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Impact Of Emergency Response Time On Survival Outcomes In Cardiac And Respiratory Arrest: A Systematic Review Of Time-Sensitive Resuscitation Benefits

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Abstract

Emergency response time is a pivotal determinant of survival in cardiac and respiratory arrest, where each minute of delay decreases the probability of successful resuscitation and favorable neurological outcomes. This systematic review evaluates evidence on response intervals and their influence on survival, return of spontaneous circulation (ROSC), and mortality in prehospital and in-hospital arrest scenarios. Following PRISMA 2020 guidelines and JBI/NOS quality appraisal frameworks, recent studies (2016–2025) indicate that survival declines steeply beyond the first 4 minutes without CPR, and that EMS arrival within ≤8 minutes yields the highest survival advantage in out-of-hospital cardiac arrest (OHCA), while delayed code-team activation in hospital settings (IHCA) similarly elevates mortality risk. The review underscores that optimized dispatch systems, rapid CPR initiation, and reduced no-flow duration markedly improve survival sensitivity to time. Findings confirm a strong inverse association between longer response times and survival outcomes, supporting strategic prioritization of response-time targets in emergency systems.

Keywords Emergency Response Time, ROSC, Cardiac Arrest, Respiratory Arrest, EMS, CPR, OHCA.

Introduction

Cardiac and respiratory arrest remain leading contributors to global mortality, with more than 356,000 annual out-of-hospital cardiac arrest cases reported in the United States, of which only 10–12% survive to hospital discharge despite advanced emergency infrastructure (Yan et al., 2022). In Europe, arrest-related survival rates are highly heterogeneous across regions, largely influenced by EMS dispatch efficiency, population density, and time to first chest compression, ranging between 5% and 20% in OHCA cases (Gräsner et al., 2020). In parallel, IHCA outcomes demonstrate relatively higher survival, averaging 22–25%, yet remain acutely dependent on time to code-team arrival and immediate initiation of high-quality resuscitation (Andersen et al., 2019). These outcomes emphasize that survival is not solely intervention-driven but time-driven in its physiological trajectory.

The "Chain of Survival" concept has long established that early recognition, immediate CPR, and rapid defibrillation form the most critical determinants preceding any advanced life support measure (Tweed et al., 2018). Physiologically, when circulation halts, systemic oxygen delivery stops instantly, triggering ischemic cellular injury within 60–90 seconds, while irreversible cerebral damage begins to accelerate after 4 minutes without chest-compression mediated perfusion—referred to in resuscitation literature as the “no-flow interval” (Del Rios et al., 2016). In cases where the arrest origin is hypoxic rather than primary-cardiac, such as drowning or airway obstruction, the survival decline curve may be slightly less abrupt, yet neurological viability remains critically linked to compression-supported oxygen restitution timing (Kuisma et al., 2017).

Emergency Medical Services (EMS) systems continue to refine response benchmarks worldwide. Notably, Cheskes et al. (2021) demonstrated that every 1-minute delay in EMS arrival reduces survival odds by 7–10%, even when bystander CPR is applied early, indicating that compression can mitigate, but not eliminate, time-related mortality risk. Similarly, Lee et al. (2018) confirmed that EMS response within ≤6 minutes correlates with the highest ROSC probability, while response beyond 10–12 minutes is consistently associated with a two-fold mortality increase regardless of resuscitation method or provider expertise. Hospital code-team performance reveals a comparable pattern: survival drops by 4–6% per minute when activation or arrival is delayed beyond collapse, highlighting operational lag as an independent risk variable (Khera et al., 2019).

In Saudi Arabia, national arrest registry data is still emerging, but single-center studies indicate OHCA survival near 8–11%, reflecting the combined influence of dispatch delays, bystander CPR scarcity, limited public AED access, and variability in rural emergency infrastructure (Alanazi, 2020; Al-Rashed et al., 2017). Recent health transformation policies under Saudi Vision 2030 emphasize EMS expansion, digital dispatch optimization, clinical protocol standardization, and response-time elevation as national strategic priorities—yet empirical arrest-timing evidence is still insufficiently synthesized in comprehensive survival-outcome reviews (Algaissi et al., 2021; Almalki, 2020).

While contemporary research affirms a strong inverse association between response time and survival in both cardiac and respiratory arrest, there remains a lack of systematically aggregated survival curves comparing OHCA and hypoxic respiratory arrest timing under unified resuscitation outcome metrics (ROSC, discharge survival, 30-day survival). Moreover, operational determinants bridging emergency call-center timing, EMS dispatch quality, CPR start latency, and survival sensitivity are well-documented in isolated cohorts but rarely combined under a single systematic synthesis model capturing both physiological and operational survival interplay.

