Actionable Patient Safety Solutions (APSS) #10:

Systematic prevention of & resuscitation of in-hospital cardiac arrest

How to use this guide

This guide gives actions and resources for creating and sustaining systematic prevention and resuscitation of in-hospital cardiac arrest. In it, you'll find:

Patient Safety MOVEMENT

Executive summary checklist

One-third of inpatient deaths may be preventable by improving systems for earlier detection and resuscitation for patients who suffer deterioration. Several of those systems are highlighted in this APSS.

Checklist for a comprehensive system for prevention and response to in-hospital cardiac arrest

- ☐ Convene an institutional multi-disciplinary steering taskforce consisting of physicians, nurses, respiratory therapists, and administrators, whose goal is to develop and optimize strategies for managing clinical deterioration and cardiac arrest prevention. Use selected internal and external data and guidelines to assess and develop a plan to reduce your institution's in-hospital cardiac arrest rate.
  - ☐ Create a formal mechanism for the use of performance improvement data to influence output actions.
  - ☐ Data should include evidence-based guidelines and scientific literature, as well as internal (institutional) data.
  - ☐ The taskforce should have input as to how data are used to improve clinical outcomes.
  - ☐ Data should be presented on a regular basis (monthly, quarterly) to hospital leadership.
- ☐ Potential hospital specific data to be collected may include:
  - ☐ Frequency, location and time of day of cardiac arrest and rapid response events trended in a run or control chart
  - ☐ Hospital mortality rate trended in a run chart
  - ☐ Types of interventions performed during rapid response events
  - ☐ Cardiac arrest events preceded by severe vital sign abnormality
- ☐ Target the most prevalent causes of arrest for prevention and resuscitation efforts.
- ☐ Consider available evidence, technology, and performance improvement data when developing resuscitation protocols.
- ☐ Foster an institutional culture of safety that promotes teamwork and transparency.

Checklist for establishing a rapid response system

- ☐ The rapid response system (RRS) should have oversight by the appropriate dedicated committee. This can be the samecommittee that oversees the code blue response..
- ☐ Criteria for RRS activation should be clearly defined and publicized to all hospital staff. Training on the significance of the criteria to patient deterioration is recommended. Activation criteria or triggers may include:
  - ☐ Vital sign patterns or thresholds
  - ☐ Early warning scoring systems
  - ☐ Software applications running predictive algorithms
  - ☐ Laboratory assessments
  - ☐ Novel technologies that assess perfusion, oxygenation, ventilation, neurologic

function, or other critical physiological processes
  - ☐ Clinical judgment of providers
  - ☐ Concern from patient and/or family
- ☐ A dedicated rapid response team (RRT) that is capable of addressing the needs of a patient who has suffered clinical deterioration. Potential participants include a critical care physician, or critical care nurse with access to a critical care physician, along with a respiratory therapist.. Many hospitals also require that the primary team be contacted at the same time as the RRT.
- ☐ Specific protocols and equipment for use by the RRT should be considered.
- ☐ Training in early recognition and prevention of deterioration should be considered for all providers.
- ☐ Family members are valuable allies who can and should be enlisted by instructing them in signs of deterioration and encouraging them to raise concerns. A hospital policy supporting the ability of a family member to initiate a rapid response (or similar) team may promote event finding, and promote earlier detection of deterioration.
- ☐ Data collection and CQI should be performed to assess RRS effectiveness and identify opportunities for improvement.

Checklist setting up a resuscitation performance system

- ☐ Optimal CPR performance by all providers must be ensured. Training should address:
  - ☐ Indications to initiate compressions
  - ☐ Proper compression rate, depth, and recoil
  - ☐ Integration of compressions and ventilations per institutional standards
- ☐ Additional CPR technology should be considered:
  - ☐ Real-time compression feedback
  - ☐ End-tidal CO2 as a guide to optimizing CPR
  - ☐ Mechanical compression devices
- ☐ Provider training should be implemented to ensure optimal resuscitation performance that is specific to provider role, clinical unit, and available technology.
- ☐ Target post-resuscitative care for arrest victims with return of spontaneous circulation.
  - ☐ Deliver optimal supportive critical care.
  - ☐ Consider targeted temperature management.
  - ☐ Consider early coronary revascularization.

