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MEETING HIGHLIGHTS

# Latest in Resuscitation Research: Highlights From the 2021 American Heart Association's Resuscitation Science Symposium

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The American Heart Association Resuscitation Science Symposium (ReSS) was held virtually from November 13 to 15, 2021. This report summarizes ReSS programming, including awards, special sessions, and workshops and scientific content organized by topic (ie, intra-arrest and postarrest care) and plenary session. Subsequent sections include special circumstances of arrest, survivorship, and new developments in mechanical circulatory support. Lastly, selected abstracts and laboratory science are summarized before a concluding year in review.

## Awards

The ReSS program committee bestowed multiple awards for significant contributions to resuscitation science. Dr Kazuo Okada, founder of the Japanese Resuscitation Council and cofounder of the Resuscitation Council of Asia, was awarded the Lifetime Achievement Award in Resuscitation Science. The CRITICAL (Comprehensive Registry of In-Hospital Intensive Care for Out-of-Hospital Cardiac Arrest Survival) study investigators received the Ian G. Jacobs Award for International Group Collaboration to Advance Resuscitation Science. The CRITICAL study team first convened in 2012 to collect Japanese prehospital and in-hospital data, incorporating data on over 2000 patients with out-of-hospital cardiac arrest (OHCA) annually, which it now makes accessible to junior investigators for mentored research opportunities. Mary M. Newman, cofounder, president, and chief executive officer of the Sudden Cardiac Arrest Foundation (https://www.sca-aware.org/), was awarded the Resuscitation Champion Award. Finally, Dr Takahiro Nakashima (University of Michigan) received the 2021 Max Harry Weil Award as a young investigator with significant promise in resuscitation science. He presented the results of his article, *Machine Learning Model for Predicting Out-of-Hospital Cardiac Arrests Using Meteorological and Chronological Data*.

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## ReSS Young Investigator Networking Event

Attended by >100 people this year, the ReSS Young Investigator Networking Event was organized by Dr Sarah Perman (University of Colorado) and Dr Sachin Agarwal (Columbia University). Dr Marina Del Rios (University of Iowa) presented *A Roadmap for Equity in Resuscitation Outcomes: Barriers, Opportunities, and Future Directions*. Finally, 6 moderated breakout networking sessions were hosted to discuss mentorship, advocacy, and grant writing. Young Investigator awards were presented to 25 early career researchers who were within the first 5 years of their academic appointments (Table S1).

## Joint American Heart Association/ Japanese Circulation Society Session

Dr Takanori Ikeda (Toho University Medical Center) and Dr David Gaieski (Thomas Jefferson University) moderated the joint American Heart Association and Japanese Circulation Society session, which focused on postarrest targeted temperature management (TTM). Dr Clifton Callaway (University of Pittsburgh) presented *TTM and Post Arrest Injury Severity in the US*, highlighting that TTM efficacy may be optimal for a particular range of post–return of spontaneous circulation (ROSC) severity. Dr Mitsuaki Nishikimi (Nagoya University) presented *Recent Experiences With TTM Tailored to Injury Severity*, sharing similar findings on the different outcome impacts of TTM based on injury severity. Lastly, Dr Karen Hirsch (Stanford University) gave a presentation entitled *Tailoring TTM for Non-Arrest Brain Injury*, providing a historical perspective along with the current trends in TTM use for stroke and traumatic brain injury.

## Women in Resuscitation Science Networking Workshop

Led by cochairs Dr Katherine Berg and Dr Anne Grossestreuer (both from Beth Israel Deaconess Medical Center), the Women in Resuscitation Networking Workshop brought together female resuscitation scientists from around the world. Dr Betsy Hunt (Johns Hopkins University) presented *The Keys to Academic Promotion and A Joyful Life in Academic Medicine*, illustrating the importance of intentional decision and the art of saying "no."

# INTRA-ARREST RESEARCH

## Plenary Session: New Directions in Intra-Arrest Management

Dr Lars W. Andersen (Aarhus University Hospital, Denmark) presented an in-depth review of new pharmacologic approaches to advanced cardiovascular life support (ACLS), specifically focusing in intra-arrest therapies and highlighting the relatively small number of interventions that have been translated from animal research into clinical studies.[1] Among these, cyclosporine and sodium nitrite are 2 of the agents evaluated in patients with OHCA; experimental evidence suggests that these 2 drugs could limit cellular injury after ischemia reperfusion, yet neither of them are currently linked to an improvement in rates of ROSC or clinical outcomes in clinical trials.[2,3] Shenfu, a traditional Chinese medicine, has also been tested in patients with OHCA, with early trial evidence that suggests a potential benefit. The therapeutic combination of vasopressin and methylprednisolone has also been tested in clinical trials and demonstrated improvement of ROSC rates but not in clinical outcomes.[4,5]

Dr Peter J. Kudenchuck (University of Washington) provided a review on defibrillation dosing during cardiac arrest resuscitation. Defibrillation is highly time- and quality-dependent, with effectiveness falling 7% to 10% per minute in the absence of cardiopulmonary resuscitation (CPR), and 3% to 4% per minute when CPR is performed.[6] Laboratory and clinical studies have suggested that applying additional physical pressure to defibrillation pads can reduce impedance and improve shock effectiveness. Double sequential external defibrillation has been studied in a trial of patients with refractory ventricular fibrillation (VF), finding that double sequential external defibrillation was associated with higher rates of defibrillation success compared with standard defibrillation.[7] In addition to optimizing CPR quality and shock delivery, stabilizing the arrhythmia substrate with the use of antiarrhythmic agents, and the treatment of underlying factors such as coronary ischemia, remain critical in the treatment of refractory ventricular fibrillation.

Dr Dana Edelson (University of Chicago) presented on the outcomes for patients with COVID-19 cardiac arrest. She highlighted factors contributing to increased incidence of both in-hospital cardiac arrest (IHCA) and OHCA rates, lower survival rates, lower emergency response times, and overall lower ROSC and survival. Because CPR has the potential to be an aerosol-generating procedure, special task forces of the American Heart Association and International Liaison Committee on Resuscitation (ILCOR) provided expert consensus recommendations to maintain the quality of resuscitation care while prioritizing the safety of health care practitioners.[8,9]

Closing the session, Dr Tom P. Aufderheide (Medical College of Wisconsin), presented a report on the National Heart, Lung, and Blood Institute–sponsored Extracorporeal Cardiopulmonary Resuscitation (ECPR) for OHCA Workshop held virtually on August 23 to 24, 2021. This workshop was intended to review the

current state of the science and identify high-priority research gaps and opportunities. The group discussed various aspects of extracorporeal membrane oxygenation (ECMO)-facilitated cardiac arrest resuscitation research, including study designs, patient selection, and protocols. It was estimated that if ECMO-facilitated resuscitation were to be implemented broadly, it could save 18 000 patients per year with functionally favorable survival outcomes in the United States alone. ECPR research has shown that the potential for recovery from ischemic insult is much greater than generally recognized, representing a window of opportunity for new and more effective interventions.

