The Use of Cognitive Aids During Emergencies in Anesthesia: A Review of the Literature

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Cognitive aids are prompts designed to help users complete a task or series of tasks. They may take the form of posters, flowcharts, checklists, or even mnemonics. It has been suggested that the use of cognitive aids improves performance and patient outcomes during anesthetic emergencies; however, a systematic assessment of the evidence is lacking. The aim of this literature review was to determine (1) whether cognitive aids improve performance of individuals and teams and (2) whether recommendations can be made for future cognitive aid design, testing, and implementation. Medical, nursing, and psychology databases were searched using broad criteria to find cognitive aids that have been reported in the literature for use in anesthetic emergencies. The reference lists of the articles selected for review were also screened to identify additional studies. Selected articles that described the evaluation of cognitive aids used in anesthetic emergencies were reviewed to determine how the content of the aid was derived, how the design was evaluated, and the success of the aid in improving technical and team performance. The search yielded 22 cognitive aids developed to support clinicians during anesthetic emergencies that had been evaluated in 23 studies. Ten studies using simulation suggested that technical performance improves with the use of cognitive aids in some anesthetic emergencies such as malignant hyperthermia, cardiopulmonary resuscitation, and airway management. However, in 3 of the simulator-based evaluations, participants had either no improvement or took longer to diagnose and treat and made more incorrect diagnoses. Four studies investigated the effect of the aids on teamwork with differing conclusions. One study suggested improved participants' coordination patterns and one found aids improved their decision-making scores, but 2 other studies indicated that there was no improvement and even provided evidence of reduced levels of team communication when teams used a cognitive aid in simulated conditions. The designs of cognitive aids were rarely considered. Education may compensate for a poorly designed aid, but only by ingraining correct actions for situations in which the aid provides little or no guidance. Cognitive aids should continue to be developed from established clinical guidelines where guidelines exist. They would also benefit from more extensive simulation-based usability testing before use. Further evidence is required to explore the effects of cognitive aids in anesthetic emergencies, how they affect team function, and their design considerations. (Anesth Analg 2013;117:1162–71)

Cognitive aids such as checklists have been commonly used in aviation since the 1930s when it was felt that aircraft were becoming too complex to fly safely without written standardized procedures.[1] Cognitive aids are tools created to guide users while they are performing a task, or group of tasks, with the goal of reducing errors and omissions and increasing the speed and fluidity of performance.[2,3] The main difference from guidelines, protocols or standard operating procedures is that they are to be used while the task is being performed (Table 1).[4] Many cognitive aids are derived from documents describing extensive and detailed sequences of actions that would be difficult to examine while undertaking a task,[1,5,6] particularly during an emergency. Secondarily, their presentation as simplified instructions also makes them useful for training.[6] A recent editorial suggested that "health care providers should not be expected to manage rare events well without the use of a cognitive aid"[7] since safety checklists have been successfully developed, tested, and used in other high-risk industries. The aim of undertaking this literature review was to critically examine the evidence to support this view that cognitive aids should be developed and used for all crises in anesthetic practice. Evidence was sought to establish (1) whether cognitive aids improve performance of individuals and teams and (2) whether recommendations can be made for future cognitive aid design, testing, and implementation.

THE PROPERTIES OF THE IDEAL COGNITIVE AID

To understand how a cognitive aid may assist someone in a crisis, it is useful to consider the properties of an "ideal" cognitive aid. During an emergency, time and cognitive resources are limited. When under stress, clinicians are less able to recall remembered lists and are more likely to become fixated.[8,9] A cognitive aid would theoretically guide stressed clinicians through a sequence of complex steps and prevent them from omitting key actions. It would also ensure that the sequence was the most effective for the situation and that unnecessary or extraneous measures were not taken. For this to happen, the cognitive aid must have the following properties: (1) Its content

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Table 1. A Terminology of Standardized Practices[4]

Term	Function	Format	Comment
Procedure (Standard Operating Procedure)	Sets out the expected standard for performing an operation or task	Lengthy and detailed document	May have legal implications if not followed
Protocol	Summarizes a complex set of procedures	Less detailed document than procedure	Potential legal implications if referring to a specific enforceable procedure
Guideline	Describes ideal actions to perform a task, usually based on evidence from research	Often lengthy documents (e.g., cardiac resuscitation guidelines)	Usually not mandatory or legally enforced
Cognitive aid	A "memory aid" specifically designed for use at the time of completion of the task	Variable, e.g., poster, computer program, mnemonic	Takes into account specific "rules of thumb" and requirements during task completion
Algorithm	A form of protocol or cognitive aid presented as a flowchart	Usually a single page poster or document	Common format for a cognitive aid
Checklist	A type of cognitive aid listing a suggested sequence of actions	May be paper- or screen-based or presented as an auditory prompt	Extensively used in other industries (e.g., aviation)
Types of checklist			
Static parallel	One operator reads and performs tasks	Nonurgent, nonsequential checklist	Example: Preanesthesia machine checkout
Static sequential with verification	A second person reads items and an operator confirms	Sequence of actions is important	Example: "Flight deck" pilot and copilot checklist.
Static sequential with verification and confirmation	Multiple team members respond to a series of items and cross-check	Ideal for team settings with multiple different roles	Example: World Health Organization Preincision "Time Out" checklist
Dynamic	One or more team members develop a plan using a branching decision tree	Complex branching algorithm. May be too complex to use in emergencies	Example: ASA difficult airway algorithm

