# Simulation training improves team dynamics and performance in a low-resource cardiac intensive care unit

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## ABSTRACT

**Introduction** : Although simulation training has been utilized quite extensively in high-income medical environments, its feasibility and effect on team performance in low-resource pediatric Cardiac Intensive Care Unit (CICU) environments has not been demonstrated. We hypothesized that low-fidelity simulation-based crisis resource management training would lead to improvements in team performance in such settings.

**Methods** : In this prospective observational study, the effect of simulation on team dynamics and performance was assessed in 23 health-care providers in a pediatric CICU in Southeast Asia. A 5-day training program was utilized consisting of various didactic sessions and simulation training exercises. Improvements in team dynamics were assessed using participant questionnaires, expert evaluations, and video analysis of time to intervention and frequency of closed-loop communication.

**Results** : In subjective questionnaires, participants noted significant ($P < 0.05$) improvement in team dynamics and performance over the training period. Video analysis revealed a decrease in time to intervention and significant ($P < 0.05$) increase in frequency of closed-loop communication because of simulation training.

**Conclusions** : This study demonstrates the feasibility and effectiveness of simulation-based training in improving team dynamics and performance in low-resource pediatric CICU environments, indicating its potential role in eliminating communication barriers in these settings.

**Keywords** : Crisis resource management, intensive care, nursing empowerment, simulation training

## INTRODUCTION

Optimal patient outcomes during Intensive Care Unit (ICU) resuscitation depend heavily on effective team dynamics among caregivers, especially in cardiac ICU (CICU) settings, where crisis events occur commonly.[1] Nearly half of adverse events in the ICU can be attributed to deficiencies in teamwork and communication.[2,3] Suboptimal team dynamics may lead to adverse patient outcomes in low-resource health-care settings as well.[4] Efforts to improve outcomes in these settings require interventions that promote an environment of effective communication and structured role clarity.

Crisis resource management (CRM) training applies a deliberative practice model to simulated crisis scenarios

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to improve communication and teamwork.[5-7] The use of simulation training for extracorporeal membrane oxygenation resuscitation education, for example, has been shown to improve team dynamics and participant comfort level.[8-10] Although simulation training has been shown to improve outcomes in many developed countries, it has not been widely adopted in developing countries due to lack of data indicating its efficacy and utility. Before the adoption of this methodology for team training in low-resource settings, further data regarding its efficacy are necessary. Given the positive impact of simulation-based team training in high-resource systems, we designed a simulation-based training curriculum that would engender cross-disciplinary teamwork in low-resource pediatric CICU and hypothesized that it would lead to measurable improvements in team dynamics and performance. We analyzed the application of such a simulation-based CRM training program in a low-resource pediatric CICU.

## METHODS

### Study design

The study is a prospective observational study of 23 health-care providers in a low-resource pediatric CICU in Southeast Asia who underwent a simulation-based team training program designed by Boston Children's Hospital. Participants were informed of the nature of the study and provided informed consent. Approval for the study was obtained from the institutional review board at Boston Children's Hospital and the local institution. The impact of the simulation training program on team dynamics and time to intervention was assessed by participant questionnaires and independent observers.

### Overall course design

The CRM training program utilized in this study consisted of four 1-h multimedia and interactive discussion sessions that introduced principles of effective teamwork and four 1-h scenario simulation sessions delivered over a 5-day period. The duration of the simulation program was established according to previous protocols.[11] Participants were divided into two training groups, each consisting of at least 1 surgeon, 1 anesthesiologist, 1 attending intensivist, and 3–4 nursing staff.

The program was initiated with a 1-h interactive lecture, in which simulation participants were introduced to the importance of effective team dynamics in hospital care. The interactive lecture emphasized three major aspects of effective team dynamics: Role clarity, closed-loop communication, and idea acceptance. Role clarity was defined as the assigning of specific clinical roles (i.e., bedside nurse, airway manager, recorder, etc.) and the delegation of specific clinical tasks during a crisis. Closed-loop communication was defined as the clear and open expression of urgent clinical information to other team members and acknowledgment of receipt of that information. Idea acceptance was defined as the thoughtful consideration of suggestions made by other team members in clinical decision-making during a crisis. To demonstrate the importance of optimal team dynamics, each group of participants was asked to participate in a "tennis ball" exercise, which has been previously utilized.[9] During the introductory session, participants were also introduced to the concept of simulation training and were shown a video demonstrating a well-executed simulation exercise. Management algorithms for low cardiac output, arrhythmias, airway distress, and cardiac arrest were also reviewed. Figure 1 depicts the overall course design.

