



How Do Resuscitation Teams at Top-Performing Hospitals for In-Hospital Cardiac Arrest Succeed?

A Qualitative Study

Editorial, see p 164

BACKGROUND: In-hospital cardiac arrest (IHCA) is common, and outcomes vary substantially across US hospitals, but reasons for these differences are largely unknown. We set out to better understand how top-performing hospitals organize their resuscitation teams to achieve high survival rates for IHCA.

METHODS: We calculated risk-standardized IHCA survival to discharge rates across American Heart Association Get With The Guidelines–Resuscitation registry hospitals between 2012 and 2014. We identified geographically and academically diverse hospitals in the top, middle, and bottom quartiles of survival for IHCA and performed a qualitative study that included site visits with in-depth interviews of clinical and administrative staff at 9 hospitals. With the use of thematic analysis, data were analyzed to identify salient themes of perceived performance by informants.

RESULTS: Across 9 hospitals, we interviewed 158 individuals from multiple disciplines including physicians (17.1%), nurses (45.6%), other clinical staff (17.1%), and administration (20.3%). We identified 4 broad themes related to resuscitation teams: (1) team design, (2) team composition and roles, (3) communication and leadership during IHCA, and (4) training and education. Resuscitation teams at top-performing hospitals demonstrated the following features: dedicated or designated resuscitation teams; participation of diverse disciplines as team members during IHCA; clear roles and responsibilities of team members; better communication and leadership during IHCA; and in-depth mock codes.

CONCLUSIONS: Resuscitation teams at hospitals with high IHCA survival differ from non-top-performing hospitals. Our findings suggest core elements of successful resuscitation teams that are associated with better outcomes and form the basis for future work to improve IHCA.

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Clinical Perspective

What Is New?

- In-hospital cardiac arrest is common and outcomes are variable across US hospitals, but the reasons for these differences are largely unknown.
- Through site visits that included in-depth interviews of 158 clinical and administrative staff at 9 hospitals, we used qualitative methods to identify 4 broad themes related to resuscitation teams at top-performing hospitals in in-hospital cardiac arrest that distinguished them from non-top-performing hospitals: (1) team design, (2) team composition and roles, (3) communication and leadership during in-hospital cardiac arrest, and (4) training and education.

What Are the Clinical Implications?

- Our findings suggest core elements of successful resuscitation teams that are associated with better outcomes.
- Although additional work is required to validate these findings in larger cohorts of hospitals, our results may assist individual hospitals to examine their own care processes for in-hospital cardiac arrest and provide specific, actionable recommendations to improve management of these high-risk patients.

Approximately 200 000 patients experience an in-hospital cardiac arrest (IHCA) each year in the United States.¹ Early initiation of cardiopulmonary resuscitation and defibrillation are critical for improving survival, given that every minute of delayed treatment decreases survival by 10%.² It is not surprising that hospitals have chosen to dedicate substantial resources to train healthcare providers in resuscitation and establish facility-wide emergency response systems to optimize their performance and improve outcomes of patients experiencing cardiac arrest. Despite these sizeable investments, however, overall rates of in-hospital survival after these events remain poor, with substantial variation noted across facilities.^{3,4}

On the surface, this variation in survival following IHCA may seem surprising. Established guidelines provide logical, sequential algorithms for advanced cardiac life support (ACLS) that are widely accepted and used across much of the world; thus, providers at most hospitals attempt to deliver the same treatments for the same reasons after the same ACLS training.^{5,6} Yet, these algorithms largely focus on guiding individuals on technical tasks at a patient's bedside. They have less frequently addressed complex issues surrounding the implementation of these algorithms in real-world settings and the fact that teams, and not individuals,

are ultimately responsible for providing resuscitation at hospitals. This is changing because recent guidelines⁷ have begun to expand on these topics given that the structure of resuscitation teams is known to vary across hospitals.⁸ However, there remains little empirical information to guide facilities on the optimal configuration of resuscitation teams despite their universal presence in hospitals over the past 5 decades.

Accordingly, we performed a qualitative study with the explicit purpose of better understanding how top-performing hospitals organize their resuscitation teams to achieve high survival rates for IHCA. Through in-depth site visits and detailed interviews of staff at multiple hospitals, we identified common themes linked to better outcomes by using a methodological approach that has been applied in diverse areas ranging from infection prevention to heart attack care.^{9–11} Our findings help unpack IHCA as a complex human task involving multiple individuals and provide novel insights that complement a large and growing literature of quantitative studies detailing differences in resuscitation care across hospitals.

METHODS

Study Design and Sampling

Data and study materials will not be made available to other researchers for purposes of reproducing the results given the sensitive nature of the interviews and the potential for reidentification of individuals. We conducted a qualitative study, which included in-depth interviews of clinical and administrative staff at top-, middle-, and bottom-performing hospitals in regard to risk-standardized survival for patients with IHCA. Using data from the national prospective Get With The Guidelines-Resuscitation registry, we identified hospitals with at least 20 patients with in-hospital cardiac arrest between January 1, 2012, and December 31, 2014 (n=192). We then used a previously described and validated method to calculate risk-standardized rates of survival to discharge for each hospital for each calendar year.¹² This method was developed to specifically facilitate hospital comparisons and allowed us to rank each hospital into quartiles of performance. We focused on risk-standardized rates of survival to discharge rather than other outcomes (eg, return of spontaneous circulation) to provide a global measure of performance for resuscitation teams.

We defined top-performing hospitals as those consistently in the highest quartile for each of 3 calendar years (2012–2014), middle-performing hospitals as those consistently in the middle 2 quartiles for each year, and bottom-performing hospitals as those consistently in the lowest quartile for each year. Next, we purposefully selected hospitals from each of these groups for site visits, taking into account several criteria determined a priori, including teaching status, number of staffed beds, and US census region. In selecting facilities, we used the concept of information power as suggested by Malterud et al.¹³ This approach provides a pragmatic method for sample selection based on certain key parameters (eg,

study aim, sample specificity, use of theory) but with specific attention to identifying a sample that will provide robust information directly related to the research question. This led us to focus on a larger number of top-performing hospitals as the most informative cases for investigating factors that promote better success during cardiac arrest; however, we still selected a few middle- and bottom-performing hospitals to gain a comparative view.

We approached 12 hospitals for site visits and 9 hospitals agreed to participate. One top-performing hospital declined after initially agreeing because of unexpected personal issues that prevented its leader of resuscitation services from participating, whereas another top-performing hospital and 1 bottom-performing hospital were concerned about the workload required. At each participating institution, the individual linked to the hospital's participation in the Get With The Guidelines-Resuscitation registry, typically the director of resuscitation, was asked for her (or his) assistance with identifying key staff members involved in IHCA for interviews. Key staff we suggested for interviews included individuals from the hospital's resuscitation team, rapid response or emergency medical team, and resuscitation committee, as well as physician trainees, nurses, attending physicians and administrative leadership in emergency medicine, hospital medicine, critical care, quality improvement, and general administration, as well. Once specific names were provided, potential participants were recruited by research staff through e-mail and by phone. Participation was voluntary and interviews were confidential. We conducted site visits until additional interviews produced no new concepts (ie, thematic saturation was reached). The institutional review board at the University of Michigan Medical School approved the research procedures and all study subjects provided written informed consent.

Data Collection and Measures

Investigators with experience in qualitative research, medicine, and nursing conducted in-depth, semistructured interviews. In most instances, interviews were conducted in-person for 1 hour with individual participants with modest incentives provided (ie, \$20 gift card). In rare situations, we conducted interviews in groups with 2 to 5 participants, if requested, and when the participants represented similar resuscitation roles at a given hospital (eg, house staff). Overall, we found that the types of comments and concepts discussed did not differ substantially between individual and group interviews. For each interview, we typically included 2 researchers (1 clinician scientist, 1 qualitative research expert) to balance content and methodological expertise. One researcher was primarily conducting the interview, whereas the other took notes and prompted the discussion with questions to clarify or elaborate on ideas.

