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REVIEW ARTICLES

Cricoid pressure training using simulation: a systematic review and meta-analysis

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Editor's key points

- The authors have synthesized evidence of the role of simulation in improving cricoid pressure application.
- Simulation was found to have a positive impact on the skills of the trainees.
- There was also some evidence of short-term retention of skills.

Summary. Cricoid pressure (CP) is commonly applied during rapid sequence intubation and may be protective during induction of anaesthesia; however, CP application by untrained practitioners may not be performed optimally. The objective of this systematic review was to synthesize the evidence regarding effectiveness of technology-enhanced simulation training to improve efficacy of CP application. Electronic databases from inception through May 11, 2011 were searched. Eligible studies evaluated CP simulation training. Independent reviewers working in duplicate extracted study characteristics, validity, and outcomes data. Pooled effect size (ES) with 95% confidence intervals (CIs) were estimated from each study that compared technology-enhanced simulation with no intervention or with other methods of CP training using random-effects model. Twelve studies (772 trainees) evaluated CP training as an outcome. Nine studies reported information on baseline skill, with 23% of providers being able to achieve the target CP before training. In a meta-analysis of 10 studies (570 trainees), CP training resulted in a large favourable impact on skills among trainees compared with no intervention (pooled ES 1.18; 95% CI 0.85–1.51; $P<0.0001$). Four studies found evidence of skills retention for CP application after training, but for a limited time (<4 weeks). Comparative effectiveness research shows beneficial effects to force feedback training over training without feedback. Simulation training significantly improves the efficacy of CP application. Future studies might evaluate the clinical impact of training on CP application during rapid sequence intubation, and the comparative effectiveness of different training approaches.

Keywords: cricoid cartilage; education, medical; intubation; patient simulation

Cricoid pressure (CP) use was advocated by Sellick[1] in 1961 to provide some measure of protection against aspiration during induction of anaesthesia. Original descriptions of the 'Sellick manoeuvre' were vague. A one-handed technique of pressure application to the midline of the cricoid cartilage with 'firm' pressure to occlude the oesophagus against the fifth cervical vertebrae was described in Sellick's original paper. Later, Vanner and Asai[2] quantified the amount of effective CP force needed as 10 Newtons (N) before induction of anaesthesia, followed by an increase to 30 N for use in anesthetized patients. Untrained healthcare professionals may apply too little pressure to the anterior larynx providing unreliable protection against regurgitation that may lead to aspiration occurrences despite application of CP, or may apply too much pressure resulting in impaired ventilation or obstructed views for tracheal intubation.[3–5] Case reports document oesophageal rupture occurring because of excessive CP.[3] It is speculated that it is this misapplication of force that has led to the ineffectiveness and unsafe use of CP in clinical practice.

Indeed, knowledge and application of CP is poor among untrained healthcare providers.[4–6] This knowledge gap among practitioners suggests that appropriate training could be a key factor in CP success, and conversely, that the absence of training could be partially responsible for the current disillusionment with the use of CP during rapid sequence intubation.

Simulation training using synthetic models or anatomical manikins improves patient safety and increases learner competence.[7] Systematic reviews show that technology-enhanced simulation in comparison with no training provides consistent benefits for learning patient-related outcomes among healthcare professionals.[8 9] Original studies on technology-enhanced CP simulation showed marked improvement in application of correct force, and simple training programmes over a short period of time can improve retention of correct CP application among a majority of participants.[10 11] However, we were unable to find a previous systematic synthesis of evidence on simulation-based training for application of CP. This systematic review aims to

critically examine the intervention of CP training/simulation compared with no intervention for CP training among healthcare providers. If technology-enhanced simulation training improves CP application, current judgements regarding the effectiveness and safety of CP application may need to be reconsidered. Armed with this information, anaesthesiologists could better determine the usefulness of CP application during airway management.

Methods

This study is a protocol-driven systematic review addressing the intervention technology-enhanced simulation of CP for training healthcare providers. The study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[12] The general methods were described previously;[8] and this study's specific methods are briefly summarized below.

Questions

This systematic review sought the answer to the questions: (i) is CP application improved with simulation training in comparison with no training? (ii) How is learning retained after CP simulation training?

