Delphi Analysis of Science Gaps in the 2015 American Heart Association Cardiac Arrest Guidelines

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***Background*—**Current cardiac arrest guidelines have limited high-quality scientific evidence to support recommendations for care. The quality of scientific evidence on which guidelines are based may correlate with improved patient outcomes and meaningful survival. We sought to develop a prioritized list of knowledge gaps in resuscitation to assist researchers, policy makers, and funding agencies in their decision-making process.

***Methods and Results*—**A 4-stage modified Delphi method was used with a panel of cardiac arrest experts. Experts addressed the prompt: "What are the top 3 gaps in knowledge involving cardiac arrest care that should be research priorities for National Institutes of Health/American Heart Association funding to have the greatest impact on public health?" Knowledge gaps were identified in the initial round, rated in a second round, and rank ordered in the third round, and they underwent final review and consensus (final round). The outcome was 10 knowledge gaps, with prioritization of the top 3 gaps. A total of 61 gaps, with 19 distinct themes, were identified by participants. The 10 knowledge gaps most likely to affect public health identified by the expert panel included, in order, the following: telecommunicator cardiopulmonary resuscitation, hemodynamic monitoring for goal-directed resuscitation, reasons why bystanders fail to respond, optimization of postarrest care, out-of-hospital cardiac arrest identification and response, individualizing resuscitation strategies, predicting patients at risk, tools for neuroprognostication, optimal airway management, and optimizing educational strategies.

***Conclusions*—**Ten priorities for cardiac arrest research were identified, but consensus was not reached on the prioritized top 3. Future research should address these gaps to potentially improve resuscitation guideline evidence quality. **(*J Am Heart Assoc.* 2018;7:e008571. DOI: 10.1161/JAHA.118.008571.)**

Key Words: cardiac arrest • consensus • Delphi • knowledge gap • resuscitation • science gap

In the United States, ≈500 000 people each year are victims of cardiac arrest, with only ≈12% to 24% surviving to hospital discharge.[1] The low survival rate continues even with a national initiative for cardiopulmonary resuscitation (CPR) training and the development of systems to improve resuscitation care both in and out of hospital.[2] Furthermore, there are concerted efforts to improve resuscitation practices with the development of evidence-based guidelines.[3,4] Despite this, the overall survival rates remain low, with only modest increases over the past decade.[2,5–7]

One of the challenges of improving resuscitation outcomes is a lack of high-quality evidence from which to develop treatment recommendations. Of the 685 recommendations in the 2010 Emergency Cardiovascular Care (ECC)/American Heart Association (AHA) Guidelines, 54% were based on low-quality evidence defined as level of evidence (LOE) C

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Clinical Perspective

What Is New?

- Using a 4-stage modified Delphi method with a panel of cardiac arrest experts, a list of 10 prioritized knowledge gaps in resuscitation science were identified addressing the question, "What are the top gaps in knowledge involving cardiac arrest care that should be research priorities for National Institutes of Health/American Heart Association funding to have the greatest impact on public health?"

What Are the Clinical Implications?

- These resuscitation science knowledge gaps, if addressed, could improve the level of evidence on which resuscitation guidelines are based as well as define focus areas for researchers, stakeholders, and funding organizations to improve the public health impact of cardiac arrest.

(correlating to low grade).[8] More recently, of the 315 updated recommendations in the 2015 ECC/AHA Guidelines, nearly three quarters were based on LOE C-Expert Opinion or LOE C-Limited Data (grade low or nonrecommendation), and only 1% were based on the highest LOE, LOE A (high grade).[8] Because the science of resuscitation drives both the development of education and implementation of resuscitation practices, the quality of evidence on which guidelines are based may correlate with improved patient outcomes and meaningful survival.

The International Liaison Consensus on Research Scientific Evidence Evaluation and AHA Guideline development processes identify many knowledge gaps,[8,9] yet neither of these prioritizes the importance of these knowledge gaps to public health. A prioritized set of gaps may assist researchers, stakeholders, and funding organizations to better understand the relationship of specific knowledge gaps and potential public health impact. The goal of this project was to develop a prioritized list of science knowledge gaps to assist researchers, policy makers, and funding agencies in their decision-making process.

