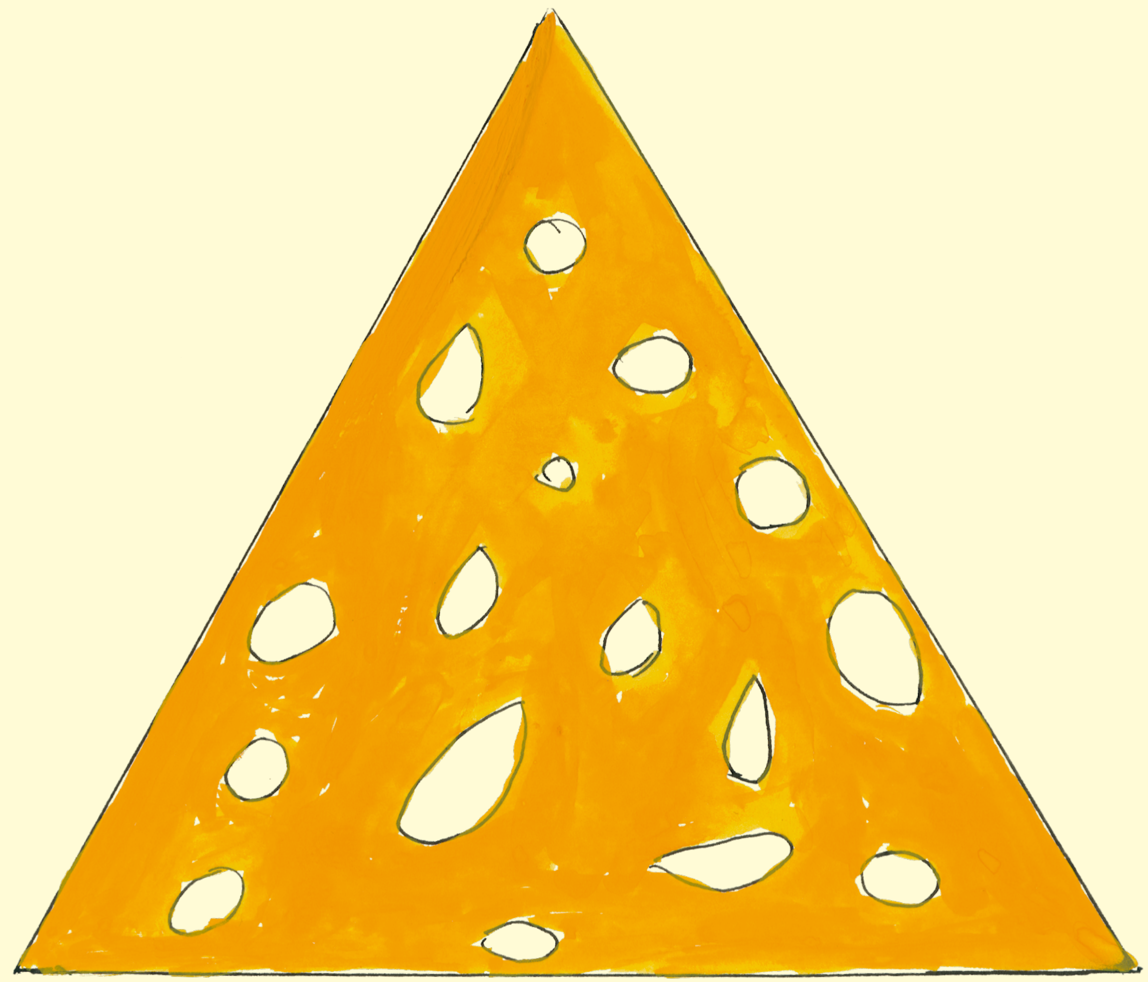
Author: Beuzekom, Martie van
Title: Latent risk factors in operating theatres and intensive care units
Issue Date: 2012-10-02

Latent Risk Factors in Operating Theatres and Intensive Care Units



Martie van Beuzekom

Latent Risk Factors in Operating Theatres and Intensive Care Units
Martie van Beuzekom

Latent Risk Factors
in
Operating Theatres
and
Intensive Care Units

Martie van Beuzekom

Cover by Peer Mascini
Printed by Mostert & van Onderen, Leiden
ISBN: 978-94-90858-13-1

Latent Risk Factors
in
Operating Theatres
and
Intensive Care Units

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. mr. P.F. van der Heijden,
volgens besluit van het College voor Promoties
te verdedigen op dinsdag 2 oktober 2012
klokke 16:15 uur

door

Martie van Beuzekom

geboren te Sliedrecht, in 1955

Promotiecommissie:

Promotor:	Prof.dr. A. Dahan
Co-promotores:	Dr. F. Boer Dr. S.P. Akerboom
Overige leden:	Prof.dr. L.P.H.J. Aarts Prof.dr. J. Damen, Radboud University Nijmegen Medical Centre Prof.dr. F.W. Jansen Prof.dr. E. de Jonge Prof.dr. J. Kievit Prof.dr. J. Klein, Erasmus MC Rotterdam

The operation of a health service depends upon a complex interaction between the patient, the environment in which care is provided and the people, equipment and facilities that deliver the care.

Sir Liam Donaldson writing in Medical Mishaps: Pieces of the Puzzle. Rosenthal M M, Mulcahy L and Lloyd-Bostock S (Eds). Open University Press, February 1999

Voor degenen die mij inspireerden
tot het schrijven van dit proefschrift

Contents

1

Introduction and Outline of the thesis

Introduction

Patient safety has become a major concern in healthcare. But how much of a problem is patient safety? The unsettling fact is that no one knows. What we "know" depends on how we gather information and on how we determine that a patient has been injured by an error. Not all errors and incidents leading to injury or damage are systematically recorded; obtaining a reliable estimate of errors is difficult.

Two questions therefore arise. How can systematic action be taken to avert preventable errors? In particular, how can we identify and prioritize remedial actions?

In accidents and injuries in other hazardous industries, such as aviation and nuclear power industry it was possible to reduce accidents and injuries by the application of lessons from cognitive psychology and human factors. The report: "To err is human: Building a Safer Health System", from the Institute of Medicine also shed a new light on the causes of medical error.[1] According to this report and other studies conducted around the globe, approximately 10% of all patients admitted to hospital suffer some kind of harm, about half of which is preventable with current standards of treatment.[2-5]

The focus of this thesis is on the Operating Theatre (OT) and Intensive Care Unit (ICU). Both are dynamic environments, with constant change and time stress in which a wide variety of high-technology equipment is used. These areas are known to have a high incidence of errors and negative outcomes. [6-8]

Errors occur where the work is done, where practitioners interact directly with the system in their roles as anaesthesiologists, surgeons, and nurses. Those events emerge from a chain of failures elsewhere in the organization, from conditions that are not directly visible. According to the Swiss cheese model, errors and serious adverse events are often preceded by a chain of individually unimportant errors and problems, in turn influenced by a wide variety of contributory factors.[9]

How medical errors occur, how they can be addressed within the health care system and how the work environment provokes errors re topics of particular interest. Deficiencies at many different levels in the organization create the context in which human error can have a negative impact. As an illustration we distinguish three levels at which errors occur (figure 1).

The highest level is personal errors. Personal it refers to the individual skills of the professional. Such human errors can be classified as knowledge-based, rule-based or skill-based and imply a specific deficit in an individual's knowledge, ability to apply procedures or specific technical skills.[10] For a long time a *person-centred* analysis and prevention approach has been dominant in proposals to improve patient safety in health care. In this approach the focus is on the ever-present 'human factor', concentrating on the individual responsible for making an error. The person-centred approach tends to concentrate on individual failure, with individual consequences, such as retraining, coaching, working under supervision and at worst punishing the employee. This approach rarely improves the behaviour of the group, leads to concealment of errors and cover-up. The end result is that safety does not improve.

At the next level are errors of team performance. The interprofessional team setting is one in which lack of broad oversight and understanding of individual functions is a core problem. In the OT team, team members often do not fully understand where everyone's work fits into the whole process. Moreover, nurses do not tend to work consistently with the same anaesthesiologist, surgeon and team, and their rotating assignment may (further) reduce understanding of system processes as they relate to particular services and procedures. Surgeons and anaesthesiologists division of labor also undermines the identification of safety issues and solutions as well as the identification of problematic practice routines in everyday work. [11] ICU team members have divergent perceptions of their communication behaviors, with more nurses than doctors reporting difficulties in speaking-up about problems with patient care.[12] Recognition of problems in team performance in aviation led to the development of training programs in team coordination, leadership and decision making known generically as Crew Resource Management. CRM is currently introduced in anesthesia and surgery.[13]

The lowest level at which errors can occur are the preconditions. Because they are not directly visible in the working environment they are described as Latent Risk Factors (LRFs). LRFs are usually identified in the analysis of accidents and incidents and therefore also described as general failures types.[14] Generally, a single underlying failure will be compensated for. It is when multiple factors come together that an incident becomes increasingly likely, as expressed in Reason's Swiss cheese model.[9] The model assumes that if errors occur, several simultaneous failures must have occurred within the organization. Error-producing conditions are poor design, maintenance failures, unworkable procedures, deficiencies in training, equipment design and use as well as poor team coordination.

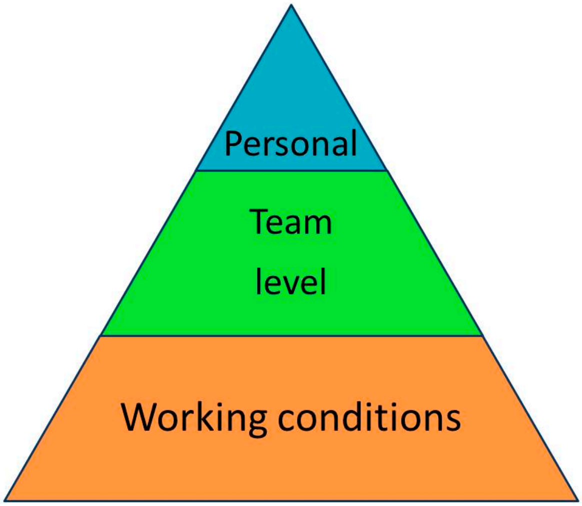


Figure 1

As a result of the recognition of the fact that individuals evoke incidents (the sharp edge), within an error predisposed environment (the blunt edge), a different approach to errors was developed. The alternative to the person centered approach to errors is the *systems approach* which focuses on the conditions under which individuals work rather than on errors by individuals.[9] This approach assumes that the work environment can shape behavior and can make certain kinds of errors less or more likely. Bringing the systems approach into medical practice clearly entails a fundamental shift in thinking about error and handling error in practice and required a comprehensive strategy for change. While most attempts to improve safety in health care are reactive, responding after someone is harmed; efforts to proactively identify and eliminate hazards have the potential to significantly and systematically improve safety.

A proactive safety management system, designed to measure and reduce the adverse impact of LRFs within an organization, may provide the answer. Proactive systems work in part by asking people to judge how frequently each of a number of factors such as training, equipment, procedures and communication impacts adversely on specific aspects of their work. This type of proactive approach allows the identification of LRFs before they give rise to errors that can compromise patient safety. Such a system may serve not only to reduce error, but also to foster a culture that, by moving away from blaming the individual and encourages reporting. This thesis describes a method for a proactive system approach.

Outline of this thesis

The hypothesis that correcting LRFs and concentrating on systemic rather than individual issues in patient safety will result in safer care was the cornerstone of the Leiden Operating Theatre Safety (LOTS) project.

The studies presented in this thesis aimed at answering the following questions:

1. Are the LRFs measured valid and reliable by the Leiden Operating Theatre and Intensive Care Safety (LOTICS) scale?
2. Has an intervention based on a safety program an effect on the LRFs: material, staffing resources and training?
3. Is there a relationship between LRFs and job satisfaction, job stress and intention to leave in anaesthesia teams?
4. Is there a difference in perception on LRFs between clinical area (OT vs. ICU) and disciplines?

