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ORIGINAL SCIENTIFIC REPORT

Implementation of the World Health Organization Surgical Safety Checklist Correlates with Reduced Surgical Mortality and Length of Hospital Admission in a High-Income Country

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Abstract

Background The World Health Organization Surgical Safety Checklist (WHO SSC) has been widely implemented in an effort to decrease surgical adverse events. The effects of the checklist on postoperative outcomes have not previously been examined in Australia, and there is limited evidence on the effects of the checklist in the long term.

Methods A retrospective review was conducted using administrative databases to examine the effects of the implementation of the checklist on postoperative outcomes. Data from 21,306 surgical procedures, performed over a 5-year time period at a tertiary care centre in Australia where the WHO SSC was introduced in the middle of this period, were analysed using multivariate logistic regression.

Results Postoperative mortality rates decreased from 1.2 to 0.92% [$p = 0.038$, OR 0.74 (0.56–0.98)], and length of admission decreased from 5.2 to 4.7 days ($p = 0.014$). The reduction in mortality rates reached significance at the 2–3 years post-implementation period [$p = 0.017$, OR 0.61 (0.41–0.92)]. The observed decrease in mortality rates was independent of the surgical procedure duration.

Conclusion Implementation of the WHO SSC was associated with a statistically significant reduction in mortality and length of admission over a 5-year time period. This is the first study demonstrating a reduction in postoperative mortality after the implementation of the checklist in an Australian setting. In this study, a relatively longer period examined, comparative to previous international studies, may have allowed factors like surgical culture change to take effect.

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Introduction

There is one surgical operation performed for every 25 people globally every year [1]. Postoperative complications occur in 25% of surgical inpatients, and the crude mortality rate after major surgery is 0.5–5% [2]. Fifty per cent of the cases in which surgery leads to harm are considered preventable [3]. Most cases in which surgery leads to harm are caused by failures of non-technical skills such as teamwork, leadership and communication [4].

In 2008, the World Health Organization (WHO) developed a Surgical Safety Checklist (SSC) in an attempt to minimise surgical adverse events. The three-phase 19-item checklist comprises various perioperative items directly targeted to assure the execution of specific safety measures. A multinational 3-month observational study followed: it reported a significant reduction in postoperative complication and mortality rates with the use of the checklist (11–7% $p < 0.001$ and 1.5–0.8% $p = 0.003$, respectively) [5]. Since that time, the WHO SSC has been implemented as a standard of care in thousands of operating rooms worldwide.

A recent literature review suggested that the effects of the checklist were inconsistent and less significant in high-income settings [6]. In 2009, the checklist was adapted for use in Australia. It was endorsed by the Royal Australian College of Surgeons and was implemented nationwide. To date, there have been minimal data on the long-term outcomes and also no studies on the effects of the WHO SSC on postoperative outcomes in Australia.

There is some evidence that for the checklist to be effective, it requires a deliberate implementation process, continual monitoring and ongoing training within frontline teams [7]. The effects of the checklist on postoperative outcomes need to be assessed to justify the laborious implementation process and the continual effort that is required to utilise the checklist. Furthermore, it is possible that the checklist may become a routine activity of checking boxes without actually driving behavioural change, thus giving staff a false sense of security [8–10].

The aim of this study was to evaluate the effect of the WHO SSC on postoperative complications, mortality and length of hospital stay over a five-year period in a high-income setting like Australia. The study also examines the effects of the checklist on high-risk groups (surgery on the elderly and emergency surgeries), examines the effects of the checklist over different time periods after its implementation and examines whether surgical duration impacts on the effects of the checklist.

Methods

Study design

A retrospective review was conducted using two hospital administrative databases in a regional tertiary care centre in Queensland, Australia. Three-month intervals over a 5-year time period were studied: four 3-month intervals before the implementation of the checklist in September 2009 and six 3-month intervals following the implementation of the checklist. The intervals were consistent for each year; thus, seasonality aligns. This period was selected as this was the time period in which established administrative databases were available. The duration of the review was thus from the 1st of October 2007 to the 30th of June 2012. Using data from the most recent meta-analysis of the effects of the WHO SSC, a calculated sample size of 4827 was required to show the effects of the checklist on postoperative complications [11]. Ethics approval was received (HREC/15/QTHS/112).