ASA = American Society of Anesthesiologists.

must be derived from "best practice" guidelines or protocols; (2) Its design should be appropriate for use in the context of the emergency situation; (3) It should be familiar, in a format that has been used in practice and training; (4) It should also assist other team members to perform their tasks in a coordinated manner. Researchers studying cognitive aids in aviation[10,11] and health care[12,13] have suggested that cognitive aids that are deficient in these areas of content, design, training, and team alignment may promote the wrong sequence of actions and potentially cause harmful effects.

If an inaccurate or poorly designed cognitive aid can cause harm, we must consider to what degree it should be assessed before it is used in the clinical environment. Currently, there are no formal standards for development and evaluation; perhaps a useful analogy is to conceptualize a cognitive aid as a medical device or tool that helps the user perform a task. The International Electrotechnical Commission (IEC) defines a medical device as "…any instrument, apparatus, implement, machine … software or similar or related article … for one or more of the specific purposes of—diagnosis, prevention, monitoring, treatment or alleviation of disease…"[14] A cognitive aid might arguably be within this definition, but a rigid legal application of the IEC standards to cognitive aids would be inappropriate. However, the IEC standard and other similar standards[15,16] might be used to evaluate current cognitive aids and guide future development. Standards such as the IEC 62366 and American National Standards Institute/Association for the Advancement of Medical Instrumentation HE75:2009 describe the design, development, and testing of medical devices in terms of content, format, and training, and these same principles could be applied to cognitive aids. Additional criteria for assessing the effects of the cognitive aid on team performance would also be appropriate.

Content

A medical device must possess the qualities that allow it to be applied to the task for which it is intended, termed its "Primary Operating Function." For a cognitive aid, these qualities are the content, or information presented within the aid that should represent the most suitable way that the task is performed, i.e., the information should represent best clinical practice.

Design

In the same way that a poorly designed clinical monitor may display all of the relevant physiological information, merely having the correct content on a cognitive aid is not sufficient. The important information needs to be ordered and made salient with appropriate alarms, color, position, and font type and size. A device should be designed to make the job as efficient and effective as possible, termed its "Usability Specification." The possibilities of harm from improper or unintended use should also be considered ("Hazard Identification"). The design should be evaluated against testable requirements; refining the device's characteristics is usually an iterative process. Poor design of cognitive aids in aviation have caused unintended effects, such as the shutdown of the wrong engine during an emergency.[10] There is no reason to assume that poorly designed cognitive aids in health care would not also lead to errors such as following the wrong arm of an overly complex flowchart.[12]

Training

The appropriate training for the users should also be considered both in general terms of who will use the device, termed "User profiles," and the training that is specific to the device. It could be argued that training in the use of a simple device is merely compensating for an inadequate design. But, training may improve the familiarity with a cognitive aid and enhance the chance of it being used effectively, even if it is an apparently simple presentation like a poster or paper checklist.

Individual Versus Team Performance

Given the nature of anesthetic emergencies, in which multiple tasks are undertaken concurrently, a cognitive aid must support both the individual and the team in managing the emergency. A cognitive aid that distracts and interrupts the team from performing their tasks may increase the risk of errors and have the opposite of the intended effect. A partial solution to this problem of distraction can be found in aviation where, in times of high workload such as takeoff and landing, only information directly related to that specific phase of flight is communicated.[17] Nevertheless, even an apparently "perfect" cognitive aid may still distract clinicians when used in context and some degree of education about how to use the aids seems unavoidable.

In this review, evidence will be examined to determine:

1. Whether written cognitive aids are of benefit to both individuals and teams during emergencies in anesthesia.
2. Whether recommendations can be made for improving the development, testing, and acceptance of future cognitive aids.

Specifically, this review is aimed toward the use of cognitive aids during crises, as this is one circumstance where they have been suggested to have a substantial role in improving safety.

