"However Beautiful the Strategy, You Should Occasionally Look at the Results": Sir Winston Churchill and Medical Checklists

Alexander F. Arriaga, MD, MPH, ScD,*† David L. Hepner, MD, MPH,†‡ and Angela M. Bader, MD, MPH†§

In this issue of *Anesthesia & Analgesia*, Burian et al[1] submit a contribution on medical checklists titled "More than a Tick Box: Medical Checklist Development, Design, and Use." They note that the acceptance of checklists by clinicians requires a systematic and comprehensive development process, a notion with which few would disagree. In the form of a special article, the authors present a proposed comprehensive framework for consideration in guiding the development and design of checklists to be effective and harmonious with the flow of medical and perioperative tasks.

As Sir Winston Churchill stated, "However beautiful the strategy, you should occasionally look at the results." Comprehensive blueprints without supporting research results are, at best, untested opinions.

There are now numerous original research studies supporting the use of checklists that are relevant to the anesthesiologist, ranging from routine care[2–5] to operating room crises.[6–8] The results of this previous research include improved provider performance, reductions in patient morbidity/mortality, and other valuable outcomes. In order for checklists to be tested in these previous studies, they of course first had to be developed, and many of these articles comment on their development process within the context of a formal research design.[9] Burian et al[1] address the paucity of dedicated articles on development/design by providing an expanded opinion piece, from a multidisciplinary set of authors consisting of a National Aeronautics and Space Administration (NASA) psychologist and scientist, as well as anesthesiologists from the University of Chicago.

It is important to separate that which is an opinion piece from a research contribution. Both can provide value, albeit in different ways. In their article, Burian et al[1] note that they "reviewed articles in the PubMed database," but the reader should be reminded that they do not claim to have performed a systematic review of the literature or meta-analysis, both of which are available in the peer-reviewed literature on various aspects of checklists in medicine.[10–12] This is perhaps why they claim to only have found 2 articles involving critical event/emergency checklists in the past 5 years that are relevant to their contribution. We, as the authors of 1 notable study on crisis checklists published in the past 5 years,[6] know that there are more articles that have given valuable insight to the many topics Burian et al[1] cover in this opinion piece. Further, limiting one's search on a topic of this scope to the past 5 years neglects the decades of peer-reviewed work published in this area. There are also landmark publications not commonly found via PubMed.[13] This may be why, for example, we had difficulty interpreting their Figure on "Purposes of Medical Checklists," which places a "critical event checklist" conceptually shifted to the opposite side of "evaluate or confirm information" (in an operating room fire, eg, there may be several steps done instinctively by a provider, with a crisis checklist or emergency manual then being used to confirm that everything was done). It also may explain why their Figure of a sample crisis checklist on bradycardia has elements with which we would disagree.

Regarding the use of a linear design for intraoperative crisis cognitive aids, this topic has been studied.[14] In a simulated anaphylaxis scenario, teamwork, communication, and overall performance were improved when a cognitive aid was used rather than with memory alone. Furthermore, a linear design in the checklist improved team performance more effectively in the simulated anaphylaxis scenario than a complex branched checklist. The authors of that study postulated that it may be easier with a linear rather than a branched cognitive aid, because it was easier for a reader to call out the items and provide a summary to the team and for team members to respond. The authors acknowledge that this may be different for an electronic version of a cognitive aid and that further research is necessary regarding checklist design. We could not agree more with these authors.

A recent review of the use of cognitive aids during anesthetic emergencies suggested that, in order for cognitive

From the *Department of Anesthesiology and Critical Care, University of Pennsylvania Health System, Philadelphia, Pennsylvania; †Department of Anesthesiology, Perioperative and Pain Medicine, Brigham and Women's Hospital, Boston, Massachusetts; ‡Ariadne Labs, Boston, Massachusetts; and §Center for Surgery and Public Health, Boston, Massachusetts.

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Address correspondence to David L. Hepner, MD, MPH, Brigham and Women's Hospital, 75 Francis St, Boston, MA 02115. Address e-mail to dhepner@partners.org.

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aids to be helpful, the content needs to be kept up to date.[15] In addition, it demonstrated that designs of cognitive aids were seldom considered. Our experience developing and designing a set of operating room checklists involved a multidisciplinary expert panel consisting of operating room directors, surgeons, anesthesiologists, nurses, specialists in simulation and surgical education, and a lead checklist developer from the Boeing Aircraft Corporation. Thoughtful implementation includes maintaining checklists that are usable, contain the key content that is at the greatest risk of being missed, and is coupled with training efforts. We have had multiple iterations of our checklists, we included a graphic designer in our efforts, and we modify them as knowledge evolves.

There is value in concepts such as "rules of thumb," but they again should be separated from statements based on science. Although the authors propose that a crisis checklist be geared toward a new attending physician during development, this is not substantiated with any evidence or data. We remind the readers that, in our simulation-based randomized controlled trial published in the *New England Journal of Medicine*, our participant teams included nurses and anesthesia providers with over 15 years of experience in their specialty. In that trial, every team performed better when the crisis checklists were available than when they were not.[6]

While the vast majority of their informal literature search was on the words "develop* (develop, developed, developing, development)" and "design," their blueprint makes claims to testing and validation, training and implementation, and ongoing evaluation, revision, and possible retirement. The authors attempt to reconcile this by creating a definition of *development* that encompasses the "entire checklist lifecycle," essentially conflating this term with postdevelopment testing, health policy, principles of implementation sciences, and the many steps that follow development. We argue that this approach could dangerously lead to a proliferation of checklists that are "developed," but fall short on science and policy with regard to the critical elements that come after a checklist is expertly created.

