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STATE-OF-THE-ART PAPER

Teamwork and Leadership in Cardiopulmonary Resuscitation

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Despite substantial efforts to make cardiopulmonary resuscitation (CPR) algorithms known to healthcare workers, the outcome of CPR has remained poor during the past decades. Resuscitation teams often deviate from algorithms of CPR. Emerging evidence suggests that in addition to technical skills of individual rescuers, human factors such as teamwork and leadership affect adherence to algorithms and hence the outcome of CPR. This review describes the state of the science linking team interactions to the performance of CPR. Because logistical barriers make controlled measurement of team interaction in the earliest moments of real-life resuscitations challenging, our review focuses mainly on high-fidelity human simulator studies. This technique allows in-depth investigation of complex human interactions using precise and reproducible methods. It also removes variability in the clinical parameters of resuscitation, thus letting researchers study human factors and team interactions without confounding by clinical variability from resuscitation to resuscitation. Research has shown that a prolonged process of team building and poor leadership behavior are associated with significant shortcomings in CPR. Teamwork and leadership training have been shown to improve subsequent team performance during resuscitation and have recently been included in guidelines for advanced life support courses. We propose that further studies on the effects of team interactions on performance of complex medical emergency interventions such as resuscitation are needed. Future efforts to better understand the influence of team factors (e.g., team member status, team hierarchy, handling of human errors), individual factors (e.g., sex differences, perceived stress), and external factors (e.g., equipment, algorithms, institutional characteristics) on team performance in resuscitation situations are critical to improve CPR performance and medical outcomes of patients. (J Am Coll Cardiol 2011;57:2381–8) © 2011 by the American College of Cardiology Foundation

Early initiation of cardiopulmonary resuscitation (CPR) and defibrillation are critical for reducing mortality and morbidity in patients after cardiopulmonary arrest (1). For every minute that CPR is delayed, the likelihood of survival decreases by as much as 10%. Thus, guidelines recommend routine training in CPR for healthcare providers to improve performance and patient outcomes (1–3). However, despite substantial efforts to make the CPR algorithms known to health-care workers, the outcome of CPR has remained poor. Observational studies on cardiac arrest revealed significant shortcomings in the performance of rescuers, which may partly explain the poor outcome of CPR (4–6). For example, CPR is frequently interrupted and the chest compression is performed too slowly, resulting in suboptimal hands-on times and low CPR quality (4–6).

Although resuscitation guidelines provide a logical, sequential algorithmic approach, they have mainly emphasized technical tasks performed by individual rescuers and have not addressed issues of adapting to the complex nature of most actual resuscitations. Part of this complexity relates to the fact that in a healthcare environment resuscitations are usually performed by teams of responders, not by isolated rescuers.

Individual characteristics of resuscitation team members such as technical skills, previous experience, communication, and leadership skills influence the course of action during a resuscitation (2,3,7,8). In addition to individual factors, social aspects and the collective interaction patterns that emerge within a team during a resuscitation event can promote or impede coordinated execution of CPR guidelines. Indeed, recent clinical observations demonstrated that suboptimal adherence to CPR guidelines and deviations

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Abbreviation and Acronym

CPR = cardiopulmonary resuscitation

from treatment algorithms are associated with lower survival rates (4–6). Controlled, systematic investigation of individual and team factors in the early moments of real-life cardiac arrest situations were rarely feasible in past years for logistical and safety reasons. Although recent advances in defibrillator technology allow feedback of individual elements of performance (e.g., depth and rate of chest compressions [4]), measurement of group/team factors in the earliest phases of real-life resuscitations still remains challenging. High-fidelity simulation studies offer an important alternative research method for this critical time period.

Recent simulator-based studies found qualitative and quantitative shortcomings in CPR, similar to those recorded in real cardiac arrests (4–6,9). Moreover, simulator-based studies have expanded the understanding of team processes during CPR. These studies stressed the importance of teamwork, leadership behavior, communication, and team hierarchy in initial performance of resuscitation teams (7,9–12). In addition, teamwork and leadership training have been shown to improve subsequent team performance during resuscitation; the 2010 American Heart Association Guidelines now recommend inclusion of these areas in Advanced Life Support and Pediatric Advanced Life Support training (2,3).

