Guidelines

Implementing human factors in anaesthesia: guidance for clinicians, departments and hospitals

Guidelines from the Difficult Airway Society and the Association of Anaesthetists

F. E. Kelly,[1] C. Frerk,[2,3] C. R. Bailey,[4] T. M. Cook,[1,5] K. Ferguson,[6] R. Flin,[7] K. Fong,[8,9] P. Groom,[10] C. John,[11] A. R. Lang,[12] T. Meek,[13] K. L. Miller,[14] L. Richmond,[15] N. Sevdalis[16] and M. R. Stacey[17]**

1 Consultant, Department of Anaesthesia and Intensive Care Medicine, Royal United Hospitals Bath NHS Foundation Trust, Bath, UK
2 Consultant, Department of Anaesthesia and Critical Care, Northampton General Hospital, Northampton, UK and Difficult Airway Society Professor of Anaesthesia and Airway Management
3 Honorary Visiting Professor, University of Leicester, College of Life Sciences/Leicester Medical School, Leicester, UK
4 Consultant, Department of Anaesthesia, Guy's and St Thomas' NHS Foundation Trust, London, UK
5 Honorary Professor, Bristol University, Bristol, UK
6 Consultant, Department of Anaesthesia, Aberdeen Royal Infirmary, Aberdeen, UK, and Past President, Association of Anaesthetists
7 Professor, Aberdeen Business School, Robert Gordon University, Aberdeen, UK
8 Consultant, Department of Anaesthesia, University College London Hospitals NHS Foundation Trust, London, UK
9 Professor, Department of Science, Technology, Engineering and Public Policy, University College London, UK
10 Consultant, Department of Anaesthesia, Liverpool University Hospitals NHS Foundation Trust, Aintree, Liverpool, UK
11 Operating Department Practitioner and Head of Clinical Education, University College Hospitals NHS Foundation Trust, London, UK
12 Assistant Professor, Human Factors Research Group, Faculty of Engineering, University of Nottingham, UK, and previous Chair of Healthcare Sector Group, Chartered Institute of Ergonomics and Human Factors
13 Consultant, Department of Anaesthesia, James Cook University Hospital, Middlesbrough, UK, and Vice President, Association of Anaesthetists
14 Consultant, Department of Paediatric Anaesthesia, Birmingham Women's and Children's NHS Foundation Trust, Birmingham, UK and Trainee Committee, Association of Anaesthetists
15 Consultant, Department of Anaesthesia, Swansea Bay University Health Board, Swansea, UK, and previous trainee representative Difficult Airway Society
16 Professor, Centre for Implementation Science, King's College London, London, UK
17 Consultant, Department of Anaesthetics, Intensive Care and Pain Medicine, University Hospital of Wales, Cardiff, UK, Deputy Dean, Health Education Improvement Wales, and Board Member, Association of Anaesthetists

Summary

Human factors is an evidence-based scientific discipline used in safety critical industries to improve safety and worker well-being. The implementation of human factors strategies in anaesthesia has the potential to reduce the reliance on exceptional personal and team performance to provide safe and high-quality patient care. To encourage the adoption of human factors science in anaesthesia, the Difficult Airway Society and the Association of Anaesthetists established a Working Party, including anaesthetists and operating theatre team members with human factors expertise and/or interest, plus a human factors scientist, an industrial psychologist and an experimental psychologist/implementation scientist. A three-stage Delphi process was used to formulate a set of 12 recommendations: these are described using a `hierarchy of controls´ model and classified into design, barriers, mitigations and education and training strategies. Although most anaesthetic knowledge

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of human factors concerns non-technical skills, such as teamwork and communication, human factors is a broad-based scientific discipline with many other additional aspects that are just as important. Indeed, the human factors strategies most likely to have the greatest impact are those related to the design of safe working environments, equipment and systems. While our recommendations are primarily provided for anaesthetists and the teams they work with, there are likely to be lessons for others working in healthcare beyond the speciality of anaesthesia.

Recommendations

Design

1 Design of medical equipment should include input from human factors experts at an early stage. The medical equipment procurement process should include human factors assessments.

2 Design of drug ampoules and packaging should incorporate human factors principles to optimise readability and reduce the risk of mis-selection: anaesthetists, pharmacists and procurement departments should ensure that these principles are prioritised during their purchasing processes.

3 Design of safe working environments should incorporate human factors principles. Regular reviews should be carried out to ensure that safety has not been compromised.

Barriers

4 Operating theatre list planning and scheduling should include additional time allocated for complex cases and for high turnover lists to enable adequate preparation and reduce time pressures on staff.

5 Cognitive aids, including algorithms and checklists, should be designed and tested using human factors principles to ensure usability and efficacy.

6 Non-technical skills can be learned and developed, and should be practised during everyday work to ensure that staff become skilled in their use and are able to use them effectively.

Mitigations

7 Investigation of critical incidents and adverse events should be performed by teams that include members with human factors training using a human factors investigative tool. Lessons identified should be shared.

8 Morbidity and mortality meetings should be part of the regular work of all anaesthetic departments and should also include learning from cases that go well. Time within job plans should be allocated to enable staff to prepare for and attend these meetings.

Education and training

9 Human factors education and training should be provided at an appropriate level for all anaesthetists and all members of operating theatre teams. It should include the role of good design in healthcare, an appreciation of a systems perspective, the importance of non-technical skills and strategies to improve these.

10 Non-technical skills training and interprofessional simulation training: Teams that work together should train together. Non-technical skills should be learned during classroom and in-theatre teaching, woven into all anaesthetic workshops and courses and rehearsed during regular interprofessional simulation training.

Time and resources should be allocated to allow for this.

Well-being

11 Staff well-being should be optimised by hospitals and anaesthetic departments by implementing organisational strategies.

Strategy

12 Each anaesthetic department should have a human factors lead with an appropriate level of training. Every hospital should have patient safety leads with appropriate training and qualifications; in England, this is already included in Health Education England recommendations.

What other guideline statements are available on this topic?

There are no existing guidelines on this topic.

Why were these guidelines developed?

Human factors principles and strategies have been incorporated successfully into safety critical industries, including nuclear power, offshore oil and gas, aviation, construction, rail and the military. Implementation of human factors principles, education and methods within healthcare [1] has made some progress in the past 20 years but remains patchy [2]. Systematic and sustained implementation of human factors science has the potential to reduce the need to rely on exceptional human performance to improve the safety of patients and the well-being of staff.

This guidance is written for anaesthetists, multidisciplinary teams, clinical and non-clinical managers, hospital chief executives and boards and the leaders of national bodies. There are likely to be lessons for others working in healthcare beyond the speciality of anaesthesia.

Many of the terms used in this paper are part of the common language of human factors science but may not yet be familiar to healthcare staff. Most terms are explained or defined in this paper or the accompanying narrative review [3]. In addition, a comprehensive glossary of human factors terms alongside healthcare examples has been produced by the Clinical Human Factors Group [4].

How and why does this statement differ from existing guidelines?