We initially built the interview guide based on a clinical framework developed from expert opinion and conceptually using the Tuckman stages of group organization.¹⁴ This was subsequently enriched by using the empirical results of a national survey that we conducted within Get With The Guidelines-Resuscitation hospitals and previously published.¹⁵ We then specifically piloted this interview guide at 2 institutions (ie, the University of Michigan and Ann Arbor VA Medical Center) before applying it during the site visits. This

pilot testing allowed us to revise the questions to improve clarity and understanding.

Interviews began with a question about an individual's role at the hospital and in resuscitation. We then inquired about their perspectives on care of patients before, during, and after IHCA, often asking participants to describe their involvement in a recent or memorable IHCA as an example. We asked specifically about teamwork and leadership during resuscitation and quality efforts in IHCA and other areas. Finally, we asked about holistic processes around IHCA, including data collection, overall views about their hospital's best practices, and their most needed areas of improvement. All interviews were conducted using a standard semistructured interview guide that included open-ended questions to elicit detailed accounts about participants' experiences with IHCA, with subsequent probing questions based on the interviewee's response (Table 1). All interviews were audio recorded, transcribed by independent, professional transcriptionists, and then deidentified for analysis.

Data Analysis

We performed thematic analysis to develop and apply consistent and comprehensive coding to the open-ended, textual data from the interview transcripts.^{16–18} This approach to conducting qualitative analysis has been widely applied in health research¹⁹ and is well suited to answer questions around individual experiences, views, and opinions, and to evaluate practices and processes across organizations, as well. Iteratively developed codes, which reflect the emergent themes of these data, allow for verbatim quotations or observations to be catalogued into their essential concepts.

We followed a generally recommended process to construct a preliminary codebook.²⁰ Each member of the research team read several interview transcripts to ensure content immersion. The research team then developed a codebook together using examples from the data. Next, transcripts from

Table 1. Interview Guide Topics

Sample Open-Ended Questions for Interviews
1. Let's start by having you describe what you do.
2. Please describe your hospital's policies and practices related to preventing IHCA and selecting patients appropriate for resuscitation care.
3. Please describe the process by which your hospital responds to the event of IHCA.
4. Please describe how your hospital cares for patients following IHCA if they survive.
5. Who is responsible for oversight and QI efforts related to IHCA at your hospital? (eg, CPR committee)
6. In the last 3 years, please describe the major initiatives your hospital has undertaken to improve care of patients with IHCA.
7. Please describe your perception of administrative support for QI efforts and specifically for initiatives related to IHCA at your hospital.
8. If you could change 1 thing about the IHCA care processes at your hospital, what would it be?
9. If you were helping other hospitals improve IHCA care, how would you recommend they structure a program?

CPR indicates cardiopulmonary resuscitation; IHCA, in-hospital cardiac arrest; and QI, quality improvement.

the initial 2 sites were coded and discussed by multiple team members to ensure intercoder agreement and further refine the codebook. Codes were defined within categories, structured initially on the timeline of IHCA (concepts related to before, during, and after the event), and reviewed after successive site visits. This allowed us to refine the properties and dimensions of existing codes, and to identify new codes to fit concepts as they developed from the data, as well. Multiple team members coded 25% of the same transcripts for the first 5 sites to enhance consistency.

All research team members reviewed the coded transcripts and collated data, as well, from code reports around single codes to identify broader patterns of meaning (ie, themes). In this phase, we evaluated the themes against the data to develop a detailed analysis of each and to decide on an informative name for each theme. The process of refining codes and describing themes continued after each site visit until we found no new concepts in remaining transcripts, thus ensuring thematic saturation. To enhance rigor, we triangulated in at least 3 ways: (1) having multiple investigators code data and participate in analysis and interpretation; (2) performing interviews with multiple informants; and (3) collecting hospital documents and protocols about resuscitation, and attending resuscitation committee meetings at sites whenever possible. The diversity of backgrounds and experiences among the research team promoted a more in-depth discussion and understanding of the conceptual content of the data. We involved all research team members in regular team meetings during the analytic phase with disagreements discussed openly and consensus reached through collaborative discussions.

We maintained documentation through minutes from team meetings of the construction of the code structures and definitions, and the principles, as well, that we used in defining and applying the codes to theme development. Using the coded data, we summarized key themes in tables that helped describe the hospitals' experiences with IHCA and resuscitation teams. We entered all data in MAXQDA to facilitate review, analysis, and reporting. The authors had full access to the data and take full responsibility for its integrity. All authors have read and agree to the article as written.

RESULTS

Study Hospitals and Staff

Tables 2 and 3 (including the Table in the online-only Data Supplement) display characteristics of the 9 hospitals and key staff that participated in the study. Overall, we interviewed between 12 and 29 participants per hospital for a total of 158 individuals across multiple disciplines, including physicians, nurses, other clinical staff, and administration. In total, there were 78 hours and 29 minutes of interviews, yielding 778482 transcribed words.

Themes of IHCA Performance

Based on the perceptions of the participants, we identified 4 broad themes that distinguished resuscitation

Table 2. Hospital Characteristics

Hospital	Region	No. of Staffed Beds	Mean Risk-Standardized Survival Rate, Percentile, 2012–2014	Mean No. of In-Hospital Cardiac Arrests per Year, 2012–2014	Teaching Status
A	Midwest	>800	95.5	288.0	Major
B	West	200–400	12.9	25.3	Non teaching
C	South	>400–800	97.3	93.3	Non teaching
D	Midwest	200–400	87.7	57.0	Major
E	West	200–400	56.1	68.7	Minor
F	South	>800	2.9	130.7	Minor
G	Midwest	200–400	81.7	73.3	Minor
H	Northeast	>800	88.7	140.7	Major
I	Northeast	>400–800	5.4	129.3	Minor

teams at top-performing hospitals in IHCA in comparison with non-top-performing hospitals (Table 4). These themes reflected (1) team design, (2) team composition and roles, (3) communication and leadership, and (4) training and education. Differences across these 4 themes are discussed in greater detail in the next sections, including representative quotations.

Team Design

In general, top-performing hospitals had dedicated or designated resuscitation teams versus ad hoc resuscitation teams at non-top-performing hospitals. Dedicated teams were used by many top-performing hospitals and referred to the presence of a core group of nursing or respiratory therapy staff with no clinical responsibilities during a given shift that superseded their roles on a resuscitation team.

I think what we have is again the fact that you have the 'team'... You're not waiting for someone to leave something that they're doing. You have a dedicated team that's this is all they're doing, waiting for us, like having a fire service... You're not looking who will respond today.

—Attending Critical Care Physician; Hospital A; Top-Performing

Frequently, these team members had specific clinical expertise used for other emergency services such as rapid-response teams or other acute conditions.

They do rapid response, they do code response, they are part of our sepsis team and our difficult airway response team...

—Critical Care Nurse; Hospital H; Top-Performing

Some top-performing hospitals had designated, rather than dedicated, teams. What distinguished

Table 3. Type of Staff Interviewed at Study Hospitals

Type of Staff	No. of Interviews
Physicians (nonadministration)	
Critical care and emergency medicine physician	9
Anesthesiologist	3
Hospitalist and other	9
Resident physician	6
Nurses (nonadministration)	
Nurse manager	11
Nurse practitioner/clinical nurse specialist/certified registered nurse anesthetist	4
Nurse educator	12
Nurse code team member or emergency department/critical care nurse	35
Emergency department/intensive care unit/coronary care unit director/supervisor	10
Other staff (nonadministration)	
Pharmacy	8
Respiratory therapist code team member	9
Other (intravenous/laboratory code team member, ECG, biomedical services, chaplain, security)	10
Administration	
Senior leadership (president, vice president, chief medical and nursing officers)	9
Director of service lines (eg, critical care, emergency medicine, anesthesia, cardiac catheterization laboratory, pharmacy)	9
Quality and data management team	9
Other (department administrator, advanced cardiac life support trainer)	5
Total	158

designated teams was that their nursing and respiratory therapy staff may have other clinical responsibilities that involved direct patient care, but systems were in place for shedding these quickly when an IHCA occurred.

