Medical Research Archives



**Published:** February 29, 2024

**Citation:** Davies-Jones GR and Munigangaiah S, 2024. The Relevance of World Health Organization Surgical Safety Checklist to Spinal Surgery, Medical Research Archives, [online] 12(2). https://doi.org/10.18103/mra.v12i2.5122



**DOI**
https://doi.org/10.18103/mra.v12i2.5122

**ISSN:** 2375-1924

RESEARCH ARTICLE

# The Relevance of World Health Organization Surgical Safety Checklist to Spinal Surgery

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ABSTRACT
Across the 193 member states of the World Health Organization (WHO) an estimated 234 million operations were conducted worldwide in 2008 (1 per every 25 human beings on the planet). These numbers have continued to increase to 312.9 million by 2016. Surgical errors involving the wrong site, wrong procedure or wrong patient occur at a rate of 1 in 112,000. This equates to 2,000 estimated 'never events' every year with a significant associated physical and psychological burden on patients and surgeons and financial and reputational burden on health organisations involved in litigation for such errors.
The WHO Surgical Safety Checklist (WHOSSC), produced in 2009 is now synonymous with safety in the operating theatre.
This checklist imposes a process of scrutiny at the key steps of the patients journey through theatre. The key details scrutinised have been shown to improve patient outcomes and theatre efficiency. Several studies have looked at adapted checklists specific to different specialties and it is becoming clearer that whilst the overall benefit of the original checklist is undeniable, in some speciality areas a more deliberate and nuanced application of the checklist to address specific problems could be of value.
As a specialism, spinal surgery differs from others with a significant risk of a perioperative complication leading to harm and morbidity, permanent disability or even death. Iatrogenic spinal cord injury requires high-level resources and prolonged, sometimes lifelong rehabilitation. Other complications include cerebrospinal fluid leak, blood loss, new neurologic deficit, hardware failure, proximal junctional failure, pseudarthrosis, and surgical site infection. Wrong level spinal surgery (WLSS) is a complication specific to spinal surgery and studies have reported WLSS effecting 50-68% of spinal surgeons at some point in their career. The risks of these complications can be mitigated by factors, some of which are included in the WHOSSC and others with are lacking.
This scoping review looks at how surgical checklists; both the original and modified versions have and could be used to address the surgical safety challenges specific to spinal surgery.

## Introduction

With the explosion of surgery volumes in the early 2000's[1] and beyond [2,3], problems with unsafe practices were becoming more prevalent[4] and more and more of a danger to patients. Surgery volumes had overtaken those of childbirths with at least a ten-fold difference in mortality[5]. Mortality and morbidity from surgical complications compared to levels of harm seen in malaria and tuberculosis[5]. At least half of the cases in which surgery leads to harm are considered preventable[6-8].

In 2004, the World Health Assembly (WHA) founded the World Health Organisation Patient Safety international alliance to tackle issues of adverse effects in unsafe healthcare[9].The Global Initiative for Emergency and Essential Surgical Care[10] and the Guidelines for Essential Trauma Care[11] were also set up to focus on access and quality. In 2005, WHO Patient Safety began issuing Global Patient Safety Challenges, which bring together teams of specialists in order to put together clinical guidelines and tools for research that address patient safety issues, such as hand washing.

In January 2007, an international consultation meeting was held on the second Global Patient Safety Challenge, called Safe Surgery Saves Lives. One of the recommendations of this Global Patient Safety Challenge was the adoption of a checklist for use in surgical procedures.