While there are numerous existing documents related to human factors in healthcare, including those relating to drug safety, design, cognitive aids and non-technical skills,

this is the first guideline to our knowledge which describes specific implementation strategies for human factors.

Introduction

Human factors is an evidence-based scientific discipline which aims to make it easy for workers `to do the right thing´ and difficult, or ideally impossible, for workers to `do the wrong thing´ [3, 5, 6]. The terms `human factors´ and `ergonomics´ can be used interchangeably and can be combined as `human factors/ergonomics´ [2, 6].

Human factors accepts that humans are fallible, that human error cannot be eliminated [7] and that personal and team performance vary and are likely to deteriorate in high-pressure situations [8]. Human factors includes non-technical skills, such as teamwork and communication, but is a much broader speciality with many other components. Human factors is both the scientific discipline concerned with the understanding of interactions among humans and other elements of a system [9], and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance [9].

Human factors strategies can be categorised into four domains according to a hierarchy of controls model [9, 10]. These four domains can be arranged in a pyramid shape according to their likely effectiveness. Design (of environment, equipment and systems) is the strategy likely to be most effective and forms the base of the pyramid. `Designing out´ the chance of an error occurring reduces the requirement for exceptional human performance commonly relied upon in healthcare [5, 9, 11]. Design strategies are followed in order by barriers (which trap errors), mitigations (which reduce the consequences of errors) and education and training (Fig. 1).

The current UK healthcare system is more like the hierarchy of controls pyramid turned upside down (Fig. 2), with heavy reliance on high levels of human performance and a resultant small and unstable foundation for safety. We propose that systematic implementation of human factors in healthcare would result in the creation of a broad-based, stable foundation for improving patient safety and staff well-being [6]. A multilevel approach is required to achieve this, with actions from national bodies, hospitals, anaesthetic departments, multidisciplinary teams and individuals. We describe a framework to embed evidence-based human factors practices within anaesthesia. Much of this guidance is focused on actions that anaesthetists can take as part of their wider role in hospital safety. There are lessons for others in healthcare beyond this specialty.
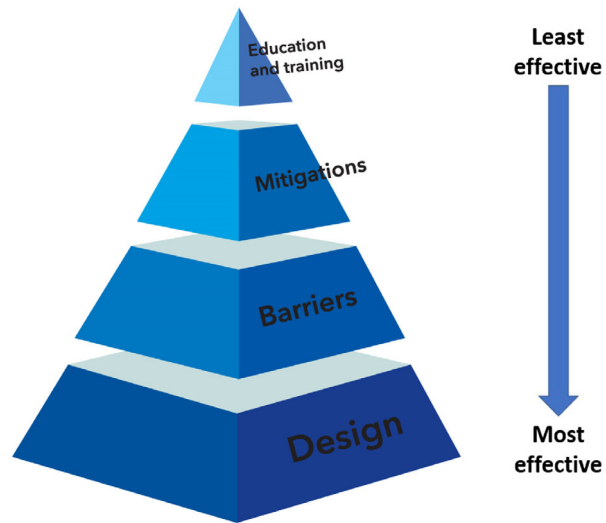
Figure 1 Hierarchy of controls model for improving patient safety and staff well-being.
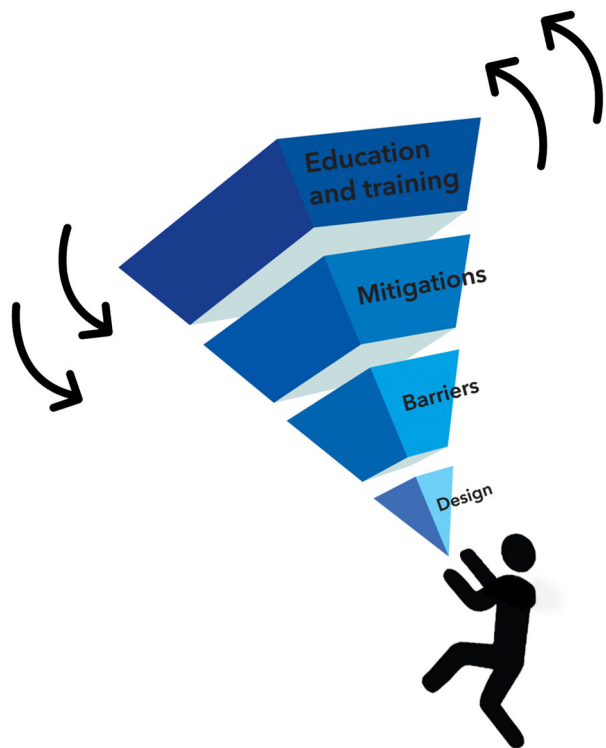
Figure 2 The hierarchy of controls turned 180°, to depict the current situation in healthcare.

Methods

In 2017, 15 multidisciplinary members with a well-recognised interest and/or expertise in human factors were recruited to form a human factors Working Party, including anaesthetists; an industrial psychologist; a human factors scientist; an experimental psychologist/implementation scientist; a senior operating department practitioner; and two anaesthetic trainee representatives.

Consensus from all 15 members of the Working Party was sought to formulate a set of recommendations using a three-stage Delphi process [12, 13] between 2018 and 2020.

- Round 1: 47 recommendations were proposed by Working Party members, based on expertise, available evidence and existing clinical practice guidelines.
- Round 2: all Working Party members anonymously and independently rated each recommendation using a 5-point Likert scale using an online survey tool (https://www.surveymonkey.co.uk). In addition, members were able to propose changes to the wording of the recommendations and suggest possible mergers. The combined results were then discussed by the Working Party at a series of meetings: those recommendations rated as `extremely important´ or `important´ by ≥ 80% of the group were accepted, those rated `extremely important´ or `important´ by < 50% of the group were discarded, and those in the 50–80% range were discussed further by the group and either merged with other recommendations or discarded. Using this process, the second Delphi round reduced the initial 47 proposed recommendations to a list of 15. As is standard with Delphi methodology, Working Party members were then asked to suggest any further recommendations for consideration: two more were added, giving a total of 17 recommendations at the end of round 2.
- Round 3: Working Party members independently and anonymously scored the recommendations again, and after discussion a final list of 12 recommendations was produced.

A 100% (15/15) return rate for each stage of the Delphi process was achieved. The guideline development process took 5 years (2017–2022). During this time, the Working Party met in person 11 times, and communicated regularly via email and virtual meetings, to develop, draft and finalise a narrative review paper [3] and this guideline and implementation paper. Two literature searches were performed, in November 2018 and October 2020. Draft versions of the guidelines were presented at the DAS Annual Scientific Meeting 2018, the World Airway Management Meeting 2019 and in part at the DAS Annual Scientific Meetings in 2020, 2021 and 2022. The final version was ratified by the DAS committee and the Board of the Association of Anaesthetists.

Strategies for anaesthetists to improve human factors

Strategies for improving human factors in anaesthesia are discussed below and shown in Fig. 1.