Our [ICU Floor Nurse] can't get off the unit...she would let the supervisor know at the beginning of her shift, and say I'm not going to be able to go to a code tonight if it gets, if one gets called. So then they come up with a plan beforehand, on who's going to assume that role so they're not doing it in the moment, during the crisis.

—Nurse Supervisor; Hospital G; Top-Performing

In contrast, non-top-performing hospitals created resuscitation teams ad hoc in response to an IHCA.

We don't assign code nurses anymore. As soon as we hear it called, you will see if there's people in the hallway, or a head sticking out doors.

—Critical Care Nurse; Hospital B; Bottom-Performing

Table 4. Recommendations for Resuscitation Teams

Theme	Recommendations
Team design	Hospitals should establish dedicated or designated teams for in-hospital cardiac arrest.
Team composition and roles	Hospitals should ensure the participation of diverse disciplines during in-hospital cardiac arrest, including physician, nursing, respiratory therapy, and pharmacy expertise. Hospitals should develop systems to include trainees while ensuring the availability of advanced expertise as needed. Hospitals should define clear roles and responsibilities of team members before or early during in-hospital cardiac arrest so tasks are clearly delineated in the early minutes of the event. These should include a focus on core skills including chest compressions, airway management, and intravenous access.
Communication and leadership	Hospitals should encourage the development of approaches that improve communication (eg, closed-loop communication) and emphasize respect across multiple disciplines. When communication breaks down, the hospital should have a system in place to correct behavioral issues without being punitive. Leadership during in-hospital cardiac arrest requires focus. Identifying high-quality and clearly identified leaders within resuscitation teams is essential for successful teamwork.
Training and educational efforts	Hospitals should implement mock codes that are (1) regular and unscheduled; (2) occur in actual patient rooms and high-risk areas; (3) multidisciplinary; and (4) include post-mock code debriefing.

So, we've got a broken process of who would respond to codes...And that's another one of my wish lists is to either consolidate that in some form or fashion or, again, to have a dedicated team...

—Respiratory Therapist; Hospital F; Bottom-Performing

I know some hospitals have code teams...No, we don't have that...we don't have a code team.

—Resident Physician; Hospital I; Bottom-Performing

Team Composition and Roles

Team composition did not differ across hospitals in regard to inclusion of physicians, nurses, anesthesia, and respiratory therapists. Top-performing hospitals reported more support staff (eg, pharmacy, clerical, security, and spiritual staff) for their emergency response systems, and greater acknowledgment of the diversity and experience required to fully perform resuscitation care, as well. One top-performing hospital also described greater familiarity among team members as an advantage.

The team's been working together for so many years that they've built up a really great rapport, and they know each other's skill and their deficits...team work wise...and that's the only reason why you have the outcome.

—Clinical Nurse Specialist and Educator; Hospital C; Top-Performing

Top-performing hospitals also tended to have clearly defined roles and responsibilities for team members during an IHCA.

Fifteen years ago when I started it was a free for all... So when (Medical Director) took over and, and kind of structured everything... You just show up and you know what you're supposed to do, and there's no screaming and there's no yelling.

—Critical Care Nurse; Hospital G; Top-Performing

At non-top-performing hospitals, specific roles and responsibilities of members were less clear, even well into the response, generating variable degrees of distress.

Very honestly things are more chaotic... I just feel a different level of anxiety when you come to these codes and roles are not always as clearly defined.

—Critical Care Attending Physician; Hospital E; Middle-Performing

It's kind of situation by situation... Respiratory always goes right to the airway to start with the airway, which is intuitive, and then in terms of the other staff, it just kind of depends. They seem to be comfortable assigning their own roles...

—Emergency Medicine Physician; Hospital B; Bottom-Performing

We also saw major differences in the presence of resident physicians and their function during an IHCA. At non-top-performing hospitals, resident physicians were, at times, described as a weakness given the frequent turnover of trainees.

I don't mean [residents] suck, but look at what we give 'em. They come in as first years, they don't know anything. They come in as second years, they sort of know what's going on. By the third year, they're starting their stride. They start to get good at what they do, and then they graduate and leave, and then we're back to the people that are being fed through the PEZ container...

—ACLS Instructor; Hospital I; Bottom-Performing

At top-performing hospitals, on the other hand, specific back-up plans for resident physicians involved more experienced clinicians.

What happens a lot is the MICU resident will take ownership of the code and then the fellow will be as a supportive role. And depending on their code experience, you know, they might fly pretty much independently or they might need some guidance in terms of either fellow suggestions or nursing suggestions...

—Critical Care Nurse; Hospital H; Top-Performing

Top-performing hospitals also spent time empowering bedside nurses in their roles as first responders, including allowing them to defibrillate without the presence of physicians if indicated.

When I came here, the policy was nurses couldn't press the button to defibrillate. They could charge the monitor, they could recognize Vfib, they couldn't press the button...it looked like the ceiling of the Sistine Chapel where one physician's finger was reaching across and trying to make contact with the button. And (Nurse Leader) and (Physician Leader) and others realized that that was ridiculous. We couldn't get a physician in the room in 2 minutes reliably, and they certainly wouldn't be up to speed on what needed to be done, so nurses defibrillate now...

—Nursing Educator; Hospital A; Top-Performing

One thing that has frustrated me or did frustrate me as a bedside nurse, was that I was ACLS trained, I was ACLS trained to administer medications... But the culture was "never," you know, you never push epi, you never do anything without a doctor even though we are being trained... We did make a decision about 2014... our shocks are now delivered within 1 minute... CPR is generally delivered or started in under 1 minute for a witnessed cardiac arrest for certain.

—Critical Care Nurse; Hospital H; Top-Performing

Hospitals perceived essential skills like chest compressions quite differently when performed by different individuals in these roles. In 1 top-performing hospital, chest compressions were highly valued and their performance was limited to specific individuals (eg, a critical care nurse):

I mean the days of, you know, letting the nursing student or the paramedic student do the CPR, they just... they don't really happen anymore.

—Emergency Medicine Nurse; Hospital G; Top-Performing

In contrast, a bottom-performing hospital valued this skill less and suggested it was easily performed by less experienced providers.

We teach the techs that they can do compressions in code situations. If we have nursing students, we'll let them do compressions. We have plenty of people to rotate through in general so we'll rotate anyone through to do compressions.

—Nursing Education; Hospital F; Bottom-Performing

Last, crowd control was universally considered a problem because of the arrival of nonteam members.

Our biggest problem is too many people show up... We have codes where there's 17 to 22 people who respond... So sometimes it's difficult determining who's in charge of this code...

—Nursing Supervisor; Hospital I; Bottom-Performing

Communication and Leadership

Top-performing hospitals described different patterns of communication that encouraged multidisciplinary

discussion and mutual respect across team members. This did not mean that communication was universal or that tension never arose, but that specific mechanisms to address breakdowns were available.

I think we have really good codes, and then we have codes that don't run well. On really good codes, the communication is fantastic...If I had to do a percentage, probably 75 are good communication, and there's 25 that aren't.

—Critical Care Nurse; Hospital H; Top-Performing

We're very, very fortunate in that my great partner is our senior medical director here at the hospital, so he and I work very closely together. So I'll hear it in fact more from him...He'll say, hey, did you hear about [the resuscitation team] had a call last night, there was a concern between [team nurse] and the physician... So that lets me know that I didn't even have to be part of that process. It got escalated appropriately and [the senior medical director]...will take whatever feedback and then do whatever investigating needs to happen.

