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### Title

Development and Implementation of Checklists for Routine Anesthesia Care

### Permalink

<https://escholarship.org/uc/item/5sq274dj>

### Journal

Anesthesia & Analgesia, 121(4)

### ISSN

0003-2999

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### Publication Date

2015-10-01

### DOI

10.1213/ane.0000000000000923

Peer reviewed

# Development and Implementation of Checklists for Routine Anesthesia Care: A Proposal for Improving Patient Safety

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Checklists and related cognitive aids have become an integral part of health care safety processes,<sup>1-9</sup> such as the “surgical time out.”<sup>1,2</sup> There are good data to support the impact of checklists in improving the quality of health care professional’s handoffs of care, as well as adherence to care standards in perioperative crisis situations.<sup>3,10,11</sup> A survey in our own department confirms this trend toward increasing interest in checklist usage, with an overwhelming majority of physicians and certified registered nurse anesthetists (CRNAs) stating that they would use checklists for handoffs and in emergency situations.<sup>12</sup>

Use of crisis checklists in anesthesia often draws parallels to similarities between piloting an aircraft and performing anesthesia.<sup>13-15</sup> However, it is important to mention that the philosophy of using checklists in the cockpit does not originate from their use in emergencies (which by their nature rarely occur in real life), but rather from their use during routine flight management.<sup>16</sup> Commercial airline and private pilots usually complete a series of checklists to confirm the status of their aircraft during each flight cycle<sup>16</sup>: before pushback from the gate, on starting the engines, taxiing, takeoff, after takeoff, top of the climb, before descent, during approach, and before landing. Every flight concludes with a shutdown checklist back at the gate.

Routine and nonroutine cockpit checklists are usually used quite differently: The “abnormal event” (“read-and-do”) checklist walks pilots step-by-step through crisis and other, nonfamiliar situations, e.g., an unusual instrument warning. In contrast, routine (“read-and-check”) checklists are used to confirm an otherwise routine task typically already completed by the flight crew. This is despite the fact that the flight crew almost always know these tasks from memory.

Contrary to popular belief, the use of checklists in the cockpit as opposed to relying on memory does not originate from the fact that there are too many tasks to memorize reliably. Checklists in commercial airplanes may consist of as few as 2 items.<sup>16</sup> There is a deeply embedded cockpit culture to never rely solely on memory or vigilance to ensure that all vital systems of the aircraft during routine flights are set as required (personal communication with Cpt Ch Sullenberger [ret.] 2012, Cpt Al Langelaar [Aero Consulting Experts] 2013, and Cpt Joerg Krombach [Lufthansa] 2012). From the very early stages of flight training and throughout their ongoing professional evaluations, pilots are consistently taught and trained to refer to written cognitive aids at defined key moments, no matter how familiar they are with the required tasks. Even in single-pilot cockpits from fighter jets to small private planes, the use of checklists is a standard procedure for both routine processes and in emergency situations. However, the consistent use of checklists does not prohibit pilots from critically thinking through specific situations and deviating from the standard procedures when necessary.

Incorporation of checklists for routine operations into aviation was developed from the analysis of adverse outcomes. Even the most competent and experienced crew members can forget simple routine daily tasks because of distraction and fatigue.<sup>16-19</sup> In contrast, many health care professionals still believe that competent providers will always reliably recall and complete all necessary tasks when performing routine anesthesia from memory.<sup>12</sup> Similarly, some anesthesia professionals consider that using a routine workflow checklist is “unnecessary” and an “insult on their practice,” which will only create “mindless autobots.”<sup>20</sup>

## THE PHILOSOPHY OF ROUTINE WORKFLOW ANESTHESIA CHECKLISTS

Performing routine anesthesia often requires a series of tasks, which if omitted can put the patient at an increased risk. Based on Perrow’s<sup>21</sup> “Theory of the Normal Accident,” the interactions of tasks managing an anesthetized patient are about as tightly coupled, and even more complex, than flying an aircraft.<sup>22</sup> Because adverse events are underreported, the exact rate of mishaps and errors for many critical anesthesia incidents remains unclear. However, studies of the completeness of preparation of the anesthesia workplaces before induction found that 10% to 17% of the time at least 1 important item was either missing or not functioning.<sup>23,24</sup> Thus, it is not surprising that “failure to check

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Accepted for publication July 7, 2015.

