The critical nature of debriefing in high fidelity simulation-based training for improving team communication in emergency resuscitation

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Abstract

Emergency resuscitation in Intensive Care Units (ICUs) requires effective team communication to orchestrate the joint performance of several individuals. While team simulation training has proven an effective means to improve communication skills in high-risk environments, the influence of debriefing content on simulation-based learning is less clear. In the present study, ten ICU teams completed three consecutive cardiac resuscitation scenarios, followed by a three-month follow-up. Control teams received a debriefing based on resuscitation technical skills after each of the first three scenarios while the experimental teams’ debriefing focused on team communication. Results showed that while information sharing improved for all teams, communication quality improved only for experimental teams, and these training benefits dissipated after three months. The study helps develop a methodology for assessing team communication and highlights the importance of frequent team simulation-based training and debriefing in emergency medicine that includes both technical and non-technical skills.

KEYWORDS: simulation; teamwork; team communication; training; emergency medicine; debriefing; resuscitation.
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INTRODUCTION

The importance of non-technical skills such as leadership, communication, and teamwork are increasingly emphasized as part of an effective response to clinical emergencies (Sarcevic, Marsic, & Burd, 2012; St.Pierre, Hofinger, Buerschaper, & Simon, 2011). Team effectiveness can be explained by the degree to which members engage in processes for sharing information (e.g., questioning, cross-checking, setting up coordination and priorities, and contingency planning; Bowers, Jentsch, Salas, & Braun, 1998; Morey et al., 2002). Effective communication can mitigate interruptions and act as a buffer against errors by expediting a common awareness of intentions and actions of others, which in turn enables collaboration of coordinated actions (Orasanu, 1994). Ineffective communication in cross-professional teams is often underpinned by the inherent differences across domains and the ways in which they collaborate (Gillespie, Chaboyer, Longbottom, & Wallis, 2010). Given the critical role that team communication plays in a healthcare setting, effective information sharing is clearly an important skill to be developed. Simulation exercises offer a useful tool for training the specific hands-on proficiency required in emergency medicine, but can also provide an environment for nurturing positive teamwork skills. While simulation-based training is emerging as a promising avenue, there is often variation in the content of such training particularly with regard to the development of non-technical skills, i.e. a set of interpersonal and cognitive attributes that complement clinical skills (i.e., technical skills) and contribute to safe and efficient task performance (Helmreich, Merritt, & Wilhelm, 1999). The aim of the current work is twofold: 1) to examine the role of debriefing in high fidelity simulation-based training for improving team communication in emergency resuscitation 2) to develop a methodology that can be used for the assessment of team communication in simulated environments.
The importance of communication to patient care

Communication is essential in the time-pressured and dynamic setting of emergency medicine, and is a significant aspect of teamwork that cannot be overlooked (e.g., Cooke, Gorman, & Kiekel, 2008). Effective and coordinated decision making requires gathering, synthesizing, and cross-checking all information available to the team. A lack of communication may therefore result in inaccurate or incomplete knowledge, with team members instead ‘filling in the gaps’ with individual biases, assumptions, or heuristics (Croskerry, 2005; McDonald, 1996). In a medical setting, team members all have different roles (e.g., surgeon, anesthetist, nurse) and will likely all possess slightly different knowledge about a patient depending on the nature and the timing of their involvement (e.g., conducting a physical examination, checking medical history, monitoring vital signs). Transfer of information can break down in any of a number of ways: due to message content (the sender or recipient encodes or decodes information inaccurately), the audience (key individuals are excluded), or timing (information is given or received too late; Lingard et al., 2004). Effective communication allows teams to build a shared mental model which in turn is associated with better team performance and the ability to cope with difficult, novel, and evolving situations (Marks, Zaccaro, & Mathieu, 2000; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Shared knowledge helps build and maintain team situation awareness (SA), so that all members share a common frame of reference for the team task (Bolman, 1979). While individual SA is considered to be underpinned by the cognitive processes of perception, comprehension, and projection (Endsley, 1995), team SA cannot simply be regarded as the combination of individual members’ SA. A shared awareness brings an additional and unique level of complexity with the need for additional processes and behaviors such as information sharing and the coordination of activities (Salas, Prince, Baker, & Shrestha,
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1995). Communication is thus paramount, especially given the dynamic nature of ICU: As circumstances evolve, the medical team may need to modify their understanding of the situation accordingly by questioning inconsistencies, confirming and cross-checking information, and communicating pertinent information to the rest of the team (Bolman, 1979). A breakdown in communication will impact upon coordinated and informed decision-making, potentially compromising patient care (Gluyas, 2015; Walker, 2008).

