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Review

The use of cognitive aids in the operating room: a systematic review

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Abstract

Background: **Cognitive aids (CAs) are clinical tools guiding clinical decision-making during critical events in the operating room. They may counteract the adverse effects of stress on the non-technical skills of the attending clinician(s). Although most clinicians acknowledge the importance of CAs, their uptake in clinical practice seems to be lagging behind. This situation has led us to investigate which features of CAs may enhance their uptake. Therefore, in this systematic review we explored the optimums regarding the 1) timing to consult the CA, 2) person consulting the CA, 3) location of the CA in the operating room, 4) CA design (paper vs. electronic), 5) CA lay-out, 6) reader of the CA and 7) if the use of CAs in the form of decision support tools lead to improved outcome.**

Methods: **Seven PICO-questions guided our literature search in 4 biomedical databases (MEDLINE, Embase, Web of Science and Google Scholar). We selected English-language randomized controlled trials (RCTs), observational studies and expert opinions discussing the use of cognitive aids during life-threatening events in the operating theatre. Articles discussing non-urgent or non-operating room settings were excluded. The quality of evidence was evaluated with the Grading of Recommendations Assessment, Development and Evaluation (GRADE).**

Results: **We found 7 RCTs, 14 observational studies and 6 expert opinions. All trials were conducted in a simulation environment. The person who should trigger the use of a cognitive aid and the optimal timing of its initiation, could not be defined by the current literature. The ideal location of the cognitive aids remains also unclear.**

A favorable lay-out of an aid should be well-structured, standardized and easily readable. In addition, several potentially beneficial design features are described.

RCT's could not demonstrate a possible superiority of either electronic or paper-based aids. Both have their advantages and disadvantages. Furthermore, electronic decision support tools are potentially associated with an enhanced performance of the clinician. Likewise, the presence of a reader was associated with an improved performance of key steps in the management of a critical event. However, it remains unclear who should fulfill this role.

Conclusion: **Several features of the design or utilization of CAs may play a role in enhancing the uptake of CAs in clinical practice during the management of a critical event in the operating room. However, robust evidence supporting the use of a certain feature over another is lacking.**

Keywords: **Perioperative Care, Operating Room, Decision Support Techniques.**

Introduction

When anesthesiologists deal with life-threatening critical events in the operating room, stress may significantly impair their memory retrieval, decision-making and situational awareness. This potentially results in delays in treatment and occurrence of medical errors[1-5]. Cognitive aids or emergency manuals are clinical tools that guide clinical decision-making by providing evidence-based key steps in treatment. Examples of such cognitive aids are illustrated in the articles of Burden

et al.[3] and Goldhaber-Fiebert et al[7]. In multiple studies in simulation-environments, their use was associated with fewer medical errors, improved team-communication and a reduction in the time to complete essential tasks[1,2,6-8]. The majority of clinicians also seems to be willing to use cognitive aids in daily practice. Furthermore, a conceptual framework[7] exists that enables effective clinical implementation of cognitive aids and consists of 4 key elements: 'create', 'familiarize', 'use clinically' and 'integrate'[2,6,7]. Nevertheless, in many operating theatres, their uptake into clinical practice seems to be lagging behind[2,6]. This conflicting situation raises the question how the implementation and use of cognitive aids in the operating room could be improved[9]. In particular, it is still unclear: 1) by whom the use of cognitive aids should be initiated; 2) when the use of cognitive aids should be triggered; 3) which is the best location for them in the operating room; 4) how they should best be designed; 5) whether paper-based or electronical-based cognitive aids are better; 6) if they should serve as a dynamic decision support tool; and 7) if a 'reader' is beneficial[7,9]. These questions are also reflected in the key elements of the prior-mentioned conceptual framework[7]. Therefore, the purpose of this systematic review is to clarify these uncertainties.

Methods

This systematic review was not prospectively registered, but was carried out according to the '24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research', as described by Muka et al[10]. We report the systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-checklist (Appendix 1)[11].

Search strategy

We recapitulated our uncertainties in several 'PICO' (Problem/ Intervention/ Comparison/ Outcome) questions (Appendix 2) which guided our literature search in four biomedical databases: MEDLINE, Embase, Web of Science and Google Scholar. The search terms that were used, comprised a combination of "cognitive aid", "emergency manual", "perioperative care", "operating room", "anesthesia" and "implementation science". Detailed search strategies are reported in Table I. Additionally, the reference lists of the included articles were manually screened for publications that could also meet the eligibility criteria.

Eligibility criteria

Because of the apprehension that not many RCTs would have studied our PICO questions, we did not limit our inclusion to randomized controlled trials (RCT), but decided to also include observational studies, as well as expert opinions discussing the use of cognitive aids in life-threatening events in a clinical or simulated operating theatre, written in English and published between January 1st 2010 and June 1st 2020. Articles investigating the use of cognitive aids in non-life-threatening situations and non-operating room settings (e.g. the emergency department) were excluded.

Quality assessment

The certainty of the evidence was assessed using the GRADE (Grading of Recommendations, Assessment, Development, and Evaluation) methodology[12-14].

The certainty of the evidence for each outcome was graded as 'high', 'moderate', 'low' or 'very low'.

When using GRADE, randomised controlled trials and observational studies by default receive the grade of 'high' and 'low', respectively. Potential downgrading can occur and is based on 5 factors:

Table I. — Search strategies.

Search strategies	
MEDLINE	((cognitive aid) OR (emergency manual)) AND (perioperative care) (MeSH term), ((cognitive aid) OR (emergency manual)) AND (operating room) (MeSH term), ((cognitive aid) OR (emergency manual)) AND (anesthesia) (MeSH term) and ((cognitive aid) OR (emergency manual)) AND (implementation science)
Embase	('cognitive aid' OR 'emergency manual') AND 'perioperative care', ('cognitive aid' OR 'emergency manual') AND 'operating room', ('cognitive aid' OR 'emergency manual') AND 'anesthesia' and ('cognitive aid' OR 'emergency manual') AND 'implementation science'
Web of Science	TOPIC: (cognitive aid) OR TOPIC: (emergency manual) AND TOPIC: (perioperative care), TOPIC: (cognitive aid) OR TOPIC: (emergency manual) AND TOPIC: (operating room), TOPIC: (cognitive aid) OR TOPIC: (emergency manual) AND TOPIC: (anesthesia), TOPIC: (cognitive aid) OR TOPIC: (emergency manual) AND TOPIC: (implementation science)
Google Scholar	cognitive aid OR emergency manual AND perioperative care, cognitive aid OR emergency manual AND operating room, cognitive aid OR emergency manual AND anesthesia and cognitive aid OR emergency manual AND implementation science.

limitations in study design (which pose risk of bias), inconsistency, indirectness, imprecision, and publication bias. Three factors may upgrade the study quality: large effect size, dose-response gradient, and plausible confounding[12-14].

The GRADEpro software (https://www.gradepro.org) was used to create evidence profiles for the outcomes of interest.

Data synthesis and analysis

Due to the qualitative nature of several investigated outcome measures and the inclusion of expert opinions, we a priori decided not to perform a quantitative meta-analysis. Instead, we aimed at conducting a systematic review.

Ethical approval

The Education-Support Committee (OBC) of the KU Leuven Biomedical Sciences Group stated that our systematic review did not require evaluation by a research ethics committee. This statement was obtained on the 12th of November 2019 and is annexed in Appendix 3.

Results

Study flow

Figure 1 depicts our selection process. Of the 1971 articles initially identified by our search, we eventually selected 70 articles for full-text review. Manual screening of the reference lists of these 70 articles yielded an extra 19 articles that were not identified in our initial search. After full-text assessment of these 89 articles, 62 articles were excluded based on eligibility criteria. Thirty-two articles contained no relevant information regarding to our research questions, 25 articles were excluded due to the study design (case reports, case series, editorials and conference abstracts) and 5 articles were excluded due to a non-emergency or a non-medical setting. Eventually, we included 27 articles in our qualitative synthesis.

