The Effect of Teaching Nontechnical Skills in Advanced Life Support: A Systematic Review

Philippe Dewolf, MD^{1,2} , Geraldine Clarebout, PhD³, Lina Wauters, PhD¹, Joke Van Kerkhoven, MD¹, and Sandra Verelst, MD, PhD^{1,2}

ABSTRACT

Objectives: The objective of this study was to evaluate the effect of nontechnical skills (NTS) training on performance in advanced life support (ALS) simulation. Furthermore, we aimed to determine the ideal frequency of training sessions for an optimal retention and the value of debriefing.

Methods: A systematic search was performed using PubMed, EMBASE, WoS, ERIC, CINAHL, and the Cochrane Library conducted through August 1, 2018. All primary studies mentioning NTS in ALS education were included. Three reviewers independently extracted data on study design and outcome. The MERSQI approach was used to evaluate the overall quality of evidence.

Results: Of the 10,723 identified articles, 40 studies were included with a combined total of 3,041 participants, ranging from students to experts. Depending on the focus of the study, articles were categorized in NTS ($n = 25$), retention ($n = 8$), and feedback ($n = 10$). Incorporating NTS during ALS simulation showed significant improvements in timing for performing critical first steps. Furthermore, good leadership skills had a favorable effect on overall technical performance and teamwork during simulation improved team dynamics and performance. Finally, debriefing also had a beneficial effect on team performance. One particular type of debriefing does not appear to be superior to other types of debriefing.

Conclusion: Team simulation training resulted in improved NTS and a reduction in the time required to complete a simulated cardiac arrest. Therefore, a formal NTS program should be introduced into ALS courses. Feedback and repetitive practice are key factors to train NTS. The impact of training on team behaviors can persist for at least 3 to 6 months. In conclusion, understanding and improving NTS may help to create more effective teams. The effect on patient outcome requires further investigation.

Survival from out-of-hospital cardiac arrest (CA) remains low around 10.3% with survival depending on location of arrest, initial rhythm, and patient and rescue factors.¹ Therefore, the American Heart Association (AHA) and European Resuscitation Council (ERC) guidelines emphasize the importance of technical skills (TS).² However, errors are frequently the result of failure in nontechnical skills (NTS).³

Therefore, the quality of NTS in terms of teamwork, leadership, communication, and situational awareness is likely just as important for achieving a better patient outcome.^{3–7}

As a result, NTS training was recently included in several medical courses, including the advanced life support (ALS) course.^{8–11} This training can potentially reduce patient morbidity and mortality by enabling

From the ¹Department of Emergency Medicine, University Hospitals Leuven, Leuven, Flanders, Belgium; the ²Faculty of Medicine, KU Leuven, Leuven, Flanders, Belgium; and the ³Faculty of Psychology and Pedagogical Sciences, Centre for Instructional Psychology and Technology, KU Leuven, Leuven, Flanders, Belgium.

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Address for correspondence and reprints: Philippe Dewolf, MD; e-mail: philippe.dewolf@uzleuven.be.

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deliberate selection, sequencing of cases, and practice without risking patient safety.^{12–14}

The integral ALS training with attention to both TS and NTS is currently most commonly based on simulation.^{15,16} Simulation-based training is not only affected by the quality of the scenario and the instructor's expertise, but also by the feedback process.¹⁷ In this respect, debriefing serves as a reflective feedback process in which learners are encouraged to discuss the strengths and weaknesses of their performance.^{18–20}

However, the optimal design of ALS training remains unknown.²¹ Although simulation training of resuscitation teams is recommended,^{8,9} the question remains where NTS should be placed within this training. Furthermore, it is unclear whether NTS integration will have an effect on clinical performance and/or patient outcome. Therefore, this systematic review aims to investigate the effect of NTS training on performance in ALS, the ideal frequency of training sessions for an optimal retention of learned TS and NTS, and the value of debriefing sessions in a simulation setting. This systematic review will provide information to an ongoing project (Pro Rea Study and Revival ++) to create a new way to simulate advanced cardiac life support in a mixed-reality platform.

METHODS

Protocol and Registration

The methodology and report of the present systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.²² The review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO CRD42017064446).

Study Design and Database Search

A systematic search was performed using PubMed, EMBASE, WoS, ERIC, CINAHL, and the Cochrane Library to identify all eligible studies. The search strategy was developed and executed in consultation with an experienced research librarian. All six databases were searched electronically until August 1, 2018. References of all relevant articles were searched for additional studies. No language restrictions were applied. Unpublished studies were not included. The search strategy combined Medical Search Headings and Subheadings (MeSH) terms (in PubMed) with Boolean

operators 'AND' and 'OR' to capture all relevant article suggestions. Data Supplement S1 (available as supporting information in the online version of this paper, which is available at <http://onlinelibrary.wiley.com/doi/10.1002/aet2.10522/full>) shows the search terms and strategy.

Eligibility Criteria

We included all primary studies, regardless of the design, involving human subjects mentioning NTS in case of ALS education. NTS include leadership, teamwork, communication, and situational awareness. Leadership is defined as the process that requires specific coordination activities such as distributing tasks, assigning work, and enforcing rules and procedures.²³ Teamwork includes clarity of goals, applicable communication, and defined roles. Situational awareness (SA) is defined as the perception of the elements in the environment within the volume of time and space, the comprehension of their meaning, and the projection of the status in the near future.²⁴

Furthermore, studies referring to the degree of booster effect in terms of retention of skills in ALS training were included. Finally, studies on the influence of feedback after the training of NTS in ALS simulations were also included. Studies lacking empirical data and abstracts without full-text articles were excluded.

Study Selection and Data Extraction

Three independent reviewers (PDW, GC, and SV) screened all titles and abstracts for inclusion using the eligibility criteria. The Covidence software platform, which is owned by Veritas Health Innovation in Victoria, Australia, was used as screening tool. Subsequently, the same reviewers independently screened all of the full texts of potentially eligible studies for final inclusion. Authors were contacted if important data were missing from potentially eligible studies. Disagreements (40 of the 289 full articles) between the reviewers were resolved by consensus.