METHODS

A literature search was performed for articles describing the use of cognitive aids in anesthetic emergencies. The MEDLINE (full database from 1950), EMBASE, Cochrane library, and PsycInfo databases were searched in all fields and MeSH for the terms "anesthesia/anaesthesia," and for each of the terms: "algorithm," "checklist," "cognitive aid," "standard operating procedure," and "guideline." No restrictions on language were made, and the search criteria were as broad as possible to ensure the literature was comprehensively covered. The reference lists of the articles selected for review were also scanned to identify additional studies not found using the original search terms. Articles were included if they met the following criteria:

- A cognitive aid was used or tested (papers merely referencing the development or existence of cognitive aids were excluded).
- The paper was specifically relevant to emergencies encountered in anesthetic practice such as airway emergencies or cardiac events.
- The cognitive aid related to anesthetic emergencies rather than the routine care to prevent emergencies such as machine checkouts.
- The paper described a cognitive aid that was not only for an educational or assessment purpose.

Papers were also included if they involved the use of a cognitive aid by a group other than anesthesia providers and if the aim of the aid was to assist in emergencies that might also occur during anesthetic care (e.g., the management of cardiac arrest). For each of the papers included, 6 aspects were used to examine the content, design, and training:

- How the content of the cognitive aid was derived
- How the aid was designed
- How the aid was evaluated, such as surveys of perceived usefulness, performance data in real or simulated settings, or patient outcomes
- Whether education had been provided on the use of the aid
- Effects on team functioning
- Evidence of successful implementation as demonstrated by accepted use in the clinical environment or improved clinical outcomes.

RESULTS

A flowchart of the search strategy and results are given in Figure 1. The Cochrane, EMBASE, MEDLINE, and PsycInfo database searches produced 18, 4222, 4472, and 55 results, respectively.

After a manual review of their abstracts, most articles were rejected because they did not refer to the use of a

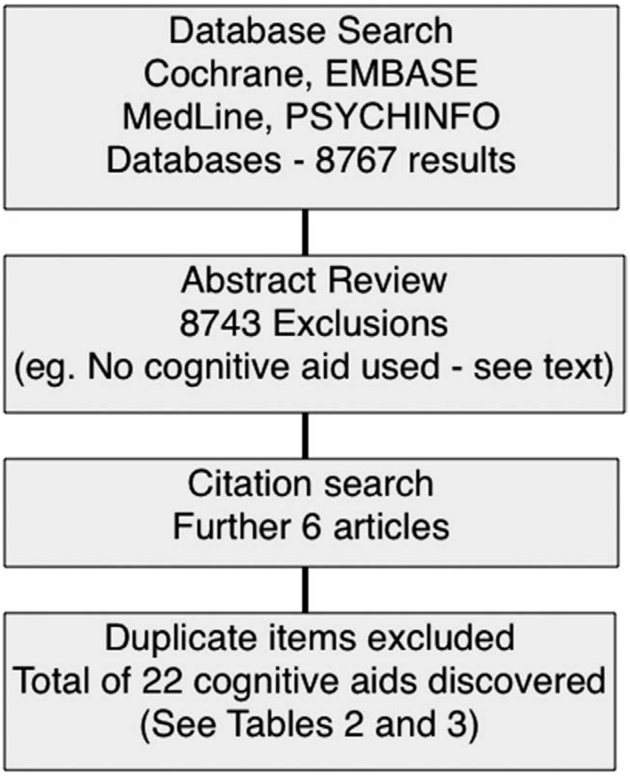

Figure 1. Literature search process.

specific cognitive aid. In total, 22 cognitive aids were found described in 23 evaluation papers. One cognitive aid was evaluated in 3 separate studies,[18–20] and 1 study evaluated 2 different cognitive aids.[18] Table 2 presents the studies reporting the cognitive aids, focusing on their content and how their content was developed. Table 3 presents the same studies, but focuses on how the cognitive aids were evaluated.

Content of the Cognitive Aid

Seven of the 22 cognitive aids were developed to help in a range of anesthetic crises, whereas the rest helped with specific crises or related groups of crises such as cardiac arrest or airway emergencies. The Abbreviated Stanford Manual was developed from one of the earliest cognitive aids found for a variety of crises in anesthesia, the crisis management handbook by Gaba et al.,[22] now nearly 20 years old.

The content of 13 cognitive aids was derived from existing national guidelines[18,19,26,29,30,32–37,40,42] including all of the aids relating to management of cardiac arrest of adults[32–37] and neonates.[40] This may reflect the existence of established national and international guidelines for cardiopulmonary resuscitation.

Most of the aids with content derived from local expert consensus did not explain how the content was decided upon. The exception to this was the Australian Patient Safety Foundation (APSF) crisis management handbook,[24] which has been extensively documented.[23] A series of 7 national meetings of up to 100 anesthesiologists per meeting was held, and a consensus for ideal management was reached for each crisis. The authors subsequently condensed this content into a 74-page manual that used a common mnemonic for many emergency situations in anesthesia.

