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Article

Creating High Reliability Teams in Healthcare through *In situ* Simulation Training

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Abstract: The importance of teamwork on patient safety in healthcare has been well established. However, the theory and research of healthcare teams are seriously lacking in clinical application. While conventional team theory assumes that teams are stable and leadership is constant, a growing body of evidence indicates that most healthcare teams are unstable and lack constant leadership. For healthcare organizations to reduce error and ensure patient safety, the true nature of healthcare teams must be better understood. This study presents a taxonomy of healthcare teams and the determinants of high reliability in healthcare teams based on a series of studies undertaken over a five-year period (2005–2010).

Keywords: team formation; *In situ* simulation; behavior markers; active failures; high reliability; interdisciplinary teams

1. Introduction

Effective teamwork and communication in healthcare teams has long been recognized as essential for patient safety. Since the early 1990s, research on healthcare teams has indicated that communication and collaboration have an important effect on patient morbidity and mortality [1-3]. The landmark Institute of Medicine (IOM) report *To Err is Human* emphasized the importance of teamwork and communication in healthcare by concluding that the healthcare system is unsafe and errors can be prevented by improved teamwork and systems design [4]. In subsequent reports, the IOM indicated that healthcare teams are poorly understood and the quality of communication varies extensively across healthcare teams, with serious consequences for patient safety [5,6].

In recognition of the importance of teamwork, there has been growing attention to understanding healthcare teams and providing team training to improve performance. Conventional team theories developed in industry have been used to describe healthcare teams [7]. These theories assume that most professional teams are formally established and have stable membership with the opportunity for extensive team training [7]. Team development, including the evolution through the typical phases of forming, storming, norming, and performing, as well as stable team leadership are key features of conventional teams based on traditional team theory [8,9]. With this understanding of healthcare teams, most training efforts have focused on either enhancing the technical skills of individuals or training stable teams to reach a level of high collective performance [10]. However, the traditional model of teams does not adequately address the dynamic, complex nature of the healthcare setting in which teams function, and the need for an expanded theoretical understanding of healthcare teams and how to best train them for high performance has been recognized.

This article proposes a new understanding of healthcare teams based on a set of studies of rapidly formed teams undertaken over a five-year period (2005–2010). We use *In situ* simulation of obstetrical emergencies to explore the determinants of high reliability in healthcare teams. Unlike laboratory simulation, in situ simulation is a team-based simulation strategy that takes place in the setting in which patient care is delivered [11]. Because it takes place where teams normally function, in situ simulation uncovers latent conditions in the environment and organizational processes that contribute to medical error [12,13]. *In situ* simulation has been effectively used in this series of studies both as a research methodology to better understand healthcare teams and as a powerful training method to improve team behavior and communication.

There is a wide variety of types of teams in healthcare organizations. While conventional management theory and research apply to non-clinical healthcare teams, they have serious limitations for understanding the critical event teams that make up the subjects of our *in situ* simulation training and research. In this article, we present a summary of our research to expand on the conventional understanding of teams by presenting a taxonomy of three types of clinical teams in healthcare, including a conceptual model of the importance of teamwork in high reliability. Next, we review the *in situ* simulation methodology and results of a multi-year serial study involving 6 hospitals, 46 simulation trials, and 892 staff that examined the effect of *in situ* simulation on the behavioral markers, breaches, and health outcomes of obstetric unit teams. Our recommendations include strategies to improve high reliability, enhance team performance, and reduce patient injury through interdisciplinary team training.

2. Taxonomy of Healthcare Teams

The conventional model of stable teams with constant leadership does not apply to the majority of healthcare teams. Our research with critical event teams has led to a conceptual taxonomy of clinical healthcare teams to describe their true complexity, most of which do not have stable membership. Table 1 shows the three types of healthcare teams in this model: (1) ongoing teams; (2) microsystem teams; and (3) rapidly-formed teams. An ongoing team fits the conventional understanding of healthcare teams as stable with fixed leadership. Ongoing teams have formally established structure and goals, and team members work together in a consistent manner over time. The four stages of forming, storming, norming, and performing are common features of ongoing teams [8]. Medical procedure labs, small private practices, and community pharmacies are a few examples of ongoing healthcare teams.

Table 1. Taxonomy of clinical healthcare teams.