Study characteristics

Tables II-VI summarize the characteristics of these 27 studies. We found 7 randomized controlled trials, 14 observational studies and 6 expert opinions. We found no studies that investigated the use of cognitive aids in clinical practice. All studies took place in a simulation environment. The quality assessment of the included studies is shown in Appendix 4. Overall, the current evidence is scattered and of 'low' to 'very low' quality.

PICO 1 – Timing of consulting the cognitive aid

Two retrospective observational studies investigated the time at which the use of a cognitive aid was triggered[16,17]. The selected articles are summarized in Table II.

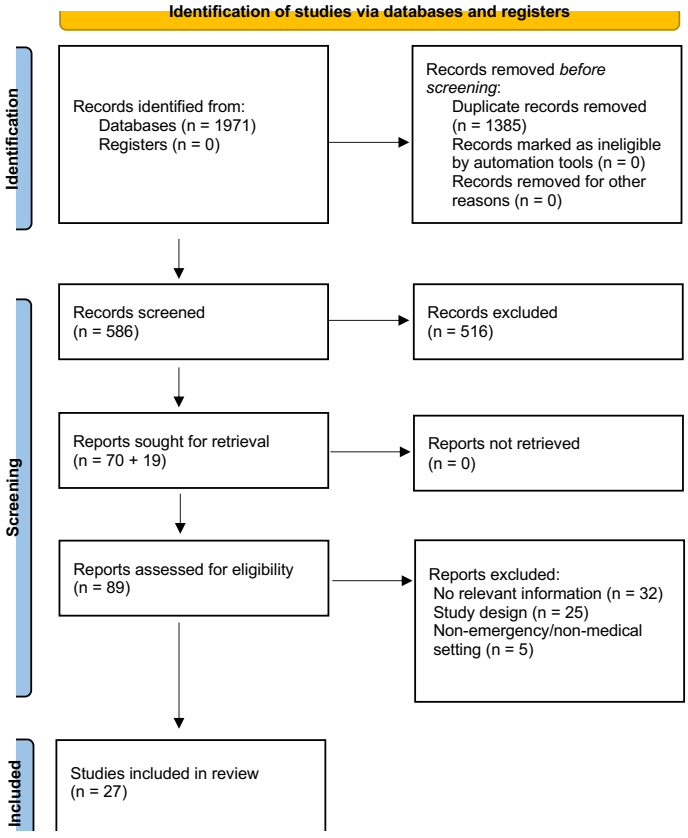

Fig. 1 — [11,15]

In both studies, there was a delay between the onset of a crisis event and the time at which the cognitive aid was used in the majority of simulated cases. Cognitive aid use was often initiated only after performance of at least one key step in treatment[16], or ascertainment of the clinical diagnosis[17]. The delay occurred more frequently in more commonly occurring crisis events, such as hypoxemia[16]. Neither of these studies investigated whether early versus late introduction of the cognitive aid affected clinical outcome.

PICO 2 – Person triggering the use of a cognitive aid

One retrospective observational study investigated who should trigger the use of a cognitive aid in a critical event[17]. The selected article is summarized in Table II.

In this study, the team leader, team members, and simulation instructors which had the role of facilitator, triggered its use in respectively 25%, 60% and 15% of cases. Whether the choice for a particular trigger person impacted clinical outcome was not investigated.

PICO 3 – Location of the cognitive aid

One RCT 2, 1 observational study[19], 2 surveys[18, 20] and 1 expert opinion 21 discussed the optimal location of the cognitive aid in the operating theatre. The selected articles are summarized in table III.

In the RCT, no statistically significant difference was found in the use of a cognitive aid between study arms where a cognitive aid was either placed in clear sight or not (clear sight: 8 of 40 encounters (20%); versus not in clear sight: 6 of 38 encounters (16%) respectively, p = 0.690)[2]. This observation contrasts the statement that "cognitive aids should be (highly) visible and easily accessible", found in the discussion of 1 survey and in 1 expert opinion[20,21]. In another survey completed by 114 anesthesiologists, the most frequently preferred location of the cognitive aid was the anesthesia station in the operating room (92.11% of participants), as compared to the code cart (7.02% of participants) and the anesthesia office (0.88%[18]. 1 observational study, 1 survey and 1 review solely emphasized the importance of a standardized and consistent location[19-21].

PICO 4 – Paper-based versus electronically-based cognitive aid design

Three RCTs[22,23,27], 1 survey[24] and 2 expert opinions[21,26] discussed whether a paper-based cognitive aid design should be preferred over an electronic design. The selected articles are summarized in Table IV.

Two RCT's demonstrated a significantly higher mean checklist performance (15.70 ± 1.93 vs 12.95 ± 2.16; P < 0.0001) and median technical skills (80 [72-84] vs 61 [55-65]; P= 0.0002) in the group randomized to the electronic design as compared to the group with a paper-based cognitive aid[22,27]. However, in another RCT, the overall performance did not significantly improve with the use of an electronically-based design, neither did it reduce the time to initiate the use of the cognitive aid[23].

In a survey, both paper-based and electronic manuals were deemed useful and beneficial[24]. One advantage of paper-based manuals is a better perceived reliability, for example: full functionality offline. Disadvantages of paper-based cognitive can be summarized as user-interface errors and its confinement by available space and size in the case of pocket-size cards[21,24,25]. Advantages of electronic (dynamic) aids include the ease of updating and customization, the 'ready to use'-facet, the feasibility of being more adapted to a specific situation (context-aware), and in the case of a decision support tool, automatic presentation of the right content at the right time. However, electronic aids may have several disadvantages, such as the necessity of communicating software, hardware and algorithms that synthesizes and presents the content of incoming data. Electronical manuals with a touchscreen can be associated with difficulties in use if the touchscreen is either not or too sensitive[24,26].

PICO 5 – Lay-out/design of the cognitive aid

Three randomized controlled trials[2,27,35], 7 observational studies[16,19,28,33,34,36,37] and 5 expert opinions[7,29,30,31,32] investigated whether particular characteristics are beneficial to the lay-out of the emergency manuals. The selected articles are summarized in Table V.

5a. General lay-out

One RCT demonstrated a significantly greater use of emergency manuals in scenarios where the cause of the critical event was known, than in scenarios where the diagnosis was not yet known (an uptake of 45% versus 2%; P < 0,01)[2]. Second, according to two observational studies and two expert opinions, the cognitive aid should have a standardized, structured and easily readable design[19,30-32]. Other favorable features include a single-page design and minimal color-blocking[37]. Third, graphics, charts and pictures can also be part of a cognitive aid. However, overcrowding the cognitive aid with abundant information should be avoided[19,30-32]. For electronic aids specifically, an intuitive approach, short navigation pathways and fully-offline functionality may be beneficial[33].

5b. Design process and redesigning

One RCT and one expert opinion highlighted the importance of redesigning the cognitive aid based on its users' feedback, in-situ testing and local customization[27,30]. In this randomized controlled trial, the participants with the electronic aid showed significantly higher median technical skills than those with the paper-based aid (80 [72-84] vs 61 [55-65]; P=0.0002). These enhanced results may be linked to the altered design of the cognitive aid. These design alterations were based on user's feedback collected in a previous trial[25,27].

5c. Linear design versus branched design versus experimental design

With regard to the structure of the cognitive aid, 3 options are mentioned in the literature: a linear design, a branched or an experimental design. One RCT and 3 case-controlled trials investigated whether a particular design resulted in an enhanced performance by the clinician or an increased use of the cognitive aid. The RCT 35 and one case-controlled trial 37 demonstrated the potential advantage of a linear design compared to a branched structure. The linear design produced the shortest answer-period and a significantly higher overall team performance and score[35,37].

On the other hand, two case-control trials[34,36], demonstrated a greater ease of use of experimental aids as compared to a linear design. Favorable design elements of experimental aids included: content organized in color-coded blocks, an identical position of those color-coded blocks on cognitive aids and emergency manuals supporting sampling behavior[34,36].