Methods

The data that support the findings of this study are available from the corresponding author on reasonable request.

Objectives and Participants

The goal of this evaluation was to gain consensus on the knowledge and science gaps in resuscitation after publication of the 2015 AHA Guidelines for CPR and ECC. Specifically, the objectives of the study were to develop the following: (1) a top 10 list of knowledge gaps and (2) a prioritized top 3 list of knowledge gaps. A modified Delphi method was used to develop consensus among an expert panel of leaders in the field.[10–14] The Delphi method is a well-described structured process for building consensus from a group of informed experts.[10] It includes multiple rounds of data collection combined with feedback to the panel originally meant to occur as a face-to-face process. The modified Delphi method uses asynchronous electronic communication to gather information, provide feedback, and report results to a panel of experts.[11] In this evaluation, the modified Delphi method was selected because of the need for a diverse panel of experts from a national organization who could be more readily engaged through electronic communication.

In October 2016, an invitation to participate in the Delphi process was sent by E-mail to 100 cardiac arrest experts identified from the author list of the 2015 AHA Guidelines for CPR and ECC published in November 2015.[2,15] These individuals have previously been established as subject matter experts in cardiac arrest by the AHA ECC Committee. Ideal panel sizes for the Delphi method have been cited at ≈10 to 18 participants to allow for group dynamics to be established.[16–18]

Participation and completion of the project was voluntary, and no personal information was collected until after the final round. Participant responses were maintained in a separate database from contact information to ensure anonymity of the process. This project was approved by the institutional review board and granted an exemption.

Data Collection Process

To obtain group consensus, 4 rounds of surveys, with specific tasks, were administered electronically following the modified Delphi method between October 2016 and December 2016.[10,14,19] Reminders to participate were sent out ≈1 and 2 weeks after each round's survey invitation, in accordance with Dillman's tailored design method to improve survey response and participation through multiple survey invitations.[20] The main outcome of interest was development of consensus on a prioritized list of knowledge gaps in cardiac arrest research that, if addressed, have the greatest impact to public health.

Round 1

The initial round of data collection focused on having the experts identify specific knowledge gaps in cardiac arrest research through an electronic questionnaire. Participants were presented with a simple prompt:

"What are the top 3 gaps in knowledge involving cardiac arrest care that should be research priorities for National

Institutes of Health/AHA funding to have the greatest impact on public health?"

In answering this query, participants were asked to consider the priorities of the Institute of Medicine report titled, "Strategies to Improve Cardiac Arrest Survival: A Time to Act" and guidelines directed at cardiac arrest care (2010 and 2015 AHA/ECC Guidelines). Participants were directed to individually enter 3 specific gaps in the electronic questionnaire with a short rationale. Responses were collected, and qualitative analysis was used to develop themes identified by the participants to continue in the next rounds.

Round 2

Participants were asked to rate the importance of each knowledge gap in relation to its impact on public health. Each participant was provided identified themes from round 1 in alphabetical order. Participants were then asked to consider the importance of each gap theme (and rationale) and its impact on public health and rate the importance of these gaps. Participants individually rated the themes using a 5-point Likert-type scale, from 1 ("not at all important") to 5 ("very important/critical"), in an electronic questionnaire. The mean importance rating was calculated for each theme, and the top 10 themes by mean importance were advanced to round 3 on the basis of an a priori decision.[21]

Round 3

In round 3, participants were asked to revise their judgments on the basis of feedback from the prior round and to individually rank order the top 10 themes identified in round 2 in an electronic questionnaire. To allow expression of dissenting opinions, rationales for ranking items outside of the group consensus were requested.

Round 4

At the beginning of the final round, participants have identified the themes, scored each theme for importance to public health, and rank ordered the themes into a top 10 list.

To assess for agreement within the group about the top 3 prioritized knowledge gaps identified in round 3, participants were provided the top 3 gaps and asked whether the prioritized list answers the following prompt:

"What are the top 3 gaps in knowledge involving cardiac arrest care that should be research priorities for National Institutes of Health/AHA funding to have the greatest impact on public health?"

