CHECKLIST APPLICATION IN AVIATION AND HEALTHCARE

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ABSTRACT

Aviation and healthcare are professional domains that are characterized by high safety requirements. Human failure is identified as the major cause for aviation accidents and medical complications. In both fields, checklists – that are applied in regular and abnormal situations – are reliable and capable tools to meet the high safety aspirations and to reduce or avoid mistakes and their partially severe consequences. The benefits of this rather simple method are exploited best when they are embedded in an overall safety culture of the organization. Checklist discipline, correct application and teamwork are key for their effective contribution to safety – be it in surgery or flight. Moreover, checklists support decision-making due to their capacity to reduce complexity and ambiguity. The structured, standardized proceeding is in particular valuable. This paper describes how checklists function generally and how their application in aviation spilled over to medicine and became also indispensable in daily business.

KEYWORDS

checklist, safety, aviation, medicine, decision-making

INTRODUCTION

The utilization of checklists as a tool for safety and quality management is widely established and appreciated in many professional domains. This holds also true for the fields of aviation and healthcare which clearly benefit from the application of specifically developed, purposeful checklists. Both branches have a variety of commonalities that are related to the responsible work in environments that are characterized by specific safety requirements, a significant workload under (time) pressure, the occurrence of distractions, indispensable team-coordination and considerable amounts of (changing) information. In order to meet the particular safety and quality standards in both fields, checklists are an effective support because of their capability to organize complexity, reduce ambiguity – without simplification – and to promote professional decision-making. Their successful implementation and diligent application are closely tied to certain preconditions. This relates among others to the demands regarding checklist design, the precise representation of the content and the indispensable acceptance of the users. This paper is intended to describe the methodology behind checklists and to demonstrate their contribution as a practical decision aid for medicine and aviation. In general, checklists are practical working aids in the form of concisely written documents[1] with a definite purpose orientation. Scope and envisioned context define the development of the concrete checklist. Their core function is being a memory aid that relieves the user cognitively and thereby prevents or reduces avoidable mistakes resulting from distracted attention and limited human capacities. They can help to structure complex processes or tasks, ensure and document completeness, consistency and compliance with due diligence obligations. Needless to say, they do not replace professional skills, judgment, knowledge or expertise at all. They rather represent reliable support, routine and structure in regular day-to-day work or in abnormal situations. Regardless of their practicality and simplicity of application, checklists have a multitude of advantages, that are summarized in the following table.

[1] Here, focus is put on the written/printed form, although illustrated, electronic or (less reliable) mental checklists exist as well.

Advantages	Explanation
Acceptance: well-known, tested, capable, effective, established and valued working aid	*Worldwide use of the method, institutional development (e.g. WHO, aviation safety culture)*
Application: efficient due to the accurate, comprehensible, uniform and brief structure; Individual or collective application (team)	*Focus on the suitability for the intended application → otherwise revision and adaptation Individual procedure or with team members*
Acronyms for specific checklists serve as mnemonic for recalling the right steps.	*Examples from aviation/medicine: IMSAFE, PAVE, TRAMP*
Teamwork: integrates, coordinates and respects all team members and their contribution by design, facilitates effective teamwork and mutual understanding	*Acknowledges the professional significance of teamwork, levels out differences, can enhance communication*
Workload: reduction of complexity and time-consumption, clear, unmistakable allocation of tasks, facilitation of professional cooperation, coordination and adequate, transparent division of labor, smooth shift handover and delegation of tasks	*Transparent, purposeful segmentation of complex tasks, workflows or processes in reasonable (sub-)steps, apportioning of tasks and responsibility. Documentation of completion. (Clarifies briefly, who does/did/will do what, why, in which order, how and when.)*
Support: help for staying focused in stressful situations, after interruptions or distractions	*Prevents negligent actions, omission or forgetting of important points/interdependencies*
Training of new staff members	*Supportive measure for introductive training of new staff, facilitates independent work*
Reference guide and orientation in complex tasks/processes/extensive timespans, relieves memory, support in non-normal situations	*Contains essential information for reference in compact form, helps keeping track of the current status, structures processes/projects/tasks*
Documentation and protection for cases of error or complaints, for internal and organizational requirements, comparison, quality control, adherence to quality and safety standards	*Legal record for possible lawsuits, verification of completion and compliance with due diligence obligations and standards, control that no prescribed steps are skipped/forgotten (safety culture/just culture)*
Cost: comparably inexpensive method	*relatively uncomplicated development*
Uncomplicated adjustment to changing requirements with revised versions, easy translation into other languages, adapted formats	*Improvement of the checklist according to demands of the organization, the users, learning from mistakes, or to factual changes → continuous reuse of an existing checklist is possible*
Criticism	
Perception as a burden of even more paper-work and an artificial procedure, application for the procedure's sake, use requires prior knowledge, dependence and reliance on checklists instead of knowledge and skills	

Table 1. Advantages of Checklist Application

The benefits of checklist implementation are obvious, but their effectiveness finally depends on the acceptance of the user. Insofar, it is on the one hand crucial to convince[2] and to train staff members and on the other hand to design checklists appropriately. Basically, there are two variants of checklists: *do-confirm* and *read-do* types, whereby the concrete development follows their intended usage.