Design of the Aid

The 22 cognitive aids discovered by this search were presented in forms as diverse as handbooks, cards, posters, or desktop or handheld computer-based help systems (Table 2). Two of the studies did not describe how the aid was presented.[28,29]

For 11 of the 22 cognitive aids, the design process was not described. Mills et al.[34] described a subjective method of design by a working group, with the addition of an index and ring for attachment to the code cart. Participants reported that the additions improved the ease of use, although none of the questions in a later survey specifically addressed aspects of design. Only 1 of the 22 cognitive aids was developed using an iterative method that is the standard for other medical devices.[27]

Evaluation of the Aid

The cognitive aids were evaluated by surveys, simulation studies, and analyses of case reports (Table 3). The 3 studies that collected survey data[21,34,41] concentrated mainly on how often the aid was used and how aware clinicians were of it in the clinical setting. These survey data will be dealt with in the section on implementation. Where the cognitive aids were tested, it appears they were not measured against any criteria, and in only 1 was the design altered to improve the usability as suggested by the international standards for medical devices (IEC 62366 Sections 5.6 and 5.9).[14]

Simulation-based studies were used to evaluate whether the cognitive aids could be useful in emergencies. In 13 studies, researchers assessed technical performance such as speed of task completion and number of errors and omissions.[18,19,25–27,31–33,36–38,40,42] All but one of the studies used a part task trainer or mannequin-based simulators. The exception was the study by Berkenstadt et al.[25] that used a screen-based computer simulator to determine whether an electronic help system reduced the number of knowledge-based errors.

Ten of the 13 studies suggested an improvement in technical performance in diverse activities ranging from the management of an airway to managing malignant hyperthermia crises. Two of the remaining 3 studies showed no improvement in neonatal (Bould et al.[40]) and adult (Schneider et al.[32]) resuscitation. Coopmans and Biddle[26] showed a longer delay to diagnose and intervene during emergencies when a personal digital assistant device was provided.

Observational studies and case reports have also been used to determine the effect of introducing cognitive aids. Both Heidegger et al.[28] and Combes et al.[29] observed fewer failed intubations when a standardized approach was used. Marshall and Flanagan[39] reported that treating anesthesiologists believed that successful management of malignant hyperthermia was due to the use of a cognitive aid improving their task management, reducing omissions, and improving team performance.

The Australian Patient Safety Foundation took a larger scale approach by retrospectively analyzing thousands of incident reports from a national database. The first 2000 reports were used to determine whether a standardized approach (the “COVERABCD” algorithm) could have prevented or mitigated the incident using a “walkthrough” of the algorithm described by the cognitive aid.[23] They found that 60% of incidents could have been rectified in <1 minute had the aid been used.

Training in the Use of the Cognitive Aid

Reports of formal orientation to the users about the cognitive aid were found in 8 of the 23 evaluation studies.[18,25–27,32,33,36,37] In 3 of the remaining 15 studies, the cognitive aid was deliberately not shown to participants before they used it, but participants were informed that a cognitive aid would be present.[31,38,40] Presumably, this strategy was taken to determine whether the aid could be used effectively without prior knowledge of its contents or structure. In 2 studies that found no difference in performance while using a cognitive aid, participants were allowed to familiarize themselves with the aid before using it.[26,32]

Effects on Team Functioning

Only 4 aids have been evaluated with regard to their effects on team functioning beyond the ability to merely perform tasks accurately and efficiently.[18,20,40,42] Manser et al.[20] observed the ability of teams to manage a malignant hyperthermia crisis when they referred to cognitive aids on personal digital assistants or cards that they carried. Teams that scored highly on a clinical performance score were more likely to discuss their assessment of the situation than the division of tasks. It was suggested that the cognitive

Table 2. Summary of Cognitive Aids (Grouped by Type of Incident That the Aids Were Designed to Address) and How the Aid Was Developed and Designed with Related Publications