## Original Science Presentation Session: New Insights for Intra-Arrest Management

Dr Frederick J. Brown (Washington University) presented a Bayesian reanalysis of the ALPS (Amiodarone, Lidocaine, or Placebo Study in Out-of-Hospital Cardiac Arrest) data showing a favorable risk difference for neurologically favorable survival (modified Rankin score ≤3) with antiarrhythmics versus placebo (Table 1). Antiarrhythmics likely lead to increased probability of neurologically intact survival but with small magnitude of benefit. Dr Masashi Okubo (University of Pittsburgh) investigated intra-arrest transport versus continued on-scene resuscitation in pediatric OHCA using the ROC (Resuscitation Outcomes Consortium) Epistry data set from 11 sites in the United States and Canada, with no significant difference noted in survival to discharge. Dr Shengyuan Luo (Rush University) presented data on early versus late administration of epinephrine in adults with shockable rhythm OHCA. After adjustment across subgroups, patients receiving late epinephrine (>4 minutes between defibrillation and dose) had lower odds of prehospital ROSC, survival to hospital discharge, and favorable neurological outcome at discharge. Using an observational cohort of post-ROSC adults with OHCA, Dr Betty Yang (University of Washington) investigated whether the association between increasing epinephrine dose and functional survival from OHCA is modified by TTM. A significant interaction between epinephrine dose and TTM status was found showing the relative benefit of TTM increased with increasing number of epinephrine doses.

**Table 1. Original Science Presentation Session: New Insights for Intra-Arrest Management**

| Lecture | Presenter | Country |
|---|---|---|
| Antiarrhythmic use and the posterior probability of neurologically intact survival in a reanalysis of the amiodarone, lidocaine, or placebo study in out-of-hospital cardiac arrest | Frederick J. Brown | USA |
| Association of intra-arrest transport versus continued on-scene resuscitation with survival to hospital discharge among pediatric patients with out-of-hospital cardiac arrest | Masashi Okubo | USA |
| Early compared to late administration of epinephrine in adults with shockable initial rhythm out-of-hospital cardiac arrest | Shengyuan Luo | USA |
| Does targeted temperature management modify the association between increasing epinephrine dose and survival outcomes following out-of-hospital cardiac arrest? | Betty Yang | USA |

# POSTARREST RESEARCH

## Plenary Session: Updates in Postarrest TTM

The conference plenary session on TTM opened with moderators Drs. Maaret Castren (Helsinki University Hospital) and Yew Woon Chia (National Healthcare Group). Dr Niklas Nielsen (Lund University) presented the recent TTM2 trial (Hypothermia versus Normothermia after Out-of-Hospital Cardiac Arrest),[10] which randomized adults with OHCA and presumed cardiac or unknown cause to hypothermia (33 °C) versus controlled normothermia for 24 hours, finding no difference in 6-month all-cause mortality or neurological outcome. More cardiac arrythmias requiring intervention were observed in the hypothermia arm, but otherwise, no difference in adverse events was noted. Several criticisms of the trial were addressed including time to goal temperature and illness severity compared with other studies.

Dr Nicholas Johnson (University of Washington) provided historical context for the evolving evidence, suggesting potential real-world worsening in OHCA outcomes after the first TTM trial.[11–14] He reviewed recent literature demonstrating an interaction between illness and brain injury severity and dose of TTM,[15–18] with recommendations that future trials enrich their populations with those most likely to benefit from TTM and other therapies based on illness severity.

Dr Jerry Nolan (Royal United Hospital) discussed normothermia as a possible new standard after cardiac arrest. After reviewing historical temperature management recommendations from ILCOR, he summarized a new systematic review and meta-analysis,[19] concluding that TTM at 32 °C to 34 °C did not result in improved outcome compared with normothermia. The ILCOR taskforce recommended that fever should be actively prevented by targeting temperature ≤37.5 °C, and again acknowledged that there may be subpopulations who would benefit from lower temperatures.

Dr Alexis Topjian (University of Pennsylvania) discussed 2 major randomized trials in pediatric IHCA and OHCA, neither of which demonstrated benefit with cooling to 33 °C compared with normothermia.[20,21]

Dr Topjian then highlighted the importance of long-term neurocognitive and behavioral outcomes, discussing a new trial testing the duration of TTM in children with a 1-year primary outcome of an ordinal behavioral score.

## Original Science Presentation Session: Postarrest Care Beyond TTM

Dr Martin Meyer (Copenhagen University Hospital) discussed a substudy of the interleukin (IL)-6 IMICA (Inhibition for Modulating Inflammation After Cardiac Arrest) trial.[22] The authors reported that IL-5 and IL-6 levels were higher in the tocilizumab arm as compared with the placebo arm at all analyzed postrandomization time points. The authors hypothesized that the higher IL-6 levels and the lower C-reactive protein levels in patients randomized to tocilizumab may be explained by occupation of the IL-6 receptor by tocilizumab (Table 2). Dr Alexandra Weissman (University of Pittsburgh) described a novel study exploring the use of nanopore genetic sequencing for the identification of bacterial infection in initial survivors of cardiac arrest. Infection following cardiac arrest can be difficult to diagnose because of concurrent inflammation from ischemia–reperfusion injury as well as other postarrest factors. Nanopore sequencing technology returned results more quickly than standard microbiologic approaches, but with similar pathogen detection. Dr Ericka Fink (University of Pittsburgh) reported on neuroprognostication via early results from the POCCA (Personalizing Outcomes After Child Cardiac Arrest) study. Among 164 initial survivors of pediatric cardiac arrest at 14 pediatric intensive care units, survival with favorable Vineland Adaptive Behavior Scale scores (>70) at 1 year was best predicted by neurofilament light chain and ubiquitin carboxyl-terminal esterase-L1 (UCH-L1). Dr Aris Karatasakis (University of Washington) reported on early (within 6 hours), head-to-pelvis ECG-gated computed tomography angiogram (computed tomography first) imaging after sudden cardiac arrest.[23] The following injuries were observed among the 104 sudden cardiac arrest victims: rib fractures (74%), sternal fractures (18%), pulmonary contusions (13%), mediastinal hematomas (10%), liver or spleen lacerations (6%), pneumothoraces (5%), pulmonary lacerations (3%), mainstem intubations (2%), and hemopericardium (1%). Similar rates of injury were seen among the 27% of patients who received mechanical chest compressions compared with those who received standard chest compressions only.