The three reviewers independently extracted the following data from the included studies: year of publication, characteristics and number of participants and assessors, aim of the study, study design, duration and topic of the intervention or course, method, evaluation type, outcome, and conclusions. Data were entered into a predeveloped and piloted data collection form. Only explicitly reported data were abstracted; no data were imputed.

Outcome Measures

The primary outcome was the influence of NTS in ALS training. Secondary outcomes were respectively the ideal frequency of training sessions for an optimal retention of learned TS and NTS and the value of debriefing sessions in a simulation setting.

Risk of Bias

Three independent reviewers (PDW, GC, and SV) performed risk of bias of the included studies using the Medical Education Research Study Quality Instrument (MERSQI).^{25,26} This instrument allows assessing the methodologic rigor of articles, includes a comprehensive list of review items, and has a growing body of validity evidence.²⁷ MERSQI adopts the Kirkpatrick four-level model to approach the effectiveness construct. The first level (reaction) focuses on the participants' perceptions of the intervention. The second level (learning) evaluates knowledge, skills, and attitudinal change. The third level (behavior) measures changes in behavior. Finally, the fourth level (results) focuses on the organization benefits as a result of the intervention.²⁸ The included studies were assessed for study design, number of sampling institutions,

response rate, type of data, validity evidence for evaluation instrument scores, sophistication and appropriateness of data analysis, and outcome. Each domain was assessed as low, unclear, or high risk of bias. All disagreements were resolved by consensus.

Data Synthesis and Analysis

All included studies were classified into three categories: NTS, retention, and feedback (multiple categories possible). Within NTS, subcategories were introduced including general NTS and studies specifically focusing on teamwork, leadership, communication, stress, or situational awareness. The inclusion of all studies was summarized in a PRISMA flow chart.

RESULTS

Study Selection, Population, and Topic of the Intervention

A total of 10,723 citations were eligible for title and abstract screening. Of these, 289 full-text reports were reviewed, resulting in the final inclusion of 40 studies (Figure 1). Depending on the focus of the study, studies were categorized in NTS ($n = 25$), retention

Figure 1. PRISMA flow diagram.

($n = 8$), and feedback ($n = 10$). Of these, two studies were categorized in both NTS and feedback,^{29,30} and one study in both NTS and retention³¹ (These articles are marked with an asterisk in the tables.) Within the NTS section, studies were subdivided in the following topics: general ($n = 7$),^{11,29,30,32–35} teamwork ($n = 8$),^{10,31,36–41} leadership ($n = 4$),^{23,42–44} communication ($n = 3$),^{45–47} stress ($n = 2$),^{48,49} and SA ($n = 1$).⁵⁰ A combined total of 3,041 participants were included, ranging from students to experts. The majority of the studies were based on simulated ALS scenarios, except for three studies. One focused on an ALS course⁵¹ and two on real-time ALS interventions.^{52,53} There was a large heterogeneity in both the age of the patient and the setting of the simulated ALS scenarios. A detailed overview of results is available in Data Supplement S2.

Study Design

All included studies had a prospective design, except for one retrospective study.³⁴ The majority of the studies were randomized controlled trials ($n = 23$) or pre/post studies ($n = 6$). Four studies were observational trials.^{37,42,50,54} The remaining seven studies had a different study design from one another and from the previously described studies.^{44,45,49,53,55–57}

Aims, Methods, and Demonstrated Impact on Performance

A meta-analysis is not performed since the different studies were conducted under heterogeneous conditions. As a result, data could not be compared in a reliable way. Despite these difficulties, results are summarized for all subcategories.

NTS (Table 1 and 2). Seven studies investigated the effect of NTS on general performance. They all showed significant improvements in timing for performing critical first steps, in team management or teamwork knowledge Table 1 and 2.

Four studies focused on leadership during simulation.^{23,42–44} While one study investigated the influence of sex on leadership performance,⁴² the other three investigated the impact of leadership seminars on performance.^{23,43,44} These three studies showed a significant association between good leadership skills and overall technical performance. Three studies on communication showed shorter no-flow time rates, although results were not consistently significant.^{45–47}

Eight studies focused on teamwork during simulation.^{10,31,36–41} With the exception of one study,¹⁰ specific instructions on teamwork during simulation improved team dynamics and performance.

Finally, in two studies, the objective was to evaluate the effect of stress on performance.^{48,49} External stressors had a negative impact on nontechnical performance and on some aspects of technical performance. The introduction of a brief stress coping strategy moderately decreased stress but had no effect on performance in a study by Hunziker et al.⁴⁸

Retention (Table 3). The goal of all included studies was to evaluate retention of theoretical knowledge and/or clinical skills after simulation training. Of the eight studies focusing on skills retention over time, one study demonstrated that skills did not decay.⁵⁴ Four studies showed a decline of performance over time, with a faster decline of practical skills compared to theoretical knowledge.^{51,55,58,59} Two studies investigated the effect of repeated training on skills retention.^{60,61} One of these showed a significant improvement of procedural skills and teamwork behaviors.⁶¹ The other study showed a nonsignificant positive trend.⁶⁰ Finally, one intervention on teamwork behaviors persisted after 6 months.³¹ In general, training sessions had a beneficial effect on theoretical and practical skills. The latter seem to degrade faster over time Table 3.

Feedback (Table 4). The objective of all studies was to evaluate the importance of debriefing on team performance. A wide variety of debriefing types was evaluated: self-debriefing, instructor-guided debriefing, oral debriefing, video-assisted debriefing, focused and corrective feedback (FCF), and structured and supported debriefing (SSD). Six of the included studies assessed the value of feedback immediately after training,^{20,29,30,56,62,63} while two studies assessed the importance of debriefing at different time intervals.^{57,64} The two remaining studies used observational periods.^{52,53} In general, debriefing had a favorable effect on team performance. One particular type of debriefing does not appear to be superior to other types of debriefing Table 4.