Eligibility criteria

Eligible studies were original comparative studies, randomized or observational, published in any language that investigated the use of technology-enhanced simulation to teach CP application to healthcare providers at any stage in training or practice, in comparison with no intervention or an active simulation-based (e.g. application of CP on high-fidelity manikin) or non-simulation training activity (e.g. reading an article on the topic of CP). We followed previously defined criteria for technology-enhanced simulation.[8] Included studies specifically assessed learning of CP application as an outcome.

Study identification

An electronic search strategy specialist with expertise in conducting systematic reviews and content expert investigators conducted an electronic search through Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, PsychINFO, ERIC, Thompson Reuters Web of Science, and Scopus. The full search strategy had been published elsewhere.[8] The last date of the search was May 11, 2011. This search was extended with an updated focused MEDLINE search in June 2012 using the search terms (cricoid pressure OR Sellick) AND ('simulation' OR simulate OR 'education' OR 'training'). This updated search yielded 100 articles of which nine were unique (i.e. were not identified in the original search). Additional studies were identified by review of the reference sections of all eligible studies and solicitation from content experts.

Inclusion was determined based on independent review of each of the identified articles by two study investigators. Eligibility of potential candidate studies (as determined by either reviewer) underwent full text review by the two reviewers working independently and in duplicate. The reviewers calibrated their judgements. Disagreements were harmonized by consensus.

Data collection

Reviewers working independently and using validated collection forms[8] extracted all data from the full text versions of eligible studies. Study characteristics included author, publication year, sample size, study population (age), training level of learners, clinical topic, training location (simulation centre or clinical environment), and outcomes. Additionally, several features of effective simulation were also coded. These features include feedback, use of repetition and multiple learning strategies, time spent learning, curricular integration, and the timing of outcome assessment (less than or greater than 1 month after training). Also, reviewers performed focused abstraction of selected additional information on training characteristics unique to CP simulation.

Study quality was independently assessed by two reviewers using the Medical Education Research Study Quality Instrument (MERSQI)[13] and an adaptation of the Newcastle-Ottawa scale (NOS) for cohort studies.[14]

Statistical analysis

SAS 9.1 (SAS Institute, Cary, NC, USA) software was used for all analyses. Statistical significance was defined by two-sided alpha of 0.05, and interpretations of clinical significance emphasized confidence intervals (CIs) in relation to Cohen's effect size (ES) classifications ($>$0.8=large, 0.5–0.8=moderate).[15]

Studies were grouped according to comparison (no-intervention, non-simulation-comparison, or simulation-comparison). We planned a priori to quantitatively pool, using meta-analysis, results whenever three or more studies evaluated a common comparison. We also planned a priori subgroup analyses based on study design (randomized vs non-randomized) and selected instructional design features (multiple vs few learning strategies, and the presence or absence of human standardized patient). A priori sensitivity analyses excluded studies with imprecise ES estimation, namely estimates using P-value upper limits or imputed standard deviations.

Heterogeneity (across-study inconsistency) was quantified using the I^2 statistic, which estimates the percentage of variability across studies not because of chance.[16][17] I^2 values $<$25% indicate low heterogeneity and values $>$50% indicate high heterogeneity. Random-effects models were used to pool weighted ESs when large inconsistency was discovered.

Additional qualitative synthesis was conducted on studies excluded from meta-analyses including descriptions of learners, the simulations studied, baseline skill level of participants and the outcomes of those studies.

Results

Trial flow

Our search yielded 10 912 articles from which we identified 988 comparative studies of simulation-based training. After screening, we found 12 studies[4][10][11][18–26] of

simulation-based training for application of CP (Fig. 1) enrolling a total of 772 trainees.

Study characteristics

Tables 1 and 2 summarize study features. Included studies date from 1986 to 2007. One article[26] was published in Japanese. Most trainees were nurses or nursing students (*n*=296) or physicians in practice (*n*=98).

Each study reported one or more skills outcomes (i.e. a measure of performance in a simulated setting) such as the amount of cricoid force applied relative to a target, or the ability to maintain force within a desired range for a certain amount of time. We coded one such outcome per study. Only one study[19] assessed outcomes on a living human, by testing the performance of CP on an anesthetized patient in an operating theatre after CP training; otherwise, included studies assessed outcomes in a simulation environment. No study evaluated the application of CP during rapid sequence induction in either a simulation or clinical care environment.