**Table 2. Original Science Presentation Session: Beyond Targeted Temperature Management**

| Lecture | Presenter | Country |
|---|---|---|
| Changes in cytokine responses by treatment with tocilizumab in OHCA | Martin Meyer | Denmark |
| Real-time nanopore sequencing for bacterial pneumonia after OHCA | Alexandra Weissman | USA |
| Personalizing outcomes after child cardiac arrest: a preliminary biomarker report | Ericka L. Fink | USA |
| Prevalence and patterns of resuscitation-associated industry detected by head-to-pelvis computed tomography after OHCA resuscitation | Aris Karatasakis | USA |

OHCA indicates out-of-hospital cardiac arrest.

# SPECIAL CIRCUMSTANCES

## Plenary Session: Special Circumstances in Resuscitation

Dr Carolyn Zelop (New York University) highlighted that US maternal mortality in cardiac arrest has increased >50% in the past 25 years, the highest rate of all developed nations.[24] Maternal cardiac arrest requires an understanding of physiological changes during pregnancy and a modified ACLS algorithm to account for the management of 2 patients. Dr Todd Kilbaugh (University of Pennsylvania) presented on mitochondrial function in mediating neurologic outcomes in post–cardiac arrest animal models,[25,26] neurometabolic optical monitoring devices for cerebral metabolism,[27] and advanced approaches to neuroimaging and biomarkers for prognostication after neurologic insult. Focusing on postarrest neuroprognostication, Dr Hirsch (Stanford University) described how withdrawal of life-sustaining treatment represents the majority of avoidable deaths because of perceptions of poor prognosis. Current neuroprognostication studies are limited by sample size, study design, and postarrest care, but ongoing research aims to predict patient outcome after cardiac arrest. Dr Horowitz (New York University) discussed the underrecognized role that pulmonary embolism plays in cardiac arrest. Though the mainstay of therapy is systemic thrombolysis, there have been recent advances in the intra-arrest management of pulmonary embolism, including catheter directed therapies and venoarterial ECMO.

## Plenary Session: Survivorship—Current Needs and Knowledge Gaps

Survivorship and recovery after cardiac arrest begins with resuscitation and may span years for patients, families, and care providers. Awareness and advocacy for comprehensive recovery expectations at hospital discharge and referral to specialty rehabilitation resources have increased with recent 2020 American Heart Association guidelines.[28] Dr Sachin Agarwal (Columbia University) presented on ongoing studies to characterize the role of psychological well-being on

the long-term quality of life and cardiovascular prognosis after cardiac arrest. He discussed behavioral intervention studies aimed to alleviate fear of recurrence and death along with work on intensive rehabilitation and postdischarge clinics. Dr Susanne Muehlschlegel (University of Massachusetts Medical School) discussed the forgotten stakeholders in brain injury: the family and providers. She presented results from a 2-phase qualitative study through a National Institutes of Health (NIH)-sponsored virtual workshop to understand the information families need in the first 48 hours after cardiac arrest or traumatic event. This included family needs for emotional, physical, and spiritual support. Dr Sana Al-Khatib (Duke University) discussed the indications and long-term management of implantable cardioverter defibrillators. For arrest survivors, implantable cardioverter defibrillators are indicated when reversible causes are not identified and meaningful survival >1 year is anticipated. Additionally, remote monitoring has improved the early detection of arrhythmias, device malfunction, and inappropriate shock delivery. Dr Samantha Fernandez Hernandez (Baylor University College of Medicine) discussed her own 2020 cardiac arrest (during her first year of neurology residency) and 1-year survivorship journey. Highlighting the cognitive and psychological effects of survivorship and her quick return to her training program, she called for a systematic discussion of recovery expectations and improved access to resources for follow-up after cardiac arrest.

## Original Science Presentation Session: Developments in ECPR and ECMO

Dr Daniel Rob (General University Hospital) presented a post hoc analysis of the Prague OHCA trial, where patients with refractory OHCA were randomized to hyperinvasive strategy of ECPR and percutaneous coronary intervention compared with standard care (Table 3). The hyperinvasive strategy resulted in better neurologic outcomes and 180-day survival compared with standard care; importantly, no patients with initial pulseless electrical activity or asystole survived, suggesting ECPR with immediate percutaneous coronary intervention should be reserved for initial shockable rhythm cohorts. Dr Arianne Agdamag (University of Minnesota) presented *Supraglottic Airway Devices Are Associated With Asphyxial Physiology Upon Arrival for ECPR in Patients With Refractory OHCA Treated With Prolonged CPR*. Among an initial shockable rhythm cohort potentially eligible for ECPR, supraglottic airways were significantly more likely to fail the predefined resuscitation continuation criterion. Dr Jensyn VanZalen (University of Michigan) presented *Impact of Leukocyte Filtration and Leukocyte Modulation on Recovery of Heart Function After Prolonged Cardiac Arrest Treated With ECPR in a Porcine Model*. Pigs with induced VF arrest underwent pronged mechanical CPR followed by hours of ECMO support, weaning, and necropsy. During the ECMO phase, the authors tested a leukocyte filter and a leukocyte immunomodulation device in the circuit, but no significant clinical differences (ie, recovery in cardiac function) between devices and control were observed. Dr Emilie Gregers (Copenhagen University Hospital) presented on early lactate clearance and association with survival in refractory OHCA treated with ECPR in Denmark. Among 226 patients with OHCA treated with ECPR over a 9-year period, survivors showed lower initial lactate levels compared with nonsurvivors. Lactate clearance was higher in survivors at most time points tested, whereas other markers, such as platelets and leukocytes, were not.

**Table 3. Original Science Presentation Session: Developments in ECPR and Extracorporeal Membrane Oxygenation**

| Lecture | Presenter | Country |
|---|---|---|
| Immediate percutaneous coronary intervention in patients with refractory out-of-hospital cardiac arrest | Daniel Rob | Czech Republic |
| Supraglottic airway devices are associated with asphyxial physiology upon arrival for ECPR in patients with refractory OHCA treated with prolonged CPR | Arianne Agdamag | USA |
| Impact of leukocyte filtration and leukocyte modulation on recovery of heart function after prolonged cardiac arrest treated with ECPR in a porcine model | Jensyn VanZalen | USA |
| Early lactate clearance is associated with survival in a national cohort of refractory out-of-hospital cardiac arrest patients managed with extracorporeal cardiopulmonary resuscitation | Emilie Gregers | Denmark |

CPR indicates cardiopulmonary resuscitation; ECPR, extracorporeal cardiopulmonary resuscitation; and OHCA, out-of-hospital cardiac arrest.