Chapter 2 gives an overview of accident theories and of LRFs. Accident theories are frameworks to study accidents. LRFs exist within the systems analysis theory. These LRFs describe the total working environment as they emerged from the analysis of accidents. They have been identified through a combination of factor analysis of questionnaire data and logical analysis adapted from the original structure developed for oil and gas.

Chapter 3 reports details of the development and the psychometric properties of the Leiden Operating Theatre and Intensive Care Safety (LOTICS) scale. The scale assesses the state of the individual LRFs through a questionnaire of personnel working within the Operating Theatre and the Intensive Care Unit. The questionnaire is analogous to a health check, assessing a limited number of well-chosen diagnostic vital signs

Chapter 4 describes a prospective study, concerned with the question whether an intervention leads to improvement on LRFs. It was anticipated that addressing specific LRFs, rather than just a general awareness campaign, will contribute to the prevention of future errors and consequently to improved patient outcomes. It describes the implementation of a patient safety program in the Operating Theatre.

Chapter 5 emphasizes the causal relationship between working conditions and the delivery of quality of clinical care. It was determined that LRFs, which enhance patient safety, can have a positive effect on the well-being of specialist anaesthetists, trainees in anaesthesia and nurse anaesthetists.

Chapter 6 explores the influence of the clinical area (Operating Theatre and Intensive Care Unit) and disciplines on rating of LRFs. Identification of differences between clinical areas or disciplines would allow tailoring the measures directed at LRFs that are below standard. Tailoring is necessary because correction of the various LRFs would require entirely different preventive actions. Obtaining input from all workers in the clinical areas guarantees that a broader spectrum of LRFs will be addressed, since each discipline has its focus for LRFs.

References

1. *To Err Is Human: Building a Safer Health System.* Washington DC: National Academy Press, 2000.

2. Brennan TA, Leape LL, Laird NM *et al*. Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I. *N Engl J Med* 1991; **324**: 370-6.

3. Leape LL, Brennan TA, Laird N *et al*. The nature of adverse events in hospitalized patients. Results of the Harvard Medical Practice Study II. *N Engl J Med* 1991; **324**: 377-84.

4. Gawande AA, Thomas EJ, Zinner MJ *et al*. The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery* 1999; **126**: 66-75.

5. Vincent C, Neale G, Woloshynowych M. Adverse events in British hospitals: preliminary retrospective record review. *BMJ* 2001; **322**: 517-9.

6. Carthey J, de Leval MR, Reason JT. The human factor in cardiac surgery: errors and near misses in a high technology medical domain. *Ann Thorac Surg* 2001; **72**: 300-5.

7. Thomas AN, Panchagnula U, Taylor RJ. Review of patient safety incidents submitted from Critical Care Units in England & Wales to the UK National Patient Safety Agency. *Anaesthesia* 2009; **64**: 1178-85.

8. Lawton R, McEachan RR, Giles SJ *et al*. Development of an evidence-based framework of factors contributing to patient safety incidents in hospital settings: a systematic review. *BMJ Qual Saf* 2012; **21**: 369-80.

9. Reason J. *Managing the Risks of Organizational Accidents*. Hampshire, England: 1997.

10. Rasmussen J. Human error and the problem of causality in analysis of accidents. *Philos Trans R Soc Lond B Biol Sci* 1990; **327**: 449-60.

11. Espin S, Lingard L, Baker GR *et al*. Persistence of unsafe practice in everyday work: an exploration of organizational and psychological factors constraining safety in the operating room. *Qual Saf Health Care* 2006; **15**: 165-70.

12. Thomas EJ, Sexton JB, Helmreich RL. Discrepant attitudes about teamwork among critical care nurses and physicians. *Crit Care Med* 2003; **31**: 956-9.

13. Howard SK, Gaba DM, Fish KJ *et al*. Anesthesia crisis resource management training: teaching anesthesiologists to handle critical incidents. *Aviat Space Environ Med* 1992; **63**: 763-70.

14. Wagenaar WA, Hudson PTW, Reason JT. Cognitive Failures and Accidents. *Applied Cognitive Psychology* 1990; **4**: 273-94.

2

Patient safety: Latent Risk Factors

British Journal of Anaesthesia **105** (1): 52–9 (2010)
doi:10.1093/bja/aeq135

BJA

Patient safety: latent risk factors

M. van Beuzekom[1]*, F. Boer[1,2], S. Akerboom[3] and P. Hudson[3,4]

[1] OR Centre, J4-Q and [2] Department of Anaesthesiology, Leiden University Medical Centre, PO Box 9600, 2300 RC Leiden, The Netherlands
[3] Department of Psychology, Leiden University, The Netherlands
[4] Department of Safety Science, Delft University of Technology, The Netherlands

* Corresponding author. E-mail: m.van_beuzekom@lumc.nl

Key points

- The system approach focuses on working conditions rather than on errors of individuals.
- This approach assumes that systems must be designed to prevent humans from making errors.
- The factors that promote errors are described as LRFs.
- Understanding how LRFs affect safety can enable us to design more effective control measures.

Summary. The *person-centred* analysis and prevention approach has long dominated proposals to improve patient safety in healthcare. In this approach, the focus is on the individual responsible for making an error. An alternative is the *systems-centred* approach, in which attention is paid to the organizational factors that create precursors for individual errors. This approach assumes that since humans are fallible, systems must be designed to prevent humans from making errors or to be tolerant to those errors. The questions raised by this approach might, for example, include asking *why* an individual had specific gaps in their knowledge, experience, or ability. The systems approach focuses on working conditions rather than on errors of individuals, as the likelihood of specific errors increases with unfavourable conditions. Since the factors that promote errors are not directly visible in the working environment, they are described as latent risk factors (LRFs). Safety failures in anaesthesia, in particular, and medicine, in general, result from *multiple* unfavourable LRFs, so we propose that effective interventions require that attention is paid to interactions between multiple factors and actors. Understanding how LRFs affect safety can enable us to design more effective control measures that will impact significantly on both individual performance and patient outcomes.

Keywords: medical errors; quality assurance, health care; risk management; safety

Patient safety has become a major concern in the healthcare system. Two questions therefore arise. How can systematic action be taken to avert preventable errors? In particular, how can we identify and prioritize remedial actions?

For a long time, a *person-centred* analysis and prevention approach has dominated proposals to improve patient safety in healthcare. In this approach, the focus is on the ever-present 'human factor', concentrated on the individual responsible for making an error. Such human errors can be classified as knowledge-based, rule-based, or skill-based[1] and imply specific deficits in an individual's knowledge, ability to apply procedures, or specific technical skills, respectively. As a result of this vision, solutions typically involve (re-)training, extra supervision, and even disciplinary actions applied to individual doctors and nurses. An alternative is the *systems-centred* approach,[2] in which attention is paid to the organizational factors that create the precursors for those individual errors. The questions raised by this approach might include asking *why* an individual had such specific gaps in their knowledge, experience, or ability. Anaesthetists have made significant advances in patient safety through systematic incident monitoring and analysis, paying attention to the design and ergonomic aspects of equipment, implementing safety devices, and considering fatigue and cognitive overload.[3 4] Despite this growing recognition of the role of human error in anaesthesia, it still remains unclear what should best be done to mitigate its effects[5] and how its occurrence can best be prevented or mitigated in the first place. The problem is that solutions are often proposed as a result of the most recent analyses or the introduction of new technologies, neither of which may tackle the problems that are the most pressing in a wider context.

The *systems-centred* approach assumes that humans are fallible and that systems must be designed so that humans are prevented from making errors. An example is the pin index for connections of gas cylinders that prevents erroneous connections, removing the possibility of error. Human performance involves a complex interaction of factors, including the inseparable tie between individuals, their equipment, and their general working environment. Where the environment is one that makes errors by individuals more likely, we can identify the underlying problems that will have been present in the system, often recognized but long tolerated. The factors that make errors more likely, or more dangerous, can be characterized as latent risk factors (LRFs). Generally, a single underlying failure will be compensated for. It is when multiple factors come together that an incident becomes increasingly likely, as expressed in Reason's Swiss cheese model.[6] It is important to understand *why* a highly trained individual can commit an error and how events and conditions coincided to permit it. Understanding how and which LRFs affect safety should enable us to design more effective control measures that will impact significantly on both individual performance and patient outcomes.[7]

Accident theories

High-risk systems, which are typical of our technologically complex era, include not only nuclear power plants and commercial aviation, but also hospitals and anaesthesia systems, and the practice of medicine. An analysis of many different technological systems shows how certain general characteristics can make systems either inherently safer or inherently more dangerous.[8] In high-risk systems, no matter how effective safety devices are, some types of accidents are often seen as inevitable because the system's complexity leads to multiple and unexpected interactions.[9] Perrow's Normal Accident Theory[10] proposes that certain types of accident will happen regardless of the number of safety devices. Perrow characterized systems according to two important dimensions: *interaction* and *tight or loose coupling*. A task or process is said to have complex interaction if there are many alternative and interrelated subtasks at any point in its completion. Complex interaction reflects high levels of specialization and interdependency among their various components and creates opacity to those within the system. The coupling dimension describes the extent to which an action in the task or process is related to its consequences. A system is tightly coupled if serious and unrecoverable consequences are likely to occur immediately after a mistake is made—hence, tightly coupled systems are unforgiving, and at high risk for accidents, and must therefore be made more reliable. The pace of recent development suggests that the practice of hospital medicine, and especially the operating theatre (OT), is becoming both more complex and more tightly coupled, thus both more opaque and less forgiving when things go wrong.

Reason's Swiss cheese model[2] was originally developed for domains such as oil and gas, aviation, railways, and nuclear power generation. It revolutionized accident investigation worldwide and has since gained widespread acceptance and use in healthcare.[11] This model has the advantage of explaining why accidents are so rare, even in high-risk activities. High technology systems have many defensive layers: some are engineered (alarms, physical barriers, automatic shutdowns, etc.), others rely on skilled individuals (anaesthetists, surgeons, pilots, control room operators, etc.), and yet others depend on procedures and administrative controls. The model assumes that if errors occur, several simultaneous failures must have occurred within the organization. Although adverse events occur where the work is done, where practitioners interact directly with the system in their roles as anaesthesiologists, surgeons, and nurses, those events emerge from a chain of failures elsewhere in the organization, from conditions that are not directly visible. According to the model, serious adverse events and complications are often preceded by a chain of individually unimportant errors and problems, in turn influenced by a wide variety of contributory factors.[2] To investigate errors proactively, using the concepts of the Swiss cheese model, various groups have developed a variety of tools and approaches. The Tripod-Delta (Diagnostic Evaluation Tool for Accident prevention) tool is a checklist-based approach to carrying out 'safety health' checks.[12] The four levels of the Human Factors Analysis and Classification System (HFACS) have been applied to aviation[13] and to cardiovascular surgery.[14] HFACS can also be applied to help understand the interplay of human factors in the OT environment and the organizational context.[15] Others have argued for 'a systems approach to surgical safety',[16] suggesting that it is necessary to study all aspects of the system that comprises a surgical operation, including such issues as equipment design and use, communication, team coordination, factors affecting individual performance, and the working environment.

Both Normal Accident Theory and the Swiss cheese model direct attention to systemic issues but do not, of themselves, provide a structure of underlying factors that can serve as a taxonomy of causes. Such a taxonomy is required to diagnose why accidents are occurring and to support prioritization of remedial actions in ways that go beyond the purely symptomatic. The next section describes such a list, specifically developed for the OT and anaesthetic practice, but based upon the Tripod-Delta methodology developed for the Swiss cheese model.

Latent risk factors

Analyses of major disasters, ship accidents, accidents in the exploration and production of oil and gas, railway operations, and aviation have shown that the contributing causes that occur in all these accidents can be captured with a limited classification system. These underlying latent causes can be categorized into a limited number of classes: LRFs.[17 18] The choice of a particular taxonomic structure is driven by the need to capture all types of potential causes together with the need to identify where in the organization remedial actions can be put in place. These LRFs describe the total working environment, the setting in which accidents and incidents occur. The LRFs identified in the OT environment[19] are listed in Table 1 and described in further detail below. They have been identified through a combination of factor analysis of questionnaire data and logical analysis adapted from the original structure developed for oil and gas.[2 12 16 17] Each of the 10 factors is prefaced with a short description relevant to anaesthetic practice, although most are equally applicable in the wider hospital setting.