Four studies[10 11 20 21] trained participants at two target levels of cricoid force, simulating CP application in awake *vs* anesthetized patients. Four of the 12 studies used a commercial model such as an anatomical manikin.[11 19 24 25] The other eight studies used investigator-made CP trainers calibrated by the use of weighted scales,[4 18 23 26] volume displacement,[20 22] or pressure transduction.[10 21 22] Three studies using anatomical manikins evaluated for correct anatomical placement of CP.[19 24 25] Two studies using investigator-made CP trainers used a one-handed CP application technique modelled after the original Sellick description of CP application.[10 23]

Study quality

Table 3 summarizes study quality. The number of enrolled participants ranged from 30 to 135 with a median of 51.5 (interquartile range 38–86). Two studies were randomized.[19 22] One study reported data on <75% of enrolled participants and did not describe those lost to the follow-up.[10] All outcomes were objectively determined (using a variety of dynamometers),

Fig 1 Trial flow.

Potentially relevant studies identified and screened for retrieval (*n*=10 912)
- 10 297 from initial database search
- 606 from article reference lists and journal tables of contents
- 9 from updated database search

Studies excluded, with reasons (*n*=8324)
- Not original research (1314)
- Did not use technology-enhanced simulation (5343)
- No health professions learners (488)
- No comparison group or time point (1179)

Studies retrieved for more detailed evaluation (*n*=2588)

Studies excluded, with reasons (*n*=1600)
- Not original research (150)
- Did not use technology-enhanced simulation (486)
- No health professions learners (98)
- No comparison (866)

Studies potentially appropriate for inclusion in the review (*n*=988)

Studies excluded, with reasons (*n*=976)
- Duplicate reports of previously published data (11)
- Same intervention, different outcomes (3)
- Insufficient data to extract effect size (4)
- No relevant outcomes (13)
- No training for cricoid pressure (945)

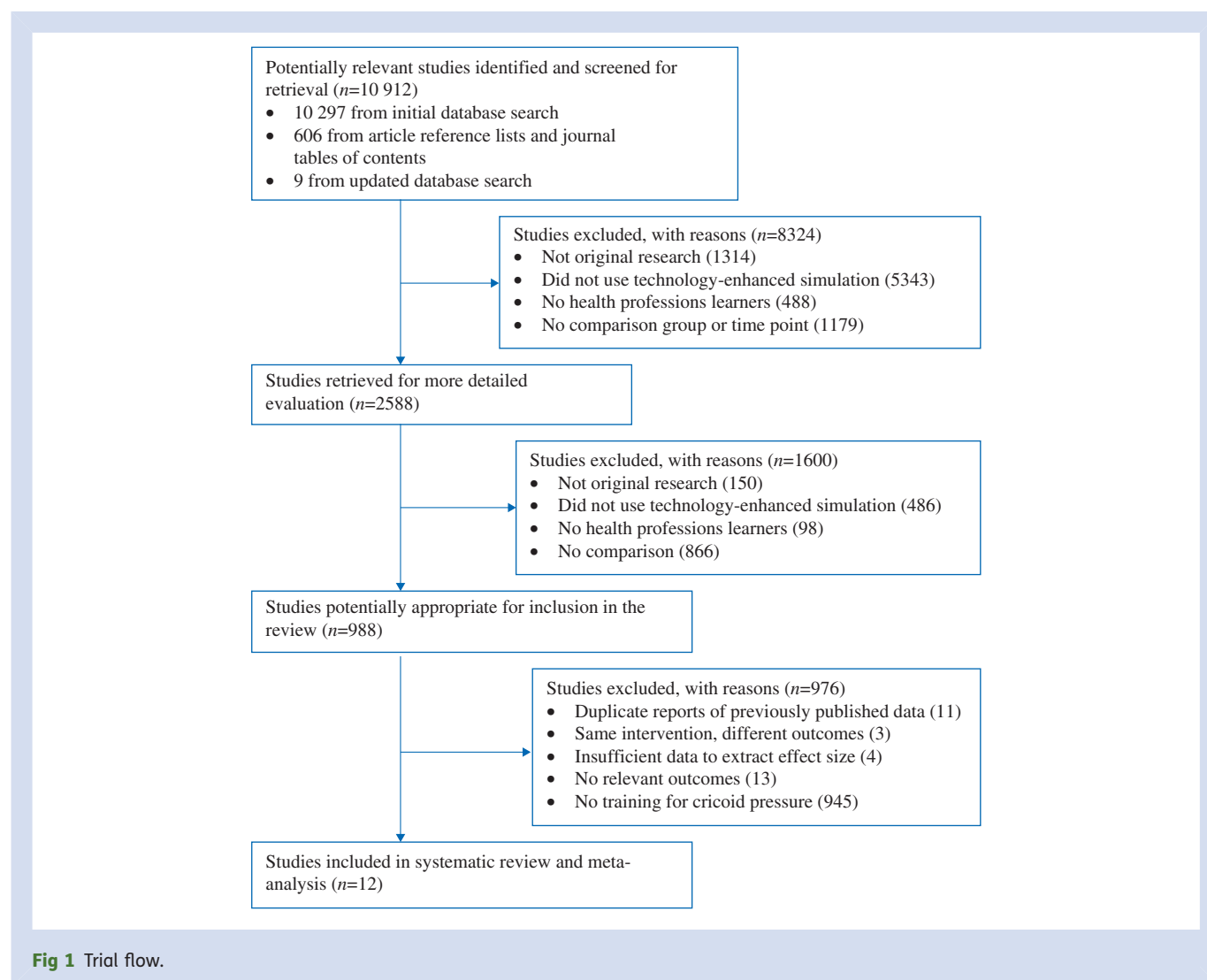Studies included in systematic review and meta-analysis (*n*=12)