Herein, we provide a targeted review that focuses on simulator studies and summarizes the current state of knowledge about how team interaction affects the quality of early phases of resuscitation in cardiac arrest. Specifically, we illustrate how detailed, real-time analysis of the complex interplay between team members, their communication, and the role of leadership and team hierarchy can shed light on fundamental aspects of group interaction that materially affect the performance of resuscitative teams. We also highlight opportunities to address critical gaps in these areas.

Simulation for Training and Research

High-fidelity medical simulation has become increasingly important for education in emergency situations (2,3). It allows not only teaching of theoretical knowledge and empirical algorithms, but can improve the hands-on skills of rescuers without harming patients or traumatizing inexperienced rescuers (13–15). Further, it allows practice of situations that occur infrequently, but where rapid application of necessary skills and knowledge is crucial, such as in cardiac arrest. Video-assisted debriefing allows additional training benefit by providing immediate, objective post-performance review rather than relying on recollection of events (16).

Simulation also provides an important research venue that allows rigorous assessment of complex interactions during emergency situations in a realistic yet safe environment (17). Many research groups have created highly realistic settings using life-sized mannequins placed in a standard intensive care unit room where the physiology of the computer-based patient, such as vital signs and continuous electrocardiogram tracings, can be manipulated. The mannequin can also talk with healthcare professionals, creating a personal relationship between rescuer and "patient" (15). An important advantage of simulation methodology is that, unlike in actual emergency situations, a controlled, standardized experimental situation can be created, to which multiple interventions can be applied and directly compared. This provides the experimental opportunity to disentangle patient factors from team factors, thus letting research teams isolate these team factors for careful study. Video recording facilitates detailed analysis of team interactions. Thus, simulator studies have become an important research instrument and can complement studies from real-life settings. This is especially true for CPR as logistic, medical, and ethical constraints are difficult to overcome in clinical studies.

Teambuilding: Importance of First Responders

When cardiac arrest occurs, the immediate and skilled action of first responders is critical (2,3,18). Once the resuscitation team arrives, a coordinated rapid and efficient exchange of information, along with continuous hands-on CPR measures, is essential. There are scarce data on this initial phase of real-life resuscitation, and the available research is often based on historical recollection of the participants, which might be biased. Because simulation studies allow observation and data collection from the onset of a critical situation, they are particularly conducive to studying early events (11).

In in-hospital arrests, the first responder to a crisis is often a nurse. Studies have demonstrated that nurses are hesitant to use a defibrillator in the absence of a physician, despite adequate technical training on its use and indications (19). A simulator study investigating adherence of first responders to CPR algorithms found that nurses as first responders rapidly diagnosed the condition of the patient and called for help (20); however, significant delays in the initiation of basic life support and particularly in the use of the defibrillator were observed, indicating that nurses as first responders may fail to translate their knowledge and skills into timely and effective activity (21). Subsequently, the availability of a physician increased the number of defibrillations administered. The role of team member status and team hierarchy may provide a useful explanatory framework for this empirical observation.

Sociological theories can help to explain the influence of hierarchy on team behavior. For example, expectation states theory is an important sociological conceptual framework that can help explain many observed findings of empirical studies of resuscitation team performance. Expectation states theory focuses on how members of groups decide how competent other members of the group are in performing a task. These decisions—about how competent other team members are to perform the task at hand—are called performance expectations. Performance expectations reproducibly lead to interaction hierarchies: if the team perceives that one member is especially qualified to do the task at hand, other team members will defer to that member and may volunteer fewer ideas and information in the process of completing the task. A key insight from expectation states theory research is that human beings routinely use status characteristics to form these performance expectations: we innately use such factors such as occupation, sex, and race to decide how competent others are—even though these factors may be unrelated to actual competence in a particular task. Research in sociology has overwhelmingly shown that this is a fundamental characteristic of group interactions (22–24).