Medical resuscitation is a frequent Intensive Care Unit (ICU) emergency that requires both technical and non-technical skills, and can be particularly vulnerable to communication failures. For example, cardiopulmonary resuscitation (CPR) is a commonly occurring ICU emergency consisting of three essential but competing tasks of chest compressions, artificial ventilation and electrical defibrillation to maintain circulatory flow and oxygenation during cardiac arrest. Individual activities in this acute medical situation are largely inter-reliant, so the appropriate information must be shared at the right time to enable team members to coordinate by actively constructing a shared and accurate mental model of the situation. Cardiac resuscitation teams with better leadership communication have been shown to perform higher quality cardiopulmonary resuscitation with faster defibrillation, lower no-flow time (i.e. limiting pauses in CPR delivery), more adequate ventilation, and better rate and depth of chest compressions (Yeung, Ong, Davies, Gao, & Perkins, 2012). Team dynamics including communication and leadership however, have been highlighted as needing significant improvement in resuscitation practice (Norris & Lockey, 2012). Communication is often cited as the main source of teamwork error in trauma resuscitation (Sarcevic et al., 2012). In fact, communication breakdowns are identified as a leading cause of the Joint Commission’s annual classification of patient safety events (sentiment events) resulting in death, permanent harm or
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severe temporary harm and intervention to sustain life (The Joint Commission, 2014).

Resuscitation in ICU is particularly challenging as the typical ICU is dynamic; rapid changes such as patient condition and interruptions challenge the ability for efficient and complete information transfer during a crisis situation (Grundgeiger, Sanderson, Macdougall, & Venkatesh, 2010), which in turn will impair team SA. Individual members who may have never met form teams as the situation develops (Østergaard, Dieckmann, & Lippert, 2011), and furthermore, several intermediate teams may form before the complete intervention team is established (Manser, 2009). As a result, the ad-hoc, cross-professional nature of the ICU makes it particularly vulnerable to problems with team communication that can affect patient safety (Lingard et al., 2004; Reader, Flin, Mearns, & Cuthbertson, 2009), and thus is an important environment in which to focus the current study.

Simulation & CRM Training

The need to integrate effective communication principles in healthcare is becoming widely recognized within simulation-based training in resuscitation (Daniels & Auguste, 2013; Reader, Flin, & Cuthbertson, 2008). The 2010 American Heart Association guidelines for cardiopulmonary resuscitation specifically recommend the inclusion of teamwork training such as leadership skills and other ‘non-technical’ aspects in training to improve resuscitation outcomes (Meaney et al., 2013). Lessons can be learnt from the aviation domain in which Crew (or Crisis) Resource Management (CRM), is used to train principles of individual and team behavior in ordinary and crisis situations (Singh, Petersen, & Thomas, 2006). CRM focuses on the skills of dynamic decision-making, interpersonal behavior, and teams (Gaba, 2010; Gaba, Howard, Fish, Smith, & Sowb, 2001). A key CRM objective is the ability to train effective communication and leadership (Andersen, Jensen, Lippert, Østergaard, & Klausen, 2010;
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Sandahl et al., 2013). CRM communication training objectives include standardization of critical information, directed communication (rather than open-ended broadcast to the room), “closed-looped” communication (both the sender and receiver have acknowledged the information transfer), and the use of situation updates by “thinking aloud” (Fanning, Goldhaber-Fiebert, Undani, & Gaba, 2013; Gaba, 2010; Helmreich et al., 1999).

Multidisciplinary simulation-based team training using CRM is recognized by many researchers and practitioners as an integral component of ongoing quality-improvement efforts to improve the teamwork skills that cannot be taught in a typical classroom setting (Daniels & Auguste, 2013). Medical CRM training is typically conducted either in situ or in dedicated simulation centers, across learner populations from novice to expert, and conducted as single-discipline courses or with multidisciplinary and inter-professional teams (Fanning et al., 2013). Such exercises have proven a useful tool for analyzing communication patterns and errors in ICU teams (Nishisaki et al., 2011), for assessing residents’ CRM skills as performed as part of a team (Kim, Neilipovitz, Cardinal, Chiu, & Clinch, 2006) and for developing teamwork abilities in ICU (Okuda et al., 2009). Simulation exercises permit a high level of scenario realism that allow learners to practice technical and non-technical skills without threat to patient safety (Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2005). However, high-fidelity simulation might be more suitable for experts rather than novice learners, as the increased realism can potentially overwhelm the novices and distract from the learning objective (Alessi, 1988). Simulation-based training, and importantly the debriefing afterwards, provide a promising opportunity for developing these non-technical skills in emergency medicine. Simulation focuses on active learning, building confidence and enhancing judgment, while debriefing provides purposeful direction to help improve thinking and clarify thought processes (Mayville, 2011). High-fidelity
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simulation and debriefing are viewed as educational modalities critical for learning (Salas et al., 2008). Debriefing can be accomplished through several methods, including verbal feedback in-situ and video-assisted verbal discussion immediately following the simulation exercise to assist students in assessing their performance (Dufrene & Young, 2013; Garden, Le Fevre, Waddington, & Weller, 2015). Participants tend to consider debriefing as the most important part of training (e.g., Gaba et al., 2001). Indeed, structured debriefing (Gaba et al., 2001; Marks et al., 2000) is a proven qualifier in standardized aviation communication and is linked to team performance (Campbell & Bagshaw, 2002). One meta-analysis of 46 studies found that debriefs improve individual and team performance relative to a control group by approximately 25% (Tannenbaum & Cerasoli, 2013). According to their meta-analysis, debriefing works best when structured and facilitated, and properly aligned. According to the alignment principle, when the training objective is to improve team effectiveness, it is optimal to conduct debriefs with teams, to focus on improving the team, and to measure the performance of the team as a whole.