Table 1 Detailed information on study features. *Training: MS, medical student; PG, postgraduate physician trainee; MD, practicing physician; RN, nurse or nursing student; EMT, emergency medical technician/paramedic/first responder or EMT student; D, dentist or dental student; V, veterinarian or veterinary student; C, chiropractor or student; O, other/mixed. †Design: NR, non-randomized; RCT, randomized controlled trial. ‡Force instruction: N, Newton; kg, kilogram. §CP trainer type: investigator-made (e.g. weighted scale, pressure transducer, or syringe), manufactured. ‖Comparison: NI, no intervention; OE, other education; SS, different training methods of simulation (simulation vs simulation). ¶MERSQI, Medical Education Research Study Quality Instrument total score (18 points maximum). #NOS, Newcastle-Ottawa scale for cohort studies (6 points maximum)

Author (year)	Participants; training*	Design†	Force instruction‡	CP trainer type§	Comparison‖	Follow-up for CP skill retention	MERSQI (18 points max)¶	NOS (6 points max)#
Ashurst and colleagues (1996)[10]	49 MD, RN	1 group, NR	20 N 40 N	Investigator-made	NI	14–21 days	11	0
Herman and colleagues (1996)[11]	53 MS, PG, MD, RN, O	1 group, NR	20 N (2 kg) 30–40 N (4.1 kg)	Commercial with author modification	NI	3 months	12	1
Meek and colleagues (1999)[4]	135 O	1 group, NR	40 N (4 kg)	Investigator-made	NI	No follow-up	12	1
Flucker and colleagues (2000)[20]	30 MD, RN, O	1 group, NR	20 N 40 N	Investigator-made	NI	1 week 1 month	11	1
Clayton and colleagues (2002)[18]	40 RN, O	1 group, NR	30 N (3 kg)	Investigator-made	NI	No follow-up	12	1
Owen and colleagues (2002)[24]	50 PG, RN, EMT	1 group, NR	30 N	Commercial with author modification	NI	No follow-up	13	1
Kopka and colleagues (2004)[21]	36 RN, O	1 group, NR	10 N (1.02 kg) 30 N (3.06 kg)	Investigator-made	NI	No follow-up	12	1
Kopka and colleagues (2005)[22]	64 O	RCT	30 N	Investigator-made	NI	No follow-up	13.5	4
Shimabukuro and colleagues (2006)[26]	34 PG, MD, RN	1 group, NR	30 N (3.03 kg)	Investigator-made	NI	1 month	9	1
May and colleagues (2007)[23]	110 MD, RN	2 group, NR	30–40 N (3.06–4.075 kg)	Investigator-made	NI	No follow-up	11.5	2
Quigley and colleagues (2007)[25]	70 MD, RN	2 group, NR	25–35 N	Commercial	OE	4–6 weeks	11.5	3
Domuracki and colleagues (2009)[19]	101 MS, RN, RN	RCT	20–30 N	Commercial	SS	No follow-up	13.5	5

