International Journal of Applied Research 2023; 9(11): 05-20

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor (RJIF): 8.4
IJAR 2023; 9(11): 05-20
www.allresearchjournal.com
Received: 16-06-2023
Accepted: 18-07-2023

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Impact of checklists on inpatient safety: A review of recent literature

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DOI: https://dx.doi.org/10.22271/allresearch.2023.v9.i11a.11336

Abstract
Background: Increase in public education and demands for patient-centred care prompt further research into transparent, organized and, above all, safe medical care. The checklist appears capable in theory to resolve some of the issues of patient safety, however its relevance and value in current practice has been questioned and adoption remains low among medical communities worldwide.
Objective: to conduct a systematic review of articles of the current effect of checklists on patient safety in terms of improving patient outcomes and reducing medical errors in the inpatient setting.
Methods: Search was conducted using Google Scholar with no language or study design restrictions and included keywords ‘checklist’, ‘impact’ and ‘patient safety’. Publications before January 2016 were excluded to more closely reflect its impact in current medical practice. Only studies on quantitative measures of impact were included. Case reports, editorials, letters, commentaries, reviews, overviews and conference abstracts were excluded. Studies with checklists employed as part of a ‘bundle’, impact assessed in a simulated setting, involved outpatient setting were excluded. Titles that obviously did not match the review’s aim were also excluded.
Main Results: 114 articles were identified, of which 19 satisfied the eligibility criteria. Articles evaluated checklist impact in terms of patient outcomes (mortality, adverse events, length of hospital stay) and staff adherence to standard guidelines. Studies reported mixed results of checklist impact in patient related outcomes, however uniformly found statistically significant improvements in staff adherence (mean number of items completed 8.7 (SD=1.5) without checklist to 10.9 (SD=1.1) items with checklist out of 12 items, $p<0.0001$). Several studies also reported significant effects when completed checklists are compared with patient related outcomes (20.0% when checklist not completed vs 11.3% when checklist completed, p=0.026).
Conclusion: The studies concluded a possible contribution of the checklist in patient-related outcomes, with much inconsistency in findings among different studies. The few articles reporting on staff adherence however provided significant uniform improvement following checklist implementation. There is a need for more high-quality quantitative studies to effectively conclude its impact in patient safety. As for now, the checklist remains relevant and should be applied at a broader scale, with research priority on checklist design and quality indicators to be included.

Keywords: Patient related, outcomes, however uniformly

Introduction
Background
In the current era where internet is widely available and information is shared almost instantaneously, there is increasing societal unrest towards the medical and surgical community. Increased public education and health awareness led to societal uproars for better and, more importantly, safer patient care [1]. This is especially evident following the occurrence of various adverse events arisen due to medical errors [2 3], causing demands for more transparency, accountability and measurable outcomes [4]. Such errors include medical never events [5 6], diagnostic errors [7, 8, 9] and care omission [4 10]. For example, a study in US estimates a diagnostic error frequency of 5% in adult patients [7]. In the emergency department alone, the presence of diagnostic errors can be up to 35% for a common chief complaint such as abdominal pain [11]. In the Infectious Disease setting, calls for measuring tools for inappropriate antimicrobial use have also emerged [12, 13].

Such problems are also seen among paediatric [10, 14, 15] and neonatal settings [4, 16]. Furthermore, the continuing healthcare expansions also poses several risks towards patient safety [17]. Currently, research efforts towards addressing and resolving such patient safety risks are still ongoing [18, 19, 20, 21, 22, 23]. Interventions such as the checklist have been proposed to be potentially useful for such problems in view of its simplicity [24, 25] and evident effects with its appropriate implementation [2]6, and has seen a broader range in its utilization since it was first introduced in 2009 [25]. Among them, only a few checklists have been validated to see worldwide use, such as the WHO Surgical Safety Checklist (WHO SSC) [25, 27], the Surgical Patient Safety System (SURPASS) checklist [28], and the recently introduced WHO Safe Childbirth Checklist (WHO SCC) [29]. While there may be checklists developed for other healthcare sectors and has demonstrated to have significant positive impacts on the delivery of care [30, 31, 32, 33, 34, 35, 36, 37, 38, 39], their adoption for worldwide use [5] and advancement [40] remains hindered by a disappointing lack of systematized research. The lack of validated checklists in contrast to the abundance of healthcare sectors in the current era of medicine demonstrates the underdevelopment of checklist culture in the field of healthcare [41]. Moreover, the initiative for implementation of checklists also encounters several barriers [36, 42, 43]. In particular, its role in medicine has been negatively perceived among the medical community [44, 45, 46, 47], and has been criticized for its reliance on operator competence [48], time consumption [10], issues with staff compliance [10], failures in design [22] and encumbrance as well as autonomy restriction on the operator [22]. Research onto impact of checklists have also been regarded to contain poor insight on its complex interactions with the factors influencing patient safety [42, 49]. Such problems have led to questions regarding the role of relatively primitive tools such as the checklist in the current, rapidly advancing field of medicine and surgery, in contrast to other alternatives [50, 51, 52, 53]. Based on these foundations, this review aims to investigate the relevance of checklist usage in the current practice of inpatient care, by researching recent literature on its impact on inpatient safety. To understand its current role in current healthcare, however, we must first understand the rationale and conceptual mechanisms behind its use.

Checklist and Patient Safety: A Brief History

Patient safety is an emerging but nevertheless important aspect of healthcare. Its development and realization has greatly enhanced the effectiveness of modern healthcare in providing safe, patient-centred care. This concept first bore fruit in the twentieth century following realization of the presence of medical errors in healthcare. It is a science developed to implement the primary instruction of the visionary Hippocrates: First, do no harm (primum non nocere). Its practice was initially non-uniform, in which the responsibility for the patient's safety primarily lies on the individual doctor in charge, and is taught to junior staff primarily by a 'learning by doing' method [54]. Pioneers of patient safety championed the science of prevention of medical failures garnered attention of other healthcare professionals and policy makers of the west at the time [55]. Subsequent investigations yielded the publication of landmark reports including 'To Err is Human' by the institute of medicine (IOM) of the United States of America [23, 56] as well as 'An Organisation with a Memory' by the department of health in the United Kingdom in 2000 [57]. These two reports piqued the interest of healthcare research and inspired the establishment of national and international agencies to investigate and address this issue [58, 59]. Among the various interventions devised to improve patient safety, the introduction of checklists has been one of the most impactful [60]. One of the most revolutionary interventions is the creation of the World Health Organization Surgical Safety Checklist (WHO SSC) [25] and its inclusion into the 'Safe Surgery Saves Lives' initiative [61, 62], which caused significant declines in both surgical morbidity and mortality [25], and is now used to aid surgical procedures worldwide [26, 63]. The implementation of checklists onto surgery and ultimately modern healthcare was first inspired by the use of checklists in field of commercial aviation and flight, where pilots utilized scores of checklists each specific for a different scenario to ensure all necessary actions are to be taken to address each scenario [44]. Since then, significant effort has been invested in the creation of useful and effective checklists for different medical disciplines [64, 65]. Of these disciplines, the checklist especially benefitted the field of surgery [66] due to its supportive role in the operative phase, where majority of adverse surgical outcomes occur [9].