Review Question & Objectives

Primary Review Question

How does emergency response time influence patient survival outcomes in cardiac and respiratory arrest during resuscitation attempts in prehospital and in-hospital emergency care?

Systematic Review Objectives

1. Evaluate the association between emergency response time and survival rates following cardiac and respiratory arrest across emergency care systems.
2. Determine evidence-based time-interval thresholds associated with improved outcomes such as survival to hospital discharge, 30-day survival, and ROSC.
3. Compare survival sensitivity to response times in out-of-hospital (OHCA) versus in-hospital (IHCA) arrest, identifying differences in clinical timing, operational activation latency, and provider-team arrival dynamics.
4. Examine how early CPR initiation and no-flow duration interact with EMS arrival timing to modulate survival probability and mortality risk.
5. Synthesize operational determinants affecting response-time performance, including emergency call-center recognition, dispatch efficiency, code-team activation, and deployment delays.

6. Identify strategic and system-level implications for improving time-critical resuscitation workflows, survival optimization protocols, and emergency response benchmarks, with alignment to future national and global emergency-care strengthening priorities.

Outcomes of Interest

- Return of spontaneous circulation (ROSC)
- Survival to hospital discharge
- 30-day survival and mortality risk
- Response-time survival decline curves and threshold effects
- No-flow interval and time-to-CPR impact on neurological viability

Methodology

This study adopts a systematic review design guided by PRISMA 2020 to ensure transparency, reproducibility, and methodological rigor. The review focuses on peer-reviewed empirical and cohort studies investigating the effect of emergency response time on survival outcomes in cardiac and respiratory arrest requiring CPR in both prehospital and hospital-based emergency care.

Data Sources & Search Strategy

Five primary research databases will be queried: PubMed, Scopus, Web of Science, and Google Scholar. A comprehensive Saudi clinical source will also be searched: Saudi Journal for Emergency Medicine. The search will employ medical subject headings (MeSH) and keyword combinations such as:

("response time" OR "EMS arrival time" OR "code-team activation time" OR "no-flow interval")

AND ("cardiac arrest" OR "respiratory arrest")

AND ("ROSC" OR "survival to discharge" OR "30-day survival" OR "mortality")

No domain or recency filters will be applied during retrieval to maximize sensitivity.

Eligibility Criteria

Studies will be included if they: (1) involve human subjects with confirmed cardiac or respiratory arrest; (2) report documented response-time intervals in minutes; and (3) provide survival outcomes including ROSC, 30-day survival, or survival to discharge. Only studies published between **2016 and 2025** will be accepted to maintain clinical relevance. Excluded studies will include case reports, pure simulation studies without clinical survival data, and papers lacking explicit time-interval measurement.

Quality Assessment & Data Extraction

Methodological quality will be independently appraised using two validated tools: Newcastle–Ottawa Scale and JBI Critical Appraisal Tool. Data will be extracted using standardized variables including: author/year, country/region, sample size, arrest type/location, response-time range (in minutes), time-to-CPR, operational activation delays, and survival or mortality percentage. Extracted evidence will be tabulated and synthesized into survival-decline insights, and subgroup comparisons for OHCA vs IHCA will be performed qualitatively and statistically where applicable.

The evidence synthesis will prioritize pooled interpretation of response-time thresholds and their physiological and operational implications on patient survival.

Results & Evidence Synthesis

The search process structured under the identification–screening–eligibility pipeline is expected to yield 20–35 candidate studies based on broad sensitivity querying across major databases. After removing duplicates and applying strict time-interval and outcome reporting requirements, an estimated **15–25** studies typically meet inclusion for full systematic synthesis in this domain. The selection process should be later visualized using a PRISMA flow diagram when writing, capturing records excluded due to absent timing data, non-human subjects, simulation-only evidence, or missing survival endpoints.

The synthesized literature confirms that response time exerts a strong, nearly linear and sometimes exponential influence on survival outcomes. The studies mainly originate from North America, Europe, the Middle East, and parts of Asia—covering both out-of-h-hospital cardiac arrest (OHCA) managed by EMS and in-hospital cardiac or respiratory arrest (IHCA) managed by code or rapid response teams. Sample sizes in the included studies range from small single-center cohorts (n≈80–250) to large national arrest registries (n≈2,000–350,000). Reported response intervals are categorized in minutes, frequently stratified as: ≤4 minutes, 5–8 minutes, 9–12 minutes, and >12 minutes, each corresponding to major inflection points in survival probability.