Table 2 Characteristics of included studies. *Numbers reflect the number of participants enrolled. †The number of studies and trainees in some subgroups (summing across rows or columns) may sum to more than the number for all studies because several studies included >1 comparison arm, >1 trainee group, fit within >1 clinical topic, or reported multiple outcomes. ‡Number of participants given only for entire sample, not separated by role; participants counted under 'other/ambiguous/mixed'

Study characteristic	Level	Number of studies (number of participants*)
All studies		12 (767)
Study design	Two groups	3 (235)
	One groups (pretest-posttest)	9 (532)
Group allocation	Randomized	2 (165)
Comparison	No intervention	10 (596)
	Non-simulation training comparison	1 (70)
	Alternate simulation training comparison	1 (101)
Participants†	Medical students	2 (3)
	Physicians in postgraduate training	3 (22)
	Physicians in practice	6 (98)
	Nurses in practice	10 (296)
	Other/ambiguous/mixed‡	9 (348)
Quality	Newcastle-Ottawa≥4 points	2 (165)
	MERSQI≥12 points	7 (479)

but none were blinded. The mean (SD) MERSQI (maximum 18 points), and NOS (maximum 6 points) study quality scores were 11.8 (1.2) and 1.8 (1.5), respectively.

Baseline skill

Nine studies reported information on baseline skill.[4 10 11 18 20 21 23 24 26] Eight of these reported the percentage of providers who could apply CP at a target force level.[4 10 18 20 21 23 24 26] The number of providers able to achieve this target ranged from 8 to 41%, with a weighted average of 23%. Three studies[10 11 20] reported the average force applied by CP application before training with participants achieving forces other than the desirable target forces before CP training [31.4 N (target 40 N),[10] 16.2 N (target 20 N),[11] 23.8 N (target 20 N)[20]]. There was wide variation in the baseline CP force applied among individuals in each study.

Meta-analysis: effectiveness in comparison with no training

Ten studies[4 10 11 18 20–24 26] (570 trainees) compared simulation-based training with no intervention and were included in the meta-analysis. ESs ranged from 0.63 to 2.88 (Fig. 2). The pooled ES was 1.18 (95% CI, 0.85–1.51;

$P<0.0001$). According to Cohen's classification, this indicates a large favourable impact on skills.[15] Although between-study inconsistency was high ($I^2=87\%$), all individual ESs favoured the simulation intervention—indicating that studies varied in the magnitude, but not the direction of benefit. There were no significant differences between studies for the type of trainer model (commercial *vs* investigator-made) used for CP training [pooled ES 1.31 (95% CI, 0.35–2.27) *vs* 1.12 (0.77–1.48); $P_{interaction}=0.72$]. The funnel plot was visually asymmetric. Assuming this suggests publication bias, trim-and-fill analyses revealed a revised ES of 1.04 (95% CI, 0.75–1.32).

Comparative effectiveness: simulation compared with non-simulation instruction

Two studies made comparisons with another active form of instruction (i.e. comparative effectiveness research).[19 25] Both studies reported significant between-group differences immediately after training using force feedback CP simulators. Quigley and Jeffrey[25] reported a non-randomized study showing simulation-based CP training with feedback was superior (88% of subjects achieving correct CP in the simulator) compared with reading from a journal article (33% achieved correct CP). Domuracki and colleagues[19] reported a randomized trial in which CP simulation-based training with force feedback was significantly more effective than similar training without feedback when applying CP to anaesthetized patients (38% achieving target CP *vs* 19%, respectively).

Skill retention

Retention of CP skill was assessed in five studies.[10 11 20 25 26] The shortest CP skill retention reported was 1 week after training[18] and the longest follow-up for retention of CP application was 3 months.[11] Quigley and Jeffrey[25] reported that between-group differences (training with feedback on applied pressure *vs* training without feedback) present immediately after CP training were no longer evident when participants were followed up 4–6 weeks later.

Discussion

This systematic review and meta-analysis concludes that simulation training compared with no intervention significantly improves the application of CP by healthcare providers. Furthermore, limited evidence suggests that simulation-based training using feedback enhances correct CP application compared with either reading about the technique (self-regulated learning) or standard verbal instruction (instructor-regulated). However, the preferred approach including force to be applied, CP training model to use, and instructional design remain unknown.