Hospital setting

The hospital examined is a public Australian regional tertiary care centre. Tertiary care centres are highly specialised hospitals which include particularly complex medical or surgical procedures. The > 700-bed hospital's setting is classed as Outer Regional Australia (RA3) by the Australian Statistical Geography Standard. This standard is based on its distance to a range of population centres. It has a regional catchment area of about 148,000 km^2. The nearest other tertiary care centre is over 900 km away.

Checklist implementation

The checklist was implemented in this regional tertiary care centre, in September 2009. The specific checklist that was implemented was a checklist adapted from the World Health Organization Surgical Safety Checklist to the Australian setting by the Royal Australasian College of Surgeons in consultation with the Australian and New Zealand College of Anaesthetists, the Royal Australian and New Zealand College of Ophthalmologists, the Royal Australian and New Zealand College of Obstetricians and Gynecologists, the Australian College of Operating Room Nurses and the Perioperative Nurses College of the New Zealand Nurses Organization. Since implementation, a monthly observational audit of checklist compliance for ten random surgical procedures has been conducted by the nursing unit manager.

Databases

Two administrative databases were used for data extraction. The Operating Room Management Information System (ORMIS) was used to extract data for all surgical procedures performed during each study interval. Operative details for each procedure were extracted: the operation date, length of time in the operating theatre, anaesthetic type, surgical specialty group, procedure code and procedure description. The nine surgical specialty groups were: head and neck, neurosurgery, cardiothoracic, general, obstetrics and gynaecology, ophthalmology, urology, vascular and orthopaedic. Patient details such as the patient identification number, date of birth and gender were also extracted.

The Hospital Based Corporate Information System (HBCIS) was then used to match patient identification numbers and an operation date falling within the admission and discharge dates of an inpatient episode of care. Administrative data were extracted for each procedure: the admission date, discharge date, admission status (emergency or elective), length of stay, hospital readmission within 30 days and date of death. Data for 14 specific postoperative complications as defined by the American College of Surgeons' National Surgery Quality Improvement Project (ACS-NSQIP) were also extracted from this database using the International Classification of Diseases (ICDAM-10) system.

All patients underwent inpatient surgery. Readmission rates were to the studied hospital. For those undergoing more than one surgery in an episode of care, we limited the analysis to the first procedure per patient. As per ethics requirements, only surgeries in those aged over 18 years were included. All 21,306 surgical procedures performed in the given time period were included.

Outcomes

Operative mortality was defined as the rate of death occurring in the hospital or within 30 days of surgery. The length of hospital stay and rates of readmission within 30 days after discharge were examined. Complications included one or more occurrences of postoperative acute renal failure, bleeding requiring transfusion of four or more units of red cells within the first 72 h of surgery, cardiac arrest requiring cardiopulmonary resuscitation, coma of 24 h duration or more, deep vein thrombosis, acute myocardial infarction, unplanned intubation or ventilation use for more than 48 h, pneumonia, pulmonary embolism, respiratory failure, major wound disruption, surgical site infection, sepsis or the systemic inflammatory response syndrome and septic shock. The occurrence of one or more of the above listed complications was counted as the total complication rate for each procedure.

Covariates

Patient demographics (age and sex) and surgical variables (emergency status, surgical specialty, anaesthetic type and duration of the procedure) were extracted. Anaesthetic types were summarised into general anaesthesia and regional anaesthesia (epidural, spinal or plexus anaesthesia), and combinations of general and regional anaesthesia were classified as general anaesthesia.

Statistical analysis

The unadjusted rates of surgical complications and mortality over the five years are presented as a descriptive graph.

The main inferential statistical analysis was made using the whole five-year time period. An analysis for shorter time periods after the checklist's implementation (<1 year, 1–2 years and 2–3 years) and an analysis for two high-risk groups (surgery on the elderly >60 years and emergency surgeries) was also conducted. The main statistical analysis was repeated for all outcomes such as mortality, length of admission, readmission, total complications, any complications as well as a number of specified surgical complications. The analysis for shorter time periods around implementation and for the two high-risk groups included the outcomes mortality and any surgical complication.