In terms of the specific content, one study demonstrated that debriefing on the physical skills required for CPR tasks (e.g., chest compression quality, defibrillation timing) was evaluated by respondents to be more useful for improving their knowledge, performance, and confidence in CPR than was debriefing on cognitive skills (e.g., communication, heart rhythm recognition, medication dosage) following resuscitation of actual pediatric cardiac arrest patients (Zebuhr et al., 2012). In a similar manner, Bond and colleagues (2006) studied emergency medicine residents’ perception of high-fidelity mannequin-based simulation and two debriefing styles on patterns of thought that may lead to suboptimal decisions (i.e., metacognition regarding error). The technical debriefing condition provided more information on the clinical knowledge topics covered by the scenarios while cognitive debriefing focused more on various types of
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metacognitive (i.e., thinking about one’s own thinking) error for clinical decision making. Results showed that while the cognitive debriefing group made more and qualitatively richer comments regarding the cognitive error concepts, the technical debriefing was better received.

While there is ample evidence showing that technical debriefings help with the acquisition of medical knowledge (Tannenbaum & Cerasoli, 2013), relatively little is known about how non-technical debriefings may help with the development of non-technical skills such as team communication, known to improve SA and contribute to team safety and efficiency (Helmreich et al., 1999). Indeed, the 2010 International Consensus guidelines for team emergency cardiovascular care identifies specific knowledge gaps on the differential effectiveness of debriefings on technical versus non-technical skills (Soar et al., 2010). Further investigation is required to assess whether non-technical debriefing can help with the acquisition of team non-technical skills such as team communication, and to isolate its effect from the actual training intervention.

Team communication measurement

Assessing a team’s communication skills is no simple task. The traditional approach is to observe and rate team members’ communication, but this is often time consuming and can sometimes face problems of inter-rater reliability. As an alternative and more objective method, Blum and colleagues developed a measure of information sharing by giving information probes to individual team members and assessing the extent to which each probe was exchanged among members (Blum, Raemer, Carroll, Dufresne, & Cooper, 2005). Reluctance of team members to convey unique patient information to other team members is linked with poor decision making and reduced team performance (Stasser, 1992; Wittenbaum & Stasser, 1996). Blum and colleagues’ technique required a confederate to isolate one of the team members and divulge a
piece of predetermined information about the patient (e.g., that the patient is HIV positive). There were four such probes placed in each scenario, and teams were tested immediately afterwards on their knowledge of these unique pieces of clinical information, as an indicator of the extent of team information sharing during the simulation exercise. Based on this probe technique, the effectiveness of team training was assessed by comparing the percentage of group sharing between the first scenario and the last (which followed simulation-based communication training). While the authors found no difference in group sharing between pre- and post-training scenarios (28% and 26% respectively), this may reflect issues with the method rather than the ineffectiveness of the training exercise. The placing of probes by the confederate was difficult to do discretely (about a third were possibly overheard), meaning that the number of correctly placed probes varied between scenarios (sometimes only one out of four). There was also the possibility that results were distorted by memory bias, since the authors only considered the information as having been shared if the trainee remembered having heard it. Blum and colleagues concluded that the use of planted probes to test for information sharing is potentially viable as a research tool, but it needs further development in order to overcome the issues with probe placement.

The present study

The current study is based on the notion that teams can improve their communication skills through high fidelity simulation-based training and debriefing. A first objective of the study was to examine the unique contribution of debriefing content on team communication training. We were specifically interested in determining whether a debriefing oriented towards the training objective is essential to observe a training benefit, or whether team communication could be improved with high fidelity simulations, regardless of debriefing content. This
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investigation was conducted by employing realistic resuscitation teams and by specifically manipulating the focus of post-scenario debriefings. Experimental teams received communication-oriented debriefing aligned with the training objective, while control teams were presented with debriefing focusing on technical skills (not aligned with the training objective). If debriefing content plays a critical role in the training of non-technical skills such as team communication, only teams debriefed on communication would improve their communication skills, or at least, the training benefit would be greater than that observed for teams debriefed on technical skills only. Evidence supporting this claim would further our knowledge on the effect of specific components of simulation training to improve communication in inter-professional teams.

A second objective of the study was to develop a methodology that can be used for the assessment of team communication in simulated environments. In order to assess the impact of training on communication skills, we first took a measure of communication quality based on CRM principles. This involved seven communication skills that were evaluated by two raters in three 8-min segments of the 24-minute scenario. Using this as a baseline measure, we then aimed to compare this to the pattern of results with a new methodology to assess team communication – information sharing. Using an adaptation of Blum and colleagues’ (2005) method, we placed unique probes with each of the team members, but included these in team members’ written introduction to the scenario, rather than requiring them to be communicated orally by a confederate. Furthermore, we were able to circumvent the issue of memory bias that may have affected Blum and colleagues’ study by videotaping the scenario and checking back objectively whether or not the critical information was shared by team members. The use of information
sharing as a method to assess team communication is less time consuming, logistically less complex, and less subjective than the traditional approach.