Nevertheless, opinion pieces provide inherent value. It should be viewed as a success when research not only leads to improved outcomes, but also a forum of discussion from other specialties. The lead author of their work is a senior research psychologist in the Human Systems Integration Division at NASA, and she provides insightful comments on design that may be hard to find elsewhere. Her external validation of principles such as use of certain fonts and use of enough white space to enhance readability are invaluable. The commentary on accomplishment methods (ie, Do and Confirm, Read and Do, Flow), written by a lead author from NASA, is a contribution to the medical literature. This only emphasizes the importance of scientific work that involves multidisciplinary expertise, not only within medicine but across other industries.

With regard to collaboration, their subtle note on "checklist retirement" of certain checklist designs, while possibly well intentioned, may unnecessarily foster internal competition within a movement in its infancy. There is no universal standard for crisis checklists or emergency manuals to even be available, let alone used, during an operating room crisis. Any patient safety or scientific tool should undoubtedly undergo refinement and evolution, as well as local customization. Customization at the institutional level is critical for checklist usability and relevance, and is strongly encouraged in the checklist literature.[6] We hope that the priority discussion at this point is not *which* crisis checklist/emergency manual version to universally use in an emergency, but rather a cultural acceptance that patients and providers may be better off if rare and life-threatening events were not just managed by "memory alone." The Emergency Manuals Implementation Collaborative was created to "foster the adoption and effective use of emergency manuals to enhance our patients' safety."[16] It does not limit itself to 1 version of crisis checklist or emergency manual, but rather has links to different versions that different institutions have found helpful via efforts such as scientific testing and local implementation. A listing of these crisis checklists and emergency manuals can be found at www.emergencymanuals.org.

In summary, opinion pieces play a role in generating discussions, but we must be careful not to substitute opinion for evidence-based scientific validation of checklist methodologies. We hope that Burian, et al's[1] article "More than a Tick Box: Medical Checklist Development, Design and Use" will serve to remind clinicians of the importance of careful development and testing of health care innovations to ensure success.

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Contribution: This author helped prepare, write, and edit the article.
Name: David L. Hepner, MD, MPH.
Contribution: This author helped prepare, write, and edit the article.
Name: Angela M. Bader, MD, MPH.
Contribution: This author helped prepare, write, and edit the article.
This manuscript was handled by: Nancy Borkowski, DBA, CPA, FACHE, FHFMA.

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More Than a Tick Box: Medical Checklist Development, Design, and Use

Barbara K. Burian, PhD,* Anna Clebone, MD,† Key Dismukes, PhD,* and Keith J. Ruskin, MD†

Despite improving patient safety in some perioperative settings, some checklists are not living up to their potential and complaints of "checklist fatigue" and outright rejection of checklists are growing. Problems reported often concern human factors: poor design, inadequate introduction and training, duplication with other safety checks, poor integration with existing workflow, and cultural barriers. Each medical setting—such as an operating room or a critical care unit—and different clinical needs—such as a shift handover or critical event response—require a different checklist design. One size will not fit all, and checklists must be built around the structure of medical teams and the flow of their work in those settings. Useful guidance can be found in the literature; however, to date, no integrated and comprehensive framework exists to guide development and design of checklists to be effective and harmonious with the flow of medical and perioperative tasks. We propose such a framework organized around the 5 stages of the checklist life cycle: (1) conception, (2) determination of content and design, (3) testing and validation, (4) induction, training, and implementation, and (5) ongoing evaluation, revision, and possible retirement. We also illustrate one way in which the design of checklists can better match user needs in specific perioperative settings (in this case, the operating room during critical events). Medical checklists will only live up to their potential to improve the quality of patient care if their development is improved and their designs are tailored to the specific needs of the users and the environments in which they are used. (Anesth Analg 2018;126:223–32)

Few clinicians appear to be undecided when it comes to medical checklists—these tools tend to be liked and embraced or disliked and avoided. Despite their demonstrated efficacy in some medical settings,[1–7] perioperative checklists have yet to deliver many of their promised benefits,[8–12] and some medical professionals complain of growing "checklist fatigue" and reject them outright.[13,14] This can be attributed, at least in part, to poor design and content[2,12,15–19]; inadequate introduction and training[20,21]; unenthusiastic or incomplete application[9,22–24]; duplication with other safety checks[10]; poor integration with existing work flow[11,12,25]; and professional, institutional, and national cultural barriers.[8,13,14,26,27] Most of these issues relate to the human factors of checklist development, design, and use.[28,29] Checklists have a life cycle. They are conceived, designed, tested and evaluated, implemented, and revised or, when necessary, retired. Each of these phases requires critical decisions and actions; neglecting any of them will result in an ineffective checklist that users will dislike and ultimately ignore or discard.