Participants could agree or disagree in the electronic questionnaire and then were allowed free text space to provide a rationale for disagreement. Group consensus was defined using a published benchmark of a 75% majority of the experts agreeing to the top 3 list of prioritized knowledge gaps.[22]

Statistical Analysis

Descriptive statistics were calculated using STATA IC 12.1 (StataCorp LP, College Station, TX). Qualitative analysis was performed by 3 independent reviewers (A.P., R.C., D.W.) to find the main themes of gaps identified in round 1, as previously noted. Rationales for the distinct themes were summarized by the 3 reviewers using as much of the submitted language from participants as possible. Mean importance scores were calculated in round 2 for each theme. On the basis of the method described in detail previously, the rank ordering of the prioritized list was determined by assigning points to each rank option, with a rank of 1 (most important) equal to 10 points and a rank of 10 (least important) equal to 1 point.[21] Total points were calculated and themes were ranked by the subsequent total point value obtained. In addition, the percentage of respondents who selected each gap in their top 5 rankings was calculated. This was used as an objective metric of the consensus process. As the group reaches consensus, the percentage of experts ranking the themes in the top 5 would have less variability (ie, higher percentages for fewer themes). Majority consensus was defined as at least 75% of participants agreeing with the prioritized list of top 3 gaps.[22]

Results

Participant Characteristics

At the beginning of the study, 22 experts assented to being part of the Delphi process. A total of 13 participants completed all 4 rounds of the modified Delphi process. Seven participants (54%) were women, 12 (92%) were physicians, 6 (46%) had primary appointments in pediatrics, and an additional 6 (46%) had primary appointments in emergency medicine. No significant conflicts of interest were reported (Data S1). All participants were confirmed to have been selected by the AHA as content experts in cardiac arrest and, thus, directly involved in the 2015 AHA/ECC Guidelines development process and publication. Four participants (31%) were authors of the Institute of Medicine report on cardiac arrest,[2] and 3 (23%) were involved in development of the *International Consensus on CPR and ECC Science With Treatment Recommendations* for the International Liaison Consensus on Research.[8]

Delphi Results

A total of 61 knowledge gaps with rationales were submitted by 22 participants in round 1. From these identified gaps, 19 distinct themes were derived by 3 reviewers during qualitative analysis. A set of top 10 themes by mean score advanced to round 3 (Table 1). For round 2, there was a 73% retention rate

Table 1. Top 10 Themes and Associated Rationale, as Decided by the Expert Panel

Rank	Mean Importance Score	Gap Theme	Rationale
1	4.56	Hemodynamic monitoring for goal-directed resuscitation during cardiac arrest	For both IHCA and OHCA, we must monitor the effectiveness of care during resuscitation and develop optimal targets for goal-directed resuscitation using available hemodynamic/physiologic measures (blood pressure and end tidal carbon dioxide) that will result in improved outcomes.
2	4.47	Dispatch-directed CPR (T- CPR)	Dispatcher-directed CPR (T-CPR), especially for children and those with primary asphyxial cardiac arrest, needs to be evaluated. Validated instructions should be developed for specific age groups (infants and neonates) and situations (asphyxial). Outcomes, such as ROSC, hospital admission, hospital discharge, survival, and improved neurological outcome, should be assessed.
3	4.44	Optimization of postarrest care	After ROSC, the optimal prehospital and in-hospital care for cardiac arrest patients is poorly defined. More studies are needed to examine factors, such as hypothermia/targeted temperature management, titration of medications and oxygen, and appropriate hemodynamic monitoring/targets for optimal neurological outcomes and quality of life.
4	4.25	Individualizing resuscitation strategies for victims of cardiac arrest	We need to better understand the individual patient characteristics that drive choices in care during arrest. Better understanding of the physiological features of various cardiac arrest causes will help develop recommendations for when ventilations are required or use of compression-only CPR would provide better outcomes.
5	4.19	Developing tools for early neuroprognostication	Lack of robust, reliable, evidence-based strategy results in both premature prognostication of futility and overuse of resources when care is futile. Optimizing tools for neuroprognostication will help contextualize outcomes
6	4.13	Understanding the reasons why bystanders fail to respond	Bystander CPR and use of an automated external defibrillator are associated with marked increased survival for OHCA. We do not have a strong understanding of why some bystanders choose not to respond nor how best to educate, train, and motivate laypeople (particularly youths) to recognize cardiac or neurological emergencies and take appropriate actions.
7	4.13	Optimizing educational strategies for healthcare providers	How do we best train providers for improved recognition and initial treatment of at-risk patients to prevent cardiac arrest? How do we best train providers to improve outcomes of cardiac arrest? Does frequent rolling refresher training combined with debriefing improve team performance and the process of care?
8	4.00	Using novel technology for OHCA identification and response	Many cardiac arrests in the community are unwitnessed. New technologies may offer strategies to recognize unwitnessed cardiac arrest in the community, increase the use of bystander CPR, and decrease emergency medical services response time.
9	3.94	Determining the optimal airway management strategy for cardiac arrest patients	Significant risk/harm is possible from overoxygenation or underoxygenation. Definitive studies are needed to examine issues, such as initial airway control strategies (endotracheal tube vs supraglottic airway) and optimal use of oxygen during CPR for neonates.
10	3.80	Predicting patients at risk for cardiac arrest	Many victims of OHCA experience cardiac arrest with no history of symptoms. Predicting which patients may experience cardiac arrest could result in better outcomes by activating a response or getting the patient to the "right" environment before arrest. Providers do not have adequate sensitivity and specificity to identify those patients needing emergency interventions. What vital sign changes and changes in rhythms best predict a higher risk of cardiac arrest?