**Method**

**Participants**

Participants were 60 healthcare professionals (24 females, 36 males) aged 26 to 59 years ($M = 40$ years, $SD = 9.30$), recruited from ICUs of two Quebec City hospitals. All participants provided written informed consent, and agreed to non-disclosure throughout the duration of data collection. Participants were randomly assigned to 10 six-member teams within their respective hospitals. Each team contained an intensivist (a senior physician), a senior resident, a respiratory therapist, two nurses, and an orderly. Five teams were then randomly assigned to the experimental group (debriefed on communication skills), while the other five teams were assigned to the control group (debriefed on technical skills).

**Setting**

**Simulation environment.** The APPRENTISS training and research center (Université Laval, Quebec City, Canada), mimics a full ICU environment (Figure 1). Each simulation room is equipped with actual medical devices and a high-fidelity patient simulator (Medical Education Technologies Inc., Florida). This patient simulator is a computer-driven, full-sized mannequin, programmed to respond in a coherent pathophysiological and pharmacological manner to medical interventions. The simulation rooms are also equipped with a recording array of cameras and microphones, while the simulator and monitors are operated from an adjacent control room.

[Figure 1]

**Scenarios.** Four 25-minute scenarios based on Advanced Cardiac Life Support (ACLS; Neumär et al., 2010) resuscitation procedures were designed to elicit team communication. In
each scenario the baseline patient presents a Pulseless Electrical Activity (PEA) or malignant tachyarrhythmia, requiring the medical team to intervene according to ACLS protocol. Scenario 1 was pulseless ventricular tachycardia due to a transfusion error; Scenario 2 was PEA due to septic shock, hypovolemic shock and coagulopathy; Scenario 3 was an idioventricular rhythm with hyperkalemia and acidosis, as well as an allergic drug reaction; and Scenario 4 was a pulseless rapid atrial fibrillation following a spontaneous pneumothorax.

**Communication Measures**

**Communication Quality.** The quality of team communications was assessed by four raters blind to the group assignment, scenario order, and purpose of the study. Raters viewed video recordings of the simulation sessions and provided time-stamped ratings with Observer XT 10 software (Noldus Information Technology Inc., USA). Observed team members wore different colored caps to facilitate individual coding (Figure 1). Raters included a research associate and three research assistants in psychology that had prior experience in rating team communications. Although the communication grid developed in the current study did not require raters to have prior medical knowledge, they all received a short training by a respiratory therapist and an anesthesiologist to become familiar with the technical jargon that could be used during scenarios. Their training ended with the viewing of a video recording showing a simulation session from a pilot study.

Raters coded communication quality using seven communication markers shown to be critical in crisis management (St.Pierre et al., 2011, Chapter 12): message clarity, message coherence, message content, closed-loop communication, shared plan of action, active information exchange, and active listening (see Appendix A for definitions). Each team member received three ratings by the observers, one for each 8-min segment of the video, on a paper-and-
pencil visual analogue scale regarding the seven communication markers. The visual analogue scale was a 10-cm horizontal line with the words "Absent" and "Present" at each end and the middle indicated by a vertical line (see Appendix A). Raters were asked to put a cross on the straight line at the point that most accurately expressed their assessment of that member’s communication skill. Using a ruler, the score was determined by measuring the distance (cm) on the 10-cm line between the "Absent" anchor and the rater’s mark, providing a score between 0 and 10 that was rounded to the nearest 0.5. Ratings were then averaged across the three 8-min segments to generate a mean score for each team member regarding the seven communication markers.

**Information Sharing.** Information sharing was assessed using Blum et al.’s (2005) technique of tracing clinical information (probes) among team members. This approach is based on research showing that the extent to which team members convey unique patient information to other team members is linked to decision-making quality and team performance (Stasser, 1992; Wittenbaum & Stasser, 1996). Embedded in the scenario preamble, team members received a unique piece of information (a "probe") that conveyed important information for patient management. The probe was mixed with the other information included in the scenario preface and was specific to each team member. Example probes were that the patient is difficult to intubate (intensivist), the patient is taking cocaine (respiratory therapist), the patient did not receive antibiotics (nurse 2), and the patient has pinkish-colored urine (orderly). Two independent observers (different from those who had rated communication quality) viewed all video recordings of the simulation sessions and checked whether team members shared their probe during the simulation. Data collected by the two observers were compared for quality assurance and any discrepancy between observers was checked by a third-party.
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Procedure

Each team’s individual training day began with a standardized introduction to the APPRENTISS center, followed by a non-recorded, 20-minute practice scenario to allow familiarization with the simulation environment. Throughout the day, all teams participated in the first three 25-minute scenarios. The order of scenarios remained consistent throughout the study (scenarios 1, 2 and 3). Before each simulation, team members were given four minutes to read the scenario preface adapted to their role. Teams were debriefed immediately after each simulation by the same trained instructor. In each debriefing session, the instructor provided video-assisted feedback to all six team members on communication skills, or on technical skills alone, depending on the experimental condition. Three months later, teams participated in the fourth simulation scenario (scenario 4) without any debriefing. Team composition remained constant across all simulations.

