White Paper

Enhancing Resuscitation Process Reliability Through Visual Guidance and Human-Factor Support

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Abstract

This white paper presents PaceAid, a visual guidance and timing-cue device designed to support high-quality CPR. Drawing on resuscitation science and human factors research, PaceAid bridges the gap between training and real-world execution, offering a low-complexity, process-support tool for clinical and public settings.

Introduction

High-quality cardiopulmonary resuscitation (CPR) is a critical determinant of cardiac arrest outcomes, yet the quality of CPR delivered in real-world settings is highly variable [1]. The American Heart Association (AHA) has emphasized five core elements of high-quality CPR: minimizing interruptions, achieving adequate rate and depth, avoiding leaning, and preventing excessive ventilation, while noting that performance varies widely across systems and contexts [1]. This variability is influenced not only by training and technical skills but also by human factors such as stress, cognitive overload, environmental distractions, and the challenges of team coordination during high-acuity events [1,2]. These realities highlight the need for interventions that support CPR performance at the process level, reinforcing consistent, guideline-aligned actions without diagnosing or treating medical conditions.

Background and Evidence

Resuscitation research has consistently shown that maintaining an appropriate chest compression rate during CPR is critical to its physiological effectiveness [1]. When compression rates fall below recommended thresholds, the likelihood of achieving return of spontaneous circulation (ROSC) decreases

sharply, whereas excessively rapid compressions can diminish coronary perfusion and reduce the proportion of compressions that reach adequate depth [1]. Data from the ROC Epistry (Resuscitation Outcomes Consortium Epidemiologic Registry) provides some of the strongest evidence linking compression rate to survival, identifying an optimal target of approximately 100 to 120 compressions per minute. Rates that consistently fall outside this range, either slower or faster, are associated with reduced survival to hospital discharge, underscoring the sensitivity of outcomes to rate variability [1]. These findings highlight the need for tools that help responders maintain consistent, guideline-aligned pacing, particularly in stressful or low-frequency events where performance drift is common.

One of the most consistent observations in resuscitation science is the gap between guideline-based standards and the CPR delivered in practice [1]. Even in controlled systems with formal training and monitoring, chest compression rate, depth, and continuity often deviate from recommended targets [1]. In community and layperson settings, this variability is often magnified by infrequent exposure to cardiac arrest, long intervals between training and real events, and high emotional stress. Over time, skills learned in CPR courses degrade, particularly in compression rate, depth, and correct sequencing, contributing to performance decay when individuals are called upon to act. Although organizations may invest heavily in initial training, the absence of simple, real-time support during an event can limit the translation of that training into consistent performance.

Human-Factor Challenges

Stress and cognitive load are central to the gap between training and performance. Simulation studies of nurses and other clinical personnel have shown that CPR scenarios elicit measurable physiological stress responses, including changes in heart rate variability that correlate with personality traits and prior cardiac arrest experience [2]. During CPR training, participants often experience heightened arousal and stress, which can impair concentration, decision-making, and the ability to recall algorithmic steps [2]. In real events, these effects are likely amplified by the emotional weight of treating an actual patient, the presence of family members, and the complexity of the clinical environment. From a

human-factors perspective, any tool that reduces cognitive burden, simplifies task sequencing, and provides a stable external reference point has the potential to support more consistent CPR performance under stress.

Visual Guidance and Feedback

Feedback and guidance technologies have emerged as one strategy to improve CPR quality. Studies of real-time feedback devices in training environments, particularly those providing immediate visual feedback on parameters such as compression depth and rate, have shown improvements in chest compression quality among laypersons [3]. In a randomized controlled manikin study, real-time visual feedback during CPR training significantly improved laypersons' compression performance compared with training without such feedback [3]. These findings support the concept that visual information, when presented clearly and in real time, can help individuals align their actions more closely with desired performance targets. Although many existing feedback devices are designed primarily for training, the underlying principle that visual cues can support motor performance and adherence to standards has broader implications for process-support tools used during actual resuscitation.