Mean importance score is scaled from 1 to 5, from 1 ("not at all important") to 5 ("very important/critical"). CPR indicates cardiopulmonary resuscitation; IHCA, in-hospital cardiac arrest; OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation; T-CPR, telecommunicator CPR.

(16/22 participants). Mean importance scores of the top 10 themes were high for all 10 themes consistently, with the participants placing significant importance on each of these themes. In round 3, 14 participants rank ordered the top 10 themes, developing a final list of prioritized knowledge gaps, which is presented in Table 2. The round 3 and 4 retention rates were 64% (14/22 participants) and 59% (13/22 participants), respectively.

The top 10 prioritized gaps were achieved using the experts' ratings (round 2) and rankings (round 3). Table 2 describes the overall ranking of the 10 themes by the total points awarded by the experts' evaluation. The themes achieving the highest scores were dispatch-directed CPR, hemodynamic monitoring for goal-directed resuscitation during cardiac arrest, and understanding the reasons why bystanders fail to respond.

Table 2. Final Ranking of the Top 10 Knowledge and Science Gaps in the 2015 AHA Guidelines, as Determined by the Expert Panel

Gap Theme	Frequency of Occurrence Ranks: 1 2 3 4 5 6 7 8 9 10 Points: 10 9 8 7 6 5 4 3 2 1*	Total Points	Rank Order of Total Points	% of Experts Ranking in Top 5
Dispatch-directed CPR (telecommunicator CPR)	4 2 2 1 1 2 0 1 0 0	100	1	77
Hemodynamic monitoring for goal-directed resuscitation during cardiac arrest	3 2 1 0 1 3 0 2 0 1	84	2	54
Understanding the reasons why bystanders fail to respond	3 1 2 2 0 0 0 2 2 1	80	3	62
Optimization of postarrest care	0 2 2 1 4 0 0 3 1 0	76	4.5	69
Using novel technology for OHCA identification and response	0 1 3 2 2 2 1 0 1 1	76	4.5	62
Individualizing resuscitation strategies for victims of cardiac arrest	2 0 1 1 2 2 3 0 1 1	72	6	46
Predicting patients at risk for cardiac arrest	0 3 2 0 1 2 1 1 1 2	70	7	38
Developing tools for early neuroprognostication	0 1 0 2 1 1 3 1 3 1	56	8.5	31
Determining the optimal airway management strategy for cardiac arrest patients	1 1 0 3 0 0 1 2 1 4	56	8.5	38
Optimizing educational strategies for healthcare providers	0 0 0 1 1 1 4 1 3 2	45	10	15

Points were assigned on the basis of individual expert panel ranking and summated for final ranking by total points. The percentage of experts who ranked a theme in the top 5 was also calculated, demonstrating the range of expert rankings of each theme. AHA indicates American Heart Association; CPR, cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest.