Debriefing for the experimental and the control group was identical in style and duration (60 minutes each), differing only in content. Teams assigned to the experimental group were debriefed on CRM-based aspects of communication within their team. The instructor emphasized medical errors related to communication, the role of the team leader in communications, communication centralization, and the importance of message clarity (i.e., content, non-verbal consistency, diction, tone and language). Discussions included the importance of closed-loop communication, directly addressing the message recipient, active listening, using communication to build situational awareness, and information sharing towards building a shared mental model (e.g., joint work plan). Teams assigned to the control group were debriefed on technical and medical performance including the team’s differential diagnosis (i.e., list of common causes of a primary symptom), correct scenario diagnoses and appropriate patient management. Discussions
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included ACLS skills and the treatment of the patient relative to the scenario (e.g., transfusion error, septic shock, etc.). While questions and concerns related to communication may have been addressed in certain cases, they were not initiated by the instructor. All of the topics discussed in the experimental and the control group are presented in Appendix B. Those topics were all discussed in the first debriefing. Then, after each simulation, only problematic topics were discussed again. In order to prevent study bias, participants were told that the purpose of the study was to examine whether high-fidelity simulation can be used to improve teamwork. The real objective of the study was only disclosed to participants at the end of the study.

Results

Demographics

The summary of demographic information is presented in Table 1. A small amount of missing data (frequencies ranging from 1 to 4) was found for three of the five variables. Independent t-tests revealed no group difference regarding age, \( t(57) = 0.11, p = .91 \), number of years passed graduation, \( t(43) = 0.19, p = .85 \), and years of experience in ICU, \( t(55) = 0.50, p = .62 \). In line with these results, chi-square tests of independence showed no relation between prior experience with simulation and group (\( \chi^2(1) = 0.69, p = .41 \)), as well as no relation between prior experience with CRM training and group, (\( \chi^2(1) = 0.08, p = .77 \)).

Communication quality

Inter-rater reliability. All simulation sessions were coded by four raters. Intraclass correlations were performed to determine the reliability of ratings between the four raters (raters 1 and 2, raters 1 and 3, and so on). Intraclass correlation coefficients ranged from .78 to .88, indicating a strong agreement between raters.
Percentage of communication effectiveness. Table 2 reports the mean rating and standard deviation associated with the seven communication markers. As shown in the table, four of the seven communication markers (message clarity, active listening, message coherence, and message content) consistently received near perfect scores by the raters. A principal component analysis with varimax rotation was conducted on the seven communication markers to examine whether these markers could be divided into coherent factors that are independent of one another. Only factors with an eigenvalue higher than 1 were interpreted. Using this criterion, three factors were extracted from the data. The first factor explained 44.13% of the variance and included closed-loop communication ($r = .91$), shared plan of action ($r = .89$), active information exchange ($r = .92$), and message clarity ($r = .67$). The second factor explained 16.71% of the variance and included message content ($r = .78$) and active listening ($r = .74$). Finally, the third factor explained 14.63% of the variance and included message coherence ($r = .94$). Based on these results, we decided to compute a measure of communication effectiveness that was based on the four communication markers included in the first factor only (closed-loop communication, shared plan of action, active information exchange, and message clarity). This decision was motivated by two main reasons: (a) these communication markers explained almost half of the variance observed in the data and, (b) the other two factors included markers that showed ceiling effects and could prevent the detection of differences between experimental conditions. As internal consistency was good between the four markers included in the first factor (Cronbach's alpha = .87), we computed a measure of communication effectiveness for each team member by adding the score of those four markers (closed-loop communication, shared plan of action, active information exchange, and message clarity). The metric was then
transformed into a percentage (a 100-point scale) instead of a 40-point scale in order to facilitate data interpretation.

Table 2

Effects of group and simulation sessions on communication effectiveness. Due to the occasional inability to interpret team members’ communication and the withdrawal of two participants at simulation 4, there was a small percentage of missing values (0.02%) that were replaced by linear trend. Figure 2 illustrates the percentage of communication effectiveness as a function of group and simulation session. Communication effectiveness was analyzed using a mixed model (PROC MIXED, SAS 9.1.3, SAS Institute) with the repeated statement to model correlations among measurements made on the same participant through simulation session. The model included group (experimental, control), simulation session (1 to 4) and their interaction as fixed factors, as well as a random effect to account for correlations between scores from participants belonging to the same team. Maximum likelihood was used as the estimation method and the alpha level was set to .05. The analysis revealed a significant main effect of simulation session, $F(3, 174) = 13.76, p < .001$, but not of group, $F < 1$. More importantly, the two-way interaction was significant, $F(3, 174) = 3.24, p = .02$. Post hoc contrasts with Bonferroni adjustment were conducted to determine whether the effect of group was similar across simulation sessions. Results showed that communication effectiveness was greater for experimental than for control teams at simulation 3 ($p = .02$). However, no group difference was found at simulations 1, 2 and 4 ($p = .57, .82, .25$, respectively).