5d. Local adaptation

Two observational studies and 2 expert opinions highlighted the potential benefit of local customization. Adopting cognitive aids and adapting to local settings and standards could enhance the institutional engagement and local ownership. However, there is a risk for overcrowding the cognitive aid with too much specific information. In addition, local adaptation may lead to clerical errors[7,19,30,33].

5e. Sampling behavior

Certain features of the design of a cognitive aid may better meet the clinicians' behavior when they sample the cognitive aid for certain information. In 2 case-control studies, an experimental design was correlated with a greater ease of use and quicker identification of information when compared to a linear design. This was, at least in part, attributed to certain design features that enhanced the sampling of information[34,36]. This role of certain design features to meet the clinician's sampling behavior is supported by experts[16].

5f. Role clarity

One case-control study assessed if the use of cognitive aids with roles defined (CARD) could improve team performance. In this trial, 3 groups were compared: [no CARD], [CARD without instructions how to use CARD], and [CARD with instructions how to use CARD]. No significant difference in team performance was found between the three groups. The authors only subjectively noted an improved role recognition, improved task awareness and reduced cognitive load of the team leaders[28].

PICO 6 – Decision support systems in cognitive aids

Decision support tools are dynamic 'smart computer checklists' that can adapt their content to a specific scenario and assist the decision-making of clinicians in emergency situations. 22, 26 Two RCTs 22, 38 and 1 expert opinion 26 discussed the use of these systems as cognitive aids. The selected articles are summarized in Table V.

In both RCTs, the participants performed significantly more steps in the management of a simulated crisis event when they used an electronic decision support tool than when only relying on their memory or a paper-based emergency manual[22,38]. A near-perfect adherence to the guidelines was obtained with the decision support tool combined with a reader in one RCT[38]. Other advantages of electronic decision support tools include their ability to automatically record the steps that were taken during the management of a crisis-event, and their context-awareness, i.e. their ability to adjust their advice according to the patient's condition[38]. However, these systems require specialized hardware and software[26].

PICO 7 – The person reading the cognitive aid during a critical event

One RCT[38], 2 observational studies[3,39], 2 surveys 18, 20 and 3 expert opinions[7,21,30] discussed the role of a reader of the cognitive aid during a critical event. The selected articles are summarized inTable VI.

In 1 RCT, 1 observational study, 1 survey and 2 expert opinions, the presence of a reader was associated with an accelerated and improved performance of key steps in the management of a critical event[3,7,20,30,38]. The presence of a reader released the leader from the burden of examining the cognitive aid while being occupied with clinically important tasks in the management of the critical event. In addition, the participants expressed a higher sense of satisfaction in the debriefing[3].

However, the benefit of a reader was not consistent over all studies. In 1 prospective

observational study that investigated the effect of the presence of a reader on the time to start key steps in a critical event, no benefit of having a reader was shown[39]. Experts advise to only appoint a reader if sufficient team members are present[20,21].

If a reader would be appointed, the best person to fulfill this role remains unknown. In one survey, 58%, 24%, 11% and 7% of experienced participants, respectively, would appoint the role to the senior physician, the junior physician, the anesthesia nurse and the operating room nurse[18]. Some experts advise to appoint this role to a team member with a background in anesthesia care[38]. Other experts let this decision depend on cultural preferences, the training background and the availability of staff[21]. Whether the choice for a particular person impacts the clinical outcome, has not been investigated.

Discussion

In our systematic review, we aimed at finding an answer to the question how the implementation and use of cognitive aids in the operating room could be improved.

The optimal timing of consulting the cognitive aid could not be determined. However, two retrospective observational studies demonstrated a time delay between the onset of a crisis event and the timing at which a cognitive aid was first consulted. Therefore, it may be important to consider designing a cognitive aid in a way that facilitates delayed access of the cognitive aid into the critical event[16,17].

The best person to trigger the use of a cognitive aid also remains unknown. In a recent narrative review, Goldhaber-Fiebert et al. suggested that the first crisis team member who becomes available and is not immediately needed for manual patient care, should immediately retrieve the cognitive aid[40].

The optimal location for the cognitive aid in the operating theatre is also unclear. The literature only seems to suggest that the cognitive aid should be placed at a highly visible, accessible and standardized location[2,18-21]. Interestingly, Marshall suggests: "to remind us of the cognitive aid, we have to associate it with the risk, task or situation[41]." It may therefore be important to place the cognitive aid that addresses specific critical events in the vicinity of the place where these critical events may take place. For example, placing the cognitive aid for the treatment of local anesthetic system toxicity in room where regional anesthesia is practiced, may improve its uptake.

We found mixed results in different RCTs regarding the question whether an electronically-based design should be preferred over a paper-based cognitive aid. We did not perform a meta-analysis to summarize the results of these RCTs as the number of participants in the three different RCTs was very low[22,23,27]. Therefore, in the results section, we have summarized theoretical advantages and disadvantages of both designs.

The optimal lay-out of a cognitive aid remains to be determined. The major part of the literature that we retrieved suggested that the lay-out of a cognitive aid should be well-structured and easily readable. Therefore, graphics and charts may be part of a cognitive aid, but overcrowding the cognitive aid with too much information should be avoided. Additionally, redesigning a cognitive aid based on user-feedback, and local adaptation seem to be encouraged[41]. The latter may reinforce institutional engagement and local ownership. Currently, there is insufficient evidence to prefer an experimental design over a linear or branched design. However, the experimental design may have several benefits such as better meeting sampling behavior and may therefore be of interest for future research. In a similar way, decision support tools potentially offer important benefits due to their dynamic nature, but lack sufficient evidence to recommend them for clinical practice.

Last, the majority of the literature seems to support appointing a person that reads out loud the key steps during the management of a crisis[40]. Which person that should fulfill this role is still unclear but it may seem advantageous to appoint this role to a person with a background in anesthesia care.

Our results may have shed some light on several ways to improve the implementation and use of a cognitive in aid in the operating room. We highlighted several important aspects at the level of the design and use of the cognitive aid. However, we should not forget that effective implementation of a cognitive aid depends on more than its practical use. Effective implementation at an organizational level also encompasses other essential elements such as advocacy by local champions, leadership buy-in, customization to local standards and protocols, an interprofessional implementation team, training and culture change[7,30,40,41].

A conceptual framework literature to guide the complex clinical implementation of these cognitive aids has been described. It consists of 4 main elements that overlap and interact with each other: 1) create an emergency manual or adapt one that already exists, 2) familiarize clinicians with the emergency manual, 3) ensure that the cognitive aids can be clinically used, for example by local adaptation, and 4) implement the emergency

manual into the local professional practice by educating the caregivers on the use of cognitive aids[7,41].

Educating clinical care personnel on the use of cognitive aids has several goals: 1) to get clinicians acquainted with their existence, their content, their design and lay-out, 2) informing the clinicians about their purpose and intended use, and 3) to inform clinicians about their limitations. Additionally, during educational sessions, concerns about the use of the cognitive aid as well as obstacles that prevent them from being used may be addressed. Last, it may also be essential to train the use of a cognitive aid in a simulation setting[7,41,42].

Unfortunately, our conclusions are severely limited by the lack of robust evidence in the literature that we found. First, this could be the result of the small sample sized RCT's and observational studies we found in the literature. By including expert opinions in our eligibility criteria, an attempt was made to find some answer to our research question, but this answer should be interpreted with extreme caution due to the very low quality of evidence.

Second, our limited conclusions may partially be attributed to the limitations in our search strategy. Bias could manifest as screening, selection and data extraction was not done in duplicate. Furthermore, we had predefined time and language restrictions.

Third, several blind spots were identified that may limit the extrapolation of our finding to the clinical practice. All of the studies that we retrieved through our literature search were conducted in a simulation environment. Studies that investigate how the implementation may be improved in a real-life operating room are unfortunately lacking. In addition, the majority of the included subjects were trainees, rather than experienced anesthesiologists which in clinical practice are the main people who deal with life-threatening situations.