How Checklists Improve Patient Safety

The checklist appears in many forms in the field of healthcare [67, 68]. Those commonly used are:

A criteria of merit (COM) checklist includes a rating and ranking of attributes to evaluate. It functions similarly to a laundry list, where items, tasks or criteria are categorized with no particular order. An example of a COM checklist in the healthcare setting is the Medical Equipment Checklist.

A sequential Checklist factors in the order of steps of an executable task. In this checklist, the grouping, order and flow of the items are relevant. An example of a sequential checklist in the healthcare setting is a Procedure Checklist.

A flowchart checklist displays the essential steps of a task that include points of decision for the user to assess the status quo of the task and to select individual items of the task based on that assessment. It is primarily used in the form of diagnostic checklists where it serves as a decision aid for the operator.

While many may claim the checklist to be a simple 'memory aid' or a rule, research has provided evidence showing that it is much more [49]. To explain the role of checklists in improving patient safety in healthcare, we must first dissect the term 'organizational routines'[69], which is not merely a standard, detailed course of action but, according to Feldman and Pentland (2003), consists of two key dimensions: Ostensive and performative [69]. The ostensive dimension of a routine is the abstract ideation of it, used to refer to certain activities or to justify a certain action (know that) [69]. The performative dimension on the other hand relates to agency, consisting of 'actual performances by specific people, at specific times, in specific places' (know how) [69]. The checklist, therefore, serves as an artefact that aids in the ostentive aspect of a routine [69]. It is evident how checklists can serve as a cognitive tool that promotes interaction between professional bodies if we factor in the inherent multiplicity of each routine compounded by the interaction of routines in highly complex professional domains such as healthcare. Kupier (2017) described checklists as 'hubs' that connect interdisciplinary routines [70]. They are social interventions that interfere with both the practical and social ways of routines and work [70]. For example, the WHO Surgical.

Safety Checklist consists of three parts: A morning briefing of upcoming procedures by the whole surgical team; and two moments during the procedure: A time-out right before making the incision; and a sign out before the patient leaves the operating theatre [25]. Each of these moments mandate inter-disciplinary communication and promotes social interactions between healthcare team members so that information is understood uniformly.
The most impactful use of the checklist is seen in the field of surgery with the introduction of the surgical safety checklist [25], although the reasons behind it remain obscure and under investigated [42]. Several studies and reviews have shown that implementation of safety checklists benefit patient safety in various ways, including improvements in communication for critical decisions [22], teamwork and overall safety climate [1]. A study theorized that the checklists effectively enabled junior staff to speak up to their superiors, thus diffusing the hierarchal social structure in the operating theatre [10]. Use of surgical safety checklist have demonstrated significant positive effects in patient care including timely antibiotic administration and appropriate prevention of hypothermia [48]. In the US, it has been reported that appropriate implementation of the Surgical Safety Checklist may have significant contribution in reducing healthcare related costs by preventing major surgical complications at virtually negligible costs [71]. Its success in this field also prompted other specialties to devise their own safety checklists, including paediatric surgery [15, 16, 72]. Several studies measured outcomes following the implementation of a daily Quality Rounds Checklist (QRC) in trauma intensive care, and has demonstrated that such a simple intervention significantly increased healthcare team compliance with evidence-based prophylactic measures and decreased complications [37, 38, 39]. The use of checklists also had significant effects in facilitating handover processes, providing cognitive aid and, more importantly, improving staff compliance to standard routines [21]. In the primary care setting, checklists have been proposed as a potential solution for reducing diagnostic errors by improving diagnostic reasoning and removing cognitive biases [8]. Checklists have also developed for clinicians to prevent the occurrence of 'never events' [6]. Despite all this, it remains, in essence, a supplementary tool for the clinician or surgeon, and is ultimately reliant on the operator's clinical competency for its effects [48].

Issues with The Checklist
Although evidently effective, the checklist is far from perfect, and faces several challenges in its successful creation, implementation and subsequent acceptance into the medical community [49]. There are two factors interfering with the creation of a checklist. First, it explicitly prescribes behaviour, while established professional routines are mostly implicit entities—encompassing tacit knowledge. Although these routines structure work, they are not supplemented by codified artefacts [73]. Second, professional routines are mostly segmented. Socialization into sub-disciplines among professionals also creates a sense of their profession which includes its duties, boundaries, values, aspirations and relation to others. Different routines, therefore, guide behaviour in the various sub-disciplines [73]. While the checklist may be easily incorporated into other industries such as aviation and engineering, their applications in the medical field remain remarkably crude and limited [42, 44]. Previous research has stated that, despite many serious and thorough attempts—for example, creation of the Surgical Safety Checklist and numerous research proving its effectiveness, the medical profession still reports low compliance rates [36, 42, 45, 46, 52]. The reluctance of medical professionals to accept change and their reliance to their own autonomy is often blamed for the prevalence of this. Experiences with the surgical safety checklist identified issue with its compliance such as tackling staff scepticism and disinterest in checklist use [60, 20, 58, 23, 27, 26]. A lack of motivation is often considered one of the most important barriers to implementation [42, 45]. This is especially evident among the residents responsible for recording the checklists, as it was reported to increase their already heavy workload [24, 45]. Furthermore, the usage of such tools does not account for the presence of excessive variability and fluidity of modern medicine renders the creation of rigid, systematic checklists unhelpful or even harmful to patients, as it does not guarantee optimal, personalized care [3]. In other words, with the implementation of systemic concepts and organization into the complex field of modern medicine, medical professionals are forced to disregard the artful human side of medicine, leaving medical practices structured and cold. Policy makers in the field of medicine must therefore carefully weigh the pros and cons of implementing interventions to strike a perfect balance in creating enough interventions to deliver optimal care without over encumbering the workload of healthcare professionals.

Objective of the Study
We sought to conduct a systematic review of articles of the current effect of checklists on patient safety in terms of improving patient outcomes and reducing medical errors in the inpatient setting.

Methods
Definition of Patient Safety
The term 'patient safety', as beguiling simple and intuitive as it is sounds, embodies such a large yet elusive aspect of healthcare and is difficult to be defined medically. Patient safety is defined as 'the reduction of risk of unnecessary harm associated with health care to an acceptable minimum' [8]. This definition covers not only the responsibility a medical doctor has towards his or her patient's safety during inpatient and outpatient care, but it also expands towards bigger issues involving hospital organization, drug manufacture and even hospital design.

Definition of a Checklist
A checklist is defined, quite simply, as 'a list of action items, tasks or behaviours arranged in a consistent manner, which allows the evaluator to record the presence or absence of the individual items listed' [7]. It serves as cognitive aid to healthcare professionals, used to highlight essential criteria for a process to be carried out. It is used in the context of medicine alongside Clinical Practice Guidelines (CPG), Pre-printed protocols or flowcharts to achieve the goal of providing memory support for the healthcare professional, in its case primarily for discrete routine tasks. Primary

examples of such checklists include the World Health Organization Surgical Safety Checklist (SSC) [25], the Surgical Patient Safety System (SURPASS) checklist [28], and more recently, the World Health Organization Safe Childbirth Checklist (SCC) [29]. Checklists are implemented with the primary aim of preventing medical errors in routines that may lead to medical adverse events. It is to be emphasized that the checklist is by itself a supportive cognitive tool and is therefore in no way a direct influence onto patient safety without strict adherence of the user.