The following procedure was used for outcomes that are dichotomous. Zero-order correlation between all independent variables was checked before including them in the multivariate regression models. A choice was made whether significant correlations were found between independent variables. Remaining independent variables were entered into a multivariate logistic regression model, adjusting for possible confounding effects of age, gender, elective or emergency surgery, surgical specialty, type of anaesthesia and length of time in the operating theatre. One multivariate logistic regression was conducted for each outcome.

Mann–Whitney's test was used to compare the outcomes of length of admission and the total complications rates before and after implementation of the checklist.

The level of statistical significance was set to 0.05. The software Statistical Package for the Social Science [SPSS], version 23, was used.

Results

Effects of introduction of checklist

During data collection periods over five years, 21,306 surgical procedures were included in analysis.

Implementation of the checklist was associated with a 23% decrease in postoperative mortality [1.2–0.92%, $p = 0.036$, OR 0.74 (0.56–0.98)] and a 9.6% decrease in the length of hospital admission (5.2–4.7 days, $p = 0.014$) (Table 1).

Three outcomes were significantly increased following the implementation of the checklist: the rate of readmission within 30 days of discharge [4.4–5.3% $p = 0.0033$ OR 1.2 (1.1–1.4)], major wound disruption [0.60–0.93% $p = 0.027$ OR 1.5 (1.1–2.1)] and septic shock [0.013–0.18% $p = 0.0091$ OR 14 (1.9–110)].

The change in postoperative mortality observed during the study period was independent of the duration of surgery ($p = 0.28$).

High-risk-group analysis

There were reductions in mortality of a similar magnitude observed in the elderly and emergency subgroups, but these changes were not statistically significant (Table 1).

Complications over time

There were no large deviations in postoperative events or mortality in a specific year during the five-year period (Fig. 1). Statistically significant changes linked to the introduction of the WHO SSC were only seen in the long-term perspective: in the overall 5-year analysis (Table 1) and 2–3 years post-implementation interval (Table 2).

Discussion

This study found a statistically significant decrease in rates of postoperative mortality and the length of admission after the implementation of the WHO SSC.

Generalizability

The hospital examined is in a regional setting, and it is well documented that regional centres have higher rates of postoperative adverse events when compared to urban settings with a higher patient flow [12–15]. The patient demographics also vary considerably from other centres in our state. There are proportionally three times as many people who identify as being of Aboriginal or Torres Strait Islander descent (Indigenous Australians) in this particular region compared to the state average. It is well documented that Indigenous Australians have a high burden of disease. In 2009, a cardiac surgery study found that patients who identify as Indigenous Australians had a seven times greater risk of operative mortality and nearly three times greater risk of late mortality compared to those who did not identify as being of Indigenous descent [16]. These results were attained after adjusting for known predictors of surgical mortality. The regional location of the hospital and the patient demographic factors may have allowed the checklist to have a larger latitude for an effect, compared to studies conducted in urban settings in other high-income settings.

Surgical safety culture

This study has a very extended follow-up period (2 years before and 3 years after the implementation of the checklist). The main analysis includes the entire pre- and post-implementation groups to reduce potential type 2 statistical errors for specific postoperative complications. In the interval subgroup analysis, the effects of the checklist on mortality were only significant in the 2–3-year interval. Although the findings did not reach statistical significance, the 1–2-year interval had a considerably lower p value than the <1-year interval. This may be because the cultural change associated with the use of the WHO SSC requires time. Prior studies with a shorter follow-up period may not have shown the full effects of the WHO SSC.

The checklist is said to work by direct and indirect factors. Direct factors such as ensuring that the right site of surgery is marked should directly influence some surgical complications. Therefore, the checklist should have a direct effect on surgical outcomes which would become evident shortly after implementation. The checklist also works indirectly to increase teamwork, communication and leadership, thereby building a culture of surgical safety. This cultural change would take some time to develop. In this study, the positive effects of the checklist on postoperative outcomes only became evident in the long-term follow-up analysis. This may indicate that the checklist has little direct effect on specific items it contains, rather encourages a safe surgery culture. Nonetheless, other factors that may confound the long-term results such as secular trends and improvements in surgical technique over this period of time must be kept in consideration.

