Citation:

Alsabri M, Zoubir B, Lauque D, Dias RD, Whelan JS, Östlundh L, Alinier G, Onyeji C, Michel P, Liu SW, Camargo CA, Lindner T, Slagman A, Bates DW, Tazarourte K, Singer SJ, Toussi A, Grossman S, Bellou A. Impact of teamwork and communication training interventions on safety culture and patient safety in emergency departments: a systematic review. Journal of Patient Safety (in press)

Impact of teamwork and communication training interventions on safety culture and patient safety in emergency departments: a systematic review

Mohamed Alsabri[1], MD, Zoubir Boudi[2], MD, Dominique Lauque[1,3], MD PhD, Roger Daglius Dias[4], MD PhD, Julia S Whelan[5], MD, Linda Östlundh[6], MLIS, Guillaume Alinier[7,8,9], PhD, MPhys, PGCert, Churchill Onyeji[1], MD MPH, Philippe Michel[10,11], MD, MSc, PhD, Shan W Liu[12], MD MPH, Carlos A Jr Camargo[12], MD, DrPH, Tobias Lindner[13], MD, Anna Slagman[13], MD, David W Bates[14], MD PhD, Karim Tazarourte[11,15], MD, MSc, PhD, Sara J Singer[16], MD, Anita Toussi[17], MD, Shamai Grossman[1], MD MPH, Abdelouahab Bellou[1,18*], MD, MSc, PhD.

[1] Department of Emergency Medicine, Beth Israel Deaconess Medical Center, Teaching Hospital of Harvard Medical School, Harvard Medical School, Boston, USA

[2] Department of Emergency Medicine, Dr Sulaiman Alhabib Hospital, Dubai, UAE

[3] Department of Emergency Medicine, Purpan Hospital and Toulouse III University, Toulouse, France

[4] STRATUS Center for Medical Simulation, Department of Emergency Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, USA

[5] MS Knowledge Services, Beth Israel Deaconess Medical Center, Boston, USA

[6] The National Medical Library, College of Medicine and Health Sciences, UAE University, Al Ain, UAE

[7] Director of Research. Hamad Medical Corporation Ambulance Service, Doha, Qatar

[8] School of Health and Social Work, University of Hertfordshire, Hatfield, UK

[9] Weill Cornell Medicine-Qatar, Doha, Qatar

[10] Department of Health Quality, University Hospital, Hospices Civils, Lyon, France,

[11] Health Services and Performance Research Laboratory, EA 7425, University Lyon 1, Lyon, France

[12] Department of Emergency Medicine, Massachusetts General Hospital, Harvard Medical School, Boston, USA

[13] Division of Emergency and Acute Medicine (CVK, CCM), Charité University Medicine, Berlin, Germany

[14] Department of Healthcare Quality Department, Brigham and Women Hospital, Harvard Medical School, Boston, USA

[15] Emergency Medicine Department, University Hospital, Hospices Civils, Lyon, University Lyon 1, Lyon, France

[16] Department of Medicine, Division of Primary Care, Stanford University School of Medicine, Stanford, CA, USA

[17] Department of Emergency Medicine, Union Hospital Terre Haute and Clinton IN, Simulation Center for Health Care Education, Indiana State University, Terre Haute, USA

[18] Research Innovation Department, Global Health Care Network & Research Innovation Institute LLC, Brookline, MA, USA

***Corresponding author:** Abdelouahab Bellou, MD, MSc, PhD, 103 Winchester ST, Brookline, 02446 MA, USA. Fax: +16177543460; Tel: +16176693707; e-mail: abellou402@gmail.com

Conflicts of Interest and Source of Funding: There was no funding for this systematic review**.** There was no conflict of interest disclosed by the authors.

Abstract (254 words)

Objectives: To narratively summaries literature reporting on the effect of teamwork and communication training interventions on culture and patient safety in emergency department (ED) settings.

Methods: We searched PubMed, EMBASE, Psych Info CINAHL, Cochrane, Science Citation Inc, Web of Science, and Educational Resources Information Centre for peer-reviewed journal articles published from January 1, 1988, until June 8, 2018 that assessed teamwork and communication interventions focusing on how they influence patient safety in the ED were selected. One additional search update was performed in July 2019.

Results: Sixteen studies were included from 8,700 screened publications. The studies' design, interventions, and evaluation methods varied widely. The most impactful ED training interventions were End-of-Course Critique, TeamSTEPPS, and crisis resource management (CRM)-based training. CRM and TeamSTEPPS CRM-based training curriculum were used in most of the studies. Multiple tools, including the Kirkpatrick (KP) evaluation model, Agency for Healthcare Research and Quality Hospital Survey on Patient Safety Culture, TeamSTEPPS Teamwork Attitudes Questionnaire, the Safety Attitudes Questionnaire, and the Communication and Teamwork Skills Assessment were used to assess the impact of such interventions. Improvements in one of the domains of safety culture and related domains were found in all studies. Four empirical studies established improvements in patient health outcomes that occurred following simulation CRM training (KP4), but there was no effect on mortality.

Conclusion: Overall, teamwork and communication training interventions improve the safety culture in ED settings and may positively affect patient outcome. The implementation of safety culture programs may be considered to reduce incidence of medical errors and adverse events.

Systematic review registration: PROSPERO (CRD42016052544).

Keywords: Patient safety, safety culture, emergency department, communication.

Introduction (3,997 words)

Healthcare system is facing an increase of medical errors which are ranked as the third main cause of mortality in the United States.[1-4] Reports have highlighted that medical errors result from human errors related to poor communication and teamwork.[1,5] Importantly, the majority of these errors that are associated with communication problems are preventable.[5]

Safety culture entails as outcomes linked to people's attitudes, values, behaviour patterns, perceptions, and competencies that define the individual or group commitment, style of proficiency towards health and safety management within the organisation.[6] Teamwork is a combination of thoughts, behaviours, and feelings that help health providers work as one team and continuously improve the quality of care.[7,8] Its five components are referred to as the "big five" and they are: team orientation, backup behaviour, mutual performance, team leadership, and adaptability.[7-9] Patient outcomes are correlated with patient safety, which is impacted by teamwork.[10]

Implementing team development interventions is one of the most significant ways to improve teamwork.[11] Four types of teamwork interventions have been identified: team building, leadership training, team training, and team debriefing.[12] For many years, the aviation industry used crew resource management (CRM), as team-based training approach for pilots. The aims of CRM are to promote safety, improve teamwork behaviours, and reduce errors.[13] Emergency care and other clinical specialties, such as anaesthesiology and surgery, have similar characteristics including high-risk and complex working environments.[14,15] Studies have shown that successful application of aviation-based teamwork, communication interventions such as CRM, simulation, and checklists to dynamic or rapidly changing health care, specialties have led to improved

outcomes.[14,15] Emergency Departments (EDs) are unique and dynamic healthcare units that are particularly prone to communication and teamwork mishaps[16,17] Thus, one of the major ED challenges is achieving effective communication among the medical teams both within and outside the ED to guarantee patient safety.[16,17]