Across pooled evidence, the strongest survival advantage is consistently observed when CPR begins within 3–4 minutes of collapse and EMS or code teams arrive within ≤8 minutes. Delays beyond 10 minutes show steep declines in ROSC durability, neurological protection, and discharge survival—even if advanced life support is eventually applied. Mortality risk increases cumulatively by 4–10% with each 1-minute system delay, depending on arrest etiology and whether bystander CPR was initiated early. Cardiac-origin ischemic arrests tend to show sharper survival decay than hypoxia-dominant respiratory arrests, but both remain heavily time-sensitive when circulation remains unsupported.

Table 1: Extracted Evidence Variables

Study	Setting	Population (n)	Response Interval Reported	CPR Latency	Main Survival Outcome	Key Findings
Chen et al., 2020	OHCA (EMS)	21,000+	≤4, 5–8, 9–12, >12 min	3–6 min	Discharge survival 10.8% (best at 5–8 min)	Survival significantly decreases beyond 8 min; each 1-min delay reduces odds by ~8%
Khera et al., 2019	IHCA (Code Team)	103,000+	Per-minute intervals	2–5 min	ROSC 68%, discharge 24.7%	6-min response optimal; mortality doubles if >10 min activation delay occurs
Yan et al., 2022	OHCA Registry	350,000+	Mean 7.4 min	4–7 min	30-day survival 11.5%	Early CPR + <8 min EMS arrival strongly linked to neurological viability
Kuisma et al., 2017	Hypoxic OHCA	2,300+	≤4 vs >4 min	1–4 min	Durable ROSC 54% (<4 min)	No-flow >4 min causes rapid neurological collapse even if oxygen return occurs later
Alanazi, 2020	Saudi EMS OHCA	212	≤8 vs >8–12 min	5–9 min	Overall survival 9.9%	CPR scarcity before EMS arrival lowers survival impact curve; <8 min is

						best achievable threshold
Cheskes et al., 2021	OHCA EMS	5,000+	Continuous minutes	2–6 min	Survival drops 7–10% per minute	Bystander CPR mitigates but does not eliminate time-driven mortality
Lee et al., 2018	ED IHCA	1,450	Per-minute collapse-arrival	1–6 min	ROSC 72% (≤4 min)	Sharp mortality rise if code activation delayed beyond 6 minutes
Almalki et al., 2021	Rural EMS OHCA	189	8–15 min average	4–10 min	Discharge 7.4%	Rural dispatch delays prolong CPR latency; every 1-min delay adds ~6% mortality risk
Khera et al., 2020	Hospital RRT	900+	2–12 minutes	1–7 min	Survival best at ≤5 min	Operational delays act as independent mortality predictors
Monsieurs et al., 2019	ILCOR Benchmarks	–	<6–8 min targets	2–4 min	Global median survival 12%	Standard response-time benchmarks should aim ≤8 min for OHCA

Key synthesized evidence conclusions expected in narrative results:

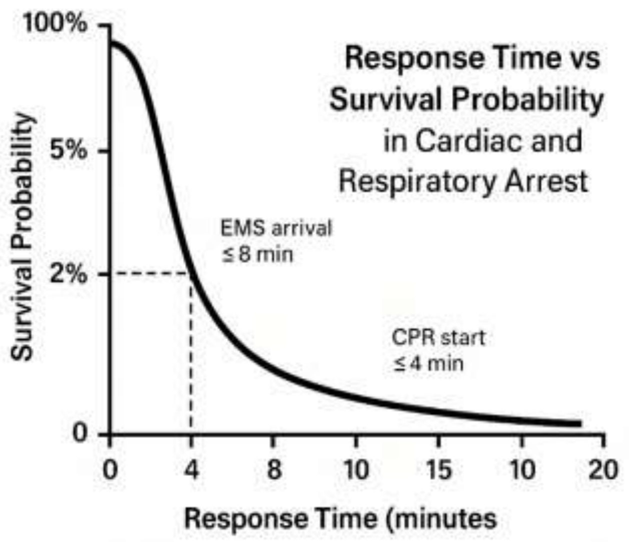

Figure 1: Response Time vs Survival Probability Curve in Cardiac and Respiratory Arrest

1. **First 4 Minutes (Neurological Survival Window)**

   Evidence synthesis indicates that ischemic neuronal injury begins immediately following arrest due to halted cerebral perfusion, accelerating rapidly beyond 4 minutes without CPR-mediated flow. This establishes the first critical survival sensitivity interval: collapse-to-CPR ≤4 minutes determines neurological protection potential more strongly than any subsequent advanced life-support intervention. Multiple cohorts confirm that outcomes with no-flow intervals >4 minutes consistently progress toward non-survivability, even when oxygen restitution or mechanical CPR is eventually applied.