—Senior Nursing Officer; Hospital C; Top-Performing

At non-top-performing hospitals, communication during an IHCA was described more frequently as chaotic, confusing, or unsatisfactory with gaps in practices endorsed by guidelines like closed-loop communication where team members explicitly acknowledge and verbalize requests as they are done.

Communication just needs to get better. There are some residents who are really good at giving direct orders or finding roles, closing the loop, all that stuff. But, there are some who aren't trained on that and they don't know how to do it and so, will talk softly or they won't give a complete order and things kind of get lost.

—Critical Care Nurse; Hospital I; Bottom-Performing

Interviewer: Would you be able to identify one or two things that you really think—as it pertains to resuscitation care specifically—where you would like to see things improved further...? Participant: Communication. Closed-loop communication.

—Nurse Coordinator; Hospital E; Middle-Performing

Another key part of communication was the presence of strong leadership during the IHCA.

Intensivists usually will take over... you role model off of him. So if he is calm and, you know, everything seems to be calm. So I have seen a lot of codes where if they get real anxious, then it makes the whole room anxious.

—Nurse Manager; Hospital A; Top-Performing

At 1 top-performing hospital, good leadership was highly valued, regardless of whether the team leader was a physician or nurse. Indeed, a coleadership model

with nurses who were specialized members of the resuscitation team was highlighted.

Interviewer: So who's running the code?

Participant: Again, if there's a physician there, then usually...most of the time it's going to be the [resuscitation team] nurse because she is ACLS certified, so she's going to be calling the drugs and things like that. The physician may come in and sort of weigh in on what's happening, but they're looking to the [resuscitation team] nurse a lot of times.

—Respiratory Therapist; Hospital C; Top-Performing

There is just a very wonderful collaboration that is felt between the hospitalists and the [resuscitation team]. When they're...a hospitalist responds to a code, they respond, but they defer to the [resuscitation team]. Meaning, not that the hospitalist is being lazy but that they know that...their expertise, and they defer to them because of that expertise.

—Clinical Nurse and Educator; Hospital C; Top-Performing

Training and Educational Efforts

All hospitals discussed training and educational efforts around resuscitation, but varied in their implementation of these efforts. A notable example was mock codes, which were described as more in-depth at top-performing hospitals. Specifically, mock codes were: (1) unplanned and held on a regular basis, (2) conducted in actual patient rooms rather than simulated environments, (3) multidisciplinary, and (4) included structured postdebriefing.

One top-performing hospital described mock codes in high-risk areas targeted for improvement because of low traffic or a higher incidence of codes. They also focused on teamwork and communication during the mock codes.

So the mock codes will typically actually take place in areas that are maybe a low traffic area or someplace not everybody knows where it's located so that it helps facilitate people finding their way through the building.

—Pharmacist; Hospital D; Top-Performing

If there's codes happening outside of the ICU or CCU, then we target those areas for mock codes.

—Critical Care Nurse Educator; Hospital D; Top-Performing

"And it's all about team training, less clinical, more team..."

—Cardiology Physician; Hospital D; Top-Performing

Non-top-performing hospitals did not describe the same type of processes for mock codes. When present at these hospitals, mock codes were generally perfunctory

tory, not multidisciplinary and conducted in simulated environments.

There's too many people who...well, I'm busy with other things. You can't be pulling me away for this stuff [mock codes], you know, that kind of an attitude. And to me, that's really the only way you get a true mock code, you know.

—Clinical Nurse and ACLS Instructor; Hospital I; Bottom-Performing

On the mock code side, generally physicians don't participate in the mock code...

—Nurse Educator; Hospital F; Bottom-Performing

Beyond mock codes, top-performing hospitals often enhanced their educational opportunities by introducing newer teaching approaches that often emphasized multidisciplinary care.

The ACLS is more about teamwork in allowing everyone to experience each of the roles so that they have a deeper understanding of how the team works. We call it a sport, you know, it's because...it requires communication, it requires performance. And you don't learn to play football by yourself.

—ACLS Instructor; Hospital A; Top-Performing

DISCUSSION

We describe the findings from a national qualitative study to understand how top-performing hospitals organize their resuscitation teams to achieve high survival rates in patients with IHCA. Based on the perceptions of the participants we interviewed, we discovered 4 broad themes that distinguish top-performing hospitals: team design, team composition and roles, communication and leadership, and training and educational efforts. In general, we noted that top-performing hospitals had formally organized teams composed of members from diverse disciplines with delineated roles and responsibilities. We also found top-performing hospitals more commonly encouraged strong communication and leadership during an IHCA while supporting training and educational efforts like comprehensive mock codes. To our knowledge, this is the first multicenter evaluation of the performance of resuscitation teams during IHCA using qualitative methods, and we believe our results will be valuable to hospitals interested in improving outcomes for these events.

Providing high-quality resuscitation can be difficult for hospitals. IHCAs are sudden and unexpected events that can stress the resources of even the most resilient organizations. After the initial publication of seminal studies of the potential life-saving benefit of chest compressions, noninvasive ventilation, and defibrillation in the early 1960s,^{21–23} reports began to surface

about different hospitals' approaches to providing resuscitation.^{24–26} Given widespread concerns about the best processes for applying these treatments, numerous professional organizations then developed protocols to standardize cardiopulmonary resuscitation, basic life support, and ACLS. In the 1970s, these protocols were standardized by groups like the American Heart Association into ACLS, a focus of resuscitation care that has continued largely uninterrupted over almost 5 decades.²⁷ Regulatory organizations have also been interested in ensuring adequate provision of resuscitation. For example, The Joint Commission mandates standardized policies and procedures for providing resuscitation services within healthcare organizations, including the availability of emergency equipment and adequate training of individual providers.²⁸

Despite this considerable attention to IHCA, surprisingly few recommendations have been made about how resuscitation teams should be ideally constructed. National data suggest up to a quarter of hospitals may not even have resuscitation teams and the variability around practices in the design, composition, and roles and responsibilities of team members is believed to be substantial.⁸ Furthermore, it is uncertain whether differences in many of these features lead to differences in IHCA performance. It is in this context that our findings are particularly striking and useful because we noted substantial differences in the ways that top-performing hospitals distinguished themselves. We summarize these findings in Table 4 as a set of potential recommendations for clinicians and hospital administrators to consider in designing their systems for resuscitation.

Our findings highlight the importance of dedicated or designated resuscitation teams at hospitals. Top-performing hospitals described dedicated teams as a powerful way of achieving the consistent clinical expertise and teamwork required for effectively managing these high-stakes events. However, dedicated teams are not likely to be feasible at many hospitals, as they can require resource investments that may be barriers for some facilities. This constraint led other top-performing hospitals to use designated teams where resuscitation team members are identified a priori as predetermined responders to an IHCA. We also found that some top-performing hospitals sought ways to leverage the clinical expertise of resuscitation teams in different ways across their hospitals to offset resource investments. An analogy raised by 1 hospital was the current trend to still have dedicated firefighters available for fires while expanding their involvement with other critical emergencies.²⁹

Our findings also indicate that hospitals need to carefully craft the composition of their teams and the roles and responsibilities of the providers on these teams. Ideally, inclusion of members of the team should con-

sider the cognitive and technical skills that are required to perform a successful resuscitation, not simply titles. One top-performing hospital seemed to find great success by being very specific about assigning roles and responsibilities so that individual responders knew what to do immediately on arrival at an IHCA. At other top-performing hospitals, there was a focus on delineating team member roles and responsibilities as early as possible during an IHCA.

Improving communication and leadership during an IHCA should also be a top priority for facilities, although our findings also suggest that these elements are influenced by factors related to other themes. For example, hospitals with a dedicated team were likely to face fewer challenges with communication and leadership by virtue of a smaller cohort of providers being responsible for all acute resuscitation care. Finally, our data revealed the benefits of incorporating mock codes into training and educational efforts. Key features of a robust mock code program to more accurately simulate real-world IHCAs included conducting events that were nonscheduled, held in actual patient rooms and at all times of day, and multidisciplinary. Mock codes should also be efficient to achieve staff buy-in and include multidisciplinary post-mock code debriefing.

