Actionable Patient Safety Solutions™ (APSS™):

In-Hospital Cardiac Arrest

How to use this guide

This APSS provides evidence-based actions and resources for executives, leaders, clinicians, and performance improvement specialists. This document is intended to be used as a guide for healthcare organizations to examine their own workflows, identify practice gaps, and implement improvements. In it, you'll find:

Best Practice Summary: A high level summary of evidence-based, clinical best practices. (page 2)

Executive Summary: Executives should understand the breadth of the problem and its clinical and financial implications. (page 2)

Leadership Checklist: This section is for senior leaders to understand common patient safety problems and their implications related to in-hospital cardiac arrest. Most preventable medical harm occurs due to system defects rather than individual mistakes. Leaders can use this checklist to assess whether best practices are being followed and whether action is needed in their organization around in-hospital cardiac arrest. (page 3)

Clinical Workflow: This section includes more specific information about in-hospital cardiac arrest across the continuum of care. Leaders should include the people doing the work in improving the work. This section outlines what should be happening on the frontline. Clinicians can use this section to inform leaders whether there are gaps and variations in current processes. This is presented as an infographic that can be used for display in a clinical area. (page 5)

Education for Patients and Family Members: This section includes more specific information about in-hospital cardiac arrest across the continuum of care. Leaders should include the people doing the work in improving the work. This section outlines what should be happening on the frontline. Clinicians can use this section to inform leaders whether there are gaps and variations in current processes. This is presented as an infographic that can be used for display in a clinical area. (page 5)

Performance Improvement Plan: If it has been determined that there are gaps in current practice, this section can be used by organizational teams to guide them through an improvement project. (page 6)

What We Know about In-Hospital Cardiac Arrest: This section provides additional detailed information about in-hospital cardiac arrest. (page 9)

Resources: This section includes helpful links to free resources from other groups working to improve patient safety. (page 10)

Endnotes: This section includes the conflict of interest statement, workgroup member list, and references. (page 11)

Citation: Patient Safety Movement Foundation. (2022). In-Hospital Cardiac Arrests Actionable Patient Safety Solutions. Retrieved from https://patientsafetymovement.org/community/apss/

Patient Safety MOVEMENT

Best Practice Summary

Admission

- ☐ Determine every patient's code status and advanced directives and make sure it is readily available on the EMR
- ☐ Every patient will by default be resuscitated unless otherwise ordered. Special attention should be paid to those who might not prefer resuscitation or only limited resuscitation.
- ☐ Identify the individual responsible for making decisions in the event the patient is not able to make decisions for themselves and obtain their contact information.

Monitoring and Recognition of Deterioration

- ☐ See Rapid Response Team APSS and other similar protocols for monitoring (Lott et al., 2021; Brady et al., 2011; Sandau et al., 2017).

Cardiac Arrest Event

- ☐ Check for patient response. If the patient does not respond:
- ☐ Check for a pulse. If there is no pulse, or if a definitive pulse is not felt in 10 seconds, active the emergency response team and immediately initiate CPR if the patient's code status does not indicate otherwise.
- ☐ **Follow validated algorithms for resuscitation, such as those from the following organizations:**
  - ☐ American Heart Association
  - ☐ American Red Cross
  - ☐ The Royal Children's Hospital Melbourne
  - ☐ Resuscitation Council UK

Post-Arrest Management

- ☐ Follow protocols for post-cardiac arrest care (Lott et al., 2021; Peberdy et al., 2010).

Executive Summary

The Problem

Up to 80% of patients who experience a cardiac arrest in the hospital will show symptoms in the 24 hours prior, and yet early detection mechanisms and intervention processes are often insufficient to avoid a preventable death (Kim et al., 2015; Chon et al., 2013).

The Cost

It has been estimated that the incidence of in-hospital cardiac arrest hovers around one to five events per 1000 admissions (Liu et al., 2011). Studies show that effective rapid response teams and early clinical assessments are associated with a 15% reduction in mortality (Rocha et al., 2018) and a 52% decrease in in-hospital cardiac arrest occurrences (Goncales et al., 2012)., resulting in a significant reduction in length of stay and uncompensated healthcare costs.

The Solution

Many healthcare organizations have successfully implemented systems to reduce presentable death and harm from in-hospital cardiac arrest. This document provides a blueprint that outlines

the actionable steps organizations should take to successfully reduce in-hospital cardiac arrests and summarizes the available evidence-based practice protocols. This document is revised annually and is always available free of charge on our website.

Leadership Checklist

Use this checklist as a guide to determine whether current evidence-based guidelines are being followed in your organization:

Involve key stakeholders, including patients and family members, in improvement work.

- ☐ Involve those on the frontline in identifying hospital units that are 'poor' locations for a code (e.g., MRI due to strict protocols related to the magnet, office settings due to potential for patients to not be immediately identifiable). Understand why these locations are deemed as poor locations for a code.
- ☐ Involve the organization's Patient and Family Advisory Council (PFAC) in improvement efforts.
- ☐ Involve those who may benefit from observation (e.g., students, quality improvement specialists, etc) in the code response itself.
- ☐ Assess cardiorespiratory/cardiopulmonary assessment and treatment skills on an ongoing basis. Use mock scenarios and simulation for educational purposes.
- ☐ Consider additional education beyond biennial completion of the standard basic life support courses to improve resuscitation performance, with emphasis on high quality CPR. See Appendix A and Appendix B.
- ☐ Improve the ease with which patients and family members can activate the rapid response team. Implement a consistent, inclusive patient and family education program to explain how, why, and when to activate a rapid response team. Consider offering patients and family members CPR training. See Education for Patients and Family Members.
- ☐ Review events preceding a cardiac arrest with those on the frontline to identify potential for future prevention.