*Each number in the display represents the number of respondents selecting a particular ranking for an item.

The final prioritized list of gaps included themes that may improve outcomes throughout the continuum of patient care (Table 2). All the gaps addressed both adult and pediatric patients. Out-of-hospital care was the exclusive focus of 30%, with the remaining 70% addressing both in-hospital and out-of-hospital care. One gap focused on prevention, with the goal of predicting patients at risk of cardiac arrest. Identification and directed response were important for another gap using novel technology in the out-of-hospital setting. The need to optimize resuscitation practices was noted in 60% of gaps, including hemodynamic monitoring for goal-directed resuscitation, understanding why bystanders fail to act, leveraging technology to enhance response, individualizing resuscitation strategies, and optimizing airway management strategies and education for healthcare providers. Post–cardiac arrest management was a focus of 2 gaps, including one on the optimization of postarrest care and another identifying the need to develop validated tools for early neuroprognostication.

The final prioritized list of the top 3 knowledge gaps included the following: (1) development of validated dispatcher-directed (telephone) CPR instructions and assessment of outcomes after deployment; (2) development of optimal targets in hemodynamic monitoring for goal-directed resuscitation during cardiac arrest; and (3) understanding the reasons why bystanders fail to respond and ways to educate,

Table 3. Extrapolated Potential Impact of Addressing Key Knowledge Gaps on Survival for OHCA Using National Epidemiological Data

Theme Addressed	US Population	Incidence of EMS-Treated OHCAs	Total EMS Cardiac Arrests[27]	Intervention	Survival Rate (All Rhythm), %	Survival to Hospital (All Rhythm)	All Rhythm Survival	% Increase in Survival
T-CPR	321 000 000	52/100 000	167 241	Current bystander CPR provision only	12[1]	. . .	20 068	208
	321 000 000	52/100 000	167 241	Optimized T-CPR and bystander CPR	37[28]	. . .	61 879	. . .
Neuroprognostication[26]	321 000 000	52/100 000	167 241	WLS <72	. . .	41 810	9198	26
	321 000 000	52/100 000	167 241	WLS >72	. . .	41 810	11 589	. . .
Optimizing postarrest care[30]	321 000 000	52/100 000	167 241	No CRC	8.9	. . .	14 884	57
	321 000 000	52/100 000	167 241	CRC	14	. . .	23 414	. . .

Extrapolation conducted similar to that outlined in Elmer et al.[26] CPR indicates cardiopulmonary resuscitation; CRC, cardiac receiving center; EMS, emergency medical service; OHCA, out-of-hospital cardiac arrest; T-CPR, telecommunicator CPR; WLS, withdrawal of life support.

train, and motivate laypeople to respond to cardiac and neurological emergencies. A simple majority consensus was reached, with a total of 7 of 13 (62%), although this did not meet our goal of a 75% majority consensus.[22] One additional respondent agreed with the list but presented a different prioritized order than the group consensus.

Discussion

To address the public health impact of cardiac arrest, focused efforts need to be made on addressing the knowledge gaps in research that will drive innovation and implementation in resuscitation science. As part of this goal, we leveraged the knowledge of resuscitation experts to identify 10 high-yield science gaps where researchers, stakeholders, and funding agencies may direct resources to improve survival from cardiac arrest. This approach has been used in other areas to improve outcomes by effecting research decisions to direct attention and funding at significant public health problems.[23,24] In this study, the expert panel generated a list of 10 prioritized knowledge gaps but was unable to reach consensus on the top 3 at our predetermined 75% level.

Using a modified Delphi technique, the top 10 list of knowledge gaps included themes related to out-of-hospital and in-hospital cardiac arrest management.[25] At the onset of a cardiac arrest event, the expert panel noted the importance of leveraging technology to improve rapid identification and response along with enhancing CPR provision by improving bystander and dispatcher response (telecommunicator CPR). As the victim's care is transferred from initial rescuers, optimizing care through improved airway management strategies, hemodynamic monitoring, and individualized goal-directed management becomes an important consideration. As the patient attains return of spontaneous circulation, experts noted that improved postarrest care and developing tools to assist in neuroprognostication become critical. Finally, in the in-hospital setting, improved educational strategies would assist healthcare provider provision of care and early identification of patients "at risk" of cardiac arrest, improving patient management to prevent cardiac arrest.

