Chapter 44. Crew Resource Management and its Applications in Medicine

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Background

Patient care, like other technically complex and high risk fields, is an interdependent process carried out by teams of individuals with advanced technical training who have varying roles and decision-making responsibilities. While technical training assures proficiency at specific tasks, it does not address the potential for errors created by communicating and decision making in dynamic environments. Experts in aviation have developed safety training focused on effective team management, known as Crew Resource Management (CRM). Improvements in the safety record of commercial aviation may be due, in part, to this training.[1] Over the past 10 years, lessons from aviation's approach to team training have been applied to patient safety, notably in intensive care unit (ICU) and anesthesia training.[2,3] This chapter reviews the literature on Crew Resource Management, also known as Cockpit Resource Management, and describes adaptations of this training framework to medicine.

Practice Description

Crew Resource Management in Aviation

Crew Resource Management has been widely used to improve the operation of flight crews. The concept originated in 1979, in response to a NASA workshop that examined the role that human error plays in air crashes.[4] CRM emphasizes the role of human factors in high-stress, high-risk environments. John K. Lauber, a psychologist member of the National Transportation Safety Board, defined CRM as "using all available sources—information, equipment, and people—to achieve safe and efficient flight operations."[5,6] CRM encompasses team training, as well as simulation (also referred to as *Line-Oriented Flight Training*, or LOFT), interactive group debriefings, and measurement and improvement of aircrew performance.

There is no universal CRM training program. The Federal Aviation Administration (FAA) allows air carriers to customize their CRM programs to best suit the needs of individual organizations. Therefore, training programs vary somewhat from carrier to carrier, making it difficult to describe operational components. Furthermore, these programs continue to evolve as aviation technology changes and more is learned about group dynamics.

One CRM model focuses on the elements of human effectiveness.[7] The 3 primary components of effective crew management are safety, efficiency, and morale. Specific factors related to aircrew performance are categorized, and serve as the basis for training and research. These factors include materials, organization, individual, and group process variables associated with performance.[8] Examples of outcomes that result from these input variables are safety, efficiency, and customer satisfaction.

Subsequently, Helmreich and colleagues proposed a modified conceptual framework for CRM, termed the "Error Troika,"[9] to display a hierarchy of 3 error countermeasures. At the first level, CRM includes training on how to avoid errors. At the second level, potential errors are "trapped" before they are committed. At the third level, mitigation of error consequences occurs.

From a practical standpoint, CRM programs typically include educating crews about the limitations of human performance.[10] Trainees develop an understanding of cognitive errors, and how stressors (such as fatigue, emergencies, and work overload) contribute to the occurrence of errors. Multi-day CRM training programs typically require participants to assess personal and peer behavior. Operational concepts stressed include inquiry, seeking relevant operational information, advocacy, communicating proposed actions, conflict resolution and decision making.

Prevalence and Severity of the Target Safety Problem

The field of aviation has a substantial history of collecting and analyzing safety-related data. Historically, human error has caused or contributed to over 50% of aviation accidents. In an analysis of 35,000 reports of incidents over 7.5 years, almost 50% resulted from a flight crew error, and an additional 35% were attributed to air traffic controller error.[11] Root cause analyses (Chapter 5) by safety experts have found that errors frequently occur because flight crews fail to effectively manage the resources available to them (eg, fail to verify information when uncertain about it, fail to plan for contingencies).[11] Naval aviation reports provide similar results, with one study reporting 59% of "Class A mishaps" (serious consequences including fatality, destroyed aircraft, and major injury) attributed to some degree to aircrew factors.[12] These and similar analyses have catalyzed tailored prevention strategies including CRM for commercial aviation,[1] and "aircrew coordination training" (ACT) for Naval aviators.[12]

Study Design and Outcomes

Measures

Although the most obvious and meaningful measure of CRM effectiveness would appear to be airline accident or "near miss" rates, these objective measures have not been used in commercial aviation studies. Helmreich suggests that it is not possible to use these measures, because accident rates are very low and "near misses" are voluntarily reported.[10] Furthermore, the content and structure of CRM training programs are variable.[10]

In response, researchers have developed tools that assess the effectiveness of CRM in other ways. These tools include attitudinal surveys and peer performance rating questionnaires, including the NASA/University of Texas Line/LOS Checklist (LINE/LOS Checklist),[13] the Cockpit Management Attitudes Questionnaire (CMAQ), and the Flight Management Attitudes Questionnaire (FMAQ). The LINE/LOS Checklist is used to rate crew performance on critical behaviors during specific segments of flight (eg, not rushing through briefing period, exhibiting high levels of vigilance in both high and low workload conditions, etc). Ratings on each behavioral element (ie, model for teamwork) range across 4 levels from poor to outstanding.