Evaluation Type and Assessors

The quality of the interventions was assessed by ALS experts in the vast majority of the studies, blinded to the allocation of the participants. Experts were trained

Table 1
Study Characteristics and Outcome of the Included Studies, Categorized in NTS

General	Study	Participants	Aim	Methods	Outcome
	Blackwood et al. 2014 ¹¹	15 residents (pediatrics)	To determine whether NTS skills improve resuscitation performance.	Didactic refresher course - randomization in control (no further instructions) or intervention group (additional NTS training) - assessment as team leader using two sequential scenarios.	1-h NTS teaching session significantly improved time to critical initial steps of resuscitation and NTS performance as measured by OGRS. No significant difference in time to initiation of CPR.
	Boet et al. 2011 ^{29*}	50 residents (anesthesiology)	<ol style="list-style-type: none"> To examine the effectiveness of NTS training on NTS during resuscitation. To assess the effectiveness of self-debriefing versus instructor debriefing on NTS performance. 	Instruction in the principles of NTS for crisis management - pretest - randomization in video-assisted self-debriefing or instructor-guided debriefing group (both using ANTS) - posttest.	Significant improvement of NTS with NTS training. No significant difference in the degree of improvement in NTS performance between self-debriefing or instructor debriefing.
	Burden et al. 2014 ³²	52 residents (internal medicine)	To assess the effectiveness of SIM versus LEC NTS training on NTS performance.	Pretest - debriefing - randomization in the LEC (two lectures about team management) or SIM group (simulation-based education with deliberate practice) - posttest (6 months later).	After intervention, both the SIM and the LEC groups showed improved rare event and team management. Significantly better performance of SIM group compared to LEC group based on diagnosis announcement, asking for suggestions and task assignment.
	Coppens et al. 2018 ^{30*}	116 nurses (students)	To investigate whether integrating a course on NTS principles and team debriefings in simulation training increases self efficacy, team efficacy and technical skills.	Randomization in control and intervention (NTS course prior to simulation) group - simulation training 1 - guided team debriefing (only intervention group) - simulation training 2.	The intervention group significantly increased on self-efficacy and team efficacy, while the control group only increased significantly on team efficacy. The intervention group scored significantly higher on team efficacy compared to the control group.
	Hicks et al. 2012 ³³	14 residents (physicians and surgeons of Canada EM program, junior and senior).	<ol style="list-style-type: none"> To evaluate the feasibility of NTS (CREW) training. To identify shifts in team-based behaviors and attitudes. 	Precourse simulation - prelearning - precourse survey - CREW course - postcourse survey and simulation.	Postcourse survey shows overall highly positive assessment of quality, relevance, and potential impact of CREW training. Positive nonsignificant trends in resident behavior for all six categories of the OGRS from pre- to postcourse as well as overall team leader performance.

(Continued)

Table 1 (continued)

	Study	Participants	Aim	Methods	Outcome
	Riem et al. 2012 ³⁴	50 residents (postgraduate years 2-5 anesthesiology).	To evaluate the relationship between TS and NTS during simulation.	Retrospective analysis of video-recorded simulation (intraoperative CA secondary to a malignant arrhythmia).	Both significant correlations between TS and NTS ($r = 0.45$, $p < 0.05$) and between TS and ANTS subgroups (teamwork, decision making, and task management; $r = 0.31-0.45$).
	Sawyer et al. 2013 ³⁵	42 (4 attendings, 6 fellows, 29 nurses, 3 respiratory therapists)	To evaluate the impact of interprofessional TeamSTEPPS training on teamwork skills during resuscitation.	Brief introduction video - pretest questionnaires on teamwork attitudes and knowledge - pretest simulation-based training - Team STEPPS fundamental course - posttest questionnaires - posttest simulations - debriefing.	Significant improvements in teamwork skills for team structure, leadership, situation monitoring, mutual support, and communication after TeamSTEPPS training ($p < 0.001$). Doubling of number of times a nurse challenged the incorrect medication order by the physician. Significant improvement of teamwork knowledge and attitude toward teamwork.
Leadership	Amacher et al. 2017 ⁴²	216 medical students (4th year)	To compare female and male rescuers in regard to CPR and leadership performance.	Randomization in female, male and mixed groups - simulation on high-fidelity mannequin - data analysis on group and individual level (leadership and timing of TS).	Significant difference between male and female rescuers concerning leadership and CPR performance. Female rescuers show inferior CPR performance, which can partially be explained by fewer unsolicited CPR measures an inferior female leadership.
	Cooper 2001 ⁴³	68 physicians (internal medicine) and nurses	To evaluate the effectiveness of a leadership development seminar introduced into the Resuscitation Council (UK) ALS Provider course.	Baseline simulation - randomization in control (standard ALS program) or intervention (standard ALS program including leadership development seminar) group - posttest.	The leadership development program significantly improved leadership performance in the training situation.
(Continued)					

Table 1 (continued)