Among the included studies reporting baseline skill, fewer than one-fourth of participants were able to apply CP force within the target range before training (using previously established targets[27–31]). Furthermore, Shimabukuro and colleagues[26] stated that CP application was confused by some participants with the Backwards Upwards Rightwards

Table 3 Quality of included studies. *Mean (SD) MERSQI score was 11.8 (1.2); median (range) was 12 (9–13.5). †Mean (SD) Newcastle-Ottawa scale score was 1.8 (1.5); median (range) was 1 (0–5). ‡Comparability of cohorts criterion A was present if the study (i) was randomized, or (ii) controlled for a baseline learning outcome; criterion B was present if (i) a randomized study concealed allocation, or (ii) an observational study controlled for another baseline trainee characteristic

Scale item	Subscale (points if present)	Number (%) present; $n=12$
MERSQI*		
Study design (maximum 3)	1-group pre–post (1.5)	9 (75)
	Observational 2-group (2)	1 (8)
	Randomized 2-group (3)	2 (17)
Sampling: number of institutions (maximum 1.5)	1 (0.5)	10 (83)
	2 (1)	1 (8)
	>2 (1.5)	1 (8)
Sampling: follow-up (maximum 1.5)	<50% or not reported (0.5)	1 (8)
	50–74% (1)	0
	≥75% (1.5)	11 (92)
Type of data: Outcome assessment (maximum 3)	Subjective (1)	0
	Objective (3)	12 (100)
Validity evidence (maximum 3)	Content (1)	7 (58)
	Internal structure (1)	0
	Relations to other variables (1)	1 (8)
Data analysis: appropriate (maximum 1)	Appropriate (1)	11 (92)
Data analysis: sophistication (maximum 2)	Descriptive (1)	1 (8)
	Beyond descriptive analysis (2)	11 (92)
Highest outcome type (maximum 3)	Reaction (satisfaction) (1)	0
	Knowledge, skills (1.5)	12 (100)
	Behaviors (2)	0
	Patient/healthcare outcomes (3)	0
Newcastle-Ottawa scale (modified)†		
Representativeness of sample	Present (1)	2 (17)
Comparison group from same community	Present (1)	3 (25)
Comparability of comparison cohort, criterion A‡	Present (1)	2 (17)
Comparability of comparison cohort, criterion B‡	Present (1)	2 (17)
Blinded outcome assessment	Present (1)	0
Follow-up high or those lost described	Present (1)	11 (92)

Pressure (BURP), a manoeuvre used for difficult intubation, before CP feedback training. Although limited, the available evidence we present suggests that most untrained healthcare providers do not achieve optimal CP application.

CP training with feedback was effective for CP application whether performed using realistic anatomical manikins (typically commercial products) made to look and feel like a trachea, or investigator-made CP trainers that purely served as dynamometers. Given the similar effectiveness for commercial and investigator-made training models found in this systematic review, it appears that CP training is effective regardless of the degree of similarity with which the model mimics the physical appearance of the human body. Recent recommendations have urged the standardization of CP application using a three-finger technique not unlike the original depiction of the Sellick manoeuvre.[32] We echo that future research should include standardized study methodology with consistent CP position, direction, and force application.

Unfortunately, skill performance fades over time. Ashurst and colleagues[10] report that CP force application was retained in an acceptable range by most subjects after 14–21 days, but Quigley and Jeffrey[25] reported that CP skills mastered by participants after initial CP training were not sustained at 4–6 weeks. Available evidence does little to guide the structure, content, or a time line for 'refresher' training for CP application. Not unlike the call for further research on refresher training for ACLS, future studies of CP training could better define the rate at which CP skills deteriorate, and identify best practices to prevent such deterioration.[33]