Type of Team	Features	Example	Team Members	Duration	Term
Ongoing (conventional)	Fixed staff with common training and stable leadership	GI procedure lab	−1 MD −2 RN −2 support staff	Worked for 4 years together	52 weeks per year, 3 days per week (M, W,F), 8 hours per day
Microsystem	Fixed and variable staff with a common work environment and common tasks	Orthopedic surgery unit	−8 MD −1 Fellow −1 Resident −25 RN −2 Med students −15 CNA −2 float staff	Some have worked together for years, some rotating through short term	Varies by staff member (MD is permanent staff, fellow is one year, float staff could be one day)
Rapidly-Formed	Temporary and spontaneous with limited or no previous team interaction	Obstetrics emergency	−1 MD −1 MDA −1 CRNA −3 RN −1 HUC −1 NNP −1 Scrub Tech −1 SCN nurse	Identical combination of staff are not likely to have worked together	Any time, 24/7

Most inpatient healthcare teams can be described as clinical microsystem teams, defined as the smallest organizational unit where patient needs are met and value is created [14]. A microsystem can be made up of the clinical unit that provides the basic building block of care: a small group of healthcare professionals and support staff working together with the shared goal of providing patient care [15]. An example of a clinical microsystem team is the staff of an orthopedic surgical unit. Such microsystem teams can achieve high performance by emphasizing value and creating a culture of safety [16]. Though often perceived as stable, the team members of a clinical microsystem team include both fixed and variable staff serving in the unit for different lengths of time. Although the concept of a microsystem team can be applied in both an inpatient and outpatient setting, we use it in an inpatient context.

A rapidly formed team is comprised of a group of healthcare staff that comes together unplanned to address a specific, often emergent, purpose [17]. Though rapidly formed teams usually consist of highly trained professionals, they might not know each other, they are unlikely to have all worked together previously, and they are unlikely to ever perform together again in the same configuration. Rapidly formed teams, which are also referred to as contingency teams [18], temporary teams [19], action teams [20], and critical event teams [12] face more significant complexity and time pressures than other types of healthcare teams. An example of a rapidly formed team is a code team that forms on an inpatient unit in response to an emergency.

Table 2 illustrates an example of the staff members of a microsystem team in an adult orthopaedic surgical unit at a teaching institution. A total of 105 staff members are present on the unit in the course of a year, making up the seven disciplines that can combine to form a team. There are a total of 10.8 million combinations of patient care teams possible within this clinical microsystem over the course of the year on the unit (8 × 1 × 6 × 30 × 25 × 15 × 20 = 10,800,000). Table 2 also shows the time each individual in a staff position has likely spent on the unit, ranging from years for permanent MD, RN, and technicians to weeks for residents and students to days for float staff. Though the orthopedic surgery unit itself is a stable microsystem within the hospital, the teams within the unit exhibit significant variability in membership.

Table 2. Example of a microsystem team: Adult orthopedic surgery unit at a university hospital.

Position	**Number in Unit**	**Time on Unit**
Attending physicians	8	Varies (months to years)
Medical fellows	1	One year
Medical residents	6	Six weeks
Medical students	30	Two weeks
Orthopedic Surgical Nurses	25	Varies (months to years)
Certified Nursing Assistants	15	Varies (months to years)
Float nurses and technical staff	20	Day(s)–week(s)
Total Staff	105	
Total combinations of teams possible: 10.8 million		

Table 3 shows an example of a rapidly formed team in the labor and delivery unit of one hospital [21]. A total of 208 staff members make up the six disciplines needed to form a critical event team during an obstetrics emergency. As the table shows, there are a total of 381 million possible combinations of teams that could form in this hospital in response to a single obstetrics emergency (81 × 50 × 16 × 12 × 14 × 35 = 381,000,000), suggesting that any team consisting of the same individuals is very unlikely to happen more than once.

Table 3. Example of rapidly-formed team possibilities for an obstetrics emergency.

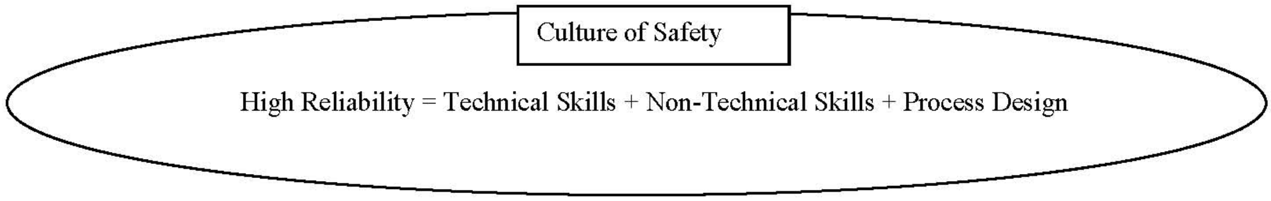
Position	**Number in Unit**
Obstetricians	81
Labor and Delivery Nurses	50
Anesthesiologists	16
Neonatal Nurse Practitioners	12
Scrub Technicians	14
Certified Registered Nurse Anesthetists	35
Total Staff	208
Total combinations of teams possible: 381 million	