	read-do checklist	**do-confirm checklist challenge and response** checklist
method	***read listed item → carry out task*** working step-by-step according to instruction	***carry out task → confirm completion*** working from memory, relatively free in sequence
purpose	concise summary of repetitive tasks in processes requiring the exact completion of individual steps in required sequence, guidance through the process, emphasis on precision and accuracy	verification of task completion, to avoid overlooking of important steps in complex processes, segmentation and reduction of complexity, emphasis on timely application, correctness and completeness
examples	fixed procedures, instructions, recipes	pre-flight checklists

Table 2. Main Types of Checklists

According to the organization's objectives and particular requirements, the matching type of checklist is chosen. Due to the variety of relevant tasks, a considerable number of such documents can accumulate. Therefore, it is worthwhile, to add the collection of developed checklists to an organization's process library that contains useful explanations and comments as well. Larger organizations have staff, who is responsible for checklists, their consistent development and proper application. As mentioned above, the creation of a checklist is not necessarily complicated, since templates are effortless available.
Usually, the well-known tabular layout consists of a column with checkboxes on the left-hand side of a page and next to it a column containing the list of items. Other checklists may lack the checkboxes – often in aviation related lists – because they are read and confirmed aloud. The clear arrangement of the content is very important with regard to easy legibility. Though, the formal design might seem trivial at first sight, the careful and thoughtful proceeding to create a sound checklist cannot be underestimated. The document is a synoptic summary of *only* essential items. Insofar, the creation requires a clear understanding of tasks or processes and their components.[3] Detailed instructions and explanations or comments are intentionally left out, but partially, references to further

[2] Gawande (2022) describes in detail the difficulties in overcoming reluctance and in convincing users and their organization to integrate checklists into their clinical work.

[3] Gawande (2022) recommends having five (but not more than ten) items on a checklist.

information is included.[4] If a specific sequence is required, the respective chronological order has to be considered. In order to keep the document short, it is clear that checklist application requires prior knowledge, experience and skills of the user.[5] KVWL (2024) recommends the PDCA cycle to systematically create a professional checklist.[6]

1) ***Plan:*** *identification of the problem (root causes), problem analysis, collection of relevant information and brainstorming about the process, systematization of gathered ideas and information, derivation of a conclusive written document, evaluation and control of the checklist.*
2) ***Do:*** *Approval and implementation of the developed checklist.*
3) ***Check:*** *Review of the precedent stage's effectiveness. The practical application reveals whether the checklist is suitable, effective, accepted by the intended users and if possible deficiencies (missing items, order, layout, difficulties in application, imprecisions) can be detected. Again, compilation of problems (root causes and solutions), identification of ideas for improvement and lessons learned.*
4) ***Act:*** *Improvement and adaptation of the checklist according to the results of the precedent check-phase.*
   If the result is satisfactory → end of the procedure
   If the result is not satisfactory → new PDCA cycle

The recommendations for checklist development according to Boorman (Nuclino Blog, 2019) consist of four essential aspects, whereby the first *"Investigate your failures" (1)* relates to the mentioned planning phase of the PDCA cycle. For Boorman "friction points" in routines become the starting point for a new checklist. The second advice is *"Focus on the 'stupid' stuff" (2)*, which means not going into detail, but providing precisely only the necessary, basic key points. Gawande (2022) emphasizes this criterion as well, since many avoidable (medical) errors result from rather simple causes.[7] The third aspect focuses on the tangible side of the checklist: *"Keep it simple" (3)*. Boorman summarizes, that the content shall be presented in a compact manner which does not exceed one page. Unnecessary color shall be avoided and in order to prevent distraction and to promote easy readability; a sans serif font is recommended. The fourth criterion covers the mentioned dichotomy regarding the general type: *"Decide between a 'do-confirm' or a 'read-do' checklist" (4)*. The first is rather suitable for verification after completion of the task from memory. The second type is recommended for tasks that require high precision. As seen, the significance of user-friendliness cannot be underestimated.[8] The orientation on those, who work with the checklist, has many facets which range from legibility, readability, format, material to the circumstances of application (e.g. during night-time). Checklists and their aim a closely tied to their acceptance, discipline and correct use. The following recommendations from OAS (2001) relate to the occurrence of avoidable aviation accidents caused by incorrect application or failure in checklist use: "Make a habit of using checklists consistently. Do your checklist when the workload is low. Avoid distracting conversation when performing checklists. Treat any checklist interruption as a red flag that could cause you to miss a critical item." (OAS, 2001)

Undoubtedly, these recommendations are generally valid for the application of any checklist. The last two points refer to disturbances and interruptions in performing a checklist which can lead to errors. Linde et al. (1987) investigated from a linguistic point of view interruptions during checklist application in a cockpit. According to their analysis, it is key to manage in particular the actual duration of the interruption *(hold)* and to resume *(continue)* the checklist. The authors remark that it is not completely under the control of the crew if and how often disturbances (radio communication, other tasks in the cockpit etc.) occur, but how long it takes until focus is guided again on the checklist can rather be influenced. Other, seemingly trivial, conditions can hinder the correct completion as well: missing of the checklist, using the wrong document, insufficient readability or practical inconvenience. If the application is perceived as a time-consuming burden or additional workload, the intention is taken ad absurdum, because users might tend to disregard the checklist completely.