### Presimulation questionnaire

Before participation in the simulation training course, participants completed a questionnaire in which they rated their baseline utilization of role clarity, closed-loop communication techniques, and idea acceptance in clinical practice. Participants rated their clinical environment in each of these parameters on a scale from 1 to 5, with 1 ("strongly agree") representing high competency and 5 ("strongly disagree") representing deficiency.

### Simulation scenarios

The simulation sessions were designed to replicate the native work environment and were conducted in a bed space within the CICU using clinically available equipment (medication carts, monitors, ventilation, and surgical instruments). Participants were instructed to speak in language of their own preference. The scenarios presented in the training course included patients experiencing low cardiac output, supraventricular tachycardia (SVT), cardiac tamponade, and respiratory distress.

The simulation exercises were performed on a newborn patient simulation mannequin (Newborn HAL S3010 Tetherless Newborn Simulator, Guamard Scientific, Miami, FL), which was connected to a bedside monitor displaying vital signs and physiological data. This high-fidelity mannequin simulates full body assessment incorporating both auditory and visual cues including cyanosis, chest wall movement, pulses, heart sounds, breath sounds, and movement of extremities. Participants utilized physiological data and symptoms provided by the simulation mannequin to diagnose, perform interventions, and assess the response to interventions. Interventions could include (1) administration of intravenous fluids and medication, (2) ventilation by endotracheal intubation or bag-valve-mask, (3) ventilation by endotracheal intubation or bag-valve-mask, (3) Electric defibrillation, and (4) cardiopulmonary resuscitation. Figure 2 shows the simulator setup.

For each simulation session, a primary bedside nurse was assigned, and all other participants were asked to leave the vicinity of the bed space. Course facilitators presented background information regarding the patient diagnosis, past medical history, and recent surgical procedure to the primary nurse. The nurse was instructed to conduct routine activities of patient care and recruit additional help as needed. Other than providing background clinical information to the primary nurse, course facilitators did not interact with participants during the exercise. Following a period of stability, perturbations in vital signs were generated remotely by course facilitators. Within a single simulation exercise, multiple hemodynamic or respiratory perturbations were provided, and each perturbation was treated as a separate event during subsequent analysis. Participants' responses to changes in vital signs were recorded by video and by the observing simulation staff. Following the simulation, a debriefing was conducted during which participants were asked to reflect on challenges and possible solutions related to role clarity, closed-loop communication, and idea acceptance.

### Daily evaluation of simulation performance

After each session, participants completed a questionnaire assessing the team's utilization of role clarity, closed-loop communication, and idea acceptance. Respondents rated themselves and their team members with respect to the above criteria on a scale from 1 to 5, with a score of 1 ("strongly agree") representing optimal and 5 ("strongly disagree") representing deficient performance in each component of team dynamics.

A blinded observer reviewed a video recording of the simulation exercise and measured parameters relating to team dynamics as well as time to therapeutic intervention during simulation. To derive the frequency of role clarity, the total number of instances in which a team member designated a role or delegated a task was divided by the total time of the exercise. Similarly, the frequency of closed-loop communication was calculated from the number of instances, in which team members utilized closed-loop communication. Video analysis was also used to determine the time duration between hemodynamic or respiratory perturbation (change in vital signs or critical laboratory value) and appropriate therapeutic intervention by the team. Appropriate intervention was defined as adenosine administration or cardioversion for SVT, defibrillation for ventricular tachycardia, bag-mask ventilation or intubation for respiratory distress, and fluid administration or inotropic support for low cardiac output/hypotension. The time duration between perturbation and team response for each group was plotted over time.

### Program evaluation/assessment

At the conclusion of the simulation training program and at 1 month after its completion, participants completed a questionnaire in which they assessed the improvement in their team dynamics as a result of simulation training. Questionnaires were specifically designed to determine integration of closed-loop communication, role clarity, and idea acceptance into their clinical practice as a result of simulation exercises [Table 1]. In addition to these questions, participants were asked to rate their overall improvement in team dynamics, the improvement in patient care attributable to improved team dynamics, and how often they thought simulation should be repeated.