Study	Participants	Aim	Methods	Outcome
Hunziker et al. 2010 ²³	189 medical students (4th year)	To assess the influence and sustained effect of technical versus leadership instructions on medical performance in a high-fidelity simulated CPR.	Baseline simulation - standardized resuscitation algorithm instructions - randomization in technical instruction (correct positioning of arms and shoulders) or leadership instruction (leadership and communication) group - posttest (4 months later): randomization into new teams of 3 within same randomization arm.	The leadership instruction group demonstrated significantly longer hands-on time, short time to first meaningful measure, earlier start with chest compressions and ventilation, and more leadership utterances. The rate of correct arm and shoulder positions was higher in teams with technical instruction.
Yeung et al. 2012 ⁴⁴	40 (9 family medicine, 11 critical care, 6 critical care nurses, 10 advanced nurse practitioners, 4 resuscitation officers)	1. To identify the relationship between leadership skills and the quality of CPR associated tasks. 2. To identify factors affecting leadership skills.	Briefing - resuscitation simulation (videorecorded) - measurement of team leader characteristics using bivariate correlations.	Strong significant associations between good leadership skills and overall technical performance of complex skills by CASTest, weaker with shock pauses, total hands-off ratio, and time to first shock (still significant). No associations with simple CPR tasks.
Communication Yamada et al. 2014 ⁴⁵	13 (5 physicians, 2 fellows, 3 nurses, 3 hospitalists)	To determine if the use of standardized communication techniques decreases the errors committed by resuscitation teams during simulated complex neonatal resuscitation.	Each participant performed as lead resuscitator. Two members of the CAPE staff trained in the use of a standardized resuscitation lexicon acted as assisting nurses. Two scenarios: in one scenario nonstandard communication was used by the nurses; in the other, one standard resuscitation lexicon. Scoring of team performance.	No significant difference in error rate, time to initiation of PPV, or time to initiation of CC in both scenarios. In standardized resuscitation lexicon scenarios communication techniques were used more than twice as often. In nonstandardized communication scenarios subjects and nurses more frequently exchanged clarifying statements and qualitative statements about breath sounds and less frequently used closed-loop communication.
Fernandez Castela et al. 2015 ⁴⁷	180 medical students (5th year)	To determine whether single team member NTS training is linked to positive CPR outcomes and TLV.	BLS and ALS course (90-min lecture, three instructor-led interactive tutorials: BLS, airway management, rhythm recognition/defibrillation) - randomization in NTS-TL or ALS add-on group - simulation.	Nonsignificantly shorter NFT rates after NTS-TL training. Significantly higher ADH scores and higher proportions in all four TLV categories for teams of NTS-TL group. None of four categories were significantly related to either ADH or NFT.

(Continued)

Table 1 (continued)

Study	Participants	Aim	Methods	Outcome
Fernandez Castelao et al. 2011 ⁴⁶	176 medical students (5th year)	<ol style="list-style-type: none"> To evaluate the impact of interactive video-based NTS training on NFT, TLV and FV. To analyze the effects of TLV accuracy level on NFT in early phases of CPR. 	BLS and ALS course (90-min lecture, 3 instructor-led interactive tutorials: BLS, airway management, rhythm recognition/defibrillation) - randomization in NTS training or additional ALS training (ALS add-on) group - simulation.	Significantly lower NFT rates in NTS training group. No categories were significantly related to NFT rates. All four TLV category proportions were significantly higher in the NTS training group than in the ALS add-on group. Significant differences in FV between the two groups were only found for unsolicited information.

ALS = advanced life support; BLS = basic life support; CPR = cardiopulmonary resuscitation; NTS-TL = NTS team leader training; ALS add-on = additional ALS training; TS = technical skills; NTS = nontechnical skills; ANTS = anesthesiology NTS; CA = cardiac arrest; TeamSTEPPS = Team Strategies and Tools to Enhance Performance and Patient Safety; ADH = adherence to the European Resuscitation Council 2010 ALS algorithm; TLV = team leader verbalization; NFT = no-flow time; FV = follower verbalizations; CAPE = Centre for Advanced Pediatric and Perinatal Education; SIM = simulation-based; LEC = lecture-based.

*Both NTS and feedback^{29,30} and one study in both NTS and retention.³¹

in the use of a specific evaluation tool in 30 of the 40 included studies. In the remaining studies, the training level of assessors was not mentioned. Fifteen different evaluation tools were used to assess the quality of the intervention.

NTS. The included studies used a variety of evaluation tools of which the vast majority had validity evidence: Team Emergency Assessment Measure (TEAM), Leadership Behaviour Description Questionnaire (LBDQ), Cardiac Arrest Simulation (CAS-test), Anesthesiology Non-Technical Skills (ANTS), Team-STEPPS Team Performance Observation Tool (T-TPOT), Ottawa CRM Global Rating Scale (OGRS), Human Factors Attitude Survey (HFAS), Simulation Team Assessment Tool (STAT), Neonatal Resuscitation Program (NRP), University of Auckland Behavioral Rating Scale (ABRS), Clinical Teamwork Scale (CTS), and General Self-Efficacy Scale (GSES). Eight studies used evaluation tools without validity evidence^{32,37,41,45–48,50} and three studies^{31,34,49} had a combination of both.

Retention. Seven studies used evaluation tools based on resuscitation guidelines (NRP, AHA, Pediatric Advanced Life Support [PALS], ERC),^{31,54,55,58–61} while one study used practical skill stations.⁵¹ Two studies included theoretical assessments.^{51,59}

Feedback. Seven of 10 included studies used evaluation tools with validity evidence (Mayo High Performance Teamwork Scale [HPTS], OGRS, NRP-Evaluation, ANTS, TEAM, ARBS, CTS and GSES).^{20,29,30,53,56,63,64} Of the three remaining studies, one used interviews with focus groups⁵⁷ and two used checklists.^{52,62}

Risk of Bias

The median MERSQI score of all articles included was 12.5, with scores ranging from 7.5 to 15 (Addendum A1-8).