Figure 2

Additional contrasts were performed to examine specifically whether communication effectiveness was improved at the end of the training day and whether that improvement still
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remained after three months. First, the short-term effect of training was assessed by contrasting the percentage of communication effectiveness observed at simulation 1 (at the beginning of the training day) with that at simulation 3 (at the end of the training day). No significant difference was observed for the control group ($p = .19$), while communication effectiveness was found to increase from simulation 1 ($M = 71.75\%$) to simulation 3 ($M = 85.44\%$) for the experimental group ($p < .001$). Second, the long-term effect of training was evaluated by contrasting the percentage of communication effectiveness observed at simulation 1 (at the beginning of the training day) with that at simulation 4 (three months later). No significant difference was observed between simulations 1 and 4, neither for the control group ($p = 1$), nor for the experimental group ($p = .24$). Third, the retention effect was assessed by contrasting communication effectiveness observed at simulation 4 (three months later) with that of simulation 3 (at the end of the training day), indicating the extent to which the short-term benefit of training dissipated after three months. Results showed a significant decrease in communication effectiveness from simulation 3 to 4 for the control group ($p = .0497$), as well as for the experimental group ($p < .001$).

Information sharing

A 2 (Group: experimental, control) × 4 (Simulation session: 1-4) mixed analysis of variance (ANOVA) was conducted on the percentage of probes shared by team members within the simulation session. The .05 level of significance was adopted and the Greenhouse-Geisser correction was applied when appropriate. A percentage of 100\% for instance would mean that all six team members shared their probe with the other team members, while a percentage of 50\% would mean that only three of them shared their information during the simulation session. Figure 3 shows the percentage of shared probes for both groups as a function of simulation
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session. Results revealed a main effect of simulation session, $F(3, 24) = 9.15, p < .001, \eta^2_p = .53$. Post hoc contrasts with Bonferroni adjustment revealed a short-term benefit of training, i.e. a greater percentage of shared probes at simulation 3 than at simulation 1 ($p = .01$). However, no long-term training effect was observed when contrasting the percentage of shared probes at simulation 1 with that at simulation 4 ($p = 1$). Finally, results showed a significant decrease regarding the percentage of shared probes from simulation 3 to simulation 4 ($p = .04$). Neither the effect of group nor the two-way interaction was significant, $Fs < 1$.

[Figure 3]

DISCUSSION

This study examined the impact of team training using high-fidelity simulation and debriefing as a means to improve team communication quality and information sharing within a multidisciplinary ICU team. First and foremost, our results suggest cross-professional team simulation training is worthwhile. Regardless of whether debriefing focused on communication or technical skills, teams that were allowed to train together for a brief period were better at sharing unique patient information; a communication skill that has been found to be associated with team performance (Stasser, 1992; Wittenbaum & Stasser, 1996). All teams shared more critical patient information by the end of the simulation day compared to at the beginning. Second, our study suggests that debriefing plays a critical role in the training of team communication and that its content should match the training objectives. Brief exposure to simulation training followed by a communication-based debriefing was successful in improving communication effectiveness among team members after the third training session. However, no training benefit was observed on communication quality when simulations were followed by a traditional debriefing with a focus on technical skills.
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Debriefing. Whereas all teams received video assisted debriefing after the simulation, only those who were exposed to communication-based debriefing were successful in improving their communication effectiveness. This suggests that debriefing content should match with the training objectives to be effective, and that discussing communication non-systematically, as was the case for control teams, was not enough to improve communication quality significantly. Nevertheless, our study suggests that simulation per se is a powerful tool for improving team information sharing as both groups shared more unique information by the end of the training day. It is possible that – regardless of debriefing content – the benefits of timely information sharing become apparent simply through participation in the simulated scenarios: after all, ensuring that others are privy to all patient information can help with diagnosis, and thus is directly related to team performance. However, the quality of communication – the manner in which this information is conveyed to other team members (i.e., clarity, coherence, closed-loop communication, etc.) – may be a more subtle skill that only improves when debriefing explicitly addresses these issues.

The study provides further support for the benefits of simulation-based training in healthcare teams, and in particular the importance of simulation training on team performance and team cognition (Fernandez et al., 2017). Regardless of debriefing content, all teams improved their information sharing which is a key determinant of team performance in emergency teamwork training (Morey et al., 2002). A greater level of information exchange contributes to a higher level of team SA, by ensuring that all team members are aware of critical patient information (Mathieu et al., 2000), as well as the decisions and actions that are being taken. Poor communication can lead to incomplete knowledge, misunderstandings, and the use of individual heuristics (Croskerry, 2005) which in turn can affect the SA, with the team not
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benefitting from a shared understanding of the current situation and the factors that could affect it at any given time (Salas et al., 1995). Indeed, it has been suggested that to gain SA, medical personnel adopt an approach of “aggressive skepticism” to avoid medical error (Stone, 2001); that is, they should be constantly evaluating, questioning, and information sharing within the team. There may be reasons for not sharing information and failing to achieve a high level of SA, such as complacency, heuristics, or lack of staff assertion; these are factors that are addressed in aviation training to improve communication and efficiency, and are now being recognized in medicine (Singh et al., 2006).