Although the existing literature provides some extremely useful suggestions,[2,16,18,30–38] there is currently no comprehensive, integrated framework to guide the development and design of robust, effective medical checklists. For example, both Project Check and the Healthcare Financial Management Association (HFMA) provide "checklists" for developing medical checklists.[35,36] Both have their roots in the development of the World Health Organization (WHO) Surgical Safety Checklist and are therefore only partially relevant to non "time-out" checklists (eg, shift handovers, critical event response in operating rooms or intensive care units). Guidance is often limited in scope or broadly stated (eg, "Use simple sentence structure and basic language")[36] and often has not been updated to reflect recent research regarding human performance and cognitive psychology related to checklist design and use.[19,39]

Nonetheless, these resources provide a valuable starting point for considering checklist development and design. This article builds on this guidance to provide a comprehensive blueprint for the development or revision of medical checklists.[a] It is organized around 5 stages that should always be part of the checklist life cycle: (1) conception, (2) content determination and design, (3) testing and validation, (4) training and implementation, and (5) ongoing evaluation, revision, and possible retirement. Our blueprint incorporates important advances in the understanding of human performance, cognition, and team behavior to help advance the science of medical checklist development, design, and use to improve patient care.

The "checklist" label has been applied to everything from a tool that helps physicians figure tax deductions,[47] to a guide for manuscript peer-review,[48] to an algorithm for resuscitation during cardiopulmonary arrest,[49] to the WHO Surgical Safety Checklist.[32,50] We reviewed articles in the PubMed database published in the past 5 years to determine

From the *Human Systems Integration Division, NASA Ames Research Center, Moffett Field, California; and †Department of Anesthesia and Critical Care University of Chicago, Chicago, Illinois.

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Address correspondence to Barbara K. Burian, PhD, Human Systems Integration Division, NASA Ames Research Center, Mail Stop 262-4, Moffett Field, CA 94035. Address e-mail to Barbara.K.Burian@nasa.gov.

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[a]Several sources[40–42] also provide information that may be useful to developers of evaluation checklists, such as those used to record or evaluate the performance of students during simulation training or ensure that treatments have been completely implemented. Similarly, some useful guidance may also be found in other resources[43–46] though this guidance is specific to aviation checklists so is not completely relevant to the development, design, and use of clinical medical checklists.

the degree to which recent medical literature addresses the checklist development life cycle, but limited our review to only checklists used in clinical practice. Search terms of article titles included "checklist" AND "develop*" (develop, developed, developing, development; N = 124), "checklist" AND "design*" (design, designed, designing; N = 15), and "checklist" AND "checking" (N = 2). Of these 141 articles, 50 were discarded (38 nonclinical checklist or non-English articles, 2 duplicates, 9 abstract only, 1 no abstract nor article available) leaving 91 articles that were subjected to a full text review. Thirty of these articles are specifically relevant to anesthesiologists: perioperative period (n = 11), critical care (n = 11), obstetric anesthesia (n = 4), and pain management (n = 4). Further findings are reported below.

DEVELOPING EFFECTIVE MEDICAL CHECKLISTS

First, we must clarify some terminology. Checklist development and design are quite different concepts and should not be used interchangeably. Development refers to the entire checklist life cycle—conception, design, evaluation, use, modification, and termination. Design is one phase of development (though highly interrelated to other phases) and pertains specifically to checklist appearance, format, layout, and functioning.

Similar confusion exists in the medical literature about checklist accomplishment methods (Do and Confirm, Read and Do, Flow), the formatting of action items (challenge-response, imperative statement), means of accomplishment (read aloud or silently),[12,51] and the number of individuals involved during checklist accomplishment (1, 2, or more). "Do and Confirm" refers to checklists used to verify, after the fact, that certain actions have been performed or information has been gathered or recorded. "Read and Do" pertains to checklists used to guide actions step-by-step, in real time. (Some checklists, such as the WHO Surgical Safety Checklist,[50] combine elements of both.) The "Flow" accomplishment method is similar, in practice, to "Read and Do" but pertains to accomplishment of embodied checklists.[52,b] Written action items can be formatted in the challenge-response style (Volatile anesthetics…Off) or as imperative statements (Turn off volatile anesthetics). Any of the 3 accomplishment methods and action items formatted in either style can be performed by 1 person (text read silently or aloud) or by 2 or more people (text typically read aloud).

Conception

The first phase of checklist development is conception, which requires recognizing and analyzing a clinical concern to determine what causes and contributes to the problem. This analysis is ideally conducted by a multidisciplinary team that includes clinicians, human factors and patient safety experts, and relevant administrators.[53] The team should consider various options rather than simply deciding to construct a checklist,[18,54] which might not be the best solution.[28–30,38,55,56] This important phase is given scant attention in the literature and possibly also in practice. Only 7 of the 91 articles reviewed mentioned issues associated with conception. If a checklist is the best solution, the development team should not immediately begin writing down checklist items, but should start instead by thoroughly exploring the checklist's purpose[1] and desired outcomes (see Figure 1).

Although diverse checklist taxonomies have been proposed,[2,15,16] medical checklists can be most simply organized by the 3 overarching circumstances in which they are used[51]: (a) normal situations (eg, time-out checklists,[50] equipment setup,[18,57] shift handover,[58] procedure completion,[52] treatment guidance[1]); (b) emergencies (eg, critical event checklists)[4,59]; or (c) atypical situations that are not a part of usual daily practice but that also are not critical events (eg, a broken surgical instrument). In our review, 89 articles pertained to normal checklists, 2 involved critical event/emergency checklists, and none addressed atypical situations.