DISCUSSION

NTS

Introducing NTS training proves to be challenging due to the variety of methods described in the literature. Nevertheless, based on previous studies, we would propose to start with a prelearning course that handles the most important NTS topics like team

Table 2
Study Characteristics and Outcome of the Included Studies, Categorized in NTS

Study	Participants	Aim	Methods	Outcome
Teamwork Chung et al. 2011 ³⁶	70 (32 resident physicians, 38 nurses)	To compare CPR team dynamics and performance between a conventional simulation training group and a script-based training group.	Baseline simulation - randomization in control (didactic lecture and simulation with debrief) or script group (only training using resuscitation script) - evaluation based on checklist 1 week before and 1 one week after training.	Both conventional as script-based training improved team dynamics, performance and leadership. No significant difference between both methods.
Emani et al. 2018 ³⁷	23 (8 nurses, 8 anesthesiologists, 6 surgeons, 1 cardiologist)	To assess the effect of low-fidelity simulation based NTS training on team dynamics and performance.	Introduction to teamwork and simulation - presimulation questionnaire - four simulations (including daily participant questionnaire, observer review, and video analysis) - postintervention questionnaire - 1-month follow-up questionnaire.	In subjective questionnaires, participants noted significant improvement in team dynamics and performance over the training period. Video analysis revealed a decrease in time to intervention and significant increase in frequency of closed-loop communication due to simulation training.
Fernandez et al. 2013 ³⁸	229 (165 medical students, 64 residents; years 1-3 EM)	To evaluate the efficacy of a cTPT intervention on medical emergency teamwork and patient care performance.	Randomization in cTPT intervention or placebo intervention (no discussion of specific teamwork behaviors nor their implementation) group - two simulation scenarios.	Teams receiving the cTPT intervention engaged in a greater number of appropriate teamwork behaviors and performed better with regard to standards for patient care than teams receiving placebo training.
Lemke et al. 2016 ³⁹	15 fellows (pediatric EM)	To compare traditional versus RCDP simulation-based medical education.	Pretest 1- randomization in RCDP simulation or traditional simulation group - posttest 1-3 months wash-out period - posttest 2 (retention)/pretest 1 - reversal of groups - posttest 2.	RCDP simulation group showed significant improvement for all STAT scores except basics, this was not true for the traditional simulation group. For the STAT human factors subsection, a significant greater improvement is seen for the RCDP simulation group compared to the traditional simulation group.
Mahramus et al. 2016 ⁴⁰	71 (18 residents, 23 registered nurses, 30 respiratory therapists)	To assess the effectiveness of a 2-h multidisciplinary teamwork training.	Pretest - debriefing - teamwork training lecture - posttest - self-assessment and observers' assessment.	Significant improvement of mean scores on the TEAM tool from first to second simulation. Positive program evaluation by participants.

(Continued)

Table 2 (continued)

Study	Participants	Aim	Methods	Outcome
Rovamo et al. 2015 ¹⁰	99 physicians (17 pediatricians, 16 anesthesiologists, 14 gynecologists, 31 midwives, 21 neonatal nurses)	To evaluate the impact of NTS and ANTS instruction on teamwork during simulation.	Introduction - randomization in control group (no further instructions) or intervention group (1-h interactive lecture on ANTS and NTS, self- and peer assessment after simulation): each team participated in two scenarios and observed two scenarios - debriefing after each scenario.	No difference for mean leadership, teamwork, task management, and total TEAM score between the E- and C-group. No increase in TEAM score between the first and second scenario. Specialty of team leader accounted for consistent differences between the total teamwork scores (more improvement when anesthesiologist was team leader). No significant effect of instruction or repeated scenarios on the total teamwork scores.
Thomas et al. 2007 ⁴¹	40 interns (23 pediatricians and combined internal medicine and pediatrics, 12 family medicine, 5 obstetrics and gynecology)	To measure the effect of including teamwork skills and information about human error in NRP training on teamwork.	Randomization in standard NRP training (only NRP course) or intervention group (teamwork and human error component instruction included using lecture, role play, short video clips, followed by NRP course) - simulation.	Intervention group exhibited significantly more frequent information sharing, inquiry, and assertion than the standard NRP training group. All intervention groups practiced vigilance and workload management vs. only 20% of the teams in the standard NRP training group.
Thomas et al. 2010 ^{31,*}	100 interns (35 pediatricians, 8 combined pediatrics and internal medicine, 22 family medicine, 20 EM, 15 obstetrics and gynecology)	1. To evaluate the effectiveness of incorporated team training on teamwork behaviors and NRP performance quality. 2. To compare low-fidelity skills stations with high-fidelity skills stations within the team training group.	Randomization in standard NRP course with low-fidelity skills stations (control), LFT, or HFT group - simulation (three scenarios, debrief after each scenario) - follow-up simulation 6 months postcourse.	The HFT group had higher teamwork event rates than the control group. No difference between LFT and control group. Both the HFT and the LFT groups showed significantly better workload management compared to the control group. No significant association between teamwork training intervention and NRP performance. Significantly shorter resuscitation duration for the HFT group compared to the LFT and control group as well as for the LFT group compared to the control group. After 6 months: more frequent team behavior in LFT and HFT groups. No effect on vigilance, workload management, NRP performance, or resuscitation duration.

(Continued)

Table 2 (continued)

Study	Participants	Aim	Methods	Outcome
Stress	Hunziker et al. 2013 ⁴⁸	124 medical students (4th year)	<ol style="list-style-type: none"> To describe stress patterns experienced during an ALS scenario. To investigate whether perceived stress is associated with CPR performance (hands-on time and time to start CPR) and/or leadership statements. To investigate whether a task focusing strategy reduces perceived stress levels and whether this translates into better CPR performance. 	<p>Baseline ALS scenario - video-assisted debriefing focusing on ALS algorithms - randomization in control (no further instructions) or intervention group (10-min instruction to cope with stress including two task focusing questions) - study ALS scenario.</p> <p>More stress was associated with less hands-on time. No significant correlations were found between stress and time to start CPR or number of leadership statements. When examining stress levels at different time points, no significant difference was found between the groups. Participants with more leadership statements started earlier and performed more uninterrupted CPR. No differences between the groups with regard to time to start CPR.</p>
	Krage et al. 2017 ⁴⁹	30 (20 residents, 10 physicians; all anesthesiology)	To determine whether nontechnical performance is affected by the level of external stressors and whether specific domains of nontechnical performance are differentially affected.	<p>Randomization of both sequence of scenarios (VF first vs pulseless VT first) as well as the presence of stressors (scenario with external stressors first vs scenario without external stressors first). Stressors included in the scenario: scripted family member distracting team leader and constant radio noise at ± 70 db.</p> <p>Nontechnical performance scores were significantly lower when external stressors were present compared to control scenarios. In group of participants who started with external stressors scenario, ANTS scores significantly increased in second scenario. Better nontechnical performance was associated with better technical performance.</p>
Situational awareness	Rosenman et al. 2018 ⁵⁰	123 (41 of each group) residents and nurses (EM), medical students	To develop and evaluate a novel approach to simulation-based TSA measurement in interprofessional EM teams.	<p>Simulation - individual team member completion of several measures: 1) TSA measure, 2) team perception of shared understanding measure, 3) team leader effectiveness measure - review of recordings and coding by trained raters using a team clinical performance measure.</p> <p>TSA agreement ranged from 0.19 to 0.9 (mean = 0.61). TSA positively correlated with team clinical performance ($p < 0.05$). Team experience, team leader effectiveness, and team perception of shared understanding did not correlate with TSA. Team leader effectiveness positively correlated with team perception of shared understanding ($p < 0.001$).</p>