Anticipate process barriers early.

- ☐ Set up simulation training and mock scenarios to identify process barriers.
- ☐ Outline the 'picture perfect' room for an emergency response (e.g., what are all of the tools/resources needed in that scenario?).
- ☐ Select representative users and representative environments for device usability testing (e.g., don't choose only experts for usability testing) (Karsh & Scanlon, 2007).
- ☐ Build a clear plan when there is a shortage of supplies or personnel (e.g., medication shortages or product replacements). Identify where these resources exist in the organization when one unit is at maximum capacity and ensure these resources are flexible to accommodate (e.g., personnel from other units understand their roles when having to cover in other areas of the organization).
- ☐ Indicate crash cart readiness visually (e.g., note with green visual tags which crash carts are 'ready to go' and note with red tags which crash carts need to be 'reassembled or sterilized'). Consider standardizing who is restocking crash carts and when instead of restocking as needed on the units.
- ☐ Establish a feedback loop to the hospital operator to ensure the operator understands

what teams are available to deploy.

- ☐ Standardize the hospital's triage system to admit patients to the appropriate level of care according to their clinical condition and severity.

Standardize protocols and expectations.

- ☐ Create a culture where everyone feels empowered to call for help at the earliest indication. See Rapid Response Teams APSS. It might be beneficial to include a low-risk 'phone a friend' model where less experienced personnel can get a quick opinion before activating a Rapid Response Team.
- ☐ Establish a Resuscitation Outcomes Steering Committee (ROSC). See Appendix C for more information.
- ☐ Clarify cardiac arrest safety guidelines specific to the location (e.g., MRI safety rules).
- ☐ Include an established score, like the National Early Warning Score 2, in the medical chart to detect variations in clinical condition of the patient.
- ☐ Ensure that cardiac arrest and rapid response protocols are embedded into clinical workflows, whether electronic or paper. Clarify who on the emergency response team will remove all non-code team members from the area upon arrest.
- ☐ Ensure adequate training and documentation of resuscitation competencies and skills.
- ☐ Standardize expectations for communication. See Hand-Off Communication APSS.
- ☐ Strengthen efforts for post-resuscitation care to improve survival upon discharge after an in-hospital cardiac arrest (Girotra et al., 2020).
- ☐ Standardize a response team member responsible for minimizing distractions to the team member doing chest compressions.
- ☐ Apply medication safety principles in emergency response environments and ensure protocols are the same throughout the organization to minimize the cognitive load during high-stress situations.
- ☐ Designate a group responsible for stocking the crash carts in the standardized way and establish a clear line of communication with this group if changes are made to equipment, supplies, etc (ASA, n.d.).
- ☐ Expect that all team members involved in a code will debrief after each code.
- ☐ Follow guidelines for infection prevention (ISRRS, 2020).

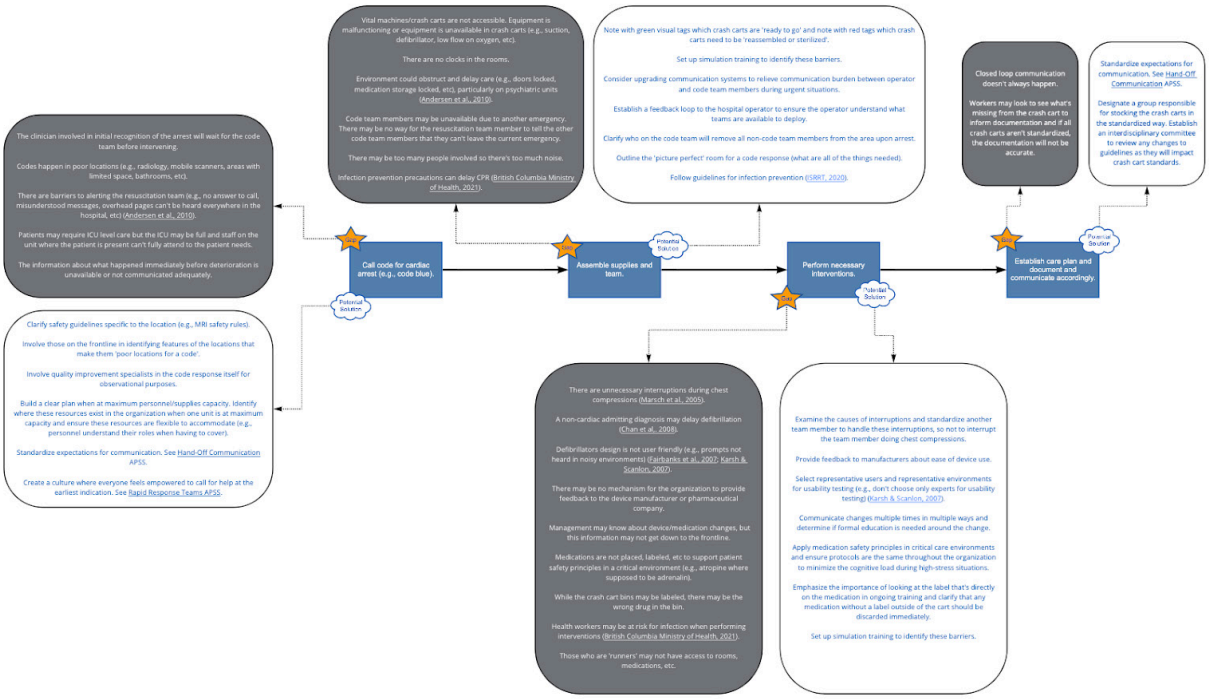
Sustain improvements.