Device Description

PaceAid is a Class I FDA-registered medical device designed as a visual, human-factor-oriented process-support tool to aid CPR performance by providing step-by-step prompts and timing cues during emergency responses. It does not diagnose or treat medical conditions and is not a substitute for CPR training, automated external defibrillators (AEDs), or emergency medical services (EMS). Instead, PaceAid is intended to serve as an external cognitive aid, helping responders organize their actions, maintain a consistent compression rhythm, and follow a structured sequence aligned with established CPR processes. Framing PaceAid as a human-factor intervention emphasizes its role in supporting human performance under stress rather than altering clinical care decisions. PaceAid is intentionally visual-only to minimize auditory clutter in already noisy resuscitation environments, reduce cognitive load, and provide a shared, non-intrusive reference point that supports team coordination without interfering with

critical verbal communication. Additionally, PaceAid is constructed from nonconductive materials, ensuring safe and effective use throughout CPR and defibrillation procedures.

The rationale for a visual, timing-cue-based device is grounded in multiple converging lines of evidence. First, the AHA and others have underscored that consistent adherence to CPR quality metrics is essential yet difficult to sustain in practice [1]. Second, human factors and stress research in CPR scenarios shows that responders experience acute stress that can impair attention and memory, particularly among those with less frequent exposure to cardiac arrest [2]. Third, training studies demonstrate that visual feedback mechanisms can measurably improve CPR performance in simulated settings by helping users regulate compression characteristics [3]. Although PaceAid is not a feedback device per se and does not measure compressions, it leverages the same basic principle: providing simple, clear visual information to guide human action in a time-critical, cognitively demanding task.

Implementation and System Integration

From a hospital perspective, resuscitation quality is as much a systems issue as it is an individual skill issue. The AHA consensus statement on CPR quality calls for system-level strategies to consistently monitor and improve CPR performance, including metrics, feedback, and continuous quality improvement initiatives [1]. In this context, visual guidance tools can be viewed as low-complexity, low-maintenance systems that complement existing resuscitation infrastructure. They can be deployed in both clinical and non-clinical areas, used by interprofessional teams and ancillary staff, and integrated into rapid response and code blue processes without introducing additional noise or audio signals that could interfere with communication. A visual-only design is particularly advantageous in environments where alarms and verbal orders are already abundant.

In addition to supporting clinical staff, hospitals increasingly recognize the importance of preparedness in public or non-clinical spaces within their facilities, such as lobbies, cafeterias, and administrative offices. In these areas, the first responders to a collapse may include security personnel, administrative staff, or visitors with varying levels of medical training. For these responders, stress, limited recency of training, and uncertainty about the correct sequence of actions can delay CPR initiation

and lead to inconsistent performance. A visual guidance tool that is quickly accessible and easy to follow may shorten hesitation time and support more structured action in these settings, aligning with broader hospital goals for safety and public-facing emergency readiness. PaceAid's role as a human-factors intervention is not limited to individual performance. In multi-responder scenarios, a shared visual reference can aid team coordination by making the expected sequence and timing of actions visible to everyone involved. The AHA consensus statement on CPR quality emphasizes the importance of team-level logistics and coordination in delivering high-quality CPR [1]. When team members can align their actions around a common visual cue, for example, a timing indicator for compressions, there is potential to reduce confusion, minimize redundant commands, and support smoother role transitions. While further research is needed to quantify these effects in clinical environments, the theoretical foundation is consistent with human-factors principles applied in other high-reliability domains.

Evidence from CPR training and simulation also suggests that individuals benefit from external structure when learning and performing complex, time-sensitive tasks. A study of nurse stress during CPR simulation shows that personality traits and prior experience shape stress responses, which in turn may affect performance [2]. In such contexts, tools that scaffold performance by providing clear, sequential cues and pacing information can help standardize behavior across individuals with different experience levels. Similarly, a randomized trial demonstrating improved CPR quality with real-time visual feedback during layperson training underscores that visual information can directly influence how people perform compressions, even when they are not experts [3]. These findings collectively support the idea that simple, well-designed visual prompts and timing cues can play a meaningful role in shaping CPR performance, both in training and in real-world applications.