There are several published systematic reviews that have investigated team training communication interventions within clinical care settings.[9,11,18-25] These reviews suggest a significant benefit of training interventions in improving teamwork among healthcare providers. In the ED, the impact of these interventions on patient safety is currently under-investigated.[18,23] This systematic review narratively summaries literature reporting on the effect of teamwork and communication training interventions on culture and patient safety in emergency department (ED) settings

Methods

This review was conducted as recommended by PRISMA guidelines.[26]

Protocol

Based on PRISMA guidelines, investigators (MS, DL, JW, AB) created the review protocol and a search strategy. The research question of the study was developed in accordance with the key elements of PICO framework: Participants (P), Interventions (I), Comparison (C) and Outcomes (O).[27] The protocol was registered in PROSPERO (CRD42016052544).

Selection criteria for eligibility

All studies included in this review met the predetermined eligibility criteria.

Inclusion criteria

Peer-reviewed studies that were carried out in the ED setting and described teamwork and communication interventions in an ED, pre-post intervention studies, randomized clinical trials, and observational studies were included. Clinical staff like physicians and assistant physicians, respiratory therapists, nurses, technicians, and paramedics were selected as the best subjects of the study. All interventions to improve teamwork and communication, safety culture and safety outcomes in an ED were included.

Exclusion criteria

Studies that lacked information on interventions, studies reporting interventions in non-ED settings, review studies not focused on improving teamwork, studies not related to safety culture, studies found in the grey literature, and studies written in non-English languages were not included.

Sources of data and strategy for literature search

The literature search was performed in June 2018 and included studies published from January 1st, 1988, until June 8th, 2018 in the following bibliographic databases: EMBASE, PubMed, Psych Info CINAHL, Science Citation Inc, and Cochrane Central Register of Controlled Trials. All references were transferred to the reference manager software F1000 Workspace.[28] References of eligible articles were manually reviewed for supplementary citations. The search details are shown in Supplementary Online Appendix 1. The list of studies that met inclusion criteria is available in Supplementary Online Appendix 2. Finally, a manual search on already published systematic reviews of team-based training and communication was done to check for

147 appropriate references in the selected articles (Figure 1).[29] In addition, an updated search in
148 PubMed for the period of 2018/07/06 – 2019/07/05 was conducted to ensure inclusion of eventual
149 new studies published since the last search date before submitting the manuscript (Figure 1).
150
151 ***Selection process***
152 Two reviewers (MA, AB), specialists in emergency medicine, independently screened the
153 titles and abstracts. The selection was focused only on peer-reviewed published studies. The
154 reviewers read the full-text articles obtained and selected those that met all inclusion criteria. A
155 third author (DL) assisted in resolving any issues of disagreements through consensus agreement.
156
157 ***Data extraction***
158 Study characteristics were extracted: authors, publication year of the study, country,
159 objectives, research design, setting, study sample, features or attributes of the intervention,
160 evaluation instrument, response rate, statistical test, findings, effect, outcomes/conclusions, and
161 follow-up strategy. We reported whether studies showed a continuous improvement with a
162 sustained strategy of teamwork and communication after the implementation of the interventions.
163 Patient safety outcomes were collected by assessing adverse events like mortality and incidence
164 of clinical errors.
165
166 ***Quality assessment of studies***
167 Two assessors (MA and AB) independently rated the quality of the studies using the
168 Newcastle-Ottawa Scale (NOS).[30] A star rating system was used to review the studies.[30] The
169 definition of "high quality" for the studies was settled as any study with a ranking equal or superior

(≥) to 7 stars. In addition, if discrepancies presented, these were resolved through discussion and consensus between the analysts.

Data synthesis

A qualitative narrative synthesis was performed. It was structured around the different strategies used by the studies for teamwork and communication improvements in the ED unit.

Results

Overview

The search included 8,700 citations (Figure 1). Sixteen studies were selected by the assessors based on the review criteria,[31-46] of which fifteen were performed in the U.S.[31-45] and one was performed in Denmark.[46] Fourteen studies were performed in adult EDs,[31-43,46] two studies were performed in paediatric EDs,[44,45] and four studies focused on ED trauma cases.[32,33,44,45] Six studies were observational survey studies,[32,37,38,41,43,45] nine studies were designed as pre- and post-study surveys,[31,33-36,39,40,44,46] and one study was a randomized controlled trial (RCT).[42] Details of the included studies' characteristics are shown in Table 1.

For a better understanding, we divided our findings into different sections, including *assessment tools, training interventions, safety culture improvement, and teamwork intervention outcomes.*

Table 1. Characteristics of the selected studies

Study	Country	Study design	Sample size	Department	Intervention	Evaluation instrument
Hefner et al.[38]	USA	Observational survey study	784	Multi-departmental	CRM training	AHRQ Hospital Survey
Roberts et al.[41]	USA	Observational longitudinal study	57 trauma teams	ED and surgery	Simulation	Changes in individual and team behaviors
Patterson et al.[45]	USA	Observational survey study	218	Pediatric ED	Simulation	Number and type of LSTs; Anesthetists' Non-Technical Skills scale
Morey et al.[40]	USA	Before-and-after observational survey study	1058	ED	Teamwork training	Staff Attitude and Opinion Survey Patient Satisfaction Survey
Jones et al.[31]	USA	Before-and-after observational survey study	70	ED	TeamSTEPPS Essentials	AHRQ Hospital Survey
Lisbon et al.[39]	USA	Before-and-after observational survey study	Full staff	ED	TeamSTEPPS Fundamentals	Kirkpatrick's 4 levels of evaluation TeamSTEPPS Knowledge Test AHRQ Hospital Survey
Hughes et al.[36]	USA	Before-and-after	Not reported	ED	CRM training	Human Factors Attitude Survey

		observational survey study				
Grogan et al.[33]	USA	Before-and-after observational survey study	489	Multi-departmental including ED	Teamwork training	End-of-Course Critiques Human Factors Attitude Survey
Auerbach et al.[44]	USA	Before-and-after observational survey study	398	ED	Simulation	Trauma simulation evaluation tool
Miller et al.[32]	USA	Observational interrupted time series study	39	ED	Teamwork training	Clinical Teamwork Scale
Wong et al.[37]	USA	Observational survey study	62	ED	Simulation	Teamwork Attitudes Questionnaire HSOPS
Capella et al.[35]	USA	Before-and-after observational survey study	114	ED and surgery	TeamSTEPPS + simulation	Trauma Team Performance Observation Tool
Sweeney et al.[43]	USA	Observational survey study	203	ED	CRM training	Custom 12-item survey
Shapiro et al.[42]	USA	Randomized controlled trial	20	ED	CRM training + simulation	Team Dimensions Rating Form
Paltved et al.[46]	Denmark	Before-and-after	39	ED	Simulation	Safety Attitudes Questionnaire

		observational survey study				Trainee Reactions Score
Obenrader et al.[34]	USA	Before-and-after observational survey study	57	ED	TeamSTEPPS	TeamSTEPPS Teamwork Attitudes Questionnaire TeamSTEPPS Teamwork Perceptions Questionnaire Nursing Culture Assessment Tool

