Anaesthesia 2020, 75 (Suppl. 1), e34–e38 doi:10.1111/anae.14830

Review Article

Human factors and the safety of surgical and anaesthetic care

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Summary

Safety of patients in the operating theatre relies on a cordial and efficient working relationship between all members of the theatre team. A team that communicates well, defines the roles of its members and is aware of their limitations will provide safe patient care. In this review, we will examine how human factors engineering – the science of how to design processes, equipment and environments to optimise the human contributions to performance – can be used to improve safety and efficiency of surgery. Although these are often dismissed as 'common sense', we will explain how these solutions emerge not from healthcare but from diverse disciplines such as psychology, design and engineering.

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Accepted: 7 August 2019
Keywords: design; ergonomics; human factors; patient safety; risk
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Introduction

A review of the United Nations and World Health Organization data found that, globally, over 234 million operations are carried out annually [1]. Sadly, up to 3% of these procedures will have a major complication, and 1 million people will die during, or within the following days after, an operation. It was also found that nearly half of these complications were preventable [1]. There is a disproportionate number of people receiving surgical care in higher income countries with the poorest third of the world's population (residing in countries in which annual per capita expenditure on health is US $100 or less) receiving just 3.5% of the operations undertaken worldwide. Equity of service and reducing the burden of surgical errors, particularly in under-resourced countries, could have a dramatic impact on health budget spending and efficacy of surgery.

Perhaps the most publicised adverse event during surgery in recent years is the death of Elaine Bromiley [2]. As most anaesthetists are aware, Mrs Bromiley died from asphyxia in the presence of experienced anaesthetists, nurses and an ear, nose and throat surgeon. All of the equipment required to perform emergency front-of-neck airway was available but not used. As some members of the team were aware of what needed to be done but their concerns were not heard, it appears that a lack of teamwork, assertiveness and communication lie at the core of the team's failure. Indeed a re-analysis of cases of the 4th National Audit Project into airway events found that all 12 of the cases examined had similar failings in team processes [3]. So how do we improve these 'non-technical skills' of individuals and the team performance?

Team briefings before embarking on a list or difficult case have been suggested as a way to share key information, concerns and intended strategies. However, routine briefings at the start of an operating list are still unusual in many organisations. Even when formalised, these briefings may take place after the period of danger has passed, such as with airway management [4].

Team briefings allow prospective planning for expected events but, where events are unexpected, team members should be familiar with emergency procedures for rectifying the situation [5]. Knowledge of the protocols and actions are only part of the story, as emergencies require coordinated effort by all members of the team in the context wherein the emergency occurs [6,7]. In-situ simulation training of crisis management by the whole team in the actual clinical setting is perhaps the most effective way of building this teamwork [8]. Indeed, in-situ obstetric simulation training and, more recently, cardiac arrest training have been proven to improve clinical outcomes [9]. This is likely to be more effective than practising in a simulation centre as knowledge of where equipment is, how to communicate, form the team and coordinate activities is more realistic. Recent changes that include in-situ simulation into process redesign – so called 'translational simulation' – are becoming more widespread and frequent [10]. They have the potential to help understand and address the barriers to effective teamwork and have been demonstrated to improve performance.

Further extension of in-situ simulation into other operative settings is required, such as for the intra-operative and peri-operative management of cardiac arrest, anaphylaxis and major haemorrhage. Ensuring this happens with all team members as a routine has significant financial and efficiency burdens on an already stretched health service, but might conceivably be included as part of an annual certification process.

Routine checklists

Apart from checklists for emergency care that can be utilised during crises, routine checklists have demonstrated substantial potential to improve safety and efficiency. Surgical safety checklists have been implemented in most hospitals throughout the world. The most common is the 'Surgical Time Out' implemented by the World Health Organization [11]. This has resulted in a global acceptance of a formal time out policy which is modified for each health network. In Scotland, recent work has shown that a reduction in mortality and improvement of postoperative outcomes is possible with the introduction of the checklist, contributing to a reduction in surgical mortality by 36.6% over a decade [11]. The reasons for this are complex and poorly understood. Completion of the checklist has been found to increase the number of briefings, discussion of roles and responsibilities, but no improvement in situation awareness or other team outcome measures has been found in direct comparisons [12]. One theory is that, following a period of discomfort in the introduction of the checklists, the social structure becomes less hierarchical in the operating theatre. Anecdotally, junior staff are more likely to speak up and identify problems that might be missed.