Finally, we did not address the question if the amount of cognitive aids that are available in the operating room may impact their uptake. While not having a cognitive aid available in the operating room will obviously not help in its implementation, the availability of too many cognitive aids may also impair their uptake.

Additionally, we could ask ourselves: 'Are there certain circumstances that could benefit more from the use of cognitive aids?'

Conclusion

We attempted to answer the question how to the implementation and use of cognitive aids in the operating room could be improved. However, our answer was severely limited by the lack of robust evidence. Therefore, this systematic review highlights the need for further research.

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References

1. Groombridge CJ, Kim Y, Maini A, Smit DV, Fitzgerald MK. Stress and decision-making in resuscitation: A systematic review. Resuscitation 2019, 144: 115-122.
2. Siddiqui A, Ng E, Burrows C, McLuckie D, Everett T. Impact of Critical Event Checklists on Anaesthetist Performance in Simulated Operating Theatre Emergencies. Cureus [online serial] 2019, 11: e4376. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6553673/pdf/cureus-0011-00000004376.pdf [accessed 10 September 2020].
3. Burden AR, Carr ZJ, Staman GW, Littman JJ, Torjman MC. Does Every Code Need a "Reader?" Improvement of Rare Event Management With a Cognitive Aid "Reader" During a Simulated Emergency. Simul Healthc 2012, 7: 1-9.
4. Koers L, Eveleens FM, Schlack WS, et al. Cognitieve leidraad voor noodgevallen op de OK. Ned Tijdsch voor Geneeskd [online serial] 2015, 159: A8325. https://www.ntvg.nl/system/files/publications/a8325.pdf [accessed 10 September 2020].
5. Alidina S, Goldhaber-Fiebert SN, Hannenberg AA, et al. Factors associated with the use of cognitive aids in operating room crises: a cross-sectional study of US hospitals and ambulatory surgical centers. Implement Sci 2018, 13: 1-12.
6. SD Marshall. Helping experts and expert teams perform under duress: an agenda for cognitive aid research. Anaesthesia 2017, 72: 283-295.
7. Goldhaber-Fiebert SN, Macrae C. Emergency Manuals: How Quality Improvement and Implementation Science Can Enable Better Perioperative Management During Crises. Anesthesiol Clin 2018, 36: 45-62.
8. Simmons WR, Huang J. Operating Room Emergency Manuals Improve Patient Safety: A Systematic Review. Cureus [online serial] 11: e4888. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6689479/ [accessed 10 September 2020].
9. Hepner DL, Arriaga AF, Cooper JB, et al. Operating Room Crisis Checklists and Emergency Manuals. Anesthesiology 2017, 127: 384-392.
10. Muka T, Glisic M, Milic J, et al. A 24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research. Eur J Epidemiol 2020, 35: 49-60.
11. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ [online serial] 2021, 372: n71. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8005924/ [accessed 20 December 2020].
12. Granholm A, Alhazzani W, Møller MH. Use of the GRADE approach in systematic reviews and guidelines. Br J Anesth 2019, 123: 554-559.
13. Schünemann HJ, Higgins J, Vist GE, et al. Chapter 14: Completing 'Summary of findings' tables and grading the certainty of evidence. https://training.cochrane.org/handbook/current/chapter-14 [accessed 15th September 2020].
14. Woolf S, Schünemann HJ, Eccles MP, Grimshaw JM, Shekelle P. Developing clinical practice guidelines:

Types of evidence and outcomes; values and economics, synthesis, grading, and presentation and deriving recommendations. Implement Sc [online serial] 2012, 7: 61. https://implementationscience.biomedcentral.com/track/pdf/10.1186/1748-5908-7-61.pdf [accessed 20 December 2020].
15. Moher D, Liberati A, Tetzlaff J, et al. Preferred Reporting Items for Systematic Reviews and Meta-analyses: The PRISMA Statement. PLoS Medicine [online serial] 2009, 6(7): e1000097. https://www.bmj.com/content/bmj/339/bmj.b2535.full.pdf [accessed 20 December 2020].
16. Clebone A, Watkins SC, Tung A. The timing of cognitive aid access during simulated pediatric intraoperative critical events. Pediatr Anesth 2020, 30: 676–682.
17. Meffert A, Baudrier D, Benhamou D, Mattatia L, Blanié A. Use of cognitive aids in anaesthesia crisis scenarios: Observational analysis from video recording during simulation. Anaesth Crit Care & Pain Med 2020, 39: 251–252.
18. Huang J, Sanchez K, Wu J, Suprun A. Best Location and Reader Role in Usage of Emergency Manuals During Critical Events: Experienced Emergency Manual Users' Opinion. Cureus [online serial] 2019 11(4): e4505. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6584297/ [accessed 15 January 2021].
19. Gleich SJ, Pearson A, Lindeen KC, et al. Emergency Manual Implementation in a Large
Academic Anesthesia Practice: Strategy and Improvement in Performance on Critical Steps. Anesth Analg 2019, 128: 335-341.
20. Goldhaber-Fiebert SN, Pollock J, Howard SK, Merrell SB. Emergency Manual Uses During Actual Critical Events and Changes in Safety Culture From the Perspective of Anesthesia Residents: A Pilot Study. Anesth Analg 2016, 123: 641–649.
21. Goldhaber-Fiebert SN, Howard SK. Implementing Emergency Manuals: Can Cognitive Aids Help Translate Best Practices for Patient Care During Acute Events? Anesth Analg 2013, 117: 1149–1161.
22. Shear TD, Deshur M, Benson J, et al. The Effect of an Electronic Dynamic Cognitive Aid Versus a Static Cognitive Aid on the Management of a Simulated Crisis: A Randomized Controlled Trial. J Med Syst [online serial] 2019, 43(6). https://link.springer.com/content/pdf/10.1007/s10916-018-1118-z.pdf [accessed 15 January 2021].
23. Watkins SC, Anders S, Clebone A, et al. Mode of Information Delivery Does Not Effect Anesthesia Trainee Performance During Simulated Perioperative Pediatric Critical Events. Simul healthc 2016, 11: 385-393.
24. Watkins SC, Anders S, Clebone A, et al. Paper or plastic? Simulation based evaluation of two versions of a cognitive aid for managing pediatric peri-operative critical events by anesthesia trainees: evaluation of the society for pediatric anesthesia emergency checklist. J Clin Monit Comput 2016, 30: 275–283.
25. Lelaidier R, Balança B, Boet S, et al. Use of a hand-held digital cognitive aid in simulated crises: the MAX randomized controlled trial. Br J Anaesth 2017, 119: 1015–1021.
26. Grigg E. Smarter Clinical Checklists: How to Minimize Checklist Fatigue and Maximize Clinician Performance. Anesth Analg 2015, 121: 570-573.
27. Donzé P, Balanca B, Lilot M, et al. 'Read-and-do' response to a digital cognitive aid in simulated cardiac arrest: the Medical Assistance eXpert 2 randomised controlled trial. Br J Anaesth 2019, 123: e160-e163.
28. Di Renna T, Crooks S, Pigford A, et al. Cognitive Aids for Role Definition (CARD) to improve interprofessional team crisis resource management: An exploratory study. J Interprof Care 2016, 30: 582–590.
29. Evans D, McCahon R, Barley M, Norris A, Khajuria A, Moppett I. Cognitive Aids in Medicine Assessment Tool (CMAT): preliminary validation of a novel tool for the assessment of emergency cognitive aids. Anaesthesia 2015, 70: 922–932.
30. Abir G, Austin N, Seligman KM, Burian BK, Goldhaber-Fiebert SN. Cognitive Aids in Obstetric Units: Design, Implementation, and Use. Anesth Analg 2020, 130: 1341-1350.
31. Schild S, Gruendner J, Gulden C, Prokosch HU, St Pierre M, Sedlmayr M. Data Model Requirements for a Digital Cognitive Aid for Anesthesia to Support Intraoperative Crisis Management. Appl Clin Inform 2020, 11: 190–199.
32. Clebone A, Burian BK, Watkins SC, Galvez JA, Lockman JL, Heitmiller ES. The Development and Implementation of Cognitive Aids for Critical Events in Pediatric Anesthesia: The Society for Pediatric Anesthesia Critical Events Checklists. Anesth Analg 2017, 124: 900-907.
33. Schild S, Sedlmayr B, Schumacher AK, et al. A Digital Cognitive Aid for Anesthesia to Support Intraoperative Crisis Management: Results of the User-Centered Design Process. JMIR Mhealth Uhealth [online serial] 2019, 7(4): e13226. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6658227/ [accessed 30 March 2021].
34. Clebone A, Burian BK, Tung A. The effect of cognitive aid design on the perceived usability of critical event cognitive aids. Acta Anaesthesiol Scand 2020, 64: 378–384.
35. Marshall SD, Sanderson P, McIntosh CA, Kolawole H. The effect of two cognitive aid designs on team functioning during intra-operative anaphylaxis emergencies: a multi-centre simulation study. Anaesthesia 2016, 71: 389–404.
36. Clebone A, Burian BK, Tung A. Matching design to use: a task analysis comparison of three cognitive aid designs used during simulated crisis management. Can J Anesth 2019, 66: 658–671.
37. King R, Hanhan J, Harrison TK, et al. Using eye tracking technology to compare the effectiveness of malignant hyperthermia cognitive aid design. Korean J Anesthesiol 2018, 71: 317-322.
38. McEvoy MD, Hand WR, Stoll WD. Adherence to Guidelines for the Management of Local Anesthetic Systemic Toxicity Is Improved by an Electronic Decision Support Tool and Designated 'Reader'. Reg Anesth Pain Med 2014, 39: 299–305.
39. Hilton G, Daniels K, Goldhaber-Fiebert SN, Lipman S, Carvalho B, Butwick A. Checklists and multidisciplinary team performance during simulated obstetric hemorrhage. Int J Obstet Anesth 2016, 25: 9-16.
40. Goldhaber-Fiebert SN, Merrell SB, Agarwala AV, et al. Clinical Uses and Impacts of Emergency Manuals During Perioperative Crises. Anesth Analg 2020, 131: 1815-1826.
41. Marshall S. The Use of Cognitive Aids During Emergencies in Anesthesia: A Review of the Literature. Anesth Analg 2013, 117: 1162–71.
42. Burian BK, Clebone A, Dismukes K, Ruskin KJ. More Than a Tick Box: Medical Checklist Development, Design, and Use. Anesth Analg 2018, 126: 223-232.