Limitations and strengths

This review is limited primarily by the number, methodologies, and quality of the included studies, a limitation common to all systematic reviews. Only one study assessed outcomes on living humans,[19] and this was in a controlled
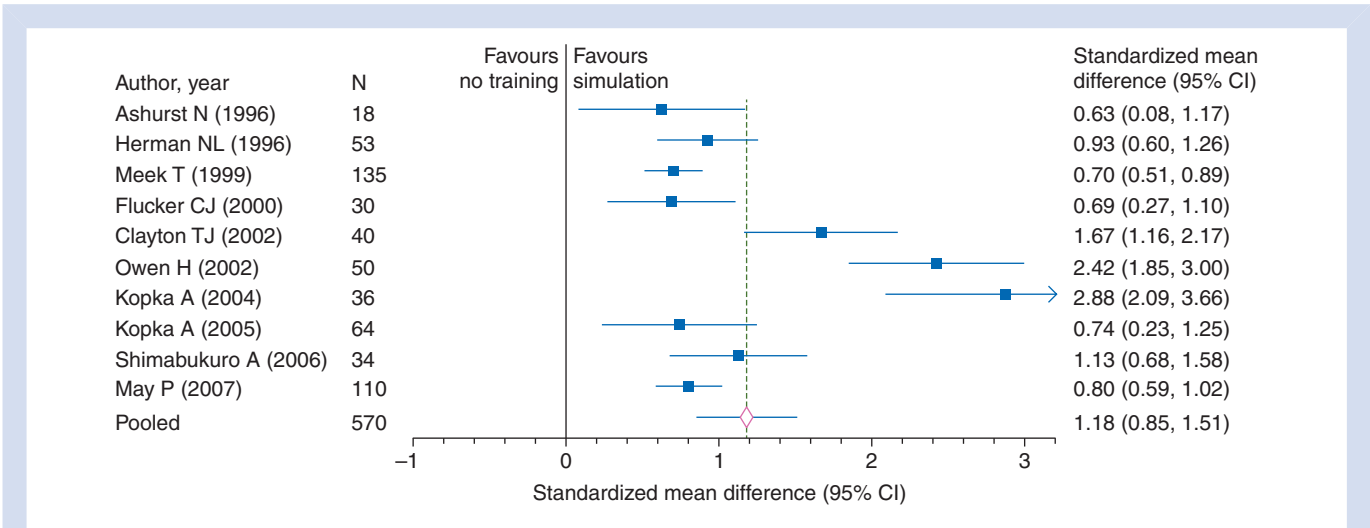
Author, year	N		Standardized mean difference (95% CI)
Ashurst N (1996)	18		0.63 (0.08, 1.17)
Herman NL (1996)	53		0.93 (0.60, 1.26)
Meek T (1999)	135		0.70 (0.51, 0.89)
Flucker CJ (2000)	30		0.69 (0.27, 1.10)
Clayton TJ (2002)	40		1.67 (1.16, 2.17)
Owen H (2002)	50		2.42 (1.85, 3.00)
Kopka A (2004)	36		2.88 (2.09, 3.66)
Kopka A (2005)	64		0.74 (0.23, 1.25)
Shimabukuro A (2006)	34		1.13 (0.68, 1.58)
May P (2007)	110		0.80 (0.59, 1.02)
Pooled	570		1.18 (0.85, 1.51)

Fig 2 Random-effects meta-analysis of studies comparing CP training with no intervention. Simulation compared with no intervention; positive numbers favour the simulation intervention. Boxes represent the standardized mean difference and bars represent the 95% CI. The solid vertical line represents no effect and the dashed vertical line indicates the pooled effect across all studies as calculated using a random-effects model.

Table 4 Considerations for future studies of simulation-based medical education of CP application according to stages of translational science research[7 40]

	T1—studies examining critical factors in the simulation environment	T2—studies examining impact on patient care practices	T3—studies examining impact on the health of individuals and society
Questions	What instructional design features (e.g. feedback, repetition, distributed practice, clinical variation, and mastery learning) will optimize skill acquisition and maintenance?	How does CP training affect provider behaviors during patient care (ideal CP position, technique, and force application)? How can CP be coordinated among members of the anaesthesia team? What is the ideal time and for how long should CP be applied (e.g. relative to administration of induction agents, placement of airway device or both)?	How does CP training affect patient care outcomes? What is the cost of CP training (e.g. equipment, loss of productivity of personnel)?
Outcomes	Assess skill on simulator different than that used for training Assess skill on simulator after time delay	Assess CP performance using observation rating scale Assess CP pressure using transducer between provider and patient Assess team performance during standard and difficult or prolonged airway management	Successful intubation Adverse events prevented by CP (e.g. aspiration) Adverse events precipitated by CP (e.g. regurgitation of gastric contents, oesophageal damage) Cost of training

setting (not actual patient care). Few studies used a separate comparison group. Additionally, our review found high inconsistency (heterogeneity) across studies ($I^2 > 80\%$). Although all studies demonstrated beneficial effects to technology-enhanced training for CP application, there was insufficient information to determine whether some techniques may be more effective than others. Only two studies reported comparative effectiveness research for CP training (e.g. comparison with active intervention), and of these only Domuracki and colleagues[19] compared different approaches to CP training. Also, there were no studies that provided direct comparisons of different training models.