### Statistical analysis

Results of questionnaires completed by participants were collected, and the median score for each question was displayed. A Friedman test was utilized used to detect differences in participant scores across multiple test attempts. $P < 0.05$ was considered to be statistically significant. Participants who did not participate on day 1 but joined for later simulation exercises were excluded from this analysis. Nonparametric comparisons of responses from different groups of respondents (nurses, physicians in training, and doctors) were performed using a Mann–Whitney U-test. Spearman rank correlation test was used to detect the association between training day and communication or role clarity score, with a significant $P$ value indicating a relationship between the variables.

## RESULTS

### Demographics

A total of 23 participants participated in eight simulation sessions over a 5-day period. Nurses ($n = 8$), anesthesiologists ($n = 8$), surgeons ($n = 6$), and cardiologists ($n = 1$) were divided into two groups and participated in four simulation sessions each.

### Presimulation questionnaire

The median responses to the questions given in the presimulation questionnaire are displayed in Table 2. The median score for each of the six questions was 1 – "strongly agree/excellent" or 2 – "agree/good," indicating a perception of overall proficiency in team dynamics before simulation.

### Daily participant questionnaires

Table 3 depicts the median participant response given to the six questions asked on the daily participant evaluation administered after each simulation session over the 4-day training program. A significant improvement in each component of team dynamics (role clarity, effective communication, and idea acceptance) was detected over the study period by a Friedman test ($P < 0.05$).

### Observer analysis

Time to intervention following a perturbation in hemodynamic or respiratory status decreased

**Table 1: Questions asked in participant questionnaires by component of team dynamics**

| | Role clarity | Effective communication | Idea acceptance |
|---|---|---|---|
| Presimulation questionnaire | Q1: Roles are defined clearly | Q2: Comfortable seeking help from peers<br>Q3: Problems are presented clearly<br>Q4: Understand the thresholds for communication | Q5: Ideas are valued |
| Daily participant evaluation | Q1: You understood your role<br>Q2: Others understood roles | Q3: Problems were presented clearly<br>Q4: Understood the thresholds for communication<br>Q5: Overall communication during exercise | Q6: Ideas were valued |
| Postsimulation questionnaire | Q1: Roles are more clearly defined<br>Q2: More likely to define roles | Q3: More comfortable seeking help from peers<br>Q4: More comfortable expressing ideas to supervisor<br>Q5: More comfortable speaking up in a crisis<br>Q6: More likely to use closed-loop communication<br>Q7: Higher understanding of thresholds for communication | Q8: Ideas are valued more |
| 1-month follow-up | Q1: Roles are clearer<br>Q2: How often are roles defined | Q3: More comfortable seeking help from peers<br>Q4: More comfortable expressing ideas to supervisor<br>Q5: How often is closed-loop communication used | |

**Table 2: Presimulation questionnaire data**

| Question asked | Median score (IQR) |
|---|---|
| Roles are clearly defined | 2 (1-2) |
| Comfortable seeking help from peers | 1 (1-1) |
| Problems are presented effectively | 2 (2-2) |
| Understand thresholds for communication | 1 (1-2) |
| Ideas are valued | 2 (1-2) |
| Knowledge base | 2 (2-3) |

1: Strongly agree/excellent, 2: Agree/good, 3: Neutral/fair, 4: Disagree/poor, 5: Strongly disagree/very poor. IQR: Interquartile range

**Table 3: Daily participant questionnaire data**

| Component assessed | Median score (IQR) | | | P* |
|---|---|---|---|---|
| | Day 1 (*n*=15) | Day 2 (*n*=7) | Day 3 (*n*=7) | |
| You understood your role | 1 (1-2) | 1 (1-1) | 1 (1-1) | 0.043 |
| Others understood roles | 2 (2-3) | 1.5 (1-2) | 1 (1-2) | 0.026 |
| Problem presentation | 2 (1-2) | 1 (1-1) | 1 (1-1) | 0.004 |
| Communication thresholds | 1 (1-2) | 1 (1-1) | 1 (1-1) | 0.020 |
| Overall communication | 2 (1-3) | 1 (1-2) | 1 (1-1) | 0.018 |
| Ideas valued | 2 (1-2) | 2 (1-2) | 1 (1-1) | 0.033 |

