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What Do We Really Know About Crew Resource Management in Healthcare?: An Umbrella Review on Crew Resource Management and Its Effectiveness

Martina Buljac-Samardžić, PhD,* Connie M. Dekker-van Doorn, PhD, RN,† and M. Travis Maynard, PhD‡

Objective: The aim of this article was to present an overview of the crew resource management (CRM) literature in healthcare. The first aim was to conduct an umbrella review on CRM literature reviews. The second aim was to conduct a new literature review that aims to address the gaps that were identified through the umbrella review.

Methods: First, we conducted an umbrella review to identify all reviews that have focused on CRM within the healthcare context. This step resulted in 16 literature reviews. Second, we conducted a comprehensive literature review that resulted in 106 articles.

Results: The 16 literature reviews showed a high level of heterogeneity, which resulted in discussing 3 ambiguities: definition, outcome, and information ambiguity. As a result of these ambiguities, a new comprehensive review of the CRM literature was conducted. This review showed that CRM seems to have a positive effect on outcomes at Kirkpatrick's level 1, 2, and 3. In contrast, whether CRM has a positive effect on level 4 outcomes and how level 4 should be measured remains undetermined. Recommendations on how to implement and embed CRM training into an organization to achieve the desired effects have not been adequately considered.

Conclusions: The extensive nature of this review demonstrates the popularity of CRM in healthcare, but at the same time, it highlights that research tends to be situated within certain settings, focuses on particular outcomes, and has failed to address the full scope of CRM as a team intervention and a management concept.

Key Words: crew resource management, teams, training, teamwork, intervention, systematic review, patient safety

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H ealthcare organizations located around the globe are increasingly facing the challenge of providing higher levels of care with the same or even less means.[1] The demand for care is growing rapidly because of the increasing life expectancy, number of aging people, comorbidity, and treatment possibilities. At the same time, the supply of care cannot be increased because of

From the *Erasmus University Rotterdam, Erasmus School of Health Policy & Management; †University of Applied Science Rotterdam, Kenniscentrum Zorginnovatie, Rotterdam, the Netherlands; and ‡Department of Management, College of Business, Colorado State University, Fort Collins, Colorado.

Correspondence: Martina Buljac-Samardzic, PhD, Erasmus University Rotterdam, Erasmus School of Health Policy & Management (ESHPM), ESHPM (J7-29), PO Box 1738, 3000 DR Rotterdam, the Netherlands (e-mail: buljac@eshpm.eur.nl).

government-initiated cost-saving programs that aim to keep healthcare systems affordable and sustainable. As a result, teamwork is seen as a key ingredient in helping healthcare organizations face this environmental dynamism. Several studies support the notion that teamwork is one of the most critical components of a high functioning healthcare system (e.g., the study by Rosen et al[2]). Similarly, the importance of teamwork was loudly acknowledged within the Institute of Medicine hallmark report "To Err Is Human, Crossing the Quality Chasm," which evidenced a link between the lack of teamwork and preventable medical errors. In addition, they cited that training in team behavior is essential given its role in reducing medical errors and increasing patient safety.[3,4]

Consequently, healthcare organizations are using interventions that aim to improve team functioning. In particular, Hughes et al[5] (2016) showed in their meta-analysis the high potential that team training programs in healthcare had on a variety of outcomes including patient health. Although there are various teamwork training programs being used within the healthcare industry, crew resource management (CRM) is likely the most well-known and widely applied intervention within healthcare organizations aimed to enhance team functioning and improve patient safety.

Crew resource management is often referred to as a training intervention that covers nontechnical skills such as situational awareness, decision making, teamwork, leadership, coping with stress, and managing fatigue.[6] A typical CRM training program comprises a combination of information-based methods (e.g., lectures), demonstration-based methods (e.g., videos), and practice-based methods (e.g., simulation, role playing).[7] However, at its core, CRM is a management concept that aims to maximize the use of all available resources (i.e., equipment, time, procedures, and people).[8] In addition, CRM is an intervention that addresses all aspects of organizational operations rather than being limited to the introduction of a specific training to achieve a specific outcome. As such, the general aim of CRM interventions is "to provide members with the knowledge, skills, and attitudes needed to respond to highly demanding situations in a competent manner that proactively seeks to minimize the risk of errors."[9] Crew resource management is thus a system-wide approach that seeks to avoid errors, detect errors before they occur, and mitigate the consequences of errors that are not detected in a timely fashion.[10]

As a result of the theorized promise surrounding CRM initiatives, there is a large and rapidly increasing amount of literature that has evaluated CRM in different (especially high-risk) healthcare settings.[11] Most of these studies report a positive effect of CRM at 1 or more levels of Kirkpatrick's framework for evaluation of interventions: reactions, learning/knowledge, behavior, and organizational outcomes (see Appendix 1, http://links.lww.com/JPS/A376). As a result of the growing body of evidence focused on CRM and its potential, multiple literature reviews have been conducted with the aim to provide an overview of what CRM entails and its impact. For example, in 2014, 2 reviews were published on CRM: a meta-analysis by O'dea et al[7] (2014) and a systematic review by Verbeek-van Noord et al[12] (2014). O'dea et al[7] (2014) found 20 studies that evaluated CRM in the acute

healthcare domain. Based on their work, they concluded that CRM has a large effect on knowledge and behavior and a small effect on attitudes.[7] However, the evidence for an effect on clinical care outcomes was unsupported in their meta-analysis, as was the long-term impact of the training. In comparison, Verbeek-van Noord et al[12] (2014) found 22 studies that evaluated classroom-based CRM training on safety culture in a broad range of healthcare domains. They concluded that results regarding the effect of CRM on safety culture were mostly mixed.[12] In addition to this unclear picture of the impact of CRM on safety culture, these 2 studies also provide a vivid example of the reviews that have been conducted in this area—they include studies with a variety in levels of quality, and the impact that CRM has depends on how effectiveness is defined. In addition, it should be emphasized that the conclusions derived from such reviews are not based on the same studies given that the target group and CRM content are often different from one review to another. Of the 42 studies included in these 2 reviews, only 2 were included in both reviews.[13,14]

This lack of overlap speaks to the high level of heterogeneity of studies that exist within the overall CRM literature. In part, this heterogeneity is caused by differences in the CRM curricula, the healthcare setting, the target group within a healthcare setting, and the methods used to evaluate a given CRM intervention. We are not the first to point out these "issues" within the CRM literature. In a recent literature review, Gross et al[11] (2019) pointed out these diversities and concluded that CRM seemed to be an umbrella concept of human factors and safety training.

As such, we echo prior sentiments speaking to the need for a comprehensive and structured overview of the CRM literature to ascertain what is really known about CRM in healthcare, given that this has yet to be addressed. Here, we seek to address this gap as this study aims to synthesize the scientific knowledge on CRM by analyzing the results of all literature reviews conducted on CRM to date. This will hopefully provide us insights regarding the current state of the literature based on prior literature reviews. However, given the discrepancies and gaps in the literature reviews conducted thus far, within the current study, we will also conduct a more comprehensive review of the literature with the intent to provide a more complete picture of research conducted on CRM within healthcare to date and highlight where future research is needed.

This literature review consists of 2 phases. The goal of the first phase is to synthesize the findings from all literature reviews (not only systematic reviews) addressing CRM within healthcare settings. During this phase of our work, we will conduct an umbrella review (e.g., the study by Aromataris et al[15]) of the CRM literature. The second phase of our work aims to review the CRM literature from 2006 to August 2019 addressing the gaps that were identified through the umbrella review process.

METHODS: PHASE 1: UMBRELLA REVIEW OF CRM LITERATURE REVIEWS

Search Strategy

We searched the following databases to locate literature reviews conducted to date on the topic of CRM: EMBASE, Medline, and Web of Science. The search involved a combination of the key words "CRM" OR "crew resource management" OR "crisis resource management," in combination with (i.e., AND) "review (see Appendix 2, http://links.lww.com/JPS/A377)." This search strategy resulted in 215 hits. This search was expanded by a manual search in Google Scholar. These hits were subject to a stepwise evaluation process as shown in Figure 1. First, the title and abstract were evaluated by adhering to the inclusion and exclusion criteria (see hereinafter), which narrowed our population down to 32

articles. Two of the authors followed these steps, and in the case of disagreement or doubt, it was proceeded to the next step. Second, this subset of articles was evaluated by looking at the entire texts while using the same criteria. This narrowed the list of reviews down to 14 articles. Two of the authors followed this step, and in the case of disagreement, a third author was included in the discussion to make the final decision. In addition, the author team closely analyzed and summarized the reference list of each article to identify any additional articles that may not have surfaced through the literature search process. This step resulted in 2 additional articles. As a result, in total, our umbrella review consisted of the 16 literature reviews that were selected.

Inclusion and Exclusion Criteria

The criteria for inclusion in our study were as follows: the article needed to (1) present a literature review (e.g., systematic, narrative), (2) that was written (or translated) in English, (3) published in a peer-reviewed journal, (4) with a focus on how CRM can improve performance, and (5) focused (at least partly) on CRM in healthcare. We did not weigh the quality of the literature reviews into the inclusion criteria to capture all potentially relevant studies. Likewise, we did not include (nor exclude) articles based on the actual content of the CRM intervention. As such, if the authors of the underlying literature reviews referred to CRM, an inclusion criterion 4 was met. We also included reviews that presented several team interventions that also included CRM, as long as it was clear which articles focused on a CRM intervention and could therefore be extracted. In addition, we did not consider publication year in our decision as to whether to include or to exclude a particular article. Each of these decisions was made in an attempt to ensure that we were able to identify all reviews of the CRM literature within healthcare.

That said, we did apply certain exclusion criteria. Specifically, literature reviews were excluded when (1) no overview of articles was presented as a result of the literature search, (2) the presented articles were not focused on CRM but, for example, on education, and (3) reviews in which articles on CRM *in healthcare* were not present or represented in an overview of results. Literature reviews that focused on a variety of settings that also included healthcare were included in our umbrella review, but these reviews were selectively summarized and analyzed so as to emphasize the findings relevant to the healthcare context.

Analysis

The 16 literature reviews that were included in our umbrella review are summarized in Table 1. Within this table, we highlight the author, year, title, aim/research question, methods (inclusion and exclusion criteria), setting, number of articles included within the underlying literature review, main result/conclusion, and the quality of the methods using the AMSTAR (A Measurement Tool to Assess Systematic Reviews) tool.[29] The AMSTAR consists of 11 items and results in a score ranging from 0 to 11. Based on the 16 literature reviews, 3 categories were constructed, reviews that focused on (1) CRM training in general, (2) simulation training, which is seen as crucial element of CRM, and (3) team training in which CRM is seen as 1 type of team training.