## LATE-BREAKING ABSTRACTS

Dr Christian Spaulding (Hôpital Européen Georges-Pompidou) presented *Emergency Versus Delayed Coronary Angiogram in Survivors of Out-of-Hospital Cardiac Arrest Without ST Segment Elevation (EMERGE) Trial*, which randomized OHCA without ST elevation or obvious cardiac cause to immediate versus delayed (48–96 hours after ROSC) coronary angiography. Stopped early for low enrollment, there was no difference in 180-day neurologically intact survival nor physiologic or length of stay secondary outcomes. Dr Rudolph Koster (Academic Medical Center, Amsterdam) described the use of a text message alert system to increase lay defibrillation via automated external defibrillator for VF occurring in the home. Adjusted results showed a significant increase in survival with the intervention, although this was not significant in terms of neurologically intact survival.

There was also a statistically significant decrease in the proportion of patients who did not receive CPR before emergency medical service's arrival and in the time to defibrillation. Dr Robert Sutton (University of Pennsylvania) reported on results from a randomized multicenter trial of the following quality of care interventions: frequent physiologic-directed point-of-care CPR trainings and monthly debriefing intervention in pediatric in-hospital cardiac arrest. No statistically significant difference was found with the intervention in terms of survival and neurologic outcomes, but diastolic blood pressure, ventilation rate, and postarrest systolic hypotension did significantly improve. Dr Brian Weil (University at Buffalo) presented data on the effect of triiodothyronine nanoparticles on early postresuscitation brain injury in a porcine model of OHCA. Neuron-specific enolase increase was significantly lower, and regional neuronal injury and hippocampal ultrastructure damage was attenuated in the 2 groups that received triiodothyronine nanoparticles compared with epinephrine controls. Dr Saket Girotra (University of Iowa) reported the results of a multicenter prospective observational study exploring the impact of suspected or confirmed COVID-19 infection on IHCA survival using the American Heart Association's Get With The Guidelines-Resuscitation registry. After adjustment, survival to hospital discharge and acute resuscitation survival was significantly lower in patients with suspected or confirmed COVID-19 infection. Patients who were COVID-19 positive were also found to receive significantly more delayed defibrillation but significantly fewer delays in epinephrine than patients who were COVID-19 negative.

## BEST OF THE BEST ORAL ABSTRACTS

Dr James M. Gray (Cincinnati Children's Hospital) used data from the PediRES-Q (Pediatric Resuscitation Quality) network from 2015 to 2020 at 19 sites to assess the prevalence of inappropriate defibrillation attempts during pediatric IHCA. In 157 events, 380 shocks were delivered; 30% were deemed inappropriate and 13% indeterminate by 2 pediatric cardiologists reviewing preshock rhythms. Dr Jing Li (University of Illinois, Chicago) presented her team's development of TAT-PHLPP, a novel peptide administered to improve neurologically intact survival in mouse models of asystolic arrest. Administration of the TAT-PHLPP novel peptide compared with normal saline showed significantly improved 3-day survival with better neurological function, cerebral blood flow, and metabolic markers. Dr Mitsuaki Nishikimi (Hofstra University) showed that cardiac arrest is associated with depleted plasma phospholipids, which could then be supplemented to attenuate injury. Specifically, higher levels of lysophosphatidylcholine docosahexaenoic acid in humans 1 hour after ROSC were associated with better neurological outcomes and higher gray–white matter differentiation. Subsequent rat models and mixed primary brain cell cultures showed neurologic benefit with supplemented lysophosphatidylcholine docosahexaenoic acid. Dr Gitte Linderoth (Copenhagen University Hospital) showed how live video via bystander smartphone in conjunction with medical dispatcher conversation improved hand position, compression rate, and CPR depth in OHCA.

## ORAL ABSTRACTS

Dr Takahiro Nakashima (University of Michigan) developed a machine learning model in Japan to predict daily OHCA incidence using meteorological data. Dr Nakashima and his team are currently developing a US prediction model using the CARES (Cardiac Arrest Registry to Enhance Survival) and National Aeronautics and Space Administration meteorological data. Dr Nicholas Morris (University of Maryland) conducted a retrospective cohort study of CARES data to investigate TTM use in racial minority survivors following OHCA. Although no disparities between Black and White patients were observed, Hispanic/Latino populations received TTM less often. Dr Ziad Nehme (Ambulance Victoria, Australia) looked at the incidence and outcomes of refractory and nonrefractory VF in cardiac arrest using the Victorian Ambulance Cardiac Arrest Registry in Victoria, Australia. Odds of refractory VF increased with male sex and presumed cardiac cause, but decreased if event was witnessed by emergency medical services, or if bystander CPR or shock were administered. Decreased survival was associated with age and refractory VF. Dr Mads Christian Tofte Gregers (Copenhagen Emergency Medical Services) showed increased citizen responders to OHCA during the COVID-19 outbreak in Denmark. More citizens in the lockdown period did chest compressions only. Dr Amy Xiao (University of Pittsburgh) monitored the long-term outcomes in patients with post–cardiac arrest with poor neurological outcomes using data from a regional referral center in Western Pennsylvania. Ten percent of survivors were discharged with severe functional and neurological disability with subsequent high emergency department use, a 4-month median survival, and 57% 1-year mortality.

## LABORATORY SCIENCE

Dr Ryosuke Takegawa (Hofstra University) presented rat models of prolonged (12 versus 6 minutes) cardiac arrest showing correspondingly longer time to

reappearance of electroencephalogram activity with longer downtime (12 minutes). Additionally, time from ROSC to cerebral oxygen saturation nadir increased with prolonged arrest times. Dr Aurora Magliocca (Milan University) investigated kynurenine pathway inhibition, via genetic deletion of its rate-limiting enzyme, indoleamine dioxygenase. Postarrest indoleamine dioxygenase–deleted mice had increased neurological function scores and survival, with decreased brain edema and preserved white matter integrity. Dr Hui Li (Anhui Medical University) hypothesized that ivabradine can attenuate hypoxia/reoxygenation injury by inhibiting excessive autophagy in H9c2 cardiomyocytes. Induced hypoxia then reoxygenation resulted in decreased cardiomyocyte viability with increased autophagy markers, which were then attenuated by ivabradine via the PI3K/Akt/mTOR pathway. Dr Yusuke Endo (Hofstra University) highlighted that transcutaneous $CO_2$ and arterial $CO_2$ dissociate during shock. He hypothesized that the gradient can be a noninvasive, sensitive measure of hemorrhagic shock in pig models. He monitored the impact of hemorrhage and transfusion on hemodynamic parameters including cardiac output and systemic oxygen delivery. The transcutaneous $CO_2$ and arterial $CO_2$ gradient was strongly correlated with cardiac output and oxygen deliver during hemorrhagic shock and resuscitation, showing its potential as a less-invasive monitoring tool.