During the conception phase, developers must also consider how the planned checklist will be used (see Table 1), how it will fit into and affect existing workflow (minimal disruption is essential),[11,12,25] and how it will relate to other existing checklists or safety checks.[10,27] In what physical environment will it be used and who will participate in its accomplishment[18] and why? What presentation mode (eg, paper, electronic)[14,60] will best allow the purposes and goals of the checklist to be fulfilled?

After these questions have been answered, the development team should revisit the question of whether a checklist is the best tool to address the problem. Consistent and proper use of checklists changes how a task is accomplished by imposing standardization that did not previously exist. If standardization or a memory or decision-making aid is not needed or is already in place, then a checklist is unlikely to be a good solution.[25,61]

Determining Content and Design

Literature reviews, focus groups, Delphi consensus,[62] task analyses,[18] subject matter interviews, and personal experience are well-established methods for identifying appropriate content. Seventy-five of 91 articles reviewed reported using 2 or more of these approaches. The amount of information and level of detail to include in checklists are among the most difficult issues to resolve during development; choices are driven by competing considerations.[19,31] Highly experienced professionals may need fewer prompts and less information than more junior colleagues; under stress or high workload, however, even the most seasoned professionals experience a decrease in performance[1,25,63–65] and may forget an important step. We believe that a good rule of thumb is to gear the level of detail toward the most junior clinician expected to practice independently, and thus use the checklist without supervision—critical event checklists, for example, should be geared toward a new attending physician.

Inappropriate or unnecessary technical content undercut a checklist's effectiveness.[17–19,33,65] Medical checklists designed to ensure that every step has been executed correctly sometimes include inconsequential items or actions that can no longer be performed after the fact. For example, "Prepare the location with towel or padding under patient…" should not be included on a Lumbar Puncture

[b]Embodied checklists involve equipment, tools, or materials and it is the organization of the equipment/materials/tools itself, sometimes with additional ancillary textual or graphical information, which guides or structures its use. An example of an embodied checklist is the Central Line Dressing Change Procedure developed using the principles of adherence engineering by Drews.[52]

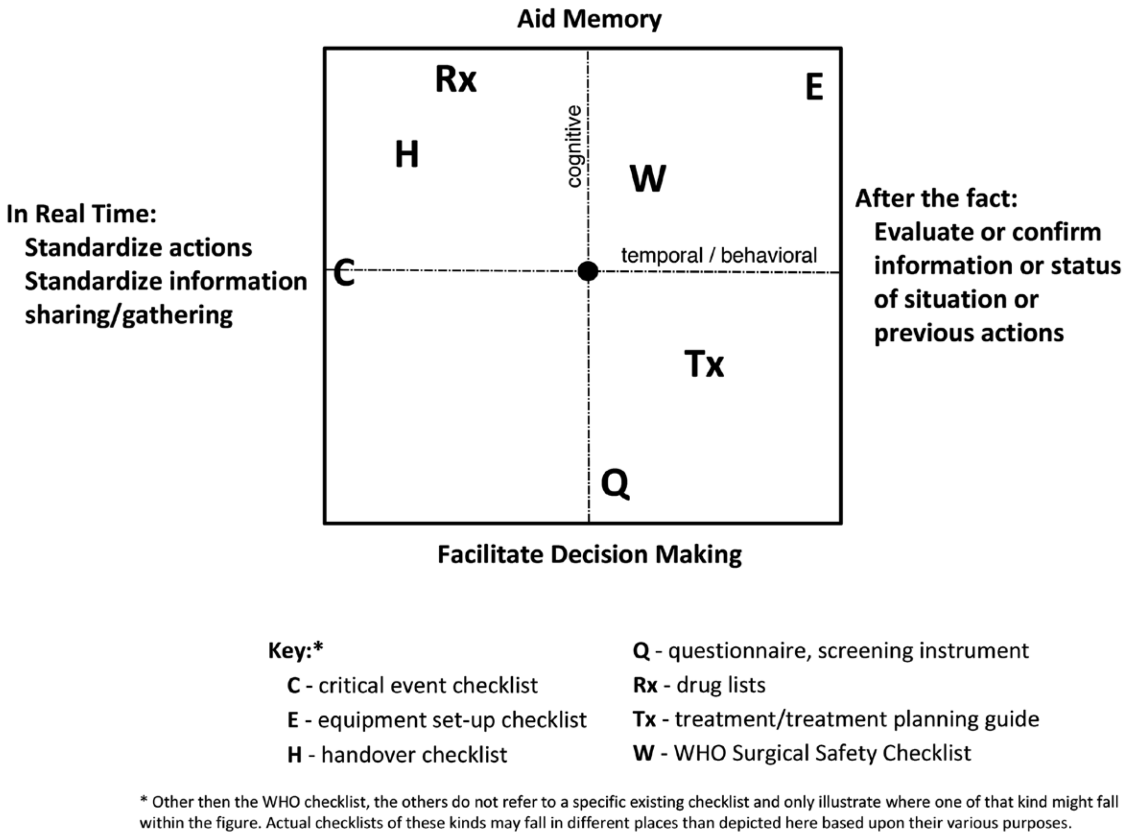

Figure 1. Purposes of medical checklists. To use: Begin on the center dot and then adjust position vertically on the "cognitive" axis according to the degree to which the checklist is needed to aid memory or facilitate decision making—staying in the center if both are needed equally. Then move left or right within the figure to the degree that the purpose of the checklist is to standardize action and/or information sharing/gathering in real time versus evaluate or confirm information or status of a situation or previous actions after the fact. Engaging in this exercise will help development teams agree to the overall purposes of their checklist. The WHO Surgery Safety checklist and other sample checklists have been placed within the figure as illustrations.