The WHOSSC was developed from the WHO Guidelines for Safe Surgery, which set out 10 essential objectives for safe surgery[12]:

1) The team will operate on the correct patient at the correct site.
2) The team will use methods known to prevent harm from administration of anaesthetics, while protecting the patient from pain.
3) The team will recognize and effectively prepare for life-threatening loss of airway or respiratory function.
4) The team will recognize and effectively prepare for risk of high blood loss.
5) The team will avoid inducing an allergic reaction or hypersensitivity.
6) The team will ensure that the surgical site is marked by the surgeon prior to the procedure.
7) The team will perform a "time-out" before the procedure, during which all team members verify the correct patient, procedure, site, and other important details.
8) The team will ensure that essential imaging is displayed and reviewed before the procedure.
9) The team will complete a thorough instrument, sponge, and needle count before and after the procedure.
10) The team will debrief after the procedure to discuss what went well and what could be improved

Modelled on the pre-flight checklist pilots undertake, this tool serves to remind the surgical team of important items to be performed before and after the surgical procedure to achieve the above and in turn reduce adverse events such as surgical site infections or retained instruments. Haynes et al.[13] carried out the study that introduced the 19-item checklist to 8 test case hospitals around the globe. Following implementation of the WHOSSC, the study found mortality rate decreased from 1.5% to 0.8% ($p=0.003$), overall inpatient complication rate dropped from 11% to 7% ($p<0.001$) and specific complications such as infection ($p<0.001$) and wrong site surgery ($p<0.47$) decreased across all sites.

The WHOSSC was first published by the World Health Organization (WHO) and soon made a mandatory requirement for all NHS hospitals in England and Wales in 2009. The evidence in the intervening years has continued to support its benefit to patient safety. A population cohort study was carried out by some of the original authors of the above study, looking at all acute hospital admissions across Scotland between 2000 and 2014[14]. Of the 12,667,926 hospital admissions identified, 6,839,736 involved a surgical procedure. A surgical cohort inpatient mortality rate of 0·76 was observed in 2000 whereas by 2014 and with adoption of the WHOSSC it was down to 0·46. The checklist was associated with a 36·6% relative reduction in mortality ($P < 0·001$). The rate of mortality rate decrease was also accelerated by the checklist; 0·003% per year decreases before; 0·069% per year decreases during and 0·019% decreases per year after implementation.

A systematic review and meta-analysis of the effect of the WHOSSC on postoperative complications by Bergs et al.[15] in 2014 found evidence highly suggestive of a reduction in postoperative complications and mortality following the implementation of the WHOSSC but acknowledged that more high quality studies were needed to confirm this trend.

The checklist is designed to be a simple, transmissible, and measurable but also something that could be integrated as seamlessly as possible into established process within operating theatres. It was designed so it didn't matter about the level of complexity or surgery, expertise of staff, healthcare setting or speciality amongst other factors. It operates at a much more basic level, adjusting human behaviour and operating room, even healthcare culture. The WHO recommends adapting the surgical safety checklist to suit local needs but adaption of the checklist for specific surgery types or speciality areas remains uncommon. Some would cite James et al.[16] who concluded in their study that adding layers of precautions and detail may yield diminishing returns rather than make a checklist more fit for purpose through adaption. However, a specialty focussed approach to intraoperative guidelines and adapted checklists may be able to reduce risks specific to these areas and also increase engagement of the professionals that use them.

Spinal surgery is a specialism with its own nuances. The complication rate after spinal surgery ranges between 7 and 20%[17-23], compared to 5% in orthopaedic surgery generally[24]. These numbers have remained relatively static over the years[25]. The array of potential adverse events during and after spinal surgery is broad and dependent upon the complexity of the procedure. Moreover, procedures employing anterior, lateral and transthoracic approaches have even more specific risks such as dysphagia, recurrent laryngeal nerve injury and oesophageal perforation in the case of anterior cervical discectomy and fusion (ACDF) surgery.

Whilst suggesting all complications can be prevented by even a well-executed checklist is naive, developing a consistent approach to mitigating risk and responding effectively to acknowledged potential complications is certainly attainable. In their study, Barbanti-Brodano et al.[26] investigated the introduction of the WHO Safety Surgical Checklist as a preventive measure to reduce complications in spinal surgery. The reported a reduction in the overall incidence of complications following the introduction of the WHOSSC. The pre-checklist incidence of complications was 24.2% (2010) but in the years following introduction of the checklist, the incidence of complications was 16.7% (2011) and 11.7% (2012) with a mean of 14.2% ($P<0.0005$).

In our review article, some specific risks and nuances of spinal surgery are considered in the context of how the principles of The WHOSSC have been or could be applied to make spinal surgery safer.

