Impact of crisis resource management simulation-based training for inter professional and interdisciplinary teams: a systematic review

Lillia Fung, Sylvain Boet, M. Dylan Bould, Haytham Qosa, Laure Perrier, Andrea Tricco, Walter Tavares, and Scott Reeves

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Abstract

Crisis resource management (CRM) abilities are important for different health care providers to effectively manage critical clinical events. This study aims to review the effectiveness of simulation-based CRM training for interprofessional and interdisciplinary teams compared to other instructional methods (e.g. didactics). Interprofessional teams are composed by several professions (e.g. nurse, physician, midwife) while interdisciplinary teams are composed by several disciplines from the same profession (e.g. cardiologist, anesthesiologist, orthopaedist). Medline, EMBASE, CINAHL, Cochrane Central Register of Controlled Trials, and ERIC were searched using terms related to CRM, crisis management, crew resource management, teamwork, and simulation. Trials comparing simulation-based CRM team training versus any other methods of education were included. The educational interventions involved interprofessional or interdisciplinary healthcare teams. The initial search identified 7,456 publications, 12 studies were included. Simulation-based CRM team training was associated with significant improvements in CRM skill acquisition in all but two studies when compared to didactic case-based CRM training or simulation without CRM training. Of the 12 included studies, one showed significant improvements in team behaviours in the workplace, while two studies demonstrated sustained reductions in adverse patient outcomes after a single simulation-based CRM team intervention. In conclusion, CRM simulation-based training for interprofessional and interdisciplinary teams shows promise in teaching CRM in the simulator when compared to didactic case-based CRM education or simulation without CRM teaching.

More research however is required to demonstrate transfer of learning to workplaces and potential impact on patient outcomes.

Introduction

In 1999, the Institute of Medicine (IOM) estimated that 100,000 annual deaths were attributed to clinical errors in the United States (Kohn, Corrigan, & Donaldson, 2000). The most common sources of errors were not from failures of clinical knowledge or skill, but rather deficiencies with communication, coordination and teamwork (Reeves, Lewin, Espin, & Zwarenstein, 2010; Williamson, Webb, Sellen, Runciman, & Van der Walt, 1993). According to the IOM the majority of clinical errors were not the result of individual actions, but rather a failure of teams, systems or processes. This led to a call to: train in teams those who are expected to work in teams (Kohn et al., 2000).

While all communication, coordination and teamwork abilities are relevant in routine elective patient care, they are particularly important for crisis resource management (CRM) situations, i.e. life-threatening emergencies, for which urgent and coordinated actions between different disciplines and professions are needed to ensure safe patient care. CRM includes clinical as well as communication and teamworking abilities, however for the purposes of this paper we will focus only on the communication and coordination abilities which have been shown to be essential for the delivery of collaborative care (Cheng, Donoghue, Gilfoyle, & Eppich, 2012; Gaba, Howard, Fish, Smith, & Sowb, 2001). Therefore, in this paper when we use the phrase “CRM” we refer to principles such as leadership and followership, communication, teamwork, resource use, and situational awareness (Cheng et al., 2012). The abilities that are

required for effective CRM are often dependent on effective interprofessional practice (Willems, Waxman, Bacon, Smith, & Kitto, 2013).

Background

In 2010, a large North American study demonstrated that an interprofessional training program for operating room teams (surgeons, anesthesiologists, nurses, and technicians) was associated with a lower surgical mortality (Neily et al., 2010). While interest in team-based training continues to grow (Buljac-Samardzic, Dekker-van Doorn, van Wijngaarden, & van Wijk, 2010; Salas et al., 2008; Weaver et al., 2010), the best method of delivering training has yet to be determined (Cheng et al., 2012; Ostergaard, Dieckmann, & Lippert, 2011). Gaba and colleagues (2001) promoted simulation as the ideal setting to teach and practice team based CRM skills. Simulation has not only been shown to be an effective tool for teaching new knowledge, skills, and behaviours compared to no intervention (Cook et al., 2011), but a recent review concluded that simulation was more effective than traditional clinical education approaches (e.g., “see one, do one, teach one” approach) at achieving specific skill acquisition goals (McGaghie, Issenberg, Cohen, Barsuk, & Wayne, 2011). Simulation not only brings together members from various professions (interprofessional, e.g. nurse, physician, midwife) or disciplines (interdisciplinary, e.g. cardiologist, anesthesiologist, orthopaedist), but it allows teams to practice the management of high-stakes clinical emergencies in an environment uncoupled from adverse events.

Reviews exploring the use of simulation to teach CRM, however, are limited. For instance, one previous review (Doumouras, Keshet, Nathens, Ahmed, & Hicks, 2012) demonstrated

positive participant feedback and changes in team behaviours in the simulator, but provided limited evidence related to transfer of learning to the workplace or patient benefits. This earlier review also had significant limitations: the studies included were limited to medical residents, and only three out of 15 included studies were of interdisciplinary teams, interprofessional teams were not included (Doumouras et al., 2012).

This paper reports the findings from a systematic review aimed to assess: (i) the effectiveness of simulation-based CRM team training compared to any other educational intervention among interprofessional or interdisciplinary teams, and (ii) determine whether simulation-based CRM team training leads to the modification of attitudes, skill/knowledge acquisition, changes in behaviours, and improved patient outcomes.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement was used to guide the reporting of this review (Moher, Liberati, Tetzlaff, & Altman, 2010).

Protocol

A review protocol was compiled and revised by the authors including researchers (AT, LP, SR), educators (SB, MDB), and clinicians (SB, MDB, WT, HQ, LF). This is available from the corresponding author upon request.