Funding: Departmental funds.

Conflict of Interest: See Disclosures at the end of the article.

Reprints will not be available from the authors.

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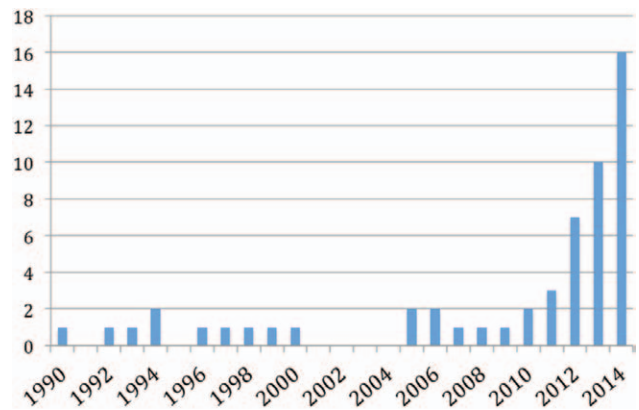
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DOI: 10.1213/ANE.0000000000000923

or inspect” was identified as the cause in 22% to 33 % of all critical incidents with significant negative outcome.<sup>25,26</sup> Existing data, similar to aviation accidents, indicate that the lack of provider competence has rarely been a major contributing factor to anesthesia errors with negative outcome.<sup>26</sup> Instead, there are “temporary and atypical lapses in the vigilance of otherwise competent anesthetists.”<sup>26</sup> Haste, distraction, fatigue, inattention, boredom, and failure to check have been factors associated with preventable anesthesia mishaps in >60% of adverse events.<sup>27</sup>

Despite these data, there are few, if any, reports on the development and implementation of a checklist system similar to that used by pilots, designed to prevent errors or omissions during all stages of routine anesthesia care. Introduction of “appropriate protocols” for checking equipment and handoffs were first suggested in the 1980s.<sup>26,28</sup> Although such protocols can certainly help clarifying and standardizing workflows, they usually remain memorized aids rather than printed or electronic checklists.

In 2009, the original World Health Organization Surgical Safety Checklist<sup>1</sup> incorporated some basic aspects of a preinduction checklist, but the scope of this checklist is too broad to cover the specific items that have been shown to be key factors in error or omissions in anesthesia. Others have studied or promoted anesthesia-specific, preinduction checklists.<sup>14,23,24</sup> For example, Hart and Owen<sup>14</sup> published simulation results after developing a preinduction checklist for cesarean delivery under general anesthesia. The authors reported a surprising finding: Although 95% of participants in simulation trials considered the checklist to be helpful, and 80% would like to use it in training situations, only 40% believed that the checklist was useful in real clinical settings. More recently, the Anesthesia Patient Safety Foundation surveyed anesthesia professionals regarding the need for a preinduction checklist. Based on the positive results, a preanesthetic induction patient safety checklist draft was developed, and a grant was offered to study the implementation and performance of this checklist.<sup>20</sup> The bias of anesthesiologists to consider the induction phase as the most critical time of anesthesia is well described.<sup>27</sup> However, this period in fact contributes only to 26% of preventable mishaps in anesthesia.<sup>27</sup> The majority of incidents instead happen during the maintenance of anesthesia,<sup>27,29</sup> and the emergence phase seems to be as hazardous for preventable mishaps as the induction phase (24%).<sup>27</sup> This speaks to the potential utility of checklists for these phases of the anesthesia workflow.