## Principle: A Tool to Change Culture

The phrase "culture eats strategy for breakfast" is attributed to the management consultant and writer Peter Drucker. In the context of the WHOSSC it is acknowledged that a checklist is little more than a piece of paper without the engagement of those that use it.The Keystone ICU project was a landmark initiative aimed at improving patient safety in intensive care units in Michigan, USA[27].

The project was a collaboration between patient safety experts at Johns Hopkins University and the Michigan Hospital Association. The project was designed to improve patient safety by promoting a culture of safety, improving communication, and implementing evidence-based standard practices to reduce rates of catheter-related bloodstream infections and ventilator-associated pneumonia. What made the project so precocious was that the primary study intervention focused on improving culture, teamwork, and communication through the implementation of so-called CUSP (Comprehensive Unit-based Safety Program) principles[28]:

1) Assemble the team: Bring together a multidisciplinary team of experts to identify and address safety issues.
2) Engage the senior executive: Secure the support of senior leadership to ensure that the CUSP method is implemented effectively.
3) Understand the science of safety: Use the science of safety to identify and address the underlying causes of safety issues.
4) Identify defects through sensemaking: Use sensemaking to identify defects in the system and develop strategies to address them.
5) Implement teamwork and communication: Foster a culture of teamwork and communication to improve patient safety.
6) Apply CUSP: Use the CUSP method to implement evidence-based practices to reduce rates of catheter-related bloodstream infections and ventilator-associated pneumonia.
7) Spread patient and family engagement: Engage patients and their families in the care process to improve patient safety

Whilst the use of a standard procedure checklist was one aspect of the programme, the project and other work acknowledges that a checklists power comes in its power to prompt team communication and collaboration[29].

The strength and quality of an organization's teamwork culture is linked to iatrogenic risk in healthcare. Research across specialty domains such as paediatric general and spinal deformity correction surgery support the notion that strong teamwork amongst frontline staff is associated with complication risk reduction suck as surgical site infection[30-33]. Conversely, poor, or dysfunctional communication in the surgical environment is associated with a negative effect on patient care[34-35]. In the Gawande et al.[35] study of 146 error reports across several Massachusetts teaching hospitals, communication errors were cited in 43% accounts with 70% involving contribution from 2 or more clinicians.

The presence of barriers to communication in all surgical teams is a fundamental assumption of the WHOSCC. Another assumption of the WHOSCC is that there is a hierarchy in the operating room[36]. The idea of the WHOSCC process is to empower any member of the team to raise concerns pertaining to patient safety and flatten this hierarchy. No single individual can complete the checklist alone and this reinforces the strength of the collective[37]. Individual roles and responsibilities in the team are set, delegating important tasks so no one individual has too many moving parts to focus on.

Literature supporting the principle that checklists promote a collective mentality include work by Lingard et al.[38] who reported 73% of operating department team members in their unit agreed that use of a surgical checklist strengthened the team. Taylor et al.[36] noted benefits of implementing the WHOSCC have been observed with regards to perceived respect communication and teamwork, and Sexton et al.[39] reported a positive effect of checklist use on attitudes to safety, job satisfaction, stress recognition, working conditions and creating a climate of safety and collaboration. Job satisfaction and a sense of purpose and identity within a wider team also enhances staff retention and the resulting familiarity amongst teams breeds safety and efficiency[40-41].

## Prose: Scope for Specificity

A potential detriment of widespread checklist use is “checklist fatigue.” Decades of experience from the airline industry show that checklists can reduce overall compliance[13]. Users fail to engage with the checklist properly yet continue to rely on it. Factors such as being too extensive or used in too broad a set of circumstances are thought to contribute to this phenomenon of checklist fatigue. In certain specialty areas the use of the original WHOSSC fails to address specific concerns and this also risks engagement.