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Table II. — PICO 1 & 2 – Timing of consulting the use of a cognitive aid & person triggering the use of a cognitive aid.

Author/ study design	Population/ comparison/ intervention	Results/ comparison	Limitations
Clebone A, Watkins SC, et al.[16] Retrospective observational study: reanalysis	> 89 anesthesia caregivers > Re-analysis: measurement of time from event trigger to cognitive aid use > Re-analysis: measurement of number and type key action before cognitive aid was accessed	> Average time between event trigger and cognitive aid use: 258 sec. > In 62/65 simulations the participants accessed the cognitive aid after at least one key action already had been performed > Variation in time to trigger the use of cognitive aid, influenced by type of scenario (P= 0,03) *For more common events the cognitive aids are accessed later than cognitive aids for less common events *For rare events, fewer key actions are performed before cognitive aid access. Time for event trigger to cognitive aid access is shorter > Delayed access in the cognitive aid design -> may enhance the effectiveness of the cognitive aid > Cognitive aid use depends on the situation. More common events -> cognitive aid designed to allow 'sampling' and support delayed access	> Retrospective analysis of data from simulated events: concern about the applicability of> the results to a real-life situation > The participants are anesthesia residents or student nurses a and not experts > The participants received copies of the cognitive aid in advance through mail (a few days before the simulation session). Not a representation of a real-life event > Only exploration of the events for which a cognitive aid was assigned to and/or chosen by the participants. Maybe other results when assigning cognitive aids to other scenarios
Meffert A, Baudrier D, et al. [17] Retrospective cross-sectional observational study	> 2nd and 3rd anesthesia residents > Video-analysis of 53 simulation sessions	> Use of cognitive aid is in 25%, 60% and 15% respectively triggered by the leader, one of the followers or one of instructors > Initial use occurs mostly after the initial diagnosis (90%). The cognitive aid used to confirm the diagnosis	> Small sample size

Table III. — PICO 3 – Location of the cognitive aid.

Author/ study design	Population/ comparison/ intervention	Results/ comparison	Limitations
Siddiqui A, Ng E, et al.[2] Randomized controlled trial	> Senior anesthesia trainees (78 simulations) > Visual availability of the checklist > A diagnose-based versus a generic event - based checklist	> Checklist in clear view -> no significant difference in uptake: 16% versus 20% (P= 0,69)	> Participants = anesthesia trainees. The cognitive aid is meant for the whole team > No data about retention at a later stage
Huang J, Sanchez K, et al. [18] Survey	> Survey of 114 experienced emergency manual users (anesthesiologists)	> Best location according to participants in critical events: 92,11% anesthesia work station, 7,02% code cart, 0,88% anesthesia office	> Small sample size > Participant's bias: influenced by age, ethnicity, geographical location, … > No evidence of improved clinical outcome when choosing a particular option. It's a survey about (subjective) preference
Gleich SJ, Pearson A, et al. [19] Prospective cohort observational study	> 59 (attending anesthetists, anesthesia residents, anesthesia nurses and student anesthesia nurses) > Observing the phases of implementing when creating an emergency manual at a large anesthesia institution > Testing of the created emergency manual in verbal- simulated crisis events on adherence to critical steps pre-implementation and 6 months after implementation	> Improved adherence to critical steps when using cognitive aid after Implementation process. Important factor(s) of that implementation process: * Need for a standard location in the OR, for example: the anesthesia workstation -> increase familiarity	> Selection bias: the participants of the pre-implementation faze are different from those after 6 months > Concern about the generalizability of the results (single center) > Small sample size when testing the new emergency manual > Members of the anesthesia team are aware of the study -> more attentive to emergency manual location and utility before being tested > No control group to compare
Goldhaber-Fiebert SN, Pollock J, et al. [20] Survey	> Anesthesia residents participating in preimplementation and post-implementation surveys respectively 34 and 42 > Pre-implementation and post-implementation surveys to assess the clinical use of cognitive aids in the operating room	> Cognitive aids highly visible in the OR -> more accepted in the institution	> Single center study > Selection bias: residents who complete the survey, may feel more strongly for or against cognitive aids > Participants are only residents. Cognitive aids affect the whole team > The data of the survey only represented 2 cross-sectional time points. In the future need for additional data collection from multiple time points > The data in this study only begin to suggest relevant themes. More rigorous qualitative interviews in the future are necessary to identify facilitators and barriers of cognitive aids
Goldhaber-Fiebert SN, Howard SK [21] Expert opinion	/	> Location: consistent place in the OR, visible and easily accessible without blocking the daily workflow, for example: near/on the anesthesia workstation	/

Table IV. — PICO 4 – Paper-based versus electronically-based cognitive aid design 1/3.