Attempts to implement checklists for routine anesthesia care, including preinduction checklists, seem to have had little traction. This is in part because the culture in health care has not embraced checklists, especially before the success of the surgical safety check in the early 2010s. Flaws in design and implementation of previously developed routine checklists may have played a partial role in their lack of adoption. However, since the earlier reports described above, there has been an increased acceptance of checklists by health care professionals, paralleled by an exponential increase in publications (Fig. 1). On the basis of evidence for checklist use from the aviation industry and the gap observed in the health care industry, we set out to develop



**Figure 1.** Number of publications indexed in Medline that includes search terms “anesthesia” and either “cognitive aid” or “checklist.”

and evaluate the utility of a series of routine workflow checklists for the anesthesia workplace.

### DEVELOPMENT OF A ROUTINE ANESTHESIA WORKFLOW CHECKLISTS SERIES AND INDIVIDUAL CHECKLISTS

Based on the available literature and our own experience and observations at different institutions in the United States and Europe, the Anesthesia Checklist Focus Group at University of California San Francisco/San Francisco General Hospital has developed checklists for routine anesthesia workflow. The underlying design of this checklist series is based on the established processes used in the aviation industry. We combined findings from literature review with the personal knowledge of 2 authors, holding private pilot licenses, of this article. Furthermore, we were able to interview 9 commercial airline pilots (3 of those being instructors) from 4 different airlines and 2 retired military fighter pilots on their insight and experience using routine cockpit checklists. Finally, we also included our own observations of routine cockpit checklist use by professional pilots during 5 routine flights and 8 professional full-scale airplane simulations in 2 major airline training centers. On the basis of these findings, we generated a checklist series for routine anesthesia workflow (Appendix 2). The sequence of checklists includes the following:

1. Technician setup of the anesthesia workplace
2. Provider setup of the anesthesia workplace (including anesthesia machine check)
3. Preinduction
4. Postinduction
5. “Sweep Checklists” (5- and 30-minute interval)
6. Emergence
7. Technician turnover of the anesthesia workplace

In the absence of existing nonemergent checklists in anesthesia, all but one of the individual checklists were created de novo. Although referring to existing examples of preinduction checklists,<sup>14,20,23,24</sup> all individual checklists were created based on the general recommendations from published checklists.<sup>2,4,14,24,30-35</sup> On the basis of the aforementioned work, we concluded that checklists for routine

anesthesia workflow should be developed based on the following design concepts:

- Do not exceed 10 items per checklist.
- Reduce wording of each item to a minimum while maintaining specificity to the task being checked.
- Do not incorporate an audit tool into the checklist.
- Do not require written check-off or signature confirmation of completion.

Individual items on each checklist were based on the process described by Thomassen et al.<sup>24</sup>: This, combined with information on common mishaps and omissions from our own departmental “Near-Miss” and “Morbidity & Mortality” database, generated an initial list of potential items for each checklist. The initial checklist drafts were tested and modified to improve checklist utility over a period of 1 year by members of the focus group.

We designed our checklists to be completed within a short period of time (<15 seconds) to maintain focus on the patient, monitors, and anesthesia machine. We avoided the inclusion of additional tasks that were solely audit or documentation requirements. As modeled by the airline industry, we defined best practice “trigger moments” for each individual checklist that facilitates standardized use of routine checklists within our institution (Appendix 2 has individual triggers listed at the bottom of each checklists). Apart from the postinduction checklist, all routine checklists are used during moments when there are no immediate patient care tasks to complete or focus on. With this in mind, we found that completing the postinduction checklist immediately after securing the airway seemed to be the best time to perform the postinduction check.

### INTEGRATION OF CHECKLISTS WITHIN THE ANESTHESIA WORKPLACE

Finding a place to store and display checklists in an already packed anesthesia workplace proved to be a significant challenge. We learned that even motivated anesthesia providers will not use checklists stored in a drawer. Instead, we concluded that the checklists must be within the immediate vicinity of the provider and instantly displayed to be used. These findings and conclusion match those described by Goldhaber-Fiebert and Howard<sup>4</sup> regarding the storage and display of emergency manuals. Attempts to display routine checklists through laminated cards, a document holder, or in booklet form were not successful. Therefore, we decided to develop a software application (app) that allows display of the checklists by securely mounted tablet computers attached to the anesthesia machine (Fig. 2). An additional advantage of using this approach was that the routine checklists could be in the same place as checklists for provider handoff and crisis management.