In contrast, CMAQ is used to evaluate the attitudes of crewmembers within and between organizations, pre- and/or post-CRM training. Results are intended to serve as a proxy for measuring crew process and performance.[14] The instrument has been validated by comparing self-reported attitudes with performance ratings made by experienced Check Airmen, experts trained in peer evaluation.[15] The FMAQ is a revised version of the CMAQ that was developed by Helmreich and colleagues in response to attitudinal differences observed in flight crews from different countries.[16]

Observation of crew performance in simulated flights has also been used.

Representative Studies

Several studies have utilized proxy tools to test the effectiveness of CRM.[8,12,17] One study by Helmreich and colleagues consisted of an assessment of the attitudes before versus after CRM training (pre-test versus post-test).[17] Crew behaviors were noted by a trained observer using the NASA/University of Texas Line/LOS Checklist.[18] More than 2000 line flights and LOFT sessions were included in the analysis. Overall performance of crews was classified as “below average,” “average,” or “above average” by Check Airmen and LOFT instructors.

As a result of the CRM training, the percentage of crews rated as “above average” increased while the percent rated “below average” decreased. Performance ratings differed between fleets and airlines. Superior pilots also shared many common attitudes, (for example, they were aware of their personal limitations and diminished decision-making capacity during emergencies). In addition, they encouraged crewmembers to question their decisions and actions, were sensitive to the personal problems of other crewmembers, and recognized the need to verbalize plans and to train other crewmembers.

A second study by Barker and colleagues compared the effectiveness of 17 CRM-trained flight crews on military mission simulators, divided according to whether they were “fixed” or “formed” crews.[8] Nine of the crews were defined as "fixed" since they had flown together for six months or longer; the remaining 8 were “formed,” as they had flown together for less than 6 months. Each crew was asked to participate in a simulated mission. The first leg of the mission was programmed to be problem-free, but the second leg required crews to address a safety issue. As with the earlier study, crew behaviors were observed using the NASA/University of Texas Line/LOS Checklist. Surprisingly, the formed crews committed fewer minor errors, but the number of major errors did not differ significantly between the groups.[8] The authors concluded that formed crews may experience less ineffective coordination than fixed crews, as the latter might be more complacent from the routine of working together, but that further research was needed.

A third study evaluated rates of naval aviation mishaps, and the role of CRM failures.[12] While the study primarily compared crew performance in 2 types of equipment, the aircrew performance deficits were also compared with those seen during an earlier time period, prior to implementation of aircrew coordinating training (ACT) programs (the specific form of CRM used). Analysis of data from the post-ACT implementation period across the fleet revealed that 70% of human error mishaps were connected with aircrew factors, and that 56% of these resulted from at least one CRM failure. The authors noted that these percentages were similar to those reported in a separate study prior to ACT implementation. Because of a lack of controls or adjustments for potential confounders, no conclusions about effectiveness of the ACT program can be drawn.[12]

Comparison to Medicine

Sexton and colleagues compared flight crews with operating room personnel on several measures, including attitudes toward teamwork.[19] The study included more than 30,000 cockpit crew members (captains, first officers, and second officers) and 1033 operating room personnel (attending surgeons, attending anesthesiologists, surgical residents, anesthesia residents, surgical nurses, anesthesia nurses). Data from the crew members were obtained from previous administrations of the CMAQ and FMAQ to major airlines around the world (over a 15-year period). The operating room participants were mailed an analogous questionnaire (CMAQ modified[20]), administered over a period of 3 years at 12 teaching and non-teaching hospitals in the United States and abroad (Italy, Germany, Switzerland, and Israel).

The level of teamwork perceived by attending surgeons compared with other operating room staff differed markedly. A majority of surgical residents (73%) and attending surgeons (64%) reported high levels of teamwork, but only 39% of attending anesthesiologists, 28% of surgical nurses, 25% of anesthesia nurses, and 10% of anesthesia residents reported high levels of teamwork. A bare majority (55%) of attending surgeons rejected steep hierarchies (determined by whether they thought junior team members should question the decisions of senior team members). In contrast, 94% of airline crew members preferred flat hierarchies.

It was also noted that medical participants were far more likely to agree with the statement “Even when fatigued, I perform effectively during critical times.” Seventy percent of attending surgeons agreed with this statement, as well as 56% of surgical residents, 60% of surgical nurses, 57% of anesthesia residents, 55% of anesthesia nurses, and 47% of attending anesthesiologists. In contrast, 26% of pilots agreed with this statement.