ALS = advanced life support; ANTS = anesthesiology nontechnical skills; CPR = cardiopulmonary resuscitation; cTPT = computer-based teamwork process training; RCDP = rapid-cycle deliberate practice; NRP = neonatal resuscitation program; TSA = TEAM SITUATIONAL AWARENESS; VF = ventricular fibrillation; VT = ventricular tachycardia; LFT = NRP course with low-fidelity skills stations including team training; HFT = NRP course with high-fidelity skills stations including team training.

*Categorized in both NTS and feedback^{29,30} and one study in both NTS and retention.³¹

Table 3
Study Characteristics and Outcome of the Included Studies, Categorized in Retention

Study	Participants	Aim	Methods	Outcome
Bender et al. 2014 ⁶¹	50 residents (neonatology)	To evaluate the effect of a high-fidelity simulation booster session on retention of knowledge, procedural skills, and teamwork.	NRP course (baseline) - randomization in control (no intervention) or booster group (half day booster session 7–10 months later) - assessment (15 months later).	Intervention group demonstrated better procedural skills and teamwork behaviors. Deliberate practice with simulation enhances teamwork behavior.
Bingham et al. 2015 ⁶⁰	194 students (pharmacy)	To assess pharmacy students' ability to retain ALS knowledge and skills within 120 days of previous high-fidelity manikin simulation training.	Randomization in control (171, no training) or training group (23, prior ALS training session) - training session (120 days post-prior training session) - posttest.	Teams including a student who had previous simulation training demonstrated numerical superiority in ALS knowledge and skill retention within 120 days of previous training compared to those who had no previous training.
Braun et al. 2015 ⁵⁸	42 residents (pediatrics)	To investigate the duration of mastery-level resuscitation performance retention after a single 1- to 2-h simulation-based mastery learning session.	Baseline simulation until mastery level performance - randomization in T1 (posttest after 2 months), T2 (posttest after 4 months), or T3 (posttest after 6 months) group.	Residents displayed significant improvements in resuscitation performance after a single simulation-based mastery learning session. Performance declined over time, with 92% of residents still at mastery level after 2 months, 71% after 4 months, and 56% after 6 months.
Hammond et al. 2000 ⁵¹	40 nurses (critical care)	To explore the retention of theoretical knowledge and clinical skills of registered nurses 18 months post-successful completion of a 2-day ALS course.	Training session, including theoretical examination and practical assessment (requiring a pass) - retest 18 months posttraining.	Theoretical knowledge remained consistent after 18 months. Practical skills: only 75% of the nurses passed the test immediately. 25% needed a reassessment.
Skidmore et al. 2001 ⁵⁹	62 physicians (pediatrics, neonatology), respiratory therapists, nurses (neonatology)	1. To evaluate the impact of a neonatal resuscitation course on theoretical knowledge and practical skills of birthing room personnel. 2. To evaluate the retention of performance skills.	Pretest (including theoretical examination) - neonatal resuscitation course (lectures, practical sessions) - posttest 1 (immediately after course) - retention test 1 (6 months after) - retention test 2 (12 months after).	Practical performance improved for all participants to a similar degree, irrespective of the participant's initial skills. Theoretical knowledge improved and maintained after the course for a 1-year period. Practical skills began to fall off significantly after 6 months, but still maintained at a significantly greater degree, even after 1 year.
Smith et al. 2008 ⁵⁵	51 nurses (critical care)	To test registered nurses' abilities to retain ALS psychomotor skills and theoretical knowledge.	Pretest - ALS training - posttraining test (all on day 1) - randomization for final testing in T1 (posttest after 3 months), T2 (posttest after 6 months), T3 (posttest after 9 months), or T4 (posttest after 12 months) group.	Nurses retain theoretical knowledge but performance skills degrade quickly. Only 30% of participants passed ALS skills at 3 months and 14% at 12 months.

(Continued)

Table 3 (continued)

Study	Participants	Aim	Methods	Outcome
Thomas et al. 2010 ³¹	100 (35 pediatrics, 8 combined pediatrics and internal medicine, 22 family medicine, 20 EM, 15 obstetrics and gynecology)	<ol style="list-style-type: none"> To evaluate the effectiveness of incorporated team training on teamwork behaviors and NRP performance quality. To compare low-fidelity skills stations with high-fidelity skills stations within the team training group. 	Randomization in standard NRP course with low-fidelity skills stations (control), LFT or HFT group - simulation (three scenarios, debrief after each scenario) - follow-up simulation 6 months postcourse.	The HFT group had higher teamwork event rates than the control group. No difference between LFT and control groups. Both the HFT and the LFT group showed significant better workload management compared to the control group. No significant association between teamwork training intervention and NRP performance. Significant shorter resuscitation duration for the HFT group compared to the LFT and control group as well as for the LFT group compared to the control group. After 6 months: more frequent team behavior in LFT and HFT groups. No effect on vigilance, workload management, NRP performance, or resuscitation duration.
Wayne et al. 2006 ⁵⁴	38 residents (internal medicine)	To evaluate the retention of ALS skills after an educational session using a medical simulator.	Traditional ALS education - four educational simulation sessions - testing sessions at T0 (initial test at time point 0), T1 (retention test after 6 months), and T2 (retention test after 14 months).	After the simulation-based program, resident ALS skill improved significantly. The cohort was followed prospectively for 14 months and skills did not decay.