Definition of Medical Error and Adverse Event

Medical error is defined as 'an act of omission or commission in planning or execution that contributes or could contribute to an unintended result[74]. These errors could either be due to not taking a required action (omission) or taking a wrong action (commission). A medical error poses a risk towards reducing patient safety by increasing the risk of occurrence of an adverse event, however, not all medical errors result in patient harm. An adverse event is defined as 'unintended physical injury resulting from or contributed to by medical care that requires additional monitoring, treatment or hospitalization, or that results in death' [74].

Measuring Impact of a Checklist on Patient Safety

As mentioned above, patient safety is a broad but elusive aspect of healthcare and is, in practice, hard to be measured completely. Several studies have attempted to demonstrate effects of interventions on patient safety via assessing parameters of patient outcomes and human factors [63, 65, 75, 76, 77]. This review assesses the impact of the checklist on patient safety based on similar quantifiable parameters, including patient outcomes such as mortality, length of hospital stay and other adverse events, as well as medical errors, quantified in this study in terms of provider adherence to guidelines and measured by fulfilment of quality indicators in accordance to respective guidelines.

Search Strategy

On April 20, 2020, we systematically searched using Google Scholar with no language or study design restrictions and included keywords 'checklist', 'impact' and 'patient safety'. We restricted the article publication date to 2016 onwards to assess recent impact of checklists on patient safety as per our primary research objective.

Inclusion and Exclusion Criteria

As stated above, our search is restricted to studies published from 2016 onwards. Of the yielded results, studies of checklists investigated for their impact on inpatient safety are included. This includes safety checklists, handover procedures, daily rounds checklists and procedural checklists. The study included validated checklists (WHO SSC), modified versions of validated checklists as well as checklists derived from standard guidelines. Only studies on quantitative measures of impact were included. Case reports, editorials, letters, commentaries, reviews, overviews and conference abstracts were excluded. Studies with implementation of 'bundles' containing checklist use were excluded in order to assess the impact of checklist independently on patient safety. Furthermore, studies of checklist impact in a simulated setting were excluded in order to assess its impact in a practical setting. Studies involving use of checklists in the outpatient setting were excluded to focus the search onto the inpatient population, in view of the heterogeneity of illness and patient care between inpatient and outpatient settings. Titles that obviously did not match the review's aim were also excluded.

Data Extraction

We extracted data from included studies on its setting, checklist used, study design, participant groups, outcome measures and main results.

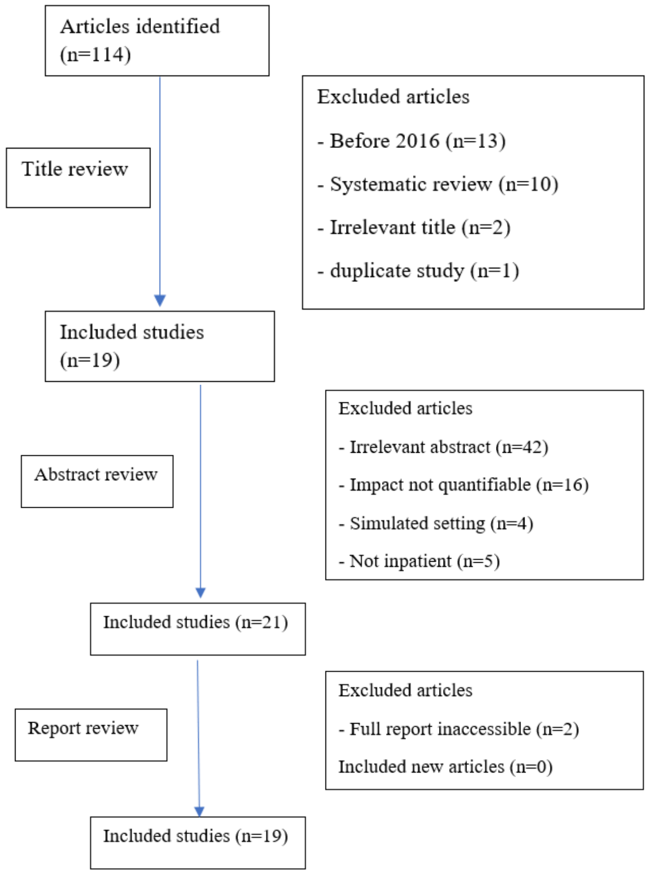

Fig 1: Article Exclusion Flowchart: Impact of Checklist Implementation on Inpatient Safety

Results

Study Characteristics

Our initial literature search yielded 114 results. Of these 144 articles, we identified 19 articles [78-96] that fit our eligibility criteria. Of these studies, 12 involved checklist use in the surgical setting [78-79, 81-84, 86, 92-96], 5 involved checklist use in the anaesthesia/critical care setting [78, 86, 88-90], 2 involved checklist use in the medical setting [81, 91]. All studies involved comparison of participant groups with checklist usage against participant groups without checklist usage. Two of the 19 studies were randomized controlled trials [80, 91], 10 studies utilized a pre/post intervention study design [78, 79, 83, 85, 86, 90, 92, 93, 95, 96], while seven studies adopted a retrospective or prospective observational study design [81, 82, 84, 87, 88, 89, 94].

Checklist Description and Study Parameters

11 studies involved use of WHO SSC or a modified version of WHO SSC [79, 80, 82, 83, 87, 89, 92-96], and eight studies

involved checklists derived from standard guidelines [78, 81, 84-86, 88, 90, 91].

11 studies included outcomes on patient mortality in their investigation of checklist impact on patient safety [81-85, 87, 89, 92-94, 96], 16 studies included adverse outcomes, including patient readmission, surgical site infections and other complications[79-89 92-96]. Seven studies investigated the impact of checklists on length of hospital stay [81, 87, 89, 91, 92, 93, 95]. Six studies investigated impact of checklist implementation on provider guideline adherence, measured as percentage fulfilment of quality indicators or application of care processes [78, 80, 86, 89-91].