*Kruskal–Wallis statistical analysis. 1: Strongly agree/excellent, 2: Agree/good, 3: Neutral/fair, 4: Disagree/poor, 5: Strongly disagree/very poor. IQR: Interquartile range

over the course of the training program [Figure 3]. The total frequency of communication increased significantly ($P < 0.01$) from 2.2 to 4.9 communications per minute for Group 1, whereas the change in communications per minute for Group 2 was not statistically significant (2.3–3.8, $P = 0.07$). The frequency of role clarity also increased over the training period for both groups, rising from 1.3–2.1 to 0.5–1.4 role clarifications per minute for groups 1 and 2, respectively. There was no statistically significant difference in the aggregate performance of Group 1 compared to Group 2.

### Postsimulation questionnaire

Figure 4 depicts the participant responses to the postsimulation questionnaire. A median response of 1 or 2 to each of the six questions indicates a perception of significant improvement due to simulation training. Scores provided by nurses on this questionnaire differed significantly from scores provided by physician staff (median score 1 [1–1] vs. 2 [2–2], respectively, $P < 0.01$).

### Follow-up questionnaire

Table 4 displays the median scores provided by participants to the questions asked in the 1-month follow-up questionnaire. A median response score of 1 (interquartile range [IQR] 1–2) was observed for questions regarding continued improvements in team dynamics. A median score of 2 (IQR 1–2) was observed for questions related to ongoing closed-loop communication in their clinical practice. Regarding optimal frequency of simulation training, 6 out of 14 respondents expressed "every month," 2 out of 14 expressed "once every 3 months," and 6 out of 14 respondents expressed "once per year."
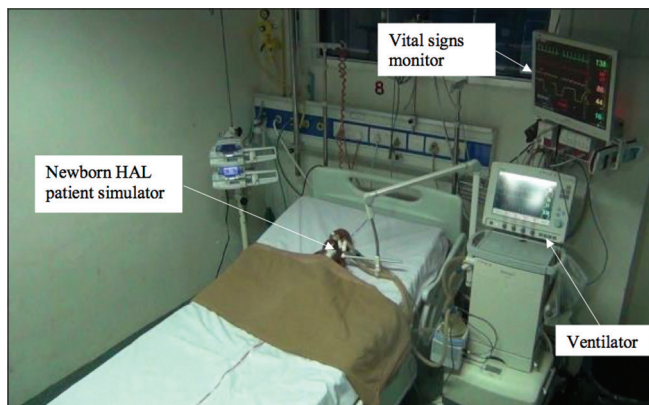
### Discussion and analysis

The purpose of this study was to investigate the effectiveness of simulation training in promoting better team dynamics among pediatric CICU caregivers in a low-resource health-care setting. The major findings were that a short simulation training session can improve participant and observer perception of team dynamics as well as time to therapeutic intervention in such healthcare environments.

Its feasibility, low cost, and high impact make simulation, a technique that is ideally suited for low-resource health-care settings in developing countries. Although this study utilized the Newborn HAL device, previous studies have shown that the type of simulator does not appreciably impact results.[12,13] The technology necessary to perform low-fidelity simulation by creating a realistic crisis environment – mannequin, monitor, and laptop with software to control monitor output – can be accessible to low-resource hospitals. Equipment necessary to conduct simulation training exercises described in this study ranges in cost from United States Dollar (USD)
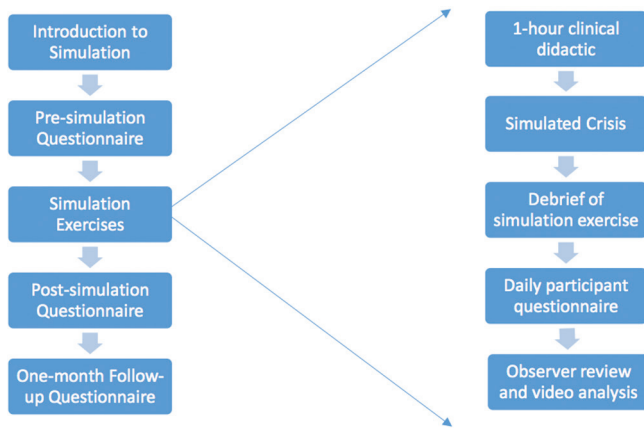
**Figure 1: Timeline of overall simulation course and daily simulation sessions including questionnaires and didactics**