Eligibility criteria

Experimental (randomized controlled trials [RCT], quasi-randomized controlled trials [method of allocating participants to treatment not strictly random]) and quasi-experimental designs (controlled before-after studies [CBA] and interrupted time series [ITS]) were eligible for inclusion. Eligible participants included all healthcare providers (e.g., physicians, nurses, emergency response team personnel, respiratory therapists, paramedics, midwives). All levels of training were included (pre- and post-registration, undergraduate, postgraduate, and staff). Studies comparing simulation-based education versus any other method of education were eligible for inclusion. The education intervention included CRM in emergency or high-stakes situations involving a team (at least two individuals from different disciplines/professions). Single learner interventions were excluded. Team training encompassed both *interprofessional* or *interdisciplinary education*. The former was defined as two or more professions (e.g., a nurse and a physician) who learn with, from, and about each other, to improve collaboration, the quality of care or both (EPOC, 2014). The latter was defined as any team of health practitioners from the same profession but from two or more clinical specialties (e.g., two physicians, one nephrologist and another cardiologist). Interventions that did not explicitly mention the terms “CRM” or “crew resource management” as interventions, but taught communication and team coordination abilities during a clinical crisis were also included. Studies were only considered for inclusion if they were published in a language understood by the study team (English or French).

[INSERT BOX 1 HERE]

The *primary outcome* collected was CRM learning acquired. Learning was categorized based on the Kirkpatrick model of educational outcomes, as modified by Phillips (1997) (Table 1). The

original classification described by Kirkpatrick was divided into 4 levels, with level 4 (highest) being “patient outcome”. Phillips added a fifth level to include return on investment of education programs (Phillips, 1997). Outcomes with Kirkpatrick levels of 2 or greater were included. Studies with only Kirkpatrick level 1 outcomes were excluded because they measured learners’ reactions, rather than objective measures of learning. Furthermore, studies with outcomes that relied solely on self-assessed data were excluded because self-assessments conducted by health care workers may be unreliable and inaccurate (Davis et al., 2006; Eva & Regehr, 2005). The only exception was data on modification of attitudes/behaviours (Kirkpatrick 2a) where self-reflection was the only means of collecting this information.

[INSERT TABLE 1 HERE]

Data Sources

A librarian (LP) searched the electronic databases including Medline, EMBASE, CINAHL, Cochrane Central Register of Controlled Trials, and ERIC on September 4th, 2012. There were no restrictions on publication year. For each database, the following search terms were used: crisis resource management, crisis management, crew resource management, teamwork, and simulation.

Study Selection

The titles and abstracts of identified citations were divided among paired authors who independently screened the citations for compliance with the eligibility criteria (SB, WT, ACT, LP, HQ and LF). Disagreements about eligibility were recorded and resolved by consensus. Two

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2
3 authors (HQ and LF) independently screened the full text articles for eligibility. Disagreements
4
5 about eligibility were recorded and resolved by consensus or the involvement of another team
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7 member (SB, MDB or SR).
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13 *Data items and abstraction*
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16 The following information was extracted from each article: study design, sample size,
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18 characteristics of the study population, context of the study environment, description of the
19
20 learning intervention, nature of the comparison group, and data on the primary outcomes, as
21
22 mentioned above. Where data was inadequately reported within the full text article, attempts
23
24 were made by email to contact the original authors of the article for clarification and further
25
26 details. Data abstraction was not blinded (Moher, Horsley, Morgan, Tricco, & Tsertsvadze,
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28 2011) and was performed by two team members, independently (LF and HQ).
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36 *Risk of bias appraisal*
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39 Risk of bias was assessed using the Review Group of Cochrane Collaboration’s Effective Practice
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41 and Organisation of Care Group tool (EPOC, 2014) by two team members, independently (LF
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43 and HQ).
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48 *Synthesis*
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51 Data were not pooled for meta-analysis because of the high degree of heterogeneity in
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53 included studies; therefore, a narrative description was conducted.
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Results

The literature search strategy identified 7456 citations (Figure 1), of which 443 were eligible for the full text review. Fifteen articles met our inclusion criteria, which represented 12 independent studies (Boet et al., 2013; Crofts et al., 2008; Crofts et al., 2007; Daniels et al., 2010; Ellis et al., 2008; Frengley et al., 2011; Jankouskas, Haidet, Hupcey, Kolanowski, & Murray, 2011; LeFlore & Anderson, 2009; Miller, Crandall, Washington, & McLaughlin, 2012; Phipps et al., 2012; Riley et al., 2011; Shapiro et al., 2004; Siassakos, Draycott, Montague, & Harris, 2009; Thomas et al., 2007; Thomas et al., 2010). Four of the articles included in the review were companion reports from the UK SaFE trial and, together were considered one independent study (Crofts et al., 2008; Crofts et al., 2007; Ellis et al., 2008; Siassakos et al., 2009).

[INSERT FIGURE 1 HERE]

Study and patient characteristics

Included articles were published between 2004 and 2013. Ten of the included articles were RCTs, (Boet et al., 2013; Crofts et al., 2008; Crofts et al., 2007; Daniels et al., 2010; Ellis et al., 2008; Frengley et al., 2011; Jankouskas et al., 2011; LeFlore & Anderson, 2009; Riley et al., 2011; Shapiro et al., 2004; Siassakos et al., 2009; Thomas et al., 2007; Thomas et al., 2010) and two were ITS studies (Miller et al., 2012; Phipps et al., 2012). Approximately 1,099 participants or 202 teams were included in the review. Total counts for participant and team numbers were approximated due to the inconsistent reporting among studies; some studies either failed to mention the number of teams (Phipps et al., 2012; Riley et al., 2011), study participants (Miller et al., 2012) or provided ranges of the number of participants on each team (Thomas et al.,

2007; Thomas et al., 2010). Comparator groups used to assess learning effectiveness varied among studies, but clustered naturally into three types: studies comparing simulation-based CRM versus didactic or case-based CRM team training (Table 2); studies comparing simulation-based CRM team training versus simulation without CRM teaching, where simulation scenarios were identical, but teaching objectives in the experimental group included both CRM instruction, while the control groups only received procedural teaching (e.g. shoulder dystocia) (Table 3); and lastly, a miscellaneous group including studies comparing a specific simulation-based teaching method or learning outcomes assessed using an ITS study design (Table 4).