ALS = advanced life support; NRP = neonatal resuscitation program; LFT = NRP course with low-fidelity skills stations including team training; HFT = NRP course with high-fidelity skills stations including team training.

Table 4
Study Characteristics and Outcome of the Included Studies, Categorized in Feedback

Study	Participants	Aim	Methods	Outcome
Boet et al. 2011 ²⁹	50 residents (anesthesiology)	1. To examine the effectiveness of NTS training on NTS during resuscitation. 2. To assess the effectiveness of self-debriefing vs. instructor debriefing on NTS performance.	Instruction in the principles of NTS for crisis management - pretest - randomization in video-assisted self-debriefing or instructor-guided debriefing group (both using ANTS) - posttest.	Significant improvement of NTS with NTS training. No significant difference in the degree of improvement in NTS performance between self-debriefing or instructor debriefing.
Boet et al. 2013 ⁶³	127 (40 operating room nurses, 40 anesthesiology residents, 40 anesthesiology fellows, 40 surgical residents, 4 surgical fellows)	To compare the effectiveness of an interprofessional within-team debriefing vs. instructor-led debriefing on team performance.	Pretest - randomization in a within-team debriefing group (teams reviewed the video by themselves) and instructor-led debriefing group (teams reviewed their scenario guided by a trained instructor) - posttest.	Significant improvement of team performance from pretest to posttest ($p = 0.008$) regardless of the type of debriefing. No significant difference in the degree of improvement between within-team debriefing and instructor-led debriefing.
Coppens et al. 2018 ³⁰	116 nurses (students)	To investigate whether integrating a course on NTS principles and team debriefings in simulation training increases self-efficacy, team efficacy, and TS.	Randomization in control and intervention (NTS course prior to simulation) group - simulation training 1 - guided team debriefing (only intervention group) - simulation training 2.	The intervention group significantly increased on self-efficacy and team efficacy, while the control group only increased significantly on team efficacy. The intervention group scored significantly higher on team efficacy compared to the control group.
Ballangrud et al. 2014 ⁵⁶	53 nurses (critical care)	To explore team performance in a simulation based emergency situation by using expert raters' assessments and/or self-assessments.	Half day of theoretic introduction on NTS principles - half day of simulations (two scenarios, followed by self-rating and expert rater's assessment of team performance).	Combination of self-assessment and expert raters' assessment helps to obtain a more complete picture of the complexity of team performance. Self-assessment and expert raters' assessment show significant differences. There is a tendency of poor performers to overestimate and high performers to underestimate their performance.
Gregg et al. 2016 ⁵²	20 residents (postgraduate years 3-5 surgery)	To determine whether directed resident feedback following full-trauma-team activation improves a resident's ability to effectively manage teamwork.	Phase 1, baseline performance scores; phase 2, evaluations following communication in-services and immediate, personalized feedback sessions; phase 3, evaluations following immediate, personalized feedback sessions.	Total maximum percentage scores for all competencies improved significantly between phases 1 and 2 and remained significantly elevated between phase 1 and 3. There was no significant change in overall scores between phases 2 and 3.
Kim et al. 2017 ⁶²	95 medical students (4th year)	To compare the educational impact of two debriefing methods (FCF vs. SSD) on team dynamics in simulation-based CA team training.	Randomization in FCF or SSD debriefing group - two CA scenarios followed by the assigned postsimulation debriefing (pretest - debrief - exercise - debrief) - posttest - evaluation of postsimulation debriefings by students - evaluation of team dynamics and team clinical performance.	The SSD team dynamics score during the test simulation was higher than at baseline. The team clinical performance score did not improve. For the FCF group, no improvements were seen. However, there were no significant differences in the improvement in the team dynamics or team clinical performance scores between the two groups.

(Continued)

Table 4 (continued)

Study	Participants	Aim	Methods	Outcome
Porter et al. 2018 ⁵⁷	17 nurses (EM)	To evaluate emergency personnel's perceptions and experiences of rating team NTS performance as part of a quality improvement cycle.	Recruitment of ED staff to participate in the testing of the TEAM tool (10-month period) – 1-h audio-recorded focus group interview directed toward the usability of the tool, assessment of identification of NTS during resuscitation events and an evaluation of team clinical performance.	Emergency nurses viewed the TEAM ratings of NTS of the medical emergency team as a useful vehicle that enabled staff to provide feedback/debrief other resuscitation team members. Defining resuscitation team roles is done much earlier in a medical emergency event.
Skåre et al. 2018 ⁵³	35 (16 midwives, 4 neonatal nurses, 15 physicians)	To evaluate whether video-assisted, performance-focused debriefings following real neonatal resuscitations improve adherence of treatment guidelines and improve TS and NTS.	Three consecutive time periods over 7 months: phase 1, baseline recording of performance and skills; phase 2, intervention period with introduction of weekly debriefings; phase 3, postimplementation period with monthly debriefings.	PPV quality improved throughout the study with 43% of infants pre- vs. 64% of infants postintervention receiving adequate PPV. Median total NRPE-score increased from 77% to 89% from the pre- to postimplementation period ($p < 0.001$) with specific improvements in the categories: group function/communication ($p = 0.001$), preparation and initial steps ($p < 0.001$), PPV ($p < 0.001$), and administration of oxygen ($p = 0.08$).
Savoldelli et al. 2006 ²⁰	42 residents (anesthesiology)	1. To assess the value of debriefing during simulation based education for NTS performance. 2. To compare oral feedback and oral video-assisted feedback debriefing.	Pretest - randomization in control (no feedback), E1 (oral feedback during debriefing), and E2 group (oral feedback including video segments during debriefing) - posttest.	Significant difference in change in overall ANTS score between the three groups ($p < 0.05$). Both experimental groups outperformed the control group. No improvement in performance for control group. No difference between the two experimental groups. Significant difference in following subgroups: task management, team working, situation awareness, and decision making. E1 group outperformed the control group for task management, team working, and decision making. The E2 group outperformed the C-group for task management and team working.