[4] Needless to say, checklists shall be free from superfluous content and any distraction. But, the cuff checklists of the astronauts from Apollo 12 were adorned with cartoons from staff members and diverse photographs. The backup commander for the Apollo12 mission Scott explains: "We spent a lot of time going through the checklist to see where we could insert something humorous. We got that centerfold off the newsstand. Then we had to get it printed on fire-proof plastic-coated paper" (Theophanides, 2011). See Jones (1996) and Theophanides (2011) for detailed checklist photographs and comments. Additionally, Boorman, the technical lead of the development of the 787's pilot system of checklists, remarks, that "an occasional emoji is a guilty pleasure we allow ourselves to indulge in" (Nuclino Blog, 2019).

[5] Nevertheless, the KVWL publication recommends checklists for training purposes of new staff in healthcare. (KVWL, 2024, p. 96)

[6] See also Bulsuk (2009) and Skhmot (2017) about the PDCA cycle.

[7] Gawande (2022) provides examples for these simple causes of error like: lack of orderly disinfection, forgetting to wash hands, not counting materials after surgery, surgery on the wrong patient etc. Checklist application can effectively prevent such easily avoidable mistakes.

[8] The NASA published a comprehensive document that is dedicated specifically to typographic aspects concerning checklists. It covers among others topics like legibility of print (font and font size), readability (italics, bolding), color and contrast (visibility depending on illumination), opacity of the paper, lamination/glare, quality of the print and viewing abilities of the user. – Degani (1992) provides examples of fatal aviation accidents caused by difficulties with checklist application (poor readability, lack of consistency). Therefore, he stresses the relevance of the quality of documents used on the flight-deck. See Degani (1992) for more details about checklist typography.

Checklist Application in Aviation

The beginning of aviation checklists is often associated with the accident of a B-17 in 1935, where experienced and trained test pilots crashed with the bomber during climb. The accident was obviously caused by pilot error due to the complexity of the new aircraft. Technical flaws of the aircraft were not responsible for the accident. As a consequence, Boeing developed a pilot checklist prescribing concretely the duties of the pilot and copilot in order not to miss any important detail to fly the plane safely.[9] The solution proved to be – compared to the considerable damage – simple but effective; since then flights with the B-17 were safe. The obvious advantages of aviation checklists spilled over to spaceflight due to their success and became an essential component of the NASA safety culture. Astronaut Michael Collins, part of the Apollo 11 mission, even coined the expression of the "fourth crew member" which underlined the essential contribution of checklists for the mission.[10] Hersch (2009) explains, that

"[a]stronauts and engineers of the National Aeronautics and Space Administration brought manuals and checklists with them from aviation where they were already well established; in space they proliferated. Composed in a language approximating English but mostly incomprehensible to the uninitiated, in-flight documentation has been the key to the complex technologies aboard all of America's spacecraft" (Hersch, 2009).

Regardless the technical advancements since the early days of checklist implementation, their significance for aviation is undisputed. (This applies not only for professional aviation like commercial or military; also, for private pilots in general aviation, proper checklist application is an essential aspect of safety.) The general distinction between the mentioned common types of checklists exists in aviation as well. Additionally, the checklist application in normal and non-normal procedures is distinguished. The first refers to the regular course of the flight and the required standard operating procedures (SOPs), whereas the second relates to emergency or abnormal conditions[11]. These parameters determine the checklist category of choice. The following table summarizes the key points of both types according to the explanations on Skybrary (2024d, 2024e, 2024f).[12, 13]

	read-do checklist	**challenge-response checklist**
formats	printed paper or electronic versions of checklists	
application	**in non-normal procedures** (also: abnormal and emergency procedures)	**in normal procedures** (**SOP** and part of crew coordination)
	1) reaction from memory 2) checklist application (EAC) 3) further action (EAC)	normal operation of the aircraft in all phases of the flight; performance from memory according to cockpit flow pattern (specific sequence of memorized actions without checklist reference); specific critical items, cross-check → **challenge-response-checklist**
process	Immediate reactions to emergency or abnormal situations on board are carried out **from memory**.	PNF reads out the respective item and PF confirms the status/configuration (e.g. altimeter, flaps)
	Action taken is then confirmed by reference to the **"Emergency or Abnormal Checklist"** (EAC), which also contains **subsequent action**.	Electronic checklists: items may disappear/change color automatically after correct completion of the task, active annotation as "checked" partially possible
	(e.g. fire, engine failure, loss of cabin pressure, pilot incapacitation, worsening weather, fuel shortage)	
purpose	"[…] support flight crew airmanship and memory and ensure that all required actions are performed without omission and in an orderly manner." (Skybrary, 2024d) → **strict focus on safety**	
	For reference: The "Quick Reference Handbook" (QRH) contains the relevant (normal/non-normal [EAC]) checklists.	

Table 3. read-do and challenge-response aviation checklists

The tabular overview highlighted the significance of effective, professional teamwork – good crew coordination – and strict adherence to SOPs as essential contributions to aviation safety at any time during operation. The correct application of **normal checklists** is an important SOP and represents a part of good flight crew discipline. (Skybrary, 2024 f) These checklists are used after having thoroughly completed from memory all parts of a SOP. Their purpose is the verification of proper accomplishment. This type of checklists is generally relevant for all phases of the flight, but especially for critical stages like takeoff, approach and landing. Normal checklists have to be initiated (requested/called for), performed and completed according to crew coordination SOPs. Skybrary (2024f) explains the routine as follows.