Design

Design of medical equipment

Well-designed medical equipment and devices which are safe, intuitive and easy to use reduce the risk of errors occurring. International standards, and those from the UK Medicines and Healthcare products Regulatory Agency (MHRA), require medical equipment manufacturers to incorporate a human factors usability engineering assessment into their product development to detect potential use errors [14, 15]. The Working Party recommends that manufacturers perform such human factors assessments from the earliest stages of product design and development (and earlier than is mandated at present), and at every stage of the product development lifecycle thereafter. This would enable improved product design and correction of any design flaws before the product is marketed.

Medical equipment procurement process

The procurement process carried out by a hospital or national body typically includes a cost analysis, an engineering assessment (including serviceability, robustness and maintenance schedules) and a limited clinical evaluation. The Working Party recommends that anaesthetists work closely with hospital procurement departments when shortlisting and selecting equipment and medical devices, using the Clinical Human Factors Group procurement guide [16] or similar. There is currently no mandate for manufacturers to release their human factors usability assessments to hospitals. The Working Party recommends that procurement departments routinely request to see these usability assessments and that manufacturers make these available.

The NHS supply chain's Clinical and Product Assurance Team (CaPA) has started to include human factors principles when developing product specifications for the NHS. It is hoped that, in time, this will support procurement departments and clinicians in choosing products that reduce error through good design.

Design of drug ampoules and drug packaging

Errors arising from drug ampoules and packaging that look similar but contain different drugs are well documented [17, 18]. Despite international [19] and MHRA [20] standards outlining the importance of good design of packaging and labelling, medication errors continue to occur. The Working Party recommends that drug manufacturers improve and standardise the design of drug ampoules and their packaging using the following strategies: larger fonts for the drug name and smaller fonts for the manufacturer name and logo; prioritise generic names over trade names; and consider colour standardisation and differentiation while being mindful of the impact of colour blindness [21].

The Working Party recommends that manufacturers include a human factors usability assessment when designing new drug ampoule labels and packaging before market release, in the same manner as described above for the development of medical equipment [17]. Such assessments are considered good practice but are only mandated at present for drug delivery devices (A. Lang, personal communication). Regarding pharmaceutical products already on the market, the Working Party recommends that anaesthetists work closely with hospital pharmacies and medication safety committees when supply contracts are negotiated, ensuring integration of `readability´ assessments under a variety of working conditions into the selection and procurement process.

Drug administration safety is likely to be improved by the routine use of prefilled syringes [22] and the design of drug infusion pumps [23]. The Working Party recommends the use of prefilled syringes for anaesthetic drugs where available. Specific non-Luer (NRFit) equipment for all neuraxial procedures (including medical lumbar puncture), regional nerve blockade and local anaesthetic infusions is designed to prevent wrong route drug administration errors. Full implementation of the changeover to NRFit equipment is recommended.

Design of working environment
Design and layout of operating theatres

A key human factors principle is designing the working environment to optimise working patterns and tasks, rather than staff having to adjust their working patterns to fit in with (or `work around´) a poorly designed or outdated environment [6, 24]. The Working Party recommends that human factors professionals are involved in the design and refurbishment of new operating theatre suites from an early stage, with `work-flow´ assessments performed to optimise the working environment for the whole team [25]. This includes design of the built environment as well as infrastructure requirements such as positioning of medical gas outlets, suction, laminar flow hoods and electrical sockets.

Lack of space during induction of anaesthesia can present difficulties when performing practical procedures

and was highlighted as a contributory factor in the death of Glenda Logsdail [26]. The Working Party recommends that the design of the area where anaesthesia is induced and the space available should be assessed using human factors principles. Regular reviews of working environment design should be carried out to ensure that safety has not been compromised.

A human factors approach can also be used to optimise the design of the workspace – the way in which the operating theatre team arrange moveable equipment each day [27]. Examples of this include standardised layout of drugs within drug cupboards [27], and positioning of bronchoscope screens [24, 28], ultrasound machine screens [24], anaesthetic machines [24] and monitors [24, 27] to minimise the need for excessive operator head movement. In addition, placing videolaryngoscope screens on the opposite side of the bed to the anaesthetic assistant ensures that the whole intubating team can see the view at laryngoscopy [3, 29].

Design of new hospital buildings

The design of any new healthcare facility, operating theatre suite, intensive care unit (ICU) or even an entire new hospital provides an opportunity to improve patient safety, efficiency and patient flow and, in doing so, improve staff well-being [3, 30]. The Working Party recommends that human factors experts are involved in hospital design at the earliest stage possible.

It is important to be clear that human factors science is not a substitute for appropriate funding. Hospitals should be designed with adequate resources, including the total number of beds, number of enhanced care/high dependency/ICU beds and the ability to cope with surges in clinical demand [31].

Barriers

Administrative barriers: policies, protocols and standard operating procedures

The Working Party recommends standardisation of policies, protocols and standard operating procedures at a national level, with regard to content, formatting and language, combined with local tailoring to best suit local need. NHS Education for Scotland (NES) has already produced national guidance for its healthcare teams [32]. Its approach could be used across the UK to raise standards and help staff when moving from one hospital to another.

Administrative barriers: operating theatre list planning

Mistakes are more likely if staff need to rush while working and/or are anxious due to potentially unachievable workloads [33–38]. This may be due to difficult and complex operations, sick patients, the skill mix of the theatre team or routine operating theatre lists with large numbers of cases [39]. The Working Party recommends that operating theatre list planning, scheduling and staffing takes these issues into account, with sufficient additional time allocated where necessary and staffing levels/skill mix adjusted if needed. It may be beneficial to schedule patients that are complex from an anaesthetic and/or surgical perspective at the start of the operating list.

Adequate time should be scheduled for a comprehensive team brief at the start of a theatre list with the whole team present [40], enabling staff to share their `mental models´ [3, 7, 8]. Adequate time should also be scheduled at the end of the list for a team debrief involving the whole theatre team [40, 41]. This allows staff to reflect together on what went well, discuss practical ways of improving the working environment and practices and provides a system for escalating concerns. If performed well, these debriefs can improve team morale, improve interpersonal working relationships and promote `flattening of the hierarchy´ within the team [40, 41]. The Working Party recommends that an end of operating list debrief is routine.

Cognitive aids including checklists and algorithms

Cognitive aids are tools designed to guide workers while they are performing a task, or group of tasks, with the aim of reducing errors while improving speed and fluidity [42]. The Working Party recommends that validated human factors principles should be used when designing cognitive aids, and usability testing should be used to improve flow and effectiveness [42, 43]. Strategies to improve readability should also be considered. These include clear formatting with left alignment; being easy to read when held 60 cm from face; using sans serif fonts (e.g. Helvetica, Avant Garde, Arial and Geneva); avoidance of underlined words and capital letters; and judicious use of bold font, italics and colour (avoiding red, green and pink where possible to help colour blind staff) [43, 44].

Well-designed checklists, when used as intended, have been shown to improve adherence to protocols [45] and improve teamwork and communication [46]. They may also improve workplace culture, help flatten the team hierarchy, empower team members to speak out when needed, promote mutual respect and improve interprofessional working relationships [47]. Algorithms, checklists and other cognitive aids should be readily available so that they can be referred to in an emergency when needed [6, 42, 48].