Although we used established techniques to improve the rigor of our findings, our study has limitations. First, we visited hospitals at a single point in time. The non-top-performing hospitals could have been on a trajectory toward improvement that was not captured in our data. To minimize this possibility, we calculated risk-standardized survival rates over a 3-year period from the cohort of hospitals we used for selection and focused on those with consistent performance in each of the 3 years for IHCA survival. Second, our interviews were based on the perceptions of the informants, and there is always the possibility of social desirability response bias in this type of work, which would occur if participants misrepresented their experiences to provide desirable answers. In a similar vein, we also could not account for whether providers at hospitals were aware of their organization's Get With The Guidelines-Resuscitation scores that are provided to participants in the registry. To address these concerns, we interviewed several key staff in each hospital to obtain a comprehensive picture of care and used scripted probes during our semistructured interviews to elicit specific details that would be difficult to misrepresent (eg, how are resuscitation teams designed). We also encouraged respondents to share both positive and negative experiences. Third, we focused only on hospitals enrolled in a large national registry and were limited in our ability to evaluate very small hospitals (<200 beds) with few cases of IHCA. Although our findings are specific to these sites, the detailed nature of the data allows

an assessment of the degree to which similar issues might occur at other institutions supporting transferability of key processes. Additional work will need to confirm the generalizability of our findings to other organizations. Finally, our study identified key themes that we hypothesize influence performance in IHCA. Additional work is needed to develop specific tools for measuring underlying features related to these themes and to quantitatively test the impact of these constructs among a larger sample of hospitals. Thus, this work requires confirmation.

For nearly 5 decades, resuscitation teams have been deployed in hospitals using variable approaches largely based on anecdote and convenience, rather than evidence. Results of this study move us forward from simply describing types of hospitals with consistently higher survival rates after IHCA to understanding potential keys to their success. Although additional work is required to validate these findings in larger cohorts of hospitals, our results will assist individual hospitals in examining their own care processes for IHCA and provide specific, actionable recommendations to improve management of these high-risk patients.

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None.

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How Do Resuscitation Teams at Top-Performing Hospitals for In-Hospital Cardiac Arrest Succeed?: A Qualitative Study

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Dr Carolyn Lam:

Welcome to Circulation on the Run, your weekly podcast summary and backstage pass to the journal and its editors. I'm Dr Carolyn Lam, associate editor for the National Heart Center, and Duke National University of Singapore.

How do resuscitation teams at top-performing hospitals for in-hospital cardiac arrest actually succeed? Well, to learn how, you have to keep listening to the podcast, because we will be discussing this right after these summaries.

The first original paper this week tells us that recent developments in RNA amplification strategies may provide a unique opportunity to use small amounts of input RNA for genome wide-sequencing of single cells. Co-first authors, Dr Gladka and Molenaar, corresponding author, Dr van Rooij, and colleagues from Hubrecht Institute in Utrecht, the Netherlands, present a method to obtain high-quality RNA from digested cardiac tissue, from adult mice, for automated single-cell sequencing of both healthy and diseased hearts.

Based on differential gene expression, the authors were also able to identify multiple subpopulations within a certain cell type. Furthermore, applying single-cell sequencing on both the healthy and injured heart indicated the presence of disease-specific cells subpopulations.

For example, they identified cytoskeleton-associated protein 4 as a novel marker for activated fibroblasts that positively correlated with known myofibroblast markers, in both mouse and human cardiac tissue. This paper raises the exciting possibility for new biology discovery using single-cell sequencing that can ultimately lead to the development of novel therapeutic strategies.

Myeloid-derived suppressor cells are a heterogeneous population of cells that expand in cancer, inflammation, and infection, and negatively regulate inflammation. However, their role in heart failure was unclear, at least until today's paper in this week's journal. Co-first authors Dr Zhou, Miao, and Yin, and co-corresponding authors, Dr Wang and Li, from Huazhong University of Science and Technology, measured the myeloid-derived suppressor cells by flow cytometry in heart failure patients and in mice with pressure overload-induced heart failure, using isoproterenol infusion or transverse aortic constriction.

They found that the proportion of myeloid-derived suppressor cells was linked to heart failure severity. Cardiac hypertrophy, dysfunction, and inflammation were exacerbated by depletion of myeloid-derived suppressor cells but alleviated by cell transfer. Monocytic myeloid-derived suppressor cells exerted an antihypertrophic effect on cardiomyocyte nitric oxide, but monocytic and granulocytic myeloid-derived suppressor cells displayed antihypertrophic and anti-inflammatory properties through interleukin 10.

Rapamycin increased accumulation of myeloid-derived suppressor cells by suppressing their differentiation, which in part mediated its cardioprotective

mechanisms. Thus, these findings revealed a cardioprotective role from myeloid-derived suppressor cells in heart failure by their antihypertrophic effects on cardiomyocytes and anti-inflammatory effects through interleukin 10 and nitric oxide. Pharmacological targeting of myeloid-derived suppressor cells by rapamycin constitutes a promising therapeutic strategy for heart failure.

In the FOURIER trial, the PCSK9 inhibitor evolocumab reduced LDL cholesterol and cardiovascular risk in patients with stable atherosclerotic disease. However, was the efficacy of evolocumab modified by baseline inflammatory risk?

While Dr Bohula from the TIMI Study Group and colleagues explored this question by examining the efficacy of evolocumab stratified by baseline high sensitivity CRP. They also assessed the importance of inflammatory and residual cholesterol risk across the range of on-treatment LDL concentrations. They found that the relative benefit of evolocumab for the prevention of adverse cardiovascular events was consistent, irrespective of baseline high sensitivity CRP. However, because patients with higher high sensitivity CRP levels had higher rates of adverse cardiovascular events, they also tended to experience greater absolute benefit with evolocumab.

In an analysis of baseline high sensitivity CRP in achieved LDL cholesterol, the authors found that at first cardiovascular event rates were independently associated with both LDL cholesterol and high sensitive CRP. Event rates were lowest in patients with the lowest hsCRP and LDL cholesterol, supporting the relevance of both inflammatory and residual cholesterol risk.

The next paper provides further evidence that residual inflammatory risk, as measured by on-treatment high sensitivity CRP, remains an important clinical issue in patients on combination statin and PCSK9 inhibitor therapy. Dr Pradhan, from Brigham and Women's Hospital and colleagues, evaluated the residual inflammatory risk among patients participating in the SPIRE-1 and -2 cardiovascular outcome trials, who are receiving both statin therapy and the PCSK9 inhibitor bococizumab, according to on-treatment levels of high sensitivity CRP and LDL cholesterol measured 14 weeks after drug initiation.

They found that among high-risk stable outpatients treated with moderate or high-intensity statins and PCSK9 inhibition, roughly one in two had residual inflammatory risk defined by an on-treatment high sensitivity CRP level of 2 or more mg per liters, and roughly one in three had values above 3 mg per liter.

PCSK9 inhibition was associated with a 60% mean reduction in LDL cholesterol but little change in high sensitivity CRP. Levels of high sensitivity CRP above 3 mg per liter were associated with a 60% greater risk of future cardiovascular events, corresponding to a 3.6% annual event rate, even after accounting for on-treatment LDL cholesterol.

Thus, PCSK9 inhibition, added to statin therapy in stable outpatients, does not lower high sensitivity CRP. Persistent elevations of CRP is associated with future cardiovascular risk in these patients, even after low levels of LDL cholesterol are achieved. If corroborated, these data suggests that inflammation modulation may yet have a role in the primary and secondary prevention of cardiovascular disease when LDL cholesterol is already controlled. Well, that wraps it up for our summaries. Now, for our future discussion.