[9] See also Taylor (2020) for a picture of the original B-17 checklist from 1944 and comments.

[10] The detailed NASA "Apollo Stowage List" for the Apollo 11 mission in 1969 is an impressive example of the contribution of checklists. (NASA, 1969)

[11] **Emergency situation** means that "the safety of the aircraft or of persons on board or on the ground is endangered for any reason"; an **abnormal situation** represents conditions where "it is no longer possible to continue the flight using normal procedures but the safety of the aircraft or persons on board or on the ground is not in danger" (Skybrary, 2024e).

[12] PF = pilot flying, PNF = pilot non-flying

[13] Dismukes et al. (2010) discuss based on a qualitative study deviation from checklist application in cockpits and analyze how checklist discipline can be improved effectively. See also Degani et al. (1990) for comments about checklist misuse or rejection.

1) *Initiation of normal checklists: requested by the PF, read by PNF (if the PF fails to initiate, the PNF suggests it according to good CRM practice[14]), preferably during times of lower workload (prevention of time pressure/interruption) → requires sound time and workload management, respectful teamwork*

2) *Conduction of normal checklists: with challenge-and-response method[15], response of PF to critical items, less-critical items can be challenged/responded by PNF alone → standard rules and phraseology for normal checklists (purpose: reduction of ambiguity, improved crew communication)*

   Conduction of the checklist according to the specific rules until" (checklist name) checklist complete" marks the end of the procedure. Some normal checklists contain intended hold points where the list can be paused. (support by electronic displays of normal checklists available)

3) *Management of interruptions: in case of an interruption of a normal checklist the PF announces an explicit, formal "Hold (stop) checklist at (item)"and continues analogously "Resume (continue) checklist at (item)". (repetition of the last completed item before the interruption in order to prevent omission)*

As shown above, the management of **non-normal** cases differs from the regular proceeding. The applicable EAC handbook contains both, the relevant emergency and abnormal checklists, and prescribes actions which serve as initial response element. (EAC and the Operations Manual have to be congruent.)[16] In this context, Gordon et al. (2013) highlight an important aspect of non-normal situations: people might tend to do *something* instead of taking time to assess the problem first and then doing the *right thing*. Additionally, focus on operating the aircraft has to be maintained at any time. Therefore, the authors recapitulate a reasonable, practical approach: "One major airline had a fairly simple emergency checklist philosophy: recognizing that any emergency would raise the stress level as well as the potential for making a bad situation worse by rushing into a solution, the airline's policy was that the first step in any crisis was to first fly the airplane and then to assess the situation." (Gordon et al., p. 128)
Here, the view remains narrowed to the common application of normal checklists, since central aspects of day-to-day routine use are of particular interest.

As mentioned before, acronyms serve as **memory aids** for pilots to recall easily the steps of essential checklists.[17] – The considerable workload in a cockpit, the necessary constant situational awareness and the changing environment require a lot of attention by the crew. Therefore, mnemonics are useful for two particular reasons: Firstly, memory aids can relieve the memory in routine operations. Secondly, mnemonics help direct "the mind towards required actions during periods of uncertainty, or intense activity and/or emergency; i.e. preventing distraction from less critical issues" (Skybrary, 2024a). – The *IMSAFE* checklist is a method for self-assessment in order to verify whether a pilot is generally fit to fly. Partially, the additional E for emotion is included. This brief self-check facilitates the decision before flight whether it is safe to operate an aircraft or not. The *PAVE* checklist is used for a more complex pre-flight risk assessment and also determines whether the risks are acceptable and it is safe to conduct the flight. The document's items are mainly mandatory due to legal prescription.

1) ***IMSAFE** = **I**llness, **M**edication, **S**tress, **A**lcohol, **F**atigue, **E**ating (**E**motion).*
2) ***PAVE** = **P**ilot, **A**ircraft, en**V**ironment, **E**xternal Pressures.*

According to FAA (2022), the first step *P* is the connection of both checklists, whereby *IMSAFE* clarifies the safe physical and mental state of the pilot. Additionally, this step refers to the completeness of licenses and required certificates. Further, currency and proficiency reflect the skills and experience of the pilot. *A* relates to the aircraft and includes among others the pilot's familiarity with the aircraft, all required documents and equipment on board, fuel and the required capacities. *V* stands for the pilot's risk assessment concerning the weather, airport, terrain, airspace and conditions and time constraints. The last step *E* takes other external factors into consideration that could increase the risk of the flight. These factors, for example, include external expectations, avoidance of delays for passengers or emotional

[14] Checklist application is nonnegotiable and regulations require that the respective checklists have to be completed. So, it is the duty of each team member to insist on the proper use, as Gordon et al. emphasize (2013, p. 128).
[15] The application of challenge-response-concept reflects also the overall safety culture of aviation that recognizes the limited human capacities and the possibility of failure, because "[…] human factors principles dictate a challenge-and-response process between two crewmembers for conducting checklists and drills, in recognition of the susceptibility of memory to failure at critical moments" Skybrary (2024a).
[16] For more information about EAC see also Skybrary (2024e), (2024 g).
[17] For more details about pilot memory aids and the respective regulations (FAA) see also: FAA (2022), Skybrary (2024a) and Pilot Institute (2023).

pressure. – As seen, both checklists serve for risk identification and assessment prior to flight. Thereby, adherence to prescribed safety standards is the main goal. Of course, the application of mnemonics in aviation is not intended to replace the use of checklists. The mentioned acronyms rather serve as a mental hook for pilots and help to keep all items in mind.