### PROJECT PROGRESSION AND CURRENT STATUS

With support from a grant from the University of California Office of the President, and in collaboration with a software design company specializing in health care programs (ChatrHealth, San Francisco, CA), the app was developed and made available in all 10 operating rooms of our

institution. The  $\beta$  version was initially tested and refined over a 3-month testing phase in April to June 2014. After education of all faculty, CRNA, and residents, the routine workflow checklists were introduced in the operating rooms at San Francisco General Hospital in July 2014. Within a few weeks, staff members increasingly began incorporating most or all of the routine checklists within their workflow and provided consistently valuable feedback to improve the general design and specific checklists. Updates were made on a weekly basis, and we are currently using the 51st software version.

Six months after initial implementation refinement, the use of checklists for routine anesthesia care became formally incorporated into the normal workflow at our hospital. This decision was supported by reports of events and oversights that were caught when using the routine checklists. The decision was also based on an analysis of anesthesia incidents presented at our morbidity and mortality conference, which occurred when staff members were not using routine checklists.

### PROVIDER SURVEY ON THEIR EXPERIENCE AND PERCEPTION USING ROUTINE CHECKLISTS

To better understand factors affecting checklist adoption and usage, we conducted an anonymous electronic survey 8 months after implementation. The survey was approved by our local IRB, and requirements for written informed consent were waived (University of California, San Francisco,



**Figure 2.** Tablet computer mounted on the anesthesia machine displaying routine and crisis anesthesia checklists at San Francisco General Hospital.



Committee on Human Research, Office of Research Administration, San Francisco, CA; IRB 14-13259). The survey was e-mailed to all faculty and CRNA who worked a minimum of 1 day per week (23 faculty and 16 CRNAs). The response rate was 90% (faculty 82% and CRNA 100%).

Seventy-one percent of respondents agreed that routine checklists are important for patient safety, 3% disagreed, and 26% were neutral. Ninety-two percent reported that they used the checklists at least some of the time, and 43% stated that they used them most of the time or always. Of those not always using the checklists, 61% stated that they simply forgot to use them. Seventy-four percent of staff members responded that routine checklists prevented them from forgetting to prepare or check equipment or complete a task at least once.

Distraction from patient care is a frequently raised concern with any health care checklist, and this was a frequent concern when we presented our project to colleagues or other health care professionals. Thus, the survey also asked if using routine anesthesia checklists might distract them from patient care. No one responded with “definitely yes,” and only 1 provider (3%) responded with “probably yes.” However, with 34% responding “maybe,” we do believe that the long-term success of routine anesthesia checklists will be strongly connected to addressing any remaining concerns related to provider distraction and alteration of the workflow.

### LIMITATIONS AND POTENTIAL SIDE EFFECTS

Acknowledging that the health care industry has no established culture for routine workflow checklists, the successful introduction of these in anesthesia cannot occur solely by a mandate from above, but needs to be built and implemented with input from the anesthesia professionals who will use them. The example from San Francisco General Hospital demonstrates that a successful integration of routine checklists is possible through an iterative process that engages providers in design, detailed education and training, constant reminders, feedback on near-miss events, and support by departmental leadership. However, checklists are not “silver bullets” that are able to avert all preventable errors. Diligence is critical because airline incidents and accidents have occurred despite completion of checklists, with investigations revealing that in some instances, pilots just mechanically recited the checklists.