RESULTS: PHASE 1: UMBRELLA REVIEW OF CRM LITERATURE REVIEWS

Quality of the Literature Review

Upon pulling together the literature reviews conducted on CRM in healthcare to date and conducting our umbrella review of such work, it became apparent that there is a strong variation
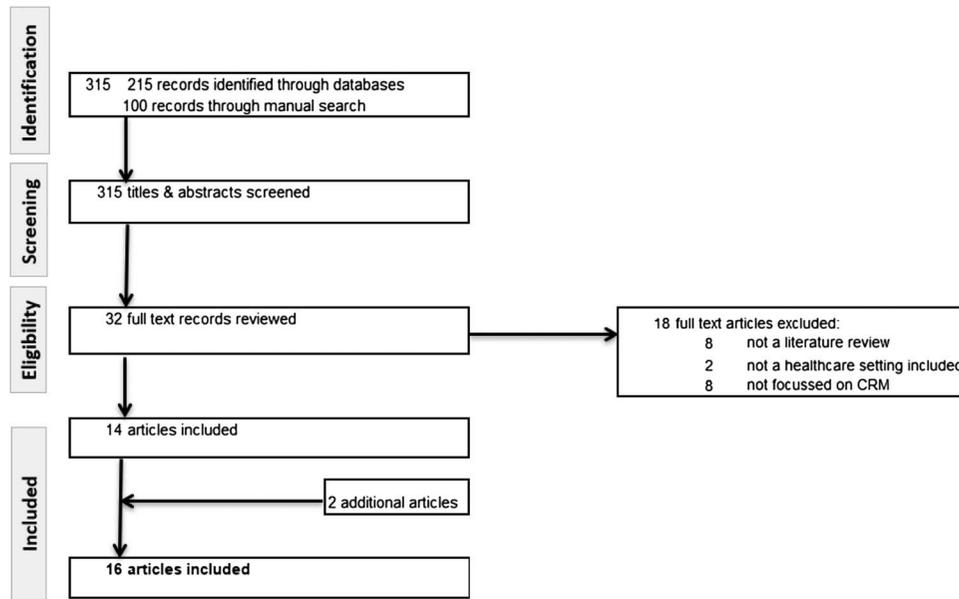
FIGURE 1. Flow chart phase 1.

between how the 16 literature reviews were conducted and documented. Only 9 of the 16 reviews presented a flowchart that shows the process from initial search until the final set of articles in detail.[7,11,12,16,17,22–24,26,27] Others gave a short description of this process.[25] Likewise, 2 reviews did not present the full summary table of the selected articles and instead only provided a selection of information.[18,19] These and other factors are reflected in the AMSTAR rating, which varies between 3 and 10 with Gross et al[11] (2019), McCulloch et al[27] (2011) and O'Connor et al[19] (2008) receiving the highest AMSTAR scores.

Overall Findings

Table 1 provides a summary of the 16 CRM literature reviews included within our umbrella review. This table highlights some of the key areas of consensus across all the reviews. For instance, all of the reviews provide evidence of the positive effects of CRM on participant reaction, knowledge, attitude, skills, behavior, learning, transfer of knowledge to workplace, safety culture, and teamwork (e.g., communication, coordination) within the healthcare setting. However, although, at a high level, the positive effects of CRM exist, the picture is far from universal across all 16 literature reviews. For instance, the review by Salas et al[20] (2006) suggests that the impact of teamwork training is mixed. Even those who found evidence of benefits of CRM were of varying strengths. For instance, O'dea et al[7] (2014) suggest that CRM had large effects on knowledge and behavior and a small effect on attitudes. In comparison, O'Connor et al[19] (2008) found that the strength of the relationship with attitudes and behaviors was large while the effect with knowledge was only medium.[19]

Building upon these mixed results, Table 1 also provides insights into other areas of heterogeneity among the reviews. To start, there is substantial variability in the number of studies included in each review (range from 7 to 64 underlying articles). In part, this variability may be the result of the target group examined within each review—from no limitation or all healthcare settings to a specific healthcare setting (e.g., acute care, hospitals), department (e.g., emergency department), or team (e.g., interprofessional teams). Likewise, what CRM entails varies across these various reviews to include techniques such as CRM training, simulation training, simulation crisis resource management training, and classroom-based CRM training.

Synthesis of Themes

Based on our review of the 16 CRM reviews conducted to date, we have identified a variety of issues that raise questions concerning whether any of these reviews provides a complete picture of the CRM literature. Looking closer, we found 3 clusters of ambiguity: in *definition* of CRM, in *outcomes*, and in *information*.

Definition Ambiguity

As each literature review focuses mainly or partly on CRM, it could be expected that a clear description of what CRM entails was presented. Table 2 provides an overview on how the 16 literature reviews described CRM. This table indicates that CRM typically covers competences like knowledge, skills and attitude, and topics such as teamwork, leadership, situation awareness, decision making, and communication. At the same time, Table 2 demonstrates that there is no clear standard set of competencies or topics that CRM should address. Gross et al[11] (2019) show a list of key words that are used to describe CRM (e.g., communication, situational awareness, leadership, teamwork, decision making, briefing). However, there is a lack in operationalization of terminology, and therefore, it seems that a universal definition of CRM does not exist. This causes a considerable gap in knowledge about what CRM includes and which elements are the ones that precisely alter behavioral processes and subsequently improve patient safety. Most of the selected literature reviews do not address this issue and circumvent this by pretending that there is consensus about what CRM training interventions actually entail. Interestingly, only 7 of the 16 literature reviews included a description of the CRM training in their summary of the results.[7,11,18,20,26–28] These descriptions show us that CRM curricula vary significantly. McCulloch et al[27] (2011) suggest that the instructional methods of CRM training could consist of classroom-based methods only, or leverage simulation-based methods only, or a combination of both. O'dea et al[7] (2014) provide insights from the standpoint of variation in training time between different methods. Information-based methods, such as lectures, vary between 1 hour and 1 day. Practice-based methods,

TABLE 1. Summary of Selected Literature Reviews: Phase 1

Authors (Year)	Aim/Research Question(s)	Methods: Inclusion and Exclusion Criteria	Setting	Number of Articles	Main Findings	AMSTAR
I. Reviews that focus on CRM						
Boet et al[16] (2014)	"To gain a better understanding of the impact of simulation-based CRM teaching on transfer of learning to the workplace and subsequent changes in patient outcomes."	Inclusion criteria: "studies that used simulation-based CRM teaching with outcomes measured at Kirkpatrick level 3 (transfer of learning to the workplace) or 4 (patient outcome)." Exclusion criteria: "studies measuring only learners' reactions or simple learning (Kirkpatrick level 1 or 2, respectively)"; "papers reporting solely self-assessment data and considered a level 1 (reaction) outcome"; and articles where it's was not possible to "separate out teaching and/or assessment of technical skills from nontechnical skills in an acute care context."	Acute care settings	9	"CRM skills learned at the simulation center are transferred to clinical settings, and the acquired CRM skills may translate to improved patient outcomes, including a decrease in mortality."	9
Fung et al[17] (2015)	"To assess: (i) the effectiveness of simulation-based CRM team training compared to any other educational intervention among interprofessional or interdisciplinary teams and (ii) to determine whether simulation-based CRM team training leads to the modification of attitudes, skill/ knowledge acquisition, changes in behaviors, and improved patient outcomes."	Inclusion criteria: articles with following study characteristics (i.e., randomized controlled trials, quasi-randomized controlled trials, controlled before-after studies, or interrupted time series); patient characteristics (i.e., all healthcare providers and all levels of training); and learning intervention (i.e., interprofessional or Interdisciplinary education, CRM, and simulation-based)	Healthcare	15	"CRM simulation-based training for interprofessional and interdisciplinary teams shows promise as a superior training method over traditional nonsimulation clinical teaching of CRM principals." "All but one of the included interprofessional and interdisciplinary studies found significant improvements in at least one of the learning outcomes when using simulation-based CRM team training compared to alternate forms of training, such as didactic teaching or case-based learning." "No studies reported outcomes that were worse in the simulation-based CRM training group compared to any comparator group."	7
Gross et al[11] (2019)	"To identify what is subsumed under the label of CRM in a healthcare context and to determine how such training is delivered and evaluated."	Inclusion criteria: healthcare staff, individually constructed training formats addressing CRM principles or aviation-derived human factors, studies reporting both the intervention and its effect, published in an academic journal, either in English or German.	Healthcare	64	Almost half of the studies "did not explain any key word of their CRM intervention to a reproducible detail. Operating room teams and surgery, emergency medicine, intensive care unit staff and anesthesiology came in contact most with a majority of the CRM interventions delivered in a 1-day or half-day format. Trainer qualification is reported seldomly. Evaluation methods and levels display strong variation."	10
Maynard et al[18] (2012)	To provide clarity by providing a review of the literature, to highlight the current state of the literature and to identify areas to be addressed by researchers in this field going forward.	A number of search techniques were used. Detailed information on the methods is lacking.	Healthcare	7 (presented)	CRM and teamwork training programs generally seem beneficial to individual employees, the groups and teams within such settings, and overall healthcare organizations.	3

Study	Objective	Inclusion/Exclusion Criteria	Setting	No.	Findings	Score
O'dea et al[7] (2014)	"To determine the aggregate size of the effect of CRM training in acute care settings at four different levels of evaluation: reactions, learning, behavior and clinical care outcomes. Additionally, to identify biases in the research evidence in order to improve the quality of future CRM training interventions in healthcare and also the quality of evaluations of those interventions."	Inclusion criteria: "studies must report CRM-type training interventions that are focused on improving teamwork within healthcare teams in acute care environments; and training effectiveness must be assessed at least one level of Kirkpatrick's evaluation hierarchy." Exclusion criteria: "training that focuses on specific technical skills or procedures rather than on teamwork; and studies that relate to patient or relative centered communication or collaboration, and studies aimed at administrators, leaders or managers."	Acute care settings	20	"The meta-analysis of CRM-type team training in healthcare found that participants like this type of training." "There was a large effect of training on knowledge, a small effect of training on attitudes and a large effect of training on behavior." "The evidence for an effect on clinical care outcomes, or the long-term impact of the training, was unsupported in this meta-analysis."	8
O'Connor et al[19] (2008)	"To use meta-analyses techniques to evaluate the effectiveness of CRM training."	Inclusion criteria: "an evaluation had to be reported from at least one of the first three levels of Kirkpatrick's (1976) evaluation hierarchy: reactions, learning (attitudes and knowledge), or behaviors."	All settings	16 (4 HC)	CRM had a large effect on attitudes and behaviors and a medium effect on their knowledge.	10
Salas et al[20] (2006)	To provide "the state of CRM training evaluations since the Salas et al (2001) review and extends it to areas beyond aviation cockpits."	Inclusion criteria: articles that present "the findings of a study evaluating the impact of CRM training on trainees' reactions, learning, or behaviors and/or its impact on the organization."	All settings	28 (12 HC)	Although no study was covered "that suggests CRM training does not work, approximately half of the studies indicated mixed results, leading us to question its effectiveness."	8
Verbeek-van Noord et al[12] (2014)	"To evaluate the evidence of the effectiveness of classroom-based crew resource management training on safety culture (…)."	Inclusion criteria: articles on "training focussed on health-care teams in hospitals and covered at least two CRM topics (e.g., communication and leadership)." Exclusion criteria: "studies evaluating CRM in preclinical medical education, outside healthcare, in primary care, and dental care"; "CRM training courses based (partly) on high-tech simulation techniques"; and "manuscripts based on qualitative research."	Hospitals	22	"Training settings, study designs, and evaluation methods varied widely." "Most studies reporting only a selection of culture dimensions found mainly positive results, whereas studies reporting all safety culture dimensions of the particular survey found mixed results."	8
Zeltser and Nash[21] (2010)	"To report on the body of empirical data about CRM training in clinical settings and to provide a conceptual framework for evaluating its effectiveness in medicine."	Inclusion criteria: "published in peer-reviewed journals, printed in the English language, published in the past 20 years, and presented original data."	Clinical settings	19	"The purpose of each of the selected studies was to evaluate the effectiveness of a CRM training program for clinical providers." The authors present "a conceptual framework for evaluating such programs and generating evidence for organizational impact. The framework identified a classification for outcomes measures, which were classified as either learner measures, process measures, or organizational measures."	7