What we know about prevention and resuscitation of in-hospital cardiac arrest

Cardiac arrest involves the unexpected loss of cardiac function, breathing, and consciousness. The majority of patients demonstrate signs and symptoms of instability and deterioration long before arrest occurs. In-hospital cardiac arrest is a major preventable cause of patient morbidity and mortality. However, survival rates reported by large databases have remained relatively stagnant at 10-20 percent for several decades. This is in sharp contrast to individual institutions that have taken a non-traditional approach to resuscitation training, practice, and oversight, with survival-to-discharge rates that approach 50 percent.

Systematic prevention of in-hospital cardiac arrest – and effective resuscitation when it does occur – includes staff training and leadership support to:

- Identify patients at high risk of cardiac arrest
- Recognize and reverse physiological deterioration
- Provide optimal CPR for arrest victims

This APSS gives recommendations to:

- Improve resuscitation systems of care
- Establish a rapid response system (RRS) to identify and respond to patients displaying signs/symptoms of deterioration
- Improve resuscitation performance, with emphasis on high quality CPR
- Provide optimal post-resuscitative care
- Integrate technology into clinical resuscitation practice
- Use data to inform and modify the resuscitation system

Rapid response systems (RRS) can prevent a substantial percentage of in-hospital cardiac arrest.

- Most in-hospital cardiac arrest victims demonstrate signs/symptoms of deterioration some time prior to arrest so as to allow intervention and arrest prevention.
  - This is particularly true in the non-ICU areas.
- Barriers to early recognition and prevention of arrest include:
  - Absence of an organized system that identifies and responds to deteriorating patients
  - Lack of knowledge on the part of the bedside staff
  - Social and cultural barriers that impair communication of nurse and other front level providers concerns to physicians and other team members
  - Overconfidence that cardiac arrests are rare and easily prevented
  - Inadequate/inappropriate monitoring
  - Institutional barriers, including unclear criteria, for summoning additional help
  - Improper training and expertise of rapid response team members
  - Poor engagement of patient and family members
- Effective RRS programs include the following four elements:
  - Administrative oversight of all aspects of the program, with a goal of reducing non-ICU morbidity and mortality.
  - Means for detecting deterioration and calling for critical care-trained help. This includes a combination of the following:

- Mechanisms for patient- and family-activated rapid response.
- Dedicated training of bedside nurses in the early recognition and response to deteriorating patients.
- Designation and training of a specialized response team that includes a critical care nurse and respiratory therapist as well as access to a critical care physician.
- Development of monitoring practices and protocols and establishment of calling criteria. These may include vital sign thresholds or patterns, scoring systems (e.g., NEWS), predictive algorithms and computer models, and provider/patient/family concerns.
- Creation of a safety culture that supports any and all calls for additional help.

o A specific, designated team capable of rapid patient evaluation and escalation of care where appropriate. Traditionally, critical care-based physicians and nurses lead these teams and administer care.

o Appropriate data collection and analysis efforts that seeks to understand local epidemiology of deterioration, follows patterns and trends, adjusts detection and response efforts to meet patient needs, and establishes appropriate training programs.

Staff CPR skills are inadequate

The foundation for successful arrest resuscitation is the performance of high-quality CPR. The published literature documents suboptimal performance of CPR by hospital providers.