checklist that is intended to be reviewed after completion of the procedure.[16] Since checklist use may interrupt workflow,[66] content should "earn" its way into the checklist; cost (disrupted workflow) must be compared to benefit (reduced chance of human error).[18]

Aviation checklists, after which many medical checklists have been patterned,[67] may appear simple in their design and use, falsely suggesting that they should be easy to construct and implement in medicine. In fact, they are quite complex and can be exceedingly difficult to design well.[17,19,25,51,68] Additionally, medical settings are quite different than cockpits, necessitating medical checklist designs and accomplishment methods that are also quite different (see discussion of "Sampling" in the following section).

We have also observed misapplication of findings from basic cognitive psychology research,[69] such as guidance that checklists should contain no more than 5 to 7 items because of limited short-term memory capacity.[35,36] Information does not need to be retained in short-term memory when it can be referenced on a checklist, so this restriction is unnecessary. However, checklists should be no longer than absolutely needed.

A checklist's usability and effectiveness are directly dependent on a multifaceted set of interrelated development and design issues[17,19,68]; an introduction to these is presented in Table 1 (B. K. Burian, PhD, unpublished document, 2016)[17] and Figure 2. For example, the physical properties of a checklist are, in part, determined by how the information is presented (eg, paper size or type of electronic device and size of display). This influences the ease with which the checklist is accessed, its usability under various environmental conditions (eg, in a darkened procedure suite), the options available for content presentation (eg, layout, font size), and how a user navigates through the checklist, progressing from item to item.[19,70] Although the design of a medical checklist must be tailored to the setting, its purpose, and intended use, some design fundamentals can be applied to all types of medical checklists. Examples include the use of a san serif font, a clean layout (ie, enough white space to enhance readability), and a logical flow of items and information.[35,36]

The intended purpose and use of the checklist (identified during the conception phase), as well as other considerations such as cost, will guide decisions about the best presentation modality, which, in turn, will affect decisions about formatting and layout of content and the overall design and functionality of the checklist. We suggest that rapid-cycle prototyping and simulation be conducted to evaluate the utility of checklists during this stage, before significant resources are spent in later stages of development.[33,53]

Table 1. Some Factors Affecting Checklist Design[a]

Category	Elements
Type (operational use)	• Normal situations • Atypical/off-nominal situations • Critical events/emergency situations
Purpose	• Aid memory/provide information: ○ Support quick access of time-critical information ○ Support easy access to non–time-critical information • Facilitate decision making • Guide/direct/order step-by-step actions/considerations in real time • Facilitate/standardize communication/treatment/planning/information gathering across individuals or teams: ○ Structure interactions among checklist users ○ Develop/ensure a shared understanding of a situation/patient's status • Confirm that specific actions have been accomplished • Evaluate existing patient or task status or situation
How used	• Step-by-step in linear sequence; accomplished all or mostly in entirety • Step-by-step not in linear sequence; accomplished all or mostly in entirety • Step-by-step but start point varies and is not at the beginning of the checklist (commonly seen with critical event/emergency checklist use) • Sampled only for specific information
Content/item types	• Text (including numbers and abbreviations) • Pictures, drawings, sketches • Graphics, icons, emoticons/emoji • Shapes, 3-dimensional objects • Schematics • Symbols, bullets • Tables • Formulas • Videos/links to videos • Kit, materials/tools/equipment (embodied checklists only)
Presentation modality	• Paper • Mechanical • Stand-alone electronic (includes mobile devices) • Integrated electronic (receives input from sensors, electronic medical records) • Embodied (includes materials/tools/equipment put together in a structured kit)
Functionality	• Static (includes static with options for different contexts) • Dynamic (electronic presentations only) • Active error trapping/identification (electronic or embodied only) • Visual/audible alerts/alarms (electronic or embodied only)
Content presentation	• Order and timing • Grouping/sections • Formatting and layout ○ Lists/ordered lists (electronic versions may include links/hyperlinks) ○ Flowcharts ○ Tables ○ Inset text boxes/windows ○ Kit/material/tools/equipment (embodied checklists only) • Appearance and emphasis, including font, font size, bolding, use of color
Accomplishment	• Number of personnel involved ○ 1 ○ 2 or more • Means ○ Written/manual input ○ Read/conducted silently by single user ○ Read/conducted audibly by user(s) ○ Conducted audibly by user(s) and electronic checklist with an audible interface ○ Physically conducted by one user or jointly by more than one user (embodied checklists only) ○ Autonomous accomplishment through input from sensor or digital (eg, electronic medical record) data • Method ○ Do-and-confirm ○ Read-and-do ○ Flow (embodied checklists only)