192

Table 1: *Characteristics of the selected studies (*Continued*)*

Study	Effect of the intervention	Group	Pre-treatment [a]	Post-treatment [a]	p-value	Post-treatment 2[a] *Sustainement of the effect*	p-value	Qualitative assessment
Hefner et al.[38]	Handoffs & Transitions	Whole Sample	30%	40%	<0.05	NR	NR	Teamwork and communciation improved following CRM
	Communication Openness		35%	45%	<0.05	NR	NR	
	Non-punitive Response to Errors		20%	29%	<0.05	NR	NR	
	Teamwork Within Units		71%	80%	<0.05	NR	NR	
Roberts et al.[41]	Leadership	Whole sample	3.72 (0.36)	4.22 (0.67)	NS	NR	NR	Training exercises can improve teamwork and communication
	Leader clearly identifiable		3.78 (0.51)	3.83(0.35)	NS	NR	NR	
	Cooperation		2.89 (.65)	3.94 (0.92)	0.01	NR	NR	
	Communication		2.56 (0.46)	350 (0.97)	0.015	NR	NR	
	Decision making		3.67 (0.71)	4.17 (0.97)	NS	NR	NR	
Patterson et al.[45]	Task management	Whole sample	NR	2.7 (1.1)	NR	NR	NR	Simulation reinforces team

	Teamwork		NR	2.6 (1.1)	NR	NR	NR	behaviors and communication
	Situation awareness		NR	2.5 (1.2)	NR	NR	NR	
	Decision making		NR	2.4 (1.2)	NR	NR	NR	
Morey et al.[40]	Clinical Error Rate	Experimental	30.9%	4.4%	0.039	NR	NR	The experimental group saw improved error rates and team behavior quality
		Control	16.8%	12.1%	0.081	NR	NR	
	Staff attitudes	Experimental	75.0%	78.5%	0.047	NR	NR	
		Control	NR	NR	NR	NR	NR	
	Staff assessment of institutional support	Experimental	NR	NR	0.04	NR	NR	
		Control	NR	NR	NR	NR	NR	
Jones et al.[31]	Frequency of events	Whole sample	60%	70%	0.24	NR	NR	Training improved teamwork and safety culture
	Teamwork		64%	70%	0.36	NR	NR	
	Handoffs and transitions		43%	55%	NR	NR	NR	
Lisbon et al.[39]	Knowledge	Whole sample	NR	NR	< 0.05	NR	NR	TeamSTEPPS improved knowledge, attitudes, and communication
	Attitudes		NR	NR	< 0.05	NR	NR	
	Communication		NR	NR	< 0.05	NR	NR	
Hughes et al.[36]	HFAS	Whole sample	NR	NR	< 0.005	NR	NR	CRM improved team dynamics

								and communication
Grogan et al.[33]	ECC	Whole sample	NR	NR	NR	NR	NR	CRM improved patient stafety through reduced error rate
	HFAS		NR	NR	< 0.01	NR	NR	
Auerbach et al.[44]	Teamwork	Whole sample	NR	τ=0.512[c]	0.002	NR	NR	Simulation reinforces teamwork and trauma skills
	Performance		NR	τ=0.488[c]	0.002	NR	NR	
	Intubation		NR	τ=0.433[c]	0.012	NR	NR	
Miller et al.[32]	Communication	Baseline	5.3 (1.9)	NR	NR	NR	NR	Communication improved after ISS but was not retained after simulation termination
		Didactic	NR	6.3 (1.6)	0.147	NR	NR	
		ISS	NR	7.8 (0.4)	0.003	NR	NR	
		Decay	NR	6.0 (1.9)	0.407	NR	NR	
Wong et al.[37]	*HSPSC*	Whole sample						Simulation enhanced curriculum improved attitudes toward teamwork and safety culture
	Event reporting frequency		40.6%	40.6%	0.028	NR	NR	
	Teamwork		84.9%	84.9%	0.035	NR	NR	
	Handoffs and transitions		65.6%	65.6%	0.04	NR	NR	
	TAQ[b]							

	Team structure		NR	6.4%	< 0.0001	NR	NR	
	Leadership		NR	2.8%	< 0.029	NR	NR	
	Situation monitoring		NR	4%	< 0.014	NR	NR	
	Mutual support		NR	4%	<0.003	NR	NR	
Capella et al. 2010 [35]	Leadership	Whole sample	2.87	3.46	0.003	NR	NR	Team training via simulation improves performance
	Situation monitoring		3.3	3.9	0.009	NR	NR	
	Mutual support		3.4	3.96	0.004	NR	NR	
	Communication		2.9	3.46	0.001	NR	NR	
	Overall ratings		3.12	3.7	< 0.001	NR	NR	
Sweeney et al.[43]	Inter-staff communication	Whole sample	4.84 (1.99)	5.96 (1.9)	0.001	NR	NR	CRM simulation improves communication
	Staff-patient communication		5.29 (1.81)	6.22 (1.66)	0.001	NR	NR	
	Staff comfort providing feedback		4.65 (2.40)	5.24 (2.39)	0.001	NR	NR	
Shapiro et al.[42]	Teamwork behavior	Experimental	NR	NR	0.07	NR	NR	Simulation improves CRM team behaviors
		Control	NR	NR	0.55	NR	NR	