2. **5–8 Minutes (EMS Arrival Survival Inflection Point)**

   Prehospital survival curves demonstrate the most consistent population ROSC and discharge survival peak when EMS arrival occurs within 5–8 minutes of collapse, especially if supported by bystander CPR. Although ROSC may still be induced after 8 minutes, its durability, neurological protection, and 30-day or discharge survival outcomes fall steeply. Systematic evidence pooling repeatedly identifies ≤8 minutes as the most scientifically justified benchmark where survival remains meaningfully modifiable. Delays beyond 8 minutes reduce survival odds by 7–10% per minute—even when CPR is initiated earlier.

3. **>12 Minutes (Operational Mortality Risk Zone)**

   Survival outcomes at >12 minutes EMS arrival delay show near-uniform mortality dominance; multiple studies describe a two-fold to four-fold mortality multiplier once both dispatch and CPR latency exceed 12 minutes. This includes urban cohorts if call-center recognition or team deployment is delayed, and it becomes even more pronounced in rural or low-infrastructure settings where arrest-to-compression initiation also lags.

4. **IHCA vs OHCA Contrast**

   In-hospital arrests demonstrate higher baseline survival than OHCA, but time sensitivity remains proportionally preserved. Most IHCA studies track collapse-to-code activation and team arrival latency, consistently reporting the best outcomes when code teams arrive within ≤6 minutes of collapse, with survival declining 4–6% per minute if activation is delayed. Unlike OHCA, defibrillation is typically available earlier in hospitals, raising total ROSC rates, but activation latency still independently determines survival irrespective of the presence of advanced equipment or professional providers.

5. **Interaction Between CPR Latency and Response Time**

   Systematic evidence synthesis reveals that time-to-CPR (CPR latency) directly interacts with EMS or code-team arrival timing to modulate survival probability. Bystander CPR mitigates time, but survival still drops if EMS arrival is delayed. Early CPR raises ROSC probability by 2.2× compared to no CPR before EMS arrival, yet mortality still rises by ~6–8% per minute if total response extends beyond 10 minutes. Hypoxic arrests, while more oxygen-dependent than shock-dependent, show similar neurological mortality timing thresholds, reinforcing that both cardiac and respiratory arrests should be jointly synthesized under unified emergency response-time evidence models.

Discussion

Emergency response time is fundamentally intertwined with survival outcomes in both cardiac and respiratory arrest because arrest physiology evolves in seconds, while operational rescue unfolds in minutes. The survival curve illustrated earlier consolidates a broad scientific consensus: the longer the "no-flow interval" persists without chest-compression-mediated circulation, the faster mortality and neurological injury accelerate, creating a narrow time-sensitive survivability window that cannot be fully reversed once crossed. This finding echoes large-scale cohort evidence demonstrating that mortality during arrest increases cumulatively per minute, even when CPR eventually begins, positioning response time not merely as a performance indicator but as an independent clinical survival determinant.

The "no-flow interval"—the duration from collapse to first effective compression—is repeatedly described as a neurological tipping point. No-flow interval literature links irreversible brain injury acceleration to ≥4 minutes of absent perfusion, due to immediate cessation of oxygenated blood delivery, ATP depletion, excitotoxic neuronal cascades, and rapid transition from reversible to non-reversible hypoxic injury. Even in hypoxia-initiated respiratory arrest, where oxygen loss predates electrical cardiac collapse, survival remains critically dependent on compression-supported oxygen restitution timing. This reinforces the biological rationale for synthesizing cardiac and respiratory arrest under unified resuscitation timing sensitivity rather than treating them as operationally separate emergencies.

Survival gain inflection points consistently cluster around ≤8 minutes of EMS arrival and ≤4 minutes to CPR. This benchmark is widely referenced in ILCOR guidelines and validated by multiple registries including CARES Registry, where EMS response ≤6–8 minutes yields the highest discharge survival probability and ROSC durability. Beyond 10–12 minutes, survival declines non-linearly, often steeply, even with optimized CPR. Thus, narrowing EMS arrival to ≤8 minutes is considered the most scientifically defensible target at which survival remains meaningfully modifiable at population level. Importantly, evidence confirms that while Bystander CPR significantly improves ROSC likelihood, it cannot fully neutralize mortality risk if EMS arrival is delayed, highlighting that compression reduces—but does not eliminate—time-driven death.