- First responders are often reluctant to initiate chest compressions, resulting in prolonged ischemic periods and poor outcomes. This may reflect uncertainty regarding arrest status or an underappreciation for the importance of early CPR.
- There are often frequent and prolonged interruptions in chest compressions, reducing cardiac output and lowering the likelihood of a return of spontaneous circulation. This often reflects the misperception that other tasks (rhythm analysis, defibrillation, airway management, vascular access) are more important than chest compressions.
- Chest compressions are generally too fast and shallow, with poor chest wall recoil, limiting cardiac output during CPR.
- Ventilations are generally too fast, increasing intrathoracic pressure and limiting cardiac output during CPR.
- Suboptimal CPR performance may reflect inadequate training.

o 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.

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" in that educational content is delivered to individual provider groups, defined by provider type (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 RRS team 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. 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 embolus 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 U.S. 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.

Leadership plan

Demonstrate leadership's commitment to comprehensive system of prevention and resuscitation of cardiac arrest

- Hospital administration and clinical leadership must commit to supporting the development and maintenance of an institutional program of cardiac arrest prevention and resuscitation, including support for program leadership and a commitment to provider training.
- Establish an Outcomes Steering Committee (OSC), which 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 optimizing the response to deterioration. Reporting from the institutional OSC should be upward to institutional leaders; horizontal to other committees, hospital units, and service lines; and downstream to providers.
- The resuscitation system of care should reduce preventable deaths by decreasing arrest incidence through an organized RRS program and improving arrest survival.
- 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 OSC by hospital leaders and broad representation of various hospital groups on the OSC.
    - Effectively modifying training content to address provider and workplace-specific needs and issues, and giving routine feedback of institutional data on patient deterioration and resuscitation data.
    - Ultimately, the cardiac arrest prevention and resuscitation program should become the primary vehicle to reduce preventable deaths and ensure an institutional culture of safety.

Support rapid response system (RRS) development with funding and infrastructure

- Administration should provide financial support for the Rapid Response System including the establishment and training of the RRT.
- Oversight of the RRS program may occur through the OSC or another dedicated, multi-disciplinary committee with strong OSC linkage. Representation from the following hospital entities should be ensured:
    - Administration
    - Cardiac arrest resuscitation team
    - Critical Care
    - Education
    - Risk Management
    - Performance Improvement
    - Data/Analytics
    - Palliative Care/Hospice
- Support to designate RRS team members should be anticipated. Several models may be considered, depending upon coverage area, staffing models and presence of trainees.

Considerations include:
  - Critical Care RN, RT, access to critical care MD
  - ICU-based versus "patrolling" RRS team
  - Integration with cardiac arrest team members
  - Specialized protocols & equipment
  - Regular training
- Data collection and documentation should include:
  - Documentation in the patient care record
  - Data collection to assess RRS program effectiveness
  - CQI efforts to guide program development and education
  - Core data from each encounter should include at a minimum: location and time, reason for calling, prior vital signs, diagnostic and therapeutic interventions performed, other key consultations or decisions, and post call disposition of the patient. Patient identifiers linkable to other databases such as ICU admissions and arrests should be used as well.
  - Feedback from patient or family regarding patient/family perceptions of the reason for the RRS call, events leading up to the call, outcome and effectiveness of the call.

Support resuscitation performance with funding and infrastructure

- Administration should provide financial support to adequately staff and train resuscitation teams. This may require shifting of work responsibilities, and likely additional expenses for training and equipment purchases.
  - Focus should be on ensuring optimal CPR performance.
  - Resuscitation team leadership training should include team management and integration of technology.
- Additional infrastructure support may be required for CQI activities related to resuscitation.
- Specific attention should be placed on optimal post-resuscitative care

Action plan

Implement training, technology, and data analysis to improve outcomes

- Establish a steering committee to provide ownership and accountability for preventing arrest and optimizing resuscitation performance.
- Implement a rapid response system (RRS) to target early recognition of deterioration and arrest prevention.
- Implement training, technology, and data analysis to improve resuscitation outcomes. Training should be adaptive to provider type, unit, and available technology and address role expectations in resuscitation events.
- Develop a treatment algorithm based on institutional capabilities, technology, CQI needs, and institutional interpretation of scientific evidence.