This is important to resuscitation because these hierarchies can create barriers to information exchange and action. In the previous example, if nurses perceive themselves as lower status team members, they may be less likely to initiate action, despite being highly competent, because the legitimacy of their action in the situation may be questioned (25). Furthermore, these hierarchies can lead to formal or informal "rules" within an institution that specify the sequence of decision making and which team members may initiate action; the corollary being that the costs of initiating action may be quite high for team members who are considered lower status (26). This points out an important area for future research. In other fields, previous studies have shown that a number of interventions can reduce hierarchy. In one study, investigators increased the perceived (but not actual) complexity of a task to change performance expectations of group members; this improved the group's task performance (23). Managerial interventions in which the institution actively changed performance expectations of otherwise lower status individuals have also successfully changed group behavior (24). Future studies should translate these types of interventions into the resuscitative setting.

The interaction mechanisms that form hierarchies in teams are complex and the factors that facilitate or constrain information exchange, decision making, and action are influenced not only by the group's composition, but also by conditions such as previous relationships and interactions. Knowledge that team members have about one another, beyond generalized stereotypes associated with sex, race, age, or occupation, may also influence team interactions. In emergency situations, it is critical that all team members contribute during the very early stages of the crisis. If only high status members provide definitive information (such as diagnoses), the ensuing hierarchy may prevent the open flow of information. In line with this, empirical resuscitation studies have shown that providers who openly shared information by thinking aloud, performing periodic reviews of data, and voicing specific findings were found to perform better (21). These actions may modify performance expectations by including the entire group, not just the resuscitation leader, in the review and decision-making process, thus improving information flow across the group interaction hierarchy. This might explain why these findings have been shown to apply not only to nurses, but also when physicians were first responders (9).

Influence of Team Building on CPR Performance

The process of team building, occurring in the early and most vulnerable phase of resuscitation, is of particular importance. This early time point is difficult to capture in real cardiac arrests and thus simulator-based studies provide important insights. One simulator study assessed the effects of ad hoc team building compared with pre-formed teams on the adherence to guidelines-based CPR algorithms in groups of general practitioners and hospital physicians in a randomized, controlled trial (9). Participants were assigned to pre-formed teams, in which 3 physicians were present during the patient interview and when the cardiac arrest started or to ad hoc teams, in which the 1 physician who did the patient interview was the first responder, and the other 2 joined. The ad hoc teams displayed important shortcomings in their performance compared with pre-formed teams: they demonstrated significantly less uninterrupted CPR time and their first defibrillation and administration of epinephrine were also significantly delayed. In a real resuscitation, these factors are likely to translate into worse patient outcomes (1).

The process by which a team forms materially influences the quality of its performance. Several lines of research in other fields have consistently demonstrated higher performance in established teams (27), concluding that the negotiation of group member roles, including leadership, are important factors. In the study noted previously (9), the ad hoc teams had fewer leadership utterances than did pre-formed teams, despite the short period of time that pre-formed teams had to interact before the crisis. One explanation for this finding may be that members of the pre-formed teams had the opportunity to access the same information about the patient as opposed to relying on 1 physician to relay information of his or her choosing. This highlights the importance of rules about resuscitations and other crisis events that require immediate and open sharing of specific findings and refraining from early diagnoses by individual team members (28).

Association of Leadership Behavior and Performance

Lack of leadership and poor teamwork result in poor clinical outcomes for groups performing CPR and other emergency tasks (9,29–31). Leadership in task-oriented situations can be defined as the process that requires more specific coordination activities such as distributing tasks, assigning work, and enforcing rules and procedures (32). The importance of leadership and communication has been elucidated in pediatric emergencies in which communication breakdowns and deficient leadership are estimated to contribute to as many as 70% of perinatal deaths and injuries (12). For adult patients, a study investigated the relationship between leadership behavior, team behavior, and task performance using video-recorded real-life resuscitation events (33). Clearer leadership was associated with more efficient cooperation in the team and also with better task performance. Notably, leaders who participated hands-on in the emergency, as opposed to adopting a coordinating role, were less likely to be efficient leaders, and team performance tended to suffer.