At the same time, it is crucial to maintain clear boundaries about what process-support tools can and cannot claim to achieve. While high-quality CPR is associated with improved survival and visual or feedback tools can support CPR performance, no single device should be portrayed as a determinant of clinical outcomes [1]. PaceAid should be positioned as one component of a broader resuscitation system

that includes training, AED access, EMS activation, and hospital-level quality improvement frameworks. Its value lies in helping humans perform a difficult task more consistently under stress, not in altering the underlying pathophysiology of cardiac arrest.

For hospitals considering integrating a visual guidance tool, several practical considerations arise. Implementation planning may include identifying priority deployment locations, such as code carts, AED cabinets, rapid response bags, and public-facing areas; developing concise staff orientation materials; and incorporating the device into simulation and mock-code scenarios. Because PaceAid's operation is visual and non-diagnostic, training can focus on when to use the device, how to orient it, and how to incorporate its cues into existing protocol-driven responses, rather than on technical parameters or device calibration. Early implementation could reasonably be paired with observational beta testing to document usability, workflow fit, and user feedback.

PaceAid's versatility extends far beyond hospital walls, making it an invaluable resource in virtually any setting where cardiac arrest may occur. Its visual, step-by-step guidance and timing cues are designed for rapid deployment by both trained professionals and lay responders, enabling effective CPR in high-stress environments. Emergency medical services (EMS) teams, paramedics, and fire departments can integrate PaceAid into their response kits to reinforce structured, guideline-aligned compressions during chaotic scenes. Police officers and school personnel can use it to bridge the gap between training and real-world emergencies. At the same time, athletic trainers and coaches can rely on it for immediate action on sports fields, where sudden cardiac events are increasingly recognized. Beyond these contexts, PaceAid is equally suited for public spaces, workplaces, and community venues, wherever CPR may be required, providing a simple, non-intrusive visual reference that supports confidence, consistency, and coordination when seconds matter most.

Usability and Workflow Integration Evaluation

PaceAid was beta tested in real-world clinical settings during adult code blue (cardiac arrest) events at Saint Peter's University Hospital in New Brunswick, New Jersey. The evaluation included physicians, nurses, respiratory care practitioners, residents, and other skilled providers, all of whom

received prior instruction on device operation. Between January and December 2025, 12 dates yielded 16 documented cardiac arrest events and 27 completed evaluation forms. Quantitative analysis of Likert-scale responses (1 = Strongly Disagree; 5 = Strongly Agree) showed consistently high ratings across key usability and performance domains. Participants strongly agreed that PaceAid was easy to set up and operate (mean = 4.69), provided clear instructions (mean = 4.58), and enhanced confidence in performing CPR (mean = 4.81). Respondents also reported that the device effectively guided CPR performance (mean = 4.69) and supported adherence to established guidelines (mean = 4.35). Notably, 96% of respondents said they would recommend PaceAid to others learning or practicing CPR. Overall, findings suggest that PaceAid is a valuable human-factor intervention that promotes structured, guideline-compliant CPR in high-acuity environments. Limitations of this beta test include its single-site scope, modest sample size, adult-only cases, and feedback restricted to skilled providers, which may limit generalizability to lay responders.

Conclusion

Resuscitation science has well established variability in CPR performance, and major organizations, including the AHA [1], recognize the need for system-level strategies to support high-quality CPR. Human-factor research shows that stress and cognitive load affect performance in CPR training and likely in real events as well [2]. Training studies show that visual feedback can improve CPR compression quality among laypersons, reinforcing the broader principle that visual cues can shape performance in time-critical tasks [3]. In this context, visual guidance and timing-cue devices such as PaceAid can be understood as human-factor-oriented, process-support tools designed to help responders act more consistently under stress. By offering a low-complexity way to reinforce structured, guideline-aligned CPR actions, PaceAid aligns with hospital efforts to strengthen resuscitation processes, support diverse responder groups, and enhance overall emergency preparedness.

Learn More

For additional details on PaceAid and its four models, visit the official product website:

www.paceaid.com

References

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