Cognitive aid (papers describing evaluation)	Purpose of cognitive aid	Source content	Presentation	Design process
Abbreviated Stanford manual (Neily et al., 2007[21])	Management of a range of anesthetic crises	Local expert consensus derived from book by Gaba et al., 1994[22]	Booklet designed for use in the OR/ electronic download	Not stated
Australian Patient Safety Foundation (Runciman et al., 2005 [23])	Management of a range of anesthetic crises	National expert consensus conducted by the Australian Patient Safety Foundation, 1996[24]	Handbook designed for use in the OR. A common approach is used with further subalgorithms	Not stated
Computerized help system (Berkenstadt et al., 2006[25])	Management of a range of anesthetic crises	Local expert consensus	Online electronic help system	Not stated
PDA device (Coopmans and Biddle, 2008[26])	Management of a range of anesthetic crises	National expert consensus	Personal digital assistant	Not stated
OR Critical Event Checklist (Ziewacz et al., 2011[27])	Management of 12 common operating room crises	Local expert consensus	Booklet of checklists	Iterative testing using immersive simulation
Swiss airway algorithm (Heidegger et al., 2001[28])	Management of the difficult airway	Local expert consensus	Not stated	Not stated
Modified ASA algorithm (Combes et al., 2004[29])	Management of the difficult airway	National consensus guidelines	Not stated	Not stated
ASA algorithm (Berkow et al., 2009[30])	Management of the difficult airway	National consensus guidelines	Laminated poster of ASA difficult airway algorithm	Not stated
NASA airway checklist (Seagull et al., 2007[31])	Airway management by novices	Local expert consensus and task analysis	Audiovisual computer-based prompts for intubation versus traditional paper-based version with written instructions and diagrams	Not stated
Helper computerized prompts (Schneider et al., 1995[32])	Management of cardiac arrest emergencies	National consensus guidelines	Displayed prompts on touch screen computer	Not stated
ARC 1993 guidelines: long and short (Ward et al., 1997[33])	Management of cardiac arrest emergencies	National consensus guidelines	Two wallet-sized "checklists" (termed "long" and "short") with actions required during a cardiac arrest	Not stated
Modified AHA Handbook (Mills et al., 2004[34])	Management of cardiac arrest emergencies	National consensus guidelines	Handbook designed for use in cardiac codes to be kept on the code cart. Tabbed pages introduced for easy navigation	Not stated
EMD-aide (Dyson et al., 2004[35])	Management of cardiac arrest emergencies	National consensus guidelines	Paper representation of mnemonic sent by post	Not stated
Cell phone prompts (Merchant et al., 2010[36])	Management of cardiac arrest emergencies	National consensus guidelines	Audio prompt only via cell phone	Not stated but pilot tested with 3 volunteers
iResus app. (Low et al., 2011[37])	Management of cardiac arrest emergencies	National consensus guidelines	Displayed flowchart on smartphone	Not stated
Pilots' checklist (Hart and Owen, 2005[38])	Management of general anesthesia for emergency cesarean sections	National expert consensus	Electronic auditory prompts of actions required for general anesthesia for emergency cesarean section	Not stated (existing aviation checklist device)
OCA poster (Burden et al., 2012[18])	Management of obstetric cardiac arrest	National consensus guidelines	Laminated posters	Not stated
MHAUS poster (Harrison et al., 2006[19]; Manser et al., 2009[20]; Burden et al., 2012[18])	Management of malignant hyperthermia crises	National consensus guidelines	Participants' own textbook, or personal digital assistant (Harrison and Manser). The MHAUS poster was available in all studies	Not stated
Australian MH cards (Marshall and Flanagan, 2007[39])	Management of malignant hyperthermia crises	Local expert consensus	Task cards, with lists of actions for each team member	Not stated
NRP poster (Bould et al., 2009[40])	Management of neonatal resuscitations	National consensus guidelines	Poster for use in neonatal resuscitation with clinical situation and suggested desired actions	Not stated
AAGBI LA toxicity poster (Picard et al., 2009[41])	Management of local anesthetic toxicity	National expert consensus	Checklist of actions and recommended doses of Intralipid®	Not stated
ASRA LA toxicity poster (Neal et al., 2012[42])	Management of local anesthetic toxicity	National consensus guidelines	Checklist of actions and recommended doses of Intralipid®	Not stated

ASA = American Society of Anesthesiologists; PDA = personal digital assistant; OR = operating room; EMD = electromechanical dissociation; NASA = National Aeronautics and Space Administration; ARC = American Red Cross; OCA = Obstetric Cardiac Arrest; MHAUS = Malignant Hyperthermia Association of the United States; MH = malignant hyperthermia; NRP = Neonatal Resuscitation Program; AAGBI = Association of Anaesthetists of Great Britain and Ireland; LA = local anesthetic; ASRA = American Society of Regional Anesthesia and Pain Medicine.

Table 3. Methods of Evaluation and Outcomes for Each of the Cognitive Aids (CAs) Tested