TABLE 1. *(Continued)*

Authors (Year)	Aim/Research Question(s)	Methods: Inclusion and Exclusion Criteria	Setting	Number of Articles	Main Findings	AMSTAR
II. Reviews that focus on simulation						
Doumouras et al[22] (2012)	"To appraise and summarize the design, implementation, and efficacy of peer-reviewed, simulation-based CRM training programs for postgraduate trainees (residents)."	Inclusion criteria: "articles that were written in English; were published in peer-reviewed journals; included residents; contained a simulation component; and included a team-based component." Exclusion criteria: "articles that included staff/ fellow physician or medical student training; bore no evaluative component for residents; did not include crisis scenarios; and did not train and evaluate residents in a team environment."	Surgery	15	"Residents find utility in simulation training and that it can change team-based team behaviors in crisis scenarios." There is a high degree of satisfaction and perceived value that reflects robust resident engagement. "However, the evidence for translating and measuring the extent of performance from the simulator to the clinical domain remains elusive."	7
Murphy et al[23] (2015)	"To determine the current state of knowledge about the key components and impacts of multidisciplinary simulation-based resuscitation team training."	Inclusion criteria: articles that include evaluation of in-hospital resuscitation teams; articles on medical practitioners and allied health staff. Exclusion criteria: articles focused on teams in nonacute settings such as primary care (palliative care, community) or rehabilitation; articles on team performance of end-of-life care; communication tools and clinical handover techniques.	Emergency department	11	The relationship between team training and team performance is supported. "Simulation is an effective method to train resuscitation teams in the management of crisis scenarios and has the potential to improve team performance in the areas of communication, teamwork and leadership."	9
Tan et al[24] (2014)	To "describe and explore the actual state of multidisciplinary team simulation in surgery."	Inclusion criteria: "articles that were written or translated to English; published in peer-review journals; contained a simulation component, included surgical trainees/surgeons within a multidisciplinary OT team; and were published during 1990–2012." Exclusion criteria: articles that "did not train or evaluate multidisciplinary groups in a simulated OT environment (…); assessed only a single professional group (…); included nonsurgeon groups as scripted confederates (…); and assessed only technical skills."	Surgery	26	"Surgical team simulations are feasible and have received largely positive reactions from participants and some have reported changes to their behavior and interaction within a team environment from this form of learning."	6
III. Reviews that focus on team training in general						
Buljac-Samardzic et al[25] (2010)	"Which types of interventions to improve team effectiveness in healthcare have been researched empirically, for which target groups and for which outcomes? To what extent are these findings evidence based?"	Inclusion criteria: "peer-reviewed English-language publication; a focus on healthcare; a focus on how to improve (and not only measure) team effectiveness; and empirically researched results."	Healthcare	48 (15 CRM)	"Three categories of interventions were identified: training, tools, and organizational interventions." "Studies show that team training can improve the effectiveness of multidisciplinary teams in acute (hospital) care." Studies that presented high quality evidence were mostly simulation and CRM training.	7

Author (year)	Objective / Inclusion & Exclusion criteria	Setting	N (CRM)	Key findings	Score
Low et al[26] (2018)	"To describe and evaluate the effects of team-training within intensive care medicine" and "to assess the quality of research and further describe the different team typologies, educational modalities, utilized curricula and the specific skills taught" — Exclusion criteria: "studies focusing on staff from outside the ICU (e.g., staff from emergency departments or medical students), education for individuals (not teams) and studies from non-English journals."	Intensive care medicine	27 (12 CRM)	"Team-training has been studied in multiple ICU team types, with CRM and TeamSTEPPS curricula commonly used to support teaching via simulation." "Team-training in ICU is well received by staff, facilitates clinical learning, and can positively alter staff behaviors." "Few clinical outcomes have been demonstrated and the duration of the behavioral effects is unclear."	8
McCulloch et al[27] (2011)	"To identify and evaluate evidence that training of healthcare workers in communication and teamwork improves job performance or patient outcomes." Inclusion criteria: randomized and nonrandomized studies; interventions with healthcare workers and healthcare teams. Exclusion criteria: in case "no training intervention was specified; no posttraining evaluation was performed beyond staff attitude and opinion surveys; if it was impossible to define the study population; and in case of lack of numerical data on outcomes."	Healthcare	14 (14 CRM)	"The evidence for technical or clinical benefit from teamwork training in medicine is weak. There is some evidence of benefit from studies with more intensive training programmes (...)." "Most reported improved staff attitudes, and significantly better teamwork after training."	10
Weaver et al[28] (2014)	"To provide an updated narrative synthesis of the body of evidence evaluating team-training in acute care settings (...)." Inclusion criteria: articles between January 2000 and December 2012. Exclusion criteria: articles that were "only descriptive in nature; conducted in non-English–speaking populations or if primarily targeting students or trainees."	Acute care setting	26 (9 CRM)	The "synthesis suggests that there is moderate to high-quality evidence that team-training can positively impact healthcare team processes and, in turn, clinical processes and patient outcomes." "A key finding is that the studies demonstrating the most robust evidence for effectiveness have implemented team-training as a bundled intervention (...)."	8

such as a simulation, vary between 2 hours and 1 day. Although most CRM training interventions had a 1/2- or 1-day format,[11] they can last up to 2 or 3 days.[31–33] Recently, Gross et al[11] (2019) explicitly addressed the issue of a lacked shared definition by showing that less than half of the studies in their systematic review provided information that would allow the CRM intervention to be replicated. In addition, they suggested minimum requirements for describing the intervention design (i.e., aims, methods, contents) in future CRM articles.

Outcomes Ambiguity

In addition to the lack of consistency regarding the conceptualization of a CRM training, there also seems to be a lack of agreement regarding the impact of CRM interventions in terms of the relationship between CRM programs and the impact of such an intervention on a variety of outcomes.[7] As suggested previously, the 16 literature reviews included in our umbrella review seem to present a clear picture that CRM has a positive effect on outcomes. However, when we look across different outcomes, there are different results. Namely, the impact of a CRM training is especially clear at Kirkpatrick's hierarchy evaluation level 1 (i.e., reaction) but lacks consistency when looking at level 2 (i.e., learning) and level 3 (i.e., behavior).[7,19] Likewise, it is widely debated whether CRM training has an effect on the bottom line: performance outcome such as improvement in specific patient safety outcomes (Kirkpatrick's level 4). The review by Salas et al[20] (2006) states that the evidence included in their review is mixed.[20] As a result, some suggest that the relationship between CRM and patient safety is not yet proven. Others, however, point out that there are a couple of studies that have shown CRM to have a beneficial effect for patients but also recognize the limitations regarding the conceptualization and the quality of evidence.[11,16,17]

An underlying issue is that the variety of outcome measures that have been examined within CRM research is challenging to fit precisely into Kirkpatrick's categories, which resulted in alterations such as splitting level 2 into attitude (2a) and knowledge/skills (2b) or including marks (e.g., *) that represents deviations such as using qualitative evaluation methods (instead of quantitative), as well as varying the time at which outcomes are measured (i.e., right after the training intervention or after a delay). Nevertheless, only 5 of the 16 literature reviews clearly present the measures used in their findings.[7,11,12,17,18,27] Such a sentiment was shared by Gross et al[11] (2019) who suggested minimum requirements for describing the evaluation (i.e., method of evaluation, sample group size, statistical data, outcomes) for future CRM articles.[11]

Information Ambiguity

As detailed in Table 1, many of the reviews conducted to date have focused on the relationship that CRM training interventions have on various outcome metrics. However, there is a lack of information provided in the literature reviews conducted thus far regarding the first and last step in this process: implementation of CRM and sustaining the effects. The review conducted by Verbeek-van Noord et al[12] (2014) is the only review that presented information on the implementation strategy. In addition, Gross et al[11] (2019) discussed studies with an implementation strategy.[11] Similarly, only Tan et al[24] (2014), Verbeek-van Noord et al[12] (2014), and O'dea et al[7] (2014) explicitly address the sustainability of results as they highlight the period over which the effect of CRM was measured. This is unfortunate given that multiple reviews acknowledge the need for more evidence regarding the sustainability of CRM initiatives (e.g., the study by Maynard et al[18]). In addition, Gross et al[11] (2019) emphasize the importance of considering

training conditions to include factors such as the trainer qualification and the number of participants.[11]

Measures to grade the level of evidence or the methodological quality could help make a judgment regarding an article. The level of evidence of the selected CRM articles by the reviews is often not quantified. Tan et al[24] (2013) and McCulloch et al[27] (2011) are the only ones to address the quality of evidence per study. Tan et al[24] (2014) even conclude that all the selected articles (on multidisciplinary simulation training) in their review present a low quality of evidence.

Conclusion Phase 1

Most of the 16 selected reviews base their conclusion on different domains in healthcare. This contributes in part to the interesting finding that within these reviews, there is a lack in overlap between the 16 literature reviews regarding the presented studies. When looking across the 16 reviews, if one were to merge the studies reviewed, it would result in 274 articles in total with 190 of these articles being unique. By digging into the reviews that have been conducted to date, only 17 of the articles were included within 3 or more of the reviews, only 49 of these 190 articles were actually presented by 2 or more reviews, and the remaining 141 articles were presented in only 1 review. Recently, the systematic literature review conducted by Gross et al[11] (2019) seems to present the most comprehensive overview of the CRM literature. However, although more comprehensive than others, within their review, only a third of the articles included overlap with the other 15 reviews. Because of the high level of heterogeneity of the present literature reviews, the need to present one overall review is still present. As a result, within phase 2, we conducted our own literature review of the healthcare CRM literature with the aim of being more comprehensive than any single review conducted to date.

METHODS: PHASE 2: COMPREHENSIVE CRM LITERATURE REVIEW

As a result of the conclusion of phase 1, we conducted a new literature review on CRM in healthcare with the aim of providing the most comprehensive review of this literature stream to date and thereby filling several of the identified gaps noted during our umbrella review (i.e., phase 1).