# YEAR IN REVIEW

## Year in Review—Adults

Dr Lance Becker (Hofstra University) presented the 2021 year in review for adult OHCA science by organizing the highlights of the year into 5 main groupings of publications: highest clinical impact, critical clinical themes, impact of COVID-19, disparities, and pipeline concepts and basic science discoveries. Publications with the highest clinical impact covered such topics as ECMO, TTM, and angiography after cardiac arrest. The Advanced Reperfusion Strategies for Patients with Out-of-Hospital Cardiac Arrest and Refractory Ventricular Fibrillation (ARREST): A Phase 2, Single Centre, Open-Label, Randomised Controlled Trial demonstrated that protocolized ECPR can save patients who would have otherwise died with standard ACLS.[29] The TTM2 trial demonstrated similar survival and neurological outcome in patients with OHCA treated with 33 °C versus fever prevention (<37.5 °C).[10] Desch et al found no survival benefit of immediate compared with delayed angiography for postarrest patients without ST-segment elevation.[30] Harhash et al provided a risk stratification score to identify who may be best suited for angiography after OHCA,[31] demonstrating evolution beyond the standard one-size-fits-all approach commonly used in resuscitation trials.

In a study of IHCA, vasopressin with methylprednisolone soon after the first dose of epinephrine increased the rate of ROSC compared with placebo,[5] but did not improve 30-day survival or neurologic outcome. Blomburg et al from Denmark found that machine learning can outperform dispatchers in recognizing OHCA in emergency calls.[32] Justification for a "stay and play" approach is supported, because survival of patients transported intra-arrest is lower than in patients where crews continued the resuscitation at the scene.[33] These data suggest that in the absence of an ECPR pathway or other hospital-based resuscitation strategy (eg, coronary angiography) for select subgroups, intra-transport compared to on-scene resuscitation is associated with lower probability of survival. Although we are still learning the impact of COVID-19 in resuscitation, 2 key facts are clear: mortality for OHCA has increased during the COVID-19 pandemic,[34] but also ECMO for COVID-19 under relatively pragmatic circumstances is not futile.[35] In regard to inequities, a study by Dr David Asch (University of Pennsylvania) noted that differences in mortality for COVID-19 was heavily determined by the hospital where patients received their care.[36] Another study by Valbuena et al noted that pulse oximeter data and their interpretation have a strong racial bias: 25.5% of Black patients with normal pulse oximeter readings have occult hypoxemia when compared with arterial blood gas measurements.[37] This is in comparison with 10.2% of White patients, demonstrating an important limitation to this gold-standard tool.

## Year in Review—Pediatrics

Dr Dianne Atkins presented the year in review in pediatrics. Three main topics included were updates in clinical science, systems of care, and educational science and programs. A CARES study found that rescue breathing in addition to CPR provides a survival benefit over compression-only CPR, especially in children under the age of 12 years,[38] likely reflecting the effect of respiratory arrest as the primary cause in these patients. Kienzle et al reported an improvement in neurobehavioral outcomes with epinephrine dosing intervals of <2 minutes compared with dosing intervals >2 minutes, and that the improved outcomes are largely attributable to epinephrine promoting a faster ROSC with shorter duration of CPR.[39] A systematic review and meta-analysis by Chang et al found an odds ratio for survival of 0.4 with administration of bicarbonate.[40] The 2010 guidelines downgraded bicarbonate; however, about 50% of patients with IHCA continue to receive it.[41] A study by Fowler et al found that the creation and deployment of a post–cardiac arrest care pathway with a computerized order entry set did not improve pathway adherence or overall outcomes, but

was associated with increased survival to hospital discharge for children with IHCA.[42] One of the most impactful systems of care contributions this year was the Pediatric Core Outcome Set for Cardiac Arrest (P-COSCA) initiative, designed to provide a framework for consistent outcomes reporting in pediatric cardiac arrest studies.[43] A new training program developed in Spain demonstrated that children as young as 4 years can be taught to recognize cardiac arrest and call for help, and children >5 years of age can be taught CPR.[44]

## ILCOR Update

Dr Katherine Berg presented ILCOR updates. She provided an overview of ILCOR, an international organization with member councils from around the world with the vision to save lives globally through resuscitation. Dr Berg also discussed World Restart a Heart day, celebrated on October 16, an ILCOR sponsored program to promote citizen CPR programs to improve survival. ILCOR is interested in expanding its global reach and diversifying its membership to increase the participation of women as well as people in regions with high cardiovascular mortality.

# CONCLUSIONS

The ReSS meeting, a global conference devoted to cardiac arrest basic, clinical, and population science, brought a range of new science and perspectives to a challenging field that continues to exhibit significant knowledge gaps. Participants in ReSS expressed the hope that the following year would see a return to an in-person scientific meeting to improve networking and stimulation of new collaborations to improve the science of saving lives.