[INSERT TABLE 2, 3 & 4 HERE]

Team profiles

Five studies involved interprofessional teams (Crofts et al., 2008; Crofts et al., 2007; Daniels et al., 2010; Ellis et al., 2008; Frengley et al., 2011; Jankouskas et al., 2011; Shapiro et al., 2004; Siassakos et al., 2009), and five were both interprofessional and interdisciplinary (Boet et al., 2013; LeFlore & Anderson, 2009; Miller et al., 2012; Phipps et al., 2012; Riley et al., 2011), while two only involved interdisciplinary teams (Thomas et al., 2007; Thomas et al., 2010). Physicians and nursing were the most common professions, represented in 12 and nine studies, respectively. Midwives (Crofts et al., 2008; Crofts et al., 2007; Ellis et al., 2008; Phipps et al., 2012), certified registered nurse anesthetists, physician assistants (Phipps et al., 2012; Riley et al., 2011), social workers and respiratory therapists (LeFlore & Anderson, 2009) were included in six studies. One study (Miller et al., 2012) mentioned technicians, pharmacists, clerks, and respiratory therapists, but how many and the extent of their involvement was unclear. Lastly,

three studies (Boet et al., 2013; Daniels et al., 2010; LeFlore & Anderson, 2009) reported prior simulation exposure among 15% to 54% of participants.

Context of the simulated crisis

Crisis scenarios used to teach CRM principles were divided into three themes: acute/critical care event (Boet et al., 2013; Frengley et al., 2011; Jankouskas et al., 2011; Miller et al., 2012; Shapiro et al., 2004), obstetric emergencies (Crofts et al., 2008; Crofts et al., 2007; Daniels et al., 2010; Ellis et al., 2008; Phipps et al., 2012; Riley et al., 2011; Siassakos et al., 2009), and neonatal resuscitation (LeFlore & Anderson, 2009; Thomas et al., 2007; Thomas et al., 2010). Examples of acute/critical care event include trauma activations (Miller et al., 2012), cardiac arrhythmias in the operating room (Boet et al., 2013), airway emergencies (Frengley et al., 2011), and basic life support (Jankouskas et al., 2011). Emergencies involving obstetric teams involved post-partum haemorrhage (Siassakos et al., 2009); eclampsia (Daniels et al., 2010; Ellis et al., 2008); uterine rupture and placental abruption (Riley et al., 2011); and dystocia (Daniels et al., 2010).

Simulation characteristics

High-fidelity, computer-controlled mannequin simulators in a simulation lab were the most common simulator platform used by seven studies (Boet et al., 2013; Crofts et al., 2008; Crofts et al., 2007; Daniels et al., 2010; Ellis et al., 2008; Frengley et al., 2011; Jankouskas et al., 2011; Shapiro et al., 2004; Thomas et al., 2010). Another four studies used in-situ simulators, where simulation trials took place in real work-place settings: three involved standardized patients

(Phipps et al., 2012; Riley et al., 2011; Siassakos et al., 2009) and one with high-fidelity, computer-controlled mannequins in a real emergency department (Miller et al., 2012). Only one study used a low-fidelity simulated baby as the sole simulation intervention (Thomas et al., 2007). Two studies evaluated outcomes comparing simulation modalities with varied results; for example, Thomas and colleagues (2010) demonstrated better scores on validated team behaviour measurements with high-fidelity compared to low-fidelity simulators, meanwhile papers in the UK SaFE study showed either no difference (Ellis et al., 2008) or better outcomes in patient-actor perceived scores for team safety and communication in the low-fidelity groups, using patient-actors and basic mannequins, compared to the high-fidelity groups in a dedicated simulation centre (Crofts et al., 2008).

Learning intervention

CRM was only explicitly described in seven studies (Boet et al., 2013; Crofts et al., 2008; Crofts et al., 2007; Daniels et al., 2010; Ellis et al., 2008; Jankouskas et al., 2011; LeFlore & Anderson, 2009; Phipps et al., 2012; Shapiro et al., 2004; Siassakos et al., 2009). Remaining studies described “teamwork and human error” (Thomas et al., 2007; Thomas et al., 2010), “teamwork and communication” (Miller et al., 2012), “human factors and crisis management” (Frengley et al., 2011), or employed TeamSTEPPS®, an evidence-based teamwork curriculum focused on leadership, situation monitoring, mutual support, and communication (Riley et al., 2011). Length of didactic CRM teaching ranged from brief (<30 min) (Boet et al., 2013; LeFlore & Anderson, 2009), to lasting hours (2-4 hours) (Phipps et al., 2012; Thomas et al., 2007; Thomas et al., 2010), one day (Crofts et al., 2008; Crofts et al., 2007; Ellis et al., 2008; Siassakos et al.,

2009) or were unspecified (Frengley et al., 2011; Jankouskas et al., 2011). Some studies also included additional reading material (Crofts et al., 2008; Crofts et al., 2007; Ellis et al., 2008; Siassakos et al., 2009), videos (Shapiro et al., 2004; Thomas et al., 2007) or webinars (Riley et al., 2011). Evaluation of the effect of didactic CRM presentations on the simulation experience took place immediately after the presentation, except in two studies where the simulation took place 3 – 5 days (Phipps et al., 2012) or up to 8 weeks later (Miller et al., 2012).

Debriefing was involved in all studies, but instructor expertise, duration, and methods varied. Instructors underwent simulation and teamwork training programs in three studies (Crofts et al., 2008; Crofts et al., 2007; Ellis et al., 2008; Phipps et al., 2012; Thomas et al., 2007), while seven studies used “expert” simulation and or CRM training instructors (Jankouskas et al., 2011; LeFlore & Anderson, 2009; Miller et al., 2012; Shapiro et al., 2004; Thomas et al., 2010), some with up to 2-years of experience (Boet et al., 2013; Daniels et al., 2010). Instructor experience was not mentioned in two studies (Frengley et al., 2011; Riley et al., 2011). When reported, duration of feedback ranged from 15 minutes to 2 hours (Daniels et al., 2010; Miller et al., 2012; Riley et al., 2011). Video-assisted debriefing was included in six studies (Boet et al., 2013; Daniels et al., 2010; Jankouskas et al., 2011; LeFlore & Anderson, 2009; Phipps et al., 2012; Shapiro et al., 2004). One study included “within team” debriefing among simulation participants without an instructor (Boet et al., 2013), while another had “instructor-modelled learning” where trainees complete a simulation scenario followed by an observed expert modeled learning simulation scenario and modified debriefing (LeFlore & Anderson, 2009).