The prioritized list of knowledge gaps identified by the expert panel aligns closely with the recommendations outlined in the Institutes of Medicine report, "Strategies to Improve Cardiac Arrest Survival: A Time to Act."[2] Specifically, the Institute of Medicine report recommends the following: enhancing emergency medical service systems, with an emphasis on dispatcher and high-performance CPR (eg, gaps 1 and 2, Table 1); improving strategies for in-hospital arrest (eg, gaps 3 and 5) and special resuscitation circumstances (eg, gap 4); promoting the use of innovative technologies (eg, gap 8) and treatments (eg, gaps 1 and 4); and improving bystander response and CPR provision (eg, gap 6). The concurrence with the Institute of Medicine recommendations lends further credence to the possible impact of addressing these gaps.

The top 10 identified knowledge gaps, when placed in the context of the magnitude of public health impact (lives saved), further demonstrate the importance of identifying knowledge gaps for funding choices. Using the method described by Elmer et al,[26] we estimated the potential impact of addressing 3 of the identified themes that have been studied previously in out-of-hospital cardiac arrest (OHCA): telecommunicator CPR, improved neuroprognostication, and optimizing postarrest care (Table 3). Nationally, there are ≈167 000 emergency medical service–treated OHCAs in the United States, with a survival rate of ≈12%.[1,27] In systems in which telecommunicator CPR is optimized, all rhythm survival from OHCA is ≈37%.[28] If telecommunicator CPR were implemented nationally, as recommended by the AHA,[29] the expected impact on OHCA survival would be 41 810 lives saved annually, doubling overall survival. Following this same logic, as outlined by Elmer et al, implementation of a national neuroprognostication standard (eg, no withdrawal of life support for <72 hours after return of spontaneous circulation) would save 2300 lives per year, amounting to a 26% increase in OHCA survival.[26]

Implementation of standards of postarrest care would also have a significant impact. For example, the use of cardiac arrest centers in the Save Hearts in Arizona Registry & Education data set demonstrated a 14% survival rate compared with 8.9% survival of cardiac arrest patients managed at non–cardiac arrest centers.[30] Again, assuming 167 000 emergency medical service–treated OHCAs, national implementation of optimized resuscitation care (eg, cardiac arrest receiving centers) would lead to 8500 additional lives saved annually, accounting for a 57% increase in OHCA survival. As a conservative estimate examining only OHCA, focused funding directed at merely 3 of the defined knowledge gaps may lead to a substantial increase in survival of victims of cardiac arrest. Application of the identified themes to in-hospital cardiac arrest victims would likely lead to even greater increases in survival overall.

We were unable to reach majority consensus for the top 3 themes after 4 rounds, and opinions were unlikely to converge with additional work because of a wide range of opinions. The inability to reach stronger consensus may be related to the cognitive burden of ranking prioritized gaps because there were numerous highly important competing themes. Each theme was clearly selected by the panel because of the high impact of the knowledge gap in improving outcomes for patients and public health. The overall rankings did not concur with experts' individual rankings of the top 5 themes (Table 2), and no theme achieved strong individual top 5 ranking by >80% of the panel. For example, although many participants highly ranked the gap on optimization of postarrest care, no participant ranked it as the most important theme, decreasing the points to which it was assigned. On the contrary, there was a wide range of rankings for the gap on hemodynamic monitoring for goal-directed resuscitation during cardiac arrest, but many participants ranked this highly, increasing the overall points assigned. On tasking experts to deterministically rank order this list, it is possible many began to think in a less scientific manner and instead make value decisions on where funding should be spent.