Checklists, especially those for routine workflow, cannot be endlessly extended in an attempt to capture any potential mistake. Instead they need to focus on the most frequent or hazardous omissions. This leads to several consequences: Even when consistently applied, checklists cannot prevent all potential errors or oversights. Furthermore, the specific outline of routine checklists should not be blindly copied. Although certain items on routine checklists are clearly essential, the inclusion or exclusion of others can be debated. Individual workflow and risk assessments of the institution should determine whether a specific checklist item on routine checklists fits their needs and their workflow. The airline industry again exemplifies such a necessity, because checklists for the same type of plane may differ significantly among several airlines.

Our survey results demonstrate that routine checklists are able to catch errors or oversights. However, at this

point, we are not able to further substantiate in detail to what extent routine checklists are able to prevent errors. Furthermore, although errors and oversights are common, true patient harm resulting from those errors remains rare, and we are not able to demonstrate the impact of routine checklists on the prevention of actual patient harm; extended, multicenter studies would be needed to obtain sufficient data. Finally, although we were able to demonstrate that routine checklists are able to prevent errors, we cannot assume that the use of routine checklists will not cause any negative side effects.

The need for tablet computers in our app-based approach led to a much higher initial cost (including lockable mounts to secure the iPads from theft). In addition, care must be taken to properly clean the screen and the mount during each case turnover to prevent infections by cross-contamination.<sup>36</sup> However, cross-contamination is not a problem unique to tablet computers, because this can happen when using (laminated) paper checklists. Tablet computers in the operating room raise concerns for theft, misplacement, and distraction of the anesthesia provider from installation and use of apps other than the checklists. For these reasons, we locked the iPad in place with a lockable mount and also locked the iPad user interface to allow only the use of the checklist app (“guided access”). With proper counter measures as described earlier, we believe that the benefits of using a checklist app on a tablet computer outweigh the limitations.

### CONCLUSIONS

We report the development of checklists for the routine phases of anesthesia care and their incorporation into the workflow of the anesthesia provider. Checklist design and usage were modeled after checklists used by the aviation industry for their routine workflows. Within a few weeks of implementation, the checklists were being used by most providers for much of their workflow, and their use has helped reduce errors and omissions during routine anesthesia care. It remains to be seen whether the use of checklists for routine anesthesia care in our institution is sustained and becomes permanently incorporated into the culture or whether the concept spreads to other institutions. Additional studies and efforts are needed to validate and quantify checklist utility, their ability to improve anesthesia quality and safety, and the barriers to their becoming routinely used. ■

### DISCLOSURES

**Name:** Jens W. Krombach, MD.

**Contribution:** This author helped design the study and write the manuscript.

**Attestation:** Jens W. Krombach approved the final manuscript.

**Conflicts of Interest:** Jens W. Krombach consulted for ChartHealth, the application software developer, without compensation. The described checklist application (“app”) was developed by the author and is the intellectual property of UCSF. Currently, the software app is only used for research purposes and is not publically available. The plan is to release the app to the public for free without financial gain, although it is conceivable that the author could financially benefit from dissemination of the technology in an unanticipated way.

**Name:** James D. Marks, MD, PhD.

**Contribution:** This author helped design the study and write the manuscript.

**Attestation:** James D. Marks approved the final manuscript.

**Conflicts of Interest:** This author declares no conflicts of interest.

**Name:** Gerald Dubowitz, MD.

**Contribution:** This author helped write the manuscript.

**Attestation:** Gerald Dubowitz approved the final manuscript.

**Conflicts of Interest:** This author declares no conflicts of interest.

**Name:** Oliver C. Radke, MD, PhD.

**Contribution:** This author helped design the study and write the manuscript.

**Attestation:** Oliver C. Radke approved the final manuscript.

**Conflicts of Interest:** This author declares no conflicts of interest.

**This manuscript was handled by:** Sorin J. Brull, MD.

## APPENDIX 1

### Routine Anesthesia Checklist Survey

I am a

- Faculty (1)
- Certified registered nurse anesthetist (2)

I believe checklists for routine anesthesia care are important for patient safety

- Disagree (1)
- Neither agree nor disagree (2)
- Agree (3)

I use checklists for routine anesthesia care

- Never (1)
- Rarely (2)
- Sometimes (3)
- Most of the time (4)
- Always (5)

In reference to your response to the last question: Why do you not use routine checklists consistently?