## ARTICLE INFORMATION

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### Disclosures

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### Supplemental Material

Table S1

## REFERENCES

1. Lind PC, Johannsen CM, Vammen L, Magnussen A, Andersen LW, Granfeldt A. Translation from animal studies of novel pharmacological therapies to clinical trials in cardiac arrest: a systematic review. *Resuscitation*. 2021;158:258–269. doi: 10.1016/j.resuscitation.2020.10.028
2. Argaud L, Cour M, Dubien PY, Giraud F, Jossan C, Riche B, Hernu R, Darmon M, Poncelin Y, Tchenio X, et al. Effect of cyclosporine in nonshockable out-of-hospital cardiac arrest: the CYRUS randomized clinical trial. *JAMA Cardiol*. 2016;1:557–565. doi: 10.1001/jamacardio.2016.1701
3. Kim F, Maynard C, Dezfulian C, Sayre M, Kudenchuk P, Rea T, Sampson D, Olsufka M, May S, Nichol G. Effect of out-of-hospital sodium nitrite on survival to hospital admission after cardiac arrest: a randomized clinical trial. *JAMA*. 2021;325:138–145. doi: 10.1001/jama.2020.24326
4. Mentzelopoulos SD, Malachias S, Chamos C, Konstantopoulos D, Ntaidou T, Papastylianou A, Kolliantzaki I, Theodoridi M, Ischaki H, Makris D, et al. Vasopressin, steroids, and epinephrine and neurologically favorable survival after in-hospital cardiac arrest: a randomized clinical trial. *JAMA*. 2013;310:270–279. doi: 10.1001/jama.2013.7832
5. Andersen LW, Isbye D, Kjaergaard J, Kristensen CM, Darling S, Zwisler ST, Fisker S, Schmidt JC, Kirkegaard H, Grejs AM, et al. Effect of vasopressin and methylprednisolone vs placebo on return of spontaneous circulation in patients with in-hospital cardiac arrest: a randomized clinical trial. *JAMA*. 2021;326:1586–1594. doi: 10.1001/jama.2021.16628
6. Edelson DP, Abella BS, Kramer-Johansen J, Wik L, Myklebust H, Barry AM, Merchant RM, Hoek TL, Steen PA, Becker LB. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. *Resuscitation*. 2006;71:137–145. doi: 10.1016/j.resuscitation.2006.04.008
7. Cheskes S, Dorian P, Feldman M, McLeod S, Scales DC, Pinto R, Turner L, Morrison LJ, Drennan IR, Verbeek PR. Double sequential external defibrillation for refractory ventricular fibrillation: the DOSE VF pilot randomized controlled trial. *Resuscitation*. 2020;150:178–184. doi: 10.1016/j.resuscitation.2020.02.010
8. Edelson DP, Sasson C, Chan PS, Atkins DL, Aziz K, Becker LB, Berg RA, Bradley SM, Brooks SC, Cheng A, et al. Interim guidance for basic and advanced life support in adults, children, and neonates with suspected or confirmed COVID-19: from the emergency cardiovascular care committee and get with the guidelines-resuscitation adult and