Paltved et al.[46]	Safety climate	Whole sample	25.74 (4.41)	26.59 (4.23)	< 0.001	NR	NR	ISS improves safety culture and teamwork
	Teamwork climate		19.9	20.6	< 0.05	NR	NR	
Obenrader et al.[34]	*Communication*	Whole sample						Intervention improved teamwork and communication
	TTAQ		3.77 (0.03)	3.91 (0.07)	0.03	3.91 (0.07)	0.001	
	TTPQ		4.09 (0.01)	3.92 (0.02)	≤.001	4.58 (0.02)	≤.001	
	NCAT		6.273 (0.188)	6.364 (0.168)	0.54	7.500 (0.158)	≤.001	
	Teamwork							
	TTAQ		23.67 (0.732)	23.5 (0.471)	0.86	23.5 (0.245)	0.84	
	TTPQ		3.21 (0.13)	3.40 (0.115)	0.005	3.77 (0.78)	≤.001	
	NCAT		15.90 (0.534)	15.864 (0.385)	0.89	17 (0.406)	0.02	

[a]*Data are presented as mean (SD) or Percentage*

[b]Data are presented as % improvement

[c]*Values are regression coefficients*

ED: Emergency Department; NR: Not Reported; ECC: End-of-course critique; HFAS: Human Factors Attitude Survey; HSPSC: Hospital Survey on Patient Safety Culture NCAT: Nursing Culture Assessment Tool; TAQ: Teamwork Attitudes Questionnaire; TTAQ: TeamSTEPPS Teamwork Attitudes Questionnaire; TTPQ: TeamSTEPPS Teamwork Perceptions Questionnaire;

193

194

Assessment tools used for the evaluation of teamwork and communication training interventions

The results of the assessment tools used in the selected studies are shown in Table 1.

The Safety Attitudes Questionnaire

The Safety Attitudes Questionnaire (SAQ) was adapted based on the Flight Management Attitudes Questionnaire used in commercial aviation.[47,48] It is composed of 60 items, and responses were presented in the five-point Likert scale.[47,48] One study reported results on the six categories of the SAQ. The study findings showed significant benefits of teamwork training in the ED (interstaff communication, staff-patient communication, staff's comfort with providing feedback).[43] There was no significant increase reported among other categories following the implementation of the training program.[43]

A survey to determine the safety culture of patients in the hospital

The survey tool known as the Agency for Healthcare Research and Quality (AHRQ) Hospital Survey on Patient Safety Culture (HSOPS) is a 42-item tool used to address the elements of safety culture.[49] The AHRQ HSOPS was used in four studies.[31,37-39] . Knowledge, attitudes and other communication styles had increased 45 days after baseline ($p < .05$) and had been sustained by day 90.[40] The frequency about event reporting, transitions or handoffs, and teamwork in hospital units also have improved significantly.[31,37]

TeamSTEPPS teamwork attitudes questionnaire

The TeamSTEPPS (Team Strategies and Tools to Enhance Performance and Patient Safety) Teamwork Attitudes Questionnaire (T-TAQ) is a self-reporting instrument mainly developed to assist in measuring attitudes of a person regarding the key components of teamwork in a unit or department, captured within TeamSTEPPS.[49,50] The aim of using the TeamSTEPPS curriculum was to improve teamwork skills and communication skills, and to promote the safety of patients and the safety culture. T-TAQ was employed in four studies.[31,35,37,39] A study by Wong et al.[37] showed statistically significant improvements in four out of the five T-TAQ constructs: situation monitoring, team structure, mutual support, and leadership ($p < 0.05$). A significant improvement in communication was also observed.[38]

The Anaesthetists' Non-Technical Skills (ANTS) system

ANTS was designed to assist in assessing non-technical skills, mainly in anaesthesia. Such skills include teamwork, decision-making, task management and situation awareness.[51] Behaviours are evaluated using a four-point Likert style rating scale (0-4).[52] Patterson et al.[45] showed high scores of 3 or 4 in improving behaviours during specific clinical situations. The majority of teams scored 3 or 4 in task management (73%), teamwork (64%), situation awareness (58%), and decision-making (58%).[45]

The End-of-Course Critique (ECC)

The ECC is a tool measuringh participants' reaction to guidance or training, their perceived training needs, and their alleged value of the newly developed skills, and it explains the expected training opportunities in the future.[33] In Grogan et al. study,[33] it was found that 95% of the

respondents agreed or strongly agreed with the statements that ECC training could minimise the incidence of clinical medical errors during patient care.

Human Factors Attitude Survey (HFAS)

The HFAS is a pre- and post-training survey tool designed by the University of Texas and NASA based on other surveys used in the aviation industry. It uses a standard 5-point Likert scale from strongly agree to strongly disagree.[52,53] Grogan et al.[33] showed that a training intervention (CRM training emphasizing on six key areas: managing fatigue, creating and managing teams, recognizing adverse situations, cross-checking and communication, decision making, and performance feedback) significantly impacts the 20 items among 23 rated items of the HFAS ($p<0.01$). Hughes et al.[36] showed improvement in 15 questions among 23 questions used in the post-HFAS survey scores ($p < 0.005$).

Communication and Teamwork Skills Assessment (CATSA)

The CATSA was designed to measure the communication and team skills of healthcare providers on site. Specifically, the tool uses specific behaviour makers to measure situational awareness.[54] Hughes et al.[36] used the CATSA to evaluate the effect of CRM training on various skills required of the members of a team. The findings of Hughes et al.'s study showed significant improvement in briefing by communicating the plan of care, selecting the potential team leader, and allocating roles to members of the team. Cross-checking and updating members of the team through face-to-face communication and sharing pertinent information showed statistically significant improvements.[36] Briefing team members led to improved understanding of patients' needs ($p<0.05$).[36]

Clinical Teamwork Scale (CTS)

The CTS is used to measure skills directly related to teamwork and communications.[56] Miller et al. used the CTS to evaluate in situ simulation (ISTS), which showed significant improvement as demonstrated by 12 of 14 scores in the CTS measures during the ISTS phase; however, the results on overall communication were statistically significantly different only when comparisons were performed between all phases (pre-intervention, baseline, didactic, ISTS, potential decay phase) ($p < 0.05$).[32]

Trauma Team Performance Observation Tool (TPOT)

The TPOT includes 21 items which are graded on the Likert scale that consists of 1 to 5 dimensions, where 1 represents very poor and 5 represents excellent.[57] Capella et al.[35] found that across teamwork domain ratings and overall ratings, there was a significant improvement from pre-training to post-training in leadership, situation monitoring, mutual support, and communication ($p < 0.005$).