Staff should practise using cognitive aids as part of everyday work, as well as during interprofessional education and training, to ensure that the whole team become familiar with their content and method of use [7].

Practising non-technical skills during everyday work

Non-technical skills (NTS) are cognitive, social and personal skills that complement technical skills, and contribute to safe and efficient task performance [7, 49]. Non-technical skills in anaesthesia are well described by the Anaesthetists' Non-Technical Skills (ANTS) framework [49, 50], and include situation awareness, decision making, task management and team working. Other NTS include communication, leadership and followership [51], coping with distractions and the management of stress and fatigue [7]. Non-technical skills are not new or mysterious skills but encompass what the best practitioners do to consistently perform at a very high level [7].

Non-technical skills can be improved by team members addressing each other using their first names: this improves communication and role allocation, reduces confusion in an emergency, can improve morale and can promote a strong team safety culture [52–54]. Having names clearly displayed on badges, theatre hats [52, 53], theatre white boards or on personal protective equipment helps staff to regularly use their team members' first names [54]. Non-technical skills can also be improved by team members routinely verbalising their thoughts and actions, and in doing so sharing their `mental model´ [8, 55].

Non-technical skills are discussed in detail in the narrative review that accompanies this guideline paper [3]. Practical strategies to improve specific NTS include the following:

Situation awareness
Situation awareness is being aware of what is going on around you, thinking about what has already happened, what is happening at the present time and what is likely to happen next [7]. Strategies to improve situation awareness are described in Table 1.

Decision-making
Specific decision-making processes and sequences are used by some safety critical industries: one example is the T-DODAR tool, used by British Airways to teach pilots the basic steps for in-flight decision-making (Table 2) [59].

Teamwork
Teamwork can be improved by sharing mental models with other team members and rehearsal of specific strategies in everyday work (Table 3). An example of this is the zero-point survey, used by some emergency departments and pre-

Table 1 Practical strategies to improve situation awareness.

Strategies for use by team leaders
Lead a focused team brief, ideally using a pre-planned briefing structure, encouraging all team members to participate, anticipate and plan for difficult steps [8, 56]
Consider writing key steps on a theatre white board to share your `mental model´ and encourage `transitioning´ from one step to the next of an algorithm (personal communications, M Barley and S Marshall)
Monitor team member's actions – encourage your team members to verbalise their actions to assist with this [8]
Minimise time pressure wherever possible by early planning and preparation [8, 39]
Use the `sterile cockpit´ concept [7, 8] – remind all team members to be quiet during identified critical stages of care such as induction of and emergence from anaesthesia
Minimise distractions and interruptions – be mindful of the impact of mobile phones
Evaluate out loud regularly and invite ideas from the team [8]
Encourage team members to `speak up´ if they have concerns or ideas to solve a problem using graded assertiveness tools (Table 5). As a leader, `listen down´ for the critical phrases within these graded assertiveness tools as indications that staff are raising concerns with you
In an emergency, physically stand back from the patient (by the door in theatre, at the patient's feet in ICU, ED or on the ward) to maintain a `helicopter view´ of what is happening [8]
Strategies for all members of a team
Ensure that you are fit to work, physically and mentally (drug addictions, stress, fatigue, infections) and look out for this in your colleagues too [57]
Monitor your own behaviour and performance, watching for a move from a zone of `flow´ [8, 58] into a zone of `frazzle´ [8] or `freeze´ [8, 58] and look out for this in other team members too
Speak up if you feel patient safety is at all at risk – use graded assertiveness tools when necessary (Table 6)

Table 2 Decision-making tool.

T	**Time**	How much time do we have to do a DODAR/decide? [59]
D	**Diagnosis**	What is the problem?
O	**Options**	What are the options? Use BRAN: **B: B**enefit **R: R**isk **A: A**lternative **N:** implication of doing **N**othing
D	**Decision**	What are we going to do?
A	**Assign the task**	Who does what?
R	**Review**	What happened? What are we going to do about it?

hospital care teams before a resuscitation, which includes optimisation of the environment, assessments of personal readiness and a pre-emptive team brief [56].

Communication
The Working Party recommends the routine use of two-way communication that includes feedback. An example of this is closed-loop communication or `read-back´, where explicit confirmation is given that a message has been received [65, 66]. This helps to avoid misunderstandings and improves effectiveness. The Working Party recommends implementation of standardised handover tools. Established examples of these include SBAR (situation, background, assessment, recommendation) for routine handovers [67], SNaPPI (stop, notify, plan, prioritise, invite ideas) for

communicating information in an anaesthetic emergency [68], and a traffic light communication tool for use in operating theatres when a staff member is sent for help [69]. Other practical strategies to improve the effectiveness of communication are described in Table 4.

Task management
Practical strategies to improve task management [3, 8, 49] and individual and team performance [49, 50] are described in Table 5.

`Flattening the hierarchy´ or `reducing the authority gradient´ within a team
Some hierarchy or authority gradient within a team is necessary to enable effective leadership and followership [7]. However, a steep team hierarchy has been recognised as a contributory factor in high profile airway deaths [5, 26, 70–72], wrong side blocks [73] and other critical events. The routine use of good non-technical skills, good interpersonal working relationships and team leaders de-emphasising their status and inviting ideas from the team, helps to create a reduced authority gradient within a team [8]. Graded assertiveness tools can be used by team members to help them speak up when they feel that patient safety is at risk (Table 6). Leaders should strive to create an environment of psychological safety where all members of the team are supported to raise concerns without fear of negative comments or adverse consequences.

Table 3 Practical strategies to improve teamwork.

Team strategies
Use cognitive aids, including algorithms and checklists [42]
• Ensure that these are printed, laminated and readily available in clinical areas [42, 48] or implement specifically designed screens in clinical areas where cognitive aids can be displayed
• Nominate one team member to read out the steps of the cognitive aid in an emergency
Implement strategies to assist team members to use their colleagues' first names For example, name badges, name/role stickers [54], theatre white boards, pre-list safety briefings [40], named theatre hats [52, 53]
Implement the `civility saves lives´ concepts [60, 61]
Use strategies to improve situation awareness (Table 1)
Use strategies to improve communication (Table 4)
Team member strategies
Ensure that your skills are kept up to date: good technical skills free up cognitive capacity [62] or `make room´ in your head for good non-technical skills [63, 64]
Co-operate with your team members [8] – remember the importance of `followership´ in addition to leadership [51]
Verbalise your actions [8] and use closed loop communication [65]
Be aware that your performance is liable to fall if working when hungry, angry, late or tired (HALT) and that the same is true for your colleagues [57]
Optimise your own personal performance: prioritise sleep, exercise, regular food and drink, `stress bucket´ management, positive self-talk (Table 6) [57]

Table 4 Practical strategies to improve communication.