Equipment, design, and maintenance

By the late 1980s, a number of articles featuring human factor concepts and applications could be found in the literature, many of which dealt with anaesthesia equipment.[4 20] This factor covers the broad design of equipment, including

Table 1 Latent risk factors

Latent risk factors	Issues
Equipment, design, and maintenance	Availability, functioning, standardization design, and maintenance of machines
Staffing	Adequate staffing, skills
Communication	Work-directed communication, openness, interrelation, atmosphere
Training	Training for machines, procedures, team training
Teamwork and team training	Team performance
Procedures	Presence of protocols, adherence to protocols
Situational awareness	Awareness of present situation, own tasks, and future developments
Incompatible goals	Balance between goals and safety
Planning and organization	Process of care
Housekeeping	Hygiene

documentation and hardware, its manufacture, and maintenance. Equipment may be hard to use because of lack of attention to basic ergonomic considerations; it may break down either because of poor manufacturing standards or because it has not been maintained at all or maintained incorrectly.[11] Individuals may feel forced to apply some form of work-around that may increase greatly the chance of errors. New equipment, even when well designed and manufactured, tends to add to the complexity, opacity, and unfamiliarity of a situation.[21–24] It is not uncommon for medical staff to spend a large amount of time looking for charts and equipment; variations in equipment and lack of training in how to use it also increase the likelihood of error.[25] This LRF captures how even the best equipment can be problematical when it is not fit for purpose in the wider context of procurement, training, procedures, and maintenance practices.

Staffing

Adequate staffing is fundamental to quality care. The staff are often the last layer of defence for error occurrence, and understaffing and inadequate skill mix are threats to patient safety in the OT.[26 27] There is little published work examining the relationship between workload and either quality or safety of anaesthetic care,[23] but a survey by Singer and colleagues[28] found that 49% of respondents had witnessed production pressure resulting in what they believed to be unsafe actions by an anaesthesiologist. High rates of staff turnover degrade the collective experience in the OT to the point that educators of new staff are themselves relatively inexperienced.[14] Understaffing is one of the greatest threats to patient safety, but rapid turnover can be another.

Communication

Failures of communication between OT personnel are common.[29 30] This may involve communicating too little or even too much, too early or too late, and may involve a failure of either the person initiating the communication or the receiver, who may fail to understand or even hear the message. Most surgical errors are not attributable to an individual but involve multiple personnel and steps; 43% of such errors are thought to be due to poor communication.[31] There is evidence from a variety of sources that communications between members of health-care teams emerge as a key factor in poor care and are especially apparent where medical errors occur. Lingard and colleagues[29] took this as their starting point for an observational study of communication failures in OTs. They found that 31% of all communications could be categorized as a failure in some way: the information was missing, the timing was poor, there were unresolved issues, or key people were absent.[32]

Training

Lack of training and experience is often mentioned as sources of medical errors. In a study of surgical errors leading to malpractice claims, Rogers and colleagues[33] found that the leading causes (41%) were lack of experience and lack of technical competence. This study should be interpreted with some caution as it concerned accepted closed claims that were therefore possibly selected on the basis of liable causes. Training has been shown to decrease error and increase the ability to solve problems, particularly for inexperienced professionals.[34 35] The concept of simulation as an educational tool in healthcare is not a new idea, but its use has blossomed over the last few years. It has been most widely studied in anaesthesia. In 1992, Chopra and colleagues[36] reported that the performance of anaesthesiologists who trained on the simulator was superior to those subjects who did not receive such training. The recent enthusiasm for simulator-based training is partly driven by an attempt to increase patient safety and also because the technology is becoming more affordable and advanced.[37 38] Concerns about patient safety are leading to changes in educational methods. Simulation now plays a major role in training efforts designed to foster the acquisition of new skills and knowledge outside the clinical environment.[39]

Failure of training is often attributed as a major cause of incidents, implying a lack of competence in the person. This LRF is intended to catch the system-based failures, such as lack of needs analysis, failure to train at all, use of appropriate *vs* inappropriate training methods for the skill required, failure to assess the results of training, and lack of consideration for alternatives to person-based approaches. For instance, good design reduces the need for extensive training in the use of equipment, whereas poor design may be only partially compensated for by extensive training.

Teamwork and team training

The unintended consequences of clumsy automation, task complexity, and excessive workloads on human performance in high-risk patient environment have received much attention.[40] During the 1980s and 1990s, publications on teams in aviation appeared, documenting the belief that pilot performance is directly influenced by the nature and quality of the interactions among group members. The same is true for doctors who operate in complex environments where teams interact with technology. Much work pioneering work on the impact of team behaviour, attitudes towards safety, and professional culture on human performance in medicine has come from the department of anaesthesia of the University of Basel, Switzerland, starting in the mid-1990s.[41 42]

Individual team members may be highly skilled in their individual roles, but they are not necessarily trained in working together as a team.[43] Substantial discrepancies in perceptions of teamwork exist in the OT with physicians rating the teamwork of others as good, whereas at the same time, nurses perceived the teamwork as poor.[29 44–46] These findings mirror similar results of discrepant attitudes about collaboration between physicians and nurses in intensive care units (ICUs).[47–50] A growing awareness of the importance of team interactions of aviation crews lead to the concept of Crew Resource Management (CRM) in the 1980s.[51] Analogous training was developed by Gaba's group at Stanford (initially in anaesthesiology) and has since enjoyed global spread in healthcare.[52] CRM training involves educating and training staff to use techniques that enable individuals to communicate problems more effectively, divide task responsibilities during high workload situations, and resolve conflicts in the cockpit.[53] Crew training is considered essential for everyone to learn, but its benefits to individuals are difficult to measure if it then improves the performance of all staff.[54]

Procedures: protocols

The presence of protocols is generally considered as helpful to improve safety. Doctors and nurses often have opposing views on protocol violation and hold different attitudes to clinical work.[55] In particular, nurses appear to hold more systematized and less individualistic conceptions of clinical work than doctors. The results indicate that when best practice is defined in the form of a written protocol, deviations from these are more likely to be reported, at least by nurses. This also suggests that health-care professionals are, in general, reluctant to report behaviour that has negative consequences for the patient when that behaviour reflects either compliance with a protocol or improvisation where no protocol is in place.[56] Reluctance to report non-compliances, even when the outcome for the patient is bad, may be a function of the widespread and well-documented resistance among doctors to clinical protocols, perceived by many in the medical community as a threat to their professional competence. Alternatively, reporting on colleagues may simply reflect the professional culture. Part of the issue with protocols in the clinical setting is due to cultural factors that will be considered below, but there are also systemic issues with protocols even when they are fully accepted. These issues include the relevance, design, and accuracy of protocols and whether the system is capable of continuously amending protocols and ensuring that they are kept up to date and whether they are accepted by those supposed to use them.

Situational awareness

Situational awareness (SA) can be defined by three questions 'Where have we come from? Where are we now? Where are we going?'[57] At best, in the OT, SA requires active involvement in the progress of the operation by the anaesthesiologist, nursing, and surgical crews that make up the operating team. Shared situation awareness refers to the degree to which the team members have the same interpretation of ongoing events.[57] Surgical teams with the best outcomes were not those who were error-free, but those who successfully compensated for the errors that had occurred.[58] Good SA can provide essential corrections to problems that may arise as a result of complexity and tight coupling. SA allows proactive intervention and can drive changes in priorities as a result of changes in the patient, the OT environment, or outside the OT. Although SA may be seen as a result rather than a factor, it appears reliably as a distinct underlying factor[19] and is a skill that can be trained for.

Incompatible goals

All organizations must find a balance between their goals and safety. To some extent, there will always be a trade-off between safety and finance, because achieving the highest feasible levels of safety will cost increasing amounts of money that no organization can eventually afford to pay.[17] Incompatible goals may involve more than finance, as any choice made under pressure may create situations that are inappropriate. Incompatible goals can be regarded as one of the most fundamental LRF, as all behaviour can be seen as an adaptation to conflict situations, with errors arising when the 'incorrect' choice is made. It is not just the incompatibility of safety and finance. Safety goals can even conflict with other safety goals, such as when a requirement for a rapid unplanned surgical intervention conflicts with the need to ensure that necessary checks are carried out before proceeding. One of the problems associated with complexity is an increasing locality of priorities. Anaesthetists, surgeons, nursing staff, and administrators can all have different priorities that can easily conflict.

Planning and organization

Donabedian[59] observed in 1966 that the best outcomes depend on good processes of care, which in turn depend on the correct structures and organization being in place. Hospitals cannot control for the severity of underlying illness in patients, but they can ensure that their services are effectively staffed and organized to manage those for whom they care. For instance, changing the OT schedule overnight often leads to confusion, resulting in late starts, the wrong patient in the OT, and equipment and materials being unavailable. Since the operation programme is a coordinating mechanism and changes are often not well communicated, the lack of effective coordination results in errors and risks. Hospitals try to decrease their risks by applying rules for programme changes or better (electronic) communication about changed programmes. This LRF captures the systemic issues around having an organization that needs to be optimized to support its clinical tasks rather than, for instance, having clinical tasks altered to fit the demands of the organization. One particular issue that arises in hospitals is the disparity in structures required for different specialities.

Housekeeping

Housekeeping refers generally to tidiness, but from experience means 'a place for everything and everything in its place'. Superficially, clean and tidy environments may in fact cover a situation where everything is impossible to find, again resulting in unsafe practices seen as necessary to work around the shortcomings. In medical settings, housekeeping naturally extends to hygiene and the support and discipline required achieving levels compatible with patient and staff safety. As the use of electronic devices (i.e. mobile phones and personal digital assistants) has become commonplace in the OT and ICU in recent years, these devices are being increasingly used in close proximity to the patients. A rate of 7% bacterial contamination with potentially pathogenic bacteria was found on telephones and intercoms in patient care areas.[60] Housekeeping is a critical test of the organization, and the NHS experience in the UK suggests that this has been at least a part of many important clinical problems such as Methicillin-resistant *Staphylococcus aureus* (MRSA). Management may know that there is a problem and does not act or they may not even know that there is a problem.

Each one of these LRFs is the responsibility of the organization rather than of individuals, which is why they form an appropriate level of description for the system-based approach, as opposed to the person approach that refers to individual performance factors such as skill or vigilance. Individual clinicians, no matter how capable, do not usually define and test their own training, decide on staffing levels or scheduling, set up and ensure that protocols are up to date, fund equipment, or make sure that communication issues are discovered and attended to. It is at this organizational systemic level that the preconditions for error, such as haste, ignorance, and fatigue, are created and it as the level of the LRF that the 'disease' can be best treated, rather than relying upon a purely symptomatic and often palliative approach directed at individuals found to have failed when being hasty, ignorant, or fatigued. The question that remains however is: how can these LRFs be identified, measured, and managed in the hospital setting? Without an adequate approach to providing answers to these questions, the system-based approach remains an unachievable vision.

The list of LRFs details the organizational, management, and work environment factors in ways that make the identification of effective interventions easier. Systematic approaches to improvement, taking small concrete interventions rather than large sweeping initiatives, often impact more effectively on the culture as successes are observed in the working environment. Although effects on outcomes may not always appear immediately, the development of a virtuous circle may be expected to show gains relatively rapidly.

Measuring the state of latent risk factors

Most incident analyses only describe 'who' was involved and 'what' occurred, with limited attention paid to the underlying causes that can be captured systematically by LRFs. Although the state of the individual LRFs could be assessed objectively, their effect on workplace safety and patient safety is unknown. Therefore, other techniques have been developed in which the immediate effects on workers and accidents have been studied, notably in the oil industry and aviation.