Search Strategy

First, we searched the following databases for CRM articles: PubMed, EMBASE, Web of Science, and Google Scholar. The search involved a combination of the key words "CRM" OR "crew resource management" OR "crisis resource management" and was restricted to articles from 2006 (see Appendix 2, http://links.lww.com/JPS/A377). This search strategy resulted in 891 hits. First, similar to the process used in phase 1, 2 of the authors evaluated the title and abstract by adhering to the inclusion and exclusion criteria highlighted hereinafter and then following this with the full-text evaluation by way of the same criteria (Fig. 2). This resulted in 90 articles. Second, the presented articles within the 16 literature reviews (phase 1) were extracted and also evaluated according the inclusion and exclusion criteria. This second step resulted in 2 additional articles. Third, snowball research was applied by analyzing the included articles and their reference lists, which added 14 articles. In total, 106 articles were included.

Inclusion and Exclusion Criteria

Articles were included if they examined CRM interventions within healthcare and did so by leveraging empirical analysis. In contrast, articles were excluded if they (1) did not cover a CRM intervention, but for example, a related intervention such

TABLE 2. Descriptions of the CRM Concept

| Authors (Year)	Description of CRM Within Review
I. Reviews that focus on CRM	
Boet et al[16] (2014)	"The ultimate goal of all CRM simulation training is to increase patient safety and result in better patient outcomes."
Fung et al[17] (2015)	"CRM includes clinical as well as communication and team-working abilities. CRM refer to principles such as leadership and followership, communication, teamwork, resource use, and situational awareness."
Gross et al[11] (2019)	Salas et al[30] (1999) defined CRM training as a "a family of instructional strategies designed to improve teamwork in the cockpit by applying well-tested training tools (e.g., performance measures, exercises, feedback mechanisms) and appropriate training methods (e.g., simulators, lectures, videos) targeted at specific content (i.e., teamwork knowledge, skills, and attitudes). The purpose of CRM in high-risk organizations can be summarized as error countermeasures with three lines of defense: (1) avoidance of error, (2) trapping incipient errors before they are committed and (3) mitigating the consequences of those errors which occur and are not mitigated."
Maynard et al[18] (2012)	Possible CRM training components: patient safety overview within healthcare, role of CRM in other industries and within healthcare to address safety, communication, normalization of deviance, ingredients for effective teamwork, conflict, team briefings, team debriefings, assertiveness, situational awareness, shared mental models, red flags, and decision making.
O'dea et al[7] (2014)	"The purpose of CRM training is to promote safety and enhance efficiency through optimum use of all available resources: equipment, procedures and people. The focus of CRM training is not on technical skills but rather cognitive and interpersonal skills, such as communication, situational awareness, problem solving, decision making, leadership, assertiveness and teamwork. Training is usually designed to develop generalizable, transportable teamwork competencies that learners can apply across different settings and teams. Instructional methods include: information-based methods (e.g., didactic lecture); demonstration-based methods (e.g., behavioral modeling, videos); and practice-based methods (e.g., simulation, role playing)."
O'Connor et al[19] (2008)	CRM training can be defined as "a set of instructional strategies designed to improve teamwork in the cockpit by applying well-tested tools (e.g., performance measures, exercises, feedback mechanisms) and appropriate training methods (e.g., simulators, lectures, videos) targeted at specific content (i.e., teamwork knowledge, skills, and attitudes) (Salas et al, 1999, p.163).[30]" "An introductory CRM course is generally conducted in a classroom for 2 or 3 days. Teaching methods include lectures, practical exercises, role playing, case studies, and video of accident re-enactments. CRM courses typically cover core topics such as teamwork, leadership, situation awareness, decision making, communication, and personal limitations."
Salas et al[20] (2006)	"CRM is an instructional strategy that trains crews to effectively use all of their available resources (i.e., people, equipment, and information). CRM training has been defined as a set of "instructional strategies designed to improve teamwork in the cockpit by applying well tested training tools (e.g., performance measures, exercises, feedback mechanisms) and appropriate training methods (e.g., simulators, lectures, videos) targeted at specific content (i.e., teamwork knowledge, skills, and attitudes)" (Salas et al, 1999, p.163).[30]" "… it can be conceptualized as a team training strategy focused on improving crew coordination and performance."
Verbeek-van Noord et al[12] (2014)	"CRM typically includes educating teams about the limitations of human performance. Operational concepts include inquiry, seeking relevant operational information, assessing personal and peer behavior, communicating proposed actions, conflict resolution, and decision making."
Zeltser and Nash[21] (2010)	Not clear.
II. Reviews that focus on simulation	
Doumouras et al[22] (2012)	"Simulation-based crisis resource management (CRM) training using a realistic computer-controlled mannequin is believed to be a useful strategy for teaching team-based skills. This methodology allows for repeated instruction and deliberate practice while posing no threat to patients."
Murphy et al[23] (2015)	"It (referring to simulation) is based on the experiential learning theory which provides devices, staff, virtual environments and contrived situations that replicate the clinical environment and events that arise in professional situations."
Tan et al[24] (2014)	Not clear.
III. Reviews that focus on team training in general	
Buljac-Samardzic et al[25] (2010)	"CRM encompasses a wide range of knowledge, skills, and attitudes including communication, situational awareness, problem solving, decision making, and teamwork."
Low et al[26] (2018)	"Crew resource management (CRM) is an educational curriculum that was initially developed for the aviation industry to improve safety, communication and decision making. CRM was adapted to healthcare when patient simulators were used in anesthesia training programs and highlights five essential core concepts: team structure, leadership, situational awareness, mutual support and communication."
McCulloch et al[27] (2011)	Not clear.
Weaver et al[28] (2014)	"A specific team-training strategy focused on developing a subset of teamwork competencies including hazard identification, assertive communication and collective management of available resources."
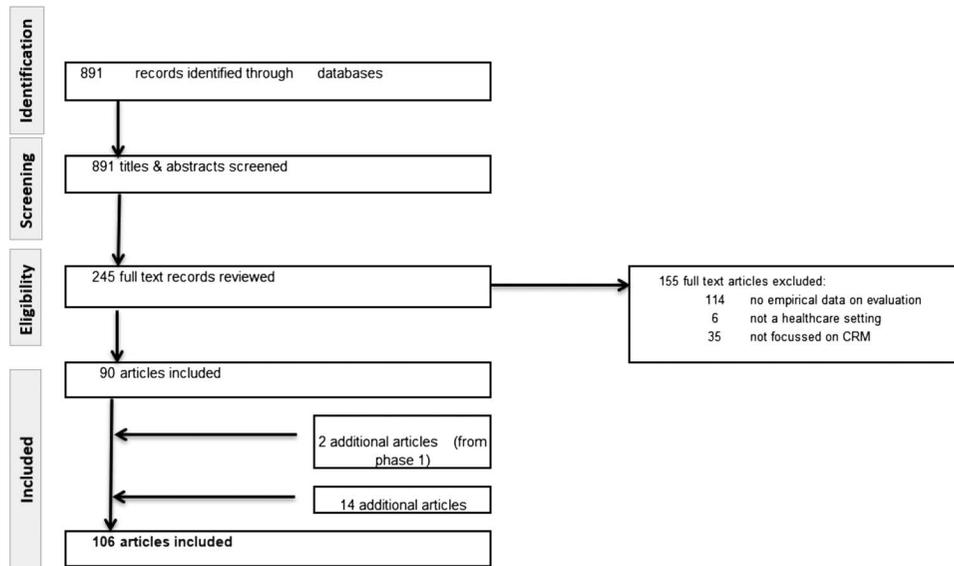
FIGURE 2. Flow chart phase 2.

as TeamSTEPPS or in case results could not be tracked backed to the CRM intervention because it was only 1 element of a bigger intervention; (2) did not present empirical data on the evaluation of CRM, but for example, only described the development of a CRM intervention or only focused on the educational improvement of CRM training; or (3) did not focus on healthcare organizations but on the profit sector or on educational institutions. However, the actual content of the CRM intervention was not considered as an inclusion or exclusion criterion. If the authors themselves referred to CRM, it was included. In addition, we did not consider methodology (e.g., quantitative, experimental, qualitative) as an exclusion criterion.

Analysis

The 106 articles were summarized in Table 3 by author, year, aim of the study, setting, study design, main results as well as the Kirkpatrick's level of outcome, implementation strategy (yes or no), and sustainability strategy (yes or no). In addition, the quality of the evidence was evaluated by MMAT (Mixed Methods Appraisal Tool). MMAT allows an assessment of methodological quality (quality of reporting) of all articles, regardless of their methodology. Although the criteria differ for each type of research, each domain for quantitative and qualitative research includes 4 criteria. The final score for each article depends on the number of criteria met and can vary from 25%, 50%, 75%, to 100% if all criteria are met. For mixed method research studies, the calculation of the final score is a little different and depends on the quality of the weakest component (qualitative, quantitative, or mixed method).[136]

RESULTS: PHASE 2: COMPREHENSIVE CRM LITERATURE REVIEW

Taking a closer look at those 106 articles, there are 3 main findings: (1) effect of the training and its sustainability, (2) implementation, and (3) variation.

The Effect of CRM Training and Its Sustainability

All studies included in our comprehensive review presented evidence that CRM had a positive effect on an outcome measure within at least 1 Kirkpatrick level. In particular, CRM seems to positively affect level 1 (i.e., reaction) and 2 (i.e., learning), based

on the high quantity of articles and the quality of the evidence noted. Likewise, the effects of CRM interventions on level 3 outcomes (i.e., behavior) are promising. However, we have to note that level 3 sometimes included the perception of behavioral change and was sometimes obtained by observations. In addition, whether CRM affects outcomes at level 4 (i.e., organizational outcome) remains unclear. Only 28 articles included level 4 in their evaluation, and the results here were mixed.

Although most studies presented a positive effect of CRM, this statement requires nuancing. First, the period in which the positive effects occurred varied from directly after the training to 4 years after the training[112] Likewise, the number of measurements varied between 1 and 3 (after intervention). Although all positive measured effects are valuable, the sustainability of these effects is equally important. Only half of the studies offered some form of sustainability intervention. Second, most studies measured multiple nontechnical skills and always reported 1 or more significant effects, but also some nonsignificant effects. Across the studies, it is not consistent as to which nontechnical skills are significant and which are not. Third, a couple of valuable outcomes were not measured. Specifically, there are no studies included in our review that described the return of investment as an outcome of a CRM intervention.[17] This gap is interesting given that within the healthcare setting where budget constraints have a high priority, this is a relevant outcome measure. Likewise, outcomes related to the well-being of caregivers are scarce. In healthcare settings where the physical and especially the emotional burden is perceived to be high, this is a valuable outcome measure for future researchers in this area to consider.