Paper (CA)	Method of evaluation	Test subjects	Education	Comment
Runciman et al,. 2005[23] (Australian Patient Safety Foundation)	Retrospective analysis of reported cases	Anesthesiologists reporting critical incidents (2000 cases)	None	Claimed that 60% of incidents would be addressed in 40–60 s using the aid
Berkenstadt et al., 2006[25] (computerized help system)	Randomized, controlled trial using screen-based scenarios	Trainee and specialist anesthesiologists (n = 48)	30-min familiarization session	Fewer knowledge-based mistakes when using aid in 11 of 12 scenarios (all $P < 0.01$)
Neily et al., 2007[21] (Abbreviated Stanford manual)	Survey of practitioners	Anesthesia providers (n = 596)	To some staff	Low incidence of use during emergencies of 7%
Coopmans and Biddle, 2008[26] (PDA device)	Crossover study. Time to identify, diagnose, and intervene in 2 mannequin-based scenarios	Certified Registered Nurse Anesthetists (n = 4)	Familiarization to settings and personal digital assistant	Longer duration to diagnose in one scenario when supplied with device (control 13 min, PDA 21 min and control 26 min, PDA 10 min). Shorter to intervene in one (control 30 min, PDA 13 min) and longer in the other (control 19 min, PDA 27 min) of the 2 scenarios. No effect sizes were reported perhaps due to small numbers
Ziewacz et al., 2011[27] (OR Critical Event Checklist)	Randomized controlled trial of performance in 8 immersive simulation scenarios	Operating room teams (n = 2)	Instructed in use of checklists	Reduction in the number of critical steps omitted when using the CA (control 11/46, CA 2/46, P = 0.007)
Burden et al., 2012[18] (MHAUS and OCA posters)	Observational study using a confederate actor to read prompts from CA	Anesthesiology residents (n = 28)	Lecture including introduction to CA	Successful completion of all 12 critical items in all groups using a reader (3 of these failed to reach significance due to initially high completion rates (P = 0.31, P = 0.14, and P = 0.06) but reduced team communication noted while reading CA ($P < 0.001$)
Heidegger et al., 2001[28] (Swiss airway algorithm)	Observational study of failed airway management	Physician and nurse anesthetic practitioners (n = 80)	Not stated	Demonstrated low incidence of failed airway management using a standard approach (6/13,248 cases)
Combes et al. 2004[29] (modified ASA algorithm)	Management of the difficult airway	Specialist anesthesiologists (n = 41)	Two-month period of skills training	Low incidence of failed airway using a standard approach (100 difficult intubations: 80 rescued using gum-elastic bougies, 15 rescued using intubating laryngeal mask airway, 2 awoken, 3 deviated from algorithm). Transient hypoxemia occurred in 16 patients
Seagull et al., 2007[31] (NASA airway checklist)	Accuracy and time to perform tasks on mannequin	Novices with no health care experience (n = 14)	None	Improved speed for 4 of 6 tasks ($P < 0.05$) and accuracy for 3 or 4 tasks ($P < 0.01$) when using multimedia- versus paper-based aid
Berkow et al., 2009[30] (ASA algorithm)	Historical incidence of emergency surgical airway procedures	Data taken from a large hospital with over 27,000 cases per year. Number of anesthesiologists not stated	Formal yearly education program. No reference to specific education on CA	Reduction in number of surgical airways over 14 y from 6.5 per year to 2.2 per year. Multiple interventions and introduction of new devices. Not solely due to CA
Schneider et al., 1995[32] (helper computerized prompts)	Randomized controlled trial of CA versus no CA	Anesthesia residents (n = 39)	Participants given up to 30 min to familiarize themselves with device	Little difference in performance between groups in managing ventricular fibrillation, with epinephrine and lidocaine given by both groups (P = 0.58 and P = 0.16). Lidocaine dose was more frequently correct (P = 0.015). More medications and infusions were given by CA group ($P < 0.001$)
Ward et al.[33] (ARC 1997 guidelines: long and short)	Randomized trial of performance of advanced life support on mannequin	Undergraduate students (n = 169)	Advanced life support training session with aid	A detailed checklist improves advanced life support skills 2 mo after training (overall $P < 0.01$)
Mills et al., 2004[34] (modified AHA handbook)	Survey of practitioners at target hospitals	Twenty nursing and medical staff at each of 50 sites (n = 1000)	Single didactic session with some staff	Poor response rate (56.5%). Many of those who responded (41%) were not aware of the CA

(*Continued*)

Table 3. (Continued)