- ☐ Measure and report number of arrest-related deaths by the total number of admissions monthly.
- ☐ Ensure there are enough staff to effectively manage necessary preventive care.
- ☐ Ensure that leaders have a simple process to oversee rapid response and resuscitation improvement work while also considering how it aligns with other initiatives across the organization.
- ☐ Consider upgrading communication systems to relieve communication burden between operator and code team members during urgent situations.
- ☐ Provide feedback to manufacturers about ease of device use.
- ☐ Communicate all changes multiple times in multiple ways and determine if formal education is needed around the change.
- ☐ Debrief on a regular basis to solicit team feedback about barriers to sustained

compliance. Adjust the plan quickly and nimbly as needed.

- ☐ Hold staff accountable for providing the standard of care and reward success.

Clinical Workflow



Expand image here

Education for Patients and Family Members

Care team members should:

- Explain to patients and family members why the patient may be at an increased risk for cardiac arrest.
- Indicate what to watch out for that may indicate deterioration.
- Outline exactly what to do, who to call, and how to report if they notice patient deterioration.
- Describe the basic components of resuscitation, such as activation of the rapid response team and CPR.
- Explain what will happen after they've made the report of potential deterioration and the family members' roles once the emergency response is called
- Explain that is family members are removed from the room during an emergency response, a professional from the organization will be assigned to provide them with ongoing updates.

Patients and family members should understand the significant value they hold to the care team in watching out for signs of potential cardiac arrest. Patients and family members can:

- Watch for significant changes in vital signs

- Watch for altered mental status
- Keep a log of medication changes
- Know where the nearest AED is located
- Understand where and how to call for help.

Performance Improvement Plan

Follow this checklist if the leadership team has determined that a performance improvement project is necessary:

☐ **Gather the right project team.** Bee sure to involve the right people on the team. You'll want two teams: an oversight team that is broad in scope, has 10-15 members, and includes the executive sponsor to validate outcomes, remove barriers, and facilitate spread. The actual project team consists of 5-7 representatives who are most impacted by the process. Whether a discipline should be on the advisory team or the project team depends upon the needs of the organization. Patients and family members should be involved in all improvement projects, as there are many ways they can contribute to safer care.

Complete this Lean Improvement Activity:
Conduct a SIPOC analysisto understand the current state and scope of the problem. A SIPOC is a lean improvement tool that helps leaders to carefully consider everyone who may be touched by a process, and therefore, should have input on future process design.

RECOMMENDED IN-HOSPITAL CARDIAC ARREST IMPROVEMENT TEAM	
• Admitting and registration staff	• Rapid response team members
• Quality and safety specialists	• Patients and family members
• Physicians (emergency medicine, critical care, anesthesiology, cardiology, etc)	• Central supply personnel
• Advanced practice registered nurse (e.g., nurse practitioners) and physician assistants	• Technologists and EHR experts
• Nurses	• Radiology department representative
• Pharmacists	• Lab department representative
• Respiratory therapists	• Social work
	• Spiritual care
	• Paramedics

Table 1: Understanding the necessary disciplines for an in-hospital cardiac arrest improvement team

☐ **Understand what is currently happening and why.** Reviewing objective data and trends is a good place to start to understand the current state, and teams should spend a good amount of time analyzing data (and validating the sources), but the most important action here is to go to the point of care and observe. Even if team members work in the area daily, examining existing processes from every angle is generally an eye-opening experience. The team should ask questions of the

Create a process map once the workflows are well understood that illustrates each step and the best practice gaps the team has identified (IHI, 2015). Brainstorm with the advisory team to understand why the gaps exist, using whichever root cause analysis tool your organization is accustomed to (IHI, 2019). Review the map with the advisory team and invite the frontline to validate accuracy.

frontline during the observations that allow them to understand each step in the process and identify the people, supplies, or other resources needed to improve patient outcomes.

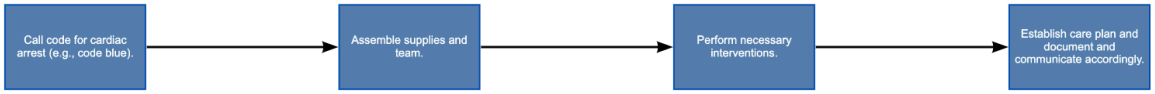


Image 2: Example process map. Click here to expand.

- [ ] **Prioritize the gaps to be addressed and develop an action plan.** Consider the cost effectiveness, time, potential outcomes, and realistic possibilities of each gap identified. Determine which are a priority for the organization to focus on. Be sure that the advisory team supports moving forward with the project plan so they can continue to remove barriers. Design an experiment to be trialed in one small area for a short period of time and create an action plan for implementation.