Implementation of CRM Training

Our review of the CRM literature also highlights that most articles present limited information on the implementation strategy of CRM interventions. That said, of the information provided, there seems to be a high level of variety in the implementation strategies that are leveraged. Information on the possibility to participate in the training was most frequently presented (e.g., CRM training that was offered during working hours, compensating the hours spent within CRM training, or providing multiple possibilities to follow the training). In addition, the status of the CRM

TABLE 3. Summary Included Articles Phase 2

Authors (Year)	Main Aim of Study	Setting	Study Design	Main Results	Impl. Strategy	Sust. Strategy	Kirkpatrick Level	MMAT
Allan et al[34] (2010)	To evaluate the implementation of a multidisciplinary in situ pCICU–CRM training program on comfort and confidence levels among participants involved in resuscitation events	pCICU	Pre-post survey	> Participants found course useful and realistic, found themselves better prepared to participate in and to lead resuscitation events, felt more confident, had a lower anxiety level to participate in events, and reported to be more likely to raise concerns about inappropriate management to team leader	No	No	1, 2	100%
Atamanyuk et al[35] (2013)	To evaluate the face validity of an affordable and realistic tool for interprofessional CRM training, and the impact on communication skills	Pediatric ICUs	Pilot study	> High face validity of the scenario, the model, and the content > High impact on practice, teamwork, and communication	No	No	1, 2, 3*	25%
Ballangrud et al[36] (2014a)	To describe intensive care nurses' perceptions of simulation-based team training based on CRM for building patient safety in the ICU	ICUs	Qualitative design based on individual interviews	> Participants experienced that the training created awareness about clinical practices and acknowledged the importance of structured teamwork for patient safety > Realistic training makes nurses more prepared to provide care	No	No	1, 2	100%
Ballangrud et al[37] (2014b)	To investigate intensive care nurses' evaluations of simulation-based team training based on CRM	ICUs	Post survey	> Participants were highly satisfied with current learning in the training and scored also high on self-confidence in learning	No	No	1, 2	100%
Bank et al[38] (2014)	To evaluate the effects of a short, needs-based pediatric CRM simulation workshop with postactivity follow-up on recognizing common errors in teamwork and improving perceived abilities to manage pediatric patients	Pediatric emergency medicine department	Pre-post survey and pre-post video assessment	> Participants improved the abilities to manage the medical and team functioning—related issues in pediatric resuscitation > Improvement in identification of CRM errors	No	Yes	1, 2, 3	100%
Batchelder et al[39] (2009)	To examine a specific element of the training and to measure and quantify changes in performance	Prehospital emergency medicine	Beginning and end of the course video evaluation and pre-post survey	> Increase in time from arrival to inflation of tracheal tube cuff > Decreased number of safety critical events > Higher CRM behavior scores > Increased confidence in prehospital anesthesia competencies	No	No	2	100%

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TABLE 3. *(Continued)*

Authors (Year)	Main Aim of Study	Setting	Study Design	Main Results	Impl. Strategy	Sust. Strategy	Kirkpatrick Level	MMAT
Blackwood et al[40] (2014)	To examine the effect of a brief CRM teaching session on pediatric advanced life support, CRM skills, resuscitation, and teamwork behavior	Pediatric hospital	Prospective randomized control pilot study	> Intervention group placed monitor leads earlier, placed an IV sooner, called for help quicker, and checked for a pulse after noticing a rhythm change quicker > Intervention group had higher crisis resource management performance scores	No	No	3*	100%
Budin et al[41] (2014)	To describe changes in perinatal nurse and physician caregiver perceptions of teamwork and safety climate after a 6-mo CRM training program	Perinatal units	Pre-post survey	> Improvement in nurses' and physicians' perceptions of teamwork and safety climate > Both groups improved	Yes	Yes	2	100%
Burden et al[42] (2014)	To compare simulation versus lecture teaching CRM skills and its effect on performance	Internal medicine	Randomized control pre-post study	> Simulation intervention improved team communication and cardiopulmonary arrest management	No	No	2, 3*	100%
Carbo et al[43] (2011)	To evaluate residents' patient safety attitudes and knowledge after an adapted CRM curriculum from other settings to internal medicine	General medicine units	Pre-post survey	> Improvement in knowledge about key skills of team training > Improvement in assertiveness > Increased likeliness to fill out an incident report for a near miss	No	No	1, 2, 3*	75%
Carpenter et al[44] (2017)	To research the effect of CRM-based medical team training on creating open, yet structured, communication	OR	Pre-post survey and checklist documentation	> Improvement in job satisfaction, safety climate, and working conditions > Improvement to adherence to checklist	Yes	Yes	2, 3	50%
Castelao et al[45] (2011)	To evaluate the effect of video-based CRM training on no-flow time and proportions of team member verbalizations	Students	Randomized control trial	> CRM training reduced no-flow time, improved team leader verbalization, and improved follower verbalization in the category unsolicited information	No	No	3	100%
Castelao et al[46] (2015)	To assess the impact of CRM team leader training (compared with ALS training) on CPR performance and team leader verbalization	Students	Prospective randomized controlled study	> CRM team leader training had higher ADH scores, team leader verbalizations, but not significantly shorter no-flow time	No	No	3	100%
Catchpole et al[47] (2010)	To examine the effect of aviation-style team training on surgical teams and to examine the organizational and social context in which the observable changes take place	OR	Pre-post observations, pre survey, and ethnographic observation	> Increased number of stop-checks, briefings, and debriefings > Intraoperative teamwork was not unequivocally improved	Yes	No	2, 3	100%
Chan et al[48] (2016a)	To evaluate how healthcare professionals perceive a simulation team-based CRM program	High-risk hospital departments	Post survey	> High scores on overall satisfaction with program, the applicability of the program, and the high standard and expertise of the trainers > Most participants would recommend the program to colleagues	No	No	1	100%

Study	Aim	Setting	Study design	Findings			Level	%
Chan et al[49] (2016b)	To evaluate participant reactions and attitudes to CRM teamwork classroom-based training and exploring potential differences in attitudes across the different healthcare professionals	Multiple hospital departments	Pre-post survey and a second post survey	> Positive effect on human factors attitude of frontline professionals > Nurses showed a greater positive shift in attitudes toward patient safety than doctors > Participants found the CRM classroom-based training program useful, relevant, and interesting	No	No	1, 2	75%
Ciporen et al[50] (2018)	To evaluate participants on performance metrics and teamwork dynamics and to evaluate CRM-based simulation at the end of the experience	Neurosurgery and anesthesiology	Pre-post survey and observations	> Participants overall agreed that the simulation was realistic, clinically applicable, and useful. No differences were found between disciplines > The simulation was found useful in facilitating improved understanding of relevant anatomy	No	No	1, 2	75%
Clarke et al[51] (2014)	To measure the development of NTSs over time	Emergency medicine	Observational longitudinal cohort study	> Improvements over time on Ottawa GRS between year 1 and 2, but no significant improvement between year 2 and 3	No	No	3*	100%
Clay-Williams et al[52] (2013)	To test the effectiveness of classroom- and simulation-based CRM training alone or in combination, in improving the teamwork attitudes and behaviors of healthcare professionals	Acute hospital settings	Randomized controlled trial, pre-post survey, another post hoc survey, and post hoc observations	> Reaction to classroom training was universally positive (to simulation training was not measured) > Improvements in knowledge and teamwork behavior after classroom training > No impact of additional simulation training next to classroom training > No improvement in teamwork attitude after classroom, simulation, or combination training	No	No	1, 2	50%
Clay-Williams et al[53] (2014)	To explore the potential for modularized CRM training to interprofessional healthcare workers	Hospital	Pre-post surveys	> Workshops met the needs of participants and provided interprofessional learning experience and practical skills > Barriers were identified for implementing learned tools/strategies	No	No	1, 2, 3*	100%
Clay-Williams and Braithwaite[54] (2015)	To test the effectiveness of classroom- and simulation-based CRM courses (alone and in combination), and identify organizational barriers and facilitators to implementation of team training programs in healthcare (process evaluation of Clay-Williams et al,[52] 2013)	Acute hospital settings	Randomized controlled trial, pre-post interviews, and post implementation interviews	> Improvement in knowledge and teamwork behavior after classroom training > Facilitators and barriers (i.e., hospital time and resource constraints and poor organizational communication) for implementation were identified	Yes	No	1, 2, 3	100%

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TABLE 3. *(Continued)*

Authors (Year)	Main Aim of Study	Setting	Study Design	Main Results	Impl. Strategy	Sust. Strategy	Kirkpatrick Level	MMAT
Cooper et al[55] (2008)	To compare the safety climates between departments and to assess the impact of the simulation-based CRM training on safety climate	Anesthesia departments	Pre-post survey	> Different climate scores among hospitals, no difference between the trained and untrained	No	No	2	75%
Coppens et al[56] (2018)	To investigate (i) whether integrating a course on CRM principles and team debriefings in simulation training, increases self-efficacy, team efficacy, and technical skills of nursing students in resuscitation settings and (ii) which phases contribute the most to these outcomes	Nursing students	Randomized controlled trial, pre-post survey, and observations	> Improvement in self-efficacy and team efficacy in the intervention group, while the control group only showed improvement on team efficacy > The debriefing phase contributes most to these effects	No	No	2, 3	100%
De Korne et al[57] (2014)	To evaluate the implementation of a broad-scale TRM program on safety culture	Eye hospital	Pre-post interviews and observations	> Increasing safety awareness and social team interaction > Increased number of reported near incidents > Stabilization of number of wrong-side surgery to a minimum (after reduction)	Yes	No	1, 2, 3, 4	100%
Duclos et al[58] (2016)	To assess the impact on major surgical complications of adding a CRM-based team training program after checklist implementation	OR	Cluster randomized trial, case reports on adverse events and compliance of checklist use	> Improvement in surgical outcomes (i.e., major adverse events), with no difference between trial arms across intervention and control hospitals	No	No	4	100%
Emani et al[59] (2018)	To research the effect of low-fidelity simulation-based crisis resource management CRM training on team performance (in low-resource setting)	pCICU	Pre-post questionnaire and observations	> Improvement in team dynamics and performance > Decrease in time to intervention > Increase in frequency of closed loop communication > No difference in performance	No	No	3	100%
Falcone et al[60] (2008)	To evaluate the effectiveness of a multidisciplinary trauma training program (that emphasizes CRM training techniques) on team performance	Pediatric trauma care	Beginning to end of the study observations	> Improvement in overall performance (appropriate and timely care) and performance of specific resuscitation domains	Yes	No	2	100%
Fore et al[61] (2013)	To assess the impact of sterile cockpit principle on interruptions and distractions (during high-volume medication administration) and number of medication errors	Medical oncology unit at VA Health System	Pre-post design for medical error rates and post design for distractions	> Decrease in interruptions or distractions > Reduction in medication error rate	Yes	No	3, 4	100%
France et al[62] (2008)	To evaluate the impact of CRM training on team compliance with perioperative safety practices	Surgical departments	Observational study	> Compliance with 60% of integrated safety and CRM practices > Compliance scores showed a downward trend over time	Yes	No	3	100%