Before you speak	Catch your colleague's attention [8], for example: • Using their first name • Making eye contact • Putting your hand on their shoulder Structure and planning: plan what you are going to say, for example • Most important information first (`serial position effect´) [8] • Use the situation, background, assessment, recommendation (SBAR) structure [67] Timing: consider whether or not your colleague is ready to receive your information [8], for example • ``I have something that I need to tell you, are you ready to listen to me?´´ • ``Are you ready to receive information?´´
What you say and how	Avoid abbreviations and jargon [8] Use repetition [8], for example: ``Please give 10, one zero, micrograms of adrenaline intravenously´´  Ensure clarity, using speed, tone and emphasis and avoiding abbreviations [8], for example ``is not´´ instead of ``isn't´´
Use specific communication tools	• Closed loop communication (`read back´): explicit confirmation is given that a message has been received [65] • Graded assertiveness tools (Table 6) • Standardised handover tools, for example -SBAR: situation, background, assessment, recommendation [67] -SNaPPI for handover to a colleague arriving in an emergency situation: stop, notify, plan, prioritise, invite ideas [68] -Traffic light tool for use in theatres to clarify the urgency with which help is required: red emergency, amber alert, green query [69]
Optimise non-verbal communication	This can be just as important as verbal communication and can have a beneficial or detrimental effect on team members [8] Be aware that team members tend to mirror their leader's and team members' body language (`mirroring of implicit communication´) [8] `Be like a swan´ – although you might be feeling anxious inside (with your `feet paddling hard beneath water´), act as if you are calm and composed (as a swan might appear above water)
Use systematised communication	Listen out for specific phrases, for example terminology used in graded assertiveness tools (Table 2)

Mitigations

Use of non-technical skills in an emergency

Examples of effective use of NTS in an emergency are described in Table 7.

Actions after a death in theatre

Operating theatre teams should stop working after an unexpected death in theatre or critical event where a patient comes to harm if at all possible/practical [75]. In order to maintain the safety of other patients, staff should be assumed to be not fit to work for the rest of their shift [75]. The Working Party recommends that staff well-being and support following a critical event, and during a post-incident investigation, are prioritised by departmental leads.

Peer support tools

Peer support tools which help staff prepare for and recover from potentially traumatic events are increasingly being recognised to reduce the likelihood of developing psychological harm [3]. An example is Trauma Risk Management (TRiM), developed in the military and used successfully in healthcare [3, 76].

Investigation of critical events and adverse outcomes

Operating theatres are high-risk environments [77]. Between 2015 and 2022, more than 60% of the 3033 never events reported in the NHS occurred in operating theatres [78]. The Working Party recommends that investigations of critical events and adverse outcomes should be carried out by teams that include individuals with human factors training using appropriate human factors investigation tools. Lessons identified should be shared and actions for improvement should be monitored. Human factors investigation tools aim to identify all contributory factors in a critical event and tend to reduce the focus on the actions of individual staff, seen when other investigation methods are used [79, 80]. Examples of human factors investigative tools include the Systems Engineering Initiative for Patient Safety

Table 5 Practical strategies to improve task management in stressful situations, including optimising personal performance.

`Box breathing´	Breathe in for 4 s, hold your breath in inspiration for 4 s, breathe out for 4 s and hold your breath in expiration for 4 s [8, 57] This counteracts the effects of the sympathetic nervous system and slows the heart rate (fine motor skills and manual dexterity recognised to deteriorate if heart rate > 130/min)
Pre-task `mental rehearsal´	Mentally rehearse the various steps and procedures required for that task and/or case [8] This enhances mental readiness to perform task, anticipates problems and allows one to seek solutions ahead of actual task enactment
Pre-task `task visualisation´	Encourage staff to picture themselves completing the planned task successfully in their head [8, 59] This enhances mental readiness to perform task, anticipates problems and allows one to seek solutions ahead of actual task enactment
`Shared mental model´	Team brief before the case ensures that all team members are aware of the issues relevant to that patient and the plan for caring for that patient [40] Regular evaluations out loud by the team leader during the case [7, 8]
`Sterile cockpit´	Team are quiet during critical stages of a case [7, 8] This reduces distractions during important tasks

Table 6 Graded assertiveness tools.

Tool	Components	Example in a difficult intubation situation
CUSS [8, 74]	C = Concerned	`I'm *Concerned* that you are going to try to intubate again´
	U = Uncomfortable	`I'm *Uncomfortable* that you are still trying to intubate´
	S = unSafe	`This does not feel Safe/This feels *unSafe*´
	S = Stop	`I'm asking you to *Stop*´

(SEIPS) [81], included in the new Patient Safety Incident Response Framework (PSIRF) [82] and the Yorkshire Contributory Factors Framework [83].

Regular morbidity and mortality meetings

Local forums for learning from adverse events, such as morbidity and mortality meetings, should be part of the regular work of all anaesthetic departments [84]. The Working Party recommends that time within job plans is allocated to enable staff to prepare for and attend these meetings, and that they include learning from when things go well [85, 86] in addition to learning from cases that do not go to plan [84]. Chairs for these meetings should have human factors knowledge and should be trained to carry out this learning activity.

Education and training
Human factors training

Basic human factors awareness training should be provided for all members of the multidisciplinary team, as recommended by the Chartered Institute of Ergonomics and Human Factors [2]. This should include the importance of good design in healthcare, performance shaping factors, the importance of non-technical skills and strategies to improve these as appropriate for the role. The delivery of this training should be incorporated into learning

development plans, with time and resources allocated and review at annual appraisal. Three recent reports have also recommended such training: the Health Education England (HEE) patient safety syllabus [87], NHS Education for Scotland guidance [1, 88] and the Ockenden report [89].

A human factors education and training pathway, using classroom learning or an e-learning package [5] as one aspect of this, can be used to support staff training and achieve necessary workforce knowledge `depth and saturation´. A multi-level training pathway has been designed, with the appropriate level chosen for staff depending on their role and grade [87, 90, 91]. The PSIRF recommends that hospital patient safety leads take on human factors-focused incident investigation roles [82]. The Healthcare Safety Investigation Branch provides training for NHS safety investigators and patient safety leads that is aligned with the PSIRF.

The Working Party recommends that national bodies, hospitals, anaesthetic departments and anaesthetists weave human factors and NTS into their existing teaching in operating theatres, workshops and training courses.

Non-technical skills training

Non-technical skills can and should be learned just like any other skill. The Working Party recommends that strategies to improve NTS should be learned during operating theatre

Table 7 Non-technical skills in a crisis.