Author/ study design	Population/ comparison/ intervention	Results/ comparison	Limitation
Goldhaber-Fiebert SN, Howard SK [21] Expert opinion	/	> 3 limitations of clinical use of pocket cards: * size: card is limited by available space * set: because of size and weight limitations pocked cards cannot include a large set of potentially relevant critical events * location: use depends on whether the clinicians always carry the pocket card with them > Physical emergency manuals are thought to more useful in a critical event	/
Shear TD, Deshur M, et al. [22] Randomized controlled trial	> 34 anesthesia residents > Evaluation of task checklist performance and the performance using the Anesthesia Non- Technical Skills scoring system in a simulated scenario with a dynamic electronic cognitive aid versus a static cognitive aid (paper-based)	> Total checklist performance: significantly higher mean performance in the dynamic vs static cognitive aid group (15.70 ± 1.93 vs 12.95 ± 2.16, p < 0.0001). Most notable in dose-dependent related checklist items (P< 0,0001) > No difference in ANTS (anesthesia non-technical skills) ratings between dynamic versus static cognitive aid group	> The setting of the study is a simulation scenario. A different setting than an actual event > Only evaluation of individual performance. The effect of a dynamic cognitive aid on the team is not established > The participants are familiar with the static cognitive aid but not with the dynamic cognitive aid -> possibility of an underestimated positive effect of the dynamic cognitive aid > Simulation setting is a pediatric scenario where dose calculations are imperative. In adult scenarios more generic doses are used -> possibility of a decreased advantage of the dynamic cognitive aid in such scenarios
Watkins SC, Anders S, et al. [23] Randomized controlled trial	> Anesthesia trainees (143 simulations) > Simulation with no cognitive aid (control) versus a paper-based cognitive aid versus an electronic version cognitive aid	> Overall performance score is higher in the paper (not significant, P= 0,08) and electronic cognitive (significant, P= 0,03) aid group than the control group. The difference between paper-based and electronic-based is not significant > No significant difference in time to cognitive aid use between paper and electronic versions > No significant effect of cognitive aid use on task completion or time to call help or time to correct diagnosis or time to notify the surgeon for either cognitive aid group (paper or electronic) > In 1/3 of the scenarios assigned to cognitive aid use, the participant chose not to use the cognitive aid. No statistically difference between the 2 formats	> Single-institution study > The participants are anesthesia trainees rather than experienced clinicians > The comparison of performance between the 2 cognitive aids was influenced by the number of participants who didn't use the cognitive aid in either cognitive aid group > The high score of task completion reduced the ability to score the interrater reliability

Table IV. — PICO 4 – Paper-based versus electronically-based cognitive aid design 2/3.

Watkins SC, Anders S, et al. [24] Survey	> 44 anesthesia residents and 45 student nurse anesthetists > Survey after simulation with no cognitive aid (control) versus a paper-based cognitive aid versus electronic cognitive aid	> Both paper and electronic cognitive aid perceived as useful and beneficial on 13 survey measures > Preference for the paper version based on both quantitative and qualitative analysis > Perceived safety and reliability in paper. Concern about a potential technological failure -> the electronic cognitive unavailable > Difficult navigation of the electronic cognitive aid (touch screen too sensitive) > Paper version subjected to user-interface errors (missed pages when topics occupied more than one page, …) > Paper version not handsfree -> unable to use the cognitive aid when task demands are high -> dedicated reader maybe beneficial	> Some clinicians didn't use both cognitive aids in the simulation sessions > No demographical data on the participants who didn't complete the survey > The participants are all trainees. Possibility of other results when including experienced participants
Lelaidier R, Balança B, et al. [25] Randomized controlled trial	> 46 anesthesia residents with more than 1 year experience > Effect of a smartphone application (MAX) on the technical and non-technical performance score > Max is a hand-held, electronic cognitive aid on the smartphone	> The use of the MAX application was associated with significantly better mean technical performance (P < 0,001) > The mean non-technical performance was significantly better in the MAX- group versus control group (P < 0,001) > Overall performance, leadership, problem solving and resource use were significantly better in the MAX + group (P-values respectively 0,001; 0,003; < 0,001 and 0,006) > The portability guaranteed its availability; possibility to update the existing procedures and adapt the content to local protocols/customs	> The observers are not blinded to the use of the MAX-application > The setting of the study is a simulation scenario. Concern about the applicability of the results to a real-life situation
Grigg E. [26] Expert opinion	/	> A digital checklists -> presents the right content at the right time. It needs to adapt to contextual information (context-aware) > 'Smart' checklists could be more specific and adapted to the different stages of a crisis event. However: also challenges of 'smart checklists': Various device and software systems in the OR must communicate with one another Need for a hardware system that seamlessly interacts with 'smart checlists' Development of algorithms that synthesizes incoming data and decides when to present what kind of information	/

Table IV. — PICO 4 – Paper-based versus electronically-based cognitive aid design 3/3.

Donzé P, Balanca B, et al. [27] Randomized controlled trial	> 57 anesthesia residents > Video assessment of the technical and non-technical skills in simulated scenarios with the use of digital cognitive aid with a a 'read and do'-response versus a paper-based cognitive aid versus no cognitive aid	> The median technical skills were significantly better in the digital cognitive aid group than the paper-based cognitive aid group and the control group (80 [72-84]) vs control group 55 [50-60]; P<0.0001 and the PCA group 61 [55-65]; P1=0.0002) > The median technical skills in the paper-based group were not significantly different vs control group (P= 0.43) > The median non-technical skills were significantly better in the digital cognitive aid group than the control group (P= 0,004) > The design of the first MAX-application was altered based on the user- feedback from the previous study (Use of a hand-held digital cognitive aid in simulated crisis: the MAX randomized controlled trial) > The better technical performance in the digital cognitive aid group vs the paper-based cognitive aid may be explained by the sequential design of the digital cognitive aid	> No blinding of the observers > Analysis of data from simulated events: concern about the applicability of the results to a real-life event > The participants are anesthesia residents and not experts

Table V. — PICO 5 & 6 – Lay-out of the cognitive aid & decision support systems in cognitive aids 1/5.

Author/ study design	Population/ comparison/ intervention	Results/ comparison	Limitations
Siddiqui A, Ng E, et al. [2] Randomized controlled trial	> Senior anesthesia trainees (78 simulations) > Visual availability of the checklist > A diagnose-based versus a generic event - based checklist	> Uptake of checklist in scenarios requiring diagnose-based checklists > in scenarios requiring the use of generic event-based checklists: 45% vs 2% (P < 0,01)	> Participants = anesthesia trainees. The cognitive aid is meant for the whole team > No data about retention at a later stage
Goldhaber-Fiebert SN, Macrae C, et al. [7] Expert opinion	/	> Locally customizing an already existing tool > Risks of local customization: altering essential elements of design, adding too much content -> less readable	/
Clebone A, Watkins SC, et al. 16 Retrospective observational study: reanalysis	> 89 anesthesia caregivers > Re-analysis: measurement of time from event trigger to cognitive aid use > Re-analysis: measurement of number and type key action before cognitive aid was accessed	> Delayed access in the cognitive aid design -> may enhance the effectiveness of the cognitive aid > Cognitive aid use depends on the situation. More common events -> cognitive aid designed to allow 'sampling' and support delayed access	> The participants are anesthesia residents or student nurses a and not experts > The participants received copies of the cognitive aid in advance through mail (a few days before the simulation session). Not a representation of a real-life event > Only exploration of the events for which a cognitive aid was assigned to and/or chosen by the participants. Maybe other results when assigning cognitive aids to other scenarios
Gleich SJ, Pearson A, et al. [19] Prospective cohort observational study	> 59 (attending anesthetists, anesthesia residents, anesthesia nurses and student anesthesia nurses) > Observing the phases of implementing when creating an emergency manual at a large anesthesia institution > Testing of the created emergency manual in verbal- simulated crisis events on adherence to critical steps pre-implementation and 6 months after implementation	> Improved adherence to critical steps when using cognitive aid after Implementation process. Important factor(s) of that implementation process: * Large, easily readable, readable font type * Emergency manual printed on cleanable and water-resistant paper * Use already existing and validated emergency manuals with several customized modifications * Emergency manual should indicate task possession	> Selection bias: the participants of the pre-implementation faze are different from those after 6 months > Concern about the generalizability of the results (single center) > Small sample size when testing the new emergency manual > Members of the anesthesia team are aware of the study -> more attentive to emergency manual location and utility before being tested > No control group to compare

Table V. — PICO 5 & 6 – Lay-out of the cognitive aid & decision support systems in cognitive aids 2/5.