Traditional team training in healthcare is based on the theory that teams must train together to achieve high performance. However, as the above examples show, the majority of clinical, inpatient healthcare teams are profoundly unstable and dynamic, and training specific team combinations is impractical. A new model for understanding clinical teams and methods for training teams is needed to address their true nature and complexity.

3. High Reliability Teams

High reliability in healthcare is a method to ensure patient safety and quality of care based on systems design and non-technical skills [22]. High reliability is a concept from safety critical industries and is defined as defect-free operations for long periods of time [23,24]. A high reliability organization implements specific training to minimize errors [25] and achieves consistent quality and safety in patient care [4]. High reliability is especially important in healthcare organizations, where the cost of errors is high but errors happen infrequently [26]. Figure 1 presents a model for high reliability healthcare teams. According to the model, high reliability is a function of technical skills and non-technical skills of trained professionals and the process design of the system [27].

Figure 1. Model for high reliability teams [27].



Technical skills are the training, competence, and commitment of healthcare professionals. Education of healthcare professionals involves intense training curricula in accredited programs with ongoing, government mandated certification requirements. This high level of technical education and skill is the best developed component of health care reliability [27]. However, the technical skills and commitment of individual providers cannot counter balance the complexities of the health care systems [28] or compensate for inevitable human fallibility [29]. For these realities, non-technical skills and intentional process design are necessary for high reliability.

Non-technical skills are the cognitive and interpersonal competencies that allow for effective team performance through constructively monitoring team performance, knowledge of team roles, and a positive attitude towards working with others [26,30,31]. Two of the most important non-technical skills include communication and teamwork [32]. The third component of high reliability is the design of health care processes. All of the elements of patient care occur as the result of a process, defined as a series of steps to produce an outcome. Healthcare processes are rarely designed for quality and safety [33], leading to deterioration in system performance over time [25].

In spite of a highly committed and trained medical staff, medical care is not safe for patients and fails to deliver high quality [34]. High reliability is not commonly achieved in healthcare organizations or teams due to the failure of teamwork, communication, and process design. This model provides the conceptual framework for the use of *in situ* simulation as a training method to improve teamwork and communication and to uncover unsafe process design.

4. Research Methods

This article provides a compilation of the results and conclusions of a series of studies done over a five-year period. All necessary approvals were obtained to conduct the research in the described studies, and the hospitals and private medical staff volunteered their facilities and participation for the simulation exercises. Obstetrics crises were selected because they occur in a compressed timeline, they can be simulated *in situ*, and previous studies indicated that over 70 percent of critical events in obstetrics resulted from poor team communication and functioning [35]. The *in situ* simulation methodology, data collection, data analysis, variables and measures, and data sources for this set of studies of team performance in hospitals is described.

4.1. In situ *Simulation*

In situ simulation is a high fidelity, team-based simulation strategy that occurs in the setting in which patient care is given [13]. In this compilation, *in situ* simulation was used as both as a research methodology to study the nature of healthcare teams and as a training method to improve health outcomes. The series of 8 studies included 46 trials simulated critical events at six different hospitals representing 11,000 deliveries per year [36]. The simulated scenarios involved 823 physicians, nurses, and support staff over a five-year period (2005–2010). There were an average of 20 professional participants in each simulation, including an obstetrician, labor and delivery nurses, neonatal nurse practitioners, certified registered nurse anesthetists, a unit coordinator, and operating room staff [12].

In situ simulation involves four components: (1) a briefing for participants; (2) a simulation scenario based on actual adverse events, performed using a combination of standardized patients and manikins; (3) a structured debriefing session with all participants; and (4) correction of process issues recognized in the simulation [12]. All participants were first briefed about the purpose of the training experience and its focus on communication over technical skills [13]. The need to suspend disbelief and treat the simulated event as if it were real was emphasized [13]. Also, the briefing was used to set ground rules and establish trust. Participants need reassurance that the emphasis is on process design and team communication and there will be no repercussions for individual error or poor performance.