Technology plan

These suggested practices and technologies have shown proven benefit or, in some cases, are the only known technologies for certain tasks. If you know of other options not listed here, please complete the form for the PSMF Technology Vetting Workgroup to consider: **patientsafetymovement.org/actionable-solutions/apss-workgroups/technology-vetting/**

One of the core ART philosophies is to integrate technology into clinical practice, CQI, and training. The ART program has proven itself in facilitating this integration and documenting clinical effectiveness.

An institutional resuscitation program allows modification to clinical algorithms based on available technology and training to optimize clinical application. These are critically important in resuscitation, where staff needs to quickly interpret and respond to vital sign and sensor data. This underscores the importance of user interfaces that help clinicians interpret data, recognize patterns, and respond to therapy.

Integrating physiological data with the institutional operational response is also important to assure optimal and timely allocation of clinical resources and prevention of morbidity and mortality. This is another critical element of an ART program.

Available technologies support the 3 physiological processes identified by the ART Model of Physiology – **perfusion**, **oxygenation**, and **ventilation** – as well as data collection and monitoring:

System or practice	Available technology
ONC Meaningful Use Certified Electronic Health Record (EHR) System with the following capabilities: • Computerized Provider Order Entry (CPOE) • Drug-drug interaction check • Drug-allergy interaction check • Clinical Decision Support tools (CDS)	
Perfusion: • Vital signs • Sphygmomanometry • ECG • Capnometry • Clinical assessment (mental status, capillary refill, pulse quality, extremity temperature) • Pulse oximetry including related perfusion indices • Laboratory measures of acidosis (pH, base deficit, lactate, anion gap) • Newer modalities (near-infrared spectroscopy, orthogonal polarization, heart-rate variability)	Adhesive pulse oximetry sensor connected with pulse oximetry technology proven to accurately measure through motion and low perfusion to avoid false alarms and detect true physiologic events, with added importance in care areas without minimal direct surveillance of patients (in a standalone bedside device or integrated in one of over 100 multi- parameter bedside monitors) (Taenzer et al., 2010; Shah et al., 2012)

Oxygenation: • Vital signs pulse oximetry • Blood gas analysis • Near-infrared spectroscopy	• Implement noninvasive and continuous hemoglobin monitoring (Ehrenfeld; WFN) o SpHb adhesive sensors connected to Masimo* Radical-7 with SpHb, or a multi-parameter patient monitor with SpHb, including but not limited to:
Ventilation: • Vital signs • Respiratory volumetrics (tidal volume, respiratory rate) • Blood gas analysis • Capnometry • Capnography • Apnea monitoring	• Capnography • Apnea Monitoring o Respiratory Motion's ExSpiron o Ability to accurately measure changes in respiratory rate and cessation of breathing with optimal patient tolerance and staff ease of use in order to avoid false alarms, with added importance in care areas without minimal direct surveillance of patients o Acoustic Monitoring • Masimo* rainbow acoustic monitoring • OR o Sidestream end tidal carbon dioxide monitoring
Remote monitoring with direct clinician alert capability compatible with recommended pulse oximetry technology	• Masimo* Patient SafetyNet, or comparable multi-parameter monitoring system
Direct clinician alert through dedicated paging systems or hospital notification system	

Measuring outcomes

Rapid response outcome metrics

The goal of rapid response teams is to identify deteriorating patients and pair their clinical conditions to needs which may include:

- Escalation of observation and surveillance
- Escalation of care (typically ICU)
- Initiation of palliative therapies

Desirable outcomes of the RRS are the reversal physiologic deterioration and prevention of organ dysfunction and the alleviation of suffering if applicable. A recent consensus conference on quality metrics to assess efficacy of Rapid Response Systems recommended that hospitals should at the least measure the following:

1. Incidence of Cardiac Arrests on the wards (number/ # bed days) and the incidence of cardiac arrest responses. If palliative care increases, the cardiac arrest rate may not change, but the response rate would go down. This is an important metric because some patients will always die in the hospital: one goal would be for all those deaths to be following palliative interventions and none after the cardiac arrest response to prevent the death failed.
2. HPredictability of cardiac arrests (# of ward arrests from above meeting RRS warning criteria/ all ward arrests)
3. Timeliness of their response to ward deterioration (number of patients meeting warning criteria seen within the institutions time frame / total number of patients meeting warning criteria
4. Timeliness of critical interventions (# patients receiving critical care interventions/ total # of patients receiving RRT calls)
5. Whether the hospital allow the patient, family, other staff to activate the RRS?

Specific numberators, denominators, exclusions, and additional guidance on the use of these metrics are provided in the paper by Subbe, et al.

Cardiac arrests

Key performance indicators

Arrest Related Death: An Arrest Related Death (ARD) is defined as a patient receiving arrest resuscitative efforts (either CPR or defibrillation) at any time during admission who does not survive to hospital discharge

Outcome measure formula

Numerator: Total number of arrest related deaths

Denominator: Total number of admissions

*Rate is typically displayed as ARDs per thousand admissions (ARDs * 1,000/admissions)*

Metric recommendations

Direct Impact:

Any patient receiving resuscitative efforts

Lives Spared Harm:

$$Lives\ Spared\ Harm = (ARD\ Rate_{baseline} - ARD\ Rate_{measured} \times Admissions_{measured}$$

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. Some of the APSSs recommend technologies that are offered by companies involved in the Patient Safety Movement Foundation. The workgroups have concluded, based on available evidence, that these technologies work to address APSS patient safety issues. Workgroup members are required to disclose any potential conflicts of interest.

Workgroup

Chair

Daniel Davis, MD	Air Methods Corporation
Helen Haskell	Mothers Against Medical Error, International Society of Rapid Response Systems
Jacinda Bunch	University of Iowa

Members

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

Hania Alim	Patient Safety Movement Foundation
***Steven J. Barker**	Patient Safety Movement Foundation; Masimo
Michel Bennett	Patient Safety Movement Foundation (formerly)
Chantelle Dron	Windsor Severance Fire Rescue
Jeff Dunn	Redivus Health
Dana Edelson	University of Chicago
Russell Griffin	Heart Organization
Bill Honigman	Hoag Health
Douglas Kupas	Geisinger Health System
Brenna Lawrence	University of California, San Diego
Ariana Longley	Patient Safety Movement Foundation
Jacob Lopez	Patient Safety Movement Foundation (formerly)
Olivia Lounsbury	Patient Safety Movement Foundation
Mandy Odell	Advocate
Donna Prosser	Patient Safety Movement Foundation
Christine Raup	Geisinger Health System
Melanie Roberts	University of Colorado
Ed Salazar	Patient Advocate
Frank Sebat	Kritikus Foundation
Rebecca Sell	University of California, San Diego
Fiona Stan	Ochsner Medical Center
Eugene Tuyishime	University of Rwanda
Tyler Vadeboncoeur	Mayo Clinic
Praveen Venkatagiri	Ovum Hospitals
Sheri Villanueva	University of California, San Diego
Fiona Winterbottom	Ochsner

Metrics integrity

Robin Betts	Kaiser Permanente, Northern California Region

*This Workgroup member has reported a financial interest in an organization that provides a medical product or technology recommended in the Technology Plan for this APSS.

References

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.

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. Impact of Continuous and Noninvasive Hemoglobin Monitoring on Intraoperative Blood Transfusions. American Society of Anesthesiologists. 2010; LB05.

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.

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.

W.F.N., A. Reduction in Red Blood Cell Transfusions during Neurosurgery with Noninvasive and Continuous Hemoglobin Monitoring. Proceeding of the Society for Technology in Anesthesia Annual Meeting, 2013:51.

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.

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.