Kulkarni et al.[42] presented their experience of a pilot study that introduced a novel, spinal surgery specific checklist to Bombay Hospital. This retrospective pilot study at a single centre involved 858 patients. After exclusions, a study group (n=428) consisted of patients treated after the novel checklist was introduced and a control group (n=394) consisted of patients treated before introduction. Incidence of major perioperative complications and preventable human error were the study’s primary outcome measures. Like the Surgical Patient Safety System (SURPASS)[43], the spine surgical checklist split the surgical process into 3 episodes: Preoperative, perioperative and postoperative. In the preoperative phase a final surgical plan was agreed, and specific requirements and important information were checked and recorded. This includes items such as essential imaging and prompts to record known salient points such as transitional vertebrae, rib anomalies and spinal cord malformations. Required instruments, equipment and implants were submitted and a “bailout” surgical plan could be detailed. In the study, this section of the checklist was submitted to theatre staff the day before the planned procedure.

Salient points from the perioperative section include a prompt to record antibiotics both within 30 minutes of induction of anaesthesia and after either 4 hours of surgery or over 1.5L of blood loss, performing a drain tug, using vancomycin powder in the wound and performing final tightening of the set screws. The postoperative phase checklist includes a neurology checklist and documentation of postoperative instructions amongst other points.

Preventable adverse event rate was significantly higher before the institution of the checklist (0.14) as compared with that after the checklist was instituted (0.04). The rate of unpreventable adverse events before (0.145) and after (0.128) the checklist’s introduction was not statistically significant. The authors themselves acknowledge the limitations of this single centre which is retrospective and small in sample size and importantly doesn’t specifically address compliance and engagement. Furthermore, by expanding the checklist from 19 to 37 there is a risk of checklist fatigue by being too extensive. However, by understanding the established benefits of checklists to promote staff engagement and shared safety culture, but reworking prose in such a way as to target more specific circumstances, we believe that this work represents an example of checklists enhancing the abilities of their users rather than limiting them. Whilst extensive, the salient points are stimulating to anyone who is involved in spinal surgery regularly. We can appreciate the nuances included in the spinal surgical checklist and praise its relevance.

## Specific Problems in Spinal Surgery: Wrong Level Spine Surgery

In spinal surgery operating on the wrong level and as such wrong site, a so called never-event, is an ongoing problem. The literature suggests it is not an uncommon one. Higher estimations suggest that over half of spine surgeons will encounter at least one wrong-level spine surgery (WLSS) in their career[44-46].

An observational study by Mesfin et al.[47] assessed the formal training of spine surgery fellows in WLSS across North America. Among the fellows who responded, 30.4% had already experienced WLSS. The consequences of such incidences include effects on a patient's health, potential exposure to further procedures and anaesthetics, litigation and a negative impact on surgeon and operating team's confidence.

Increased prevalence of WLSS in the lumbar spine has been reported[49] and another interesting observation by Goodkin et al.[49] was that in occurrences of WLSS, it was predominantly the adjacent cranial level that was inadvertently operated on.

Initiatives to specifically address the problem exist. Following on from the American Academy of Orthopaedic Surgeons "Sign of Site" campaign, The North American Spine Society refined this into the so called "Sign, Mark and X-ray" or SMaX program, publishing this in 2001[50].

Intuitively, the components are laid out as:

1) Sign the surgical site before surgery: Noting the levels involved and the side to be approached.
2) Mark the level in the operating room with a radiopaque indicator on a bony landmark.
3) Radiograph the spine as a routine part of the procedure with the marker in place to confirm the level of pathology.

Accompanying the checklist is a technical document[51], which includes more detailed guidance on marker placement and localization.

Another similar initiative to tackle wrong site surgery is the Universal Protocol (UP) for Preventing Wrong Site, Wrong Procedure, and Wrong Person Surgery[52]. This is mandated by the Joint Commission (JC) for accredited hospitals. Vachhani et al.[53] looked at the effect of introducing the UP on the incidence of wrong-site surgery in a neurosurgical department. Of 15 wrong site surgeries, 14 involved the spine with an overall incidence of 0.07% and a statistically significant greater number of incidents before UP was introduced.