Impact of Checklist on Inpatient Safety

Williams *et al.* [78] investigated the effect of implementation of an ICU transport checklist on guideline compliance among transfer staff, evidenced by total number of correctly completed checklist items. They reported a significant increase in median aggregate of total checklist items correctly completed (86.7% pre-checklist vs 90% post-checklist, P=0.01). Individual improvements included knowledge of Cormack-Lehane grade (60.5% pre-checklist vs 84.2% post-checklist, P=0.021) and transport destination notification (83.7% pre-checklist vs 100% post-checklist, P=0.01). Individual reductions in compliance following checklist implementation is seen in item "checking whether oxygen cylinders were ≥ ¾ full (100% pre-checklist vs 76.3% post-checklist, P=0.002). Differences in completion rates of other individual items (adequate number of patient identifiers, a defibrillator present, a bag valve mask present, spare drugs, documentation of the presence or absence of complications, and a handover to the treating team) did not obtain statistical significance. Gama *et al.* [79] conducted a retrospective pre/post intervention study to investigate checklist implementation impact on surgical site infection (SSI) rates in two university hospitals, one in Canada and another in Brazil. Both institutes reported a decrease in SSI rates following checklist implementation, however the decreases are not statistically significant (In Canada, SSI rate decreased from 27.7% to 25.9% following SSC implementation, P=0.625; In Brazil, SSI rate decreased from 17.0% to 14.4% following SSC implementation, P=0.448). When they compared SSC completion on SSI rates, they discovered lower SSI rates in surgeries with completed checklist in comparison to incomplete checklists (20.0% vs 11.3%, P=0.026). Haugen *et al*[80] conducted a stepped wedge cluster randomized controlled trial to investigate the effects of WHO SSC on application of care processes and patient outcomes. They reported that full completion of SSC resulted in significantly increased application of care processes (surgical site marking, normothermia protecting measures and antibiotics) versus control ($p<0.001$). Upon adjustment of baseline variables, applications of two of the three care processes, namely normothermia protecting measures and antibiotic administration remained significantly increased ($p<0.001$), while site marking became non-significant (P=0.084). In terms of patient outcomes, SSC implementation is significantly associated with reductions in all investigated adverse events ($p<0.05$), all of which remained so following baseline variable adjustment except for respiratory complications (P=0.051) following adjustment for time effects. Mao *et al.* [81] reported on the effects of implementing an enteral feeding checklist, developed from studied practices, in the management of shock patients above 18 years in the ICU. The checklist group received significantly earlier enteral nutrition (EN) (mean EN 2.6 days with checklist vs 4.6 without checklist, P=.0.017) and lower mechanical ventilation rate (62.9% with checklist vs 85.0% without checklist, P=0.004). Univariate analysis and multivariable logistic regression analysis revealed no significant difference in 28-day mortality (20.0% vs 23.9%, P=0.632), 90-day mortality (25.7% vs 31.9%, P=0.490), duration of mechanical ventilation (mean 13.4 days vs 16.6 days, P=0.395) and intolerance to EN (17.1% vs 23.0%, P=0.461). However, checklist group had significantly shorter ICU stay (mean 17.3 days vs 25.7 days, P=0.043, adjusted P=0.048) compared to non-checklist group. Ramsay *et al.* [82] reported that implementation of WHO SSC resulted in significant reductions in in-hospital mortality (time series analysis yielded 0.003 absolute decrease in mortality before, 0.069 absolute decrease in mortality during and 0.019 absolute decrease in mortality after checklist implementation, $p<0.001$). Although post-implementation mortality trend did not differ with pre-implementation mortality trend (P=0.153), they reported that checklist implementation was associated with an estimated 36.6% relative reduction in mortality rate (0.72 without checklist (trend projection) vs 0.46 with checklist in year 2014). They also reported a significant difference in return to theatre trends before; during and after checklist implementation, (time series analysis yielded 0.002% increase per year before; 0.003% decrease per year during and 0.002% decrease per year after checklist implementation, $p<0.001$), as was that between pre-implementation trend and the post-implementation trend ($p<0.001$). Significant differences are also shown in estimates for return to theatre rates pre-implementation compared with post-implementation ($p<0.001$). Time series analysis showed no significant improvement in mortality rates in the non-surgical cohort (P=0.418), which did not implement WHO SSC equivalents at that timeframe. Singh *et al.* [83] conducted a retrospective pre/post intervention study to investigate effectiveness of safety checklist implementation on intraoperative and postoperative complications. They reported reductions in both intraoperative (6.14% to 2.12%, P=0.034) and postoperative (6.56% to 3.38%, P=0.13) complications following checklist application. Anaesthetic complications have seen non-significant decreases (intraoperative from 3.27% to 1.69%, P=0.26, post-operative from 1.64% to 0.85% p=0.43). Furthermore, implementation of SSC resulted in significant reduction intraoperative (3.27% to 0.85%, P=0.06) and postoperative (13.11% to 7.63%, P=0.049) mortality. Spanjersberg *et al.* [84] conducted a prospective multicentre cohort study on introduction of a pre-incision safety checklist (ISC) and its impact on inpatient mortality and adverse outcomes among a cardiac surgery population. They reported significant reductions in 120-day mortality (1.7% with ISC vs 3.0% without ISC, $p<0.01$), which remained consistent following baseline variable adjustment (HR 0.44; 95% CI 0.22-0.87). They also described significantly reduced 30-day mortality (1.1% with ISC vs 1.9% without ISC, P=0.01, adjusted P=0.03). They discovered a trend toward a lower surgical re-exploration rate (3.6% with ISC vs 4.6% without ISC, P=0.07) and deep sternal wound infection (DSWI) (0.4%% with ISC vs 0.7% without ISC, P=0.15) in the ISC group, however it was not statistically significant. They found no significant difference between both groups on the 72-hour stroke rate (0.7% in both groups, P=0.72). Suarez *et al.* [85] reviewed 266 transurethral resection of bladder tumours (TURBT) to evaluate the impact of a surgical checklist, derived from evidence based guidelines, on recurrence-free survival rates. They reported an independent, significant association, between checklist implementation and three-year recurrence free survival (HR 0.57, 95% CI 0.35-0.92, P=0.02). In cases where surgical checklist was not implemented, three-year RFS rates were significantly lower (p=0.008). They also investigated whether surgical checklist implementation affected the presence of detrusor muscle in pathologic specimen, but found no significant association (P>0.05). Joseph *et al.* [86] investigated the effect of "TRAUMA LIFE" checklist implementation on certain quality metrics. They reported a significant improvement in urinary catheter utilization (1430 to 945 utilization days, P=0.00), ventilator-associated events rate (8.46 to 0 episodes/1000 ventilator days, P=0.01) and restraint order compliance (75.6% to 89.9%, p<0.01). Checklist implementation did not significantly change CAUTI rate (8.13 episodes/1000 catheter days pre-checklist to 3.2 episodes/1000 catheter days post-checklist, P=0.24) and CLABSI rate (0 episodes/1000 line days pre-checklist to 3.5 episodes/1000 line days post-checklist, P=0.18). Rodella *et al.* [87] compared effects of WHO SSC on patient outcomes among 21 best-performer hospitals and 27 other hospitals. They reported significant improvement on rate of LOS 8 days and above (p<0.0001 in best performers, P=0.0001 in other hospitals) and 30-day readmissions (p<0.0001 in both groups). no significant association with differences with in-hospital (P=0.19 in best performers, P=0.25 in other hospitals) and 30 days post-discharge (P=0.2112 in best performers, P=0.2533 in other hospitals) mortality rate. Wichmann *et al.* [88] reported a significant association between implementation of a central venous catheter checklist and central line associated bloodstream infection (CLABSI) rate (3.8 per 1000 catheter days with checklist vs 5.9 per 1000 catheter days without checklist, P=0.001). Checklist implementation also resulted in significantly lower catheter colonization rate (21.2 per 1000 days with checklist vs 36.3 per 1000 catheter days without checklist, p<0.001). Kumar *et al.* [89] compared between modified WHO SSC implementation against inpatient safety parameters. They reported significant increases in overall documentation of quality indicator parameters (p<0.001), except for introduction of team (98.2% pre-checklist vs 99.4% post-checklist, P=0.31) and site marking (97.1% pre-checklist vs 93.5%, P=0.99). However, no significant association is established between checklist implementation and changes in post-operative urinary tract infection rates (13.6% pre-checklist vs 9.5% post-checklist, P=0.52), wound infections (8.2% pre-checklist vs 8.3% post-checklist, P=0.57), drain-related infections (3.5% pre-checklist vs 7.1% post-checklist, P=0.11), catheter related blood stream infections (1.06% pre-checklist vs 2.96% post-checklist, P=0.61), blood stream infections (2.9% pre-checklist vs 6.5% post-checklist, P=0.098), mortality (7.1% pre-checklist vs 6.5% post-checklist, P=0.51) and length of intensive care unit (ICU) stay (4.79 days pre-checklist vs 4.64 days post-checklist, P=0.703). Park *et al.* [90] conducted a prospective pre/post intervention study between implementation of anaesthesia handover checklist and data transfer among anaesthetists and surgeons. They reported that, following checklist implementation, reporting of quality indicators of data transfer increased from a mean composite value of 8.7 (SD=1.5) to 10.9 (SD=1.1) items out of a total of 12 items (p<0.0001). Independent analysis of anaesthesia staff handovers yielded a significant increase in number of reported items from 4.8 (SD=1.6) to 8.9 (SD=2.0) items, but not among surgeons (5.9 items pre-checklist to 5.5 items post-checklist, P=0.2). Van Daalen *et al.* [91] conducted a randomized controlled trial to investigate the association between self-developed antibiotic checklist derived from generic quality indicators and several outcomes, including patient outcomes, LOS, admission to ICU, mortality and appropriateness of antibiotic treatment. They reported that implementation of antibiotic checklist did not significantly change mean LOS (10.0 days pre-checklist vs10.1 days post-checklist, P=0.8). Covariate adjustment yielded similar non-significant results (10.1 days pre-checklist vs 10.4 days post-checklist, P=0.6). On the other hand, QI performances have increased between +3.0% and +23.9% per QI, and the percentage of patients with a QI sum score above 50% increased significantly (OR 2.4 (95% CI 2.0–3.0), p< 0.001). They have also reported that higher QI sum scores were significantly associated with shorter LOS (p<0.05). Bock *et al.* [92] reported a significant association between WHO SSC implementation with ninety-day (2.4% to 2.2%, P=0.02) but not thirty-day (1.36% to 1.32%, P=0.17) all-cause mortality. Checklist implementation did not significantly affect thirty-day readmission rates (14.6% pre-checklist vs 14.5% post-checklist, P=0.79). However, adjusted length of stay was significantly reduced following SSC implementation (10.4 days pre-checklist vs 9.6 days post-checklist, p<0.001). Lacassie *et al.* [93] conducted a retrospective analysis of 70639 surgical encounters to evaluate baseline-adjusted impact of SSC on patient outcomes. They reported a significant decrease in in-hospital mortality rate from 0.79% to 0.61% following SSC implementation (P=0.002) following propensity score matching, with similar results following PS weighting (P=0.013). The mean length of stay (LOS) reduced from three (IQR 1-5) to two (IQR 1-4) days following checklist implementation (p<0.01). No significant differences were found in the odds of postoperative surgical site infection. Mayer *et al.* [94] investigated the association between WHO Surgical Safety Checklist compliance and patient outcomes. They reported that poor checklist compliance, defined in their study as failure to complete one or more components of the checklist, is associated with greater risk of developing complications after surgery (16.9% to 11.2%, p<0.01). On the other hand, successful completion of all 3 components of the checklist had significantly lower rates of complication occurrence (16.9% with checklist to 9.7% without checklist, p<0.01). Overall mortality rate also showed an increasing trend when checklist was not completed but is not significant (1.0% with full completion to 1.4% when none completed, P=0.67). They also discovered a significant interaction between checklist completion and high complication risk surgeries (P=0.009), where high complication risk surgeries with full completion of the checklist encountered only slightly more complications compared to low risk surgeries and no checklist completion (Odds ratio 1.71, P=0.044). By contrast, the odds ratio for one or two components of the checklist completed were 4.26 (P=0.007) and 4.13 (p<0.001). This interaction is not significantly reproducible for low risk (P=0.23) cases. Furthermore, Population-attributable fraction (PAF) calculations revealed that 14% (95% CI 7%-21%) of the complications could be prevented if full completion of the checklist was implemented in the surgical population. O'Leary *et al.* [95] reported on implementation of WHO SSC and its effects on paediatric surgical complications and mortality within 30 days of surgery. Checklist implementation did not significantly change odds of perioperative complications (4.08% pre-checklist vs 4.12% post-checklist, P=0.9). Checklist implementation significantly associated with differences in LOS, although median LOS were the same in both groups (1 (IQR1-3) days in both groups, $p<0.001$). Both unadjusted and adjusted proportion of children who had an unplanned return to the operating room did not differ between groups (0.27% pre-checklist vs 0.24% post-checklist, adjusted OR 0.88, P=0.6). Upon individual analysis, the proportion complications did not differ significantly between pre- and post-checklist groups, apart from unadjusted electrolyte or acid-base abnormalities (0.12% pre-checklist vs 0.03% post-checklist, P=0.01). Zingiryan *et al.* [96] conducted a prospective pre/post intervention study to investigate the effect of a modified WHO SSC on the rates of nine complications related to surgeries. They reported that checklist implementation did not have a significant association with differences in mortality (2.9% pre-checklist vs 2.6% post-checklist, P=0.52), death among surgical inpatients with serious treatable complications (17.4% pre-checklist vs 16.4% post-checklist, P=0.70), sepsis (0.9% pre-checklist vs 0.7% post-checklist, P=0.53), wound dehiscence (0.2% in both groups, P=1), Postoperative venous thromboembolism (0.4% in both groups, P=0.56), postoperative haemorrhage/haematoma (0.2% pre-checklist vs 0.3% post-checklist, P=0.53), transfusion reaction (0 in both groups, P=1) and retained foreign body (0 in both groups, P=1). However, checklist implementation significantly reduced respiratory failure rates (0.9% pre-checklist vs 0.5% post-checklist, P=0.03).