The action plan should include the following:

- Assess the ability of the culture to change and adopt appropriate strategies
- Revise policies and procedures
- Redesign forms and electronic record pages
- Clarify patient and family education sources and content
- Create a plan for changing documentation forms and systems
- Develop the communication plan
- Design the education plan
- Clarify how and when people will be held accountable

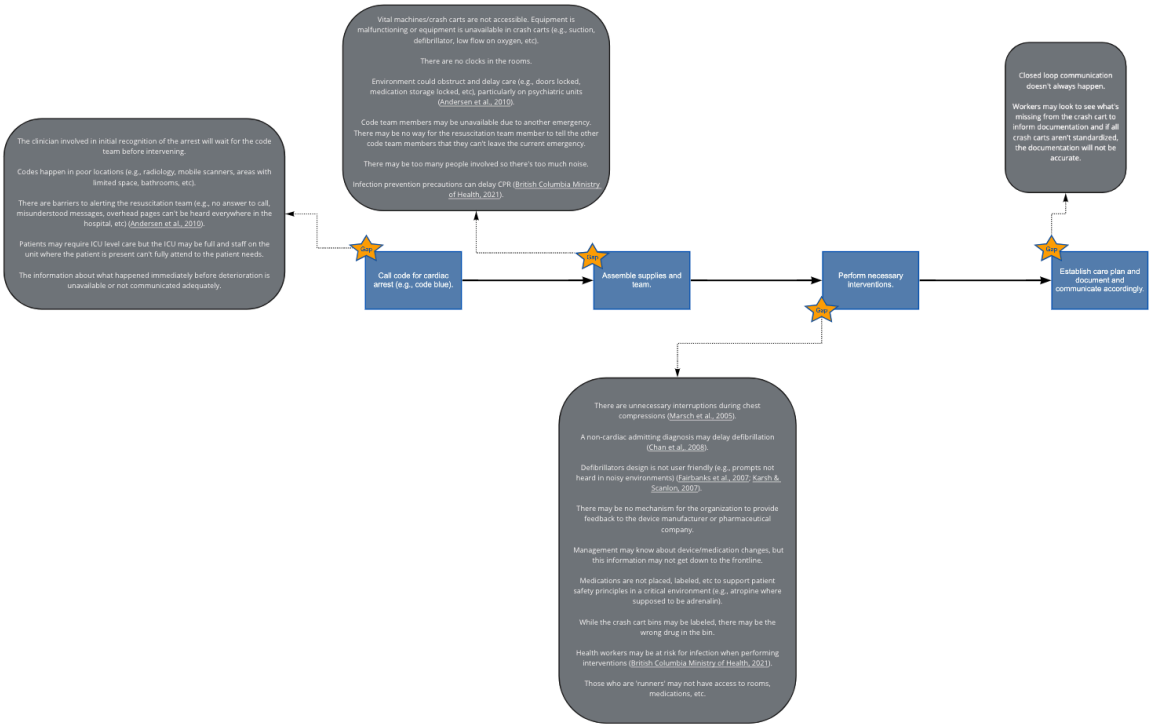


Image 3: Example process map with gaps. Click here to expand.

TYPICAL GAPS IDENTIFIED IN IN-HOSPITAL CARDIAC ARREST
• Inappropriate patient monitoring and reassessment
• Care team personnel and family members may not be aware of signs of deterioration
• Care team personnel may not know the disease process or the patient's physiology
• Challenges related to the code location (e.g., finding and getting to the code location, code in high-risk locations (e.g., radiology), etc)
• Institutional barriers, including unclear criteria, for summoning additional help
• Delays in performing chest compressions
• Access or availability to emergency equipment and crash carts
• Interruptions in performing high quality chest compressions
• Equipment is not user-friendly
• Equipment is not standardized throughout the facility
• There is no way to tell if the equipment in the crash carts has expired.
• Medication safety strategies may be lacking in critical response environments
• Poor communication pre- and post- code team intervention
• Inaccurate post-cardiac arrest documentation

Table 2: By identifying the gaps in in-hospital cardiac arrest compliance, organizations can tailor their project improvement efforts more effectively

☐ **Evaluate outcomes, celebrate wins, and adjust the plan when necessary.** Measure both process and outcome metrics. Outcome metrics include the rates outlined in the leadership checklist. Process metrics will depend upon the workflow you are trying to improve and are generally expressed in terms of compliance with workflow changes. Compare your outcomes against other related metrics your organization is tracking.

Routinely review all metrics and trends with both the advisory and project teams and discuss what is going well and what is not. Identify barriers to completion of action plans, and adjust the plan if necessary. Once you have the desired outcomes in the trial area, consider spreading to other areas (IHI, 2006).

It is important to be nimble and move quickly to keep team momentum going, and so that people can see the results of their labor. At the same time, don't move so quickly that you don't consider the larger, organizational ramifications of a change in your plan. Be sure to have a good understanding of the other, similar improvement projects that are taking place so that your efforts are not duplicated or inefficient.

Read this paper from the Institute for Healthcare Improvement to understand how small local steps

IN-HOSPITAL CARDIAC ARREST METRICS TO CONSIDER ASSESSING
• Total number of arrest-related deaths/total number of admissions (defined as a patient receiving arrest resuscitative efforts (either CPR or defibrillation) at any time during admission who does not survive to hospital discharge)
• Time to first chest compression within one minute
• Time to first defibrillation within two minutes for cardiac arrests due to shockable rhythms
• CPR quality and adherence to BLS/ACLS/PALS guidelines

- Device confirmation of endotracheal tube placement during an acute resuscitation
- Survival to discharge
- Readmission
- Length of stay
- Patient status at code
- Location of code
- Response time of RRT
- Debrief after code
- Transfers to ICU (planned and unplanned)
- 30- and 90-day mortality
- Signs of unexpected deterioration before code
- Episodes of 'futile care' that might have benefitted from an advanced directive and DNR order or palliative care consultation

Table 3: Consider evaluating related metrics to better understand in-hospital cardiac arrest presence and contributing factors.

What We Know About In-Hospital Cardiac Arrest

Cardiac arrest is defined as the sudden cessation of cardiac activity resulting in unresponsiveness of the patient, accompanied by a cease of normal breathing and circulation (Patel, 2020). An intervention to resuscitate the patient is required within moments to prevent significant harm or death. The longer the patient is without effective intervention, the greater the risk for cognitive and physical deterioration (Mędrzycka-Dąbrowska et al., 2018). Therefore, the outcomes of the patient are largely dependent on the preparedness of the hospital before the event even occurs. Studies show that preparedness of a rapid response team is associated with a 15% reduction in mortality (Rocha et al., 2018).