Previously validated measurement tools were utilized in six studies at outcome levels ranging from Kirkpatrick 2 to 4, which are detailed in Tables 2-4.

Learning outcomes

The 12 included studies reported the following range of outcomes:

Modification of attitudes and perception (Kirkpatrick 2a)

Jankouskas and colleagues (2011) compared interprofessional attitudes between simulation-based CRM trained versus simulation without CRM training, but no differences were found (p-value not reported). Pre- to post-intervention validated surveys assessing “culture of safety” attitudes among participants were described in two studies, but they also found no significant difference from baseline when composite scores were assessed (both $p>0.05$) (Phipps et al., 2012; Riley et al., 2011). In one of the two studies, however, a sub-analysis was preformed and domains specific to labour and delivery CRM dimensions demonstrated improvements in teamwork, communication, and non-punitive responses to error ($p<0.01$) (Phipps et al., 2012). Lastly, qualitative responses from an unvalidated follow-up survey by Frengley and colleagues (2011) remarked that participants retained what they learned, involved the team more, and even made changes to patient management.

CRM Skills acquired in the simulator (Kirkpatrick 2b)

Studies comparing simulation-based to didactic or case-based CRM team training (Table 2) showed improved teamwork behaviours in a post-test simulator scenario ($p<0.01$) (Frengley et

al., 2011), team efficacy, and overall teamwork with simulation-based teaching ($p < 0.03$) (Daniels et al., 2010). Studies comparing simulation-based CRM team training to simulation training without CRM teaching (Table 3) also showed better performance for CRM abilities ("anaesthetists' non-technical skills" score – ANTS; $p < 0.05$) (Jankouskas et al., 2011); more team behaviours, vigilance, better workload management (no p-value reported (Thomas et al., 2007) and $p < 0.01$ (Thomas et al., 2010)); and more "directed" comments (descriptive analysis only) (Siassakos et al., 2009). In contrast, while the UK SaFE study (Crofts et al., 2008; Ellis et al., 2008) showed improved communication, safety, and overall teamwork skills from pre- to post-test scores ($p < 0.01$), teamwork theory did not show any added benefit when compared to simulation training alone ($p > 0.37$). Lastly, two studies compared teaching methods for simulation-based CRM team training on specific communication and coordination abilities in the simulator (Boet et al., 2013; LeFlore & Anderson, 2009). Boet and colleagues (2013) demonstrated that simulation-based CRM teaching was effective in improving healthcare team CRM performance in the simulator, when team debriefing was facilitated with or without an instructor ($p = 0.01$). There was no significant difference in the degree of effectiveness between the two types of team debriefings ($p = 0.52$). In contrast, while LeFlore and Anderson (2009) had an instructor debriefing in both experiential groups, their modification on the initial simulation teaching method resulted in significant differences in CRM skill acquisition. They showed that instructor learning with modified debriefing was more effective in teaching CRM skills than self-directed learning with an instructor debriefing during team-simulated clinical scenarios ($p < 0.04$).

Knowledge or skills in the simulator (Kirkpatrick 2b)

Simulation-based CRM team training did not reveal additional benefit on error rates and response times ($p=0.43$) (Jankouskas et al., 2011), the completion of basic tasks ($p>0.05$) (Ellis et al., 2008) or multiple choice scores ($p>0.97$) (Crofts et al., 2007) when compared to simulation teaching without CRM training. Only one study (Thomas et al., 2010) found that teams who received additional teamwork training showed improved workload management ($p<0.01$) and completed resuscitations an average of 2.6 minutes faster than teams that did not receive additional teamwork training. When simulation-based team training was compared to didactic CRM training alone, multiple-choice scores were not different ($p>0.05$) (Daniels et al., 2010). In the study by LeFlore and Anderson (2009) where different simulation-based teaching styles were compared, teams with “instructor-modelled learning” had significantly better scores in eight out of 11 items on the evaluation tool compared to teams trained using “self-directed learning.”

Behaviour change in the workplace (Kirkpatrick 3)

Two studies used trained assessors to observe outcomes during real team traumas after learning CRM in the simulator. Shapiro and colleagues (2004) found no statistical difference in pre- and post-intervention behaviours in the workplace when they compared simulation-based CRM team training program ($p=0.07$) and didactic-based CRM teaching ($p=0.55$). Meanwhile, Miller and colleagues (2012) showed that teams during the didactic phase of the CRM intervention only improved on one out of 14 teamwork domains ($p=0.05$) in a real emergency department setting, while 11 out of 14 domains ($p<0.04$) improved during the simulation phase.

All measures, however, returned to baseline during their “decay” phase 1 week following the simulation phase ($p>0.41$).

Benefits to patients (Kirkpatrick 4)

Riley and colleagues (2011) demonstrated that a hospital-wide teaching simulation-based CRM team intervention reduced mean weighted adverse outcomes scores (WAOS) compared to hospitals randomized to didactic CRM teaching only or no teaching at all ($p<0.05$). This effect was seen as early as one quartile after the intervention and sustained for the 2-year study period. Likewise, Phipps and colleagues (2012) showed a reduction in adverse outcome index (AOI) from 0.052 (95% CI, 0.05-0.05) to 0.04 (95% CI, 0.04-0.05) in perinatal outcomes over 6 quarters (1.5 years) following a simulation-based CRM team training course. Both the WAOS and AOI were based on 10 quality indicators: maternal death, intrapartum neonatal death, uterine rupture, unplanned transfer to the intensive care unit, birth trauma, admission to the neonatal intensive care unit, Apgar score at 5 minutes <7 , return to the operating room, third-fourth degree perineal laceration, or the need for a blood transfusion

Return on investment (Kirkpatrick 5)

No studies showed outcomes describing return on investment of team simulation-based CRM training.