Table 1: Impact of Checklist Implementation on Inpatient Safety: Summary of Study Characteristics and Main Results

	Reference	Setting	Checklist	Study Design	Participant Groups	Outcome measures	Main results
1.	Williams [2020] *et al.* [78]	Anaesthesia/ Critical Care	16 item ICU Transport Checklist	Prospective pre/post intervention study	76 total transfers - 38 transfers with checklist - 38 transfers without checklist	- Guideline compliance of transfer staff	- Checklist implementation significantly associated with increased median aggregate total checklist items correctly completed (86.7%, 95% CI 80–92.9) before checklist vs 90% after checklist (95% CI 86.7%–100%, P=0.01).
2.	Gama *et al.* [2019] [79]	Surgical	Modified WHO Surgical Safety Checklist (SSC) 45 item SSC in Canada 25 item SSC in Brazil	Retrospective pre/post intervention study	a) Canada 842 surgical procedures - Completed SSC (98.8%) - Not completed SSC (1.2%) b) Brazil 518 surgical procedures - Complete SSC (64.0%) - Not completed SSC (36.0%)	- Rate of surgical site infection after implementation of SSC in Canada and Brazil	- No significant decreases in surgical site infections in both centres following checklist implementation (27.7% to 25.9%, P=0.625) ; Brazil (17.0% to 14.4%, P=0.448). - SSI rates are significantly lower in surgeries with completed checklist compared to surgeries with incomplete checklists (20.0% vs 11.3%, P=0.026)
3.	Haugen *et al.* [2019] [80]	Surgical	19 item WHO Surgical Safety Checklist (SSC)	Randomized Controlled Trial	3702 surgical procedures - 1398 Control procedure (37.8%) - 2304 Intervention procedure (62.2%)	- Operating room care processes (site marking, normothermia protecting measures, antibiotics) - Adverse outcome measures (wound infection, wound rupture, cardiorespiratory complications, postoperative bleeding, intraoperative blood transfusion)	- Full completion of SSC resulted in significantly increased application of care processes versus control ($p<0.001$). When adjustment for baseline variables, applications of two care processes (normothermia protecting measures and prophylactic antibiotic administration) remained significantly increased ($p<0.001$), while site marking became non-significant (P=0.084). - Implementation of SSC associated with significant reductions in all adverse outcomes ($p<0.005$). Logistic regression analysis revealed significant effects of SSC for all complications ($p<0.05$) except respiratory complications (P=0.051) after adjusting for time effects.
4.	Mao *et al.* [2019] [81]	Internal Medicine	17 item Enteral feeding checklist	Retrospective cohort study	148 patients 35 with checklist 113 without checklist	28 day mortality 90 day mortality Length of stay in	- Implementation of enteral feeding checklist for shock patients in the ICU reduces the length of hospital