Actions	Benefits
Call for help [7, 8]	Ensures that a `fresh pair of eyes´ assesses the situation which can help prevent loss of situation awareness
Declare the emergency so that the whole team is aware of what the problem is [7, 8]	``This is a `cannot intubate, cannot oxygenate´ situation´´ ``This patient is hypoxic and I am not sure why´´
If you are the team leader stand back from the patient [7, 8]	Allows the leader to survey the whole situation and can help prevent loss of situation awareness. Consider standing near the door to the anaesthetic room if in theatre or at the foot of the patient's bed if in ICU, ED, PACU or the ward
If you are the team leader, put your hands behind your back, and consider taking your gloves off if not wearing PPE	Encourages the leader to assess the situation, prioritise actions, assess their effectiveness and plan future management without being becoming involved in individual tasks – this can help prevent loss of situation awareness
Start a timer +/− say the time out loud	Can help the team keep track of how long an emergency has been running for and prevent loss of situation awareness. Can help the team implement actions to prevent hypoxic brain injury that can occur after three minutes of little/no oxygen delivery to the brain. May empower team members to speak up about transitioning from one step of an algorithm to another
Delegate one team member to keep a log of events with timings and actions taken [8]	Can be a junior team member if necessary. Can helps prevent loss of situation awareness and may empower team members to speak up
Ensure that the monitor has the sound turned on for S_pO_2 measurement and alarms	Can provide an auditory cue for team members that urgent action is required
Use team members' first names [52–54]	Improves communication and flattens the hierarchy within the team
Use closed loop communication [65]	Improves communication within the team
Re-evaluate the situation out loud [7, 8]	Ensures that the team members are aware of the situation and relevant issues, with a `shared mental model´, and may empower them to speak up if they feel that an issue has not been addressed
Invite ideas from the team [7, 8]	Encourages team members to speak out if they feel necessary, flattens the hierarchy within the team and can prevent loss of situation awareness
Use checklists, cognitive aids and mnemonics [8, 39, 42, 44, 45]	Can improve adherence to protocols and may encourage transitioning from one step of an algorithm to the next
Ask one member of the team to read out the relevant cognitive aid/algorithm	Checks adherence to algorithm, may reduce cognitive overload in the team leader
Delegate actions to team members, and outsource decision making [8]	May help the leader maintain their situation awareness
Consider writing a list of actions required and use this to prioritise actions and allocate roles within the team [8]	May improve teamwork, adherence to protocol, avoidance of duplication and avoid omitting essential tasks

training lists, classroom and lecture-based teaching and out-of-theatre workshops. The Royal College of Anaesthetists [75] and the Ockenden report [89] recommend that staff who work together should train together; the Working Party recommends that time and resources should be allocated to allow for this. Inter-professional training enables staff to learn and practise NTS which can then be refined during everyday work [92]. Regular interprofessional training may also help flatten the

hierarchy within teams and encourage staff to speak up if they believe that patient safety is compromised [92].

Teams should train for and rehearse standard operating procedures for serious and rare emergencies [75]. A recent coroner's report into the death of a patient following an unrecognised oesophageal intubation [72] commented that senior anaesthetists may become deskilled in managing emergency situations. Regular `high frequency, low volume´ NTS training can help prevent skill
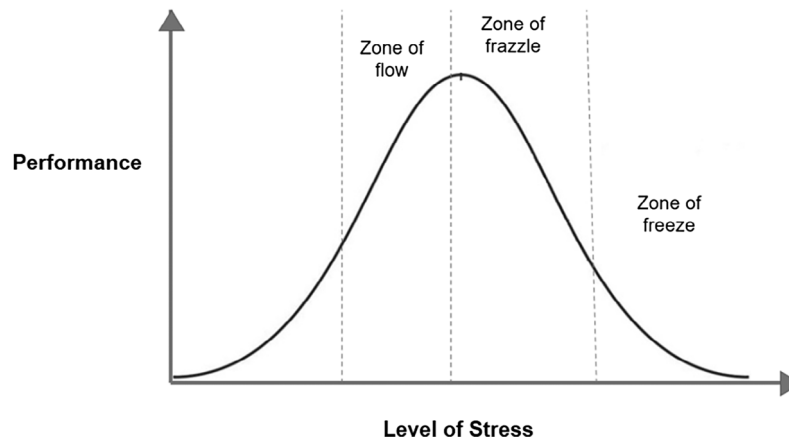
Figure 3 Modified Yerkes Dodson curve showing zones of flow, frazzle and freeze.

decay [28] and is recommended. The Working Party recommends that NTS training, including simulation training, should involve clinicians of all grades.

Simulation `train the trainer´ courses provide educators with many opportunities. Trainers may improve their own NTS knowledge, learn and practise skills for assessing NTS, optimise their debriefing skills, learn specific tools to improve NTS and become familiar with role-specific NTS frameworks [49, 50, 93–97]. The Working Party recommends that national and regional bodies increase the number of such courses.

Compulsory NTS training is a mainstay of safety-critical industries [7, 62]. In order to fully integrate NTS into anaesthetic working practices, the Working Party recommends that the provision of NTS training becomes a routine part of the work of anaesthetists and the teams they work with, with appropriate time and resources allocated. Once this is established, compulsory attendance at NTS training, potentially including simulation training, for all anaesthetists on a regular basis should be considered.

Human performance and cognitive overload

It is well recognised that human performance is liable to deteriorate in high-pressure situations [8, 63, 98]. Three zones of working for staff in high-pressure working environments have been described: a `zone of flow´ where performance is optimal [8, 99]; a `zone of frazzle´ where human performance deteriorates as pressure in the workplace rises [8]; and a `zone of freeze´ seen when pressure rises to very high levels and performance drops precipitously (Fig. 3) [8, 58]. In the zone of freeze, workers are described as being unable to communicate, make decisions, complete practical procedures or provide any

leadership [8, 58]. Workers in some safety-critical industries are taught to recognise the zones of frazzle and freeze in themselves and in their team members and learn strategies to move back into a zone of flow (Table 8) (Martin Bromiley, personal communication).

Familiarity with the technical skills needed during anaesthetic emergencies can reduce cognitive overload in high-pressure situations, freeing up cognitive capacity and making room in your head for good non-technical skills [63, 64]. An example is practising airway rescue techniques during regular multidisciplinary out-of-theatre airway workshops [100].

When a safety critical task such as tracheal intubation is found to be difficult or impossible, workers are more likely to move into the zone of frazzle or freeze. Routinely using the most effective equipment available reduces the frequency of technical failures [101, 102] and therefore maximises the likelihood of staying in the zone of flow [8]. A

Table 8 Strategies to help a leader to move from a zone of `frazzle´ back to a `zone of flow´.

Call for help [6, 7]
Re-evaluate out loud and invite ideas from the team [7, 8]
Regain your self-composure [7, 8]   • Delegate and out-source decision making   • Use `box breathing´ (Table 5) [57]   • Use your `inner monologue´: positive self-talk
Regain situational control [7, 8]   • Articulate how you feel, for example ``this situation is becoming complicated – I could do with help in managing things´´   • Write a list of problems and use it to prioritise actions   • Use mantras and mnemonics, e.g. ABCD   • Use cognitive aids [8, 42, 46]

strategic decision to ensure that the most effective equipment is routinely available throughout a department/ hospital helps protect patients from the direct complications of technical failures and also from indirect complications arising as a consequence of staff becoming cognitively overloaded.

During routine work, standardising equipment and working practices promotes patient safety by reducing the variety of medical equipment and devices available and enables staff to develop skills and expertise. This strategy needs to be supported by evidence-based procurement processes which involve human factors principles, to ensure that choices are made `upstream´ for the best devices and equipment. An example of such a strategy would be recommending the use of videolaryngoscopes for all routine intubations [3, 103–106] although this would also have to be supported by appropriate staff training to maximise the associated safety benefits.