Shear TD, Deshur M, et al. [22] Randomized controlled trial	> 34 anesthesia residents > Evaluation of task checklist performance and the performance using the Anesthesia Non- Technical Skills scoring system in a simulated scenario with a dynamic electronic cognitive aid versus a static cognitive aid (paper-based)	> Total checklist performance: significantly higher mean performance in the dynamic vs static cognitive aid group (15.70 ± 1.93 vs 12.95 ± 2.16, p < 0.0001) > Most notable in dose-dependent related checklist items (P< 0,0001) > No difference in ANTS ratings between dynamic versus static cognitive aid group	> The setting of the study is a simulation scenario. A different setting than an actual event > Only evaluation of individual performance. The effect of a dynamic cognitive aid on the team is not established > The participants are familiar with the static cognitive aid but not with the dynamic cognitive aid -> possibility of an underestimated positive effect of the dynamic cognitive aid > Simulation setting is a pediatric scenario where dose calculations are imperative. In adult scenarios more generic doses are used -> possibility of a decreased advantage of the dynamic cognitive aid in such scenarios
Grigg E. [26] Expert opinion	/	> A digital checklists -> presents the right content at the right time. It needs to adapt to contextual information (context-aware) > 'Smart' checklists could be more specific and adapted to the different stages of a crisis event. However: also challenges of 'smart checklists': * Various device and software systems in the OR must communicate with one another * Need for a hardware system that seamlessly interacts with 'smart checklists' * Development of algorithms that synthesizes incoming data and decides when to present what kind of information	/
Donzé P, Balanca B, et al. [27] Randomized controlled trial	> 57 anesthesia residents > Video assessment of the technical and non-technical skills in simulated scenarios with the use of digital cognitive aid with a a 'read and do'-response versus a paper-based cognitive aid versus no cognitive aid	> The median technical skills were significantly better in the digital cognitive aid group than the paper-based cognitive aid group and the control group (80 [72-84]) vs control group 55 [50-60]; P<0.0001 and the PCA group 61 [55-65]; P1=0.0002) > The median technical skills in the paper-based group were not significantly different vs control group (P= 0.43) > The median non-technical skills were significantly better in the digital cognitive aid group than the control group (P= 0,004) > The design of the first MAX-application was altered based on the user- feedback from the previous study (Use of a hand-held digital cognitive aid in simulated crisis: the MAX randomized controlled trial) > The better technical performance in the digital cognitive aid group vs the paper-based cognitive aid may be explained by the sequential design of the digital cognitive aid	> No blinding of the observers > Analysis of data from simulated events: concern about the applicability of the results to a real-life event > The participants are anesthesia residents and not experts

Table V. — PICO 5 & 6 – Lay-out of the cognitive aid & decision support systems in cognitive aids 3/5.

Di Renna T, Crooks S, et al. [28] Observational case-control study	> 16 interprofessional teams: No CARD versus CARD + no teaching versus CARD + didactic teaching in a simulation setting > 6 months later with 8 teams: CARD vs no CARD > Assessment method in both segments: debriefing + Video assessment of team performance in a simulation setting	> Qualitative/subjective: improved role definition and task awareness, reducing the cognitive load of leaders, reducing the sense of chaos but maybe too ridged > Quantitative: no significant difference in team performance (P > 0,05) > Quantitative: no significant difference at retention 6 months later between CARD vs no CARD	> Small sample size > The perceived better teamwork with CARD can result from the CARD-intervention itself or from to the repetitive simulation
Evans D, McCahon R, et al. 29 Expert consensus through a three-staged Delphi process	> Development of CMAT by 5 experts > Validation as an assessment tool to guide design of cognitive aids through ranking and scoring of 7 published difficult airway guidelines and comparing the results with an independent group of airway experts	> The resultant CMAT tool: valid and reliable assessment tool for difficult airway cognitive aids based on good internal consistency, fair inter-rater reliability and high levels of agreement with airway experts	> Small sample size of the 2 expert groups > Single center study
Abir G, Austin N, et al. [30] Expert opinion	/	> Cognitive aid as a clear, to the point, and goal-specific guidance > Not only limited to text. Also graphics, tables,.. > Cognitive aid based on recent available evidence and expert recommendations. Redesigned based on in-situ testing, user feedback and local customization > Cognitive aids = many forms: pocket-sized paper cards, large wall posters, electronic cognitive aids,… > Cognitive aids must be easily accessible and legible	/
Schild S, Gruendner J, et al. 31 Expert opinion/ review	> The structure of paper-based cognitive aids was reviewed to identify frequent elements and structures > The content, design and purpose of a digital cognitive aid was analyzed for additional requirements > Development of a prototype digital cognitive aid based on the derived requirements	> 20 requirements of a digital cognitive aid, for example: checklist tags, structured checklist action steps and additional information on each item > A standard format, a uniform structure is essential	> Results are limited by the resources provided in the project > Evaluation of a digital cognitive aid in a more time-pressured, urgent setting is indicated

Table V. — PICO 5 & 6 – Lay-out of the cognitive aid & decision support systems in cognitive aids 4/5.

Clebone A, Burian BK, et al. [32] Expert opinion	> Development of the Society of Pediatric Anesthesia (SPA) critical event checklist by experts	> Latest evidence- and expert opinion-based > A compromise between enough content to act versus "no-crowding" > Support a step-by-step approach > Easy-to-read display, readable font type > Single side paper > Only common and unambiguous abbreviations and symbols > Pictures and graphics to illustrate content > Tabular presentation of information if necessary > Design features: page numbers, duplicated titles, cover page including an alphabetized table of contents > Frequent reviews and updates of the checklist are indicated	> Further validation of the SPA Critical Event Checklist is needed. Only a large, single-center simulation-based evaluation of the SPA critical event checklist has been performed > The checklist needs to be regularly updated to remain relevant
Schild S, Sedimayr B, et al. [33] Observational cross-sectional study	> User-centered design to identify specific requirements of a digital cognitive aid	> Focus of development primarily on the main user (the anesthesiologist), anesthesia nurses are secondary users > Design requirements: * Intuitive operation * Short navigation pathways * Full functional for offline use > Consider to customize the checklist to local protocols > Need for role clarity and clear communication	> Participants are only anesthesiologists from hospitals but not from outpatient departments -> requirements for cognitive aids in outpatient and inpatient settings can differ > Physicians are the primary users and anesthesia nurses are secondary users. Requirements of cognitive aids for nurses can also be different > Evaluation of the prototypes as a part of the user-centered design, takes place in theory without dealing with a real crisis situation
Clebone A, Burian BK, et al. [34] Observational case-control study	> 17 anesthesia attendings, 3 anesthesia fellows and 3 nurse anesthetists > Quantitative assessment of a step-by-step control aid versus 2 experimental aid designs after use in a simulation setting	> Greater ease of use with the experimental aid than the linear step-by-step design > Favourable design elements: * Grouped content associated with the topic into color-coded blocks * Color-coded blocks in the same places on the cognitive aid * Aids that support sampling behavior when clinicians primarily use it for sampling (faster information retrieval)	> Single center study -> concern about the generalizability of the results > No stratification of the results by level of training or role > No evaluation of the effect of the different cognitive aids on the the clinical outcome > Limitation of the experimental aid itself: the experimental cognitive aids aren't numbered -> concern about how to use those aids in a step-by-step mode

Table V. — PICO 5 & 6 – Lay-out of the cognitive aid & decision support systems in cognitive aids 5/5.