Paper (CA)	Method of evaluation	Test subjects	Education	Comment
Dyson et al., 2004[35] (EMD-aide)	Recall of all 8 causes of EMD after access to 2 posters for a 4-wk period	Junior residents ($n = 149$)	Access to CA for 4 wk prior	No difference between the 2 CAs in recall of all 8 items ($P = 0.068$)
Merchant et al., 2010[36] (Cell phone prompts)	CPR effectiveness on part task trainer	Lay persons aged 18–60 y ($n = 160$)	One-minute tutorial on how to use the telephone speed dial function	Improved quality of CPR with CA regardless of a lack of previous resuscitation education. Compression rate ($P < 0.001$), depth ($P = 0.005$), and hand placement ($P < 0.001$) all improved
Low et al., 2011[37] (iResus app.)	Randomized controlled trial of performance metrics in simulated environment	Junior doctors ($n = 31$)	Ten-minute tutorial on use of iPhone application	Improved performance of CPR during simulated emergency with CA ($P = 0.02$)
Hart and Owen, 2005[38] (Pilots' checklist)	Randomized controlled trial in simulated environment	Experienced trainee and specialist anesthesiologists ($n = 20$)	None	Low numbers of items omitted (13/40, range 7–23) with the CA
Harrison et al., 2006[19] (MHAUS poster)	Observational study comparing performance with use of aid	Teams of junior anesthesiologists ($n = 48$)	None	Improved treatment scores in simulated environment when using aid for 2 groups (Spearman $r = 0.59$, $P < 0.01$ and Spearman $r = 0.68$, $P < 0.001$). Not blinded
Manser et al., 2009[20] (MHAUS poster)	Observational study comparing performance with use of aid	Teams of junior anesthesiologists ($n = 20$)	None	Coordination patterns noted to be different when CA was used (overall $P < 0.001$) with less task distribution ($P < 0.01$) and more situation assessment ($P < 0.05$). Not blinded
Marshall and Flanagan, 2007[39] (Australian MH cards)	Anecdotal evidence only	Not applicable	None	Reports of successful use in real cases
Bould et al., 2009[40] (NRP poster)	Performance of tasks, nontechnical skills assessment	Anesthesia residents ($n = 32$)	None	No improvement of technical skills ($P = 0.08$) or nontechnical skills ($P = 0.11$) with CA
Picard et al., 2009[41] (AAGBI LA toxicity poster)	Survey of facilities	Not applicable	Not applicable	Delayed uptake of guidelines after publication with 50% of facilities not implementing guidelines until over 1 y following publication of guidelines
Neal et al., 2012[42] (ASRA LA toxicity poster)	Randomized controlled trial of performance metrics and team working scores in simulated environment	Anesthesia trainees ($n = 25$)	None, but CA provided 4 wk before study	Improve technical performance with CA ($P < 0.001$). No improvement in overall teamwork score but underpowered to detect this ($P = 0.143$)

ASA = American Society of Anesthesiologists; PDA = personal digital assistant; EMD = electromechanical dissociation; CPR = cardiopulmonary resuscitation; NASA = National Aeronautics and Space Administration; ARC = American Red Cross; OCA = Obstetric Cardiac Arrest; MHAUS = Malignant Hyperthermia Association of the United States; MH = malignant hyperthermia; NRP = Neonatal Resuscitation Program; AAGBI = Association of Anaesthetists of Great Britain and Ireland; LA = local anesthetic; ASRA = American Society of Regional Anesthesia and Pain Medicine.

aid might have affected how the teams coordinated their activities. Three studies failed to find an improvement in team functioning. Studies by Neal et al.[42] and Bould et al.[40] observed individual anesthesia trainees working with "actors" performing the supporting clinical roles. No differences in nontechnical skills were found between participants using versus not using a cognitive aid in either study, although Neal et al.[42] suggested a slight improvement in the Decision Making category in the participants with the cognitive aid. Burden et al.[18] noted a reduction in the volume of communication within the team when a cognitive aid was used.

Evidence of Implementation

Evidence of implementation in the actual clinical environment was identified in 3 studies.[21,34,41] Two of these papers reported surveys of the use of cognitive aids in clinical settings. In each of these surveys only half of the respondents reported that they either would use or had used cognitive aids in emergencies.

DISCUSSION

The literature on cognitive aids in anesthesia emergencies appears to be expanding rapidly; 9 of the 23 articles found published in the last 3 years. Given the broad nature of the search and manual review of the papers, all of the cognitive aids currently available for anesthetic emergencies are likely to have been included.[43] Some cognitive aids that may improve patient safety, such as the World Health Organization Surgical Safety Checklist,[44] have not been included as they are not generally used during an emergency. There is some evidence that cognitive aids improve technical performance during emergencies, but there is much to be learned about when and why they fail.

Drawing the analogy between cognitive aids and medical devices may help us understand when and in what form cognitive aids may be useful. In common with medical devices, cognitive aids need to have the correct content, be well designed, and be accompanied by appropriate training to assist task performance. The content or knowledge contained in cognitive aids should be developed from national or international guidelines or from broad consensus. To ensure continuing usefulness, their content needs to be reviewed and adapted as knowledge changes.

The content seems to have been the main focus during the development of most cognitive aids, with more than half being derived from established guidelines. In contrast, the design processes, presentation, and the resultant usability of cognitive aids seem to have been less thoroughly considered. Only one of the cognitive aids was developed with a systematic design process and adapted as a result of evaluation data.[27] Evidence from the human factors literature suggests that poorly designed cognitive aids may lead to unintended consequences.[10,13] The use of a human factors design process, as mandated for medical devices,[45] may help to reduce the likelihood of poor design but will not eliminate it. It is also important to select appropriate measurements and testing scenarios, and then revise the design appropriately. There is little evidence that the majority of cognitive aids discovered in this literature review have been designed for the context in which they are to be used. Physical constraints of using aids, such as the ability to read, see, hear, or interact with the paper or computer-based aid, potential distraction caused by the aid, and the ability to perform concurrent tasks have not been addressed. These contextual issues could make aids very difficult to use in the actual working environment and may reflect the apparent negative effects on team communication that have been reported.[18] Research is currently lacking in this area not only in anesthesia and health care but also in other industries, despite the acknowledgment that checklist design has been a contributing factor in several airline accidents.[11] There are functional differences between a long, nonsequential checklist and dynamic decision tree, and the design chosen depends on the intended context (Table 1).