Retention

Included studies investigated retention of skills across the Kirkpatrick levels, but their outcomes were variable. For example, retention of team behaviours in simulated environments were seen up to 6 months post-intervention (Kirkpatrick 2b) (Thomas et al., 2010). Miller and colleagues (2012), however, found that CRM skills in the workplace (Kirkpatrick 3) returned to baseline only after 1 week. This may be due to a treatment effect as only 25% of the potential trauma team underwent the in-situ trauma simulation intervention. Meanwhile, two studies investigating outcomes at the level of patient benefits (Kirkpatrick 4), showed that benefits were maintained from 18 months to 2 years after a single team CRM simulation intervention (Phipps et al., 2012; Riley et al., 2011).

Risk of bias

The EPOC tool was used to appraise bias among included studies (Appendix) (EPOC, 2014). Random sequence generation was unclear in four studies (Frengley et al., 2011; LeFlore & Anderson, 2009; Shapiro et al., 2004; Siassakos et al., 2009). Allocation concealment was not mentioned in any of the RCTs. Baseline outcomes were incomplete (Daniels et al., 2010; Jankouskas et al., 2011; LeFlore & Anderson, 2009), non-existent (Thomas et al., 2007; Thomas et al., 2010) or were dissimilar (Siassakos et al., 2009) in five studies. Five studies failed to disclose baseline participant characteristics (Crofts et al., 2008; Crofts et al., 2007; Ellis et al., 2008; Frengley et al., 2011; Shapiro et al., 2004; Siassakos et al., 2009; Thomas et al., 2007; Thomas et al., 2010); one had notable differences, where the didactic group had almost twice as many deliveries per year, with a non-proportional increase in nurses and more family physicians (Riley et al., 2011). Three studies suffered from significant dropouts (Daniels et al.,

2010; Frengley et al., 2011; Phipps et al., 2012) or an uneven loss of data in one arm due to audio-visual issues (Thomas et al., 2010). Three studies were also unable to blind live assessors to the allocation of pre- versus post-intervention (Crofts et al., 2008; Miller et al., 2012; Shapiro et al., 2004), while another used an unblinded principal investigator as the simulator instructor (Jankouskas et al., 2011). Contamination bias, which occurs when members of the control group are inadvertently exposed to the learning intervention ("Cochrane Handbook for Systematic Reviews of Interventions Version 5.0.1," 2008) was at risk in two studies, one where both groups were exposed to the intervention – high-fidelity CRM – albeit in different clinical settings (Frengley et al., 2011) and another where changes in institutional policies or personnel during the study period may have contributed to contamination (Riley et al., 2011). Other biases noted included self-selection bias among volunteer participants (Daniels et al., 2010; Jankouskas et al., 2011), responder bias (Frengley et al., 2011), selection bias (Thomas et al., 2010), and sampling bias (Miller et al., 2012). Studies comparing simulation-based CRM teaching to simulation without CRM teaching (Table 3) controlled for potential contamination by separating the groups during their simulation intervention. Lastly, among the two ITS studies (Miller et al., 2012; Phipps et al., 2012), it was unclear if the intervention was independent of other changes, both studies did not comment on possible confounders or historical events during the experimental period that may have influenced outcomes.

Discussion

This review aimed to assess the effectiveness of interprofessional and interdisciplinary simulation-based CRM team training compared to any other education intervention. 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. The only interprofessional study that did not show any difference in learning outcome had a very small sample size ($n=4$) (Shapiro et al., 2004) which resulted in a lack of statistical power. No studies reported outcomes that were worse in the simulation-based CRM training group compared to any comparator group. We conclude that CRM simulation-based training for interprofessional and interdisciplinary teams shows promise as a superior training method over traditional non-simulation clinical teaching of CRM principals.

Despite correlations between clinical and team coordination abilities for individual CRM simulation training (Riem, Boet, Bould, Tavares, & Naik, 2012), this review found limited evidence to support the benefit of additional team-based simulation CRM teaching on enhancing clinical knowledge or skills. Clinical performance improved for pre- to post-intervention scores, but teams that received additional instruction on CRM teaching (Crofts et al., 2007; Ellis et al., 2008; Jankouskas et al., 2011), or added simulation to an existing didactic-based CRM intervention (Daniels et al., 2010), fared no better than those that did not. Only one study showed improved team clinical knowledge or skills with additional team training (Thomas et al., 2010). One possibility was that clinical knowledge or skill development was a general

effect of rehearsal and CRM teaching posed no additional benefit to learning. Simulation-based CRM team training, however, showed significant and reproducible improvements in CRM communication and team coordination abilities, (Daniels et al., 2010; Frengley et al., 2011; Jankouskas et al., 2011; Siassakos et al., 2009; Thomas et al., 2007; Thomas et al., 2010) which suggests the benefits seen in patient outcomes found in other studies (Phipps et al., 2012; Riley et al., 2011) were a function of specific communication and TEAM coordination abilities for CRM learned rather than clinical knowledge or skills, but more evidence is needed to affirm this.

The retention of CRM skills across the Kirkpatrick levels was inconsistent and remains unclear. Retention of CRM skills was seen up to 6 months in a simulated environment (Thomas et al., 2010), which was consistent with previous work published on non-team based interventions (Naik, Savoldelli, Joo, Chandra, & Weiss, 2007). At higher levels of learning, however, retention of CRM skills were only seen for up to one week when measured in the workplace (Miller et al., 2012). Possible reasons for this includes study design, other confounding variables affecting retention in real-life settings, or more simulation-based training may be needed for skill retention in the workplace compared to the simulator. This was further complicated by other studies that showed retention at even higher Kirkpatrick levels, (i.e., patient benefits), that lasted as long as 18 to 24 months after a single simulation-based CRM team training intervention. Possible confounders were not assessed in these studies. Therefore, it is also unclear why a simulation-based team intervention might improve patient outcomes longer than

measurable workplace performances in CRM reported in other studies and warrants further investigation.