In-hospital cardiac arrests are common worldwide and they're so important because they represent opportunities for us to improve survival. Now, yet, overall rates of hospital survival after in-hospital cardiac arrests remain poor and there is substantial variation across facilities. This may be surprising because we all seem to follow or should follow the same ACLS algorithms across the world and yet, there are different outcomes.

How do resuscitation teams, at top performing hospitals, for in-hospital cardiac arrest, how do they succeed? Pleased to be discussing this with a real star team in today's podcast. We have first and corresponding author of our feature paper, Dr Brahmajee Nallamothu. We also have Dr Steven Kronick, who is the chair of the CPR committee and both are from University of Michigan Medical School. We also have Dr Sana Al-Khatib, who is a senior associate editor of *Circ*, from Duke University. So, welcome everyone! Let's go straight into it. Maybe starting with you Brahmajee, could you tell us what inspired you to perform this study?

Dr Brahmajee Nallamothu Thank you, Carolyn, for giving us the opportunity to talk about this study. I'm an interventional cardiologist here at the University of Michigan and typically, this isn't an area that interventional cardiologists are really greatly involved with. I became interested because I also, at times, I round in the cardiac intensive care unit, and that's a place where a lot of patients often times end up after they've had an in-hospital cardiac arrest at our institution and what I've noticed over the years, is the variability in care that would be occurring out there, and then also lots of gaps in the literature.

Over a decade or so ago, I started partnering with a close friend and colleague, Paul Chan, from the Mid America Heart Institute and we started to do a series of studies on how in-hospital cardiac arrest care varies across institutions in the United States and we published a number of articles that have been in really high-profile journals over the last 10 years, but the problem has always been that even though we could describe really well what was happening, we had very little understanding of why it was happening or how certain hospitals were seeming to outperform others in this really challenging situation.

We wanted to dive a bit deeper into the questions and reasons behind top performers doing so well and that's what brought us on to doing this study.

Dr Carolyn Lam: Great. You want to tell us a little bit about it? It's really very different from the other CPR studies I've seen. Could you tell us about it and what you've found?

Dr Brahmajee Nallamothu: Sure, so in the broader framework, it's a qualitative study and what I mean by qualitative is, we didn't really collect data either through surveys or through outcome assessments. What we did was, we actually went out and talked to people.

The study though was really focused on what people call a mixed methods approach. We didn't just randomly talk to different hospitals, we actually focused on hospitals that were at the top-performing levels. We also focused on some hospitals that were non-top-performing as well, to get some contrast between the two and when I said we talked, we did this in a very systematic and pretty rigid way.

We always had four interviewers go out to nine hospitals. We split them up, so we had two content experts and then two methodologic experts in qualitative studies, and we started to interview a bunch of people. In fact, we interviewed almost 160 people across these nine hospitals.

We interviewed everyone from CEOs and hospital leadership, down to boots on the ground, including both clinical providers and even non-clinical providers, such as spiritual care, security. We tried to get this comprehensive view of what was actually happening during an in-hospital cardiac arrest across these nine hospitals, and really the results were quite fascinating to us.

For someone, like myself, that's been in this space for ten years, I tell people I learn more talking to these nine hospitals than I have in the last ten years of looking at numbers on a spreadsheet. I really started to understand, for the first time, what was really going on, how these hospitals were dealing with these challenging situations because there's no bigger emergency in a hospital, and Steve, who we're going to hear from, we talk about this, but Steve has a great line about how when an in-hospital cardiac arrest occurs, that patient automatically becomes the sickest person in an institution and yet, we haven't set up systems that really build on how to handle that in the most consistent and positive way.

Dr Carolyn Lam: Oh, my goodness, I just love that line! Now, you have to tell us, so what's the secret? What's the secret of the succeeding hospitals?

Dr Brahmajee Nallamothu: What we found in general was, that resuscitation teams at top-performing hospitals really demonstrated the following features. They had dedicated or designated resuscitation teams. They really included the participation of diverse disciplines as team members during the in-hospital cardiac arrest. There were really clear roles and responsibilities of the team members that were set up right from the front.

There was better communication and leadership, actually, during these events and finally, in the training aspect, one of the unique things we found was, the

top-performing hospitals seem to have a high rate of in-depth mock codes, that they used as strategies for getting their clinicians ready for these events.

Dr Carolyn Lam: As you were speaking I was just thinking through the experiences of in-hospital cardiac arrests that I've encountered, and you're right. These elements, though we don't talk about them much, make a huge difference. Steve, I am so curious about your outlook. I mean you must have attended a kajillion CPRs as chair of the CPR committee. Tell us, what do you think is the take home message for clinicians and hospitals?

Dr Steven Kronick: My field is in emergency medicine and as chair of the CPR committee, I have responsibility of overseeing how we respond to cardiac arrests in our hospitals. I think that many institutions spend a lot of time and effort looking at in-hospital cardiac arrests are managed, and how to improve on it. We're able to use data to help compare ourselves to similar institutions, but beyond the bottom line of either ROSC or survival to discharge, we've most relied on process measures to figure out what we're doing.

We're essentially flying blind, or at least not flying in any sort of formation when we do that. I think that this study validates some of the operational aspects of the arrest response, for those centers who use those and can help other decide where they want to direct their efforts. I think a good example that Brahmajee brought up, is this distinction we found between the use of dedicated teams, designated teams, or not having any organized team, and the impact that has on survival.

The use of these teams can mean significant use of resources but showing that it's associated with better outcomes help provide support for that concept and for those centers who might already use one of those models, it helps them to steer their efforts to improving the delivery or the efficiency of that model.

Dr Carolyn Lam: Yeah, and indeed. Congratulations to both of you, Steve and Brahmajee. I do think that these are novel contemporary data, at least the first that I know of. Sana, you handle the paper and recognize this. Could you tell us a little about what you think are the novel and important aspects?

Dr Sana Al-Khatib: I really have been a fan of this paper from the get go and yes, it doesn't have the quantitative analysis that the statistical modeling, most of us are used to. It is a qualitative study, but I think that gives it strength. It makes it unique. This type of research, it can really only be effectively done through a qualitative study that really has all the important aspects of a good qualitative study, so I do want to congratulate them. Clearly, a lot of work went into this, and I appreciate all their efforts.

In terms of the main findings, some of us might look at this data and say, well it's not surprising that those are the characteristics, or the features, of the top performing hospitals, but I felt like it was great, in terms of how the data were

presented. Encouraging hospitals to adopt this. Giving them almost like a checklist of what they need to be doing to improve the outcomes of their in-hospital cardiac arrests, in terms of ensuring that they have designated resuscitation teams.

The whole idea about diversity of participants in these arrests, and making sure everyone has a clear role and responsibility. The whole idea of making sure that somebody takes leadership and you have clear and very good communication among the different people who are doing this and great training. In fact, these people were doing in-depth mock codes. I think that spells it out very nicely and gives a lot of the hospitals, hopefully, action items that they can implement to improve the outcomes these patients. I love this paper.

Dr Carolyn Lam: Sana, I love the way you put that. Checklist, and you know what I was thinking as Brahmajee and Steve were talking earlier? I was thinking blueprint, almost, of the things that we should have. So Steve, could I ask your thoughts. I mean, are you going to put some of these things into practice in your own committee and how?

Dr Steven Kronick: There are a variety of things we can do. Some of these things are a pretty high-functioning place, but still looking at recommendations that have been laid out and how we help modify those things. Though the example is the roles that people play at an arrest. We can certainly improve on assigning those roles, how people work together as a team, and then also, getting to work more as a team, so that when they are called upon to perform those duties, they can do it in a more coordinated way.

Dr Carolyn Lam: How beautifully put. I'm going to steal a couple of minutes at the end of this podcast. I really have to because it's so rare to have Brahmajee on the line today and he's the Editor-in-Chief of *Circ: Cardiovascular Quality and Outcomes*. Brahmajee, could I ask you to say a few words to our worldwide audience about your journal?