(*Continued*)

Table 1. Continued

Category	Elements
Types of text items	• Checklist title • Condition statement (description of the condition warranting checklist use) • Diagnostic criteria/cue or symptom list • Purpose/objective of the checklist statement • Memory/immediate action items • Action items (sometimes with specification or explanatory text; includes administration of treatments and dosages) ○ Written as imperative statement (give 100% oxygen) ○ Written as challenge-response (oxygen……100%) • "Consider" items • Section headers • Information/advisory statements • Notes • Caution statements • Warning statements • Delaying items/when statements/timer items • Deferred items • Navigation items (within the checklist—typically some type of conditional item: If xyz…) • Go to items (jump out of checklist to some other checklist or information; user may or may not return to original checklist) • Checklist terminators (end of checklist)

[a]Adapted and condensed from B. K. Burian (PhD, unpublished document, 2016).[19] Several elements associated with some of the categories above have not been listed in their entirety. In addition, several other factor categories exist, which have not been included here, such as Physical, Environmental, and Social Conditions Associated with Checklist Use; Checklist Physical Properties and Interface; and Checklist Navigation; among others (see Figure 2).

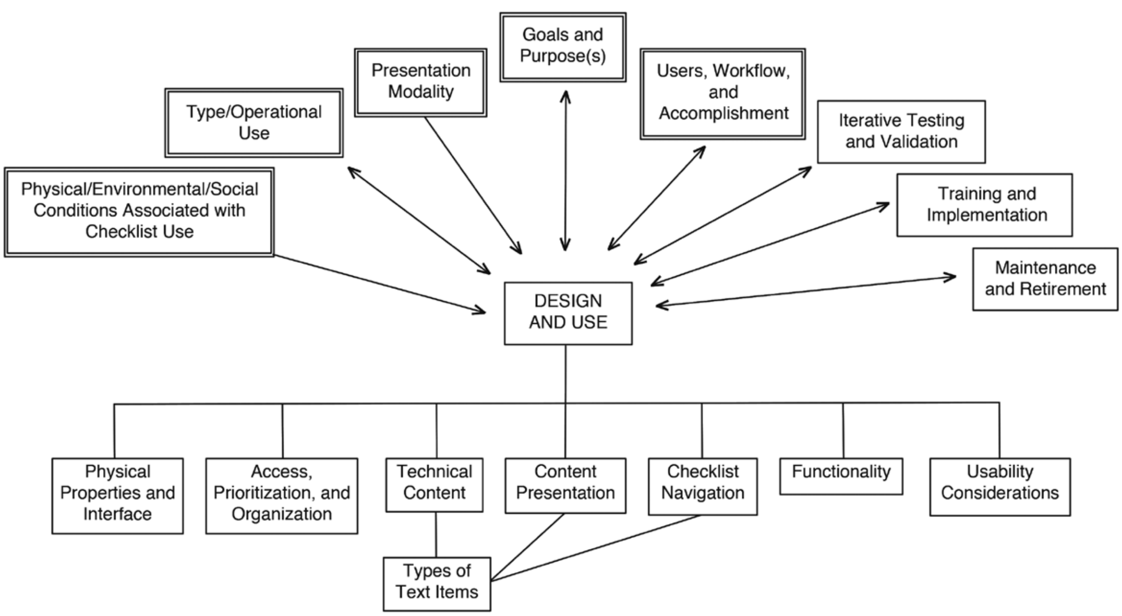

Figure 2. Human factors considerations in the development, design, and use of medical checklists. Double-lined boxes identify considerations addressed during the Conception Phase of checklist development.

It is no wonder if teams struggle with checklist design; more research is needed to identify the most effective designs for different checklist purposes and uses.[24,71] Of the 75 articles reviewed that described methods used to identify content, only 17 reported addressing design issues.

Crisis Checklists and Sampling. A checklist's design must reflect and support its use. For example, physicians may need immediate access to information in crisis checklists to ensure a successful outcome. Some crisis checklists[4,59,72] contain design elements implying that users should start at the top and proceed step-by-step,[73] such as by placing the word "Start" at the top of a list of items and numbering each step in order.[4] As part of an ongoing study, we observed that physicians often do not respond to critical events in such a linear manner. Instead, many first use existing knowledge and refer to a checklist for additional ideas or specific information (eg, drug dosages) only after starting treatment.[74] We label this type of checklist use "sampling," and it represents a distinct departure from the way that critical event checklists are currently used in aviation and other domains. Checklists designed for use in a stepwise fashion generally do not support this kind of specific information-seeking behavior. Checklists for medicine that too closely follow an aviation-oriented design may therefore be ineffective[5,75,76] or even disruptive.[77]

3 Bradycardia/Pacing ADULT

3

VERIFY DX - STABILIZE PATIENT

- Verify Bradycardia: ↓ HR ↓ BP with clinical evidence of poor perfusion
- Switch to 100% O_2, evaluate ventilation
- If ΔHR & ΔBP mild, consider:
  - glyco 0.4 mg *or*
  - atropine 0.4 mg

