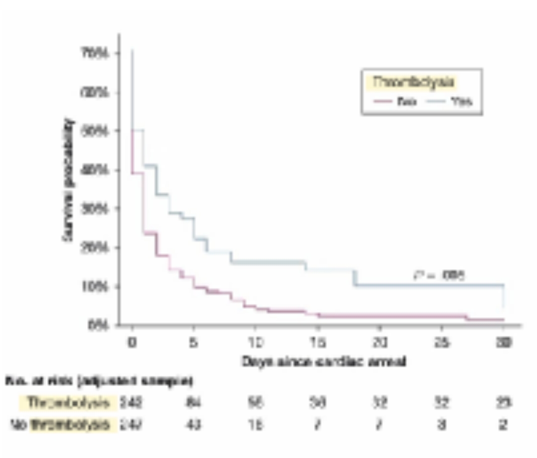

Fig. 2. Kaplan–Meier survival curves comparing thrombolysis vs no thrombolysis in PE-associated cardiac arrest. *Source*: see Ref. 14.

5.6 Guideline Statements and Ongoing Uncertainty

Guideline recommendations reflect the strength of observational data alongside the absence of randomized trials. The European Resuscitation Council recommends continuing CPR for 60–90 minutes following thrombolysis in patients with confirmed or strongly suspected pulmonary embolism (European Resuscitation Council, 2021). This recommendation acknowledges both pharmacologic realities and available outcome data, though it represents a substantial logistical and personnel commitment.

The American Heart Association adopts a more cautious position. In the 2025 ACLS update, systemic fibrinolysis is considered reasonable for confirmed PE causing cardiac arrest and may be considered for suspected PE. However, the guidelines explicitly state that the optimal duration of CPR after fibrinolytic administration remains unclear (American Heart Association, 2025).

This ambiguity leaves clinicians to balance physiologic plausibility, available evidence, and system capacity. While a minimum of 20–30 minutes of CPR following thrombolysis appears reasonable based on existing data, selected patients—particularly those with confirmed PE, witnessed arrest, or early thrombolytic administration—may warrant substantially longer resuscitative efforts.

6. Key Practice Updates From the 2025 AHA ACLS Guidelines

The 2025 American Heart Association ACLS update introduced several targeted revisions relevant to both in-hospital and out-of-hospital resuscitation. While none represent wholesale paradigm shifts, collectively they reinforce an emphasis on early decisive intervention and avoidance of unproven adjuncts (American Heart Association, 2025).

One notable update concerns cardioversion for atrial fibrillation or atrial flutter in unstable patients. The recommended initial energy level has been increased to 200 joules. This change reflects evidence that higher initial energy improves cardioversion success while paradoxically reducing cumulative electrical burden by decreasing the need for repeated shocks. Higher-energy cardioversion has also been associated with a lower likelihood of degeneration into ventricular fibrillation.

The use of double sequential defibrillation for refractory ventricular fibrillation received further scrutiny. Although early observational studies suggested potential benefit, the 2025 guidelines conclude that this technique requires additional investigation before routine adoption. Concerns include the risk of inappropriate shock timing, particularly R-on-T phenomena, and the absence of technology to ensure near-simultaneous energy delivery across devices. As a result, double sequential defibrillation is not recommended outside specialized or investigational settings.

Head-up CPR, proposed as a means of improving cerebral perfusion by reducing intracranial pressure, is explicitly not recommended outside clinical trials with appropriate oversight and community consent. Despite physiologic plausibility, available data have not demonstrated clinical benefit, and routine use is discouraged.

Finally, management of polymorphic ventricular tachycardia has been simplified. The updated recommendation emphasizes immediate defibrillation as the first-line intervention for all adults with sustained polymorphic VT. While adjunctive pharmacologic therapies such as magnesium may still be appropriate, they should not delay defibrillation in non-perfusing rhythms.

These updates align with a broader guideline trend favoring early, high-impact interventions while de-emphasizing techniques lacking robust outcome data.

7. Discussion

The controversies explored in this review reflect a broader transition in resuscitation medicine: the gradual replacement of subjective heuristics with physiologic, technology-assisted assessment. Manual pulse checks, once central to CPR decision-making, have repeatedly demonstrated poor accuracy and reliability, even among trained professionals. In contrast, tools such as capnography and ultrasound offer objective, reproducible measures of circulation and cardiac activity.

Ultrasound, in particular, occupies a unique position. When integrated thoughtfully into resuscitation workflows, it can enhance pulse assessment, identify reversible causes of arrest, and provide prognostic insight without interrupting chest compressions. However, its utility is inseparable from operator expertise and disciplined time management. Ultrasound is not a replacement for high-quality CPR but a potential adjunct that, when misused, risks distraction and harm.