The majority of patients demonstrate signs and symptoms of instability and deterioration 6-8 before arrest occurs (Mezzaroba et al., 2016). These symptoms commonly include desaturation and hypotension.

Risk Factors

- Older age
- Poor functional status prior to arrest
- Those with sepsis
- Those with pneumonia
- Those with hypotension
- Those with renal and hepatic dysfunction
- Those not on an appropriate unit (e.g. a surgery patient on a medical floor).

Clinical Implications

In US adults alone, there are an estimated 290,000 cases of in-hospital cardiac arrests each year (Andersen, 2019).

In many cases, in-hospital cardiac arrest is a major preventable cause of patient morbidity and mortality. It is estimated that between 17% (Peberdy et al., 2003) and 24% (Go et al., 2013) of in-hospital cardiac arrest patients survive to hospital discharge. For those patients who do survive to discharge, nearly 25% will be newly placed in a skilled nursing facility and many will likely suffer brain injury, injury to the nervous system, or other complications (Peberdy et al., 2003).

It has been suggested that the rates of survival to discharge post-in-hospital cardiac arrest are lower for black patients (25.2%) than for white patients (37.4%) (Chan, 2009).

In-hospital cardiac arrest etiology is distinguished by cardiac and noncardiac. Most in-hospital adult cardiac arrest events are related to cardiac complications, including, but not limited to, arrhythmias, myocardial infarction, or heart failure (50-60% of cases) (Andersen 2019). The second most common etiology is non-cardiac, or respiratory insufficiency (15-40% of cases) (Andersen 2019). Most pediatric cardiac arrests are commonly preceded by respiratory compromise (Duff et al., 2019).

Cardiac arrest at night and lack of a witness are significant causes for mortality in in-hospital cardiac arrest patients (Chon et al., 2013).

If possible, it is important to understand the patient's code status before initiating CPR but do not let this cause a delay in initiation. DNR status should be clearly communicated in multiple ways, including, but not limited to, armbands, room signs, and flagging the chart. Consider the possibility that notation of status via armbands may cause the information on the armband to be outdated if there is a patient change and a delay in replacement of the armband. The bedside nurse should know the status prior to calling the Rapid Response Team (RRT). The RRT should not do anything until they speak to the bedside nurse, regardless of code status. If there is no provider order in the chart, the patient is automatically a full code.

Resources

Resources for In-Hospital Cardiac Arrest Improvement:

- AHA: Get with the Guidelines
- AHA: Post-Cardiac Arrest Care Fact Sheet
- AHA: Resuscitation Fact Sheet
- Resuscitation Council UK: In-Hospital Resuscitation Guidelines
- In-hospital Cardiac Arrest and Preceding National Early Warning Score (NEWS): A Retrospective Case-Control Study
- Cardiac Arrest Survival Post Resuscitation In-Hospital Score (CASPRI)
- Airway and Ventilation Management During Cardiopulmonary Resuscitation and After Successful Resuscitation
- Errors in the management of cardiac arrests: An observational study of patient safety incidents in England
- "Identifying the hospitalised patient in crisis"-A consensus conference on the afferent limb of rapid response systems
- Findings of the first consensus conference on medical emergency teams

For General Improvement:

- CMS: Hospital Improvement Innovation Networks
- IHI: A Framework for the Spread of Innovation
- The Joint Commission: Leaders Facilitating Change Workshop
- IHI: Quality Improvement Essentials Toolkit
- SIPOC Example and Template for Download
- SIPOC Description and Example

Endnotes

Conflicts of Interest Disclosure

The Patient Safety Movement Foundation partners with as many stakeholders as possible to focus on how to address patient safety challenges. The recommendations in the APSS are developed by workgroups that may include patient safety experts, healthcare technology professionals, hospital leaders, patient advocates, and medical technology industry volunteers. Workgroup members are required to disclose any potential conflicts of interest.

Workgroup

Co-Chairs

Daniel Davis	Air Methods Corporation
Helen Haskell	Mothers Against Medical Error
Jacinda Bunch	University of Iowa
Ed Salazar	Patient Advocate

Current Members

Ernesto Arriaga Morales	Hospital San Angel Inn Sur
Steven Barker	Patient Safety Movement Foundation; Masimo
Richard P. Dutton	US Anesthesia Partners, Dallas
Michael A. DeVita	Columbia Vagelos College of Physicians and Surgeons; Harlem Hospital Center
Michele Holt	University of Florida, Jacksonville
Josiah Huse	University of California, Irvine
Sarah Knowles	University Hospitals- Cleveland Medical Center
Ariana Longley	Patient Safety Movement Foundation
Olivia Lounsbury	Patient Safety Movement Foundation
Donna Prosser	Patient Safety Movement Foundation
Kimberly Won	Chapman University
Robert B. Kelly	Children's Hospital of Orange County;, University of California, Irvine

Metrics integrity

Robin Betts	Kaiser Permanente, Northern California Region

Past Members

This list represents all contributors to this document since inception of the Actionable Patient Safety Solutions.