DRUG / DOSAGE SUMMARY

Atropine 0.4 mg		ΔHR & ΔBP mild
Calcium chloride 1 mg IV		Ca-channel blocker OD
Calcium gluconate 1-2 mg IV		Ca-channel blocker OD
Epinephrine 1 mg IV		No pulse
Glucagon 3-10 mg IV, then 0.07 mg/kg/hour IV infusion		Beta- or CA-channel blocker OD
Glyco 0.4 mg		ΔHR & ΔBP mild

TREATMENT

Cause	Action
Surgical stimulation	▪ If laparoscopic, de-sufflate ▪ If not laparoscopic, stop surgery
Myocardial ischemia	▪ See CHKLST 12
Beta-blocker overdose	▪ Glucagon 3-10 mg IV, then 0.07 mg/kg/hour IV infusion
CA-channel blocker overdose	▪ Calcium chloride 1 mg IV *or* ▪ Calcium gluconate 1-2 mg IV ▪ If ineffective, Glucagon at above doses
High spinal	▪ See CHKLST 8 (LAST)
External/internal pacer failure	▪ Contact electrophysiology (pager #9218)
Cardiac arrest	▪ See CHKLST 4 (Arrest)

Instructions for PACING

1. Call for Pacer/Defibrillator
2. Place pacing ECG electrodes *and* pacer pads on chest
3. Turn monitor/defibrillator ON, set to PACER mode
4. Set PACER RATE (ppm) to desired rate/min (80)
   Can be adjusted up or down based on clinical response once pacing is established
5. Increase the PACER OUTPUT (mA) until electrical capture
   Pacer spikes aligned with QRS complex. Threshold is normally 65-100mA
6. Set mA to 10mA above this level
7. Confirm pulse is present. If not, repeat steps 4-5

CRISIS MANAGEMENT (If Severe)

- Notify surgeon, call for help and code cart
- Check pulse. If no pulse:
  - Start chest compressions
  - Give epinephrine 1 mg IV
  - Consider transcutaneous pacing (see orange box)
  - If cardiac arrest, See CHKLST 4 (Arrest)
  - Consider ECMO (pager #7758)

Bradycardia/Pacing ADULT

Revision July 16, 2016

Figure 3. Bradycardia/pacing critical event checklist. BP indicates blood pressure; HR, heart rate.

We believe that it is possible to design checklists to support both sampling and a step-by-step guided response, including responding to an event already in progress. We have created a novel checklist design to support these multiple uses (see Figure 3 and Table 2). In our design, items associated with different response "phases" are grouped into color-coded blocks. This allows users to jump directly to the needed block when accessing the checklist or to jump to Crisis Management actions at any time, even when in the middle of a different block (eg, Treatment). Drugs and dosages, which are often sampled in these checklists, are repeated in their own block for easy reference. This design is optimized for paper critical event checklists; a different design approach is needed for electronic checklists.[14,18,57,60,67,78,79] Research is underway to evaluate the effectiveness of our design.

Testing and Validation

After iterative usability testing and final design completion, a new checklist should ideally be subjected to thorough validation before implementation.[33] A sufficient number of teams should use the checklist in either simulation or actual operations to allow statistical analysis of how well the checklist achieves its purpose (eg, reduces the number of errors) and whether it is used by the teams as intended, fits into the flow of work, and is easy to use. Some types of checklists (eg, those used for performance evaluations or as screening instruments) will require other types of psychometric appraisals, such as interrater reliability and criterion and construct validity.[80],[c]

In our review, 54 of 91 articles described psychometric analyses, and 25 reported that pilot testing had been conducted, although often the extent of the pilot testing appeared to be gathering user feedback through surveys. Authors of only 1 of the 10 checklists that were implemented reported having conducted psychometric and usability testing before implementation.[81]

Training and Implementation

A checklist that simply appears with no introduction, training, or rationale as to why it is needed is unlikely to be accepted.[74] Therefore, successful implementation of a checklist[8,20–23,82,83] requires an intensive educational process that should include an introduction that informs pertinent staff that a checklist is being developed and explains why and when it will be introduced. This should preferably occur well in advance of training.

[c]DeVon et al[80] provide a nice introduction to psychometric appraisal for readers wanting a refresher.