We acknowledge the importance of debriefing in simulation-based training (Fanning & Gaba, 2007); however, studies need to be done to consolidate the various methods that exist and consider cost-effectiveness . While one study showed that the presence of an expert debriefer was not systematically necessary to achieve measured CRM learning in teams in the simulator (Boet et al., 2013), another showed that more instructor-led interventions in the form of instructor-modelled learning was better (LeFlore & Anderson, 2009). Thus, there is a clear need for return on investment analysis (J. Phillips, 1995) to balance the facility and faculty costs of simulation-based training with teaching or health outcomes. This analysis should go further than asking if an intervention is effective or can be afforded in a budget. Rather it should ask whether the investment is worthwhile, after comparing the costs and outcomes together, between interventions (i.e., simulated team-based CRM training versus non simulated CRM team training or simulated individual CRM training)(Barton, Bryan, & Robinson, 2004). This cost-effectiveness information is essential for decision-makers in order to promote the use of CRM simulation team training.

Several limitations should be considered. First, many of the included studies were limited by a high risk of bias. Second, incomplete descriptions of methods in the included publications limited our ability to fully describe the studies or make judgments on their methodological quality. Third, only English and French language studies were assessed. Fourth, our searches did

not specifically include skills related team training/interprofessional training which may have resulted in missing papers that focused on these skills, unless they specifically mentioned the term CRM. As a result, studies may have been missed. Fifth, our finding might be affected by publication bias because unpublished studies were not included. Furthermore, some studies were limited by methodological shortcomings including small sample size (Shapiro et al., 2004), short follow-up time (Crofts et al., 2008; Daniels et al., 2010; Frengley et al., 2011; Shapiro et al., 2004; Siassakos et al., 2009; Thomas et al., 2007), and inadequate intervention exposure (Jankouskas et al., 2011; Riley et al., 2011). Lastly, we recognize there was significant heterogeneity in participation sample, study design, training intervention, and outcome analysis, which limited our ability to synthesize results.

Concluding comments

This review reports on 12 studies measuring learning outcomes after simulation-based CRM training for interprofessional and interdisciplinary teams of learners. Although positive outcomes were reported in all but two studies (Crofts et al., 2008; Ellis et al., 2008; Shapiro et al., 2004), generalizable conclusions cannot be reached due to the variety of learning interventions, methodologies, and outcome measurements. This review, however, demonstrates promise for the use of simulation-based CRM team training to enhance the acquisition of communication and coordination abilities for crises management, although there is still a need to align research practices and identify best practices.

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Future efforts should involve rigorous methodology, standardized learning interventions, and validated measurement tools. Areas of focus should emphasize knowledge translation into workplaces or effects on patients’ outcome (Kirkpatrick 3 and 4) or study designs that elucidate the most effective and efficient means by which simulation-based CRM training is delivered (how often, and with whom). The latter should also involve a systematic analysis of return on investment, which may aid in increased accessibility to simulation training. Importantly, this review also highlights some challenges that prevail in CRM research. As noted by Salas and colleagues (2000), CRM suffers from ‘definitional ambiguity’ where no universal definition of CRM exists. Universal outcome measurements on the effectiveness of CRM interventions are also lacking. These limitations, along with heterogeneity in study design challenge the systematic assessment of studies. Given the present nature of simulation research, we acknowledge that definitive evidence will be difficult to achieve in support of team-based CRM training. Despite this, CRM simulation-based training for interprofessional and interdisciplinary teams continues to grow as a major player in multifaceted education programs aimed towards making health care teams work safer and more effectively.

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Declaration of interest

The authors report no declarations of interest. The authors were responsible for the writing and contents of this paper.

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Figure legends

Figure 1. Search and selection of included studies

Box 1. Eligibility Criteria*Study characteristics*

Randomized controlled trials or
Quasi-randomized controlled trials or
Controlled before-after studies or
Interrupted time series

Patient characteristics

All health care providers
All levels of training

Learning intervention

Inteprofessional or Interdisciplinary education
CRM
Simulation-based

Table 1. Classification of learning outcomes according to Kirkpatrick (modified by Phillips, 1997)

Level 1: Reaction	Participants view on the learning experience
Level 2a: Modification of attitudes	Changes in attitudes towards team collaboration
Level 2b: Acquisition of knowledge and skills	Changes in CRM skill or knowledge or skill performance in the simulator
Level 3: Behavioral change	Transfer of CRM learning to the practice setting
Level 4: Benefits to patients	Improvement in health or well being of patients
Level 5: Return on investment (Phillips, 1995)	Compares the training’s monetary benefits with the costs

Table 2. Studies comparing simulation-based crisis resource management verses didactic or case-based crisis resource management team training

Source, Country	Team, participants	Study design	Context of the crisis, crisis scenario(s)	Learning intervention	Outcomes, Kirkpatrick level
Daniels et al., 2010 USA	Eight teams; two residents and two RNs, each <i>Interprofessional</i>	RCT – teams randomized to simulation-based CRM or didactic-based CRM training.	Obstetrical emergency, dystocia and eclampsia	Both groups received teaching on CRM principals. Simulation group received three hours of training in a simulation laboratory, the didactic group received three hours of lectures or video and hands-on demonstration.	Better team performance scores in simulation group ($p = 0.01$), but no difference in MCQ scores between both groups. Both measures were unvalidated. Kirkpatrick 2b
Frengley et al., 2011 New Zealand	40 teams; one critical care MDs and four RNs, each <i>Interprofessional</i>	Self-controlled randomized crossover study – teams randomized to receive case-based learning on airway scenario with simulation-based learning on cardiac scenario or vice versa. Simulation pre and post-test performance were compared.	Acute/critical, airway emergency and cardiac arrhythmia	Both groups received skill and teamwork didactic training prior to simulation. During the simulation intervention, teamwork behaviours were reinforced during simulation debriefing.	Significant improvements in scores for overall teamwork ($p < 0.01$) using the validated TBR. Clinical management also improved but no significant difference between case- or simulation-based learning. Kirkpatrick 2b
Riley et al., 2011 USA	134 participants (teams allocation not clear) of MDs, RNs, CRNA, PA <i>Interprofessional</i>	RCT – three hospitals randomized to simulation-based, didactic-based, or no team training. Groups were	Obstetrical emergency; uterine rupture, placental abruption, and post-partum haemorrhage.	Simulation group received in-situ simulation with two hour debriefing based on TeamSTEPPS®. Didactic group	In situ simulation training decreased WAOS by 37% compared to pre - intervention, while other