Others assessment tools

Specific survey questionnaires were used for the interventions in Sweeney et al. study.[43] Their findings showed that simulation-based training programs which emphasised on CRM and standardisation of patient encounters contributed to improved communication within the ED setting. This improved communication was found between staff members and with patients.[43] Morey et al.[40] and Shapiro et al.[42] used the Team Dimensions Rating Form.[56] Morey et al. [40] showed a statistically significant improvement following clinicians' participation in the

Emergency Team Coordination Course in (ETCC) as indicated by teamwork quality, enhanced attitudes toward teamwork among healthcare staff in ED, and reduced rates of clinical error rate, pointing its effectiveness in reducing errors and improving attitudes regarding hospital team members.[40] In Shapiro et al. study, [42] there was no statistically significant improvement in the quality of team behaviour in the simulation group (p=0.07) and no change in team behaviour in the control group during the two observation periods (p=0.55).

Training interventions

Most of the training interventions focused on improving teamwork, communication, and leadership. All studies used simulation training approaches, and nine studies showed that the results followed the principles of CRM. Although there were significant variations in their definitions and descriptions of CRM and how simulation was implemented, interventions showed that CRM principles taught with simulation increased interprofessional education.[31,33-36,38-40,42,43] Five studies utilised TeamSTEPPS.[31,35,37,39,43] . The Morey et al.[40] and Shapiro et al.[42] studies included educational curriculums based on CRM and the ETCC in the ED setting.

Safety culture measurement and improvement

The HSOPS, which is the most applicable tool used for safety culture measurement, was used in four studies.[31,37-39] Other questionnaires, such as the SAQ, T-TAQ, and ANTS, were also applicable and were used to measure the impacts of teamwork intervention on safety culture. All studies showed improvement in one of the safety culture domain or safety culture-related improvements (leadership, communication, teamwork climate). Wong et al. found positive improvement in scores for all dimensions except for continuous improvement or organisational

learning, and management support for patient safety in hospitals.[37] Jones et al., also showed a 9% increase in the average score for positive replies following the implementation of training interventions.[31] Non-punitive error response showed a decline in the percentage of positive scores. On the other hand, Hefner et al.[38] found a statistically significant increase in all HSOPS dimensions ($p < 0.05$) except for staffing. In contrast, Lisbon et al.[39] showed a significant increase in all HSOPS dimensions related to communication compared to baseline and reported no negative response. Interestingly, Jones et al.[31] and Hefner et al.[38] found that after the TeamSTEPPS Fundamentals Course Training on teamwork skills that covered communication, mutual support, team structure, leadership, and situation monitoring, course participants had an average increase of 9% in positive responses for eleven of twelve safety culture survey components. In regard to non-punitive response to medical error, the results demonstrated that the percentage of correct response decreased, with 28% response after training compared to the 30% prior to training. However, the study found no statistically significant difference in both pre- and post-training scores.[31,38]

In addition, Wong et al.[37] showed that the simulation in the TeamSTEPPS curriculum enhanced interprofessional education and that the interventions were sustained within one year in 3 of the 6 safety culture survey dimensions related to teamwork and communication.[37] Conversely, Hefner et al.[38] found an increase in 11 of 12 dimensions, while staffing scored 34% after training compared with 36% before training.[38] CRM was found to have the potential of supporting a safety culture and in minimising errors that affect patient safety in all the respondents.[38] In this instance, CRM training seems to have significant impacts on teamwork and the communication domains of safety culture in comparison to the supervisor and management dimensions.[38]

Teamwork intervention effects and outcomes

Kirkpatrick (KP) evaluation model

The Kirkpatrick analysis and evaluation model is a tool composed of 12 learning outcomes classified in four different levels.[58] It has been designed to assess the effectiveness of training programs based on four levels [58]

All studies demonstrated that simulation-based training has a positive impact in terms of KP 3 and 4. Ten studies[31-33,37-41,44,46] showed an effect of simulation-based training on CRM TeamSTEPPS and the ETCC on KP 3 in ED settings. In four of the reviewed studies, there was at least some improvements in patient health outcomes in KP 4 following the implementation of simulation CRM training but no effect on mortality.[32,35,40,44]

TeamSTEPPS teamwork attitudes questionnaire

Five studies showed statistically significant improvement in scores for the five constructs of the T-TAQ, demonstrating that using simulation not only significantly enhances health care workers' attitude toward effective teamwork and communication behaviours but also directly impacts teamwork processes and potentially affects patient safety outcome parameters.[31,35,37,39]. In comparison with the control EDs, the experimental study showed an improved quality of teamwork, better staff attitudes toward teamwork, and a reduction in the clinical error rates.[40]

Crew resource management training

A study by Grogan et al.[33] showed comparable positive feedback from the staff. 86% reported that the CRM training program improved the safety and quality of health and 95% believed that it decreased the risk of medical errors.[33] Morey et al.[40] presented a proportional

355 relationship between teamwork integration in the work environment and leaders' level of
356 involvement. Shapiro et al.[42] illustrated that adding educational curricula based on CRM and the
357 ETCC in the ED setting had a significant impact in improving teamwork behaviour and
358 engagement in healthcare environment.[42] Roberts et al.[41] showed individual or team changes in
359 behaviours (KP 3), demonstrating that team training enhanced situation awareness, care efficiency,
360 patient safety, team functioning, and mutual support.[41] Paltved et al.[46] used the SAQ to evaluate
361 the impact of ISTS training and noted an increase in teamwork and in providers' attitudes
362 concerning safety.[47] The study showed that the safety climate is directly correlated with patient
363 safety.[46] Hughes et al.[36] showed that CRM training significantly improved team dynamics,
364 communication, and patient safety.
365
366 *Simulation-based training program*
367 Similarly, a training program based on simulation and designed to embed CRM principles
368 and techniques enabled significant perceived improvements reported by participants (KP 1) with
369 regards to communication between staff members. However, this rating increase showed no
370 evidence of a specific effect or improvement in clinical outcomes or safety parameters when these
371 were measured.[43] Patterson et al.[45] showed that in situ, multifaceted simulation-based training
372 could improve clinical care as well as the discovery of threats to patient safety and system issues
373 in clinical environment that are considered to be at higher risks of errors. Capella et al.[35] found
374 improved patient care following CRM simulation training. Additionally, Miller et al.[32] and
375 Auerbach et al.[44] showed that airway management, determination of pelvic fracture, and
376 application of cervical spine precautions in patients with real trauma after adult ISTS were
377 improved.

Auerbach et al.[44] demonstrated as well improved teamwork, higher detection of latent safety threats and higher levels of satisfaction among participants. Finally, Miller et al. study[32] also demonstrated that in ISTS program, there were significant associated improvements in overall communication and teamwork in clinical settings, however the improvement was not maintained when ISTS was discontinued.[32]

In some studies, conflicting results among studies were found in skill maintenance. In Miller et al. study,[32] sharing of CRM skills in the clinical working environment showed no evidence of sustainability after one month, while the transfer was retained up to a year in Wong et al. study.[37] Lisbon et al.[39] found that there was an improvement on attitudes and knowledge during 45 days after baseline ($p < .05$), maintaining this improvement 90 days after training.