Applications of CRM Principles in Medicine

The Sexton study and other analyses suggest that safety-related behaviors that have been applied and studied extensively in the aviation industry may also be relevant in health care. We identified CRM applications in several dynamic decision-making health care environments: the operating room, labor and delivery, and the emergency room.[3,21,22] In addition, Gaba has noted that some other domains (eg, cardiac arrest response teams) that have active simulation training are currently incorporating a broader range of CRM-like training methods.[23] (Simulators are covered in more detail in Chapter 45).

Practice Description

Crew Resource Management in Health Care Settings

As with aviation, the medical application of CRM has required tailoring of training approaches to mirror the areas in which human factors contribute to mishaps. In anesthesiology 65-70% of safety problems (accidents or incidents) have been attributed at least in part to human error. In response, several anesthesiologists from the VA Palo Alto Health Care System and Stanford University, with funding from the Anesthesia Patient Safety Foundation, developed *Anesthesia Crisis Resource Management* (ACRM), modeled on CRM.[3,23] The original demonstration courses consisted of didactic instruction, videotape of a reenactment of an aviation disaster, videotape of an actual anesthetic mishap, simulation training and a debriefing session. Ongoing courses include the use of a textbook that catalogues 83 critical events (eg, acute hemorrhage, bronchospasm, seizures), and approaches to managing them.[24] Currently, there are 3 ACRM courses offering progressively more challenging material, a Working Group on Crisis Management Training in Health Care formed by the developers of ACRM that has initiated formal ACRM instructor training, and thoughtful consideration of pragmatic approaches to evaluating ACRM.[23]

Helmreich and Schaefer have also advanced CRM theory in the operating room environment by adapting their model of team performance. This framework describes the team performance inputs that are critical to essential team functions that in turn lead to desired outcomes (defined as patient well-being). Examples of inputs include individual aptitudes, physical environment, and culture (professional, organizational, and national). Performance functions consist of team formation and management, surgical procedures, communications, decision processes, and situational awareness.[18]

Another application of CRM to the health environment is the *MedTeams behavior-based teamwork system*, developed by Dynamics Research Corporation, and sponsored by the Army Research Laboratory. It aims to adapt research in team performance and training from military helicopter aviation to emergency medicine.[22,25,26] Thus far, specific applications have been developed for Emergency Department care and labor and delivery units.[27] The system is implemented through courses and assessment tools. The Emergency Team Coordination Course (ETCC) includes 5 team dimensions or goals (ie, maintain team structure and climate, facilitate planning and problem-solving, enhance communication among team members, facilitate workload management, improve team-building skills). Each goal is tied to specific teamwork tasks. For example, tasks for the first goal (maintain team structure and climate) include "establish team leader," "form the team," "set team goals," and "assign roles and responsibilities."[22] Like the CRM approach to the "Error Troika," the MedTeams approach is based on avoiding errors, trapping them as they occur, and mitigating the consequences of actual errors. Principles underlying the MedTeams approach include:

- Team responsibility for patients
- A belief in clinician fallibility
- Peer monitoring
- Team member awareness of patient status, team member status and institutional resources

Peer monitoring is a fundamental component of the MedTeams system, as well as a feature of the ACRM and aviation field's CRM approaches. Along with his or her clinical responsibilities, each team member undertakes the intermittent process of peer monitoring or "check" actions, engaging in this check cycle as frequently as possible. The teamwork check cycle begins with each team member monitoring his or her own situation awareness and cross-monitoring the actions of other teammates. If during the monitoring mode the *monitoring* teammate observes a suspected error in progress, that individual intervenes with a direct question or offer of information. The erring teammate may then acknowledge the lapse, correct it and continue working. Alternatively, the *monitoring* teammate may have lost situation awareness. The non-erring *monitored* colleague can then provide feedback to correct the peer's situation awareness. If team members are in strong disagreement about how patient care should proceed, advocacy, assertion and perhaps third-party involvement may be used to resolve the situation. Over time, the check cycle becomes habitual, resulting in hundreds of team checks daily, all with the potential to break the error chain.

Recently, ACRM has been extended to a full-day course on neonatal resuscitation training for neonatologists and pediatricians.[21] Called "NeoSim", the course combines traditional training methods with reviews of literature and didactic instruction with simulation. Debriefing follows, using videotape of the simulation. As with the other examples, the emphasis of teaching behavioral teamwork skills along with technical content is the hallmark of CRM interventions in health care.