Study	Aim	Setting	Design	Results				
Fransen et al[63] (2017)	To investigate whether simulation-based obstetric team training focusing on CRM in a simulation center improves patient outcome	Obstetric units	Cluster randomized controlled trail	> The composite outcome of obstetric complications did not differ between intervention and control groups > In the intervention group damage due to shoulder dystocia was reduced and invasive treatment for severe postpartum hemorrhage was increased	No	No	4	100%
Gallagher[64] (2016)	To evaluate a CRM follow-up program on long-term goals	Mother-baby and labor and delivery	Pre-post survey	> Improvement in most safety culture measurements > Improvement in hand hygiene (for labor and delivery) > Mixed results on improvement patient satisfaction	Yes	Yes	3*,4	100%
Gillespie et al[65] (2017)	To evaluate the effect of a brief team training intervention on teams' observed NOTSS	OR	Pre-posttest interrupted time series design (pre-post observation)	> Improvements in mean NOTECHS scores across the pre-posttest phases	No	No	3	100%
Gillespie et al[66] (2017b)	To evaluate a brief team training program in relation to teams' observed NTSs in surgery, teams' perceptions of safety culture, and the training implementation	OR	Mixed-methods design, including structured observations, a survey, and semistructured interviews	> Improvements in NTSs and in the use of the WHO Surgical Safety Checklist > No improvement in teamwork > Nonsignificant increase in safety climate and decrease in teamwork climate > Most participants agreed that the program highlighted the important role of individual and shared SA in identifying and managing risk	No	No	1, 2, 3	100%
Gillman et al[67] (2015)	Describe the trauma multidisciplinary crisis resource course titled S.T.A.R.T.T. (Simulated Trauma and Resuscitative Team Training)	Trauma teams	Post study and observations	> High satisfaction of participants > Improvement in Ottawa GRS > No significant improvements in Advanced Trauma Life Support checklist	Yes	No	1, 3*	100%
Gore et al[68] (2010)	To evaluate the perceived efficacy of CRM initiatives	OR	Pre-post survey	> Improvement in reporting errors (only 2 questions) and patient safety climate (only 2 questions) > No improvement in teamwork	Yes	No	2	75%
Gross et al[69] (2019b)	To establish the feasibility of chunking CRM training into microsize interventions and to compare different training approaches in the context of microlearning	Medical students	Pre-post survey and observations	> Both groups (i.e., example and lecture) showed most of the behaviors included in the instructional videos during the simulations and were able to recollect them > The didactic concept of the instruction caused a difference between the learning success of the groups	No	No	1, 2	100%

(Continued next page)

TABLE 3. *(Continued)*

Authors (Year)	Main Aim of Study	Setting	Study Design	Main Results	Impl. Strategy	Sust. Strategy	Kirkpatrick Level	MMAT
Guerlain et al[70] (2008)	To measure the effect of CRM strategies on the resultant use and perceived utility	OR	Pre-post survey	> Increasing frequency of preoperative briefing elements > Using briefings practices correlates highly with respondents' perceptions of communication, teamwork, and potential for reducing errors	No	No	2, 3*	75%
Haerkens et al[31] (2015)	To assess the effects of CRM implementation on outcome in critically ill patients	ICU	Preimplementation-post design for outcome measures, preimplementation survey design, and observations in implementation period	> Reduction of incidence of predefined complications > Reduced standardized mortality rate > Improvement in safety climate	Yes	Yes	2, 3, 4	75%
Haerkens et al[71] (2018)	To assess the effects of CRM implementation on safety climate and time spent in the trauma room, and on hospital length of stay and 48-h crude mortality of trauma patients.	Emergency department	Pre-post implementation design for outcome measures (with control group) and surveys	> Improvement in safety climate (i.e., teamwork climate, safety climate, and stress recognition) and decrease perceptions of management > Job satisfaction and working conditions did not change > Length of stay increased > Mortality rate was unchanged	Yes	Yes	2, 4	100%
Haffner et al[72] (2016)	To assess a CRM training program on the correction rate of improperly executed chest compressions and communication quality in a simulated cardiac arrest scenario	Medical students	Randomized study, pre-post survey, and pre-post observations	> Team leaders corrected improper chest compressions more often compared with the control group > Improvement in communication quality compared with the control group	No	No	2, 3	100%
Haller et al[73] (2008)	To assess the effect of a CRM intervention on teamwork and communication skills in a multidisciplinary obstetrical setting	Labor and delivery unit	Pre-post survey	> Better understanding of teamwork and shared decision making in emergency situations > Improvement in team and safety climate and stress recognition	No	No	1, 2	75%
Hänsel et al[74] (2012)	To evaluate the influence of a CRM course on situational awareness and medical performance in crisis scenarios and to compare the results with the effects of a purely clinical simulator training	Medical students	Randomized controlled trial, pre-post design with assessment tool	> The simulator training nor the CRM course influenced clinical performance > Situational awareness improved only after simulator training, not after CRM training	No	No	1, 2	75%
Hansen et al[75] (2007)	To assess the educational benefit of a CRM training and whether the damage control techniques are used in daily practice	OR	Pre survey and another post survey	> Increase of number of team members who felt comfortable performing damage control surgery with own role (particularly surgeons) > Roughly 50% of surgeons and OR nurses used damage control techniques in practice > Improvement in the ability to handle severely injured patients improved	No	No	1, 2, 3*	75%

Study	Objective	Setting	Study design	Findings				
Hansen et al[76] (2008)	To evaluate a team-oriented and CRM-based approach and its impact on trauma care	OR	Post survey	> Improvement in proficiency with damage control techniques > Team approach was perceived as crucial > Most hospitals reported modifying trauma protocols	No	No	1, 2, 3*	75%
Hay et al[77] (2016)	To evaluate implementation of a "sterile cockpit" methodology to reduce the number of distractions during procedures	Nursing staff of gastrointestinal endoscopy procedure	Pre survey and another pre-post survey and observations	> Improved awareness of distraction and its impact on patient safety > Reduction of interruptions to zero > While reducing distractions, perception of nursing quality of care improved	No	No	2, 3	75%
Hefner et al[78] (2017)	To examine the impact of a systematic multihospital implementation of CRM on staff perceptions of patient safety culture	Hospitals	Pre-post survey	> Significant improvement in dimensions of patient safety culture perception; teamwork and communication dimensions may be more likely influenced by CRM training than supervisor and management dimensions	Yes	No	2	75%
Hicks et al[79] (2012)	To describe the development, piloting, and multilevel evaluation of CREW training for emergency medicine residents	Emergency department	Pre-post survey and pre-post observational	> The training is perceived to be useful, effective, and highly relevant > Unable to detect a difference in attitude and NTSs	No	No	1, 2	75%
Hughes et al[80] (2014)	To describe the development, implementation, and effectiveness of a trauma resuscitation-focused CRM program	Trauma resuscitation	Pre-post survey and pre-post observational design	> Improvement in accuracy of field to medical command information, accuracy of emergency department medical command information to the resuscitation area, team leader identity, communication of plan, and role assignment > More likely to speak up in case of safety concerns	No	No	1, 2, 3	75%
Jankouskas et al[81] (2007)	To evaluate improvement in the NTSs of a multidisciplinary team of pediatric residents, anesthesiology residents, and pediatric nurses after participation in the CRM educational program	Pediatrics	Pre-post survey and observations	> Improvement in perceived collaboration, satisfaction with care, and teamwork skills > No significant improvement in situation awareness, decision making, and task management	No	No	2, 3	75%
Jankouskas et al[82] (2011)	To evaluate CRM training (in combination with basis life support) during a simulated patient crisis	Nursing and medical students	Experimental pre-post study	> Experimental teams compared with control teams: improvement in team process > Both experimental and control teams showed improvements in team effectiveness	No	No	3, 4	75%

TABLE 3. *(Continued)*

Authors (Year)	Main Aim of Study	Setting	Study Design	Main Results	Impl. Strategy	Sust. Strategy	Kirkpatrick Level	MMAT
Kemper et al[83] (2014)	To examine the impact of pretraining readiness factors and posttraining barriers and facilitators on follow-up on plans of action	ICUs	Pre-post survey	> Perceived barriers and facilitators after CRM training is related with taking action > Readiness factors were positive related to taking action, only when assessed together and not separately > Support of the management for patient safety before the training is a positive determinant of the number of perceived facilitators	Yes	No	2, 3*	100%
Kemper et al[32] (2016)	To assess the effectiveness of a classroom-based CRM training in ICU	ICUs	Controlled trail, pre-post survey with mixed method data	> Improvement in behavior aimed at optimizing situational awareness (based on survey, not observation) > Improvement in error management culture, job satisfaction, and patient safety culture (also in control group) > Patient outcome and situational awareness attitude were unaffected	Yes	No	1, 2, 3, 4	100%
Kuy and Romero et al[84] (2017a)	To determine whether rates of CITN patient safety adverse events change after CRM training	Surgery (VA)	Pre-post outcome measures	> Complete compliance to performance of briefings and debriefings after CRM training > Decrease of CITN events to zero after CRM training	Yes	No	3, 4	100%
Kuy and Romero et al[85] (2017b)	To describe implementation of CRM in a VA Surgical Service and to assess whether staff CRM training is related to improvement in staff perception of a safety climate	Surgery (VA)	Pre-post survey	> Improvement in safety climate	Yes	Yes	2	75%
LaPointe[86] (2012)	To observe the impact of aviation-based CRM training on the safety attitudes of perioperative (surgical) personnel	OR	Quasi-experimental pre-post survey	> Improvements in most of the safety attitudes > No reduction of error rate and safety culture	No	No	2, 4	100%
Lehner et al[87] (2017)	To establish interdisciplinary simulation-based team training as a tool to improve the care of trauma patients in the pediatric surgery trauma room	Pediatric emergency department	Pre-post survey and another post survey	> The course was evaluated as very realistic and relevant to the daily routine, detailed debriefings were evaluated as positive > Participants reported improvement in technical and/or medical skills (i.e., cardiopulmonary resuscitation) and NTSs (i.e., setting priorities)	No	No	1, 2	50%
Mah et al[88] (2009)	To evaluate mannequin-based simulations (using multidisciplinary teams of clinicians)	ICU	Pre-post (real time) observation and pre-test	> Positive relation of knowledge of sepsis guidelines and proportion of task completion, but correlations between specific tasks and related questions showed no relationship to knowledge	No	No	2, 3	75%