The most significant development in this area was the development of the TRIPOD instruments. TRIPOD is the name used originally by Shell International for what elsewhere is known as the Swiss cheese model.[12 61] TRIPOD is based on deficiencies in the working situation labelled as General Failure Types (GFTs),[12] the equivalent to the LRFs discussed above. It provides an accident analysis method to identify and classify problem areas into underlying causes, scored as GFTs that led to the accident. The reactive understanding of how accidents happen described by TRIPOD led to the development of a specific proactive instrument, TRIPOD-Delta.[62] The questionnaire is applied to workers and is based on their experience in the workplace. Where TRIPOD is retrospective, the TRIPOD-Delta instrument is prospective. Prospective methods offer significant theoretical advantages over retrospective methods. They do not rely on an adverse event having occurred. They allow the identification of latent factors in the system that may lead to hazards but that have yet to become manifested in incidents.

TRIPOD-Delta measures the 'safety health' of an organization rather than waiting for accidents to happen or even observing what actual unsafe acts people were performing. The approach taken is analogous to a health check, assessing a limited number of well-chosen diagnostic vital signs.[62] In the prospective survey, items can be either indicators of either potential problems or good practice. Possessing the former or lacking the latter can both be treated as indications that there are latent failures present in a particular LRF and generate a negative score. Failure to find indications of problems and possession of the factors that are evidence of good practice both contribute to a positive score. The sum total of poor and good indicators can then be represented as a standard score indicating whether there is a serious problem or cause for relief. TRIPOD-Delta was developed by Leiden and Manchester Universities[12 17] for the oil and gas industry and concentrated on workplace safety and lost hours due to incidents. An early version of this approach was applied to a comparison of two intensive care wards.[63] In such cases, it is possible to show that different units (wards, theatres, and hospitals) differ in their relative scores on LRFs, supporting the understanding that effective solutions should reflect the pattern of scores rather than having a 'one size fits all' approach.

The SWIFT technique is also a prospective approach. It is a systematic team-oriented technique for hazard identification adapted for healthcare and particularly suitable for environments where human and organizational factors predominate, such as the OT.[64]

We developed the Leiden Operating Theatre Intensive Care Scale (LOTICS) as an instrument to detect the underlying causes of medical errors proactively[19] by measuring LRFs (Table 1). It shows the strengths and weakness of an organization, allowing the possibility of data-driven interventions. Changes in patient safety performance can then be monitored and the effects of interventions to improve the level of patient safety can be evaluated. Similarly, LOTICS can be used for comparison of different organizations and disciplines within the medical system.

The LRFs described here are broadly equivalent to the original set of GFTs. The original set of GFTs was developed to provide coverage of all the areas that might create problems, not just technical or human, and to facilitate identification of where remedial actions might best be applied. The LRF taxonomy used has been configured to provide a better mapping onto the medical setting, and the OT in particular, rather than a set originally designed for oil and gas operations.

Culture

The system-based approach concentrates upon characteristics and behaviours of the organization, just as the person-based approach concentrates upon the characteristics and behaviours of individuals. A number of recent major accidents have highlighted the importance of the organizational culture within which both of these are played out. British Petroleum's own analysis of the Texas City refinery disaster in 2005[65] and NASA's analysis of the Columbia disaster[66] both stressed the importance of organizational culture. The culture of an organization determines how the systemic components are treated. A poor safety culture pays little attention to what is seen as unnecessary and bureaucratic, whereas a good safety culture takes the best out of what is on offer. Poor cultures deny problems until they cannot be ignored, attribute failure to personal shortcomings in individuals, and are afraid to report, both on themselves and on others. Good safety cultures, in contrast, accept accountability, treat problems once identified as opportunities to learn, understand that incidents have multiple causes, and search actively for ways to improve.

The advanced safety culture has been characterized in a number of domains under the label of High Reliability Organizations (HROs). HROs theory is based on the belief that accidents can be prevented through good organizational design and management.[67] It describes core principles of organizations that have few accidents despite operating in highly dynamic, technologically rich, and hazardous industries.[68] These were identified in diverse settings such as aircraft carrier flight operations, air traffic control, and nuclear power plant operation. They are characterized by a high level of mindfulness, deference to specific expertise, regardless of an individual's position in the hierarchy and a just and fair culture in which people feel able to report errors by themselves and others. The problem in many areas is that the organizational culture is nowhere near as advanced as an HRO, even if people think they are close to attaining that level of responsiveness to safety issues. There is a clear interaction between the organizational factors, defined in term of the LRFs, and the culture, in that less advanced safety cultures will have more identified issues and fewer implementations of good practices.

Discussion

Although the best measure of safety performance is not clear other than in terms of patient outcomes, it is certainly too multidimensional to put a single figure as a safety score. It is also clear from studies elsewhere that single changes, especially when performed without due regard for the total context, are often ineffective and may even be detrimental. One person's improvement may be another's LRF. Ideally, safety should be embodied throughout the institution, part of the culture, and minimizing possible latent causes that might accidentally combine to produce injury. This continuing search, improving with small incremental measures, is very similar to the quality concept of continuing quality improvements.[69]

Individual errors are personally attributable and it is tempting to address these errors only, as there is a clear connection between error and single agents who can be blamed. Yet, this approach still does not solve the problem of recurrent erroneous behaviour. Such errors do not occur of themselves, but arise within the context of the work environment, described by LRFs. There is a clear need to develop approaches that allow organizations to measure in an ongoing and prospective way the injuries that healthcare causes.[64]

Tackling the LRFs will improve the overall safety condition of the organization by reducing safety problems before they arise,[70] in particular if combined with explicit improvements in the safety culture. We have argued here that systematic analyses and step-by-step improvements are feasible and can impact directly on the culture. The traditional fields of practice, such as risk analysis, have so far been unable to provide many effective or long-lasting solutions. There are several reasons for this, the most important probably being that they are based on oversimplified accident models. Simple repair work will not mend the problem, because if one part of the system is changed that may affect another part of the system with unanticipated results.

Conflict of interest

None declared.

References

1 Rasmussen J. Human error and the problem of causality in analysis of accidents. *Philos Trans R Soc Lond B Biol Sci* 1990; **327**: 449–60

2 Reason J. *Managing the Risks of Organizational Accidents*. Aldershot: Ashgate Publishing Ltd, 1997

3 Gaba DM. Human error in dynamic medical domains. In: Bogner SM, ed. *Human Error in Medicine*. Hillsdale: Lawrence Erlbaum Associates, 1994; 197–224

4 Davies JM, Strunin L. Anesthesia in 1984: how safe is it? *Can Med Assoc J* 1984; **131**: 437–41

5 Phipps D, Meakin GH, Beatty PC *et al.* Human factors in anaesthetic practice: insights from a task analysis. *Br J Anaesth* 2008; **100**: 333–43

6 Reason J. Human error: models and management. *Br Med J* 2000; **320**: 768–70

7 Leape LL. New world of patient safety: 23rd Annual Samuel Jason Mixter lecture. *Arch Surg* 2009; **144**: 394–8

8 Webster CS. The nuclear power industry as an alternative analogy for safety in anaesthesia and a novel approach for the conceptualisation of safety goals. *Anaesthesia* 2005; **60**: 1115–22

9 Dain S. Normal accidents: human error and medical equipment design 1. *Heart Surg Forum* 2002; **5**: 254–7

10 Perrow C. *Normal Accidents, Living with High-risk Technologies. With a New Afterword and a Postscript on the Y2K Problem*. Princeton, NJ: Princeton University Press, 1999; 1–385

11 Reason J. Understanding adverse events: human factors. *Qual Health Care* 1995; **4**: 80–9

12 Hudson PTW, Groeneweg J, Reason J *et al.* Application of TRIPOD to measure latent error in North Sea gas platforms: validity of failures state profiles. *Proceedings of the First International Conference on Health, Safety and Environment*. Richardson, TX: Society of Petroleum Engineers, 1991

13 Shappell S, Detwiler C, Holcomb K *et al.* Human error and commercial aviation accidents: an analysis using the human factors analysis and classification system. *Hum Factors* 2007; **49**: 227–42

14 ElBardissi AW, Wiegmann DA, Dearani JA *et al.* Application of the human factors analysis and classification system methodology to the cardiovascular surgery operating room. *Ann Thorac Surg* 2007; **83**: 1412–8

15 Vincent C, Moorthy K, Sarker SK *et al.* Systems approaches to surgical quality and safety: from concept to measurement. *Ann Surg* 2004; **239**: 475–82

16 Calland JF, Guerlain S, Adams RB *et al.* A systems approach to surgical safety 2. *Surg Endosc* 2002; **16**: 1005–14

17 Wagenaar WA, Hudson PTW, Reason JT. Cognitive failures and accidents. *Appl Cogn Psychol* 1990; **4**: 273–94

18 Reason JT. *Human Error*. Cambridge, UK: Cambridge University Press, 1990

19 Van Beuzekom M, Akerboom SP, Boer F. Assessing system failures in operating rooms and intensive care units. *Qual Saf Health Care* 2007; **16**: 45–50

20 Cooper JB, Newbower RS, Kitz RJ. An analysis of major errors and equipment failures in anesthesia management: considerations for prevention and detection. *Anesthesiology* 1984; **60**: 34–42

21 Weir PM, Wilson ME. Are you getting the message? A look at the communication between the Department of Health, manufacturers and anaesthetists. *Anaesthesia* 1991; **46**: 845–8

22 Tonks A. Patient safety: safer by design. *Br Med J* 2008; **336**: 186–8

23 Leedal JM, Smith AF. Methodological approaches to anaesthetists' workload in the operating theatre. *Br J Anaesth* 2005; **94**: 702–9

24 Catchpole K, Bell MD, Johnson S. Safety in anaesthesia: a study of 12,606 reported incidents from the UK National Reporting and Learning System. *Anaesthesia* 2008; **63**: 340–6

25 Arnstein F. Catalogue of human error. *Br J Anaesth* 1997; **79**: 645–56

26 Alfredsdottir H, Bjornsdottir K. Nursing and patient safety in the operating room. *J Adv Nurs* 2008; **61**: 29–37

27 Vincent C, Taylor-Adams S, Stanhope N. Framework for analysing risk and safety in clinical medicine. *Br Med J* 1998; **316**: 1154–7

28 Singer SJ, Gaba DM, Geppert JJ *et al.* The culture of safety: results of an organization-wide survey in 15 California hospitals. *Qual Saf Health Care* 2003; **12**: 112–8

29 Lingard L, Espin S, Whyte S *et al.* Communication failures in the operating room: an observational classification of recurrent types and effects. *Qual Saf Health Care* 2004; **13**: 330–4

30 Smith AF, Mishra K. Interaction between anaesthetists, their patients, and the anaesthesia team. *Br J Anaesth* 2010; **105**: 60–8

31 Gawande AA, Zinner MJ, Studdert DM *et al.* Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 2003; **133**: 614–21

32 Firth-Cozens J. Why communication fails in the operating room. *Qual Saf Health Care* 2004; **13**: 327

33 Rogers SO Jr, Gawande AA, Kwaan M *et al.* Analysis of surgical errors in closed malpractice claims at 4 liability insurers. *Surgery* 2006; **140**: 25–33

34 Chopra V, Gesink BJ, de Jong J *et al.* Does training on an anaesthesia simulator lead to improvement in performance? *Br J Anaesth* 1994; **73**: 293–7

35 Straight M. One strategy to reduce medication errors: the effect of an online continuing education module on nurses' use of the Lexi-Comp feature of the Pyxis MedStation 2000. *Comput Inform Nurs* 2008; **26**: 23–30

36 Chopra V, Bovill JG, Spierdijk J *et al.* Reported significant observations during anaesthesia: a prospective analysis over an 18-month period. *Br J Anaesth* 1992; **68**: 13–7

37 Trotti JC, McCarthy RT. Occupational hazards in the OR. A historical perspective. *AORN J* 1989; **49**: 276–83

38 Scalese RJ, Obeso VT, Issenberg SB. Simulation technology for skills training and competency assessment in medical education. *J Gen Intern Med* 2008; **23**: 46–9