Temporary effects. In line with other research, our study showed a transient effect of simulation-based training in terms of communication quality and information sharing. The training benefits observed at the end of the training day had almost entirely dissipated by the 3-month follow-up. Such findings are not surprising given the extensive literature showing that learning is greatest immediately after exposure and then extinguishes over time (see Weinger, 2010). In the context of healthcare, Stocker et al. (2012) suggest that multidisciplinary team training programs have a 6- to 12-month learning curve, and that repeated exposure to simulation is most beneficial to CRM training. Moreover, it has been shown that basic and advanced life support knowledge and skills can deteriorate in as little as 3–6 months (Nolan et al., 2010), and that a single, isolated exposure may not be sufficient to produce lasting results (Stocker et al., 2012). Frequent team simulation-based training may be required to maintain technical and non-technical skills and to optimize the transfer of training from the simulation to real-work environments. Such recommendation is supported by the pharmacology-based model of Weinger (2010) predicting that a second exposure to simulation-based training (a redosing) before the complete extinguishing of the training benefit could lead to a higher peak effect and a longer
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duration. More research is required however to determine the optimal dose (e.g., hours of training), timing, and frequency of simulation-based training for technical and non-technical skills.

The absence of a long-term training benefit observed in the current study could also be explained by a difficulty of participants to generalize and apply simulation-based learning to the clinical environment. Two characteristics of our study may have influenced the transfer of training, and hence skill use during the three-month period between sessions 3 and 4. First, teams were composed of individuals working for the same organization. Even if the instructor emphasized the importance of communication skills during post-scenario debriefing and encouraged specific behaviors, the clinical care environment must facilitate and support these behaviors to observe a positive transfer of training. In this respect, Sandahl et al. (2013) reported that although simulation-based team training increases awareness of the need for effective communication, the observed improvements will not last without proper organizational support. Using teams composed of individuals from different hospitals could have limited the impact of organization support on the transfer of training. Second, training sessions featured static teams composed of the same team members across all four sessions. Given the ad hoc nature of ICU teams, the high number of personnel working in ICU and shift rotation, it is unlikely that the exact same teams have worked together during the three-month period. This potential discrepancy between the simulation and the clinical environment in terms of team composition might explain why team members failed to maintain their communication skills during the three-month period. Remixer teams across simulation sessions would have allowed us to ensure the training of individuals’ team skills rather than the teams’ skills as a whole, hence optimizing the transfer of training.
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Methodology. Our variable of communication effectiveness, derived from key CRM principles (St.Pierre et al., 2011), offers a promising way to assess team interpersonal skills. Four of the seven clearly defined communication markers accounted for around half the variance, and together were sensitive to improvements in communication quality following training and debriefing on communication skills specifically. The clarity of these predefined markers was confirmed by the high reliability between the four raters. In addition to this traditional observational methodology, we adopted a new measure by assessing the extent of information sharing. Developed initially by Blum and colleagues (2005), this approach requires no particular training and is more objective, logistically less complex, and less time consuming than observation, but still needed further development to test its sensitivity as a measure of communication skills. A number of modifications to Blum et al.’s methodology were made for the current study. First, by placing one unique piece of information with each team member, we were able to include more probes than in Blum et al.’s study (six rather than four), thus improving the sensitivity of the method. Second, we placed unique probes within each team member’s written introduction to the scenario, rather than relying on a confederate to convey the information covertly. This created a more standardized methodology whereby unique information was always received by team members at exactly the same point in the task, and in exactly the same manner, and did not run the risk of information being inadvertently overheard. As such, no data need be discarded due to unsuccessful probe placement. Finally, by recording scenarios we were able to circumvent the problem of memory bias – whereby team members were unsure if they had been told critical information or not – by looking back to confirm whether the critical information had indeed been shared. In addition to the face validity of this method, we were also able to demonstrate construct validity as more critical probes were shared
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during the last scenario compared to the first, as was intended by the simulation-based training exercise. While Blum and colleagues found no benefit of information sharing following simulation-based training on communication skills, the modifications made in our study showed the method of inserting critical probes within a scenario is sensitive enough to reveal differences between pre- and post-training.

CONCLUSION

Few would dispute the importance of non-technical skills such as team communication, leadership, or debriefing in promoting safe and efficient healthcare. Our results suggest cross-professional, simulation-based team training can improve team communication in a healthcare setting. Outcomes may be further enhanced when scenario debriefing content matches the training objective. Longer-term benefits will likely require recurrent training as training effects were no longer evident at the 3-month follow-up. Finally, our study makes a methodological contribution in the development of two new methods to assess team communication. While communication quality improved following communication-based debriefing specifically, information sharing appeared to be a more general measure for which the benefits from the training exercise were not limited solely to experimental teams.
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### Table 1

Demographic information and differences between the experimental and the control group.