If the checklist does work indirectly to improve surgical safety culture, then further research may be required to source the main active ingredient. It may be less about ticking boxes and more about the conversation which the boxes promote. If the main ingredient or essential features of the WHO SSC can be sourced, then it may be possible to streamline the checklist itself.

Incongruent results

Postoperative complication rates are associated with postoperative mortality rates [17] and length of stay [18]. The

Table 1 Long-term postoperative outcomes before and after the introduction of the World Health Organization Surgical Safety Checklist

Outcome (%)	Before checklist introduction	After checklist introduction	Adjusted *p* value	Adjusted odds ratio (95% CI)
All surgeries				
Mortality*	1.2	0.92	0.038	0.74 (0.56–0.98)
Length of admission (days)	5.2	4.7	0.014	**
Readmission within 30 days of discharge	4.4	5.3	0.0033	1.2 (1.1–1.4)
Experienced one or more complication	10	11	0.86	0.99 (0.90–1.1)
Total complications	13	13	0.14	**
Specific complications				
Acute renal failure	1.4	1.5	0.68	1.1 (0.83–1.3)
Bleeding	6.2	6.2	0.22	0.93 (0.82–1.1)
Resus	0.23	0.25	0.83	0.94 (0.52–1.7)
Coma	0	0.030	0.97	–
Deep vein thrombosis	0.30	0.33	0.78	1.1 (0.65–1.8)
Acute myocardial infarction	1.1	1.5	0.64	1.1 (0.81–1.4)
Intubation/ventilator use	1.5	1.4	0.18	0.85 (0.66–1.1)
Pneumonia	0.82	1.0	0.22	1.2 (0.89–1.6)
Pulmonary embolism	0.18	0.21	0.60	1.2 (0.62–2.3)
Respiratory failure	0.24	0.31	0.55	1.2 (6.8–2.1)
Major wound disruption	0.60	0.93	0.027	1.5 (1.1–2.1)
Surgical site infection	1.7	1.5	0.11	0.83 (0.67–1.0)
Sepsis	1.6	1.4	0.27	0.88 (0.69–1.1)
Septic shock	0.013	0.18	0.0091	14 (1.9–110)
Emergency surgery				
Mortality*	3.2	2.4	0.098	0.74 (0.52–1.1)
Experienced one or more complication	22	22	0.61	0.96 (0.82–1.1)
Elderly patients (>60 years)				
Mortality*	2.6	2.0	0.97	0.76 (0.54–1.1)
Experienced one or more complication	16	17	0.47	0.95 (0.81–1.1)

*Mortality, death in hospital or within 30 days of discharge

**Mann–Whitney's test, hence no odds ratio

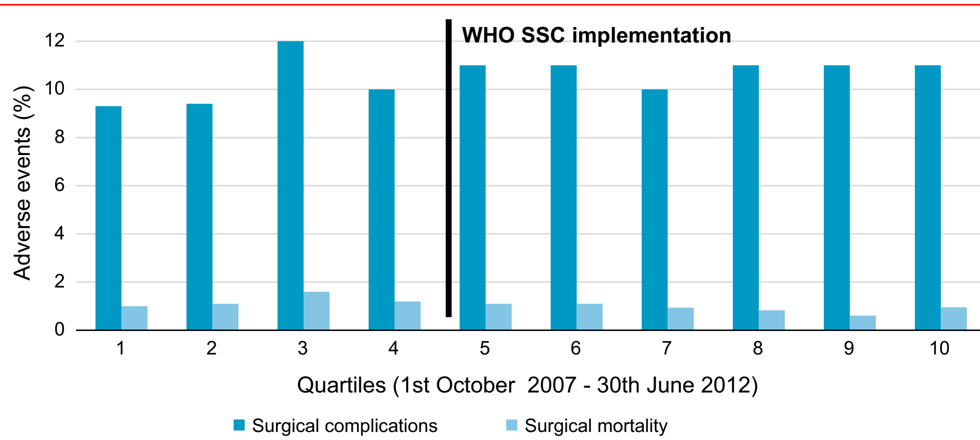

Fig. 1 Fluctuations in postoperative adverse events over a five-year time period

Table 2 Postoperative outcomes for all patients before and after the introduction of the World Health Organization Surgical Safety Checklist