In life-threatening emergencies, even the most experienced and well-trained staff are likely to find themselves in the zone of frazzle where even simple decision making can be difficult [8]. In these situations, having didactic algorithms can eliminate the need to choose between different devices during the emergency [101, 102], maximising spare cognitive capacity for managing the event.

The Working Party recommends that the most effective equipment available is used as default by all staff for all patients. Procurement decisions should be made with this in mind.

Staff well-being

Enhancing staff well-being is a key aspect of human factors. Implementation of human factors strategies in healthcare has the potential to optimise the well-being of staff as well as the safety of patients; both issues are inextricably linked and should not be viewed in isolation [2, 6, 9]. It is increasingly recognised that organisations which prioritise staff well-being provide higher quality patient care, see higher levels of patient satisfaction and are better able to retain staff [107]. Organisational strategies, including the design of safe working environments and safe working practices, should be prioritised by hospitals and departments to promote staff well-being. These include good rota design and work schedules, sufficient car parking and bicycle racks, adequate provision of lockers, showers and theatre uniforms, well-designed hospital IT systems, rest rooms for breaks during shifts and before driving home, along with the provision of food and drink in the hospital out of hours [57].

Strategy

Human factors lead

Every anaesthetic department should have a human factors lead. This could be combined with a department patient safety specialist role [108] or a department simulation lead role. NHS England and NHS Improvement require all hospitals in England to have patient safety leads who have had human factors training, as described by the HEE patient safety syllabus [82]. This will help hospitals to design safer systems of work at all levels within the organisation, investigate adverse events using systems-based human factors tools and implement lessons identified.

Such an approach should also be taken by national bodies, with the General Medical Council being an example of good practice in this respect. All General Medical Council fitness to practise decision makers, case examiners and clinical experts now receive human factors training and advice on modifying investigation processes [109].

Safety culture

Safety culture concerns attitudes, beliefs and behavioural norms regarding the prioritisation of safety in an organisation [110, 111]. Hospitals which prioritise well designed working environments, equipment and working practices are likely to have workers who find it `easy to do the right thing´ and who are better placed to provide high-quality and safe patient care [3, 6]. In addition, workers in such hospitals are likely to be better placed to be kind and civil towards their colleagues, treat them with respect [60] and have patients with better outcomes [61].

By promoting good design to improve worker well-being and patient safety, leaders of organisations can encourage an open, just and psychologically safe culture where staff are encouraged to speak up about the challenges that they face. This enables changes to be made to working environments and working practices, promoting a learning culture and a drive for continuous improvement [2, 6].

Team members should be valued and respected, encouraged to take pride in their team and supported as they strive to continually improve [8]. Workers who feel valued and respected as part of the team are likely to perform at a higher level, whereas rudeness and incivility have been demonstrated to impair team performance [8, 60, 61]. Implementing human factors strategies and developing good interpersonal working relationships helps to build a culture of respect and mutual trust.

Human factors is a scientific discipline that uses a system-design approach to improve the closely linked issues of safety and worker well-being [2]. We have

Table 9 Implementation strategies for clinicians.

Recommendation	Actions for individual clinicians that can be undertaken immediately and need no organisation-wide permission/co-ordination	Actions for clinicians that may take many months and require collaboration with colleagues and organisational co-ordination and support

1. Design of equipment and equipment procurement process	• Use the most effective equipment [101] as default (e.g. videolaryngoscopes [29, 101–106], second generation supraglottic airways [102]) if available to you
	• If you are the department equipment lead, find out where your hospital procurement department is, introduce yourself to your procurement team and ask to be involved with the anaesthetic equipment selection process
	• Raise concerns about equipment that is poorly designed with your clinical lead and/or theatre manager
	• Where equipment design contributes to harm or to a near miss, report this to the MHRA
		• Join your hospital equipment procurement group and encourage the following strategies when selecting equipment:
		  o Include human factors principles in product specification forms and decision-making
		  o Use CHFG assessment tool [16] or similar
		  o Routinely ask suppliers for human factors/usability assessments as part of the procurement process

2. Design of drug ampoules and packaging	• Take actions to reduce distractions while drawing up drugs including: drawing up drugs in silence (`sterile cockpit´ concept); only drawing up drugs in designated areas (e.g. anaesthetic room if available) • Discuss the risks of distraction during drug preparation with trainees and encourage them to implement the actions above • Use prefilled syringes if available [22], e.g. for emergency drugs such as metaraminol, ephedrine, atropine	• Join your hospital medication safety group and campaign for avoidance of similar looking drug ampoules and packaging for different drugs • Standardise location of drugs within anaesthetic room cupboards [22] • Advocate for distraction-reducing strategies to be instituted wherever medications are being prepared or administered • Discuss introduction of prefilled syringes [22] with your colleagues
3. Design of safe working environment	• Position anaesthetic machine so that patient, surgeon, machine and monitors are all visible in a minimum arc from the anaesthetic `cockpit´ [24, 25] • Consider the position of your equipment in theatre [24] - Videolaryngoscope screen on opposite side of bed to anaesthetic assistant where the videolaryngoscope has a separate screen to improve teamwork and communication [29] - Ultrasound and/or bronchoscope screen and patient in one line of sight [24] • Review the design of the area where you induce anaesthesia and the space available. Consider whether anaesthetising patients in theatre could have advantages [112] • Layout your procedure trolley (e.g. for spinal anaesthetic, central line insertion) in a standardised manner and encourage anaesthetic trainees to do the same	• Join your hospital estates group – bring your influence to involve human factors experts in design, build and refurbishment proposals • Standardise airway trolley drawers using DAS guideline drawer fronts [113] • Introduce emergency front of neck airway (eFONA) point of care boxes [102, 114] • Introduce neck haematoma emergency evacuation point of care boxes [115] • Introduce an emergency laparotomy trolley, including arterial lines/cardiac output monitor disposables, ICU subglottic drainage tracheal tubes, postoperative nutrition nasojejunal and nasogastric tubes • Standardise anaesthetic machine monitor layouts/colours to make it easier to distinguish the capnography trace and airway pressure waveform trace [112]

(continued)

Table 9 (continued)