Study	Objective	Setting	Study design	Findings			Level	%
Mahramus et al[89] (2016)	To assess the effectiveness of a 2-h teamwork training program	Cardiopulmonary arrest (code) team	Quasi-experimental design, pre-post survey, pre-post observations	> Improvement in perception and observation of teamwork > Program was evaluated positively	No	No	1, 2, 3	75%
Man et al[90] (2019)	To investigate the impact of locally adopted simulation-based CRM training on participants' perceptions and knowledge	OR and general	Pre-post survey	> Most participants reported the training to be useful and relevant in daily practice > Improvement in perception and knowledge after 1-mo postcourse but declined after 1-y postcourse	No	No	1, 2	75%
Mancuso et al[91] (2016)	To assess the effectiveness of CRM training and interventions on communication	Labor and delivery	Pre-post observation	> Improvement in quantity and quality of communication	Yes	No	3	100%
Marshall and Manus[92] (2007)	To examine the cultural impact of a CRM-based Human Factors in Healthcare Demonstration Project	Surgery	Pre-post survey	> Overall improvements in patient safety awareness and the quality of team-based behaviors and performance	Yes	Yes	2, 3	100%
McCulloch et al[13] (2009)	To assess the effect of aviation-style NTS training on the number of potentially significant errors and mishaps with potential for harm to patients and clinical outcome measures	OR	Pre-post observation, pre-post survey with clinical outcome measures	> Improvement in safety climate and nontechnical performance > Decreased operative technical error and nonoperative procedural errors > Operating time was unaffected and length of hospital stay not reduced significantly	No	No	2, 3, 4	100%
Mitchell and Dale[93] (2015)	To assess the effect of a 1-d human factors (CRM) training program	Neurosurgical theater staff	Pre-post observation with side error rates	> Prelist briefing meetings were adopted and quickly became widely used > Postlist debriefing meetings were introduced but were not widely adopted > Mean time between side errors increased from 2 to 18 mo > After the training, no errors occurred in 82 mo	Yes	Yes	1, 2, 3, 4	75%
Moffatt-Bruce et al[94] (2017)	To evaluate the costs and ROI of implementing a CRM program and to improve understanding about its financial impact	Hospitals	Retrospective analysis	> A 25.7% reduction in observed relative to expected events (725 fewer AEs) > Increased hospital savings from estimated reduction in avoidable events > Significant ROI from reduced adverse events over a 3-y period > The overall ROI for CRM training was in the range of $9.1–$24.4 million	Yes	No	4	100%
Morgan et al[95] (2009)	To determine whether simulation-based debriefing and feedback improved performance of practicing anesthetists managing high-fidelity simulation scenarios	Anesthesiology	Prospective, randomized, controlled study	> Improvement of skills > Participants from the debrief group did not overall perform better than those in the control group > The effect of the educational intervention was still evident 6–9 mo later	No	No	3*	100%

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TABLE 3. *(Continued)*

Authors (Year)	Main Aim of Study	Setting	Study Design	Main Results	Impl. Strategy	Sust. Strategy	Kirkpatrick Level	MMAT
Morgan et al[96] (2011)	To determine whether a high-fidelity simulation educational debriefing session improved the NTSs in the management of simulated anesthetic scenarios	Anesthesia departments	Pre-post observations	> No improvement in task management and team working > Improvement in situation awareness (only in the debrief group) and in decision making (for both groups)	No	No	3	100%
Morgan et al[97] (2015)	To test the effectiveness of a combined SOP (standard operating procedures) and CRM-based teamwork training intervention to improve the quality, safety, and reliability of surgical team performance	Orthopedic surgery	Controlled interrupted time series with pre-post observations and clinical outcomes	> Improvement in NTS and WHO compliance > Glitch rates decreased in the intervention as control group > No significant effect on clinical outcomes	No	No	3, 4	100%
Müller et al[98] (2007)	To establish and evaluate a CRM course combining psychological teaching with simulator training	Emergency department	Post survey	> All participants rated the course as good or very good > The psychological exercises were highly valued	No	No	1	75%
Müller et al[99] (2009)	To evaluate the effect of 2 different simulator-based training approaches, CRM, and MED (classic simulator training), on performance and stress reduction of intensivists	ICUs	Randomized design, pre-post observation design, and pre-post saliva specimen	> Improvement in NTS and clinical performances in both CRM and MED group > Increased stress during the simulation, after the training stress (that is measured by salivary α-amylase) reduced	No	No	3	100%
Neily et al[100] (2010a)	To evaluate to what degree skills taught through the CRM-based medical team training program are implemented and the impact on patient safety, processes of care, team functioning, and staff satisfaction	Surgery departments	Structured interviews	> Improvements in teamwork, safety, and efficiency > Most facilities implemented briefings and debriefings and an additional project > Sites with lower volume were more likely to conduct briefings/debriefings	Yes	No	1, 2, 3*	100%
Neily et al[101] (2010b)	To determine whether an association existed between the CRM-based medical team training program and surgical outcomes	OR	Retrospective mixed methods design with control group: structured interviews and mortality rates	>18% reduction of annual mortality rate compared with 7% in the control group > Decline in the risk-adjusted surgical mortality rate was approximately 50% greater in the intervention group compared with control group	Yes	Yes	3*, 4	100%
Nielsen et al[33] (2007)	To evaluate the effect of CRM based teamwork training on the occurrence of adverse outcomes and process of care in labor and delivery	Hospital labor and delivery units	A cluster-randomized controlled trial, pre-post design for outcome measures	> No statistically significant differences between intervention and control group for outcome measures > Mean time elapsed between the decision to perform an emergency cesarean delivery and the time of the incision was shorter in the intervention group	Yes	Yes	4	75%

Study	Aim	Setting	Method	Findings				
Nishisaki et al[102] (2009)	To evaluate effectiveness on technical and behavioral skills and feasibility (logistics and finance) of a simulation-based orientation training	Pediatric critical care fellows	Post surveys	> Improvements in clinical performance and self-confidence	No	No	1, 2, 3*	50%
O'Connor et al[103] (2013)	To develop and evaluate a CRM training program	Trainees	Pre-post survey, another post survey, and pre-post observations	> Improvement in knowledge > No improvement in speaking up about stress and behavior > Improvement in speaking up to seniors for in-between subject assessment	No	No	1, 2, 3	100%
Paull et al[104] (2013)	To investigate the effect of simulation-based CRM team training curriculum on teamwork and communication skills	Surgery	Pre-post survey and observation study	> Improvement in teamwork > Improvements in (most) observed skills	No	No	3	50%
Parsons et al[105] (2018)	To design and evaluate a CRM course that could be feasibly incorporated into any EM residency curriculum	Emergency medicine	Pre-post observations	> No improvement in leadership, problem solving, communication, situational awareness, teamwork, resource utilization, and overall CRM skills	No	No	3	75%
Phipps et al[106] (2012)	To determine whether implementing an L&D unit team training program with simulation training improves patient outcomes as well as perceptions of safety and communication	Labor and delivery units	Pre-post survey design and pre-during-post design for outcome measures	> Improvements in many dimensions of the L&D unit's safety culture, but not dimensions of the hospital-wide culture > Frequency of event reporting and the overall perception of safety did not change > Overwhelming positive patient responses to both pre-CRM and post-CRM surveys, no changes detected > The Adverse Outcome Index showed a significant decrease compared with baseline measurement	Yes	No	2, 3*, 4	75%
Pratt et al[107] (2007)	To assess the impact of CRM-based team training	Obstetrics department	Pre-post study	> Decrease in AOI, WAOS, SI, and malpractices > Improvement in safety attitude	Yes	No	3*, 4	50%
Rêgo et al[108] (2008)	To describe the development, evaluation, and outcomes of a pilot CRM course	Ambulatory surgery	Pre-post study	> All participants would recommend this course > Participants would use CRM principles in the future > Improvement in communication and the ability to assert when necessary with more senior staff	No	No	1, 2, 3*	50%
Ricci et al[109] (2012)	To measure the effect of a surgical CRM training program for all OR personnel, on WSS and RFBs	OR	Pre-post outcome measures and audit data	> Preoperative briefing increased to 99% within 4 mo > Wrong site surgeries and retained foreign bodies decreased to none, but after 14 mo without additional training, rose to 5	Yes	Yes	3, 4	75%

TABLE 3. *(Continued)*

Authors (Year)	Main Aim of Study	Setting	Study Design	Main Results	Impl. Strategy	Sust. Strategy	Kirkpatrick Level	MMAT
Rovamo et al[110] (2015)	To evaluate the impact of CRM and anesthesia NTS instruction on teamwork	Delivery units	Pre-post observation with control group	> No improvements in team performance > Experience of team leaders improved teamwork over the CRM	No	No	3	100%
Sandahl et al[111] (2012)	To describe implementation of simulator-based medical team training and the effect of this program on interprofessional working	ICUs	Case study	> Increased awareness of importance of effective communication for patient safety > Created a need to talk, which resulted in regular reflection meetings	Yes	Yes	1, 2, 3	25%
Savage et al[112] (2017)	To evaluate the multilevel effects over time of the implementation of standardized CRM-based team training and targeted system improvement projects	Pediatric surgery	Multilevel prospective single-case study	> Improvement in NTSs, the use of safety tools, and adherence to guidelines for appendectomies > Improvement in safety culture: teamwork across and within units, supervisors' expectations and actions, nonpunitive response to adverse events, and perceptions of overall patient safety > Improvement in unplanned readmissions after appendectomy	Yes	No	1, 2, 3, 4	100%
Sax et al[113] (2009)	To quantify effects of aviation-based CRM training on patient safety–related behaviors and perceived personal empowerment	Surgical departments	Pre-post survey design and check list use and error reporting over time	> Improvement in preoperative checklist use, self-initiated reports, and the percentage of reports related to environment as opposed to actual events increased > Improvement in perceived self-empowerment and creating a culture of safety	Yes	Yes	2, 3, 4	75%
Schwartz et al[114] (2018)	To implement and evaluate clinical team training, which is a combination of CRM-based medical team training and nursing CRM	VA facilities	Pre-post survey	> Improvement in communication, teamwork and situational awareness for patient safety > Observed decreases between 6- and 12-mo measurement	Yes	No	2	50%
Sculli et al[115] (2013)	To measure the effect of nursing based CRM program using a multifaceted approach	Surgical, intensive care, intensive care step down, and long-term care units	Pre-post survey and pre-post outcome measure design and follow-up interviews	> Improvements in all teamwork domain questions > Significant gains were realized in the areas of medication errors, HAPU, glucose control, FTR events, and care processes	No	Yes	2, 3, 4	100%
Shea-Lewis[116] (2009)	To investigate the feasibility of a CRM-based training to improve patient care	Obstetrics	Pre-post outcome measures and continuous surveys	> Improvement in patient outcomes, patient, and staff satisfaction	No	No	4	100%

Study	Objective	Setting	Method	Findings				
Siems et al[117] (2017)	To evaluate CRM NTS training as an improvement technique for rapid response team performance	Pediatric critical care	Pre-post observations	> Improvement in leadership, teamwork, task management, and global scores > Improvement in patient transfer regarding team leader and team introductions, floor team presentations in SBAR format, and confirmation of the plan	Yes	No	3	100%
Stocker et al[118] (2012)	To evaluate the impact of an embedded simulation-based team training program on perceived performance and to compare the effect over different phases of the program	Pediatric intensive care	Implementation and post survey	> Impact on overall practice perceived as effective > Nontechnical skills (communication and teamwork) and technical skills showed an effective impact > Increased score for effective impact over phases	Yes	No	1, 2, 3*	100%
Sundararaman et al[119] (2014)	To implement and evaluate a CRM training	Radiation oncology	Case study using objective outcomes	> Improvement in safety record: decrease in near-miss rate and elimination of all treatment deviations > High sense of teamwork combined with a high degree of personal responsibility to assure patient safety and speaking up about potentially unsafe situations > Increased efficiency	Yes	No	3, 4	100%
Suva et al[120] (2012)	To analyze the impact of a CRM program on satisfaction and learning among OR personnel and compare disciplines	OR	Pre-post survey	> High satisfaction for course organization, group dynamics, and teaching methods > Improvement in learning, especially in the domain of teamwork and safety culture, less in stress recognition	No	No	1, 2	100%
Sweeney et al[121] (2014)	To evaluate the effectiveness of Project CLEAR!, a novel simulation-based training program designed to instill CRM as the communication standard and to create a service-focused environment by standardizing the patient encounter	Emergency department	Pre-post survey	> Improvement in quality of communication between staff members and between staff and patient	Yes	No	2, 3*	75%
Tapson et al[122] (2011)	To assess to effect of a quality improvement initiative for VTE prophylaxis that combined clinical education with CRM	Surgical department	Pre-post survey and retrospective reviews of patient charts	> Immediate and retained confidence and increased knowledge in identifying process related factors leading to errors > No difference in attitude > Reviews of patient charts preinitiative and postinitiative demonstrated performance improvement in meeting guideline recommendations for the timing, inpatient duration, and use of VTE prophylaxis beyond discharge	Yes	No	2, 3*	75%