James et al.[16] carried out a retrospective review to estimate the incidence of wrong site surgery by orthopaedic surgeons applying certification with The American Board of Orthopaedic Surgeons between 1999 and 2010. They also looked at whether the implementation of UP has impacted on the incidence of wrong site surgery. A sub-analysis pertaining to spinal surgery was performed. 897 spine surgeons submitted 324085 spinal procedures in the study period. 31 surgeons (3.5%) reported a wrong-level spine surgery (0.041%). In 26 cases, more specific information was garnered. 14 incidents occurred in the lumbar spine, 2 in the thoracic spine and 8 in the cervical spine. Intraoperative imaging was taken in all cases but in 11 cases this was interpreted incorrectly. Other influential technical factors cited included patient body habitus, removal of retractors without securely marking the level and drift of tubular retractors to an adjacent level during minimally invasive surgery.

Acknowledging the persistence of the problem a decade later, Naqvi et al.[54] surveyed 105 spinal surgeons to evaluate current practice pertaining to intraoperative spinal level checks. They gathered data on level of surgical experience, historic involvement with WLSS and individual preferred techniques for level checking in the cervical, thoracic, and lumbar spine. Of the respondents, 63 (60%) performed a pre-incision check, 40 (38.1%) rechecked intra-operatively, and only 2 (1.9%) routinely performed a check prior to closure. There was variability in practice regarding anatomical landmarks utilized. In the cervical spine a consensus (75.2%) used the disc space as the primary landmark. More heterogenicity was observed in the thoracic spine. 48.6% used pedicles, 17.1% used spinous processes and the remainder of responses included laminae, disc spaces, interspinous processes and ribs. In the Lumbar spine, disc spaces were used by 41.9%. Other responses were Interspinous space (19.0%), laminae (16.2%), pedicles (12.4%), spinous process (10.5%) and facets (0.9%). Respondents tend not to acquire preoperative radiographs to specifically identify lumbosacral anomalies with only 26.8% responding that they are doing so routinely.

Risk reduction strategies to WLSS have been postulated. In response to the aforementioned survey-study, Naqvi et al.[54] proposed a pause moment prior to decompression or instrumentation to involve the entire theatre team. This strategy leans on the principle of collective responsibility and is a facsimile of WHO "time-out" moments. The value of a "time-out" moment has previously been reported by Stahel et al.[55] who attributed 72% of wrong-site surgeries in their study as being associated with the absence of a “time-out”.

One can make the argument in this respect timing is everything. Confirming a level at the start of the procedure prior to a potentially protracted and arduous exposure is irrelevant if this isn’t replicated in some way, be that radiologically or anatomically, immediately before the crux of commencing instrumentation or decompression. In this respect the concept of checklist complacency applies and there is the risk of assumptions being made that because the level of surgery was checked at the start of the procedure this applies throughout.

Other proactive steps towards reducing WLSS risk include acquiring and critically appraising pre-operative imaging to appreciate anatomic variations such as thoracic rib number, presence of cervical ribs and lumbosacral anomalies. Tins & Balain[56] reported an atypical number of vertebrae i.e. not 24 in 8.1 % of 450 patients’ whole spine MRIs. In another very recent study of 998 patients undergoing idiopathic scoliosis surgery the prevalence of an atypical vertebrae number was 9.8% (n=98)[57]. This study identified 7 variations from a typical 7C12T5L conformation and variance from this typical pattern occurred at a rate of 15.5%. 2 patients had cervical ribs and lumbosacral transitional vertebra (LSTV) were common (25.1%). Other studies report a range of figures for the incidence of Transitional lumbosacral vertebrae ranging from 1–30 %[58-65].

Many surgeons and radiologists argue that to count down from the atlantoaxial joint as the only reliable way to correctly number vertebrae. In our institution, the imaging protocol of MRI of the lumbar spine was modified considering the findings of the Tins & Balain study[56]. Such imaging now routinely includes a sagittal half-Fourier acquisition single-shot turbo spin-echo (HASTE) localiser, imaging the whole spine in around 30 seconds to allow counting down from C2.

The point of WLSS illustrates a limitation of the WHOSCC in spinal surgery. Knowing what the intended target is and successfully navigating to it are not the same thing. Performing correct level surgery requires attention to details beyond those that appear on the WHOSCC.