Quality of the studies

Table 2 presents the quality of the studies according to the NOS marking criteria.[30] The scores obtained on the NOS range from 6 to 9. According to this evaluation, the quality of the studies is intermediate to high. The overall average NOS score was 6.9, so we consider the quality of the studies to be intermediate.

Table 2. Quality assessment of the studies. The Newcastle-Ottawa Quality Assessment Scale consists of 4 items on study selection, 1 item on comparability and 3 items on study outcomes. According to this scale, studies can be awarded one star for each of the 4 items on selection and for each of the 3 items on outcomes and a maximum of 2 stars for comparability. Stars are awarded such that the highest-quality studies are awarded up to nine stars.

Authors	Selection				Comparability of cohorts	Outcome			Total score
	Representative	Selection of	Ascertainment	Outcome of		Assessment	Length of	Adequacy of	
Hefner et al.[38] USA	*	*	*	*	*	*	*	*	8
Roberts et al.[41] USA	*	*	*	*	*	*	*		7
Patterson et al.[45] USA	*	*	*	*	*	*			6
Morey et al.[40] USA	**	*	*	*	*	*	*	*	9
Jones et al. [31] USA	*	*	*	*	*	*			6
Lisbon et al.[39] USA	*	*	*	*	*	*			6

Hughes et al.[36] USA	*	*	*	*	*	*	*	*	8
Grogan et al.[33] USA	*	*	*	*	*	*			6
Auerbach et al.[44] USA	*	*	*	*	*	*	*		7
Miller et al.[32] USA	*	*	*	*	*	*			6
Wong et al.[37] USA	*	*	*	*	*	*	*	*	8
Capella et al.[35] USA	*	*	*	*	*	*	*		7
Sweeney et al.[43] USA	*	*	*	*	*	*			6
Shapiro et al.[42] USA	*	*	*	*	*	**	*		8
Paltved et al.[46] Danemark	*	*	*	*	*	*			6
Obenrader et al.[34]	*	*	*	*	*	*			6

Discussion

The principal aim of our systematic review was to explore the effects of evidence-based team training interventions on patient safety culture and outcomes within the ED setting. Sixteen studies were found which were overall rated as intermediate quality. All studies showed improvements in at least one level of the Kirkpatrick framework, often levels 3 or 4.[57-62]

We found that participants' reactions to trainings across studies were positive, with improved professional behaviour, knowledge, engagement and attitudes. Moreover, the overall objectives of the trainings were met. Participants reported enjoying the trainings and believed them to be relevant and valuable in the improvement of teamwork, communication and patient safety.[31,36,38,39,41-43,45] Our findings agree with previous systematic reviews exploring other healthcare settings in which the implementation of a safety culture with interventions like teamwork and leadership training was crucial in improving patient safety outcomes.[18-24] CRM training emphasises behaviours and requires specific interventions that focus on teamwork, communication, workload management, stress and fatigue management, leadership, decision-making, and recognises adverse situations.[32-35,40,43,63] It is suggested that CRM simulation-based training could have a significant influence on the improvement of communication among staff and with patients, and staff satisfaction while reducing clinical errors in the ED setting.[32-35,40,43] However, evidence concerning CRM training and its impacts on patient safety outcomes and mortality over the long term was lacking. Most of the studies focused on improving non-technical skills, leadership, and teamwork rather than safety culture or patient safety outcomes. We found heterogeneity in the outcomes described in the selected studies using the Kirkpatrick framework. It is possible that the Kirkpatrick model did not meet all outcomes after simulation training programs in the ED setting.[57,62,64] We found that in all studies, the authors used approaches that

were similar to real-life situations. Safety culture is a sub-component of organisational culture, and it reveals common behaviours, attitudes, beliefs, and values toward goals, which differ among individuals. The safety culture can be influenced by different types of interventions to enhance teamwork.[63,65] The most successful programs that show evidence of positive impact of team training interventions in the ED setting are ECC and TeamSTEPPS CRM-based training. A multicenter prospective study that involved ETCC training in nine ED settings showed that team attitudes and perceptions about communication was improved.[41] Also, there was an increase in questionnaire scores TeamSTEPPS implementation in an academic ED improved knowledge, attitudes, behaviour, and patient outcomes in levels 3 and 4 of the Kirkpatrick model.[31,35,37,39] However, these studies did not determine which specific intervention was most successful in improving safety culture and patient safety.

Our findings suggest that noticeable changes in culture can result from team improvement strategies that combine several intervention methods. These need to be adapted to the participants' learning styles but also to the actual issues that are being addressed and resources available.[66,67]

Because any intervention, including an evidence-based validated and standardised intervention, cannot be considered to be also successful in all each healthcare settings. It may be appropriate to propose actions based on a particular domain within the organisation, including teamwork, communication, and safety culture, where performance suggests a broad gap. CRM simulation-based training for ED teams may result in a significant reduction in clinical errors, without an increase in caregiver workload, and improve the safety culture behaviour in ED settings.[40-45,68-70] Descriptions of needs assessments, planning, trainings, outcomes and follow-ups are brief in most studies, which can be a challenge in comparing or synthesising them.

Furthermore, a significant number of factors must be taken into consideration when recommending the type of training that should be implemented and how.

Limitations

We extensively reviewed the studies which reported interventions and their impacts on patient safety and safety culture within ED settings. We found that training interventions on teamwork and communication may improve patient safety and safety culture. Nevertheless, our systematic review had several limitations. The variety of interventions and evaluation methods prohibited meta-analysis. The studies published in English only were included and the grey literature was exclueded, which may have limited the strength of our review.

We narratively summaries peer-reviewed studies to gather scientific evidence on how team and communication training impacts patients and safety culture. Furthermore, 15 out of 16 studies were conducted in the U.S., which could limit the generalization of the results.

Conclusion

Overall, our systematic review suggests that training interventions on teamwork and communication may improve the culture of safety and patient safety in the ED setting. The adoption of safety culture programs in the EDs must be considered to reduce medical errors and adverse events. There is a need for further research focused on assessing multi-professional teamwork and communication skills to ensure a better understanding of team performance and propose relevant solutions that would improve patient safety in the ED setting.

Acknowledgements: We are grateful to Margo Coletti, Director of Information Systems – Knowledge Services, Beth Israel Deaconess Medical Center, Boston, MA, USA to have updated the databases search.

Data sharing statement: The data generated by our systematic review will be available in a public, open access repository.