The simulation scenarios were based on critical obstetric events that had taken place in participating hospitals and were designed to prompt nontechnical skills [12]. Each scenario included triggers to elicit specific human behaviors that could then be measured [13]. An *in situ* obstetric critical event requires a labor and delivery room, a fetal heart tone simulator and monitor, a cervical dilation box, standardized patients, a fully equipped operating room, and two manikins [13]. Each simulation began with a nurse encounter with a patient in labor and a significant other. The simulations then go through the six typical stages of progression in an obstetric critical event [12], ending with a "code" caesarean delivery. Simulations were videotaped with both still and hand-held cameras to capture the interactions between team members [37].

Debriefing following the event took place with all participants in a conference room with the audio-video capacity to review the film from the simulation. Two expert debriefers facilitated (one obstetrician and one clinical nurse specialist). Each debriefing session was held for approximately two hours. This is far longer than most debriefing sessions and allowed participants to express their feedback on team performance and their concerns and ideas regarding patient safety [13]. The two directional structured debrief [38] began with the junior member of the team and provided each participant a chance to comment in turn [37]. The film was then reviewed and participants were given another chance to comment. Communication failures, teamwork breakdowns, and latent conditions in the physical environment were documented throughout the debriefing. During the final follow-up phase selected improvements for patient safety and care processes were made in the clinical unit as well as outside the clinical unit. The support of administrators to implement participant identified improvements at this juncture is critical [13].

4.2. Variables and Measurement

The variables identified in this series of studies include team formation/reformation, behavioral markers, breaches, and the Weighted Adverse Outcome Score (WAOS). These variables are described in Table 4.

Table 4. Description of measured variables.

Variable	Description
Team Formation/Reformation	Formation occurs when an interprofessional group with special expertise assembles to execute a task; reformation occurs when team membership or the nature of the task changes [12]
Leadership	Establishment of a person who is physically present to prioritize decisions, coordinate activities, and communicate a shared mental model
Leadership Transfer	An explicit handoff of leadership from one team member to another
Situational awareness	Conscious recognition of salient factors and conditions that contribute to safe practice that comes from monitoring surroundings and redesigning the care plan based on changing conditions [12]
Closed-loop communication	Verbal exchanges between parties who acknowledge receipt of information with reciprocal verbal interactions, in which all key information is exchanged and recommendations are verbally acknowledged [12]
Shared mental model	A common understanding of the situation and plan by all team members [12]
Breach	A gap in a defensive barrier that could lead to patient injury [42]
Weighted Adverse Outcome Score	A quality indicator representing the average adverse event score per delivery [43]

Team formation takes place when a group of persons with the necessary expertise assemble to execute a specific task, while instances when the team membership changes in a significant way by the addition or deletion of members is called *team reformation* [12]. The behavioral maker measures were determined by an evidence-based framework for best practices in healthcare teamwork developed by the Agency for Healthcare Quality and Research (AHRQ), in which five "excellent" behaviors are identified: leadership, leadership transfer, situational awareness, closed-loop communication, and shared mental model [39,40].

In medicine, an error has been defined as the failure to complete an action as intended or the use of a wrong plan to achieve an object [41]. A defensive barrier is a designed element of a system to prevent hazards from causing patient harm [29], and a breach as a gap in a defensive barrier that could lead to patient injury [42]. A breach is a failure of performance or of systems design that has the potential to lead to patient injury through the progression of accident trajectory [36]. The Weighted Adverse Outcome Score (WAOS) is a metric that evaluates the effects of teamwork on obstetrical outcomes [42] The WAOS is constructed from a set of ten weighted adverse obstetrical outcome measures and is a summary indicator representing the average adverse event score per delivery [43]. The WAOS weighting system adjusts for the severity of adverse events, unlike other obstetrical outcome indicators [44].

4.3. Data Collection and Analysis

The videotapes of simulated emergencies were extensively analyzed by medical and safety experts to identify team dynamics, team behaviors, and medical breaches [12,13,45,46,36]. Team dynamics were documented based on observed changes in team composition throughout the stages of the critical event simulation [12]. Observational tools for measurement of the behavioral marker measures were developed based on an in-depth literature review. The tool scored each behavioral marker on a scale of 0 (behavior occurred less than 50 percent of the time), 1 (behavior occurred between 50 and 90 percent of the time), and 2 (behavior occurred more than 90 percent of the time) [12]. Expert inter-rater reliability was established using the Kappa (κ) statistic for each measure. Two experts viewed and rated each film independently, and a κ greater than or equal to 0.61 was considered acceptable [47]. Table 5 provides the kappa (κ) scores for each behavioral marker measure, listed by phase of the response.