## Specific Problems in Spinal Surgery: Managing the Prone Patient

Another nuance of spinal surgery is that many procedures are performed with the patient prone, sometimes for a prolonged period. Perioperative peripheral nerve injuries (PPNI), pressure injuries, post-operative visual loss (POVL), tongue swelling and airway compromise are some of the complications that can affect the prone patient.

POVL is rare but feared. Its incidence is estimated between 0.09 to 0.20%[67-71]. Due to the gravity of the complication, a POVL Task Force was set up by the American Society of Anesthesiologists and a practice advisory was written[72]. Perioperative recommendations were made across 5 broad categories; blood pressure management, management of blood loss and administration of fluids, use of vasopressors, patient and head positioning and staging of surgical procedures. Some specific points include use of central venous pressure monitoring, maintaining a neutral neck position with 10 degrees of reverse Trendelenburg and maintaining intravascular volume.

PPNI is seen more frequently than POVL but still thankfully rare[73,74]. The most commonly effected nerves are the ulnar nerve, brachial plexus, and lateral femoral cutaneous nerve (LFCN). Most commonly reported and a significant medicolegal burden is ulnar nerve palsy[73]. A study by Kamel et al.[75] identified significant changes in somatosensory evoked potential with the prone-superman comparted to the prone, arms tucked positions. Factors such as excessive elbow flexion (>90°), direct compression of the cubital tunnel, the arm migrating during surgery and obesity are known risk factors[76-78]. Traction neuropraxias and compression induced ischemic injuries of the brachial plexus occur due to mal-positioning in prone. Excessive arm abduction (>90) hypovolaemia, hypothermia, a history of alcohol dependency and diabetes mellitus are all risk factors[76]. Finally, LFCN injury has a reported incidence of 10%–24% during posterior spine surgery[79], with compression at the anterior superior iliac spine the most prevalent cause, for example by supports or bolsters. A lean build and prolonged surgeries are risk factors[76,79].

Several checklists that focus specifically on care of the prone patient are reported in literature. Cai et al.[80] produced a 22-item checklist for safely positioning a patient prone for surgery. Whilst mainly focusing on pressure area care and positioning rather than an exhaustive list of risk factors, their checklist resulted in an average of 21 out of their 22 points being checked per case and a 95.45% implementation rate during an 87 case pilot study. This compared favourably to the pre-checklist rate of implementation.

Equally as applicable to spinal surgery, Hussein et al.[81] published their experience in introducing a change of patient position under anaesthesia or "CHOPP" checklist. This identified key items to consider and optimise before and after an anesthetised underwent a position change. Whilst robust data wasn't presented in this article, nor was a baseline measure performed, positive qualitative user feedback was reported and a high number of potential patient safety issues were identified in 70% of cases when the checklist was utilised.

Safe positioning of the prone patient requires knowledge and vigilance of multiple members of the surgical team. The WHO guidance for safe surgery references positioning somewhat indirectly in its objectives; "The team will use methods known to prevent harm from administration of anaesthetics, while protecting the patient from pain." Our observation is that positioning isn't however mentioned in the WHOSSC itself. Surgical teams rely on training, knowledge and their experience of performing hundreds of cases a year to position patients safely. The reported rates of PI and PPNI in prone surgery in particular indicate that experience alone does not mitigate for human factors which lead to error.

## Specific Problems in Spinal Surgery: Intraoperative Monitoring

Another distinction of spinal surgery from other types is the occasional reliance upon intraoperative neurological monitoring (IONM). Spinal cord and nerve root injury can occur through direct trauma, ischaemic insult and traction during deformity correction. Simultaneous monitoring with motor and somatosensory evoked potentials as well as neurogenic evoked potentials has been reported to provide an extremely high degree of sensitivity and specificity for neurologic harm[82-84]. Risk factors predisposing to altered IONM include larger degree of deformity correction, cardiopulmonary comorbidities, and labile intraoperative mean arterial pressures[85]. The ability to identify potential compromise and respond to this before neurologic damage becomes permanent has led to improvements in the rates of neurologic injury during deformity correction surgery[86].