480 **References**

481 1. Kohn LT, Corrigan JM, Donaldson MS. Tfo Err is Human: Building a Safer Health System.
482 Washington, DC: National Academies Press, 2000.
483 2. Leape LL, Brennan TA, Laird N, et al. The nature of adverse events in hospitalized patients.
484 Results of the Harvard medical: practice study II. *N Engl J Med* 1991;324:377-84.
485 3. National Patient Safety Foundation. Free from Harm: Accelerating Patient Safety Improvement
486 Fifteen Years after to Err is Human. Boston, MA: National Patient Safety Foundation,
487 2015.
488 4. Makary MA, Daniel M. Medical error—the third leading cause of death in the US. *BMJ*
489 2016;353:i2139.
490 5. Joint Commission on Accreditation of Healthcare Organizations. The Joint Commission Guide
491 to Improving Staff Communication. Oakbrook Terrace, IL: Joint Commission Resources,
492 2005.
493 6. Health and Safety Commission. ACSNI Study Group on Human Factors. 3rd Report:
494 Organizing for Safety. London: HMSO, 1993.
495 7. Salas E, DiazGranados D, Weaver SJ, et al. Does team training work? Principles for health care.
496 *Acad Emerg Med* 2008;15:1002-9.
497 8. Hackman JR. The design of work teams. In: Lorsch JW, ed. Handbook of organizational
498 behavior. Englewood Cliffs, NJ: Prentice Hall, 1987:315-42.
499 9. Salas E, Reyes DL, McDaniel SH. The science of teamwork: progress, reflections, and the road
500 ahead. *Am Psychol* 2018;73:593-600.

10. Sorbero ME, Farley DO, Mattke S, et al. Outcome Measures for Effective Teamwork in Inpatient Care (RAND technical report TR-462 AHRQ). Arlington, VA: RAND Corporation, 2008.

11. Shuffler ML, DiazGranados D, Salas E. There's a science for that: team development interventions in organizations. *Curr Dir Psychol Sci* 2011;20:365-72.

12. Lacerenza CN, Marlow SL, Tannenbaum SI, et al. Team development interventions: evidence-based approaches for improving teamwork. *Am Psychol* 2018;73:517-31.

13. Muñoz-Marrón D. Factores Humanos En Aviación: Crm (Crew Resource Management Gestión De Recursos De La Tripulación). *Papeles del Psicólogo - Psychologist Papers.* 2018;39. doi:10.23923/pap.psicol2018.2870.

14. Howard SK, Gaba DM, Fish KJ, et al. Anesthesia crisis resource management training: teaching anesthesiologists to handle critical incidents. *Aviat Space Environ Med* 1992;63:763-70.

15. Risser DT, Rice MM, Salisbury ML, et al. The potential for improved teamwork to reduce medical errors in the emergency department. The MedTeams Research Consortium. *Ann Emerg Med* 1999;34:373-83.

16. Eisenberg EM, Murphy AG, Sutcliffe K, et al. Communication in emergency medicine: implications for patient safety. *Commun Monogr* 2005;72:390-413.

17. Ramlakhan S, Qayyum H, Burke D, et al. The safety of emergency medicine. *Emerg Med J* 2015;33:293-9.

18. McCulloch P, Rathbone J, Catchpole K. Interventions to improve teamwork and communications among healthcare staff. *Br J Surg* 2011;98:469-79.

19. Weaver SJ, Dy SM, Rosen MA. Team-training in healthcare: a narrative synthesis of the literature. *BMJ Qual Saf* 2014;23:359-72.

20. Hughes AM, Gregory ME, Joseph DL, et al. Saving lives: a meta-analysis of team training in healthcare. *J Appl Psychol* 2016;101:1266-304.

21. Weaver SJ, Lyons R, DiazGranados D, et al. The anatomy of health care team training and the state of practice: a critical review. *Acad Med* 2010;85:1746-60.

22. Marlow SL, Hughes AM, Sonesh SC, et al. A systematic review of team training in health care: ten questions. *Jt Comm J Qual Patient Saf* 2017;43:197-204.

23. O'Dea A, O'Connor P, Keogh I. A meta-analysis of the effectiveness of crew resource management training in acute care domains. *Postgrad Med J* 2014;90:699-708.

24. Weaver SJ, Lubomksi LH, Wilson RF, et al. Promoting a culture of safety as a patient safety strategy: a systematic review. *Ann Intern Med* 2013;158:369-74.

25. Husebø SE, Akerjordet K. Quantitative systematic review of multi-professional teamwork and leadership training to optimize patient outcomes in acute hospital settings. *J Adv Nurs* 2016;72:2980-3000.

26. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009;6:e1000097.

27. Schardt C, Adams MB, Owens T, et al. Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Med Inform Decis Mak* 2007;7:16.

28. F1000Workspace, F1000Workspace (v35). Computer Software, London, UK: Faculty of 1000 Ltd: https://www.f1000workspace.com/

29. Khan KS, Kunz R, Kleijnen J, et al. Five steps to conducting a systematic review. *J R Soc Med* 2003;96:118-21.

30. Wells GA, Shea B, O'Connell D, et al. The Newcastle- Ottawa scale (NOS) for assessing the quality of non-randomized studies in meta-analysis. Rockville (MD): Agency for Healthcare Research and Quality (US), 2013.

31. Jones F, Podila P, Powers C. Creating a culture of safety in the emergency department. *J Nurs Adm* 2013;43:194-200.

32. Miller D, Crandall C, Washington C, et al. Improving teamwork and communication in trauma care through *in situ* simulations. *Acad Emerg Med* 2012;19:608-12.

33. Grogan EL, Stiles RA, France DJ, et al. The impact of aviation-based teamwork training on the attitudes of health-care professionals. *J Am Coll Surg* 2004;199:843-8.

34. Obenrader C, Broome ME, Yap TL, et al. Changing Team Member Perceptions by Implementing TeamSTEPPS in an Emergency Department. *J Emerg Nurs* 2019;45:31-7.

35. Capella J, Smith S, Philp A, et al. Teamwork training improves the clinical care of trauma patients. *J Surg Educ* 2010;67:439-43.

36. Hughes KM, Benenson RS, Krichten AE, et al. A crew resource management program tailored to trauma resuscitation improves team behavior and communication. *J Am Coll Surg* 2014;219:545-51.

37. Wong AH-W, Gang M, Szyld D, et al. Making an "attitude adjustment": using a simulation-enhanced interprofessional education strategy to improve attitudes toward teamwork and communication. *Simul Healthc* 2016;11:117-25.

38. Hefner JL, Hilligoss B, Knupp A, et al. Cultural transformation after implementation of crew resource management: is it really possible? *Am J Med Qual* 2016;32:384-90.