39 Riall CT. The AORN Audiovisual Committee. Thirty-three years of perioperative nursing education. *AORN J* 1993; **58**: 980–8

40 Cook RI, Woods DD. Adapting to new technology in the operating room. *Hum Factors* 1996; **38**: 593–613

41 Schaefer HG, Helmreich RL, Scheidegger D. Safety in the operating theatre—part 1: interpersonal relationships and team performance. *Curr Anaesth Crit Care* 1995; **6**: 48–53

42 Schaefer HG, Helmreich RL. The importance of human factors in the operating room. *Anesthesiology* 1994; **80**: 479

43 Entin EB, Lai F, Barach P. Training teams for the perioperative environment: a research agenda. *Surg Innov* 2006; **13**: 170–8

44 Fletcher GC, McGeorge P, Flin RH *et al.* The role of non-technical skills in anaesthesia: a review of current literature. *Br J Anaesth* 2002; **88**: 418–29

45 Yule S, Flin R, Paterson-Brown S *et al.* Non-technical skills for surgeons in the operating room: a review of the literature. *Surgery* 2006; **139**: 140–9

46 Gray BV. 100 years of caring and perseverance. *Home Healthc Nurse* 1998; **16**: 424

47 Makary MA, Sexton JB, Freischlag JA *et al.* Operating room teamwork among physicians and nurses: teamwork in the eye of the beholder. *J Am Coll Surg* 2006; **202**: 746–52

48 Helmreich RL. On error management: lessons from aviation. *Br Med J* 2000; **320**: 781–5

49 Thomas EJ, Sexton JB, Helmreich RL. Discrepant attitudes about teamwork among critical care nurses and physicians. *Crit Care Med* 2003; **31**: 956–9

50 Murphy EK. Change is nothing new to perioperative nurses. *AORN J* 1995; **61**: 792–3

51 Helmreich RL. Team performance in the operating room. In: Bogner SM, ed. *Human Error in Medicine*. Hillsdale: Lawrence Erlbaum Associates, 1994; 225–53

52 Holmes CB, Anderson DJ. Comparison of four death anxiety measures. *Psychol Rep* 1980; **46**: 1341–2

53 Helmreich RL, Ashleigh CM. *Culture at Work in Aviation and Medicine: National, Organizational and Professional Influences*. Aldershot: Ashgate Publishing Limited, 1998

54 Biedermann N. Experiences of Australian Army theatre nurses. *AORN J* 2002; **75**: 335–46

55 Parker D, Lawton R. Judging the use of clinical protocols by fellow professionals. *Soc Sci Med* 2000; **51**: 669–77

56 Lawton R, Parker D. Barriers to incident reporting in a healthcare system. *Qual Saf Health Care* 2002; **11**: 15–8

57 Endsley MR. Measurement of situation awareness in dynamic systems. *Human Factors* 1995; **37**: 65–84

58 Ulmer BC. Army nurse corps celebrates 100th anniversary. *AORN J* 2001; **73**: 8–14

59 Donabedian A. Evaluating the quality of medical care. *Milbank Mem Fund Q* 1966; **44**(Suppl.): 166–206

60 Dingwall R, Rafferty AM, Webster C. *An Introduction to the Social History of Nursing*. London: Routledge, 1988; 1–256

61 Wagenaar WA, Groeneweg J, Hudson PTW *et al.* Promoting Safety in the Oil Industry—the Ergonomics Society Lecture Presented at the Ergonomics Society Annual Conference, Edinburgh, 13–16 April 1993. *Ergonomics* 1994;**37**:1999–2013

62 Hudson PTW, Reason JT, Wagenaar WA *et al.* Tripod Delta—proactive approach to enhanced safety. *J Petrol Technol* 1994; **46**: 58–62

63 Wagenaar WASAHPTW. Safety management in intensive care wards. In: Wilpert B, Qvale T, eds. *Reliability and Safety in Hazardous Work Systems*. Hove: Lawrence Erlbaum, 1993

64 Smith A, Boult M, Woods I *et al.* Promoting patient safety through prospective risk identification: example from peri-operative care. *Qual Saf Health Care* 2010; **19**: 69–73

65 Baker JA, Bowman FL, Erwin G. *The BP U.S. Refineries Independent Safety Review Panel*. 2007

66 Smith MS. *NASA's Space Shuttle Columbia: Synopsis of the Report of the Columbia Accident Investigation Board*. 2003

67 Weick KE. Organizational culture as a source of high-reliability. *Calif Manag Rev* 1987; **29**: 112–27

68 Robert KH. Some characteristics of one type of high reliability organization. *Organ Sci* 1990; **1**: 160–76

69 Spencer FC. Human error in hospitals and industrial accidents: current concepts. *J Am Coll Surg* 2000; **191**: 410–8

70 Hudson PTW. Process indicators: Managing safety by the numbers. *Saf Sci* 2008; 1–3

71 Espin S, Levinson W, Regehr G *et al.* Error or 'act of God'? A study of patients' and operating room team members' perceptions of error definition, reporting, and disclosure. *Surgery* 2006; **139**: 6–14

3

Assessing system failures in Operating Rooms and Intensive Care Units

ORIGINAL ARTICLE

Assessing system failures in operating rooms and intensive care units

M van Beuzekom, S P Akerboom, F Boer

Qual Saf Health Care 2007;**16**:45–50. doi: 10.1136/qshc.2005.015446

See end of article for authors' affiliations

Correspondence to: M van Beuzekom, OR Centre, J4-Q, LUMC, PO Box 9600, 2300 RC Leiden, The Netherlands; M.van_Beuzekom@lumc.nl

Accepted 19 November 2006

Background: The current awareness of the potential safety risks in healthcare environments has led to the development of largely reactive methods of systems analysis. Proactive methods are able to objectively detect structural shortcomings before mishaps and have been widely used in other high-risk industries.
Methods: The Leiden Operating Theatre and Intensive Care Safety (LOTICS) scale was developed and evaluated with respect to factor structure and reliability of the scales. The survey was administered to the staff of operating rooms at two university hospitals, and intensive care units (ICUs) of one university hospital and one teaching hospital. The response rate varied between 40–47%. Data of 330 questionnaires were analysed. Safety aspects between the different groups were compared.
Results: Factor analyses and tests for reliability resulted in nine subscales. To these scales another two were added making a total of 11. The reliability of the scales varied from 0.75 to 0.88. The results clearly showed differences between units (OR1, OR2, ICU1, ICU2) and staff.
Conclusion: The results seem to justify the conclusion that the LOTICS scale can be used in both the operating room and ICU to gain insight into the system failures, in a relatively quick and reliable manner. Furthermore the LOTICS scale can be used to compare organisations to each other, monitor changes in patient safety, as well as monitor the effectiveness of the changes made to improve the level of patient safety.

Since the publication of the Institute of Medicine report *To err is human* in 2000, improving patient safety has become a core issue for many modern healthcare institutes.[1] According to this report and other studies conducted around the globe, approximately 10% of all patients admitted to hospital suffer some kind of harm, about half of which is preventable with current standards of treatment.[2–6] The question arises of how systematic action can be taken to avert these preventable errors. For a long time a person-aimed analysis and prevention approach has been the dominant approach to improve patient safety in health care. In this approach the focus is directed at the ever-present ''human factor'', being the individual responsible for making the error. Medical errors are considered the result of forgetfulness, inattention, lack of motivation and neglect.[7–9] Despite the fact that accidents are to a significant extent caused by human failure, approaches directed to human shortcomings seldom solve the problem.[10 11] There is widespread evidence from research in several domains that indicates that individual errors are often the result of structural system failures.[12] This implies that incident investigations should not be limited to the description of unsafe acts and/or situations that preceded the accidents, the active failures. Instead, investigations should particularly be directed to the identification of the system factors that contributed to the adverse event—the latent failures—which are frequently the result of management decisions.[13 14] Several studies have shown that latent failures can be grouped into a limited number of classes. Analysis of major disasters, shipping accidents, accidents in the exploration and oil production, railway operations and aircraft engineering showed 11 classes of so-called General Failure Types.[8 14] In a study conducted by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO; http://www.jcaho.com) into the root cause analyses of 2500 incidents, 10 classes of underlying causes were discerned (fig 1).

In recent years health care has increasingly accepted a systems approach for the analysis of incidents and identification of the latent and environmental conditions that lead to adverse events.[7 15–17] The translation of this approach in the medical world evolved largely to reactive methods and, in only a handful of cases, to more proactive methods.[18 19] In safety-critical domains other than health care, techniques have been developed that objectively detect structural shortcomings before they can lead to incidents and that can be used to assess and monitor the safety situation within an organisation.[20] In this study we aim to develop a comprehensive survey instrument that measures system factors contributing to adverse events (latent risk factors) in the operating theatre and intensive care unit and which identifies specific areas of concern by comparing staff reactions on system factors across units and medical disciplines. The development of the instrument is part of the Leiden Operating Theatre Safety (LOTS) study. The LOTS study aims to improve the quality of patient safety by identifying system failures and facilitating the development and evaluation of corrective actions to reduce the risk of future errors. The present article reports details of the development and the psychometric properties of the Leiden Operating Theatre and Intensive Care Safety (LOTICS) scale. In addition to the psychometric aspects of the LOTICS scale its validity was studied in more detail by including work-related safety goals as a criterion measure. It was expected that subgroups with significantly lower than average scores on latent risk factors (LRFs) would report more safety goals in the areas related to the LRFs on which they were less favourable than on LRFs for which their scores were equal to or above the average score. Further it was expected that subgroups with lower than average scores on LRFs would mention more safety goals than subgroups with equal to or higher than average scores on LRFs. We also investigated the relation between LRFs, safety culture and perceived error rate. After all, in a reporting and learning culture, system weaknesses should ''decrease'' over time as

Abbreviations: ICU, intensive care unit; LOTS study, Leiden Operating Theatre Safety study; LOTICS scale, Leiden Operating Theatre and Intensive Care Safety scale

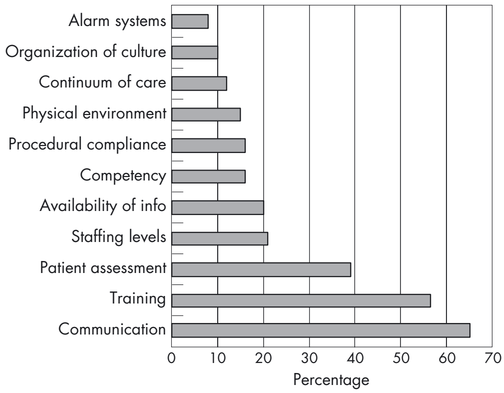


Figure 1 Most importance root causes of 2500 incidents reported to the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) (reprinted with permission from JCAHO, 2004).[21]

corrective actions are implemented.[8] In a similar vein, a more positive safety culture and fewer system weaknesses should eventually result in a reduction in error rates. Unfortunately, errors in health care are strongly underreported.[1 22] Moreover, the tendency to underreport errors has been found to be inversely related to safety culture.[23] Given these findings we expected significant correlations between LRFs and safety culture, but no significant correlation for LRFs and safety culture with perceived error rate.

METHODS

Study sample

Staff from two university hospitals and one teaching hospital in the Netherlands participated in the study. In one of the university hospitals both the operating room centre and the intensive care unit (ICU) participated. In the other university hospital only the operating room participated, and in the teaching hospital only the ICU. All nurses and medical specialists, both staff and trainees, who had been in their job three months or more were approached and invited to participate in the study. Of the 782 who met this criterion (485 from the operating theatre and 297 from the ICU) 344 completed the inventory. Of the 344 returned survey forms 330 (42%) were suitable for further analysis (40% in operating theatres, 47% in ICUs). The demographic data, working hours and working experience are given in table 1.

Survey instrument

The questionnaire comprises four parts (99 items) and has an additional demographic section where respondents fill in their department or ward, job position, contracted hours per week, job tenure, age group and gender.