pediatric task forces of the American Heart Association. *Circulation*. 2020;141:e933–e943. doi: 10.1161/CIRCULATIONAHA.120.047463
9. Perkins GD, Morley PT, Nolan JP, Soar J, Berg K, Olasveengen T, Wyckoff M, Greif R, Singletary N, Castren M, et al. International Liaison Committee on Resuscitation: COVID-19 consensus on science, treatment recommendations and task force insights. *Resuscitation*. 2020;151:145–147. doi: 10.1016/j.resuscitation.2020.04.035
10. Dankiewicz J, Cronberg T, Lilja G, Jakobsen JC, Levin H, Ullen S, Rylander C, Wise MP, Oddo M, Cariou A, et al. Hypothermia versus normothermia after out-of-hospital cardiac arrest. *N Engl J Med*. 2021;384:2283–2294. doi: 10.1056/NEJMoa2100591
11. Bray JE, Stub D, Bloom JE, Segan L, Mitra B, Smith K, Finn J, Bernard S. Changing target temperature from 33 degrees C to 36 degrees C in the ICU management of out-of-hospital cardiac arrest: a before and after study. *Resuscitation*. 2017;113:39–43. doi: 10.1016/j.resuscitation.2017.01.016
12. Johnson NJ, Danielson KR, Counts CR, Ruark K, Scruggs S, Hough CL, Maynard C, Sayre MR, Carlbom DJ. Targeted Temperature management at 33 versus 36 degrees: a retrospective cohort study. *Crit Care Med*. 2020;48:362–369. doi: 10.1097/CCM.0000000000004159
13. Salter R, Bailey M, Bellomo R, Eastwood G, Goodwin A, Nielsen N, Pilcher D, Nichol A, Saxena M, Shehabi Y, et al. Changes in temperature management of cardiac arrest patients following publication of the target temperature management trial. *Crit Care Med*. 2018;46:1722–1730. doi: 10.1097/CCM.0000000000003339
14. Young PJ, Bailey M, Bellomo R. An update on temperature management following cardiac arrest in Australian and New Zealand ICUs. *Crit Care Med*. 2021;49:e1040–e1042. doi: 10.1097/CCM.0000000000005114
15. Sawyer KN, Kurz MC, Elswick RK Jr, Virginia Commonwealth University AI. An investigation of a hypothermic to ischemic ratio in patients following out-of-hospital cardiac arrest presenting with a shockable rhythm. *Ther Hypothermia Temp Manag*. 2014;4:72–78. doi: 10.1089/ther.2013.0023
16. Callaway CW, Coppler PJ, Faro J, Puyana JS, Solanki P, Dezfulian C, Doshi AA, Elmer J, Frisch A, Guyette FX, et al. Association of initial illness severity and outcomes after cardiac arrest with targeted temperature management at 36 °C or 33 °C. *JAMA Netw Open*. 2020;3:e208215. doi: 10.1001/jamanetworkopen.2020.8215
17. Lascarrou JB, Merdji H, Le Gouge A, Colin G, Grillet G, Girardie P, Coupez E, Dequin PF, Cariou A, Boulain T, et al. Targeted temperature management for cardiac arrest with nonshockable rhythm. *N Engl J Med*. 2019;381:2327–2337. doi: 10.1056/NEJMoa1906661
18. Nishikimi M, Ogura T, Nishida K, Takahashi K, Nakamura M, Matsui S, Matsuda N, Iwami T. External validation of a risk classification at the emergency department of post-cardiac arrest syndrome patients undergoing targeted temperature management. *Resuscitation*. 2019;140:135–141. doi: 10.1016/j.resuscitation.2019.05.028
19. Granfeldt A, Holmberg MJ, Nolan JP, Soar J, Andersen LW, International Liaison Committee on Resuscitation Advanced Life Support Task F. Targeted temperature management in adult cardiac arrest: systematic review and meta-analysis. *Resuscitation*. 2021;167:160–172. doi: 10.1016/j.resuscitation.2021.08.040
20. Moler FW, Silverstein FS, Holubkov R, Slomine BS, Christensen JR, Nadkarni VM, Meert KL, Clark AE, Browning B, Pemberton VL, et al. Therapeutic hypothermia after out-of-hospital cardiac arrest in children. *N Engl J Med*. 2015;372:1898–1908. doi: 10.1056/NEJMoa1411480
21. Moler FW, Silverstein FS, Holubkov R, Slomine BS, Christensen JR, Nadkarni VM, Meert KL, Browning B, Pemberton VL, Page K, et al. Therapeutic hypothermia after in-hospital cardiac arrest in children. *N Engl J Med*. 2017;376:318–329. doi: 10.1056/NEJMoa1610493
22. Meyer MAS, Wiberg S, Grand J, Meyer ASP, Obling LER, Frydland M, Thomsen JH, Josiassen J, Moller JE, Kjaergaard J, et al. Treatment effects of interleukin-6 receptor antibodies for modulating the systemic inflammatory response after out-of-hospital cardiac arrest (The IMICA Trial): a double-blinded, placebo-controlled, single-center, randomized, clinical trial. *Circulation*. 2021;143:1841–1851. doi: 10.1161/CIRCULATIONAHA.120.053318
23. Branch KRH, Strote J, Gunn M, Maynard C, Kudenchuk PJ, Brusen R, Petek BJ, Sayre MR, Edwards R, Carlbom D, et al. Early head-to-pelvis computed tomography in out-of-hospital circulatory arrest without obvious etiology. *Acad Emerg Med*. 2021;28:394–403. doi: 10.1111/acem.14228
24. Zelop CM, Einav S, Mhyre JM, Lipman SS, Arafeh J, Shaw RE, Edelson DP, Jeejeebhoy FM, American Heart Association's Get With the Guidelines-Resuscitation I. Characteristics and outcomes of maternal cardiac arrest: a descriptive analysis of Get with the guidelines data. *Resuscitation*. 2018;132:17–20. doi: 10.1016/j.resuscitation.2018.08.029
25. Marquez AM, Morgan RW, Ko T, Landis WP, Hefti MM, Mavroudis CD, McManus MJ, Karlsson M, Starr J, Roberts AL, et al. Oxygen exposure during cardiopulmonary resuscitation is associated with cerebral oxidative injury in a randomized, blinded, controlled, preclinical trial. *J Am Heart Assoc*. 2020;9:e015032. doi: 10.1161/JAHA.119.015032
26. Lautz AJ, Morgan RW, Karlsson M, Mavroudis CD, Ko TS, Licht DJ, Nadkarni VM, Berg RA, Sutton RM, Kilbaugh TJ. Hemodynamic-directed cardiopulmonary resuscitation improves neurologic outcomes and mitochondrial function in the heart and brain. *Crit Care Med*. 2019;47:e241–e249. doi: 10.1097/CCM.0000000000003620
27. Ko TS, Mavroudis CD, Morgan RW, Baker WB, Marquez AM, Boorady TW, Devarajan M, Lin Y, Roberts AL, Landis WP, et al. Non-invasive diffuse optical neuromonitoring during cardiopulmonary resuscitation predicts return of spontaneous circulation. *Sci Rep*. 2021;11:3828. doi: 10.1038/s41598-021-83270-5
28. Panchal AR, Bartos JA, Cabanas JG, Donnino MW, Drennan IR, Hirsch KG, Kudenchuk PJ, Kurz MC, Lavonas EJ, Morley PT, et al. Part 3: adult basic and advanced life support: 2020 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2020;142:S366–S468. doi: 10.1161/CIR.0000000000000916
29. Yannopoulos D, Bartos J, Raveendran G, Walser E, Connett J, Murray TA, Collins G, Zhang L, Kalra R, Kosmopoulos M, et al. Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation (ARREST): a phase 2, single centre, open-label, randomised controlled trial. *Lancet*. 2020;396:1807–1816. doi: 10.1016/S0140-6736(20)32338-2
30. Desch S, Freund A, Akin I, Behnes M, Preusch MR, Zelniker TA, Skurk C, Landmesser U, Graf T, Eitel I, et al. Angiography after out-of-hospital cardiac arrest without ST-segment elevation. *N Engl J Med*. 2021;385:2544–2553. doi: 10.1056/NEJMoa2101909
31. Harhash AA, May TL, Hsu CH, Agarwal S, Seder DB, Mooney MR, Patel N, McPherson J, McMullan P, Riker R, et al. Risk stratification among survivors of cardiac arrest considered for coronary angiography. *J Am Coll Cardiol*. 2021;77:360–371. doi: 10.1016/j.jacc.2020.11.043
32. Blomberg SN, Christensen HC, Lippert F, Ersboll AK, Torp-Petersen C, Sayre MR, Kudenchuk PJ, Folke F. Effect of machine learning on dispatcher recognition of out-of-hospital cardiac arrest during calls to emergency medical services: a randomized clinical trial. *JAMA Netw Open*. 2021;4:e2032320. doi: 10.1001/jamanetworkopen.2020.32320
33. Grunau B, Kime N, Leroux B, Rea T, Van Belle G, Menegazzi JJ, Kudenchuk PJ, Vaillancourt C, Morrison LJ, Elmer J, et al. Association of intra-arrest transport vs continued on-scene resuscitation with survival to hospital discharge among patients with out-of-hospital cardiac arrest. *JAMA*. 2020;324:1058–1067. doi: 10.1001/jama.2020.14185
34. Chan PS, Girotra S, Tang Y, Al-Araji R, Nallamothu BK, McNally B. Outcomes for out-of-hospital cardiac arrest in the United States during the coronavirus disease 2019 pandemic. *JAMA Cardiol*. 2021;6:296–303. doi: 10.1001/jamacardio.2020.6210
35. Badulak J, Antonini MV, Stead CM, Shekerdemian L, Raman L, Paden ML, Agerstrand C, Bartlett RH, Barrett N, Combes A, et al. Extracorporeal membrane oxygenation for COVID-19: updated 2021 guidelines from the extracorporeal life support organization. *ASAIO J*. 2021;67:485–495. doi: 10.1097/MAT.0000000000001422
36. Asch DA, Islam MN, Sheils NE, Chen Y, Doshi JA, Buresh J, Werner RM. Patient and hospital factors associated with differences in mortality rates among black and white US medicare beneficiaries hospitalized With COVID-19 infection. *JAMA Netw Open*. 2021;4:e2112842. doi: 10.1001/jamanetworkopen.2021.12842
37. Valbuena VSM, Barbaro RP, Claar D, Valley TS, Dickson RP, Gay SE, Sjoding MW, Iwashyna TJ. Racial bias in pulse oximetry measurement among patients about to undergo extracorporeal membrane oxygenation in 2019-2020: a retrospective cohort study. *Chest*. 2021;161:971–978. doi: 10.1016/j.chest.2021.09.025
38. Naim MY, Griffis HM, Berg RA, Bradley RN, Burke RV, Markenson D, McNally BF, Nadkarni VM, Song L, Vellano K, et al. Compression-only versus rescue-breathing cardiopulmonary resuscitation after pediatric out-of-hospital cardiac arrest. *J Am Coll Cardiol*. 2021;78:1042–1052. doi: 10.1016/j.jacc.2021.06.042
39. Kienzle MF, Morgan RW, Faerber JA, Graham K, Katcoff H, Landis WP, Topjian AA, Kilbaugh TJ, Nadkarni VM, Berg RA, et al. The effect of epinephrine dosing intervals on outcomes from pediatric in-hospital

cardiac arrest. *Am J Respir Crit Care Med*. 2021;204:977–985. doi: 10.1164/rccm.202012-4437OC