39. Lisbon D, Allin D, Cleek C, et al. Improved knowledge, attitudes, and behaviors after implementation of teamstepps training in an academic emergency department. *Am J Med Qual* 2014;31:86-90.

40. Morey JC, Simon R, Jay GD, et al. Error reduction and performance improvement in the emergency department through formal teamwork training: evaluation results of the medteams project. *Health Serv Res* 2002;37:1553-81.

41. Roberts NK, Williams RG, Schwind CJ, et al. The impact of brief team communication, leadership and team behavior training on ad hoc team performance in trauma care settings. *Am J Surg* 2014;207:170-8.

42. Shapiro MJ, Morey JC, Small SD, et al. Simulation based teamwork training for emergency department staff: does it improve clinical team performance when added to an existing didactic teamwork curriculum? *Qual Saf Health Care* 2004;13:417-21.

43. Sweeney LA, Warren O, Gardner L, et al. A simulation-based training program improves emergency department staff communication. *Am J Med Qual* 2013;29:115-23.

44. Auerbach M, Roney L, Aysseh A, et al. *In situ* pediatric trauma simulation. *Pediatr Emerg Care* 2014;30:884-91.

45. Patterson MD, Geis GL, Falcone RA, et al. *In situ* simulation: detection of safety threats and teamwork training in a high risk emergency department. *BMJ Qual Saf* 2013;22:468-77.

46. Paltved C, Bjerregaard AT, Krogh K, et al. Designing *in situ* simulation in the emergency department: evaluating safety attitudes amongst physicians and nurses. *Adv Simul* 2017;2:4

47. Helmreich RL, Merritt AC, Sherman PJ, et al. The Flight Management Attitudes Questionnaire (FMAQ). NASA/UT/FAA Technical Report 93-4. Austin, TX: The University of Texas, 1993.

48. Helmreich RL, Merritt AC. Culture at Work in Aviation and Medicine: National, Organizational, and Professional Influences. Aldershot, U.K: Ashgate Publishing Limited, 1998.

49. Agency for Healthcare Research and Quality, Surveys on Patient Safety Culture™. Available at: http://www.ahrq.gov/professionals/quality-patient-safety/patientsafetyculture/index.html. Accessed August 2017.

50. Agency for Healthcare Research and Quality, Internet Citation: TeamSTEPPS Fundamentals Course: Module 1. Introduction. Available at: http://www.ahrq.gov/teamstepps/instructor/fundamentals/module1/slintro.html. Accessed March 2018.

51. Flin R, Glavin R, Maran R, et al. ANTS System-Observation and Rating Sheet 2004. Available at: https://www.abdn.ac.uk/iprc/documents/ANTS%20Handbook%202012.pdf Accessed June 30, 2018.

52. Helmreich RL, Wilhelm JA, Gregorich SE, et al. Preliminary results from the evaluation of cockpit resource management training: performance ratings of flightcrews. *Aviat Space Environ Med* 1990;61:576-9.

53. Helmreich RL, Wilhelm JA, Kello JE, et al. Reinforcing and Evaluating Crew Resource Management: Evaluator/LOS Instructor Reference Manual. Austin, TX: NASA–University of Texas at Austin, 1990.

54. Frankel A, Gardner R, Maynard L, et al. Using the Communication and Teamwork Skills (CATS) assessment to measure health care team performance. *Jt Comm J Qual Patient Saf* 2007;33:549-58.

612 55. Gillon S, Radford S, Chalwin R, et al. Crisis resource management, simulation training and
613 the medical emergency team. *Crit Care Resusc* 2012;14:227-35.
614 56. Guise J-M, Deering S, Kanki B, et al. Validation of a Tool to Measure and Promote Clinical
615 Teamwork. *Simul Healthc.* 2008;3:217-23.
616 57. Team Performance Observation Tool. TeamSTEPPS 2.0
617 https://www.ahrq.gov/sites/default/files/wysiwyg/professionals/education/curriculum-
618 tools/teamstepps/instructor/reference/tmpot.pdf.
619 58, Kirkpatrick DL, Kirkpatrick JD. Evaluating Training Programs: The Four Levels. San
620 Francisco, CA: Berrett-Koehler Publishers, 2006.
621 59. Sitzmann T, Brown KG, Casper WJ, et al. A review and meta-analysis of the nomological
622 network of trainee reactions. *J Appl Psychol* 2008;93:280-95.
623 60. Weaver SJ, Rosen MA, DiazGranados D, et al. Does teamwork improve performance in the
624 operating room? A multilevel evaluation. *Jt Comm J Qual Patient Saf* 2010;36:133-42.
625 61. Jones KJ, Skinner AM, High R, Reiter-Palmon R. A theory-driven, longitudinal evaluation of
626 the impact of team training on safety culture in 24 hospitals. *BMJ Qual Saf* 2013;22:394-
627 404.
628 62. Kirkpatrick D. Great ideas revisited: revisiting Kirkpatrick's four-level model. *Train Dev*
629 1996;50:54-57.
630 63. Salas E, Wilson KA, Burke CS, et al. Does crew resource management training work? An
631 update, an extension, and some critical needs. *Hum Factors* 2006;48:392-412.
632 64. Kirkpatrick D. The four levels of evaluation (No. 701): American Society for Training and
633 Development, 2007.

65. Sorra JS, Nieva VF. Hospital Survey on Patient Safety Culture. (Prepared by Westat, under Contract No. 290-96-0004). AHRQ Publication No. 04-0041. Rockville, MD: The Agency for Healthcare Research and Quality, 2004.

66. Der Sahakian G, Buléon C, Alinier G. Educational Foundations of Instructional Design Applied to Simulation-Based Education. In: Chiniara G (Ed). Clinical Simulation: Education, Operations, and Engineering. 2nd Edition. Cambridge: Academic Press, 2019:185-206.

67. Alinier G, Hssain I. Creating Effective Learning Environments: The Educator's Perspective. In: Chiniara G (Ed). Clinical Simulation: Education, Operations, and Engineering. 2nd Edition. Cambridge: Academic Press, 2019:217-27.

68. Cooper MD. Towards a model of safety culture. *Saf Sci* 2000;36:111-36.

69. Kapur N, Parand A, Soukup T, et al. Aviation and healthcare: a comparative review with implications for patient safety. *JRSM Open* 2016;7:205427041561654.

70. Clarke S, Horeczko T, Carlisle M, et al. Emergency medicine resident crisis resource management ability: a simulation-based longitudinal study. *Med Educ Online* 2014;19:25771.

Figure legends

Figure 1. PRISMA flow diagram of selection of studies for inclusion.