Table 5. Kappa (κ) scores for each measure of the observation instrument [12].

Measure	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Situational awareness	1.00	0.79	0.86	1.00	0.75	0.89
Shared mental model	0.81	0.71	0.75	0.84	0.67	0.80
Closed-loop communication	0.76	0.69	0.67	0.71	0.84	0.78
Leadership transfer explicitly conceded	N/A	0.75	0.80	N/A	0.80	0.81
Leadership established	0.89	0.82	0.84	1.00	0.81	0.84

Breaches were identified through the debrief sessions when a participant identified a team behavior that was necessary for patient safety but did not occur during the simulation [36]. This qualitative research methodology emphasizes the iterative nature of discovery in the study of human performance and teamwork [36]. Each breach was documented and subsequently classified as either an active failure or a latent condition. Using Reason's model, an active failure is an unsafe act committed at the patient/provider interface with immediately apparent consequences, and a latent condition is a dormant condition created as a result of decisions at higher organizational levels whose damaging consequences may be triggered by local situations [29,48]. Descriptive analysis was then conducted on the observed instances of team formation/reformation, the behavioral marker scores, and identified breaches.

In the final phase, the effect of a series of *In situ* simulated obstetrics emergencies on perinatal outcomes of three community hospitals was studied [44]. Outcome data were collected on all women admitted to the hospital for labor during the three year study period, allowing the calculation of WAOS scores for each hospital. Control charts and statistical process control methods were then used to quantify the performance of the process over time, and bivariate and multivariate relationships between key study variables were analyzed using Wilcoxon's rank sum test to determine normal distribution, the χ^2 test, and Fisher's exact test when sample sizes were below five [44].

4.4. Data Sources

The data for this compilation were obtained from the 8 studies in the *in situ* simulation series. Table 6 summarizes the major methods and results of each of the 8 studies.

Table 6. Series of *in situ* simulation studies in obstetric units.

Authors	Year	Methods	Primary Results
Riley, Hansen, Gurses, Davis, Miller, and Priester [12]	2008	Content analysis of video of 16 simulations at six sites for stages of response and behavioral markers	Critical response teams are not stable and have constantly changing leadership
Riley, Miller, Davis, and Sweet [21]	2008	Content analysis of video of 10 simulations in one suburban hospital for safety breaches	An average of 19.2 safety breaches occurred per trial, of which 52.6% were latent conditions and 47.4% were active failures
Davis, Riley, Miller, and Hansen [45]	2008	Descriptive study of the effect of 12 simulations in one hospital on the culture of safety and the identification of common failure modes	The most frequent failure modes in the obstetric unit were identified. Simulation was shown to improve the teamwork and safety climate of the obstetric unit.
Riley, Davis, Miller, Sweet, and Hansen [49]	2008	Content analysis of video of 16 simulations in two hospitals for errors by category	An average of 20.2 errors occurred per simulation trial, 55% of which were the result of failures to comply with policy/procedure or poor communication
Davis, Riley, Gurses, Miller, and Hansen [37]	2008	Content analysis of video of 10 simulations in one hospital for identification of failure modes	The ten most common failure modes were identified, of which five were active failures and five were latent conditions
Miller, Riley, and Davis [46]	2009	Content analysis of video of 17 simulations at four sites for communication behaviors of nurses	Key nursing communication behaviors are not consistently observed during critical events
Riley, Davis, Miller, Hansen, and Sweet [36]	2010	Content analysis of 46 simulation trials for identification of safety breaches	An average of 20.8 breaches occurred per simulation trial, of which 47.8% were latent conditions and 51.2% were active failures
Riley, Davis, Miller, Hansen, Sainfort, and Sweet [44]	2011	Small cluster randomized clinical trial to test the effect of OB *in situ* simulation training on perinatal health outcomes	*In situ* simulation training led to a 37% improvement in perinatal morbidity in the treatment hospital (*vs.* comparison hospital)

5. Research Findings

The proposed taxonomy of three types of clinical healthcare teams was based on the results from 8 studies of critical event teams. The results from each of the 8 studies in the series were critically examined and compiled by 8 variables: team formation/reformation, each of the behavioral markers, breaches, and health outcomes.