Dr Brahmajee Nallamothu: We are a kind of daughter journal to *Circulation*. We are a bit more unique than the others, in the sense that we aren't disease or subspecialty focused. We deal with, broadly, the issues around outcomes research, health services research, quality of care research, and really health policy. We publish an issue once a month. We have a broad interest in things that are really relevant to the community around outcomes research and health services research.

I will say that I really appreciate this because of the worldwide audience and reach, one of the big issues we've been very interested in is expanding our reach, from the United States to other parts of the world, and in fact, last fall, we had a global health issue, which was well received, and we received papers from across the world.

In fact, every paper in that issue was a non-US-based paper, and it touched on a number of things from issues around healthcare utilization in Asia to demographics and disease registries in Africa, and it was a wonderful experience, so I think it's a journal that we're excited about.

It was first launched by Harlan Krumholz, who has set a high bar and standard for us, and I think that my editorial team, which has been fantastic, has continued with that work. We would love to see papers from your readers and your listeners from across the world and excited about what that journal is going to be doing in the next five years.

Dr Carolyn Lam:

Oh wow! That's so cool! Well listeners, you heard it right here, first time on Circulation on the Run. Thank you so much for joining us today. Don't forget to tune in again next week.

Dr Carolyn Lam:

Welcome to Circulation on the Run, your weekly podcast summary and backstage pass to the journal and its editors. I'm Dr Carolyn Lam, associate editor for the National Heart Center, and Duke National University of Singapore.

How do resuscitation teams at top-performing hospitals for in-hospital cardiac arrest actually succeed? Well, to learn how, you have to keep listening to the podcast, because we will be discussing this right after these summaries.

The first original paper this week tells us that recent developments in RNA amplification strategies may provide a unique opportunity to use small amounts of input RNA for genome wide-sequencing of single cells. Co-first authors, Dr Gladka and Molenaar, corresponding author, Dr van Rooij, and colleagues from Hubrecht Institute in Utrecht, the Netherlands, present a method to obtain high-quality RNA from digested cardiac tissue, from adult mice, for automated single-cell sequencing of both healthy and diseased hearts.

Based on differential gene expression, the authors were also able to identify multiple subpopulations within a certain cell type. Furthermore, applying single-cell sequencing on both the healthy and injured heart indicated the presence of disease-specific cells subpopulations.

For example, they identified cytoskeleton-associated protein 4 as a novel marker for activated fibroblasts that positively correlated with known myofibroblast markers, in both mouse and human cardiac tissue. This paper raises the exciting possibility for new biology discovery using single-cell sequencing that can ultimately lead to the development of novel therapeutic strategies.

Myeloid-derived suppressor cells are a heterogeneous population of cells that expand in cancer, inflammation, and infection, and negatively regulate inflammation. However, their role in heart failure was unclear, at least until today's paper in this week's journal. Co-first authors Dr Zhou, Miao, and Yin, and co-corresponding authors, Dr Wang and Li, from Huazhong University of Science and Technology, measured the myeloid-derived suppressor cells by flow cytometry in heart failure patients and in mice with pressure overload-induced heart failure, using isoproterenol infusion or transverse aortic constriction.

They found that the proportion of myeloid-derived suppressor cells was linked to heart failure severity. Cardiac hypertrophy, dysfunction, and inflammation were exacerbated by depletion of myeloid-derived suppressor cells but alleviated by cell transfer. Monocytic myeloid-derived suppressor cells exerted an antihypertrophic effect on cardiomyocyte nitric oxide, but monocytic and granulocytic myeloid-derived suppressor cells displayed antihypertrophic and anti-inflammatory properties through interleukin 10.

Rapamycin increased accumulation of myeloid-derived suppressor cells by suppressing their differentiation, which in part mediated its cardioprotective

mechanisms. Thus, these findings revealed a cardioprotective role from myeloid-derived suppressor cells in heart failure by their antihypertrophic effects on cardiomyocytes and anti-inflammatory effects through interleukin 10 and nitric oxide. Pharmacological targeting of myeloid-derived suppressor cells by rapamycin constitutes a promising therapeutic strategy for heart failure.

In the FOURIER trial, the PCSK9 inhibitor evolocumab reduced LDL cholesterol and cardiovascular risk in patients with stable atherosclerotic disease. However, was the efficacy of evolocumab modified by baseline inflammatory risk?

While Dr Bohula from the TIMI Study Group and colleagues explored this question by examining the efficacy of evolocumab stratified by baseline high sensitivity CRP. They also assessed the importance of inflammatory and residual cholesterol risk across the range of on-treatment LDL concentrations. They found that the relative benefit of evolocumab for the prevention of adverse cardiovascular events was consistent, irrespective of baseline high sensitivity CRP. However, because patients with higher high sensitivity CRP levels had higher rates of adverse cardiovascular events, they also tended to experience greater absolute benefit with evolocumab.

In an analysis of baseline high sensitivity CRP in achieved LDL cholesterol, the authors found that at first cardiovascular event rates were independently associated with both LDL cholesterol and high sensitive CRP. Event rates were lowest in patients with the lowest hsCRP and LDL cholesterol, supporting the relevance of both inflammatory and residual cholesterol risk.

The next paper provides further evidence that residual inflammatory risk, as measured by on-treatment high sensitivity CRP, remains an important clinical issue in patients on combination statin and PCSK9 inhibitor therapy. Dr Pradhan, from Brigham and Women's Hospital and colleagues, evaluated the residual inflammatory risk among patients participating in the SPIRE-1 and -2 cardiovascular outcome trials, who are receiving both statin therapy and the PCSK9 inhibitor bococizumab, according to on-treatment levels of high sensitivity CRP and LDL cholesterol measured 14 weeks after drug initiation.

They found that among high-risk stable outpatients treated with moderate or high-intensity statins and PCSK9 inhibition, roughly one in two had residual inflammatory risk defined by an on-treatment high sensitivity CRP level of 2 or more mg per liters, and roughly one in three had values above 3 mg per liter.

PCSK9 inhibition was associated with a 60% mean reduction in LDL cholesterol but little change in high sensitivity CRP. Levels of high sensitivity CRP above 3 mg per liter were associated with a 60% greater risk of future cardiovascular events, corresponding to a 3.6% annual event rate, even after accounting for on-treatment LDL cholesterol.

Thus, PCSK9 inhibition, added to statin therapy in stable outpatients, does not lower high sensitivity CRP. Persistent elevations of CRP is associated with future cardiovascular risk in these patients, even after low levels of LDL cholesterol are achieved. If corroborated, these data suggests that inflammation modulation may yet have a role in the primary and secondary prevention of cardiovascular disease when LDL cholesterol is already controlled. Well, that wraps it up for our summaries. Now, for our future discussion.

In-hospital cardiac arrests are common worldwide and they're so important because they represent opportunities for us to improve survival. Now, yet, overall rates of hospital survival after in-hospital cardiac arrests remain poor and there is substantial variation across facilities. This may be surprising because we all seem to follow or should follow the same ACLS algorithms across the world and yet, there are different outcomes.

How do resuscitation teams, at top performing hospitals, for in-hospital cardiac arrest, how do they succeed? Pleased to be discussing this with a real star team in today's podcast. We have first and corresponding author of our feature paper, Dr Brahmajee Nallamothu. We also have Dr Steven Kronick, who is the chair of the CPR committee and both are from University of Michigan Medical School. We also have Dr Sana Al-Khatib, who is a senior associate editor of *Circ*, from Duke University. So, welcome everyone! Let's go straight into it. Maybe starting with you Brahmajee, could you tell us what inspired you to perform this study?

Dr Brahmajee Nallamothu Thank you, Carolyn, for giving us the opportunity to talk about this study. I'm an interventional cardiologist here at the University of Michigan and typically, this isn't an area that interventional cardiologists are really greatly involved with. I became interested because I also, at times, I round in the cardiac intensive care unit, and that's a place where a lot of patients often times end up after they've had an in-hospital cardiac arrest at our institution and what I've noticed over the years, is the variability in care that would be occurring out there, and then also lots of gaps in the literature.