Marshall SD, Sanderson P, et al. [35] Randomized controlled trial	> 24 teams of 3 participants (anesthesia attending or fellow + anesthesia trainee + nurse anesthetists) > Evaluation of no cognitive aid versus linear cognitive aid versus a branched cognitive aid in an anaphylaxis-simulated setting	> Scores on "overall team behavioral performance" with a linear design Significantly higher versus no cognitive aid or branched cognitive aid (P= 0,01) > Aggregate scores significantly higher with a linear design versus a branched aid design (P= 0,03)	> Before the simulation the participants are educated on anaphylaxis guidelines. They are primed to perform well -> maybe a larger effect of the cognitive aids in non-primed teams > Blinding bias: 1 of the 2 observers is present during the simulation scenario to ensure the correct implementation of the study protocol > Blinding bias: blinding of the video data for the presence of a cognitive aid is impossible because the effective use of a cognitive aid is observed in this trial
Clebone A, Burian BK, et al. [36] Observational case-control study	> 17 anesthesia attendings + 3 senior residents or fellows + 3 nurse anesthetists > 2 experimental cognitive aids vs lineair cognitive aid (control) > 2 experimental cognitive aids designed based on data from human factors and cognitive science research (clustering, color coding and consistent content location) to facilitate sampling behaviour > Eye tracking device during the simulations	> Identifying and retrieving information significant faster using the experimental aids than the linear step-by-step aid (P= 0, 006 and P< 0,001) > Significant more time looking at the step-by-step linear aid than at either experimental cognitive aids (P= 0,020 and P < 0,001)	> Data from simulated events: concern about the applicability of the results to a real-life situation > Concern about the generalizability of the results (single center) > Potential confounding variables: level of training, years in practice, age, sex > No evaluation of the whole team > Limit of 1-2 visual degrees for eye-tracking device -> specificity of the gaze of participants is limited to 3-5 lines of text > Data of the eye-tracking device influenced by lighting conditions and by how the device has been worn during the simulation
King R, Hanhan J, et al. 37 Observational case-control study	> 12 anesthesia attendings > Eye-tracking technology for a comparative evaluation of the accessibility of 5 cognitive aid designs: shortest time to formulate an answer based on the cognitive aid?	> Shortest cumulative time to formulate an answer based on the cognitive aid was 'the Society for Pediatric Anesthesia cognitive aid (P < 0,001) > Potential advantageous design elements of the Society for Pediatric Anesthesia cognitive aid include a single page, linear lay-out and simple typescript with minimal single-color blocking > "Visually salient" regions of the cognitive aid may distract the clinician from "cognitively salient" points	> Small sample size > Single-institution study > The results are only applicable for the cognitive aids used in this study > The results measured by the eye-tracking technology are maybe clinically relevant. Not a clear-cut fact
Mc Evoy MD, Hand WR, et al. [38] Randomized controlled trial	> 31 anesthesia residents > Electronic decision support + designated reader (N: 15) versus memory alone (N: 16) > Video-assessment of participants scores In a simulation setting	> The 'reader + electronic decision support' group scored higher than control: overall and critical percent correct score significantly higher (P < 0,0001) > Decision support tool via a designated reader -> near-perfect adherence to the guidelines > The electronic decision support tool: advice and recording of all steps performed by the user > The most appropriate reader = member of the anesthesia team, for example: the perioperative nurse or an anesthesia technician	> Data from a simulation scenario: a different setting compared with an actual event > Results from a single institutional residency training program > Concern about the generalizability of the results > Uncertainty that the measured outcomes result from the outline of the cognitive aid (electronic versus paper) or the method of Implementation (designated reader role) or both

Table VI. — PICO 7 – The person reading the cognitive aid during a critical event 1/2.

Author/ study design	Population/ comparison/ intervention	Results/ comparison	Limitations
Burden AR, Carr ZJ, et al. [3] Observational case-control study	> 28 anesthesia and obstetrics/gynecology residents (31 simulations) > Evaluation of critical steps in 31 simulated scenarios without reader versus with reader	> None of the participants completed all the critical steps for appropriate treatment before the introduction of the reader > All critical steps were completed after introduction of the reader > Debriefing (subjective): * Better subjective handling of the situation with the reader * Without Reader: a subjective feeling of difficulty to make the cognitive process dynamic. Introduction of the reader helped * The Reader facilitated the examination of the elements of the cognitive aid and helped the leader review the clinical situation	> Small number of subjects > Testing of 1 subject at a time. No evaluation of the whole team > A medical student = the reader. Concern about the ideal level of expertise for the reader > Debriefing immediately after the simulation session. Only the knowledge of the participants' thoughts during the debriefing was assessed > Simulation setting is housed in a laboratory and not the clinical environment of the clinician.
Goldhaber-Fiebert SN, Macrae C, et al. [7] Expert opinion	/	> Enable a reader role. A reader is helpful -> how can teams be trained to trigger the reader role themselves?	/
Huang J, Sanchez K, et al. [18] Survey	> Survey of 114 experienced emergency manual users (anesthesiologists)	> Reader: 57,89% senior physician, 23,68% junior physician, 11,4% anesthesia nurses, 7,02% operating room nurse > Reader = experienced team member with a high degree of leadership	> Small sample size > Participant's bias: influenced by age, ethnicity, geographical location, … > No evidence of improved clinical outcome when choosing a particular option. It's a survey about (subjective) preference
Goldhaber-Fiebert SN, Pollock J, et al. [20] Survey	> Anesthesia residents participating in pre-implementation and post-implementation surveys respectively 34 and 42 > Pre-implementation and post-implementation surveys to assess the clinical use of cognitive aids in the operating room	> Reader if enough people are available to help = advantage > A dedicated reader increased the rate of completion of vital actions in simulated crises	> Single center study > Selection bias: residents who complete the survey, may feel more strongly for or against cognitive aids > Participants are only residents. Cognitive aids affect the whole team > The data of the survey only represented 2 cross-sectional time points. In the future need for additional data collection from multiple time points > The data in this study only begin to suggest relevant themes. More rigorous qualitative interviews in the future are necessary to identify facilitators and barriers of cognitive aids
Goldhaber-Fiebert SN, Howard SK [21] Expert opinion	/	> When sufficient people are present, enable a reader role > Who is the ideal reader? Depends on: potential cultural issues in the OR, available staff, other patient care needs and appropriate training	/

Table VI. — PICO 7 – The person reading the cognitive aid during a critical event 2/2.

Abir G, Austin N, et al. [30] Expert opinion	/	> Designated Reader improved management of critical steps, reduced omissions of critical steps and reduced diagnostic errors	/
Mc Evoy MD, Hand WR, et al. [38] Randomized controlled trial	> 31 anesthesia residents > Electronic decision support + designated reader (N: 15) versus memory alone (N: 16) > Video-assessment of participants scores In a simulation setting	> The 'reader + electronic decision support' group scored higher than control: overall and critical percent correct score significantly higher (P < 0,0001) > Decision support tool via a designated reader -> near-perfect adherence to the guidelines > The electronic decision support tool: advice and recording of all steps performed by the user > The most appropriate reader = member of the anesthesia team, for example: the perioperative nurse or an anesthesia technician	> Data from a simulation scenario: a different setting compared with an actual event > Results from a single institutional residency training program > Concern about the generalizability of the results > Uncertainty that the measured outcomes result from the outline of the cognitive aid (electronic versus paper) or the method of Implementation (designated reader role) or both
Hilton G, Daniels K, et al. [39] Prospective observational cohort study	> 14 multidisciplinary teams (obstetricians, anesthetists, midwifes and operating room technicians) > For the simulation scenario the participants received checklist training > Observation of key management task during simulation: activation of massive transfusion protocol and begin transfusion of packed cells. Difference between team with designated reader versus without	> No difference in time before activating massive transfusion protocol or begin transfusion or administering a second-line uterotonic in the teams with designated reader versus without designated reader (P > 0,05)	> No control group: possibility of a different team performance and checklist use in teams not exposed to the training > No data collection of prior simulation training(s) of the participants > No data collection of prior participations in simulation training(s) with other members of the same team > No validation testing of the checklist used in the simulation scenario > Outcomes are surrogate measures for perinatal outcomes