40. Chang CY, Wu PH, Hsiao CT, Chang CP, Chen YC, Wu KH. Sodium bicarbonate administration during in-hospital pediatric cardiac arrest: a systematic review and meta-analysis. *Resuscitation*. 2021;162:188–197. doi: 10.1016/j.resuscitation.2021.02.035
41. Ross CE, Moskowitz A, Grossestreuer AV, Holmberg MJ, Andersen LW, Yankama TT, Berg RA, O'Halloran A, Kleinman ME, Donnino MW, et al. Trends over time in drug administration during pediatric in-hospital cardiac arrest in the United States. *Resuscitation*. 2021;158:243–252. doi: 10.1016/j.resuscitation.2020.09.040
42. Fowler JC, Wolfe HA, Xiao R, Kumar SP, Whitney JE, Hutchins L, Sutton RM, Nadkarni VM, Berg RA, Topjian AA. Deployment of a clinical pathway to improve postcardiac arrest care: a before-after study. *Pediatr Crit Care Med*. 2020;21:e898–e907. doi: 10.1097/PCC.0000000000002405
43. Topjian AA, Scholefield BR, Pinto NP, Fink EL, Buysse CMP, Haywood K, Maconochie I, Nadkarni VM, de Caen A, Escalante-Kanashiro R, et al. P-COSCA (Pediatric Core Outcome Set for Cardiac Arrest) in Children: an advisory statement from the International Liaison Committee on Resuscitation. *Resuscitation*. 2021;162:351–364. doi: 10.1016/j.resuscitation.2021.01.023
44. Varela-Casal C, Abelairas-Gomez C, Otero-Agra M, Barcala-Furelos R, Rodriguez-Nunez A, Greif R. Teaching basic life support to 5- to 8-year-old children: a cluster randomized trial. *Pediatrics*. 2021;148. doi: 10.1542/peds.2021-051408

# Supplemental Material

**Table S1. ReSS 2021 Young Investigator Awards.**

| Name | Abstract Title |
|---|---|
| Afrah Ali | Simulation Based Assessment of Trainee's Performance in Post-Cardiac Arrest Resuscitation |
| Tomoaki Aoki | Normoxic Therapy Attenuated Oxidative Stress Related mRNA Gene Expressions in a Post-Cardiac Arrest Rat Model |
| Matthew Barajas | Intravenous Waveform Analysis Correlates With Volume Status in Resuscitation in In-Vivo Rat Model |
| Frederick Brown | Antiarrhythmic Use and the Posterior Probability of Neurologically Intact Survival in a Reanalysis of the Amiodarone, Lidocaine or Placebo Study in Out-of-Hospital Cardiac Arrest |
| Alexis Cole | The Safety and Tolerability of Prolonged Inhalation of Hydrogen Gas in Air: A Phase I Clinical Trial |
| Ruben Crespo | Determinants of Stabilization for Out-of-Hospital Cardiac Arrest Patients Undergoing Extracorporeal Cardiopulmonary Resuscitation |
| Yusuke Endo | Tissue-to-Arterial Carbon Dioxide Partial Pressure Gradient as a Useful Measure for Monitoring Tissue Perfusion in a Pig Model of Hemorrhagic Shock and Resuscitation |
| Katharyn L Flickinger | Rehabilitation Reduces Depression After Cardiac Arrest |
| R. Angel Garcia | Variation in Out-of-Hospital Cardiac Arrest Survival Across EMS Agencies |
| Brian Haskins | Long-Term Functional and Quality-of-Life Outcomes of Cardiac Arrest Survivors Stratified by Shock Provider: A 10 Year Retrospective Study |
| Toshihiro Hatakeyama | Pre-hospital Physician's Presence and Neurological Outcome Among Patients Performed Pre-hospital Advanced Airway Management: A Nationwide Multicenter Observational Study in Japan (the Japanese Association for Acute Medicine-out-of-Hospital Cardiac Arrest Registry) |
| Ryan Huebinger | Time to Anti-Arrhythmic for Out-of-Hospital Cardiac Arrest |
| Changshin Kang | A New Window on a Cerebral Penumbra at Risk for a Secondary Ischemic Brain Injury in Post-Cardiac Arrest Patients |
| Shaveta Khosla | Rise in Out-of-Hospital Cardiac Arrest Cases in Chicago in 2020 |
| Shengyuan Luo | Early Compared to Late Administration of Epinephrine in Adults With Shockable Initial Rhythm Out-of-Hospital Cardiac Arrest |
| Aurora Magliocca | Modulation of Kynurenine Pathway to Prevent Brain Injury After Cardiac Arrest and Cardiopulmonary Resuscitation in Mice |
| Oscar Mitchell | Use of a QR Code Accessed Debrief Tool is Associated With Higher Rates of Debrief After In-Hospital Cardiac Arrest |
| Sivagowry Moerk | Signs of Life as a Predictor of Survival in Patients With Out-of-Hospital Cardiac Arrest and Long Low-Flow Times |

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| Ziad Nehme | Long-Term Trends in the Incidence and Outcome of Refractory and Non-Refractory Ventricular Fibrillation Cardiac Arrest |
| Norihiro Nishioka | Early Prediction of Neurological Outcome at 30 Days After Return of Spontaneous Circulation From Out-of-Hospital Cardiac Arrest |
| Masashi Okubo | Association of Intra-Arrest Transport versus Continued On-scene Resuscitation with Survival to Hospital Discharge Among Pediatric Patients with Out-of-Hospital Cardiac Arrest |
| Matthew Potter | Cognitive and Psychological Outcomes of Patients 6 Months After Cardiac Arrest or Intensive Care Stay |
| Hogul Song | Variance of the Intracranial Pressure Over Time and Relationship With Neurologic Prognosis in Cardiac Arrest Survivors Who Underwent Targeted Temperature Management |
| Kazuya Tateishi | Impact of the Number of Prehospital Defibrillation Attempts on Neurologically Intact Survival in Patients With Out-of-Hospital Cardiac Arrest and Shockable Rhythm |
| Andy Tran | A Risk-Adjustment Model for Patients Presenting to Hospitals with Out-of-Hospital Cardiac Arrest and ST-Elevation Myocardial Infarction |