As part of more broad guidance on IONM, Vitale et al.[85] developed an intraoperative checklist, designed to optimise response to changes in neuromuscular monitoring. They applied the Delphi process to lay out a consensus of expert opinion from across a spectrum of allied disciplines[87]. A 27-point checklist was agreed upon under 5 separate sub-headings. The first and arguably most influential subheading was entitled; get control of the room and listed 4 steps to prime the team to respond to a critical situation. An intraoperative pause, announcing the problem, eliminating distractions such as music and summoning experienced personnel were all listed. Other headings were predominantly based on which individuals would be carrying out the checks. An anaesthetic checklist included optimising MAP, haematocrit, and other important parameters. A surgical checklist included a stepwise approach to reversing the most recent steps, examining osteotomy sites and decrease traction or other deforming/corrective forces. A neurophysiology checklist included checking electrodes and other technical factors that might influence monitoring.

Another checklist for the same circumstances designed by Ziewacz et al.[88] followed a similar principle of delegating responses to surgeon, anaesthetist and neurophysiologist in order to promote a systematic and coordinated approach. In their study, the checklist was actually applied to 3 instances of IONM concern and subjectively performed well. Human cognitive capacity is significantly bridled by stressful, time critical circumstances and this acknowledgement forms the basis for optimism for what checklists could achieve in emergency situations. Another study by Ziewacz and colleagues[89] reported a 6-fold reduction in the failure of surgical teams to adhere to critical practices when a checklist was applied to simulated emergency situations.

Despite the theorised benefit of applying a checklist to respond to adverse IONM features, and indeed other emergency situations in spinal surgery, there is a significant paucity of research around applying either of the checklists discussed here nor any other.

## Conclusion

The benefits of the applying checklists to safety-critical situations are well reported and at this point well understood. The WHOSSC has been universally adopted since its inception, generally with a positive reception and significant academic backing. The evidence suggests use of the WHOSSC is associated with reduced rates of post-operative mortality and a reduction in complications such as wrong site surgery and surgical site infection. Groups that use the WHOSSC also like it and are ultimately made better teams by using it. Positive effects on inter-person respect, communication, teamwork, attitudes to safety and in turn stress and job satisfaction are reported.

The WHOSSC isn't however perfect and this rings true in some specialities more than others. The prose included in the fundamental WHOSSC can be considered generic at times and important patient safety features such as safe positioning are omitted. The importance of performing the correct surgery at the correct site is a primary focus of the WHOSSC, yet as we have illustrated in the case of WLSS, without a focussed, well-trained team that understands the intricacies of their task, a checklist cannot protect against these significant errors. Furthermore, some argue that the WHOSSC is somewhat reductive, and fails the recognise that the process of surgery starts with consent of the patient and often includes a comprehensive pre-operative work up and multidisciplinary discussions and planning before the patient even steps foot in hospital on the day of surgery. All these steps could be opportunities for overall risk reduction and should be considered; the total risk of any procedure is the sum of each part of the procedure[90].

With regards to spinal surgery, checklists continue to represent both an essential established part of maintaining and improving patient safety but also an area for further exploration. WLSS, safe positioning and responding to adverse IONM are but some of the potential areas where checklists could be used to reduce human errors and improve outcomes. Munigangaiah et al[91] in 2012 concluded in their review article that wrong level surgery in spinal surgery needs special emphasis and there may be an increasing role for surgical safety checklist being procedure specific especially in spinal surgery.

The WHO have always strongly advised that the WHOSSC is adapted to local and specific circumstances and the above criticism is of course only intended to stimulate discussion. 15 years since the introduction of this landmark and conclusively valuable patient safety initiative, the WHOSSC continues to influence a culture of safety. Through asserting the WHOSSCs principles but adapting it's prose we hope the humble checklist continues to be a powerful tool tackle patient safety problem that still exist across all domains of surgery.

## Conflicts of Interest Statement

The authors have no conflicts of interests to declare.

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