Chantelle Dron	Windsor Severance Fire Rescue
Jeff Dunn	Redivus Health
Dana Edelson	University of Chicago
Michel Bennett	Patient Safety Movement Foundation (formerly)
Bill Honigman	Hoag Health
Douglas Kupas Geisinger	Health System
Brenna Lawrence	University of California, San Diego
Jacob Lopez	Patient Safety Movement Foundation (formerly)
Christine Raup	Geisinger Health System
Melanie Roberts	University of Colorado
Frank Sebat	Kritikus Foundation
Rebecca Sell	University of California, San Diego
Tyler Vadeboncoeur	Mayo Clinic
Praveen Venkatagiri	Ovum Hospitals
Sheri Villanuev	University of California, San Diego
Fiona Winterbottom	Ochsner

References

Airway Safety | Patient Safety Movement. (2020). Patient Safety Movement. https://patientsafetymovement.org/clinical/airway-safety/

American Red Cross Training Services. (2020). CPR Steps | Perform CPR | Red Cross. Red Cross Training & Certification, and Store. https://www.redcross.org/take-a-class/cpr/performing-cpr/cpr-steps

Andersen, L. W., Holmberg, M. J., Berg, K. M., Donnino, M. W., & Granfeldt, A. (2019). In-Hospital Cardiac Arrest. *JAMA*, 321(12), 1200. https://doi.org/10.1001/jama.2019.1696

Awada and Maher. (2013). Reduction in Red Blood Cell Transfusions during Neurosurgery with Noninvasive and Continuous Hemoglobin Monitoring. Proceeding of the Society for Technology in Anesthesia Annual Meeting

Bilben, B., Grandal, L., & Søvik, S. (2016). National Early Warning Score (NEWS) as an emergency department predictor of disease severity and 90-day survival in the acutely dyspneic patient – a prospective observational study. Scandinavian Journal of Trauma, *Resuscitation and Emergency Medicine*, 24(1), 24. https://doi.org/10.1186/s13049-016-0273-9

Blind, K. The Impact of Regulation on Innovation. Edward Elgar Publishing. doi:10.4337/9781784711856.00022 Davis, D. (2010). A New Resuscitative Protocol. *Journal of Emergency Medical Services*. Retrieved from http://www.jems.com/articles/print/ volume-35/issue-9/patient-care/new-resuscitative-protocol.html.

Brady, W. J., Gurka, K. K., Mehring, B., Peberdy, M. A., O'Connor, R. E., & American Heart Association's Get with the Guidelines (formerly, NRCPR) Investigators (2011). In-hospital cardiac arrest: impact of monitoring and witnessed event on patient survival and neurologic status at hospital discharge. *Resuscitation*, 82(7), 845–852. https://doi.org/10.1016/j.resuscitation. 2011.02.028

Chan, P. S. (2009). Racial Differences in Survival After In-Hospital Cardiac Arrest. JAMA, 302(11), 1195. https://doi.org/10.1001/jama.2009.1340

Chon, G. R., Lee, J., Shin, Y., Huh, J. W., Lim, C.-M., Koh, Y., & Hong, S.-B. (2013). Clinical Outcomes of Witnessed and Monitored Cases of In-Hospital Cardiac Arrest in the General Ward of a University Hospital in Korea. *Respiratory Care*, 58(11), 1937–1944. https://doi.org/10.4187/respcare.02448

Davis D.P., Aguilar S.A., Graham P.G., Lawrence B., Sell R.E., Minokadeh A., Husa R.D. (2015). A Novel Configuration of a Traditional Rapid Response Team Decreases Non-intensive Care Unit Arrests and Overall Hospital Mortality. *J Hosp Med*; 10(6):352-7.

Davis D.P., Graham P.G., Husa R.D., Lawrence B., Minokadeh A., Altieri K., Sell R.E. (2015). A Performance Improvement-based Resuscitation Programme Reduces Arrest Incidence and Increases Survival from In-hospital Cardiac Arrest. Resuscitation; 92:63-9.

Ehrenfeld, J. M. (2010). Impact of Continuous and Noninvasive Hemoglobin Monitoring on Intraoperative Blood Transfusions. *American Society of Anesthesiologists*.

Girotra, S., Nallamothu, B. K., Tang, Y., & Chan, P. S. (2020). Association of Hospital-Level Acute Resuscitation and Postresuscitation Survival with Overall Risk-Standardized Survival to Discharge for In-Hospital Cardiac Arrest. *JAMA Network Open*, 3(7), e2010403–e2010403. https://doi.org/10.1001/jamanetworkopen.2020.10403

Go, A. S., Mozaffarian, D., Roger, V. L., Benjamin, E. J., Berry, J. D., Borden, W. B., Bravata, D. M., Dai, S., Ford, E. S., Fox, C. S., Franco, S., Fullerton, H. J., Gillespie, C., Hailpern, S. M., Heit, J. A., Howard, V. J., Huffman, M. D., Kissela, B. M., Kittner, S. J., … Turner, M. B. (2013). Heart Disease and Stroke Statistics—2013 Update. *Circulation*, 127(1), . https://doi.org/10.1161/cir.0b013e31828124ad

Gonçales, P. D. S., Polessi, J. A., Bass, L. M., Santos, G. P. D., Yokota, P. K. O., Laselva, C. R., Fernandes Junior, C., Cendoroglo Neto, M., Estanislao, M., Teich, V., & Sardenberg, C. (2012). Reduced frequency of cardiopulmonary arrests by rapid response teams. *Einstein (São Paulo)*, 10(4), 442–448. https://doi.org/10.1590/s1679-45082012000400009

Jones, D., Durham, L., Lighthall, G., Welch, J., DeVita, M., Garcia, L., Lippert, A., Kodal, A. M., Odell, M., Majeed, J., & Bunch, J. (2020, March 23). Recommendations for Rapid Response Teams (RRTs) and Critical Care Outreach (CCO) services in the context of the COVID-19 pandemic. International Society for Rapid Response System.