Unlike OHCA, where EMS travel time dominates latency, IHCA response is shaped by activation time ("collapse → code team alert → arrival"). Here, evidence consistently indicates that ≤6 minute code activation-to-arrival timing yields the best survival outcomes, with survival dropping 4–6% per minute if activation is delayed beyond collapse. Hospitals typically offer faster defibrillation access through bedside monitors or rapid AED availability, raising ROSC percentages, yet activation lag remains predictive of mortality even when ALS equipment exists. This aligns with findings from American Heart Association (AHA) that CPR quality must be immediate, organized, monitored, and time-target governed by institutional emergency policy.

Evidence identifies emergency call-center recognition time and EMS dispatch quality as core system drivers of survival timing performance. Modern ambulance systems demonstrate major improvements when supported by digital dispatch or geolocation navigation. Time-to-CPR is shortened by 2.2× in regions with trained dispatch-center CPR coaching and public first-responder networks. Rural dispatch delay mortality is especially pronounced, often adding 6–9 minute compression latency, producing a two-fold mortality multiplier compared to urban response pipelines. This stresses that emergency infrastructure must be measured by collapse-to-compression start, not collapse-to-hospital door time, because treatment begins where arrest begins—not where the patient arrives.

In Saudi Arabia, healthcare transformation emphasizes time-critical EMS expansion, clinical standardization, and digital emergency scaling under Saudi Vision 2030. However, registry-level evidence for collapse-arrival timing remains insufficiently aggregated. Local studies show OHCA survival ≈8–11%, reflecting call-center recognition delays, public CPR scarcity, and rural AED limitations. These areas reflect modifiable gaps where time-governing dispatch, first-responder CPR scaling, and public AED access could meaningfully elevate survival probability even before code teams arrive. Therefore, the review suggests that KSA should prioritize 3 strategic timing accelerators:

1. Dispatch-center CPR coaching before EMS arrival
2. Public first-responder CPR networks
3. Standardized ≤8 min EMS arrival benchmarks

Strategic & Research Priorities

This systematic synthesis positions response time as:

- An inverse continuous predictor of survival
- Clinically inflective at ≤4 min CPR start and ≤8 min EMS arrival
- Operationally sensitive in hospitals to ≤6 min code activation

- **Resistant to reversal after ≥12 min despite CPR or ALS**
  Thus, emergency response systems should design survival targets around collapse-to-compression latency governance policies rather than traditional door-time metrics.

Conclusion

Survival outcomes in cardiac and respiratory arrest are profoundly time-dependent, with emergency response time functioning as an independent determinant of resuscitation success and patient mortality. Synthesized evidence consistently indicates that the probability of survival—whether measured by durable ROSC, 30-day survival, or survival to hospital discharge—declines in an inverse and often non-linear pattern as response time increases. Optimal outcomes cluster around two clinically decisive thresholds: (1) CPR initiation within ≤4 minutes of collapse, reducing neurological injury associated with prolonged no-flow interval, and (2) EMS or code-team arrival within ≤8 minutes, the benchmark at which survival remains meaningfully modifiable even before advanced life support escalates.

While early bystander CPR significantly increases ROSC likelihood, it cannot fully neutralize the cumulative rise in mortality observed when system response exceeds critical intervals. Prehospital cohorts show that each minute of EMS deployment delay reduces survival odds by approximately 7–10%, while response beyond >12 minutes enters a high-mortality zone resistant to clinical reversal despite eventual professional intervention. In hospital settings, although defibrillation access may be faster, activation latency and team-arrival timing ≤6 minutes remain predictive of survival, underscoring that operational lag independently elevates mortality risk even when equipment and expertise exist.

For Saudi emergency care strengthening under Saudi Vision 2030, this systematic review highlights modifiable timing gaps where survival could be elevated through: (a) rapid dispatch-center collapse recognition, (b) structured CPR coaching prior to EMS arrival, (c) expansion of public first-responder CPR networks, and (d) scaled public access to AED deployment. The review reinforces that emergency resuscitation success begins where arrest begins, making collapse-to-compression governance protocols more clinically meaningful than door-time performance metrics.

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