Limitations

A major limitation of the Delphi method is the relatively demanding iterative process. Especially in the modified Internet-based setting, survey response rates may suffer when surveying over a period of several months. In this evaluation, the initial participation rate from the group of experts was lower than expected, likely because of the cognitive burden of developing a response to an open-ended question as well as the total time and multiweek participation required for the study (overall participation rate, 22%). Once the panel was developed in round 2, retention remained high (retention rate to round 4, 59%). A more condensed in-person meeting may have facilitated the consensus-building process. In addition, the use of recognized experts by recruiting known AHA Guideline writers was a strength of this study; however, purposeful selection of experts for the panel may have allowed for representation and balancing of the wide range of experts in the field. This study was also limited by the inability to reach consensus on the top 3 prioritized list of gaps. The context of the question posed to the expert panel, in terms of impact of these gaps to public health, likely required a value decision leading to differing opinions in the panel and the inability to reach consensus because of the numerous highly important competing themes. Convening an in-person expert panel could help improve the identification and prioritization of gaps, but may not prevent the value decision inherent in the task.

Conclusion

This evaluation used a modified Delphi technique, leveraging cardiac arrest experts to identify 10 critical knowledge gaps that have the potential to affect public health by improving outcomes from cardiac arrest. Although the expert panel was unable to reach consensus on the prioritization of the top 3 knowledge gaps, this list still provides a valuable resource that may assist researchers, policy makers, and funding agencies in their decision-making process. Future research should be directed at addressing these gaps to improve the quality of evidence on which we develop resuscitation guidelines.

Disclosures

None.

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SUPPLEMENTAL MATERIAL

Data S1. Expert panel participants with declared conflicts of interest.

Expert	Position Title	Conflict of Interest
Ericka L. Fink, MD, MS	Associate Professor, Pediatric Critical Care Medicine Children's Hospital of Pittsburgh	Grant funding (NIH, PCORI, Laerdal Foundation) in cardiac arrest outcomes and neurocritical care ICU rehabilitation
Robert A Berg, MD	Chief, Critical Care Medicine, The Children's Hospital of Philadelphia Professor of Anesthesiology and Critical Care and Pediatrics, University of Pennsylvania Perelman School of Medicine	None
Marina Del Rios, MD, MS	Assistant Professor Department of Emergency Medicine University of Illinois at Chicago, College of Medicine Community Sphere Director - Illinois Heart Rescue Project AHA Science Subcommittee Member, IOM Committee on the Treatment of Cardiac Arrest Member	5% Salary Support Medtronic Philanthropy 5% Salary Support NIH R56 funding mechanism - Hypertension research 12% Salary Support AHA Career Development Award
Jon C. Rittenberger, MD, MS	Associate Professor of Emergency Medicine, Occupational Therapy and Clinical and Translational Science, University of Pittsburgh	Travel and honoraria from C. R. Bard for presentation at 2015 Asia TTM Master's course in Seoul, Korea
Vinay Nadkarni MD, MS FCCM, FAAP, FAHA	Professor and Endowed Chair, Department of Anesthesia, Critical Care and Pediatrics, University of Pennsylvania Perelman School of	None

	Medicine	
Arthur Sanders, MD	Professor, Emergency Medicine University of Arizona College of Medicine	None
Marion Leary RN MSN MPH	Director of Innovation Research, Center for Resuscitation Science, University of Pennsylvania; Course Director, Research Residency	Grants from Medtronic Foundation, AHA, Laerdal Foundation. In-kind support from Laerdal Medical, Physic-control.
Raina Merchant, MD MSHP FAHA	Assistant Professor, Department of Emergency Medicine, University of Pennsylvania Perelman School of Medicine	None
Kelly N Sawyer, MD MS	Assistant Professor, Emergency Medicine University of Pittsburgh School of Medicine	Volunteer, AHA Emergency Cardiac Care Science Sub-Committee
Steven Charles Brooks MD MHSc FRCPC	Associate Professor, Department of Emergency Medicine, Queen's University at Kingston	Funding from Canadian Institutes of Health Research to study the PulsePoint mobile device application
Myra Wyckoff, MD	Professor of Pediatrics, University of Texas Southwestern Medical Center	None
Ken Tegtmeyer, MD, FAAP, FCCM	Professor of Clinical Pediatrics, Division of Critical Care Medicine, Cincinnati Children's Hospital Medical Center	None
Dianne Atkins MD	Professor, Pediatrics, University of Iowa	None