		compared using adverse outcome scores.		had TeamSTEPPS® only.	groups did not. No change in COS attitudes from pre to post test. Both measures were validated Kirkpatrick 4
Shapiro et al., 2004 USA	Four teams; one MD, one resident, three RNs <i>Interprofessional</i>	RCT – teams randomized to simulation-based or didactic-based team training. Outcomes during real trauma activations were compared.	Acute/critical, “three scenarios of increasing complexity”	Both teams received training on “Emergency Team Coordination”. Simulation group received additional eight hour “intensive” simulation training with debriefing. Didactic group worked in the ED for one eight hour shift in their respective groups	Simulation group showed a trend, but was non-significant towards improved team behaviours (p = 0.07) using the validated TDRF from BARS during real trauma activations. Kirkpatrick 3

Abbreviations: RCT, randomized control study; CRM, crisis resource management; MD, medical doctor; RN, registered nurse; CRNA, certified registered nurse anaesthetist; PA, physician assistant; ED, Emergency department; MCQ, multiple choice quiz; TBR, teamwork behavioural rater; WAOS, weighted adverse outcomes score; COS, culture of safety; TDRF, team dimensions rating form; BARS, behavioural anchored rating scales.

Table 3. Studies comparing the effect of simulation-based crisis resource management team training versus simulation without crisis resource management training

Source	Participants	Study design	Context of the crisis	Learning intervention	Outcomes, Kirkpatrick level
UK SaFE Study	24 teams; 5-6 members each of 1-2 MDs (junior or senior) and 3-4 midwives (junior or senior)	RCT – 2x2 factorial design where teams were randomized to training in local hospitals or at a simulation centre, and to teamwork theory or not	Obstetrical emergencies, eclampsia, postpartum haemorrhage, and shoulder dystocia (J. Phillips, 1995)	All training courses included a lecture and simulation drill (with feedback). Groups in local hospitals used low-fidelity simulation with patient-actors, while the simulation centre used a high-fidelity mannequin. Teams randomized to teamwork theory received additional instruction on communication and coordination during crisis.	Mean validated MCQ scores increased from pre to post test ($p < 0.01$) but no effect on location of training or the inclusion of team theory. Kirkpatrick 2b
Crofts et al., 2007	<i>Interprofessional</i>				Training with patient-actors improved perception of safety ($p = 0.05$) and communication ($p = 0.35$) but not with high-fidelity mannequin training. Teamwork training did not offer additional benefit. Kirkpatrick 2b
Crofts et al., 2008					
Ellis et al., 2010					Validated GRS improved from pre to post in all groups ($p < 0.01$), no additional benefit seen with location of training or additional teamwork training. Kirkpatrick 2b
Siassakos et al., 2009	four teams; one senior and two junior MDs, and	RCT - Subset of the teams who were			Quantitative content analysis showed that CRM trained
UK					

	two junior midwives <i>Interprofessional</i>	randomized to simulation training with or without CMR training.			groups had less “clutter” and fewer undirected commands. Kirkpatrick 2b
Jankouskas et al., 2011 USA	24 teams; two med students and two nursing students, each <i>Interprofessional</i>	RCT – randomizing BLS with or without additional CRM training. Team behaviours. Pre and post-test simulation behaviours were compared.	Acute/critical, basic life support in two hypoxemic arrests in a hospital setting	For the experimental group, debriefing of the pre-test sims focused on team processes and didactic content included CRM with BLS review. For teams in the control group, debriefing was on clinical skills and the didactic content included BLS only.	CRM significantly improved the team process variables of team working, task management, and situation awareness in the validated ANTS tool (p < 0.05). No difference on team effectiveness (unvalidated) variables or interprofessional attitudes. Kirkpatrick 2b.
Thomas et al., 2007 USA	Teams of two to three residents each (N=40) <i>Interdisciplinary</i>	RCT – teams randomized to low-fidelity NPR training with or without additional team training. Post intervention mega code outcomes were compared.	Neonatal resuscitation, not specified	Both arms were exposed to low fidelity baby models during the standard NRP teaching. Teamwork group had additional two hour training including lectures, more low-fidelity role playing, video clips and a questions and answer period.	Compared with the standard NRP, NRP with a teamwork and human error curriculum led interns to exhibit more team behaviours (p < 0.01), vigilance and workload management (unvalidated tools an no p-value reported) during simulated resuscitations. Kirkpatrick 2b
Thomas et al., 2010 USA	Teams three to four residents each (N=100) <i>Interdisciplinary</i>	RCT – teams randomized to either LFT NRP teaching, LFT NRP teaching with team	Neonatal resuscitation, precipitous delivery, two hypovolemia scenarios	Additional team training was similar to above.(Thomas et al., 2007)	Interns whose NRP course included a brief teamwork curriculum used more frequent teamwork

training or
HFT NRP
teaching with
team
training. Post
intervention
mega code
outcomes
were
compared.

behaviours than
those without (p
 < 0.01). Effect
was even
greater in teams
who had HFT (p
 < 0.01). The
effect of the
intervention on
team behaviours
persisted for at
least 6 months
($p = 0.03$).
Clinical NRP
performance
improved from
pre to post test,
but no
difference was
seen with
additional
teamwork
intervention, but
groups with
teamwork had
improved
workload
management
($p < 0.01$) and
faster
resuscitation
times.
Kirkpatrick 2b