Finally, we emphasize that our review focuses on training in a specific technique and using predetermined standards, rather than evaluating the appropriate use of CP application in clinical practice or the correctness of proposed standards.

This was a comprehensive systematic review following rigorous methodology. Strengths include: (i) an exhaustive literature review, (ii) studies encompassing a broad range of learners, study designs, and outcomes, and (iii) quality assessments of included studies using validated scales. Additionally, this protocol-driven study used duplicate and independent data extraction with highly reproducible coding.

Comparison with previous literature

There are no previous systematic reviews of technology-enhanced simulation for CP training. A recent broad narrative review on simulation training in anaesthesia called for research on approaches in both training and assessment of common modalities used in anaesthesia.[34] Although CP application was not among the common modalities listed, the information provided within our systematic review and meta-analysis responds to this request and provides increased understanding of the role of training for CP application. Additionally, our review is aligned with a recent systematic review showing benefit to technology-enhanced simulation for training healthcare professionals generally.[8] As simulation-based CP training is effective, we tentatively propose that all providers receive training before using CP in clinical practice.

Implications

Current expert opinion on the clinical utility of CP is polarized.[35–37] The perceived low-risk nature of the CP procedure and the high-risk nature of an aspiration event have contributed to the lasting use of CP in clinical practice. However, many airway experts and healthcare provider instructional programmes no longer advocate the routine use of CP. Indeed, the updated training guidelines for Advanced Cardiac Life Support (ACLS) in 2010 state 'the routine use of cricoid pressure in cardiac arrest is not recommended'.[38] It is possible that the rationale for not advocating the use of CP during resuscitation was in part the result of ineffective application, and to that extent we agree with those guidelines. Our review indicates that baseline skill is low for CP, and supports the suggestion that untrained practitioners should avoid this procedure. Yet, we wonder if CP in clinical practice might show improved patient outcomes if applied by well-trained practitioners.

We know little about specific instructional design features that might enhance training. Other than feedback, no specific strategies were explored in the studies identified in our review. Instructional design features such as clinical variation, distributed practice, and mastery learning may be helpful in improving the speed and degree of initial CP skill attainment and maintenance of skills so obtained.[33 39] A better understanding of skill decay, and how to prevent such deterioration, would also be helpful as well. Future studies aimed at addressing these questions would contribute substantially to the field.

CP training need not be costly, and in fact some inexpensive investigator-made models appear (within the limitations of the between-study comparisons) to be equally effective as commercial products. However, it will be helpful to conduct direct comparisons of different models and different instructional approaches to identify educational best practices for training CP application. Ultimately, CP trainers should be easy to use, inexpensive, and readily available for immediate skill training and periodic refreshing before CP use.

For all of the above-mentioned research themes, assessment of study outcomes on live humans (either skills with humans in which CP is not indicated, or behaviours in actual patient care) will be essential. A translational science research programme such as that used by McGaghie and colleagues[7] may help address critical aspects of CP application during simulation and the role of technology-enhanced simulation training for CP in improving patient outcomes in a cost-effective manner (Table 4). In this regard, the impact (T2 and T3) of technology-enhanced simulation training may be more difficult to evaluate in the context of CP application given the rare occurrence of severe adverse events directly attributable to CP misapplication. However, CP application is inexpensive and may be shown to be of low risk when performed correctly. Based on the results of this systematic review, anesthesiologists might consider revisiting the use of CP by expertly-trained individuals, particularly in those patients at highest risk of aspiration.

In conclusion, technology-enhanced simulation training significantly improves the application of CP. Additionally, it appears that feedback provided by training models is essential for learning correct force CP application. Following a single training session, it seems that correct skill for CP application will be retained for a limited time (<4 weeks).

Acknowledgements

Declaration of interest

None declared.

Funding

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Handling editor: R. P. Mahajan