Karsh, B. T., & Scanlon, M. (2007). When is a defibrillator not a defibrillator? When it's like a clock radio.... The challenge of usability and patient safety in the real world. *Annals of emergency medicine*, 50(4), 433–435. https://doi.org/10.1016/j.annemergmed.2007.06.481

Kim, W. Y., Shin, Y. J., Lee, J. M., Huh, J. W., Koh, Y., Lim, C.-M., & Hong, S. B. (2015). Modified Early Warning Score Changes Prior to Cardiac Arrest in General Wards. *PLOS ONE*, 10(6), e0130523. https://doi.org/10.1371/journal.pone.0130523

Liu, W.-L., Lai, C.-C., Hii, C.-H., Chan, K.-S., Hsing, S.-C., Cheng, K.-C., & Tan, C.-K. (2011). Outcomes and Cost Analysis of Patients With Successful In-Hospital Cardiopulmonary Resuscitation. *International Journal of Gerontology*, 5(4), 196–199. https://doi.org/10.1016/j.ijge.2011.09.016

Lott, C., Truhlář, A., Alfonzo, A., Barelli, A., González-Salvado, V., Hinkelbein, J., Nolan, J. P., Paal, P., Perkins, G. D., Thies, K. C., Yeung, J., Zideman, D. A., Soar, J., & ERC Special Circumstances Writing Group Collaborators (2021). European Resuscitation Council Guidelines 2021: Cardiac arrest in special circumstances. *Resuscitation*, 161, 152–219. https://doi.org/10.1016/j.resuscitation.2021.02.011

Mędrzycka-Dąbrowska, W. A., Czyż-Szybenbejl, K., Kwiecień-Jaguś, K., & Lewandowska, K. (2018). Prediction of cognitive dysfunction after resuscitation – a systematic review. *Advances in Interventional Cardiology*, 14(3), 225–232. https://doi.org/10.5114/aic.2018.78324

Mezzaroba, A. L., Tanita, M. T., Festti, J., Carrilho, C. M. D. M., Cardoso, L. T. Q., & Grion, C. M. C. (2016). Evaluation of the five-year operation period of a rapid response team led by an intensive care physician at a university hospital. *Revista Brasileira de Terapia Intensiva*, 278–284. https://doi.org/10.5935/0103-507x.20160045

Morrison, L. J., Neumar, R. W., Zimmerman, J. L., Link, M. S., Newby, L. K., McMullan, P. W. J., ... Edelson, D. P. (2013). Strategies for Improving Survival After In-hospital Cardiac Arrest in the United States: 2013 Consensus Recommendations: a Consensus Statement from the American Heart Association. *Circulation*, 127, 1538–63.(2001). National Academies Press. doi:10.17226/10027.

Neumar, R. W., Otto, C. W., Link, M. S., Kronick, S. L., Shuster, M., Callaway, C. W., ... Morrison, L. J. (2010). Part 8: Adult Advanced Cardiovascular Life Support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*, 122, S729–67.

Nolan, J. P., Soar, J., Zideman, D. A., Biarent, D., Bossaert, L. L., Deakin, C., ... Böttiger, B. (2010). European Resuscitation Council Guidelines for Resuscitation 2010 Section 1. Executive summary. *Resuscitation*, 81(10), 1219–1276. doi:10.1016/j.resuscitation.2010.08.021.

Patel, K., & Hipskind, J. E. (2020). Cardiac Arrest. StatPearls, . https://www.ncbi.nlm.nih.gov/books/NBK534866/#:~:text=As%20defined%20by%20the%20American,and%20no%20signs%20of%20circulation.

Peberdy, M. A., Kaye, W., Ornato, J. P., Larkin, G. L., Nadkarni, V., Mancini, M. E., Berg, R. A., Nichol, G., & Lane-Trultt, T. (2003). Cardiopulmonary resuscitation of adults in the hospital: A report of 14 720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. *Resuscitation*, 58(3), 297–308. https://doi.org/10.1016/s0300-9572(03)00215-6

Peberdy, M. A., Callaway, C. W., Neumar, R. W., Geocadin, R. G., Zimmerman, J. L., Donnino, M., Gabrielli, A., Silvers, S. M., Zaritsky, A. L., Merchant, R., Vanden Hoek, T. L., & Kronick, S. L. (2010). Part 9: Post-Cardiac Arrest Care: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*, 122(18_suppl_3), S768–S786. https://doi.org/10.1161/

circulationaha.110.971002

Rocha, H. A. L., Alcântara, A. C. C., Rocha, S. G. M. O., & Toscano, C. M. (2018). Effectiveness of rapid response teams in reducing intrahospital cardiac arrests and deaths: a systematic review and meta-analysis. *Revista Brasileira de Terapia Intensiva*, 30(3), 366–375. https://doi.org/10.5935/0103-507X.20180049

Sandau, K. E., Funk, M., Auerbach, A., Barsness, G. W., Blum, K., Cvach, M., Lampert, R., May, J. L., McDaniel, G. M., Perez, M. V., Sendelbach, S., Sommargren, C. E., & Wang, P. J. (2017). Update to Practice Standards for Electrocardiographic Monitoring in Hospital Settings: A Scientific Statement From the American Heart Association. *Circulation (New York, N.Y.)*, 136(19), E273–E344. https://doi.org/10.1161/CIR.0000000000000527

Schein, R. M. H., Hazday, N., Pena, M., Ruben, B. H., & Sprung, C. L. (1990). Clinical Antecedents to In-Hospital Cardiopulmonary Arrest. *Chest*, 98(6), 1388–1392. https://doi.org/10.1378/chest.98.6.1388

Schmid, A., Hoffman, L., Happ, M. B., Wolf, G. A. and DeVita, M. (2007). Failure to Rescue. *JONA: The Journal of Nursing Administration*, 37(4), 188–198. doi:10.1097/01. nna.0000266838.23814.65.