TABLE 3. (Continued)

Authors (Year)	Main Aim of Study	Setting	Study Design	Main Results	Impl. Strategy	Sust. Strategy	Kirkpatrick Level	MMAT
Taylor et al[123] (2007)	To assess the effect of the CRM intervention on adherence to evidence-based diabetes care standards, work processes, standardized clinical communication, and patient outcomes	Primary care clinic	A quasi-experimental, interrupted time-series design, with observation and outcome measures	> Improvement in microalbumin testing and associated patient outcome measures > CRM resulted in reorganized work processes, teamwork with new roles and responsibilities, coordination and communication, and check for omissions using checklists to structure and drive clinical workflow	Yes	No	2, 3, 4	50%
Trujiens et al[124] (2015)	To explore whether multiprofessional (CRM-based) simulation-based obstetric team training improves patient-reported quality of care during pregnancy and childbirth	Obstetric collaborative network	Pre-post survey	> Improvement in patient-reported quality of care; personal treatment during pregnancy and educational information improved, but personal treatment during delivery showed no significant difference	No	No	3*	75%
Truta et al[125] (2018)	To assess the effect of a single-day CRM training on NTSs	Emergency departments	Pre-post observations	> Improvements in all NTSs	No	No	3*	100%
Tschannen et al[126] (2015)	To evaluate an intervention using NCRM principles implemented to improve communication among RNs and physicians	General medicine telemetry units	Pre-post survey	> Nonsignificant improvement in communication openness and environmental values (both RN's and physicians) > RNs reported an increase in synchronous and asynchronous communication with physicians, physicians noted a reduction in time spent in asynchronous communication > RNs identified an improvement in the quality of synchronous communication, physicians did not note this improvement	Yes	No	2	75%
Tschannen et al[127] (2018)	To examine virtual training on CRM principles on knowledge, applicability, and intended behaviors	Trainees	Pre-post survey	> Postknowledge test scores improved > Participants reported learning new skills and knowledge and intended to use the skills/knowledge gained from the training in clinical practice	Yes	No	1, 2	100%
Turkelson et al[128] (2016)	To determine the effectiveness of a multifaceted educational strategy: simulation to introduce communication algorithm adapted from nursing CRM	ICU	Pre-post study	> Participants were satisfied > Improvement in knowledge > Improvement in interprofessional communication and manikin outcomes	No	No	1, 2, 3*	75%
Verbeek-van Noord et al[129] (2015)	To evaluate the effect of a 2-d classroom-based CRM training at emergency departments on explicit professional oral communication	Emergency departments	Controlled trial, pre-post survey, and observation	> Improvement in human interaction and the overall explicit professional oral communication score, but not in anticipation on environment	Yes	No	2, 3	100%

Study	Aim	Setting	Method	Results				
West et al[130] (2012)	To describe the application of a CRM technique, the sterile cockpit rule, to improve efficacy and safety for nursing assistants in the performance of patient care duties	Nursing units	Pre-post survey design and post outcome measures	> Improvement in efficiency: extensive improvements, dramatic decreases on all 3 measures of efficiency > Improvement in perception of nursing teamwork, patient safety, and staff moral	Yes	Yes	2, 4	75%
Westfelt et al[131] (2013)	To evaluate CRM-based training of teams of endoscopists and endoscopy nurses, to increase self-efficacy	Internal medicine university hospital	Pre-post survey	> Positive perception regarding obtained theoretical knowledge, practical skills, critical thinking, and the usefulness of the course in daily clinical work > Improvement in self-efficacy	No	No	1, 2	100%
Wetzel et al[132] (2013)	To investigate the effect of laboratory- and in situ simulation-based training sessions to improve technical and NTSs	Neonatal ICUs	Self-observed and identified latent safety threats	> Laboratory and in situ sessions resulted both in identifying LSTs and the underlying causes related to knowledge gaps, poor procedures or poor NTSs > In situ sessions resulted in improvements at the unit itself, the delivery process, or the hospital in general	Yes	No	4	50%
Wu et al[133] (2016)	To assess the effectiveness of an interprofessional CRM education program on satisfaction and safety attitude	Emergency and critical care units	Pre-post survey and another post survey	> Improvement in human factor attitudes > Positive response to the CRM training	No	No	1, 2	100%
Zech et al[134] (2017)	To evaluate a CRM-based team-training program	Obstetrics	Pre-post survey	> Strong effects in perception of competence regarding technical skills and handling of emergencies > Some indications for improvements on the patient safety culture level > Differences were found between professional groups and hospitals	No	No	1, 2	75%
Ziesmann et al[135] (2013)	To develop and evaluate a national multidisciplinary trauma CRM curriculum	Trauma teams	Pre-post survey	> High satisfaction with the course > Improvement in attitudes toward simulation and attitudes toward CRM principles, including overall scores, teamwork, and safety climate	No	No	1, 2	50%

ADH, Adherence to the 2010 Advance life support guidelines; AEs, adverse events; ALS, advanced life support; AOI, adverse outcome index; CITN, Critical Incident Tracking Network; CPR, cardiopulmonary resuscitation; EM, emergency medicine; FTR, failure to rescue; HAPU, Hospital-Acquired Pressure Ulcers; L&D, Labor & delivery; NCRM, nursing CRM; NOTECHS, NOn-TECHnical Skills; NOTSS, nontechnical skills in surgery; NTS, nontechnical skill; OR, operating room; pCICU, pediatric cardiac intensive care unit; RFB, retained foreign body; SA, situational awareness; SBAR, Situation, Background, Assessment, Recommendation; SI, severity index; TRM, team resource management; VA, Veterans Affair; VTE, venous thromboembolism; WAOS, weighted adverse outcome score; WHO, World Health Organization; WSS, wrong site surgery.

training was frequently discussed. For instance, examples include the priority status within an organization and department or if the training was compulsory or voluntary. In addition, in a few cases, an implementation team was composed as part of the implementation strategy. However, it remains an unanswered question as to the impact of how such interventions are implemented and what some potential pitfalls may be from implementing CRM. Likewise, although Weaver et al[28] (2014) noted that CRM is often implemented as a bundle of initiatives, research has yet to fully consider whether or when certain bundles represent deadly combinations rather than resulting in synergistic effects for the caregivers, patients, and healthcare organizations.

Variation

Although there is variation in what the CRM training entailed, most CRM training interventions seem to start with a didactic element (e.g., lecture, e-learning) combined with a form of simulation (e.g., high-fidelity simulator) and debriefing. The duration varied between 1/2 day and a couple of weeks. In addition to the variations present during the training, there is variation before (i.e., implementation strategy) and after (i.e., sustainability elements) the training intervention. The question remains whether and how these differences matter. Likewise, research has yet to truly address which CRM elements are best practices and which should be adjusted to create a best fit. Although such variation is typically viewed in a negative light, it can also be a good thing as evidenced by Tschannen et al[126] (2015) who showed that a tailored CRM training for nurses, the so-called nursing CRM, indicated a culture change and a more permanent effect. This study is especially valuable as it is focused on a relatively novel area for CRM research (nursing teams).

Conclusion Phase 2

Based on our *new* and more comprehensive literature review, we can clearly state that CRM seems to have a positive effect on Kirkpatrick's level 1, 2, and 3. However, effects on level 3 were not only obtained through observations but also through the perception of participants. Whether CRM has a positive effect on level 4 outcomes and how level 4 should be measured remain undetermined. Likewise, the precise manner in which to implement and embed CRM training into the organization so that the desired effects will occur and will be sustained should be given more research attention. Furthermore, future research attention is needed on how long the positive effects will sustain and what the critical factors are to sustain the effects of CRM training interventions.

DISCUSSION AND CONCLUSIONS

The extensive nature of this review demonstrates that a significant number of studies have been conducted over the past decade looking at the effects of CRM in healthcare. At the same time, our review highlights that this research tends to be situated within certain settings (i.e., acute hospital setting) and focused on particular outcomes (i.e., perceived nontechnical skills and team functioning). Accordingly, this suggests that research in this area has provided evidence that CRM is most likely to improve outcomes at Kirkpatrick's level 1, 2, and 3. However, our review also indicates that there are several gaps that remain within the CRM literature. Therefore, future research should attempt to more fully capture the complete picture of CRM in healthcare.

The first gap that we identified based on our review is that rather than focusing exclusively on the results of a CRM intervention at the 4 Kirkpatrick's levels, research should also examine the means by which to actually sustain these effects. In particular, studies should measure the extent to which the results of a CRM intervention can

be sustained and what factors should be implemented to enhance the gains derived from a CRM intervention over longer periods. In addition, research on the content of sustainability strategies on CRM is needed. Sustainability strategies are needed to adapt the intervention and implementation strategies to the needs and feedback of the professionals, thus building employee engagement and ensuring the long-term success of an intervention.[137] In part, such strategies may increase the variability noted within the CRM literature as the factors that assist with sustaining the benefits of CRM interventions may need to be tailored to the particular organization and its context.

The second gap that we identified is the lack of information about the importance that CRM should not be viewed as an isolated intervention but as an element of a broader Human Resource (HR) strategy in which other elements reinforce the attended changes. Research should provide insights in which HR practices (e.g., appraisal, feedback, other training) reinforce or diminish the effect of CRM. Likewise, research should consider whether certain combinations of HR practices and CRM interventions result in a "deadly combination" and thereby actually have detrimental effects. To date, most studies within the CRM literature provided too little information about the context in which CRM is implemented. To truly understand why and how CRM affects (all 4 Kirkpatrick's levels) outcomes and be able to replicate the effect (by researchers and practitioners), detailed information is required related to the context in terms of implementation process and content of HR strategies.

Limitations

Although we did our best to be as inclusive as possible with our review of the CRM literature, we excluded certain articles because we only focused on articles written in English that presented empirical data and were published in peer-reviewed journals. Consequently, we might have excluded studies that present negative or nonsignificant effects of CRM, also known as the publication bias.[138] In addition, given that our focus was only CRM, we did not include related interventions such as TeamSTEPPS or interventions that focused on only 1 element of CRM such as simulation training as CRM is a multifaceted intervention.

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