There have been concerns raised about the lack of efficient checklists and prolonged theatre times that can be associated with inappropriate or prolonged checklists. An example from the orthopaedic theatres has been inclusion of an item asking the team to check the arthroscopic or laparoscopic tower in a case not requiring this equipment – clearly a waste of time. It has been suggested that engagement and compliance with the surgical safety checklist is influenced by the perceived unimportance of individual checklist items [13]. There are conflicting data about whether the checklist fails to prevent equipment issues in the operating theatre and time and cost outcomes [14, 15]. Professional groups disagree on the importance and details of some items on the list. All agree that correct procedure is important but the anaesthetists have been found to insist on defining the exact procedure, surgical time and bleeding time, where some surgeons defined procedure as correct side and joint (e.g. 'right hip') [13]. Tailoring of the checklists is, therefore, crucial to ensure the important information and appropriate detail is included in the checklist. The items should be determined with the input of the clinical staff that are to perform the checklist as a part of the implementation strategy [16].

It is our experience that, in many instances, there is a tendency to rush through the surgical safety checklist and implementation of 'time out' can be dependent on the clinical staff involved. In many institutions there are no clear guidelines to confirm whether the nursing staff, anaesthetist, surgeon or their trainees are to lead the checklist, despite clear evidence demonstrating more comprehensive completion when it is displayed on the wall and responsibility assigned to a senior team member [17]. Audit to confirm whether the surgical checklist has been completed or performed correctly is rarely undertaken. As already noted, patients are often already anaesthetised during the checklist such that the key team member who has the biggest stake in the process, the patient, is not involved in the final confirmation of the correct procedure, side or even if surgery is appropriate.

System redesign

In some instances, the environment, tasks and team can be completely redesigned to improve performance and outcomes [18]. Rather than educating individuals on how to adapt in their roles to the context, the context itself can be modified. Simulation can be used to identify and test the processes and equipment but more complex methods from such fields as engineering and psychology can be employed in the first instance [19]. Task analysis, understanding points of failure and designing out potential problems at an early phase are useful. Even cardboard mock-ups of rooms and equipment with walk-throughs of scenarios can be used to identify potential problems [20]. Techniques such as this have been employed in ambulance design [21], extracorporeal membrane oxygenation (ECMO-CPR) resuscitations [22] and re-sternotomy of unstable patients in the ICU following cardiac surgery [23]. Specific skills are required to undertake this depending on the scope of the project. Where these skills are not available, suggested standardised methods for how equipment should be set out and even how team members should be allocated can be designed, based on simulation testing. An example of this is the Australian and New Zealand College of Anaesthetists e-learning module for the management of peri-operative anaphylaxis (Fig. 1) [24].

Redesign in an organisational sense can lead to reduced fatigue and error [25]. However, reduction of work hours in trainees may lead to unintended consequences of reduced exposure to clinical work and the skills that are needed for safe practice as a consultant. In one study, implementing the European Working Time Directive limiting trainees to 48-hour weeks, demonstrated a similarly high burnout rate in Dutch orthopaedic trainees as the older longer hours model [26]. The authors concluded that there was a "*consistent and significant association between the clinical learning climate and the overall well-being of orthopaedic trainees*." That is, there is an association between the quality of the learning environment (where trainees learn during their daily activities) and quality of life independent from the number of hours worked. Although, ensuring safe working hours is important, this should not detract from a productive learning environment. The balance between service provision and training will continue to be an issue.