Evidence for Effectiveness of the Practice

The most thoroughly studied of the medical CRM applications is ACRM, although as with the aviation examples, rigorous evaluations are challenging to design. Few studies utilize a control group, although researchers have reported assessment methods for determining both technical and behavioral performance from simulator videotapes[28] (see also Chapter 45). A before-after ACRM training analysis (Level 3 Study Design) of trainees' knowledge-base (Level 3 Outcome) for crisis yielded mixed results.[3] The average score on the post-test was significantly greater than the pre-test for one trainee class, composed mostly of residents. For the other class of experienced anesthesiologists, the test scores did not change and were at the same level as the post-test scores of class of residents. Subjective data evaluating the course indicated that trainees "uniformly felt that the ACRM course was an intense, superior form of training related to an important, but inadequately taught, component of anesthesia practice."[3] Another study of ACRM at Harvard also found that participants rated the course favorably, with over 80% responding that they felt the course should be taken every 24 months or less.[29]

As with aviation, the incremental value of this form of training is difficult to link to improvements in teamwork performance and better safety records. At the time of this literature assessment, there were no published data to describe the effects on medical error rates of the MedTeams approach. The NeoSim course participants provided positive responses to open-ended questions about their satisfaction with the course.[21]

Costs and Implementation

Helmreich has noted some of the limitations associated with CRM.[10] At this time, the evidence connecting CRM approaches to improving patient safety does not exist, notwithstanding the face validity of the approach. Nevertheless, a long history of variants of the approach offers health care a reasonable foundation from which to draw practical and evidenced-based resources[30] for further development and adaptation of CRM, as well as measurement methods to ascertain its effectiveness.

At a minimum, implementation of the CRM approach in health care settings requires customization of tools and techniques for each specific care venue, as is illustrated by adaptations implemented thus far. This customization comes at considerable cost and cannot be expected to immediately reap safety benefits. At the time of this review, approximate costs for implementing the MedTeams system ranged from \$15,000-\$35,000, with additional costs for ongoing activities (such as continuing education) that ranged from \$8,000-\$20,000 (R. Simon, personal communication, April 2001). Similarly, marginal costs for CRM-like training based on the ACRM experience are estimated at \$800 to \$2,000 per participant per day (D. M. Gaba, personal communication, June 2001). These costs do not include the overhead of starting a program (eg, simulator investment, training instructors), nor do they factor in the cost of reduced practice work hours, if these are above those devoted to current training time.

Cultural shifts in medicine are also necessary if the CRM approach is truly to take root. CRM applications are relatively novel in health care, a field in which professional training and education have traditionally focused on developing technical proficiency rather than facilitating human interaction. Although communication and decision making are central to medical practice, relatively little about this topic has appeared in medical literature, despite the fact that information flow is critical, particularly in high acuity venues such as the operating room and emergency departments. Ideas must be elicited, debated and evaluated without discrimination based on the status of the staff person offering the information.[31]

Paradoxically, the attachment to hierarchy may be the reason that a small percentage of participants can be expected to reject CRM training. Research has shown that some resistance is rooted in personality characteristics. Crew members lacking in achievement motivation and interpersonal skills are more likely to reject the training. Additionally, CRM practices decay over time, even with repeated training, requiring continuing expenditures to retain the hoped-for gains.[10]

Comment

CRM has evolved in the airline industry for more than 20 years, and has been extensively applied during the past decade. Although no definitive data link CRM to decreased aviation error *per se*, the industry has accepted the face validity of the practice, and it is now an integral part of training. Over time, survey data from thousands of civilian and military participants in the United States and abroad has been accrued. These data indicate that most flight crew members accept CRM training, and find it both relevant and useful.[7]

The studies reviewed provide some support for the notion that CRM is worth further investigation in health care. However, it cannot yet be concluded that CRM is a practice that can reduce medical errors. Additional research in this area is warranted, although measurement and study design are particularly challenging. As noted, although the evidence from aviation, where CRM is well-established, has shortcomings, data are easier to capture since CRM assessments can be grafted onto mandatory, ongoing, yearly pilot assessments conducted both in simulators and in real flights (D. M. Gaba, personal communication, June 2001). In medicine, where ongoing assessments are not the norm, capturing relevant data will be more difficult logistically and much more expensive than in aviation. Consequently, and for the analogous reasons that aviation has adopted CRM based on face validity, health care decision makers may wish to consider face validity in lieu of massive research investments.

Nonetheless, evaluations of CRM that focus on intermediate outcomes (eg, trainee performance) are feasible, and instructive for optimizing components of CRM programs. CRM design and evaluation resources are becoming more widely available,[30] and health care should continue to consult these sources, building on the advances made in other fields.

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