Table 1 Demographics

Sex	
Male	26.7%
Female	72.7%
Age	38.6 (9.97)
Working hours	31.1 (8.98)
Years employed in the organisation	
<1	7.6%
1–5	35.5%
5–10	19.7%
>10	36.1%

I. Latent risk factors

A multidisciplinary team consisting of four employees from the operating theatre, ICU and management, two anaesthesiologists and two surgeons was asked to make an inventory of possible process failures in the operating theatre and the ICU. The inventory was reviewed by the 10-member multidisciplinary supervising board of the LOTS study, to ascertain the completeness of the inventory. A total of 50 potential process failures were identified. Next, the members of the supervising board were interviewed to identify possible underlying causes and effects of these failures. Finally, the investigators categorised the underlying causes, defining 10 item categories: Staffing Resources, Communication, Planning and Coordination, Training, Procedures, Design, Material Resources, Maintenance, Teamwork and Situation Awareness. Two of these item categories were measured with scales of the Leiden Quality of Work Scale (LQWS) for Hospitals:[24] Staffing Resources (6 items) and Material Resources (5 items). Table 2 shows the items with the LQWS factor loadings and Cronbach alpha. Responses were given on a four-point Likert-type scale as follows: 1 (totally disagree), 2 (disagree), 3 (agree) to 4 (totally agree), with higher scores indicating more resources. To measure the other eight item categories a pool of 90 items was developed, and reviewed by the supervising board on phrasing (readability and applicability) and validity (completeness and relevance). Some items were deleted leaving a total pool of 74 items. Respondents indicated their agreement with each item on the four-point scale.

II. Safety culture

In this study safety culture was defined as the willingness to report, analyse and learn from errors and adverse events, which Reason called a ‘‘reporting and learning safety culture’’.[8] Safety culture was measured with nine items based on a checklist to evaluate interventions to strengthen a culture of safety[25] (for example, ‘‘After an incident not much is done’’; $\alpha = 0.77$). Responses were given on a four-point Likert-type scale ranging from 1 (totally disagree) to 4 (totally agree).

III. Perceived rate of errors

The third section asked respondents to report how often errors, near-misses and incidents occurred in their departments. The three items were scored on a six-point scale ranging from 1 (never) to 6 (very frequently).

IV. Safety goals

The fourth section asked respondents to report in free text the three most important work goals they wanted to attain in the coming year to improve patient safety in the operating room/ ICU.

Data analysis

The data were analysed using the statistical software package SPSS version 10. Exploratory factor analyses were conducted to assess the underlying factor structure of the 74-item questionnaire. The scale reliability was assessed by Cronbach's alpha. Bivariate correlations were calculated to examine the pattern of direct relationships between the LRFs, safety culture and perceived rate of errors. To examine the discriminative value of the LOTICS scale, differences in LRFs across different operational units and different medical disciplines were evaluated using one-way analyses of variance (ANOVAs) for each of the LRFs, followed by planned linear comparisons. To facilitate the analyses the study sample was divided according

Table 2 Factor structure, factor loadings and internal reliability (Cronbach's alpha) of the LOTICS scale

Communication	Information about changes in OR programme/planned procedure timely provided	0.750
$\alpha = 0.84$	Information about changes in OR programme/planned procedure are communicated through the right channels	0.685
	Adequate communication about patients with other disciplines	0.631
	Information to perform procedure available at the time when it is needed	0.620
	Adequate communication about patients between teams	0.617
	Information to perform procedure not properly communicated	0.613
Maintenance	Maintenance carried out on a regular basis	0.855
$\alpha = 0.87$	Maintenance inspection performed timely	0.808
	OR/ICU equipment badly maintained	0.731
	Maintenance schedule is lagging	0.703
Training	Adequate coaching of new personnel	0.706
$\alpha = 0.81$	Keeping employees informed about new medical/technological developments	0.634
	Training employees in the operation of new equipment	0.617
	Adequate supervision of trainees in their practical period	0.613
	Co-workers on my department have the necessary qualifications	0.531
	In OR a combination of staff junior/junior are avoided/on the ICU an adequate mix of seniority is applied	0.513
Situation Awareness	Team members alert each other to problems	0.772
$\alpha = 0.79$	Members of my team know what one another is doing	0.705
	Members of my team monitor each other's performance	0.681
	Adequate exchange of information during the operation/shift	0.571
Procedures	Accessibility of procedures/regulations/rules	0.659
$\alpha = 0.81$	Violations of procedures/regulations/rules	0.651
	Procedures/regulations/rules frequently not clear	0.543
	Procedures/regulations/rules frequently not applicable in practice	0.525
	Procedures/regulations/rules applied correctly	0.513
	Procedures taken a bit less seriously to do a better job	0.500
Design	Equipment operation is difficult	0.751
$\alpha = 0.76$	Controls or displays are hard to read	0.730
	Controls of displays are unclear and/or lacking	0.624
	Too much information on controls or display	0.563
Teamwork	I really feel I am a part of my team	0.668
$\alpha = 0.75$	Team's ability to deal with unexpected events	0.614
	Members of my team work together as a well coordinated team	0.496
	Clear view of who is doing what and when	0.453
Planning and Coordination	Organisational changes not adequately supported within the department	0.593
$\alpha = 0.75$	Lack of advance planning within the department	0.530
	Sufficiency of planning	0.501
Team Instructions	Team members debriefed on what they can expect during operation/shift	0.657
$\alpha = 0.76$	Team members sufficiently instructed during operation/shift	0.653
	I have confidence in my other team members	0.541
Material Resources	Worn-out or faulty equipment replaced in a timely way	0.582
$\alpha = 0.75$	Following new technologies when procuring new equipment	0.554
	Equipment frequently repaired	0.552
	Insufficient quality of materials and equipment	0.527
	Availability of materials and equipment at the time it is needed	0.412
Staff Resources	Enough experienced staff available	0.623
$\alpha = 0.75$	Enough support staff to provide good care	0.592
	Enough staff to provide good care	0.569
	Enough physicians to provide good care	0.557
	Enough experienced staff available	0.536

to operational unit: operating theatre (OR1 and OR2) and intensive care unit (ICU1 and ICU2), and by medical discipline: theatre nurses, anaesthesia nurses, operatin room trainees, operating room recovery nurses, physicians, and intensive care nurses. To examine the relation between staff's reported number and type of safety goals and perceptions on the latent risk factors, the subgroups by medical discipline were further divided to operational unit. Finally, subgroup means and overall means on each of the 11 LRFs were calculated. Subgroup means were then compared to the overall mean using Student's *t* test to define those subgroups answering favourable/unfavourable on LRFs.

RESULTS

Psychometric characteristics of the LOTICS scale

An exploratory factor analysis was conducted on the 74 latent risk items using principal components extraction with varimax rotation and the scree-test criterion.[26] The analysis revealed a solution with nine factors explaining 48% of the total variance. Using as criterion a cut off point of 0.40 for item loadings in the rotated factor loading matrix and interpretability of the scales, 47 items loaded unambiguously and meaningfully on one of the nine factors and with reasonable congruence with a priori content areas. The nine factors were labeled: Task-related Communication, Teamwork, Team Instruction, Training, Procedures, Situation Awareness, Planning and Coordination, Maintenance and Design. To increase the internal reliability of four scales seven items were excluded, leaving 40 items to measure the nine components. The final subscale internal consistencies are moderate to high (Cronbach α varied between 0.75–0.88). Table 2 shows the items with their factor loadings and the Cronbach value for each of the LOTICS subscales.

Correlations

Table 3 provides the correlations among all variables. Correlations between the LOTICS subscales and safety culture were all significant and positive with highest correlations found between safety culture and Training (0.40) and safety culture and Planning and Coordination (0.43). Correlations between the LOTICS subscales and perceived error rate were generally not significant. Safety culture and perceived error rate correlated statistically significantly, but correlations were weak (0.21).

Table 3 Intercorrelations between the LOTICS subscales, safety culture and perceived rate of errors

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Staffing Resources													
2. Maintenance	0.370**												
3. Training	0.550**	0.342**											
4. Situation Awareness	0.183**	0.265**	0.421**										
5. Procedures	0.267**	0.365**	0.428**	0.420**									
6. Communication	0.444**	0.334**	0.462**	0.317**	0.388**								
7. Design	0.260**	0.420**	0.196**	0.208**	0.398**	0.331**							
8. Planning and Coordination	0.456**	0.427**	0.590**	0.367**	0.517**	0.482**	0.352**						
9. Teamwork	0.403**	0.347**	0.579**	0.472**	0.475**	0.415**	0.235**	0.522**					
10. Team Instructions	0.315**	0.261**	0.522**	0.520**	0.331**	0.399**	0.141*	0.366**	0.541**				
11. Material Resources	0.547**	0.546**	0.372**	0.209**	0.407**	0.482**	0.475**	0.514**	0.326**	0.253**			
12. Safety Culture	0.239**	0.305**	0.401**	0.347**	0.338**	0.343**	0.175**	0.425**	0.333**	0.336**	0.330**		
13. Perceived error rate	0.089	0.049	0.098	0.181**	0.277**	0.147**	0.097	0.109	0.148**	0.084	0.176**	0.212**	

*$p<0.05$; **$p<0.01$ (two-tailed).

Discriminative value

Operational units

According to one-way ANOVA, eight of the 11 LOTICS dimensions discriminated significantly between different operational units (table 4). For two scales the differences between the operational units approached significance (Situation Awareness, $p = 0.062$, Procedures, $p = 0.054$). Compared with OR1, OR2 and ICU2, ICU1 reported significant more problems for Material Resources (mean difference ICU1 *v* OR1 0.20, 95% CI 0.04 to 0.35, mean difference ICU1 *v* OR2 0.17, 95% CI 0.01 to 0.34, mean difference ICU1 *v* ICU2 0.59, 95% CI 0.41 to 0.77), and for Maintenance (mean difference ICU1 *v* OR1 0.07, 95% CI 0.00 to 0.13, mean difference ICU1 *v* OR2 0.11, 95% CI 0.04 to 0.17, mean difference ICU1 *v* ICU2 0.18, 95% CI 0.11 to 0.26). ICU1 also reported more problems for Design than did OR1 and ICU2 (mean difference ICU1 *v* OR1 0.15, 95% CI 0.01 to 0.30, mean difference ICU1 *v* ICU2 0.34, 95% CI 0.17 to 0.50). Compared with the ICUs, the operating theatres encountered more problems with Teamwork (mean difference OR1 *v* ICU1 0.15, 95% CI 0.03 to 0.28, mean difference OR1 *v* ICU2 0.18, 95% IC 0.01 to 0.33, mean difference OR2 *v* ICU1 0.14, 95% CI 0.01 to 0.28, mean difference OR2 *v* ICU2 0.18, 95% CI 0.03 to 0.33). Operating theatre staff also had more problems with Training (TR) and Communication (CO) than ICU staff, with OR1 reporting more problems than ICU1 and ICU2 (TR: mean difference OR1 *v* ICU1 0.24, 95% CI 0.09 to 0.40, mean difference OR1 *v* ICU2 0.38, 95% CI 0.20 to 0.55, and CO: mean difference OR1 *v* ICU1 0.34, 95% CI 0.19 to 0.49, mean difference OR1 *v* ICU2 0.54, 95% CI 0.38 to 0.71), and with OR2 reporting more problems than ICU2 (TR: mean difference OR2 *v* ICU1 0.10, 95% CI 0.07 to 0.27, mean difference OR2 *v* ICU2 0.23, 95% CI 0.05 to 0.42, and CO: mean difference OR2 *v* ICU1 0.16, 95% CI 0.00 to 0.33, mean difference OR2 *v* ICU2 0.37, 95% CI 0.19 to 0.55).

Medical discipline

One-way ANOVA showed that all LOTICS dimensions, except for Procedures, discriminated significantly between staff in different job positions (table 5).