The importance of leadership during the early phase of resuscitation, such as the onset of a cardiac arrest, was also found in a more recent simulator study (11). Despite sufficient theoretical knowledge of resuscitation guidelines, only a minority of the physician teams were successful in their resuscitative attempt. Yet, successful teams showed significantly more leadership behavior and more explicit task distribution. Also, there was a trend toward better information transfer and fewer conflicts in successful teams. Similar results have also been found for nurses performing CPR in a simulator (34). Well-trained first-responding nurses were successful leaders in advanced life support teams (34).

A previous study found a positive association between leadership of first-responding nurses and resuscitation performance in the early phase of CPR until a physician joined the group (21). It was assumed in the study that leadership may be dynamic and that a change in group composition may evoke a change in leadership. In all groups, nurses handed over leadership to the incoming residents as soon as they arrived. However, not all residents demonstrated rapid acceptance of the leadership role. These findings confirm previous research on shortcomings of leadership skills of junior doctors (35). In addition, this confirms the importance of early stages of group formation, a finding supported almost universally across group process theories (27). However, given the status differences between experienced nurses and young physicians in training, hesitations and insecurities about adopting the leadership role are not entirely surprising. Ultimately, the study demonstrated that more leadership utterances from the resident were related to better team performance, however only immediately after their entry into the group. Thus, in addition to establishing a functional early group structure, a group's ability to adapt the leadership structure to changes in group composition is crucial.

A corollary to this finding may be that incoming professionals of higher status should not, by default, take over leadership of the resuscitation (assuming that leadership of the resuscitation is already established). The same study found that senior physicians who entered the room later in the crisis supported group performance best by asking questions that brought potential problems to the attention of the leading junior doctors rather than by making directive statements. When high status team members pose questions rather than directives or commands, such as proposing a definitive diagnosis, interactions may become more equally distributed and the status hierarchy of the group reduced, which creates more open interaction, information exchange, and collaboration.

Of note, leadership in the context of a cardiac resuscitation event is often considered a behavior adopted by 1 member of the team who assumes responsibility for managing an arrest. However, leadership can also be distributed across team members or be done by different group members at different times, depending on the situation and the group composition. Leadership thus has to be adapted to the situation and to situational changes (9,32,36).

Training and Teaching of Leadership

Given the strong association of leadership and team performance in observational studies, the question arises whether teaching leadership improves team performance during resuscitation.

In pediatrics, programs for teaching team work during CPR have improved the quality of neonatal resuscitation (12,37), and specific leadership training showed positive results in adult resuscitation training (8). Recently, a randomized, controlled trial in a high-fidelity simulated cardiac arrest scenario assessed whether teaching leadership translates into more leadership utterances and thereby improves CPR performance even long after the training (10). Participating medical students received a general debriefing on CPR algorithms in a baseline simulation. Thereafter, the students were randomly assigned to receive either 10 min of instruction on leadership skills or on technical skills such as correct position of arms and shoulders during CPR. The former focused on the importance of leadership, providing a set of rules that encouraged immediate interaction and instructions that illustrated the expected interactions (Table 1). A 4-month follow-up demonstrated that teams composed of students who received the leadership instructions made more leadership utterances and showed significantly better CPR-relevant outcomes than teams in the technical debriefing condition. They initiated CPR earlier and had more hands-on CPR time within the first 180 s of interaction. Additional analyses revealed a strong and significant correlation between leadership utterances and hands-on CPR time (correlation coefficient: 0.54, $p < 0.001$); in addition, more leadership utterances were associated with earlier initiation of CPR (correlation coefficient: -0.37, $p = 0.003$) in all groups.

Human Errors and Adverse Events

In recent years there has been increasing awareness that team interactions and communication may play a crucial role in the occurrence of medical errors (38,39). Studies have investigated the importance of interpersonal relationships with team performance and decision-making processes within surgical teams (40). Factors such as workload