						ICU Duration of mechanical ventilation Intolerance to EN feeding	stay (17.3 days vs 25.7 days, p=0.043) and lower rate of mechanical ventilation (62.9% vs 95.0, p=0.004). - Implementation of enteral feeding checklist for shock patients in the ICU is not significantly associated with change in (mean 13.4 days vs 16.6 days; p=0.395), 29 (20.0% vs 23.9%, p=0.632) or 90 day (25.7% vs 31.9%, p=0.490) mortality and intolerance to feeding (17.1% vs 23.0%, p=0.461).
5.	Ramsay *et al.* [2019] [82]	Surgical	19 item WHO Surgical Safety Checklist (SSC)	Retrospective cohort study	6839736 surgical procedures - 3629602 pre-checklist implementation - 1384425 during checklist implementation - 1825709 post-checklist implementation	- In-hospital mortality - Patient return to theatre after undertaking elective surgery	- Trend projection of time series analysis showed implementation of SSC significantly associated with 36.6% relative reduction in mortality (0.72 without checklist vs 0.46 with checklist, *p*< 0.001). Similar trend is not seen among non-surgical cohort in which SSC is not implemented. - Trend projection of time series analysis showed implementation of SSC significantly associated with lower return to theatre rates (*p*<0.001).
6.	Singh *et al.* [2019] [83]	Surgical	19 item WHO Surgical Safety Checklist (SSC)	Retrospective pre/post intervention study	482 surgical procedures - No checklist used in 244 (50.6%) - Checklist used in 236 (49.4%)	- Intraoperative and postoperative surgical and anaesthetic complication rate	- Checklist implementation associated with non- significant reductions in both intraoperative and postoperative complications (intraoperative from 6.14% to 2.12%, P=0.034. Postoperative from 6.56% to 3.38%, P=0.13). - Checklist implementation associated with non-significant reductions in anaesthetic complications (intraoperative from 3.27% to 1.69%, P=0.26. Postoperative from 1.64% to 0.85%, P=0.43) - Checklist implementation resulted in significant reduction in intraoperative (3.27% to 0.85%, P=0.06) and postoperative (13.11% to 7.63%, P=0.049) mortality.
7.	Spanjersberg *et al.* [2019] [84]	Surgical	19 item Pre-incision Isala safety checklist (ISC)	Prospective cohort study	5937 cardiac surgery patients - Checklist used (46%) - Checklist not used (54%)	- 120-day mortality - 30-day mortality - Surgical re-exploration rate - Deep sternal wound infection (DSWI) - 72 hour stroke rate	- ISC implementation significantly associated with lower 120-day mortality (1.7% vs 3.1%, OR 0.53%, 95% CI 0.36-0.77%, *p*<0.01), consistent following baseline variable balancing, and 30-day mortality (1.1% vs 1.9%, *p*<0.01). - ISC implementation significantly associated with lower 30-day mortality (1.1% vs 1.9%, 95% CI, P=0.01, adjusted P=0.03) - ISC implementation not significantly associated with surgical re-exploration rate (3.6% with ISC vs 4.6% without ISC, P=0.07), DSWI rate (0.4%% with ISC vs 0.7% without ISC, P=0.15) and 72 hour stroke rate (0.7% in both groups, P=0.72).
8.	Suarez *et al.* [2019] [85]	Surgical	8 item Transurethral Resection of Bladder Tumor (TURBT)	Prospective Pre/post intervention study	547 surgical procedures - Checklist used in 266 (49%) - Checklist not used	- 3 year recurrence-free survival rate	- Recurrence free survival rates were significantly lower at 3 years when SC was not performed. (P=0.008) - Checklist implementation

			Surgical Checklist		in 281 (51%)		independently associated with a significantly lower tumour recurrence rate (HR 0.57, 95% CI 0.35-0.92; P=0.02)
9.	Joseph *et al.* [2018] [86]	Anaesthesia/Critical Care	10 item "TRAUMA LIFE" checklist	Retrospective pre/post intervention study	All cases of Trauma Intensive Care Unit in 2013 (pre-intervention) and 2016 (post-intervention)	- Quality metrics (Catheter-associated urinary tract infections (CAUTI), urinary catheter utilization, central-line-associated bloodstream infections (CLABSI), restraint compliance, ventilator associated events (VAE))	- Checklist implementation significantly improved urinary catheter utilization (1430 to 945 utilization days, P=0.00), VAE rate (8.46 to 0 episodes/1000 ventilator days, P=0.01), restraint order compliance (75.6% to 89.9%, $p<0.01$). - Checklist implementation did not significantly change CAUTI rate (8.13 episodes/1000 catheter days pre-checklist to 3.2 episodes/1000 catheter days post-checklist, P=0.24) and CLABSI rate (0 episodes/1000 line days pre-checklist to 3.5 episodes/1000 line days post-checklist, P=0.18)
10.	Rodella *et al.* [2018] [87]	Surgical	20 item WHO Surgical Safety Checklist (SSC)	Retrospective cohort study	Best performer hospitals (75% adherence to SSCL) - 225687 patients pre-checklist - 160480 patients post-checklist Other hospitals - 434070 patients pre-checklist - 346187 patients post-checklist	- In hospital mortality rate - 30 day post-discharge mortality rate - Percentage of patients with length of stay (LOS) of 8 days or more - 30 days readmission rate	Checklist implementation not significantly associated with differences in: 1. In-hospital mortality rate - Best performer hospitals: Odds ratio [OR] 1.046, Confidence Interval [CI] 0.978-1.119, P=0.1923) - Other hospitals: OR 1.040, CI 0.972-1.113, P=0.25 2. 30 days post-discharge mortality rate - Best performer hospitals: OR 1.036, CI 0.980-1.096, P=0.2112 - Other hospitals: OR 1.033, CI 0.977-1.002, P=0.2544 Checklist implementation significantly associated with improved: 1. LOS⩾8days rate - Best performer hospitals: OR 0.873, CI 0.858-0.888, $p<.0001$ - Other hospitals: OR 0.867, CI 0.789-0.806, P=0.0001 2. 30-day readmissions - Best performer hospitals: OR 0.947, CI 0.926-0.968, $p<0.0001$ - Other hospitals: OR 0.946, CI 0.925-0.968, $p<0.0001$
11.	Wichmann *et al*, [2018] [88]	Anaesthesia/Critical Care	20 item Central Venous Catheter Checklist	Prospective Cohort Study	4416 CVL placements in total 1518 CVL placements with checklist 2898 CVL placements without checklist	- Central line associated bloodstream infections (CLABSI) rate - Catheter colonization rate	- Implementation of checklist during CVL placement significantly associated with lower CLABSI frequency (3.8 per 1000 catheter days with checklist vs 5.9 per 1000 catheter days without checklist, (Incidence rate ratio = 0.57, CI 0.39–0.82, P=0.001). - Implementation of checklist during CVL placement significantly associated with reduced catheter colonization frequency (21.2 per 1000 catheter days with checklist vs 36.3 per 1000 catheter days without checklist, Incidence rate ratio = 0.58, $p<0.001$).
12.	Kumar *et al.* [2017] [89]	Anaesthesia/Critical Care	20 item Modified WHO Surgical Safety Checklist with 9 item pre-	Prospective Cohort Study	340 surgical patients 170 retrospective patients without checklist 170 prospective	- Documentation of Quality Indicator parameters - Surgical team adherence to care	- Introduction and supervised documentation of comprehensive checklist brought out significant overall improvement in the documentation of quality indicators