Extracorporeal CPR illustrates the power—and fragility—of technologically advanced resuscitation. Early single-center and randomized data demonstrate extraordinary survival and neurologic outcomes when ECPR is deployed rapidly within highly coordinated systems. Yet multicenter experience reveals that delays, variable expertise, and fragmented logistics can negate these benefits. ECPR is best understood not as a discrete intervention but as a system-level capability whose success depends on training, patient selection, and regional organization.

Thrombolysis during PE-associated cardiac arrest further underscores the tension between physiologic plausibility and operational feasibility. Pharmacokinetic data and observational studies strongly suggest that prolonged CPR is necessary for thrombolytics to exert meaningful effect. Yet the duration required—often far exceeding traditional resuscitation thresholds—poses significant demands on personnel and resources. The absence of randomized trials leaves clinicians navigating uncertainty, guided by probability, context, and system capacity rather than definitive evidence.

Across these domains, a common theme emerges: resuscitation outcomes are increasingly determined not only by *what*interventions are available, but by *how* and *where* they are implemented.

8. Conclusions

Modern cardiopulmonary resuscitation is undergoing a quiet but consequential evolution. Evidence increasingly challenges long-standing assumptions regarding pulse assessment, resuscitation duration, and futility thresholds. Technologies such as ultrasound and extracorporeal support expand diagnostic and therapeutic possibilities but demand disciplined integration into resuscitation practice.

Current data support replacing manual pulse checks with more objective measures when feasible, considering ultrasound-guided assessment in experienced hands, and recognizing the system-dependent nature of ECPR benefit. In cases of suspected or confirmed pulmonary embolism treated with thrombolysis, prolonged CPR may be necessary and justified in selected patients.

As guidelines continue to evolve, the central imperative remains unchanged: uninterrupted, high-quality chest compressions form the foundation of resuscitation. Technologies and advanced interventions must serve this foundation, not supplant it. The challenge ahead lies in aligning physiologic insight, technological capability, and system readiness to maximize survival with meaningful neurologic recovery.

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References

1. Dick WF, Eberle B, Wisser G, Schneider T. The carotid pulse check revisited: What if there is no pulse? *Crit Care Med*. 2000;28(11 Suppl):N183–N185.
2. Yilmaz A, Akoglu H, Sonmez BM, et al. Comparison of femoral and carotid arteries in terms of pulse check in cardiopulmonary resuscitation: A prospective observational study. *Resuscitation*. 2021;158:1–7.
3. Gottlieb M. Managing cardiac arrest using ultrasound. *Ann Emerg Med*. 2023;81(3):292–300.
4. Atkinson P, Bowra J, Milne J, et al. Emergency department point-of-care ultrasound in out-of-hospital and in-ED cardiac arrest. *Resuscitation*. 2016;109:33–39.
5. Nolan JP, Sandroni C, Böttiger BW, et al. European Resuscitation Council Guidelines 2021: Adult advanced life support. *Resuscitation*. 2021;161:115–151.
6. Kleinman ME, Brennan EE, Goldberger ZD, et al. 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132(18 Suppl 2):S444–S464.
7. American Heart Association. 2025 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2025.
8. Stub D, Bernard S, Pellegrino V, et al. Refractory cardiac arrest treated with mechanical CPR, hypothermia, ECMO and early reperfusion (CHEER trial). *Resuscitation*. 2015;86:88–94.
9. Yannopoulos D, Bartos JA, Raveendran G, et al. Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation

(ARREST): A phase 2, single-centre, open-label, randomised controlled trial. *Lancet*. 2020;396(10265):1807–1816.

10. Suverein MM, Delnoij TSR, Lorusso R, et al. Early extracorporeal CPR for refractory out-of-hospital cardiac arrest. *N Engl J Med*. 2023;388:299–309.
11. Mader TJ, Smithline HA. Pharmacokinetics of tissue plasminogen activator in an isolated extracorporeal circuit. *J Vasc Surg*. 2001;34(4):683–687.
12. Chun S, Fisher M, Vojtek A, Boozel T. Pulmonary embolism–induced cardiac arrest: Ninety minutes of CPR after thrombolytics. Presented at: Annual CHEST Meeting; 2021.
13. Shafi AM, Fatima K, Siddiqui WJ, et al. Pulseless electrical activity in pulmonary embolism treated with thrombolysis (PEAPETT study). *Am J Emerg Med*. 2016;34(10):1963–1967.
14. Javaudin F, Lascarrou JB, Le Bastard Q, et al. Thrombolysis during resuscitation for out-of-hospital cardiac arrest caused by pulmonary embolism increases 30-day survival: Findings from the French National Cardiac Arrest Registry. *Chest*. 2019;156(6):1167–1175.