Checklists are an integral part of the holistic concept of safety culture in aviation. As seen, the distinct components are closely related and not only the technical skills, but also the human factor is explicitly considered. Therefore, effective checklist application does not only depend on the correct completion of individual items, it is also the result of good crew cooperation, communication and reasonable workload management. The literature highlighted the aspect of checklist discipline which comprises regular training, strict adherence to SOPs and consequence in teamwork. Checklist use in performing routine tasks is efficient, and none of the simple "stupid stuff" is overlooked. In non-normal contexts, checklists help to guide attention effectively on the relevant issues and thereby facilitate the adequate situation's management. A well-known example is the successful landing by the pilots Sullenberger and Skiles on the Hudson River of flight AWE 1549. The value of checklists, besides other tools and technological support, cannot be underestimated; their capability to reduce or avoid human error and aviation accidents is proven.

Checklist Application in Healthcare

The metaphoric expression of the *golden hour*[18] or even the *golden five minutes* vividly illustrates how precious, scarce and critical time is in medical contexts. This particular valuable amount of time relates to the fact, that time is a critical factor especially in emergency and trauma care of injured people. The *golden hour* stands both symbolically for an extraordinary period of time and the assumption, that "trauma patients have better outcomes if they are provided definite care within 60 minutes of the occurrence of their injuries" (Lerner et al. 2001, p. 758).[19] "There is a golden hour between life and death. If you are critically injured you have less than 60 minutes to survive. You might not die right then; it may be three days or two weeks later – but something has happened in your body that is irreparable." (Cowley, A., UMMS, 2024) The popular, though partially questioned, concept stems from Cowley reflecting his experience in emergency and trauma care. Regardless the controversy in the literature, the necessity of efficient use of limited time and skill is undisputed. Similar to aviation, healthcare is among others characterized by a considerable workload under time pressure and high safety requirements. As seen in the previous section, the successful use of checklists is associated with enhanced productivity, efficient workload management, good teamwork and support for both routine and non-routine tasks. The present part focuses on the application of checklists in the medical field.[20] Therefore, a particular example of worldwide use – the Surgical Safety Checklist – is, besides other examples, presented.

The development of the **WHO Surgical Safety checklist** dates back with its beginnings to the year 2007.[21] A study aimed to investigate the effects of consequent checklist implementation on the numbers of surgical complications. Therefore, a 19-item surgical safety checklist was "designed to improve team communication and consistency of care" was to reduce complications and deaths associated with surgery (Haynes et al., 2009, p. 491). The following aspects represent the key points of the study. (Haynes et al., 2009, p. 492-493)

1) *"Data suggest that at least half of all surgical complications are avoidable."*
2) *"A growing body of evidence also links teamwork in surgery to improved outcomes, with high-functioning teams achieving significantly reduced rates of adverse events."*
3) *"On the basis of [WHO] guidelines we designed a 19-item checklist intended to be globally applicable and to reduce the rate of major surgical complications."*
4) *"We hypothesized that the implementation of the checklist and the associated culture changes it signified would reduce the rates of death and major complications after surgery in diverse settings."*

In the light of the precedent discussion of aviation checklists, parallels to CRM are obvious. The emphasis on good teamwork and a cultural change – like in aviation – in the healthcare sector are integral part of the approach.

[18] The term *golden hour* refers to photography and the beauty of sunlight during the first hour after sunrise and the hour before sunset.

[19] The authors question this widely accepted idea in their study and conclude: "Our search into the background of this term yielded little scientific evidence to support it" (Lerner et al., 2010, p. 760). Contrary is the opinion of Gawande (2007) in the context of triage. He describes the grave time criticality in taking care of injured soldiers and emphasizes the golden five minutes.

[20] The discussion of checklist implementation and regarding measurable effects is heterogenous in the healthcare literature. Proponents unanimously underline the advantages of the method and emphasize the ubiquitous application in aviation, whereby others recognize the wider medical context and criticize unadjusted transfer. See e.g.: Gordon et al. (2013) and Papoutsi et al. (2018).

[21] The publication of Haynes et al. (2009) presents the results of the *WHO's Safe Surgery Saves Lives program*. See also: WHO (2024a). The development and implementation of the 19-item surgical safety checklist is explained also in Gawande (2022).

The first item relates to the "acceptance" of medical error. Sullenberger argues, that "[i]n aviation, such rationalizations for avoidable human error were rejected long ago and replaced with the creation of a robust safety system that has now become the culture of the field" (Gordon et al., 2013, p. viii).

The checklist[22] comprises three major parts which segment the surgical process into the phases: *Sign in, Time out* and *Sign out*. The checklist "is used at three critical junctures in care: before anesthesia is administered, immediately before incision, and before the patient is taken out of the operating room" (Haynes et al., 2009, p. 493). The individual steps are intended to be performed as a team. Thereby, emphasis is put on precise and efficiently guided communication. The team members have to be introduced to each other, since there is clear evidence for better performance and cooperation, when the participants know each other – at least by their name and function. This is in particular relevant for teamwork in larger organizations with changing team constellations. The roles and duties are unequivocally assigned in the checklist. This relates also to the positions to be confirmed during the process. The following table recapitulates the central checklist stages according to Haynes et al. (2009).