Table 2. Design Features to Support Multiple Uses of Crisis Checklists

Need/Use	Feature	Notes
Access the checklist at various points during the event	Checklist content is grouped into phase/topic-specific, color-coded blocks: **Verify Diagnosis (Dx) and Stabilize Patient**, **Treatment**, **Crisis Management**, **Drug and Dosage Summary**, **Instructions for Pacing**	• Checklists for other types of critical events might have somewhat different blocks, such as one to support making a differential diagnosis, or be formatted differently such as having a single list of step-by-step instructions for event response in the **Treatment** block
Find steps to complete but avoid reviewing actions that were performed prior to accessing the checklist/bypass unneeded information	Items most likely to have been performed prior to checklist access are located together in their own section	• Often, items in the first block (**Verify Dx and Stabilize Patient**) will already have been accomplished prior to accessing the checklist
Be reminded of possible causes of bradycardia/identify other possible causes if treatment for originally suspected cause is not working	Causes are listed in left column of table in **Treatment** block	• Causes are listed in order from most common to least common to minimize user search/scan time
Find the appropriate treatment based on the cause of the bradycardia	Causes and their treatments (or actions to take, such as referring to a different checklist) are presented together in the **Treatment** block	• If the cause is known but the treatment is not remembered, users can simply jump to the **Treatment** block and scan the "Cause" column for the cause of interest • This information is presented in tabular format with the headings "Cause" and "Action" for ease of reference • Tabular format also helps minimize the amount of text required for each item; for example, if presented as individual bulleted items, each might need to be written out, for example: "If bradycardia due to myocardial ischemia, see CHKLST 12"
Look for ideas/reminders of different drugs that might be used	Drugs and dosages appearing in the **Verify Dx and Stabilize Patient** and **Treatment** blocks are repeated in a separate summary block for ease of sampling/scanning	• The reason each drug might be used is also repeated in the Drug/Dosage Summary block to support users who do not have a specific drug in mind and are scanning the list for ideas
Quickly find dosing for a specific drug	Drugs and dosages appearing in the **Verify Dx and Stabilize Patient** and **Treatmen**t blocks are repeated in a separate summary block for ease of sampling/scanning	• In Figure 2, the drugs in the **Drug and Dosage Summary** block are alphabetized to facilitate a quick search when the desired drug is already known • To support other needs or for other critical events, the ordering of drugs on the list could be changed, such as listing them in the order in which they might be administered, in order from most to least commonly used, in order based on cost, or ordered based on other considerations
Quickly find steps to complete if the bradycardia is severe	Items for **Crisis Management** appear in their own labeled and red color-coded block	• Crisis management actions can be easily identified at any point during checklist use: users can go immediately to this section after accessing the checklist or can temporarily leave actions in another block and jump to this section if the situation becomes severe
Be reminded about how to administer transcutaneous pacing	Numbered, step-by-step instructions about how to administer pacing appear in their own color-coded block	• Additionally, the checklist title includes the word "Pacing" to assist users who have already decided they want to administer pacing and only need a reminder about how to do it, ie, they do not need any other information from this checklist. (The checklist title also includes the word "ADULT" to remind users that different actions/drugs/dosages may be needed for pediatric patients.)

Boldface refers to colored blocks in Figure 3.

Even the best-designed checklist requires training in its use, especially because checklists have not traditionally been part of medical work settings. During training, it is necessary to counteract common myths (eg, checklist use signifies lack of expertise)[14] and address user concerns. Training should include the checklist's purpose, who will use it, how, and when.[84] Training should also cover potential barriers to use and how to address these roadblocks when they occur.

Ideally, training would involve using the checklist as intended (eg, by a team) in simulation before it is used in actual practice. Training using standard, predictable, or "textbook" scenarios is not sufficient to ensure effective use across all situations.[85] More complex, yet realistic perturbations and combinations of conditions should be added to include judgment and decision-making practice.

If high-fidelity simulation is available, realistic scenarios can allow the participants to see firsthand how checklist use can enhance event management. High-fidelity medical simulation, however, is not an absolute requirement, particularly for noncritical event checklists. Advanced, in situ training in the clinical setting can use a nonfunctional or advanced cardiovascular life support training mannequin or an actor (eg, a training team member) who plays the role of the patient.[74,86] In low-fidelity or "tabletop" simulations, participants in a conference room are given a scenario and are asked to verbalize their actions, using the checklist as intended. Regardless of the fidelity level, a debriefing to explore participants' reactions and checklist effects should follow simulations and practice sessions.

Of the 91 articles we reviewed, only 8 discussed having conducted some form of training and 10 discussed actual implementation.

Ongoing Evaluation, Revision, and Possible Retirement

Even well-designed and validated checklists should continue to be evaluated after implementation.[11,18,24] Ideally, a system for gathering suggested revisions should be in place so that ideas for improvement can be captured. Additionally, changes to workflow, standards of practice, and new technologies may require modification of checklist content, design, and use to maintain relevance and effectiveness. Some checklists may outlive their usefulness and should be retired, rather than revised. In our literature review, no authors mentioned conducting ongoing evaluations or possible retirement following checklist implementation.

CONCLUSIONS

In 2009, Peter Pronovost, a champion of medical checklists, said "My vision is that the science of how to do checklists is in its infancy."[87] We suggest that 9 years later, we have not moved much beyond toddlerhood. We still lack a good understanding of why clinical checklists are or are not effective in different settings.[68] As many have pointed out, checklists do not work in isolation; they are part of a complicated, dynamic, sociotechnical system,[37] and many cultural and systemic changes are also necessary for checklists to achieve their potential.[25,38,51,76,88,89] Acceptance by clinicians and organizations will depend in large part on the effectiveness and usability of checklists that are well matched to the local operational and social environment.[43,78] This requires a systematic and comprehensive development process.

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Contribution: This author helped contribute to the organization and write and prepare the manuscript.
Name: Anna Clebone, MD.
Contribution: This author helped contribute to the organization and write and prepare the manuscript.
Name: Key Dismukes, PhD.
Contribution: This author helped contribute to the organization and write and prepare the manuscript.
Name: Keith J. Ruskin, MD.
Contribution: This author helped contribute to the organization and write and prepare the manuscript.
This manuscript was handled by: Nancy Borkowski, DBA, CPA, FACHE, FHFMA.

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