(Continued)

Table 4 (continued)

Study	Participants	Aim	Methods	Outcome
Sawyer et al. 2012 ⁶⁴	30 residents (22 pediatrics, 8 family medicine).	To compare the effectiveness of video-assisted debriefing vs. oral debriefing.	Randomization in oral debriefing (mental recall of the events) or video-assisted debriefing group (allowed to watch the video of the resuscitation, the facilitator stopped video at specific times to allow discussion). Each group performed three simulations, spaced over 2 months, always including same type of debriefing.	Overall resuscitation performance scores significantly improved in both groups. No significant difference between the two groups on none of the subdomains nor for time to complete any critical task.

ALS = advanced life support; TS = technical skills; NTS = nontechnical skills; ANTS = anesthesiology NTS; SSD = structured and supported debriefing; FCF = focuses and corrective feedback; CA = cardiac arrest; TEAM = team emergency assessment measure.

training and human factors theory.^{30,31,33,34-37} This can be followed by an additional lecture that starts with a group review of the precourse content.^{10,32,40,32}

Simulation is the preferable teaching method for improving a variety of NTS including SA,^{49,50,65} stress coping,^{48,49} teamwork,^{30,40,56,60,66,67} and communication.^{37,45,68,69} Indeed, specific instructions on teamwork during simulation improves team dynamics and performance.^{10,31,36-41} Also, if simulation focuses on leadership, a significant association is found between good leadership skills and overall technical performance.^{23,43,44} Less research has been done on stress management and SA. However, in the presence of external stressors, the nontechnical performance of the team leader seems to affect the entire team's technical execution.^{49,48} Therefore, stress management can be an advantage in NTS training to train team behaviors regarding cognitive processes.

A high-fidelity environment is largely preferred by trainees, suggesting that this might be the most appropriate method for future health care-focused NTS endeavors.^{33,31} None of the studies on NTS aimed to evaluate the effect of simulation-based training on patient outcome. However, observation of behavior related to outcome is probably more applicable. This is especially the case for resuscitation teams, where it would be inappropriate to measure survival rates in relation to team or leader performance alone, since survival is also dependent on factors such as the primary heart rhythm and underlying disease. For these reasons, NTS should be evaluated in relation to the context.⁷⁰

Feedback

Simulation training combined with team debriefings increases self- and team efficacy.³⁰ These findings are consistent with the model of Kolb¹⁹ and previous research by Lammers et al.⁷¹ and Leonard et al.⁷² who highlighted reflection as an important part of the simulation session. More specifically, the combination of self-assessment and expert raters' assessment provides a more complete picture on the complexity of team performance.^{29,30,53,56,63} Kim et al.⁶² found no significant difference in the educational impact of two different debriefing methods on team dynamics in simulation-based CA team training. This was consistent with the findings of other studies showing that the use of feedback significantly improved performance during simulation, regardless of the type of debriefing.^{20,64}

Retention

An intensive simulation course can achieve retention of performance for up to 12 to 14 months.⁵⁴ These intensive sessions ranged from 8 hours to 3 days. Despite their clear benefit, these sessions are practically not always feasible, which is why a single, shorter duration session is often chosen.^{31,58,60} In general, these shorter sessions have a beneficial effect on theoretical and practical skills.^{31,59,61,73} A short intensive course is therefore possible, but, while shorter courses may be more logistically feasible, learners' retention of practical skills may be correspondingly shorter.^{51,55,58,59}

LIMITATIONS

We conducted a literature search based on a predefined search strategy and applied a broad approach to the search. However, there may be a risk of studies not appearing due to missing relevant key terms in the search. Because we did not search for unpublished studies, publication bias was possible. The risk is considered small as no effect on the most desirable outcome (patient outcome such as duration of stay in hospital/intensive care unit, complication rate or mortality) was found.²⁸

Furthermore, most of the studies are small, single-center studies with no power calculation. Although the majority of the included studies were randomized controlled trials and assessors were often blinded to randomization, simulation studies have inherent potential biases due to observer bias, absence of blinding, the broad range, and validity of assessment tools. This is a major limitation of any literature review of simulation-based educational research.

CONCLUSIONS

Team simulation training results in improved nontechnical skills and a marked reduction in the time required to complete a simulated cardiac arrest. Therefore, the implementation of nontechnical skills training into advance life support courses could have a positive impact.^{43,44} Feedback and repetitive practice seem to be important factors to train nontechnical skills. The impact of training on team behaviors can persist for at least 3 to 6 months. In conclusion, understanding and improving nontechnical skills may help to create more effective teams.

Recommendations for Future Research

We recommend longitudinal research on methods of teaching effectiveness, the long-term effect of simulation training sessions and the transfer of skills to health care settings. Further research on the frequency with which simulation training sessions should be embedded in the health care setting is also necessary. This review revealed that the debriefing phase was responsible for most of the positive effects in the simulation training. However, it remains unclear which skill within NTS training contributes the most.¹¹ Finally, the effect on patient outcome needs to be further investigated, since the most favorable outcome in simulation training would be that on mortality and morbidity of the cardiac arrest patient.

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Supporting Information

The following supporting information is available in the online version of this paper available at <http://onlinelibrary.wiley.com/doi/10.1002/aet2.10522/full>

Data Supplement S1. Search terms and strategy.

Data Supplement S2. Detailed overview of results.