Phase	Tasks
Sign in	***before introduction of anesthesia*** *team members (at least nurse + anesthesiologist) orally confirm the following:* – Verification of the patient's identity, surgical site and procedure + consent – Surgical site is marked/site marking not applicable. – Pulse oximeter is on the patient and functioning. – All team members are aware of patient's known allergies. – Evaluation of patient's airway and risk of aspiration + appropriate equipment and assistance are available. – Risk of blood loss: appropriate access to fluids is available.
Time out	***before skin incision*** *the entire team + any other participants involved orally confirm the following:* – Confirmation of introduction of all team members (name, role) – Confirmation of the patient's identity, surgical site and procedure – Review of the anticipated critical events including: critical/unexpected steps, operative duration, anticipation of blood loss (specific concerns of the anesthesiologist, confirmation that prophylactic antibiotics have been administered as prescribed, confirmation of sterility, equipment availability and other concerns) – Confirmation of display of the correct patient's essential imaging results
Sign out	***before the patient leaves the operating room*** *nurse reviews the following items aloud with the team:* – name of the procedure as recorded – that, if applicable, needle, sponge and instrument counts are complete – that the specimen (if any) is correctly labeled + patient's name – relevant equipment issues *The surgeon, nurse and anesthesiologist review aloud the key concerns for the recovery and care of the patient.*

Table 4. Elements of the WHO Surgical Safety Checklist

The introduction and application of the checklist requires indeed appropriate training of the staff members in order to ensure checklist discipline, correct adherence to the items and consistent documentation. Gawande (2022) recalls the hesitancy, reluctance and skepticism during the study, since the implementation of a new procedure – involving team members from all levels equally – requires some flexibility of the organization. (In addition, the remarkable influence of the status quo bias cannot be underestimated in such cases.) The results of the study showed measurable improvements regarding patient safety. The rates of any complication, the total rate of in-hospital deaths and the overall rates of surgical-site infection and unplanned reoperation dropped at all included sites after the introduction of the checklist.[23] Insofar, the authors conclude, that "[t]he reduction in the rates of death and complications suggests that the checklist program can improve the safety of surgical patients in diverse clinical and economic environments" (Haynes, 2009, p. 496). At the same time, it is recognized, that the improvements are not singularly associated with the checklist itself: rather a more complex change, that affects the professional mindset, established new routines

[22] A training video of the complete checklist application is available online, see: (NHS, 2019). For the written form see: (Haynes et al., 2009, p. 492).

[23] See Haynes et al. (2009) for detailed and contextualized results.

and workflows and the increased sensitivity for safety aspects, has taken place around the document's application. In sum, the positive convincing results led to the global application of the checklist (in adapted form).[24]

Papoutsi et al. (2018) discuss implementation and results of the "**Frailsafe"** checklist in twelve hospitals across the UK that was intended to improve specifically the safety of older patients with reliable frailty assessments. The results of the study confirmed the skepticism about transferability of checklists to the field of geriatric care. The authors recognize rather social barriers associated with hesitancy, rejection (perception as additional workload) and established professional hierarchies and boundaries. The authors explain, that "[f]ormalizing tasks and work processes in the form of a checklist placed increased emphasis on 'work-as-imagined' […] which some hospital teams found difficult to reconcile with 'work-as-done' in the messiness of everyday practice" (Papoutsi et al., 2018, p. 315). In conclusion, the authors state that "more attention to the socio-technical work" is required instead of the introduction of as technically perceived methods.

An important aspect of healthcare work is coming quickly to sound assessments and adequate priorities. A multitude of checklists exists in order to organize daily routines in healthcare.[25] This applies among others to patient communication, administering medication correctly, triage or for ensuring the availability of complete, functioning equipment. Similar to aviation, **acronyms** help also in medicine to recall checklist items quickly. The Medication checklist acronym *TRAMP* stands for: *T*ime, *R*oute, *A*mount, *M*edication and *P*atient. The checklist is intended to increase patient safety by supporting nurses in administering medicine correctly, since "[r]esearch on medical administration errors (MAEs) shows an error rate of 60%, 34 mainly in the form of wrong time, wrong rate, or wrong dose" (Nurselabs, 2015).

The author of this text had the opportunity to gather direct information regarding checklist familiarity and use from experienced medical professionals in informal conversations. All consulted persons confirmed the significant contribution of checklists in their day-to-day work. For example, in ambulances the standard stowage lists facilitate a smooth shift handover of the vehicle and make sure that all required equipment and consumable supplies are complete. Some respondents explained to know the checklist items by-heart due to the daily repetition. The author had the chance as well to read both a First Aid checklist of a nursing home and the adapted version of the WHO Safe Surgery checklist of a large German hospital.

The First Aid checklist was extensive and detailed. It contained elements of read-do checklists and comments. The amount of details and the layout over three pages did not contribute to gaining a quick overview. Additionally, the compact presentation affected the readability. The Safe Surgery checklist reflected clearly the structure and items of the original WHO template. In comparison, the document was shorter, clearer and more precise. Considering, that the latter covers the essentials of a complex surgery, the checklist was more precise, concisely and efficient compared to the First Aid document. Insofar, the immense efforts of the WHO checklist development are obvious. Nevertheless, the individual checklist is intended to be workable for the respective organization. – The First Aid document was only available in German. Considering the fact, that nursing homes employ also international staff with different levels of local language proficiency, the development of versions in different languages is recommendable; particularly in the light of effective patient safety in emergency situations.