5.1. Team Formation/Reformation

In the first study of the series, six distinct, recurrent stages were identified in each critical event, delineated by team formation or reformation [12]. Each stage was characterized by different tasks for the team to perform and different team composition. These six stages were repeatedly observed and verified throughout the series, indicating that team reformation based on changing tasks is predictable in defined critical events. Team membership was found to be fluid throughout the stages in response to the changing responses needed. The average number of people involved in the response ranged from 3.4 to 12.6 depending on the stage, and the overall range of people involved at any given time ranged from 1 to 19 [12]. Teams formed and reformed without deliberate design or selection and without time for planning. These results indicate that the structure of rapidly formed teams is dynamic and unstable within a single event and across multiple critical events.

5.2. Behavioral Markers

Our studies on behavioral markers indicate that best-practice for high performing healthcare teams is sporadic and uneven. Findings from a video review of 16 simulated events indicated that "excellence" was achieved in establishing leadership and situational awareness 58 and 50 percent of the time, respectively, while "excellence" in shared mental model was noted 36 percent of the time, in closed-loop communication 21 percent of the time, and in leadership transfer only 20 percent of the time [12]. These results are summarized in Table 7, separated by stage of response.

Table 7. Proportion of "excellent" behavioral markers by stage (%) [12].

Behavioral marker	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Average
Establishing Leadership	69	54	64	60	36	64	58
Leadership transfer	N/A	14	13	N/A	27	22	20
Situational awareness	69	58	67	56	44	57	50
Closed-loop Communications	19	17	40	27	0	25	21
Shared mental model	44	33	40	50	25	17	36

The importance of the leader of a healthcare team emerged throughout the study results. The physical presence of the leader was identified as essential to leadership during a critical response, because only a leader who is physically present is able to maintain team performance through a shared mental model [12]. Establishing leadership was found to be the most reliably achieved behavioral marker among critical event teams. However, one consistent leader was not present through an entire event due to the changing dynamics of the team. Leadership transfer occurred continuously throughout critical events; yet "excellent" leadership transfer occurred only 20 percent of the time and was routinely the lowest performing behavioral marker.

Situational awareness was found to be maintained approximately 50 percent of the time overall, though teams were more likely to lose situational awareness during the most critical stages of the response [12]. Shared mental model and closed-loop communication are both extremely important to high performance in team responses, yet both consistently occurred less that 50 percent of the time. In addition, a lack of situational awareness and shared mental model were identified as the second and third most common active failures in simulated events [36].

5.3. Breaches

The in situ simulation methodology identified numerous safety breaches in the obstetric unit. Three analyses showed a similar number of average breaches per critical event, with 19.2, 20.2, and 20.8, respectively [21,49,36]. Table 8 shows the results of 16 trials with a total of 323 breaches categorized by type, ranked in descending order. Lapses in policies and procedures and ineffective communication were found to be the most common types of breaches.

Table 8. Breaches in defensive barriers: location and size of holes [49].

	Frequency	**Percent**
Policy and Procedures	90	27.8
Communication	88	27.2
Shared Mental Model	52	16.1
System Process	37	11.4
Equipment and Environment	34	10.5
Situational Awareness	22	6.8
Total	**323**	**100**

A similar proportion of breaches were found to be active failures across studies: 47.4% and 51.2% [37,46]. Table 9 shows raw number of breaches identified through 46 trials in six hospitals [36]. The proportion of breaches by category as active breach or latent condition is shown for each hospital and for the combined hospitals, including a 95% confidence interval. Table 10 shows the percentage of breaches in this study by category. Overall, it was found that 55% of all active failures leading to patient error in the hospital setting are caused by poor teamwork [36].

The findings from the simulation debriefing allowed for Failure Mode and Effects Analysis (FMEA) to be conducted in several of the studies [45,36]. The Joint Commission's model for FMEA was used [50]. Based on these analyses, the most common failure modes were identified as: (1) unclear role definition of team members; (2) inconsistent process for ordering blood to the operating room; and (3) lack of closed loop communication [37,21].

Table 9. Raw numbers and proportion of breaches by hospital and per simulation: latent conditions and active breaches [36].

		Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	All hospitals
Latent	N	101	58	60	69	40	133	461
Conditions	Mean/Trial	10.1	7.3	10.0	17.3	10.0	9.5	10.0
	% of Hospitals	53	48.0	46.0	66.0	45.0	43.2	47.8
	95% CI	47.5–61.6	33.6–54.3	35.4–56.2	56.5–76.2	35.1–55.9	32.8–53.5	37.8–58.7
Active	Facility	91	74	71	35	48	175	494
Breaches	Mean/Trial	9.1	9.3	11.8	8.8	12.0	12.5	10.7
	% of Hospitals	47.0	52.0	54.0	34.0	55.0	56.8	51.2
	95% CI	37.0–57.8	45.7–66.4	43.8–64.6	23.8–43.5	44.1–64.9	46.5–67.2	41.3–62.2
Total	N	192	142	131	104	88	308	965
	Mean/Trial	19.2	17.8	21.8	26.0	22.0	22.0	20.8
	% of Hospitals	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total Simulations		10	8	6	4	4	14	46

Table 10. Relative proportion of breaches by category by hospital [36].

Category	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	All Hospitals
Latent conditions							
Policy/procedure (%)	29.2	23.2	26.0	34.6	25.0	14.0	23.2
Equipment	10.4	2.8	10.7	15.4	11.4	8.4	9.3
System processes (%)	13.0	21.8	9.2	16.3	9.1	20.8	16.3
Active failures							
Situational awareness (%)	5.2	20.4	9.2	9.6	15.9	16.2	13.0
Shared mental model (%)	8.3	13.4	27.5	10.6	14.8	19.2	16.0
Communication (%)	33.9	18.3	17.6	13.5	23.9	21.4	22.3
Total (%)	100	100	100	100	100	100	100

5.4. Improved Patient Outcomes

The most recent study in our series found that *in situ* simulation as an interdisciplinary team training methodology reduced perinatal morbidity [44]. The findings indicated that a process shift occurred in the hospital being trained with *In situ* simulation, with no similar shift occurring in comparison hospitals [44]. Table 11 shows the results of a t-test performed to compare pre- and post-intervention WAOS means for all three hospitals in the study. Again, the only significant change observed was for the full-intervention condition, with a WAOS of 1.15 pre-intervention that fell to 0.72 post-intervention, a 37% decrease in this measure of perinatal harm.

Table 11. Pre-Intervention and Post-Intervention WAOS Means (and Standard Deviations) [44].

Hospital	Pre-Intervention Mean (S.D.)	Post-Intervention Mean (S.D.)	% Decrease (Pre to Post)
Full Intervention	1.15 (0.47)	0.72 (0.12)	37.4% *
Didactic-Only	1.46 (1.05)	1.45 (0.82)	−1.0%
Control	1.05 (0.79)	1.50 (0.35)	−42.7%

* Significant at the 0.05 level.

6. Discussion and Conclusion

This study proposes a taxonomy of three types of clinical healthcare teams based on how they form, why they form, and duration of operation. We focus on the rapidly formed, critical event team and by contrast provide better understanding of conventional teams and microsystem teams. Although the taxonomy is based on empirical studies of rapidly formed clinical teams, the conclusions can be extrapolated to ongoing teams and microsystem teams based on degree of team instability (the number of possible team combinations). This series of studies shows that rapidly formed healthcare teams are dynamic and unstable. Leadership is an important feature of clinical healthcare teams, but it is defined differently based on the type of healthcare team in our taxonomy. For all rapidly formed teams and for many microsystem teams, the leader is the individual who is physically present, prioritizes decisions, coordinates activities, and communicates a shared mental model [12]. This is especially important for rapidly formed teams, because leadership is not consistent throughout critical events and different individuals established leadership at different times. Our studies indicate that leadership transfer occurred frequently but was often not explicit, leading to the potential for a loss of shared mental model and breaches in safety. Leadership transfer is the lowest performing behavioral marker for two major reasons. Firstly, there is very little recognition of the presence and importance of various leaders within healthcare teams. If a leader is defined as the formally assigned individual, such as the physician, then leadership transfer between the physician and other members of the healthcare team is not even recognized. However, our definition of a leader in a critical event requires the leader to be physically present, and the physician is rarely present in the initial phases of a critical event. Secondly, the presence of various leaders in different phases of a critical event is poorly understood. Leaders come in and out of clinical events in predictable ways, but until this study there has been poor documentation of the frequency and distribution of transfers of leadership. It is becoming better understood that a major source of errors and unintended patient injury result from poor handoffs, including inadequate leadership transfer. The notable finding that leadership transfer was routinely the lowest performing behavioral marker indicates that members of dynamic clinical teams are not actively trained to recognize and assume leadership in a systematic way, representing an important area of future training and attention.