Table 1 Principles of Effective Leadership

A. Effective leadership principles for healthcare professionals.
I. Consider existing leadership. Is it adequate and adapted to the situation?
II. Make orienting remarks. Invite contributions.
III. Ask questions that highlight perceived problems.
IV. As a leader, avoid performing tasks and procedures yourself; instead assign tasks.
V. Promote exchange of information.
B. Effective leadership instructions for teaching leadership (adapted from Hunziker et al. [10]).
I. Assuming leadership is important: explaining the importance of leadership in a resuscitation situation.
II. Announce to your colleagues what you do and tell your colleagues what they should do! Assign and distribute tasks according the algorithm (e.g., "I am in charge of ventilation and you are in charge of chest compression.")
III. Decide what to do; be affirmative (e.g., "We defibrillate now." [instead of "Should we defibrillate?"]).
IV. Monitor adherence to instructions and to algorithm! Always ensure adherence to your instructions and to the algorithm. (Make sure that the person you advise really does what you told him or her to do, and check whether the team's performance adheres to the algorithm; refer to the algorithm.)
V. Make short and clear statements!

and ineffective communication were important causes of adverse events in a pediatric intensive care unit (41). Again, simulation has been used to understand in more detail how errors occur in critical situations (42,43). For example, in a pediatric resuscitation study, a large proportion of medication orders did not specify the correct dose or the requested dose was incorrect (43). Most errors were not caught before the drug was administered, which might directly influence medical outcomes in real-life settings. Another study examined how information was transmitted from rescuers to medical professionals who joined an ongoing simulated cardiac arrest situation (44). Eighteen percent of the information transmitted to incoming professionals was inaccurate. Information transmitted was more likely to be inaccurate if it was quantitative in nature and could change over time, such as the number and strength of defibrillations and number and doses of medication.

Findings from psychological research may help to understand information transmission errors in this situation. Correctly remembering even short-term information in emergency situations may be particularly difficult if there are many parallel actions taking place, a lot of competing information being transferred, or multiple distractions in the environment (45,46). If group members are concentrating on different parts of the task, they may not have an integrated view of the overall task. Many resuscitation teams adopt a countermeasure to this, assigning 1 member to record interventions and events (28). If this is not the case, specific communication habits (explicitly commenting on the ongoing task and progress (e.g., "this is the first defibrillation at 120 J") may help team members to remember important details (47,48). Table 2 summarizes principles for effective team work to avoid medical errors.

Another study investigated the influence of ambiguous information on team function and clinical reasoning (49). Resuscitation teams were confronted with a patient undergoing penicillin-induced anaphylactic shock; however, the patient also reported pain due to a failed attempt to insert a central venous catheter, which could indicate a tension pneumothorax. This incorrect diagnosis, however, could have been easily ruled out because of symmetrical breath sounds of the mannequin. Only 30% of the teams correctly diagnosed anaphylactic shock. Notably, in half of the teams, at least 1 physician reported hearing asymmetrical or absence of breath sounds on one side, even though the breath sounds were actually symmetrical. In none of the groups in which members erroneously observed breathing differences were they corrected by a colleague, even if several physicians auscultated the patient, exemplifying a confirmation bias. Research on individual and group decision making helps to explain these results and provide guidance to overcome such problems. Particularly in high time-pressure situations, individuals and groups may rely on automatic and implicit decision making (50). However, more explicit communication has been related to higher decision-making performance in ad hoc medical teams (51). This affects the group

Table 2 Principles for Effective Teamwork to Avoid Medical Errors

I. Voice specific findings; avoid diagnosing The team member assuming the leadership role should encourage information sharing and ask questions as opposed to suggesting diagnoses, especially early on during the crisis.
II. Think out loud—"talk to the room" All members of the team are encouraged to verbalize ongoing observations as the crisis unfolds. Effective leadership can facilitate this process by querying the team for observations.
III. Perform periodic reviews of quantitative information (drug dose, time, and response) Noted changes should be verbalized to the team, highlighting the change in the status of the information. Effective leadership can facilitate this process by querying the team for observations.
IV. Double-check crucial data All members of the team are encouraged to double-check crucial data and tasks, and verbalize any doubts.

in 2 important ways. First, it ensures that the entire team has a common level of knowledge via full information, which is critical to the decision-making process. Second, to the extent that teams are encouraged to engage in explicit communication and reasoning and to avoid early diagnoses reinforces a team structure that promotes exchange of critical information (48).