SUMMARY

Checklist integration and their correct application tangibly reflect the attitude towards compliance with safety standards in aviation and healthcare. Correct application effectively reduces human failure – a major cause of often avoidable aviation accidents or preventable medical complications. Insofar, checklists mirror and ensure quality and safety standards for both branches and are at the same time a capable tool to meet these aspirations. Sullenberger clarifies, that "aviation safety was improved through more than checklists, as important as those are. Checklists alone cannot cure the current fragmentation of patient care or advert tragedies […]" (Gordon et al., 2013, p. viii). The precedent discussion showed the interwoven components of the holistic aviation safety culture, where checklists are one of many essential components. Insofar, the unadjusted interprofessional transfer across settings of only one isolated method is insufficient. This relates in particular to the mindset of CRM and the appreciation of team intelligence in aviation.

As seen, checklists are a comparably simple, though effectively applicable tools to even complex situations. Due to their capability to guide attention and to reduce ambiguity and complexity, checklists are indeed a suitable instrument to promote good decision-making. Undoubtedly, the preparation of decisions can benefit from the systematic, transparently reproduceable, controlled and unemotional proceeding. The degree of checklist integration differs between aviation, where their application is widely mandatory, and healthcare. For both branches the positive effects of correct use are measurable.

[24] Urbach et al. (2014) applied the method in a study with Canadian hospitals, whereby, the positive outcomes of Surgical Safety checklists could not be observed by the authors.

[25] For example, WHO (2024b) provides an equipment checklist for a triage area. See also Nurselabs (2015) for various pharmacological mnemonics. Checklists for rescue service are part of the comprehensible compendium by Jahn et al. (2022).

REFERENCES

Bulsuk, K. (2009) *Taking the first step with the PDCA (Plan-Do-Check-Act) cycle.* [Online] https://www.bulsuk.com/2009/02/taking-first-step-with-pdca.html [last accessed: October, 28th 2024].

Degani, A. et al. (1990) *Human Factors of Flight-Deck Checklists: The Normal Checklist.* Moffett Field, California: NASA, Ames Research Center. [Online] https://ntrs.nasa.gov/api/citations/19910017830/downloads/19910017830.pdf [last accessed: October, 15th 2024].

Degani, A. et al. (1992) *On the Typography of Flight-Deck Documentation.* Moffett Field, California: NASA, Ames Research Center. [Online] https://ntrs.nasa.gov/api/citations/19930010781/downloads/19930010781.pdf [last accessed: October, 15th 2024].

Dismukes et al. (2010) *Checklists and Monitoring in the Cockpit: Why Crucial Defenses Sometimes Fail.* Moffett Field, California: NASA, Ames Research Center. [Online] https://hsi.arc.nasa.gov/flightcognition/Publications/NASA-TM-2010-216396.pdf [last accessed: October, 25th 2024].

FAA/US Department of Transportation (2022) *The PAVE Checklist.* [Online] https://www.faa.gov/sites/faa.gov/files/2022-11/PAVE_0.pdf [last accessed: October, 22nd 2024].

Gawande, A. (2007) *Better. A Surgeon's Notes on Performance.* New York: Metropolitan Books.

Gawande, A. (2022) *The Checklist Manifesto. How to get things right*. New York: Metropolitan Books.

Gawande, A. (2007) *The Checklist. If something so simple can transform intensive care, what else can it do?* In: Annals of Medicine. The New Yorker. [Online] https://leaderlikeyou.com/wp-content/uploads/2024/04/New-Yorker-Power-of-the-Checklist.pdf [last accessed: October, 26th 2024].

Gordon, S. et al. (2012) *Beyond the Checklist. What else health care can learn from aviation teamwork and safety.* Ithaka: Cornell University Press.

Haynes, A. B. et al. (2009) *A Surgical Safety Checklist to Reduce Morbidity and Mortality in a Global Population.* New England Journal of Medicine 360 [5]: 491-499. [Online] https://dash.harvard.edu/bitstream/handle/1/38846186/Gawande_Surgical%20Safety%20Checklist%20to%20Reduce%20Morbidity%20vor.pdf?sequence=1&isAllowed=y [last accessed: October 16th 2024].

Hersch, M. H. (2009) *Checklist: The secret life of Apollo's 'fourth crewmember'.*
The Sociological Review, 57(1_suppl), 6-24. [Online] https://doi.org/10.1111/j.1467-954X.2009.01814.x [last accessed: October 26th 2024].

Jahn, M. et al. (2022) *Checklisten Rettungsdienst. Notfall- und Gefahrensituationen.* 2nd edn. München: Elsevier.

Jones, E. M. (1996) *Apollo 12 CDR Cuff Checklist. Apollo 12 Lunar Surface Journal.* [Online] https://www.nasa.gov/history/alsj/a12/cuff12.html [last accessed: October, 3rd 2024].