Outcome (%)	Before checklist introduction, n = 8000	After checklist introduction	Adjusted p value	Adjusted odds ratio (95% CI)
Year <1 post-implementation, n = 4252				
Mortality*	1.2	1.1	0.59	0.90 (0.62–1.3)
Experienced one or more complication	10	11	0.91	1.0 (0.88–1.2)
Years 1–2 post-implementation, n = 4494				
Mortality*	1.2	0.89	0.11	0.73 (0.50–1.1)
Experienced one or more complication	10	11	0.87	0.99 (0.87–1.1)
Years 2–3 post-implementation, n = 4560				
Mortality*	1.2	0.79	0.017	0.61 (0.41–0.92)
Experienced one or more complication	10	11	0.77	0.98 (0.86–1.1)

*Mortality, death in hospital or within 30 days of discharge

WHO SSC aims to reduce preventable surgical error, thereby decreasing rates of specific postoperative complications and total complication rates along with the observed reduction in postoperative mortality and length of stay. However, this study does not show congruency amongst surgical adverse event outcomes. The rate of readmission, major wound disruption and septic shock significantly increased. The rates of total postoperative complications insignificantly increased, whilst postoperative mortality significantly decreased.

A stronger safety culture, which the checklist promotes, may facilitate the detection of postoperative complications and subsequently lead to a perceived increase in complications. Similar to our findings, a study by Chaudhary and colleagues reported that postoperative mortality reduced significantly (by 43%), whilst there was no significant change in total postoperative complication rates [19]. Greater or earlier detection and management of postoperative complications may decrease postoperative mortality rates. Previous studies have found a significant decrease in postoperative complication rates after the implementation of the checklist with a decrease [5, 20, 21], an increase [22] or nil significant change [23–26] in postoperative mortality rates.

A recent literature review reported on the incongruence in surgical outcome improvements following the implementation of the checklist within the published literature [6]. This phenomenon was observed both within some studies and when all significant results for the reviewed literature were compared. An effective safety improvement initiative should have consistent effects on outcomes. Studies tended to focus on positive effects of the checklist rather than evaluating the full data set of results. This may be contributed by a publication bias where studies reporting improvements in outcomes are more likely to be published.

Reliability of data

Administrative data were used to assess surgical complications. This method is commonly used but is recognised to be inferior to prospective measurements or chart review. Some outcomes examined in this study such as the specific surgical complications may be susceptible to misclassification in administrative data, especially given the long time period reviewed. Other outcomes examined including operative mortality, length of stay and readmission rates are less susceptible to administrative misclassification [19]. A drawback to the studies of long duration is that secular trends to improved surgical mortality over time may have contributed to the findings.

Aspects of the study may have been underpowered to show statistically significant results in the high-risk surgical group analysis. Mortality rates reduced by 23% in the elderly group and 25% in the emergency group; this reduction was of a similar magnitude to the overall analysis, but did not reach statistical significance.

At the hospital examined, WHO SSC compliance is prospectively monitored by the surgical nursing unit manager. Ten random surgeries per month are observed, recording compliance with the checklist. If the checklist is not completed correctly, the observer will address the issues and work with the surgical team to ensure compliance. As such, although reported compliance at the site has consistently been measured as 100%, the rate of intervention by the nursing unit manager and the unobserved compliance rate are unknown. This audit could be viewed as a coaching initiative to help drive the use of the checklist, rather than an accurate measure of checklist compliance.

The study was retrospective allowing us to examine postoperative outcomes, whilst the surgical and clinical coding team remained unaware of the study. This eliminated the Hawthorne-related effect—the tendency for some people to perform better when they perceive that their work is under scrutiny.

Conclusion

In conclusion, our study on the effects of the implementation of the WHO SSC showed a statistically significant reduction in postoperative mortality rates and the length of admission after implementation of the WHO SSC. This is the first study demonstrating a reduction in postoperative mortality after the implementation of the WHO SSC in an Australian setting. This may be contributed by the hospital's regional setting and unique patient demographics. An analysis of the effects of the checklist over different lengths of follow-up found that the positive effects of checklist only became significant in the long term. The checklist may be effective because it indirectly encourages a safe surgery culture which requires time to develop. This study examined a relatively longer time period than previous studies on the effects of the WHO SCC which may have allowed factors like surgical culture change to take effect.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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