The anaphylaxis versus pneumothorax study (49) also provided empirical evidence supporting these theoretical constructs. In this study, the way in which participants communicated determined the probability of correctly diagnosing the case. Groups who communicated explicitly and related different pieces of information to one another (as opposed to simply stating a diagnosis) were significantly more likely to make the correct diagnosis. The same was true for groups whose members engaged in thinking out loud ("talking to the room") (Table 2).

Previous sociological research also sheds light on these findings. Some types of statements carry more risk to the individual within hierarchical groups (52). Statements of opinion, such as diagnoses, are high risk and more likely to be made by higher status members of a group. This may constrain contributions from other team members. On the other hand, statements of fact, such as unambiguous observations of vital signs, are low-risk statements and more likely made by lower status group members. These differential social risks mean that information critical to patient safety may be known by lower status team members, but not conveyed to the team.

Implications for Other Emergency Situations

Although this review focuses mainly on team interaction in CPR situations, similar studies have also been conducted in other medical emergency situations such as during endotracheal intubation or in patient with trauma and shock. In fact, simulation was first introduced in medicine to evaluate human performance during anesthesia crisis situations (53). In 1987, Gaba and his team studied decision-making by anesthesiologists, using a patient simulator (53). Analysis of videotapes from these early experiments pointed at several gaps with regard to decision making and crisis management that were not systematically addressed during training. Similarly, nontechnical skills such as communication, dynamic decision making, situational awareness, and teamwork in emergency medicine has gained importance during time-critical and complex treatment of severely injured patients in multidisciplinary and interprofessional trauma teams. Studies suggested that structured trauma resuscitation team training augmented by simulation improved team performance (54).

Limitations of Simulator Studies

Simulator studies provide many opportunities and have advanced the field of resuscitation research, particularly in terms of investigating leadership, communication, and team interaction. However, although behavior patterns in the simulator are strikingly similar to those in real-life situations (17), transfer of knowledge from the simulator to the real-life clinical setting has not been clearly demonstrated (55).

The ability to reproduce standardized conditions in simulation is both a strength and a weakness. Reproducibility enables internal reliability in randomized intervention studies; however, real-life clinical conditions will obviously vary and will not perfectly reflect the content or performance of a simulated case. Although several studies have demonstrated strong perceived stress and emotional and motivational involvement of participants during the simulation, the actual stress experienced during a real emergency situation may still be more pronounced (9,56). Finally, a commonly discussed concern about simulation research is that the use of video recording will artificially improve performance because participants are aware that they are being monitored. However, there is evidence to suggest that this changes all participants' behavior in similar ways, and many participants quickly forget that they are being recorded (57,58).

As new techniques become available to record resuscitation performance in real-life settings, research based on simulator studies and actual resuscitations may be better integrated in the future. For example, newer defibrillators can accurately assess the timely occurrence of defibrillation, CPR interruption times, and chest compression rate and depth not only in real-life settings, but also in simulated CPR situations (4,59). Such observational real-world data can be used to both complement and guide simulator-based research.

Conclusions

High-fidelity simulation as a research tool has advanced the field of CPR research and has particular advantages in this arena. The ability to video record team performance in well-controlled study settings allows rigorous assessment of complex interactions during emergency situations in a realistic environment, without putting patients at risk. Simulator studies also provide the opportunity to study the earliest phases of resuscitation, which are among the most critical stage and challenging to investigate in the real cardiac arrests. A particular strength of simulator studies is the identification of issues that are not immediately obvious for healthcare teams involved in the management of the emergency. Issues such as delay in the initiation of life-saving measures and erroneous communication may have a profound impact on patients' outcome, but may not be easy to study in the field. Previous studies have established the crucial role of teamwork, effective communication, and leadership behavior in managing emergency situations. This has led to the recent recommendation (Class I, Level of Evidence: B) to include teamwork and leadership training in advanced life support and pediatric advanced life support training by the 2010 American Heart Association guidelines (2,3). Further research is therefore needed to delineate the effects of team interactions on performance of complex medical crisis management. Thereby, through further investigation, the influence of individual factors (e.g., sex differences, perceived stress), team factors (e.g., team member status, team hierarchy, handling of human errors), and external factors (e.g., equipment, algorithms, institutional characteristics) on team performance in resuscitation situations are critical future areas for investigation.

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