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>Experimental</td>
<td>30</td>
<td>39.90</td>
<td>9.32</td>
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<tr>
<td></td>
<td>Control</td>
<td>29</td>
<td>40.17</td>
<td>9.45</td>
</tr>
<tr>
<td><strong>Number of years passed graduation</strong>¹</td>
<td>Experimental</td>
<td>24</td>
<td>14.04</td>
<td>10.39</td>
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<tr>
<td></td>
<td>Control</td>
<td>21</td>
<td>14.62</td>
<td>9.99</td>
</tr>
<tr>
<td><strong>Years of experience in ICU</strong></td>
<td>Experimental</td>
<td>30</td>
<td>8.39</td>
<td>8.88</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>27</td>
<td>9.53</td>
<td>8.25</td>
</tr>
<tr>
<td><strong>% of Ss with prior experience with simulation</strong></td>
<td>Experimental</td>
<td>30</td>
<td>36.67</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>30</td>
<td>26.67</td>
<td>-</td>
</tr>
<tr>
<td><strong>% of Ss with prior experience with CRM training</strong></td>
<td>Experimental</td>
<td>30</td>
<td>26.67</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>30</td>
<td>30.00</td>
<td>-</td>
</tr>
</tbody>
</table>

¹ Not applicable to orderlies.
Table 2

Mean rating (max = 10) and standard deviation associated to communication markers.

<table>
<thead>
<tr>
<th>Communication markers</th>
<th>$M$</th>
<th>$SD$</th>
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</thead>
<tbody>
<tr>
<td>Close-loop communication</td>
<td>7.39</td>
<td>1.58</td>
</tr>
<tr>
<td>Shared plan of action</td>
<td>7.43</td>
<td>1.76</td>
</tr>
<tr>
<td>Active information exchange</td>
<td>6.39</td>
<td>1.81</td>
</tr>
<tr>
<td>Message clarity</td>
<td>9.39</td>
<td>0.71</td>
</tr>
<tr>
<td>Active listening</td>
<td>9.50</td>
<td>0.59</td>
</tr>
<tr>
<td>Message coherence</td>
<td>9.96</td>
<td>0.19</td>
</tr>
<tr>
<td>Message content</td>
<td>9.77</td>
<td>0.37</td>
</tr>
</tbody>
</table>
APPENDIX A

Description of the seven communication items rated by the observers and the rating sheet
1. Message coherence
   - Verbal and non-verbal communications are in agreement.
     - (Disconnects between verbal and non-verbal can cause confusion in message interpretation)

2. Message content
   - No possible misinterpretation of the stated message
   - The message only concerns the current case.
   - The message does not carry emotional value.

3. Message clarity
   - Sender either names or looks at the message receiver
   - The message is short and well-constructed
   - Articulation, volume and tone are appropriate

4. Close-loop communication
   - Sender provides instruction for immediate action
   - Receiver acknowledges the message is understood.
   - Receiver informs sender when task has been executed.
   - Sender acknowledges receiver.

5. Shared plan of action
   - The global evaluation of the situation and the plan of action are shared with the team.
   - Presence of team agreement of the overall plan of action.
   - Team members listen to each other in order to modify the action plan if needed.

6. Active exchange of information
   - Team members actively request situation updates.
   - Team members check that everyone knows their priorities.
   - Team members check that workload is equally divided among the team.
   - Team members provide information before being asked.

7. Active listening
   - Team members do not interrupt each other when speaking.
   - Team members ask for clarifications, details, or explanations when needed.
   - Receiver repeats or summarizes the message of the sender.
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Rating sheet

Participant (code) : _____________________
Simulation session (code) : _____________________
Video segment : _____________________

Communication markers

Message coherence
Absent______________________________ | ___________________________ Present

Message content
Absent______________________________ | ___________________________ Present

Message clarity
Absent______________________________ | ___________________________ Present

Close-loop communication
Absent______________________________ | ___________________________ Present

Shared plan of action
Absent______________________________ | ___________________________ Present

Active exchange of information
Absent______________________________ | ___________________________ Present

Active listening
Absent______________________________ | ___________________________ Present
APPENDIX B

Debriefing content for the control and the experimental group
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Debriefing topics for the control group:

1. Talk about the diagnosis, the differential diagnosis, and the treatment of:
   - pulseless ventricular tachycardia
   - ventricular tachycardia with pulse
   - pulseless electrical activity
   - asystole
   - sudden hypoxemia in the trauma patient
   - hyperkalemia
2. Discuss the initial reanimation of the patient in cardio respiratory arrest
3. Discuss the cardiac massage
4. Discuss medication mistakes and ways to address them
5. Discuss medical mistakes
6. Discuss the massive transfusion treatment
7. Discuss the treatment of the transfusion error
8. Discuss the treatment of the adult acute respiratory distress syndrome

Debriefing topics for the experimental group:

1. Discuss medical mistakes, their general causes, and communication in particular
2. Discuss the leader’s role in communications
   - Discuss the centralization of communications
   - Discuss the importance of the message’s clarity (in its content, consistency with nonverbal and paraverbal, diction, tone, language)
3. Introduce and discuss the communication loop in emergency situations
4. Discuss the importance to identify speakers and to call them out directly
5. Discuss the importance of listening to the other participants
6. Discuss the team members’ responsibilities in communication for the patients’ security, in order to improve the situational awareness
7. Discuss the importance of information sharing among participants
8. Discuss the importance of the shared model (for a joint work plan: shared mental model)