			anaesthesia consultation checklist		patients with checklist	bundles - Post-operative infection rate and mortality - Length of ICU stay	(98% vs. 32%, *p*<0.001). - There was no difference in mortality, health-care-related infection rates or length of ICU stay (P>0.05).
13.	Park *et al.* [2017] [90]	Anaesthesia/Critical Care	12 item Anaesthesia handover checklist	Prospective pre/post intervention study	120 handoffs 60 pre implementation handoffs 60 post implementation handoffs	- Quality of data transfer (Items reported) among anaesthesia and surgical staff	- Implementation of an anaesthesia handover checklist increased overall quality of data transfer (composite value increased from mean 8.7 (SD=1.5) to 10.9 (SD=1.1) items out of 12 items, *p*<0.0001) - Independent analysis of handovers yielded a significant increase in mean reported items among anaesthesia staff (from 4.8 (SD=1.6) to 8.9 (SD=2.0) items, *p*<0.0001), but not among surgical staff (5.9 items pre-checklist to 5.5 items post-checklist, P=0.2).
14.	Van Daalen *et al.* [2017] [91]	Internal Medicine	7 item Antibiotic checklist	Randomized controlled trial	853 patients in baseline group 5354 patients in intervention group 993 (19%) completed the checklist	- Patient length of hospital stay (LOS) - Appropriateness of antibiotic treatment (using generic quality indicators) - Total antibiotic use (Days of therapy per single antibiotic)	- Implementation of antibiotic checklist did not significantly change LOS (pre-intervention mean 10.0 days (95% CI 8.6–11.5) versus post-intervention 10.1 days (95% CI 8.9–11.5, P=0.8). - QI performances increased between +3.0% and +23.9% per QI, and the percentage of patients with a QI sum score above 50% increased significantly (OR 2.4 (95% CI 2.0–3.0), *p*< 0.001) - Higher QI sum scores were significantly associated with shorter LOS (*p*<0.05)
15..	Bock *et al.* [2016] [92]	Surgical	24 item WHO Surgical Safety Checklist (SSC)	Retrospective pre/post intervention study	Total sample= 10 741 patients - 5444 (50.7%) pre intervention - 5297 (49.3%) post intervention	- 90 day all-cause mortality - 30 day all-cause mortality - 30 day readmission rate - Length of stay	- Checklist implementation significantly associated with reduced ninety-day all-cause mortality (2.4% to 2.2% adjusted odds ratio (AOR) of 0.73 (95% CI, 0.56-0.96; *P* = 0.02). - Checklist implementation not significantly associated with changes in thirty-day all-cause mortality (AOR of 0.79 (95% CI, 0.56-1.11; *P* = 0.17). - Checklist implementation not associated with changes in 30- day readmission rate (14.6% in the pre implementation group vs 14.5% in the post implementation group, adjusted odds ratio 0.90 (95% CI 0.81-1.01 P=0.79). - The adjusted length of stay was significantly reduced after implementation of SSCs (10.4 days in pre implementation group vs 9.6 days in post implementation group, P < 0.001).
16.	Lacassie *et al.* [2016] [93]	Surgical	19 item WHO Surgical Safety Checklist (SSC)	Retrospective pre/post intervention study	70639 surgical procedures Checklist used in 29858 29250 patients with checklist matched with equal numbers of patients without checklist for baseline variables.	- In-hospital morbidity and mortality rate - Length of stay	- In-hospital mortality rate decreased significantly from 0.82% [95% CI, 0.73–0.92] before to 0.65% (95% CI, 0.57–0.74) after checklist implementation (OR 0.73; 95% CI, 0.61–0.89). - No significant differences in the odds of postoperative surgical site infection were obtained between time periods (estimated OR 1.13, 95% CI, 0.94–1.37).

							- The mean length of stay (LOS) significantly reduced from three (Interquartile range 1-5) to two days (interquartile range 1-4) following checklist implementation ($p<0.01$). - No significant association found between checklist implementation and odds postoperative surgical site infection (estimated OR 1.13, 95% CI, 0.94–1.37).
17.	Mayer *et al.* [2016] [94]	Surgical	19 item WHO Surgical Safety Checklist (SSC)	Retrospective cohort study	6714 general surgical patients - Checklist Completed (62.1%) - Checklist partially completed (35.6%) - Checklist not-completed (3.3%)	- Postoperative mortality and morbidity	- Checklist completion did not affect mortality reduction, but significantly lowered risk of postoperative complication (16.9% vs. 11.2%), more when all 3 components of the checklist had been completed (odds ratio ¼ 0.57, 95% confidence interval: 0.37 – 0.87, $p< 0.01$). - Successful completion of all 3 components of the checklist had significantly lower rates of complication occurrence (16.9% with checklist to 9.7% without checklist, $p<0.01$). - Calculated population-attributable fractions showed that 14% (95% confidence interval: 7%-21%) of the complications could be prevented if full completion of the checklist was implemented
18.	O'Leary *et al.* [2016] [95]	Surgical	19 item WHO Surgical Safety Checklist (SSC)	Retrospective pre/post intervention study	28772 total paediatric surgical procedures - 14458 (53.3%) (procedures without checklist - 14314 (49.7%) procedures with checklist	- 30 day perioperative complications and mortality	- Checklist implementation was not significantly associated with odds of perioperative complications (4.08% pre-checklist vs 4.12% post-checklist, adjusted OR 1.01, 95% CI 0.90–1.14, P=0.9). - Checklist implementation significantly associated with decreases in LOS, although median LOS were the same in both groups (1 (IQR1-3) days in both groups, $p<0.001$).
19.	Zingiryan *et al.* [2016] [96]	Surgical	19 item Modified WHO Surgical Safety Checklist (SSC)	Prospective Pre/post intervention study	- 61803 pre-intervention surgical procedures - 45194 post-intervention surgical procedures	- Perioperative complication rate	- They reported that checklist implementation did not have a significant association with differences in mortality (2.9% pre-checklist vs 2.6% post-checklist, P=0.52), - No significant change in rate of all 9 surgical complications after implementation of SSC for 2 years (p>0.01)