**Figure 2: Schematic depicting simulator and monitor setup**

**Table 4: 1-month follow-up questionnaire data**

| Question | Median response (IQR) |
| --- | --- |
| Role clarity has improved because of simulation | 1.5 (1-2) |
| How often do you define roles in a crisis | 2 ("often") (2-3) |
| You are more comfortable asking for help because of simulation | 1 (1-2) |
| You are more comfortable speaking up because of simulation | 2 (1-2) |
| How often do you use closed-loop communication in a crisis | 2 ("often") (2-3) |
| Simulation has improved communication overall | 2 (1-2) |
| Simulation has improved patient care overall | 2 (1-2) |
| How often do you think simulation should be repeated | 3 ("once every 3 months") (2-4) |

1: Strongly agree/excellent, 2: Agree/good, 3: Neutral/fair, 4: Disagree/poor, 5: Strongly disagree/very poor. IQR: Interquartile range

500 to USD 2500, with negligible costs for reusable supplies and equipment maintenance. The mannequin is reusable and generally lasts for 3–5 years with regular use. Thus, the low cost, practical structure, and limited personnel time commitment make simulation a feasible tool for improving team dynamics in low-resource CICU environments.

The significant improvement in perceived team dynamics before and after simulation despite high baseline ratings suggests unrecognized potential for improvement of team dynamics. Participants may not have noticed the deficiencies in their team dynamics until they participated in simulation exercises. Thus, simulation training reveals deficiencies in team dynamics and motivates self-improvement. Importantly, participants reported that improvements in role clarity, closed-loop communication, and idea acceptance persisted beyond the immediate training period.

Analysis of simulation videos by the blinded reviewer revealed significant improvement in objective metrics of team dynamics and time to therapeutic intervention as simulation training progressed. As these data are less susceptible to subjective assessment and observer bias,

they provide important evidence to support the value of simulation training. Furthermore, since the interventions performed in simulation scenarios required complex interactions among team members, the improved time to response cannot simply be attributed to improvement in technical proficiency of individual participants.

Not only did simulation training have an immediate impact on team dynamics within the simulation environment, but participants reported sustained effect up to 1 month following training exercises. The sustained effect of simulation training has been reported in several studies, but the duration of effect is not known. The durability is dependent on multiple factors including staff turnover rate, experience level, and case mix complexity.

Although this study was not designed to determine the optimal frequency and duration of training programs, most participants indicated that training every 3–6 months would be optimal in the 1-month follow-up questionnaire. The current recommendation for frequency of training in centers that regularly perform simulation training is every 6 months.