KVWL (2024) *Methoden und Instrumente. Checklisten.* [Online] https://www.kvwl.de/fileadmin/user_upload/pdf/Mitglieder/Qualitaetssicherung/Qualitaets-management_KPQM/kpqm_5_30.pdf [last accessed: October, 15th 2024].

Lerner, E. B. et al. (2001) *The Golden Hour: Scientific Fact or Medical "Urban Legend"?*. Academic Emergency Medicine, 8: 758-760. [Online] https://onlinelbrary.wiley.com/doi/epdf/10.1111/j.1553-2712.2001.tb00201.x [last accessed: October, 16th 2024].

Linde, C. et al. (1987) *Checklist interruption and resumption: A linguistic study.* Moffett Field, California: NASA, Ames Research Center. [Online] https://ntrs.nasa.gov/api/citations/19880016964/downloads/19880016964.pdf [last accessed: October, 16th 2024].

NASA (1969) *Apollo 11 Stowage List, July 15, 1969.* [Online] https://www.nasa.gov/wp-content/uploads/static/history/afj/ap11fj/pdf/a11-stowage-list.pdf [last accessed: October, 1st 2024].

NHS, National Health Service UK, Gloucestershire Hospitals Foundation Trust (2019) *Video: WHO Surgical Safety Checklist Training.* [Online] https://youtu.be/IdgXe1qva5Y?si=-o6eMJoZJJuB-peOH [last accessed: October, 20th 2024].

Nuclino Blog (2019) *The simple genius of checklists, from B-17 to the Apollo missions.* [Online] https://blog.nuclino.com/the-simple-genius-of-checklists-from-b-17-to-the-apollo-missions [last accessed: October, 27th 2024].

Nurselabs (2015) *Administering Medication Checklist "TRAMP".* [Online] https://nurseslabs.com/pharmacology-nursing-mnemonics-tips/ [last accessed: October, 27th 2024].

OAS – United States Department of the Interior Office of Aircraft Services (2001) *Aviation Accident Prevention Bulletin.* [Online] https://www.doi.gov/sites/default/files/migrated/aviation/safety/upload/PB_2001-01.pdf [last accessed: October, 27th 2024].

Papoutsi, C. et al. (2018) *Improving patient safety for older people in acute a admissions: implementation of the Frailsafe checklist in 12 hospitals across the UK.* Age and Ageing 2018, 47: 311-317 [Online] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6016694/pdf/afx194.pdf [last accessed: October, 16th 2024].

Pilot Institute (2023) *PAVE Checklist explained.* [Online] https://pilotinstitute.com/pave-checklist/ [last accessed: October, 27th 2024].

Skhmot, N. (2017) *Using the PDCA cycle to support continuous improvement (Kaizen)* [Online] https://the-leanway.net/the-continuous-improvement-cycle-pdca [last accessed: October, 29th 2024].

Skybrary (2024 a) *Pilot Memory Aids* [Online] https://www.skybrary.aero/index.php/Pilot_Memory_Aids [last accessed: October, 2nd 2024].

Skybrary (2024 b) *Decision-Making (OGHFA BN)* [Online] https://www.skybrary.aero/index.php/Decision-Making_(OGHFA_BN) [last accessed: January, 26th 2024].

Skybrary (2024 c) *NASA Pre-flight Icing Checklist.* [Online] https://skybrary.aero/bookshelf/nasa-pre-flight-icing-checklist [last accessed: October, 11st 2024].

Skybrary (2024 d) *Checklists – Purpose and use.* [Online] https://skybrary.aero/articles/checklists-purpose-and-use [last accessed: October, 1st 2024].

Skybrary (2024 e) *Emergency or Abnormal Situation.* [Online] https://skybrary.aero/articles/emergency-or-abnormal-situation [last accessed: October, 1st 2024].

Skybrary (2024 f) *Normal Checklists and Crew Coordination (OGHFA BN)* [Online] https://skybrary.aero/articles/normal-checklists-and-crew-coordination-oghfa-bn [last accessed: October, 11st 2024].

Skybrary (2024 g) *Emergency and Abnormal Checklist.* [Online] https://skybrary.aero/articles/emergency-and-abnormal-checklist [last accessed: October, 11st 2024].

Taylor, S. (2020) *Check Lists.* (contains B-17F and G checklists from 1944). [Online] https://stephentaylorhistorian.com/wp-content/uploads/2020/04/b-17-pilot-checklist.pdf [last accessed: October 29th 2024].

Theophanidis, P. (2011) *"Seen any interesting hills and valley?"* [Online] https://aphelis.net/seen-any-interesting-hills-valley-playmates-on-the-moon-1969/ [last accessed: October, 16th 2024].

UMMS/University of Maryland Medical Center (2024) *History of the Shock Trauma Center. Tribute to R Adams Cowley, MD.* [Online] https://www.umms.org/ummc/health-services/shock-trauma/about/history [last accessed: October, 16th 2024].

WHO (2024a) *WHO and Surgical Safety. Surgical Safety Checklist.* [Online] https://www.who.int/teams/integrated-health-services/patient-safety/research/safe-surgery [last accessed: October, 9th 2024].

WHO (2024b) *Triage-Area – Equipment Checklist.* [Online] https://cdn.who.int/media/docs/default-source/integrated-health-services-(ihs)/csy/iitt/triage-essential-equipment-checklist.docx?sfvrsn=6e46595c_2 [last accessed: October, 20th 2024].

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