- I simply forget to use them but I want to make them part of my standard workflow as often as possible (1)
- The software is not user-friendly enough, but I would like to use checklists as often as possible (2)
- There are often technical difficulties with the app or iPad, but I would like to use the checklists as often as possible (3)
- I only use part of the routine checklist cycle because some checklists alter my workflow too much (4)
- I only use part of the routine checklist cycle because not all of them are important (5)
- I only use them if my attending asks me to do so, otherwise I would not use them at all (6)
- Other reason (please explain) (7) \_\_\_\_\_

Has 1 or more of the routine checklists saved you from forgetting to perform a task or check something? (e.g., set NIBP cycle, suction working, turning vapor up, timely ABX administration)

- Yes (1)
- No (2)

Do you feel that using routine checklists might distract you from patient care and potentially have a negative affect?

- Definitely yes (1)
- Probably yes (2)
- Maybe (3)
- Probably not (4)
- Definitely not (5)

## APPENDIX 2

### 1. Technician setup of the anesthesia workplace

#### Tech initial workspace readiness

- Machine on, all hoses connected
- Ambu bag and jet ventilation
- Machine disinfected
- New circuit, suction, sample line
- All cables present (Spo<sub>2</sub>, electrocardiogram, blood pressure, temperature)
- Absorber checked/vapors full
- Vent and cart fully stocked
- Cric kit and gum elastic bougie  
(trigger: before leaving the operating room [OR])

### 2. Provider setup of the anesthesia workplace

#### Provider setup

- Anesthesia machine check
- Monitor prepared
- Medication complete
- Airway equipment complete
- IV/A-line systems prepared
- OR table locked  
(trigger: before leaving the OR)

### 3. Anesthesia machine checklist (GE Aestiva version)

#### Aestiva machine initial check

- Suction system complete and function check
- O<sub>2</sub> cylinder and pipeline supply
- O<sub>2</sub> sensor calibration and low FIO<sub>2</sub> alarm
- Flowmeter flow test
- Leak check low-pressure system
- Leak check breathing system
- Final status machine

### 4. Preinduction

#### Preinduction check

- High-pressure circuit test
- Vent manual mode/APL valve open
- O<sub>2</sub> fresh gas flow
- Suction accessible and functioning
- Airway equipment
- IV patent/induction medication
- Vital signs—blood pressure cycle set  
(trigger: before starting to preoxygenate)

5. Postinduction

**Postinduction check**

- Vent setting, expiratory TV, PIP
- ETCO<sub>2</sub> level and tracing
- Fresh gas flow and vapor set
- Vital sign/adjust NIBP cycle
- IV flow adjusted
- Antibiotic order checked
- Line placement  
(trigger: immediately after taping the ETT)

6. “Sweep Checklists” q5min

**5-minute sweep checklist**

- Ventilator: PIP, TV, ETCO<sub>2</sub>, EtAA
- NIBP and Interval—A-line transducer level
- HR and EKG wave image
- Temperature

7. “Sweep Checklists” q30min

**30-minute sweep checklist**

- Ventilator: PIP, TV, ETCO<sub>2</sub>, etAA
- NIBP and interval—A-line transducer level
- HR and EKG wave image
- Temperature
- Head and ETT position, circuit connections
- Pressure points padded, eye check
- Arms: Position, NM monitor, tourniquets?
- Infusion rate, check IV site (infiltration)
- Foley drainage

8. Emergence

**Emergence readiness**

- Neuromuscular recovery
- Antiemetic agents considered
- Emergency medication ready
- Airway equipment ready
- Team discussion next patient  
(trigger: when surgical closure is announced)

9. Technician turnover of the anesthesia workplace

**Tech turnover**

- Surfaces and cables disinfected
- Vent circuit switched
- Sampling line connected
- New suction and function test
- Cart restocked

(trigger: before anesthesia tech is leaving the OR)

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