Recommendation	Actions for individual clinicians that can be undertaken immediately and need no organisation-wide permission/co-ordination	Actions for clinicians that may take many months and require collaboration with colleagues and organisational co-ordination and support
4. Theatre list planning	• Before the day of surgery – review the notes of patients on the operating list and liaise with the surgeon if needed • Use the pre-theatre list team brief to raise issues of complexity that may need time/additional equipment [40] • Plan breaks for all team members [57] • If an end of theatre list debrief [40] is standard in your hospital, encourage the team during this to all choose one thing that went well and one thing that they would like to change	• Join your theatre list planning group and campaign for realistic time allowance for each procedure (individualised per clinician and taking into account training lists) and additional time allocated for theatre lists with a large number of patients • Encourage scheduling of complex patients first on theatre lists with additional time allocated and a senior anaesthetist • Introduce systems to allow the scheduling of additional time for complex patients when reviewing them in pre-operative assessment clinics • If end of theatre list debriefs [40] are not standard in your hospital, discuss with colleagues how these might be introduced,
5. Cognitive aids	• Familiarise yourself with the contents of the Association of Anaesthetists Quick Reference Handbook [48] • Use an `out of theatre intubation´ checklist when in the emergency department or intensive care unit [116] • Learn and practise using SBAR [67] and SNaPPI [68] tools • Download smart phone cognitive aid apps, e.g. iresus	• Ensure that an appropriately adapted Quick Reference Handbook [48] is present in each anaesthetic room/operating theatre • Encourage your trainees and team members to familiarise themselves with the contents of the Quick Reference Handbook [48]
6. Use of non-technical skills during everyday work	• Use your team's first names [52–54] • Verbalise actions during routine work [6, 8] • Practise closed loop communication during everyday work [65] • Discuss who you would call for help and how at pre-theatre list brief, and consider writing this on the theatre white board • Do a short safety brief with your anaesthetic assistant at the start of pre-oxygenation, outlining your plans A, B, C, D for the airway, checking equipment for each plan is readily available and checking that capnography is attached and working • Practise `box breathing´ so that you are able to use it before high stress cases (Table 5) [57] • Nominate team member to perform eFONA if needed before potentially difficult intubation in intensive care or the emergency department +/− mark cricothyroid membrane • Read about the zero-point survey [56]	• Introduce systems which help the team use each other's first names, including: 　o name/role stickers [54] and name badges 　o names on theatre hats [52, 53] 　o white board in theatre with each team member's name on it, updated during the day/night as team members change • Train teams in the concept of the `sterile cockpit´ [7, 8] and encourage it's use • Encourage use of closed loop communication within your teams and discuss this with colleagues (Table 4) [65] • Train teams in the use of graded assertiveness tools to help team members to `speak up´ when they feel safety is compromised (Table 6) and encourage senior staff to `listen down´ for key phrases • Plan a `tea trolley training´ project [117] for anaesthetists and theatre staff about graded assertiveness tools (Table 6), closed loop communication (Table 4) or multidisciplinary team capnography trace recognition [118] • Discuss actions in Tables 1-6 with colleagues
7. Investigation of critical events	• Learn to use the Yorkshire Contributory Factors Framework [83] and/or the SEIPS tool [81]	• Join your anaesthetic department and/or theatre/hospital governance team • Promote the use of human factors investigation tools with your patient safety leads

(continued)

Table 9 (*continued*)

Recommendation	Actions for individual clinicians that can be undertaken immediately and need no organisation-wide permission/co-ordination	Actions for clinicians that may take many months and require collaboration with colleagues and organisational co-ordination and support
8. M and M meetings	• Read the Scottish M and M meeting guide [84] • Practise applying the principles of the Yorkshire Contributory Factors Framework [83] or the SEIPS tool [81] during discussion of cases at M and M meetings	• Offer to be or to work with the M and M meeting lead for your department • Discuss with colleagues making M and M meetings monthly • Encourage a human factors approach to learning from incidents that are discussed • Include `learning from when things go well´ in M and M meetings – start to develop a Safety II approach [85] • Encourage your M and M meeting chair to sign up for basic human factors training as well as specific training in how to run such meetings, including: managing medical domination, ensuring everyone gets a voice, ensure a productive learning environment, ensuring the meeting and learning are democratic, actions are agreed and revisited
9. Human factors education	• Attend a human factors in healthcare course or MOOC • Include human factors and non-technical skills training in all teaching and training that you provide for your team • Watch this 10 minute film about human factors [119] • Watch the `just a routine operation´ film [5] • Read the following coroner reports: Gordon Ewing [70], Peter Saint [71], Sharon Grierson [72], Glenda Logsdail [26] • Read the CHFG glossary [4] • Read online CIEHF chapter about human factors [120]	• Attend a simulation `train the trainer´ course • Ensure all staff working in the maternity setting have annual human factors training (this could be e-learning) • Push for annual human factors training to be included as required role specific training for all teams, not just those in maternity • Encourage your colleagues to read the coroner reports and access other materials as listed in box adjacent to this
10. Use of NTS in an emergency	• Practise NTS during everyday work (Tables 1-6) [49, 50] and read about strategies to use these in an emergency (Tables 7 and 8) • Mentally visualise and rehearse emergency drills: e.g. watch the DAS 2015 guidelines eFONA video [121] and then close your eyes and mentally rehearse performing this procedure • Read the `10 seconds for 10 minutes´ article [122]	• Organise inter-professional simulation training for your team and incorporate the rehearsal of emergency drills and NTS • Discuss Tables 7 and 8 with your colleagues

11. Worker well-being	• Promote your own well-being: use `Stacey's Baker's Dozen´ [57]
	• Volunteer to be (or to assist) your department well-being lead
	• Read the Association of Anaesthetists well-being pages of their website [57]
	• Sign up for a TRiM [76] awareness course
	• Design and work to a well-being calendar
		• Introduce or assist in the delivery of the Team Immediate Meet (TIM) team `check in´ tool [123, 124] within your hospital
		• Implement the Association of Anaesthetists' suggested actions for well-being leads [57]
		• Meet with your senior management teams and lobby them to prioritise organisational strategies [57] to improve worker well-being:
		  o Car parking and bicycle rack availability
		  o Adequate supplies of theatre scrubs/uniforms
		  o Appropriate availability of showers/lockers in theatre changing rooms
		  o Hot food and drink available out of hours
		  o Availability of staff rest rooms for night shifts/before driving home

(continued)

Table 9 (*continued*)

Recommendation	Actions for individual clinicians that can be undertaken immediately and need no organisation-wide permission/co-ordination	Actions for clinicians that may take many months and require collaboration with colleagues and organisational co-ordination and support
12. Human factors lead	• Offer to be (or to work with) your department human factors lead	• Introduce basic human factors awareness training for all staff at your hospital with your hospital patient safety leads – an example can be found here [125] • Set up a hospital `human factors steering group´, drawing together interested staff from around the hospital and co-ordinating actions/learning from best practice
Safety culture	• Ask for help from colleagues when needed and make sure that other members of the team are aware that you do this • Discuss the `civility saves lives´ work with your theatre team [60] • Call out bullying/undermining behaviours when you see them [60]	• Discuss the `civility saves lives´ work [60] at a joint anaesthetic/theatre staff/surgical clinical governance meeting • Display `civility saves lives´ campaign posters [60] around your theatre suite

CHFG, Clinical Human Factors Group; M and M, morbidity and mortality; CIEHF, Chartered Institute of Ergonomics and Human Factors; NTS, non-technical skills; TRiM, Trauma Risk Management.

described strategies to implement human factors in anaesthesia in the categories of design, barriers, mitigations, and education and training. Actions to assist in the practical implementation of these strategies are summarised in Table 9.

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