Despite the perceived benefits to the team, there is minimal evidence to support an improvement in team function with the use of cognitive aids. Data suggest that cognitive aids may change team coordination and improve task completion but their effects on team processes are not clear. In particular, the study by Burden et al.[18] into the effects of a designated reader demonstrated decreased communication by the team. Reduction in team communication is generally considered deleterious to team coordination,[46] and as such the aid may have distracted the team from communicating with each other. Conversely, it may be that the remaining communication was more efficient and targeted. Further studies are needed to determine how cognitive aids affect interpersonal communication during anesthetic emergencies.

Training in the use of a cognitive aid appears to be often cursory or absent. It is reasonable to assume that familiarization to a cognitive aid before its use would mean that the participants would be more likely to use it and use it more effectively. This increased likelihood of use after education is supported by responses to Mills et al.'s survey[34] about a cognitive aid for cardiac arrest management: those who had learned about the aid from a formal orientation session were more likely to use it in an emergency than those who were not oriented to the aid. Research shows that education raises awareness of the presence of the aid and helps identify how and when the aid should be used, both stimulating its use and making its use more effective.[47] The counter argument is that a cognitive aid should be intuitive to use in an emergency situation, and that educating people to use a cognitive aid merely compensates for a poor design. Ideally, as with any medical device, for the best results the cognitive aid should be intuitive to use and should also be used only by individuals trained in its use.

Reports of implementation into clinical practice demonstrate that even when clinicians are aware of the existence of cognitive aids they often do not use them. Part of the problem of the underuse of cognitive aids may be the existence of a professional culture that does not support their use. For example, when observing the use of cognitive aids in malignant hyperthermia crises, one of the participants in Harrison et al.'s study[19] reported the view that using a cognitive aid reflected a lack of confidence or knowledge. Several other studies also report participants' comments that they did not need the cognitive aid to manage the emergency effectively.[19,21,34,40] In contrast, the results of Low et al.'s study[37] with junior doctors suggest a willingness to use cognitive aids, and their feeling that using them does not reflect a lack of competence of health professionals. A further issue that is rarely addressed is the positioning of the cognitive aid. A reminder of the aid and therefore prompting to use it can be improved by associating the aid with the task in the same way that any prospective memory task can be prompted.[48] For example, the cognitive aid for management of local anesthetic toxicity may be positioned with the Intralipid® on an emergency cart.

A recent editorial suggested that cognitive aids should be available for all rare emergencies in anesthesia[7] but this poses more questions, such as who creates, updates, and designs the cognitive aids. A regular formal review of laboratory and clinical evidence by a reputable body would be required for each emergency. The process currently used for the management of cardiac arrest by the International Liaison Committee on Resuscitation[49] would seem to be the ideal template. Levels of evidence should ideally be included and should lead to a consensus about the actions required during the emergency. This information would then be passed to a human factors design team for design, testing, and modification based on heuristic and simulation evaluation. Only then would the guidelines be available for distribution.

Cognitive aids are not commonly used during emergencies in anesthesia and at present appear not to be supported by the culture. For cognitive aids to be more broadly accepted, further evidence may be needed that they confer benefits in emergency situations. Although we know that practitioners' coordination patterns change when a cognitive aid is used, there is a need for larger prospective trials of the effect of aids on task completion, practitioners' team behaviors, and overall team functioning. Such trials will allow a deeper understanding of how teams may use an aid to best allocate roles so that they can rapidly process tasks in parallel. The trials should use robustly researched and designed aids and should assess outcome measures of accurate and rapid task completion as well as process measures of team behaviors. Testing would best occur in simulation-based settings, where the physiological variables and environment can be more tightly controlled and replicated, and there are no direct risks to patients.

Cognitive aids should be integrated into anesthesiologists' vocational and continuing education so that practitioners are aware of when and how to use them appropriately. Continuing education programs have started to advocate the use of cognitive aids in emergencies through simulation-based education[50] but such education is not readily accessible to all anesthesia providers. Any future testing of cognitive aids in simulation-based settings should first let practitioners become oriented to the aids. The maximum benefit is likely only if practitioners are familiar with the structure of each aid, and how it should be used.

As this literature review has shown, the current evidence for the efficacy of cognitive aids in emergencies is inconclusive. However, although the evidence to support the use of cognitive aids in emergencies is currently weak, the success in other settings is compelling. The lack of evidence is due to both the limited research that has been performed and the deficiencies in design and evaluation of current cognitive aids. By conceptualizing cognitive aids as medical devices, we may be able to address these deficiencies and improve the outcomes of patients experiencing anesthetic emergencies.

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