Society of Hospital Medicine. Mentored Implementation for Quality Improvement. Retrieved from http://dev.hospitalmedicine.org/Web/QualityInnovation/Mentored_Implementation/ Landing_Page.aspx.

Subbe, Bannard-Smith, Bunch, Champunot, DeVita, Durham, Edelson, Gonzalez, Hancock, Haniffa, Hartin, Haskell, Hogan, Jones, Kalkman, Lighthall, Malycha, Ni, Phillips, Rubulotta, So, and Welch. (2019). International Society for Rapid Response Systems. Quality metrics for the evaluation of Rapid Response Systems: Proceedings from the third international consensus conference on Rapid Response Systems. Resuscitation.

Appendices

Appendix A: Reason for Additional Education Beyond Biennial Completion of the American Heart Association Life Support Training Courses

The primary mechanism for maintaining resuscitation competency for most institutions is limited to biennial completion of the American Heart Association life support training courses. This approach as the sole mechanism to maintain competency has several limitations, particularly for in-hospital providers (Morrison et al., 2013; Davis, 2010):

- Biennial training is not frequent enough to maintain CPR skills, which appear to decay within 3-4 months.
- ACLS/BLS curricula are not contextual and may not reflect the unique capabilities and technologies of a particular institution and its providers.
- ACLS/BLS curricula cannot be modified to address institutional CQI needs.
- Treatment algorithms upon which the ACLS/BLS courses are based cannot incorporate the variety of new technologies that offer potential to improve outcomes.
- The ACLS/BLS curriculum does not include arrest prevention.

Appendix B: Advanced Resuscitation Training (ART): A Model for Reducing Preventable Deaths

The ART program was developed in 2007 at the University of California at San Diego (UCSD) and represents a comprehensive system of care that targets the reduction of preventable deaths in both the out-of-hospital and in-hospital environments. The ART model links scientific evidence, CQI data, technology, institutional treatment algorithms, and training. Ownership and accountability are transferred to the institution, enhancing both relevance and engagement.

ART training can be described as "adaptive," such that educational content is delivered to individual provider groups, defined by provider type (e.g., nurse, physician, respiratory therapist, technician) and clinical unit, based on patient mix and level of care provided. In addition, performance improvement data is used to address institutional and unit-specific issues. Annual training is conducted in 4-hour blocks, with content dedicated equally to prevention and response to cardiac arrest. Training format includes traditional didactics, dedicated skills sessions, and simulation. In addition to the scheduled training, ad hoc sessions are conducted based on performance improvement data trends or sentinel events.

ART clinical guidelines reflect the core elements of the International Liaison Committee on Resuscitation. Specific treatment recommendations as part of the institutional algorithm reflect available technologies as well as the collective interpretation and preferences of institutional clinical leadership. Training sessions are structured around the unique algorithms and the application of technology as part of a contextual learning philosophy.

ART employs a novel taxonomy for categorizing arrests based on physiological pattern and clinical condition. This allows anticipation of arrest based on static and dynamic risk factors and identification of deterioration patterns that allow for RRT activation and intervention prior to arrest. A stepwise approach to early detection is employed to maximize both sensitivity and specificity and integrate clinical data, technology, and hospital processes. This same taxonomy forms the basis for ART CQI efforts to guide program refinement and incorporates a strategy to categorize arrest etiology for each at-risk patient. This facilitates a systematic approach to reducing preventable deaths within each category by targeting prevention as well as effective resuscitation. In addition, this taxonomy aligns with multiple hospital-based patient safety initiatives: Sepsis, perioperative respiratory depression and sleep apnea, occult hemorrhage, dysrhythmias, deep venous thrombosis/pulmonary embolism detection and treatment, respiratory distress, neurological emergencies, and general critical care. The ART program has been successfully implemented at UCSD as well as multiple pilot sites across the US. As a direct result

of ART program implementation:

- Arrest incidence has been reduced by more than 50%.
- Survival following arrest has doubled and good neurological outcomes have tripled.
- Life support expenditures have been reduced by 25%.
- A 10-fold return on investment has been realized, with potential savings in reduced cost-of-care, medicolegal payouts, and improved reimbursement for pay-for- performance/value-based purchasing.

Appendix C: Resuscitation Outcomes Steering Committee (ROSC)

A Resuscitation Outcomes Steering Committee (ROSC) represents a multi-disciplinary institutional group with primary responsibility for the program. This group should have both ownership and accountability for outcomes and should have access to local data with the goal of using it to better understand the institution's patients' needs and to optimize the response to deterioration. Reporting from the institutional ROSC should be upward to institutional leaders, horizontal to other committees, hospital units, and service lines, and downstream to providers.

Engaging individual providers and enhancing their personal sense of ownership and accountability will help create a culture of patient safety. This can be accomplished by:

- Engaging individual providers and enhancing their personal sense of ownership and accountability will help create a culture of patient safety. This can be accomplished by:
    - Engagement and public support of the institutional ROSC by hospital leaders and broad representation of various hospital groups on the ROSC.
    - Effectively modifying training content to address provider-specific needs and issues, and giving routine feedback of institutional resuscitation data.

Ultimately, the resuscitation program should become the primary vehicle to reduce preventable deaths and ensure an institutional culture of safety.