In addition, rapidly formed teams illustrate significant variability in their use of best practice behavioral markers such as situational awareness, closed-loop communication, and shared mental model, indicating a deficit in high reliability functioning. The lack of high reliability performance in healthcare teams could be a function of the complexity of the team dynamics [12]. Variable performance may also be a function of the inconsistent leadership found in rapidly formed teams, as different leaders may set different expectations and examples for team members. Also of significance, the individual members that make up the rapidly formed teams often have not had consistent training in these behavioral markers, making their standardized use difficult. Due to this variation and complexity, rapidly formed teams require a different training methodology in team communication to improve the behavioral markers of reliability.

This study also shows that a high number of breaches in defensive barriers take place during critical events, with active failures and latent conditions being equally prominent [36]. This finding suggests that interdisciplinary teamwork training should teach individuals to recognize and prevent active failures, the majority of which include the failure to follow policies and procedures and communication error. Equally importantly, latent conditions in the clinical environment may lead to an error if not corrected. Active recognition, reporting, and correction of these latent conditions is an essential component of team performance and patient safety. *In situ* simulation helps both to provide necessary training and to recognize the latent conditions in a healthcare system, making it an important component of training for organizations that wish to achieve high reliability. Identification of failure modes gives the administrative team an additional framework for implementation of targeted counter-measures and team training that could prevent patient harm.

A significant finding articulated in this body of simulation studies is the notion that appropriate health care team training should focus not on creating 'expert teams' but on creating a 'team of experts'. The dynamic and ephemeral characteristics of rapidly formed health care teams require that individuals are trained in effective team behaviors, rather than that teams be trained together for high performance. Both rapidly formed and microsystem teams are too variable to reliably train teams together. Instead, training for high reliability teams should focus on teaching individuals the non-technical skills needed. *In situ* simulation emerges as a training methodology well suited for this purpose, as it has been shown to effectively improve team performance and patient health outcomes. These results suggest that high fidelity, experiential training is essential for changing the behavior of practicing professionals. In addition, *in situ* simulation is implicated as an important strategy for interdisciplinary team training. To date, no other study of simulation as a training methodology has shown a significant improvement in patient health outcomes. This suggests an important and expanded role for *in situ* simulation training techniques for non-technical skills to achieve high reliability and patient safety.

These findings indicate that the model for understanding and improving healthcare teams must be revised and enhanced. The conventional model of healthcare teams based on long standing teams and stable leadership is inconsistent with the nature and reality of most healthcare teams and how they function. The series of studies reviewed in this article offers refocused perspectives on: (a) the understanding of the nature and true dynamics of healthcare teams; (b) how to apply new research methodologies for studying healthcare teams; (c) models for improving health care reliability; (d) using innovative methods to train inter-professional healthcare teams in a meaningful way; and (e) demonstrating how team behavior affects healthcare safety.

In addition, the lessons learned about creating expert teams using *in situ* simulation can be of value to organizations outside of health care. The use of simulation exercises in emergency response industries such as law enforcement, firefighting, and emergency response is long recognized and has seen growth in recent years, particularly in the area of public health preparedness [51-53]. *In situ* simulation is particularly relevant in these industries, where teams are also rapidly formed in response to an unpredictable and finite event. The industries where the theories of the conventional team were developed can also glean valuable information from the dynamic nature of healthcare teams. Every business has some degree of variability in team composition, from a slow variation of employee turnover over time to the rapid variation of forming transient committees for specific projects, such as a cross functional quality improvement team. Training individuals with the skills to effectively communicate and participate in teams, along with providing the opportunity to recognize areas where active failures occur or latent conditions exist within organizational processes, can be important benefits of *in situ* simulation training in these contexts.

In situ simulation methodology provides a uniform approach to improving patient outcomes through inter-professional team training based on a revised understanding of the true nature of healthcare teams. The cumulative results from this series of studies indicate that resources should be invested in *in situ* simulation to achieve high reliability in healthcare organizations. As a research method, *in situ* simulation provides the understanding of healthcare teams necessary to formulate and support appropriate training and system design. As a training method, *in situ* simulation teaches individuals, rather than fixed teams, to become effective team members through improved communication and team behaviors. The training allows learners to acquire the skills to navigate the complexity of the real clinical environment without risk of harming a patient [54]. Medical professionals prefer meaningful training experiences that can be immediately applied to practice. Perhaps most importantly, *in situ* simulation as a healthcare team training method has been shown to improve patient outcomes. The compilation of findings from this series of studies offers a foundation for better understanding team behavior in healthcare teams and provides an effective team training framework to achieve high team performance and improve patient outcomes.

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