Over a decade or so ago, I started partnering with a close friend and colleague, Paul Chan, from the Mid America Heart Institute and we started to do a series of studies on how in-hospital cardiac arrest care varies across institutions in the United States and we published a number of articles that have been in really high-profile journals over the last 10 years, but the problem has always been that even though we could describe really well what was happening, we had very little understanding of why it was happening or how certain hospitals were seeming to outperform others in this really challenging situation.

We wanted to dive a bit deeper into the questions and reasons behind top performers doing so well and that's what brought us on to doing this study.

Dr Carolyn Lam: Great. You want to tell us a little bit about it? It's really very different from the other CPR studies I've seen. Could you tell us about it and what you've found?

Dr Brahmajee Nallamothe: Sure, so in the broader framework, it's a qualitative study and what I mean by qualitative is, we didn't really collect data either through surveys or through outcome assessments. What we did was, we actually went out and talked to people.

The study though was really focused on what people call a mixed methods approach. We didn't just randomly talk to different hospitals, we actually focused on hospitals that were at the top-performing levels. We also focused on some hospitals that were non-top-performing as well, to get some contrast between the two and when I said we talked, we did this in a very systematic and pretty rigid way.

We always had four interviewers go out to nine hospitals. We split them up, so we had two content experts and then two methodologic experts in qualitative studies, and we started to interview a bunch of people. In fact, we interviewed almost 160 people across these nine hospitals.

We interviewed everyone from CEOs and hospital leadership, down to boots on the ground, including both clinical providers and even non-clinical providers, such as spiritual care, security. We tried to get this comprehensive view of what was actually happening during an in-hospital cardiac arrest across these nine hospitals, and really the results were quite fascinating to us.

For someone, like myself, that's been in this space for ten years, I tell people I learn more talking to these nine hospitals than I have in the last ten years of looking at numbers on a spreadsheet. I really started to understand, for the first time, what was really going on, how these hospitals were dealing with these challenging situations because there's no bigger emergency in a hospital, and Steve, who we're going to hear from, we talk about this, but Steve has a great line about how when an in-hospital cardiac arrest occurs, that patient automatically becomes the sickest person in an institution and yet, we haven't set up systems that really build on how to handle that in the most consistent and positive way.

Dr Carolyn Lam: Oh, my goodness, I just love that line! Now, you have to tell us, so what's the secret? What's the secret of the succeeding hospitals?

Dr Brahmajee Nallamothe: What we found in general was, that resuscitation teams at top-performing hospitals really demonstrated the following features. They had dedicated or designated resuscitation teams. They really included the participation of diverse disciplines as team members during the in-hospital cardiac arrest. There were really clear roles and responsibilities of the team members that were set up right from the front.

There was better communication and leadership, actually, during these events and finally, in the training aspect, one of the unique things we found was, the

top-performing hospitals seem to have a high rate of in-depth mock codes, that they used as strategies for getting their clinicians ready for these events.

Dr Carolyn Lam: As you were speaking I was just thinking through the experiences of in-hospital cardiac arrests that I've encountered, and you're right. These elements, though we don't talk about them much, make a huge difference. Steve, I am so curious about your outlook. I mean you must have attended a kajillion CPRs as chair of the CPR committee. Tell us, what do you think is the take home message for clinicians and hospitals?

Dr Steven Kronick: My field is in emergency medicine and as chair of the CPR committee, I have responsibility of overseeing how we respond to cardiac arrests in our hospitals. I think that many institutions spend a lot of time and effort looking at in-hospital cardiac arrests are managed, and how to improve on it. We're able to use data to help compare ourselves to similar institutions, but beyond the bottom line of either ROSC or survival to discharge, we've most relied on process measures to figure out what we're doing.

We're essentially flying blind, or at least not flying in any sort of formation when we do that. I think that this study validates some of the operational aspects of the arrest response, for those centers who use those and can help other decide where they want to direct their efforts. I think a good example that Brahmajee brought up, is this distinction we found between the use of dedicated teams, designated teams, or not having any organized team, and the impact that has on survival.

The use of these teams can mean significant use of resources but showing that it's associated with better outcomes help provide support for that concept and for those centers who might already use one of those models, it helps them to steer their efforts to improving the delivery or the efficiency of that model.

Dr Carolyn Lam: Yeah, and indeed. Congratulations to both of you, Steve and Brahmajee. I do think that these are novel contemporary data, at least the first that I know of. Sana, you handle the paper and recognize this. Could you tell us a little about what you think are the novel and important aspects?

Dr Sana Al-Khatib: I really have been a fan of this paper from the get go and yes, it doesn't have the quantitative analysis that the statistical modeling, most of us are used to. It is a qualitative study, but I think that gives it strength. It makes it unique. This type of research, it can really only be effectively done through a qualitative study that really has all the important aspects of a good qualitative study, so I do want to congratulate them. Clearly, a lot of work went into this, and I appreciate all their efforts.

In terms of the main findings, some of us might look at this data and say, well it's not surprising that those are the characteristics, or the features, of the top performing hospitals, but I felt like it was great, in terms of how the data were

presented. Encouraging hospitals to adopt this. Giving them almost like a checklist of what they need to be doing to improve the outcomes of their in-hospital cardiac arrests, in terms of ensuring that they have designated resuscitation teams.

The whole idea about diversity of participants in these arrests, and making sure everyone has a clear role and responsibility. The whole idea of making sure that somebody takes leadership and you have clear and very good communication among the different people who are doing this and great training. In fact, these people were doing in-depth mock codes. I think that spells it out very nicely and gives a lot of the hospitals, hopefully, action items that they can implement to improve the outcomes these patients. I love this paper.

Dr Carolyn Lam: Sana, I love the way you put that. Checklist, and you know what I was thinking as Brahmajee and Steve were talking earlier? I was thinking blueprint, almost, of the things that we should have. So Steve, could I ask your thoughts. I mean, are you going to put some of these things into practice in your own committee and how?

Dr Steven Kronick: There are a variety of things we can do. Some of these things are a pretty high-functioning place, but still looking at recommendations that have been laid out and how we help modify those things. Though the example is the roles that people play at an arrest. We can certainly improve on assigning those roles, how people work together as a team, and then also, getting to work more as a team, so that when they are called upon to perform those duties, they can do it in a more coordinated way.

Dr Carolyn Lam: How beautifully put. I'm going to steal a couple of minutes at the end of this podcast. I really have to because it's so rare to have Brahmajee on the line today and he's the Editor-in-Chief of *Circ: Cardiovascular Quality and Outcomes*. Brahmajee, could I ask you to say a few words to our worldwide audience about your journal?

Dr Brahmajee Nallamothu: We are a kind of daughter journal to *Circulation*. We are a bit more unique than the others, in the sense that we aren't disease or subspecialty focused. We deal with, broadly, the issues around outcomes research, health services research, quality of care research, and really health policy. We publish an issue once a month. We have a broad interest in things that are really relevant to the community around outcomes research and health services research.

I will say that I really appreciate this because of the worldwide audience and reach, one of the big issues we've been very interested in is expanding our reach, from the United States to other parts of the world, and in fact, last fall, we had a global health issue, which was well received, and we received papers from across the world.

In fact, every paper in that issue was a non-US-based paper, and it touched on a number of things from issues around healthcare utilization in Asia to demographics and disease registries in Africa, and it was a wonderful experience, so I think it's a journal that we're excited about.

It was first launched by Harlan Krumholz, who has set a high bar and standard for us, and I think that my editorial team, which has been fantastic, has continued with that work. We would love to see papers from your readers and your listeners from across the world and excited about what that journal is going to be doing in the next five years.

Dr Carolyn Lam:

Oh wow! That's so cool! Well listeners, you heard it right here, first time on Circulation on the Run. Thank you so much for joining us today. Don't forget to tune in again next week.