Anaesthesia nurses reported more problems for LRFs than the other medical disciplines, while physicians and intensive care nurses reported fewer problems for LRFs. Inspection of the

Table 4 ANOVA mean LOTICS subscale scores for each of the operational units, with standard deviations and degrees of freedom in parenthesis: OR1, OR2, ICU1 and ICU2

	Units						
LOTICS subscales	OR1 (n = 112)	OR2 (n = 81)	ICU1 (n = 79)	ICU2 (n = 57)	F ratio	p Value	Effect size*
Staffing Resources	2.71 (0.46)[a]	2.81 (0.30)[b]	2.80 (0.35)[c]	3.24 (0.40)[abc]	24.77 (3, 324)	<0.001	0.187
Training	2.68 (0.45)[ab]	2.82 (0.38)[c]	2.92 (0.35)[a]	3.05 (0.37)[bc]	13.09 (3, 324)	<0.001	0.108
Procedures	2.70 (0.33)	2.74 (0.33)	2.64 (0.37)	2.80 (0.40)	2.57 (3, 320)	0.054	0.023
Planning and Coordination	2.72 (0.37)[a]	2.83 (0.37)[b]	2.84 (0.32)[c]	3.02 (0.38)[abc]	8.77 (3, 322)	<0.001	0.075
Communication	2.43 (0.43)[abc]	2.61 (0.39)[bd]	2.78 (0.39)[ae]	2.98 (0.33)[cde]	27.94 (3, 324)	<0.001	0.205
Teamwork	2.91 (0.33)[ab]	2.93 (0.28)[cd]	3.07 (0.31)[ac]	3.10 (0.34)[bd]	6.70 (3, 323)	<0.001	0.058
Team Instructions	2.84 (0.39)	2.84 (0.33)	2.89 (0.40)	2.98 (0.42)	1.96 (3, 315)	0.120	0.018
Situation Awareness	2.85 (0.41)	2.79 (0.44)	2.89 (0.36)	2.71 (0.47)	2.47 (3, 319)	0.062	0.023
Material Resources	2.60 (0.35)[ab]	2.57 (0.39)[cd]	2.60 (0.44)[ace]	2.98 (0.43)[bde]	25.46 (3, 317)	<0.001	0.194
Maintenance	2.78 (0.45)[ab]	2.92 (0.38)[cd]	2.58 (0.35)	3.10 (0.37)[bde]	15.94 (3, 306)	<0.001	0.135
Design	2.95 (0.32)[ab]	2.94 (0.38)[c]	2.79 (0.38)[ad]	3.13 (0.41)[bcd]	9.95 (3, 319)	<0.001	0.085

Means that differ significantly ($p<0.05$) by the Bonferroni procedure share an identical superscript within a row.
*Partial Eta squared.

Table 5 ANOVA mean LOTICS subscale scores for each of the medical disciplines, with standard deviations and degree of freedom in parenthesis

	TN (n = 78)	AN (n = 41)	ReN (n = 22)	Ph (n = 29)	Tr (n = 24)	ICN (n = 125)	F ratio	p Value	Effect size*
Staffing Resources	2.82 (0.31)[a]	2.48 (0.52)[abcde]	2.85 (0.38)[b]	2.98 (0.50)[c]	2.84 (0.33)[d]	2.93 (0.40)[e]	8.76 (3, 313)	<0.001	0.136
Training	2.76 (0.41)[ab]	2.57 (0.47)[cd]	2.75 (0.49)	3.06 (0.43)[ac]	2.75 (0.29)	2.94 (0.38)[bd]	8.27 (3, 308)	<0.001	0.117
Procedures	2.73 (0.29)	2.69 (0.36)	2.61 (0.41)	2.85 (0.48)	2.76 (0.21)	2.67 (0.36)	1.66 (3, 309)	0.144	0.026
Planning and Coordination	2.76 (0.32)[a]	2.69 (0.44)[b]	2.72 (0.53)	3.01 (0.38)[ab]	2.82 (0.25)	2.87 (0.32)	4.14 (3, 311)	<0.01	0.062
Communication	2.41 (0.43)[abc]	2.43 (0.42)[def]	2.50 (0.39)[hi]	2.88 (0.45)[adh]	2.75 (0.23)[be]	2.83 (0.35)[cfi]	17.24 (3, 313)	<0.001	0.216
Teamwork	2.93 (0.29)[a]	2.87 (0.35)[b]	2.92 (0.33)	3.15 (0.45)[ab]	2.88 (0.26)	3.05 (0.31)	4.79 (3, 312)	<0.001	0.071
Team instructions	2.92 (0.34)[a]	2.69 (0.40)[abc]	2.65 (0.37)[d]	3.08 (0.44)[bd]	2.94 (0.23)	2.89 (0.37)[c]	5.62 (3, 304)	<0.001	0.085
Situation Awareness	2.85 (0.41)	2.65 (0.47)[ab]	2.75 (0.49)	3.07 (0.43)[ac]	2.99 (0.29)[b]	2.79 (0.38)[c]	4.70 (3, 308)	<0.001	0.071
Material Resources	2.56 (0.35)[a]	2.46 (0.40)[b]	2.59 (0.34)	2.87 (0.46)[abc]	2.71 (0.26)	2.58 (0.47)[c]	3.74 (3, 306)	<0.01	0.058
Maintenance	3.51 (0.38)[a]	3.54 (0.50) [b]	3.54 (.38)	3.67 (0.49)[abcd]	3.52 (0.42)[c]	3.50 (0.33)[d]	5.46 (3, 313)	<0.001	0.085
Design	2.86 (0.36)[a]	2.94 (0.24)	2.96 (0.23)	3.14 (0.50)[ab]	3.04 (0.31)	2.89 (0.37)[b]	3.42 (3, 308)	0.005	0.053

TN, theatre nurses; AN, anaesthesia nurses; ReN, recovery nurses; Ph, physicians; Tr, trainees; ICN, intensive care nurses.
Means that share an identical superscript differ significantly ($p<0.05$) by the Bonferroni procedure within a row.
*Partial Eta squared.

data for unit differences showed, however, that it was foremost anaesthesia nurses in OR1 and intensive care nurses in ICU2 who accounted for the significant findings.

Criterion validity

The participants mentioned a total of 545 work goals to improve patient safety on their respective departments. Two people (one research staff member and one member of the supervisory board of the LOTS study) categorised the goals according to one of the 11 LOTICS subscales it referred to. The categorisation found 412 goals related to the LOTICS subscales. Safety goals that did not concern LRFs were categorised as ''safety culture'' (41), ''hygiene'' (10), ''work space'' (27), ''work climate'' (19) and ''miscellaneous'' (36).

On average 10.1 safety goals were reported for LRFs, with unfavourable scores against 3.2 goals for LRFs with favourable scores. A relatively large part of the reported safety goals (30%) were concerned with the factors communication and training, even if the factors' scores did not lag behind the average.

On average the subgroups which were less favourable on LRFs—anaesthesia nurses in OR1 and nurses in ICU1—mentioned more safety goals than the other subgroups (2.32 *v* 1.58 ($p<0.01$) and 1.98 *v* 1.51 ($p<0.01$), respectively). Most safety goals were mentioned in the areas related to the LRFs on which they were less favourable. On average the nurses in ICU2 reported more favourably on LRFs and on average mentioned fewer safety goals than the other subgroups (0.98 *v* 1.72 ($p<0.001$)). These nurses, however, had a lower score on Situation Awareness and mentioned more often safety goals that relate to this aspect than on average (13% *v* 3%). Although nurses in ICU2 reported more favourably on Safety Culture than most other medical disciplines they reported less favourably on perceived rate of errors.

DISCUSSION

If system-directed methods are used in health care to monitor and improve patient safety generally reactive methods are used.[27] Several factors influence the adequacy of these methods to identify the sensibility of the system to errors and the underlying causes of incidents. The most important factor is the level of reporting of incidents and errors. In healthcare underreporting of incidents and errors is a common phenomenon. A second factor is that most incident analyses describe only ''who'' was involved and ''what'' occurred with limited attention paid to the underlying latent failures. Even if errors and incidents are reduced to system factors, the identified failures that have led to that specific incident are not necessarily indications of weaknesses in the organisation as a whole, restricting lessons to be learned about the prevention of future similar occurrences.[14 28] Consequently, a large number of incidents has to be analysed, as in the JCAHO study, to get a reliable impression of the organisation's system weaknesses. Finally, the lack of standardised reporting and analysis precludes sharing data for benchmarking.

Given the limitations of the reactive approach the current study aims to identify system failures in the operating room and ICU, irrespective of the errors and incidents that occur by using the purposely-developed instrument, the LOTICS scale. The LOTICS scale seems to be a reliable and valid diagnostic tool with the ability to identify system failures and to differentiate between units and medical disciplines. The items are representative of the construct to be measured and they address various parts of the construct. The groups which report less favourably on LRFs mention more safety goals than groups with favourable scores and the reported goals particularly involve LRFs with unfavourable scores. Apparently absolute values matters more than relative scores, since even for those scales with only average scores (Communication and Training) the respondents suggested safety goals. Similarly, JCAHO observed that in the incident analyses of 2500 incidents over the last 10 years Communication and Training were mentioned as (additional) causes in the incidents (fig 1). Problems with communication played a role in 65% of the incidents, while training deficiencies were mentioned in 56% of cases.[18 29–33] The significance of the other LRFs in our study—Staffing Resources,[34] Procedures,[31 35] Situation Awareness,[36 37] Teamwork,[15 19 31 34 38] Team Instructions,[19] Design and Maintenance of equipment,[18 19 39 40] Planning and Coordination[13 39]—was also observed in other studies.

Correlations between the LOTICS subscales and safety culture were generally moderate and in the expected direction, indicating that individuals reporting fewer problems with LRFs scored higher on safety culture. Correlations with the perceived rate of errors were generally not significant. The correlation between safety culture and perceived rate of errors was significant but also very weak. These findings are in line with the results of another study indicating that if systemic factors and safety culture are rated favourably the probability of incidents is low but the willingness to report incidents (and the ability to recognise near-misses and incidents) is high.[23] Reversely, in organisations in which the scores on safety culture and systemic factors are more negative, more incidents occur, but the willingness to report these incidents is lower. The fact that organisations with more positive scores on safety culture are more prepared to report errors and (near) incidents may explain why the group ''nurses in ICU2'' with the most favourable LRFs has a higher perceived rate of errors than the other groups.

There are limitations to our study. The response rate varied between 40–47% and thus we may have introduced a response bias. However, there were no differences between responders and the total population on sex, age and function. This suggested that the overall results would probably not be affected by non-response bias. The results of the data set support the construct validity of the LOTICS, which needs to be confirmed in replications of this research and comparison with other measures. Further work is also necessary to examine the test-retest reliability of the LOTICS and its predictive validity.

In conclusion, we believe that the LOTICS scale can be used in both the operating room and ICU to gain insight into the system failures, in a relatively quick and reliable manner. Furthermore the LOTICS scale can be used to compare organisations with each other, monitor changes in patient safety, as well as monitor the effectiveness of the changes made to improve the level of patient safety.

ACKNOWLEDGEMENTS

The authors thank Professor H Kerkkamp, Professor of Perioperative Care and H Langeweg, location manager of the day care centre, University Medical Centre Utrecht, H van Dis, medical psychologist, C J Schuijt-Nederlof, charge nurse ICU, OLVG, Amsterdam, AAM Keijzer, charge nurse and manager ICU, Leiden University Medical Centre, Leiden and the employees of the centres for their cooperation in the study.

Authors' affiliations

M van Beuzekom, F Boer, OR Centre, Leiden University Medical Centre, Leiden, The Netherlands

S P Akerboom, Department of Cognitive Psychology, Leiden University, Leiden, The Netherlands

REFERENCES

1 **Institute of Medicine**. To err is human: building a safer health system. Washington DC: National Academy Press, 2000.

2 **Brennan TA**, Leape LL, Laird NM, *et al*. Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I. *N Engl J Med* 1991;**324**:370–6.

3 **Leape LL**, Brennan TA, Laird N, *et al*. The nature of adverse events in hospitalized patients. Results of the Harvard Medical Practice Study II. *N Engl J Med* 1991;**324**:377–84.

4 **Wilson RM**, Runciman WB, Gibberd RW, *et al*. The Quality in Australian Health Care Study. *Med J Aust* 1995;**163**:458–71.