Discussion

This review identified 19 studies that examined the impact of checklist implementation on patient safety outcomes in an inpatient setting. The studies were conducted using different study designs, and employed different checklists, which serve different purposes and measured patient safety in different contexts, from patient outcomes to staff adherence to standard guidelines. On aggregate, the majority of studies reported an overall positive impact length of stay and staff adherence to standard guidelines and care processes. However, it yielded mixed conclusions regarding overall impact on mortality as well as low significance for impact on overall occurrence of adverse events. One of the major implications of this review is the lack of high quality evidence of checklist impact in medical literature. The lack in priority may be attributed to the apparent cost-effectiveness and intuitiveness checklist implementation may seem to policy makers. It is worthy to note that while the design of checklists may seem cheap and cost-effective, this does not account for the implementation costs accompanying checklist use, such as use of antibiotics and care process equipment. Therefore, high quality quantitative studies should be done to investigate the necessity of checklist use in medical practice, and more importantly, how to design the optimal checklist. Low to moderate quality evidence, especially regarding the complex and elusive concept of patient safety, may be misleading due to presence of various uncontrolled confounding factors and risk of bias. Another important implication is that checklist application in medicine remains weak needs to be applied in more specialties, at least in the inpatient setting. A promising trend has been observed recently however, as we see an emerging development of new checklists for different uses, such as childbirth [29, 97, 98], antimicrobial stewardship [99, 100], nursing [101, 102], primary care [103], imaging [104], clinical diagnosis [105, 106], psychiatry [107], ECG interpretation [108] and otorhinolaryngology [109, 110].

Of the 19 studies reviewed, six studies [82-85, 92, 93] described a significant positive impact of checklist implementation on patient mortality, while five [81, 87, 89, 94, 96] reported no significance. Implementation of WHO SSC yielded mixed results. Studies that reported no significance had several limitations including issues with staff compliance [96] and policy enforcement [87]. Nevertheless, patient mortality is a complex parameter and is influenced by many factors, which are virtually impossible to be covered in whole by a simple cognitive tool such as a checklist. Time series analysis of recent years however, did demonstrate a drastic decrease in mortality rates among the surgical cohort following SSC implementation, which was not seen among the non-surgical cohort [82]. Whether this trend can be attributed directly to checklist implementation or other improvements along with the exponential advancement of modern medicine is debatable. Interestingly, a majority of studies [79, 81, 83, 84-86, 89, 92, 93, 95, 96] did not yield significant associations between checklist implementation and occurrence of adverse events. There are several possible explanations for this finding. The most probable is that studies have not enforced checklist compliance among operators [79, 81, 92, 93, 95, 96], which limited its impact. Small sample size [8], better surveillance in intervention group compared to control group [79, 85] and lack of variable adjustment [89]. Also, most of these evidence are of moderate quality, as they mainly utilized a non-randomized observational study design. The only randomized controlled trial which reported on adverse patient outcomes reported significant associations in adjusted overall adverse outcomes studied [80]. Of the seven studies measuring checklist impact on length of hospital stay, five [81, 87, 92, 93, 95] reported a significant positive impact, while two [89, 91] found no statistically significant association. Of the five studies, four [87, 92, 93, 95] of them concern the WHO SSC, which shows the relevance of a well-designed checklist in improving length of hospital stay. One study reported that performance of quality indicators significantly shortens length of stay [91], which gives insight on a checklist's role in this aspect. Moreover, this implies that research on quality indicators are essential for good checklist design. All included articles studying checklist impact on staff adherence to standard guidelines showed a statistically significant positive association between the two [78, 80, 86, 89-91]. This shows that the checklist does serve as a valuable cognitive aid for staff routines, which in itself a significant aspect of inpatient care. This is because the unaided performance of an individual decreases when the number of items or complexity of a task increases. Employment of a checklist also significantly improved documentation rates [89], elevating overall quality of patient care. It is also seen from a few studies that completion of the checklist is associated with significant impacts on inpatient safety, whereas non-compliance towards the checklist evidenced by incompletion of the checklist limits its effects [80, 94]. Non-compliance, therefore, becomes a primary barrier to checklist application, as well as a major hindrance for its impact measurement. It is also evident that the design of a checklist is paramount in improving patient safety, as implementation of non-validated checklists did not yield an overall significant impact on patient outcomes [81, 84, 91]. Moreover, there is no significant correlation between number of checklist items and patient related outcomes, indicating number of checklist items does not improve its impact on patient safety [79, 89, 92], whereas checklists with less items may also provide significant improvements [85, 86]. Furthermore, certain checklist items do not significantly improve or may even reduce adherence, which shows that overambitious checklist designs may be unnecessary or even deteriorating to staff adherence [78]. Unnecessary items may include checking certain equipment (such as sufficiency of oxygen in oxygen cylinders) or site marking [80], which are commonly undertaken with or without checklist use. We propose that such items should be excluded as it reduces compliance and restricts operator autonomy. In essence, the optimally designed checklist should explicitly outline the circumstances indicating checklist employment while also detail how a task is carried out, but not as to become overambitious and cover every single aspect of the task. It should cover enough essential certified quality indicators and disregard items regarded to add no value whatsoever to patient outcomes or human factors. It is therefore advisable for healthcare researchers and policy makers to involve experts in human factors in the design of checklists, and prioritize research on quality indicators. It is also imperative that the design of the checklist be tailored to the healthcare policy of each nation to optimize its effects, as it is evident that different countries have different healthcare strategies and financial investment into its healthcare sector. The checklist is meant to be a supportive tool, and should not create distress to the operators due to due to discordances in healthcare strategies.

There are some primary limitations to this review that should be considered when interpreting the findings. First, there is a lack of high quality evidence recruited, in part due to the short study period inclusion. This criteria is set limit its impact to be as relevant to the current practice as possible, in view of the rapid evolution of medicine throughout the past years. Second, the review protocol was not registered to validated protocol databases. Therefore, certain studies may be missed. Third, this review investigated checklist impact on patient safety in an inpatient population, this is to keep the findings uniform as we acknowledge that the concept of patient safety differs in inpatient and outpatient settings, evidenced by differences in quantitative parameters recruited in their investigation, sufficient to warrant completely separate systemic reviews. Fourth, the review did not include surveys of perceived impact of the checklist from the staff and the patient's perspective to keep the findings quantitative and scientific. This includes user experiences, satisfaction surveys and suggestions for improvement. As we have mentioned, the use of checklists should not drain away the humanity of medical practice. Blindly following the instructions of a checklist renders practitioners repetitive and robotic, ultimately posing a significant threat to patient safety. Flexibility therefore becomes a vital quality of checklist design and research, evidence of which is best collected through such surveys and feedback. Finally, the variety of checklists as well as the heterogeneity of medical fields included in this review, we are unable to conduct a meta-analysis. This again accentuates the issue of lack of primary statistical data concerning current literature on checklist impact in patient safety.

Conclusion

We reviewed a few recent articles that examined the impact of checklist implementation on patient safety among the inpatient population based on patient related outcomes as well as staff adherence to standard guidelines. The studies concluded a possible contribution of the checklist in patient-related outcomes, with much inconsistency in findings among different studies. The few articles reporting on staff adherence however provided significant uniform improvement following checklist implementation. This review therefore highlights the need for more high quality quantitative studies regarding its impact. We also advocate for a broader implementation of checklists in healthcare, research into its development and design, and above all, its acceptance among healthcare professionals worldwide.

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