The personnel required to conduct simulation training includes at least two nursing staff members, an intensivist or anesthesiologist, a surgeon, and an educator who provides simulation scenario and conducts feedback sessions. The necessary personnel can be located within the institution with appropriate training of the educator. An effective educator is critical to the success of the simulation training program. This individual should be a medical caregiver by training, either nurse or physician. Educator skills of facilitation, debriefing, and root cause analysis can be developed by attending several "train the trainer" courses that are available worldwide.
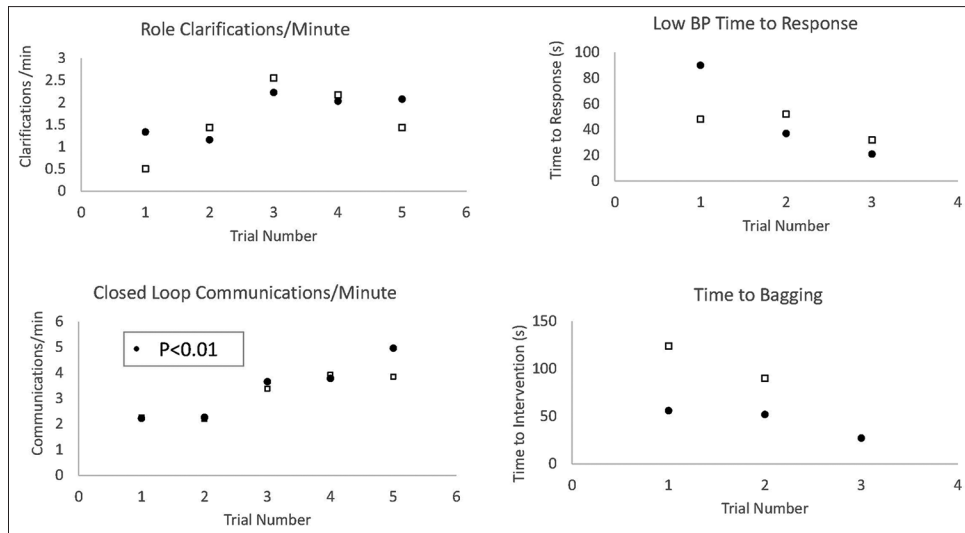
**Figure 3:** Time to response following perturbations in clinical status during simulated scenario and the frequency of closed-loop communication and role clarity are plotted as a function of simulation trial number. Group 1 data are shown in closed circles and Group 2 data are shown in open circles. Group 1 demonstrated a significant increase in the frequency of closed-loop communication (*P* < 0.05)
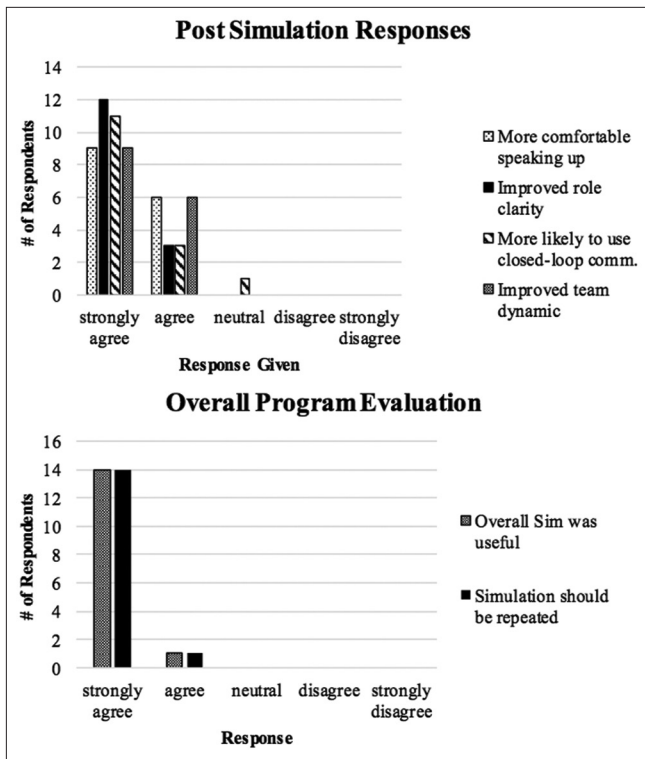


**Figure 4:** Participant responses to questions in the postsimulation questionnaire are given in bar graphs

Nursing empowerment is a key feature of improvement in team dynamics, especially in developing countries where steep hierarchy provides barriers to communication between nurses and physicians.[14,15] In this study, there was a trend toward nurses perceiving greatest improvement in components of team dynamics, suggesting a large potential for improvement among nurse participants. In environments where baseline levels of nursing empowerment and engagement are low, simulation training may demonstrate the value of nursing engagement and autonomy. By demonstrating the value of nursing engagement and establishing an expectation of nursing empowerment, simulation may also serve to improve professional practice models in developing countries.

There are several important limitations to this study. First, this is an observational study without comparison to a control group. Second, the sample size for this study was relatively small, thus limiting the power of the study. Finally, since this is a single-center study, results may not be generalizable. A multicenter controlled study is necessary to confirm the utility of simulation training in such health-care settings.

## CONCLUSIONS

Simulation training implemented in low-resource environments can result in significant improvements in communication among caregivers as well as decreases in response times to key resuscitation interventions. Furthermore, simulation fosters a culture of open communication and idea acceptance which are traditionally problematic in low-resource settings. Its feasibility and affordability make it a practical tool for improving team dynamics in low-resource medical environments, and its widespread application warrants further investigation.

### Financial support and sponsorship

### Conflicts of interest

There are no conflicts of interest.

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