Abbreviations: SaFE, Simulation and Fire-drill Evaluation; LFT, low-fidelity training; HFT, high fidelity training; NRP, neonatal resuscitation program; GRS (global rating scale); ANTS, anaesthetists' non-technical skills; GRS, global rating scale; BLS, basic life support;

Table 4. Studies comparing a specific simulation-based teaching methods or learning outcomes assessed using an interrupted time series study design

Source	Participants	Study design	Context of the crisis	Learning intervention, comparator group	Outcomes, Kirkpatrick level
Boet et al., 2013 Canada	40 teams; one anaesthesia resident, surgery resident, RN each. <i>Interprofessional</i>	RCT – teams randomized to receive “team debriefing” or “expert lead” debriefing. Pre and post team behaviours in the simulator were compared.	Acute/critical care, intraoperative emergencies with cardiac arrhythmias	Both groups received didactic CRM teaching prior to any simulation. Debriefing in both groups was modelled after the Ottawa GRS with video playback. “Team debriefing “ group did not have an expert facilitator, while the “expert lead” group did.	Validated TEAM scale scores significantly improved from pre to post-test (p = 0.01) regardless of the style of debriefing. Kirkpatrick 2b
LeFlore et al., 2009 USA	13 teams of health care students; one NP, RN, SW and RT student in each team. <i>Interprofessional</i>	RCT – teams randomized to self-directed learning with facilitated debriefing versus instructor-modelled learning with modified debriefing.	Neonatal resuscitation	Group A had a simulation pre test followed by facilitated debriefing in clinical and communication and coordination abilities, while group B observe an instructor modelled learning simulation scenario and modified debriefing. Both teams then underwent a post-test simulation scenario.	No difference in unvalidated knowledge tests when pre- vs. post-test were compared (p>0.4), Eight out of 11 items on the TET were completed faster (p<0.05) and 8 out of 10 item on the BAT were greater (p<0.04) in the expert modelled group compared to the self-directed group. Kirkpatrick 2a,b
Miller et al., 2012 USA	39 trauma activations involving staff MDs and residents, RNs, technicians,	ITS – teamwork behaviours were observed during real trauma activations and compared over	Acute/critical care, hypovolemic shock from blunt abdominal	Didactic phase included standardized lectures on team member role clarification. ISTS	Validated CTS measures for teamwork improved in 12 out of 14 domains during ISTS phase

	pharmacists, clerks, and RTs in an ED. <i>Interprofessional</i>	four periods: pre test (baseline, didactic-based phase) and post test (simulation and decay phase)	trauma and penetrating chest injury.	phase (eight weeks) included simulation highlighting teamwork and communication. Decay phase was one week following the end of ISTS phase.	compared to baseline, whereas only 1 CTS improved during the didactic phase. All CTS measures returned to baseline during the decay phase. Kirkpatrick 4
Phipps et al., 2012 USA	~185 team members (MDs, RNs, midwives, CRNA) were exposed to the intervention. <i>Interprofessional</i>	ITS - hospital wide, interprofessional simulation - based CRM intervention was applied to assess attitudes on COS, patient satisfaction and AOI data collected eight quarters pre-interruption and six quarters post interruption.	Obstetrical emergency, scenarios not described.	CRM was taught using a didactic portion (4 hours) followed by a four hour simulation days three to seven days later which incorporated more CRM into the video-assisted, expert-lead debriefing.	AOIs significantly decreased from 0.05 (95% CI 0.05-0.05) at baseline to 0.04 (95% CI, 0.04 – 0.05). Staff's attitudes towards patient safety improved and patient satisfaction was maintained. Kirkpatrick 4

Abbreviations: MD, medical doctor; NP, nurse practitioner; RN, registered nurse; CRNA, certified registered nurse anaesthetist; SW, social work; RT, respiratory therapy; OR, operation room; ED, emergency department; RCT, randomized control trial; ITS, interrupted time series; TEAM, team emergency assessment measure; TET, technical evaluation tool; BAT, behavioural assessment tool; ISTS, in-situ trauma simulation; CTS, clinical teamwork scale; COS, culture of safety; AOI, adverse outcome index

Appendix: Risk of bias summary^{a, b}

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Baseline outcome measurements similar	Baseline characteristics similar	Incomplete outcome data (attrition bias)	Blinding of outcome assessment (detection bias)	Contamination	Selective reporting (reporting bias)	Other bias	Intervention independent of other changes	shape of intervention effect pre-specified	intervention unlikely to affect data collection
Boet 2013	+	?	+	+	+	+	+	+	+			
Crofts 2007	+	?	+	?	+	+	+	+	+			
Crofts 2008	+	?	+	?	+	-	+	+	+			
Daniels 2010	+	?	?	+	-	+	?	+	-			
Ellis 2008	+	?	+	?	+	+	+	+	+			
Frengley 2011	?	?	+	?	-	+	-	+	?			
Jankouskas 2011	+	?	?	+	+	-	+	+	-			
LeFlore 2009	?	?	?	+	+	+	+	+	+			
Miller 2012					?	-		+	-	?	+	+
Phipps 2012					-	+		+	+	?	+	+
Riley 2011	?	?	+	-	?	+	-	+	+			
Shapiro 2004	?	?	+	?	+	-	?	+	+			
Siassakos 2009	+	?	-	?	+	+	+	+	+			
Thomas 2007	+	?	?	?	-	+	+	+	+			
Thomas 2010	+	?	?	?	+	+	+	+	?			

Green = low risk, yellow = intermediate risk or unclear, red = high risk.

^a A Review of author’s judgments about each risk of bias for each included study is available at request.

^b Other biases noted included self-selection bias among volunteer participants,(Daniels et al., 2010; Jankouskas, Haidet, Hupcey, Kolanowski, & Murray, 2011) responder bias,(Frengley et al., 2011) selection bias,(Thomas et al., 2010) and sampling bias.(Miller, Crandall, Washington, & McLaughlin, 2012)