Understanding safe systems

Approaches to safety by different professional groups might, conceivably, be counterproductive if based solely on the perception of that professional group. For instance, serious anaesthetic complications are rare and much less common than surgical complications, often by two or three orders of magnitude [27]. For example, there is concern that the 'beach-chair' position during shoulder arthroscopy is associated with increased risk of cerebrovascular events in

Figure 1 Video endorsed by the Australian and New Zealand College of Anaesthetists for the e-learning module on anaphylaxis management demonstrates how surgeons, anaesthetists, nurses and other theatre staff should allocate roles and work together during a peri-operative emergency [24].

comparison with the lateral decubitus position [28]. However, a recent systematic review comparing beach-chair and lateral decubitus positioning in posterior–inferior instability of the shoulder stated "*across included studies, and regardless of patient position, there were no reported incidences of neuropraxia, stroke, nonfatal pulmonary embolus, vision loss, cardiac arrest, or other previously described complications that were possibly attributable to patient positioning*" [29]. Perception of increased risk by an anaesthetist, in this example, may result in a surgeon using a different position and, subsequently, compromise or abandon an operation due to unfamiliarity in technique. It has been suggested that using the lateral decubitus position for anterior shoulder stabilisation has a lower recurrence rate [30]; however, this difference was only minor and the authors suggested that surgeon experience probably has a greater role.

Conversely, another example of the prone position for foot and ankle surgery shows that surgical adaptation to reduce anaesthetic risk can be successful. Prone positioning can be associated with inferior vena caval obstruction, ophthalmic complications, altered lung mechanics and even vertebral artery occlusion [31]. As a consequence, some surgeons have adopted equivalent positioning techniques without an increase in surgical risk, including supine, lateral and 'floppy lateral' techniques [32, 33].

The patient, of course, does not care if the complication is surgical or anaesthetic in origin, only that the safety of the procedure is as high as possible. In this situation, the safest system for the patient is one that encourages open communication between surgical and anaesthetic teams and opportunity for any concerns to be addressed before commencement of anaesthesia. Risks are rarely dealt with as a whole, nor are the compounding effects of the risks of multiple smaller procedures (or sub-procedures) within the overall episode of care [34]. Rather, discrete studies on specific complications are often reported without understanding the compromises made in other areas of care. To fully understand surgical safety there has to be a unifying approach to guide the design of future systems of care.

Three different approaches have been used to address safety in health. Classically, health has followed a 'high reliability' approach, using quality improvement methods such as 'Lean thinking' and Six Sigma borrowed from high reliability organisations in other industries to manage and mitigate risk [35]. However, as elective anaesthesia for healthy patients has approached extremely safe levels, a new paradigm of 'ultrasafe' health emerged, where risks were actively sought out and avoided [27]. Clearly, not every area of healthcare, or even every specialty of surgery can be ultrasafe due to the emergent and complex nature of health. Unlike aviation or manufacturing, there are complexities of each individual patient that can never be known, even with exhaustive testing. Humans were not designed by humans, therefore, a full understanding of developing physiological and pathological processes during surgery is impossible [36]. The third type of safety paradigm accepts this, and accepts that trained individuals, supported by well-designed environments, equipment and processes can adapt to unknown (and unknowable) situations. Proponents of 'ultra-adaptive' safety systems believe experienced clinicians contribute to safety by proactively seeking out threats and adapting to them. This aligns with the concept of 'resilience' in safety science and 'safety 2' where organisations seek to learn from clinicians' successes, as well as the occasional failures, instead of only focusing on incidents where harm occurs [37].

One of the substantial barriers to widespread redesign to improve safety and efficiency of surgical systems is the lack of knowledge and experienced human factors practitioners available to undertake these projects. Anaesthetists and surgeons are not traditionally educated in safety science, and even if they were, the skill sets of psychology and design required are generally beyond them. The Chartered Institute of Ergonomics and Human Factors (CIEHF) in the UK has identified this. In its 2018 white paper, the CIEHF asserts that every NHS organisation should have access to an individual with human factors expertise [38]. Only by embedding safety science experts within health organisations, as is the case in every other safety critical industry, will the revolution in human factors and patient safety that is needed, be able to occur. Along with carefully implemented interventions, such as checklists, new processes and equipment, human factors engineering has the potential to improve teamwork, communication, safety and efficiency of anaesthetic and surgical care.

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