5 **Gawande AA**, Thomas EJ, Zinner MJ, *et al*. The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery* 1999;**126**:66–75.

6 **Vincent C**, Neale G, Woloshynowych M. Adverse events in British hospitals: preliminary retrospective record review. *BMJ* 2001;**322**:517–19.

7 **Leape LL**. Error in medicine. *JAMA* 1994;**272**:1851–7.

8 **Reason JT**. *Human error*. Cambridge, UK: Cambridge University Press, 1990.

9 **Shojania KG**, Wald H, Gross R. Understanding medical error and improving patient safety in the inpatient setting. *Med Clin North Am* 2002;**86**:847–67.

10 **Cooper JB**, Newbower RS, Long CD, *et al*. Preventable anesthesia mishaps: a study of human factors. *Anesthesiology* 1978;**49**:399–406.

11 **Reason J**. Understanding adverse events: human factors. *Qual Health Care* 1995;**4**:80–9.

12 **Reason J**. The contribution of latent human failures to the breakdown of complex systems. *Philos Trans R Soc Lond B Biol Sci* 1990;**327**:475–84.

13 **Carthey J**, de Leval MR, Reason JT. The human factor in cardiac surgery: errors and near misses in a high technology medical domain. *Ann Thorac Surg* 2001;**72**:300–5.

14 **Wagenaar WA**, Hudson PTW, Reason JT. Cognitive failures and accidents. *Appl Cogn Psychol* 1990;**4**:273–94.

15 **Schaefer HG**, Helmreich RL. The importance of human factors in the operating room. *Anesthesiology* 1994;**80**:479.

16 **Gaba DM**. Human error in dynamic medical domains. In: Bogner SM, eds. *Human error in medicine*. Hillsdale: Lawrence Erlbaum Associates, 1994:197–224.

17 **Donchin Y**, Gopher D, Olin M, *et al*. A look into the nature and causes of human errors in the intensive care unit. *Crit Care Med* 1995;**23**:294–300.

18 **Helmreich RL**. Team performance in the operating room. In: Bogner SM, eds. *Human error in medicine*. Hillsdale: Lawrence Erlbaum Associates, 1994:225–53.

19 **Vincent C**, Moorthy K, Sarker SK, *et al*. Systems approaches to surgical quality and safety: from concept to measurement. *Ann Surg* 2004;**239**:475–82.

20 **Hudson PTW**, Reason JT, Wagenaar WA, *et al*. Tripod Delta—proactive approach to enhanced safety. *Journal of Petroleum Technology* 1994;**46**:58–62.

21 **The Joint Commission**. Root causes of sentinel events. http://www.jointcommission.org/NR/rdonlyres/FA465646-5F5F-4543-AC8F-E8AF6571E372/0/root_cause_se.jpg (accessed 24 January 2007).

22 **Leape LL**. Reporting of adverse events. *N Engl J Med* 2002;**347**:1633–8.

23 **Singer SJ**, Gaba DM, Geppert JJ, *et al*. The culture of safety: results of an organization-wide survey in 15 California hospitals. *Qual Saf Health Care* 2003;**12**:112–8.

24 **Akerboom SP**, Doef M van der, Doest L ter, et al. *Results of Quality of Work study*, LUMC.University Leiden, Leiden.Health Psychology, 2002.

25 **Steijger N**, Starren A, Keus M, *et al*. A checklist to judge safety improvement plans for safety awareness, behaviour and culture. Report: Uithoorn, TNO-Arbeid, 2003.

26 **Cattell RB**. The scree test for the number of factors. *Multivariate Behav Res* 1966;**1**:245–76.

27 **Vincent C**, Taylor-Adams S, Chapman EJ, *et al*. How to investigate and analyse clinical incidents: clinical risk unit and association of litigation and risk management protocol. *BMJ* 2000;**320**:777–81.

28 **Wagenaar WA**. *The cause of impossible accidents*. Deventer: Van Loghum Slaterus, 1986.

29 **Kluger MT**, Bullock MF. Recovery room incidents: a review of 419 reports from the Anaesthetic Incident Monitoring Study (AIMS)1. *Anaesthesia* 2002;**57**:1060–6.

30 **Gawande AA**, Zinner MJ, Studdert DM, *et al*. Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 2003;**133**:614–21.

31 **Flin R**, Fletcher G, McGeorge P, *et al*. Anaesthetists' attitudes to teamwork and safety. *Anaesthesia* 2003;**58**:233–42.

32 **Firth-Cozens J**. Why communication fails in the operating room. *Qual Saf Health Care* 2004;**13**:327.

33 **Sutcliffe KM**, Lewton E, Rosenthal MM. Communication failures: an insidious contributor to medical mishaps. *Acad Med* 2004;**79**:186–94.

34 **Sexton JB**, Thomas EJ, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. *BMJ* 2000;**320**:745–9.

35 **Lawton R**. Not working to rule: understanding procedural violations at work. *Saf Sci* 1998;**28**:77–95.

36 **Endsley MR**. Measurement of situation awareness in dynamic-systems. *Hum Factors* 1995;**37**:65–84.

37 **Gaba DM**, Howard SK, Small SD. Situation awareness in anesthesiology. *Hum Factors* 1995;**37**:20–31.

38 **Thomas EJ**, Sexton JB, Helmreich RL. Discrepant attitudes about teamwork among critical care nurses and physicians. *Crit Care Med* 2003;**31**:956–9.

39 **Cooper JB**, Newbower RS, Kitz RJ. An analysis of major errors and equipment failures in anesthesia management: considerations for prevention and detection. *Anesthesiology* 1984;**60**:34–42.

40 **Cook RI**, Woods DD. Operating at the sharp end: the complexity of human error. In: Bogner SM, eds. *Human error in medicine*. Hillsdale: Lawrence Erlbaum Associates, 1994.

4

Patient safety in the Operating Room: an intervention study on Latent Risk Factors

RESEARCH ARTICLE Open Access

Patient safety in the operating room: an intervention study on latent risk factors

Martie van Beuzekom[1*], Fredrik Boer[1,2], Simone Akerboom[3] and Patrick Hudson[3,4]

Abstract

Background: Patient safety is one of the greatest challenges in healthcare. In the operating room errors are frequent and often consequential. This article describes an approach to a successful implementation of a patient safety program in the operating room, focussing on latent risk factors that influence patient safety. We performed an intervention to improve these latent risk factors (LRFs) and increase awareness of patient safety issues amongst OR staff.

Methods: Latent risk factors were studied using a validated questionnaire applied to the OR staff before and after an intervention. A pre-test/post-test control group design with repeated measures was used to evaluate the effects of the interventions. The staff from one operating room of an university hospital acted as the intervention group. Controls consisted of the staff of the operating room in another university hospital. The outcomes were the changes in LRF scores, perceived incident rate, and changes in incident reports between pre- and post-intervention.

Results: Based on pre-test scores and participants' key concerns about organizational factors affecting patient safety in their department the intervention focused on the following LRFs: Material Resources, Training and Staffing Recourses. After the intervention, the intervention operating room - compared to the control operating room - reported significantly fewer problems on Material Resources and Staffing Resources and a significantly lower score on perceived incident rate. The contribution of technical factors to incident causation decreased significantly in the intervention group after the intervention.

Conclusion: The change of state of latent risk factors can be measured using a patient safety questionnaire aimed at these factors. The change of the relevant risk factors (Material and Staffing resources) concurred with a decrease in perceived and reported incident rates in the relevant categories. We conclude that interventions aimed at unfavourable latent risk factors detected by a questionnaire focussed at these factors may contribute to the improvement of patient safety in the OR.

Background

Patient safety is one of the greatest imperatives in healthcare today [1]. However, there are many obstacles that must be overcome to make the healthcare system truly safe. This article describes one approach to successful implementation of a patient safety program at the systemic level. A specific strategy for operationalizing a safety program is provided. Through this strategy it is possible to identify and address safety concerns proactively, to develop specific tools and resources that can be used to support an environment of safety and create mechanisms to modify the program in response to patient and staff needs as well as changing priorities. In the contrast between events that are often minor, but salient, and the major, but latent or hidden, systemic weaknesses, most attention has been devoted to the obvious problems. Success here, with individual protocols and techniques, tackles the patient safety problem one issue at a time. This article attempts to attack the deeper-seated underlying problems that, when accurately identified, allow for remedial actions that can impact whole classes of issues simultaneously.

It is increasingly accepted that adverse outcomes are often due to system failures, whereby deficiencies at many different levels create the context in which human error can have a negative impact [2-4]. Studies also have

* Correspondence: M.van_Beuzekom@lumc.nl
[1]OR Centre, Leiden University Medical Centre, 9600, 2300 RC Leiden, the Netherlands
Full list of author information is available at the end of the article

shown that organizational factors contributing to error and to safety can be grouped into a limited number of general failure classes or Latent Risk Factors (LRFs), including such error-producing conditions such as poor design, maintenance failures, unworkable procedures, shortfalls in training, less than adequate tools and equipment and inadequate staffing [5]. For example, nurse understaffing has been ranked by both the public and physicians as one of the greatest threats to patient safety in US hospitals [6]. The identification of LRFs, that may impact the expected course of care and often compromise patient safety, can support a better understanding of the operating room as a system and the identification of system components that influence patient safety [7]. A proactive systems approach to surgical safety suggests that it is necessary to study all aspects of the system that comprises a surgical operation, ranging from such issues as equipment design and use, to communication and team coordination [8,9]. Safety experts argue that proactively reducing such latent risk factors, that increase the risk of error by many individuals, will result in delivering safer care more quickly than taking measures directed, often reactively, at specific individuals [2]. Consistent with the objective of minimal patient harm, safety management in health care should be proactive rather than reactive; that is, broad risks should be anticipated and reduced before patients are harmed rather than waiting to identify specific problems and then attacking them. The question is, how can you identify such risks *before* an incident, rather than waiting for an adverse event or hoping for a report that can uncover a problem?

A proactive error management system, designed to measure and reduce the adverse impact of LRFs within an organization, may provide the answer. Proactive systems work in part by asking people to judge how frequently each of a number of factors such as staffing, supervision, procedures and communication impacts adversely on specific aspects of their work. This type of proactive approach allows the identification of LRFs before they give rise to errors that can compromise patient safety. Such a system may serve not only to reduce error, but also to foster a culture that, by moving away from blaming the individual, encourages reporting, creating a virtuous circle [10]. In the operating room (OR) errors are frequent and often consequential. In reported studies on the incidence of adverse events in hospitals, the largest number occurs in the OR. The proportion of adverse events in the operating room appears to be remarkably stable, comprising approximately 50 % of all adverse events within a hospital [1,11-13]. This suggests that the OR is a domain in which improved safety is an urgent and significant challenge. A critical first step in an improvement process involves systematically addressing those factors contributing to adverse events in the OR. Increased awareness of patient safety issues and the resources that are available to both health care practitioners and consumers can help staff ward off patient safety problems before they occur [14].

Aim of the study

This study is prospective and is concerned with the question whether an intervention, based on a safety program, leads to improvement on latent risk factors and an increase in incident reporting. It was anticipated that concretely addressing LRFs, rather than just a general awareness campaign, will contribute to the prevention of future errors and consequently to improved patient outcomes. This article describes the results of the intervention and gives suggestions for quality improvement initiatives.

Methods

Setting

A pre-test/post-test control group design was used to evaluate the effects of the interventions. The staff from one university hospital operating room acted as the intervention group (I-OR). The control group which received no interventions consisted of the staff of the OR in another university hospital (C-OR). The organizations were located in the Netherlands. At baseline and again at follow-up after 1.5 year all staff (including trainees) and operating room nurses/technicians who had been in their job three months or more were approached and invited to fill out the survey. The study was approved by the Research Ethics Board of the Leiden University Medical Centre (the Netherlands).

LOTS-study

The hypothesis that correcting LRFs, concentrating on systemic rather than individual issues, will result in safer care became the cornerstone of the Leiden Operating Theatre Safety (LOTS) project. This project aims to identify system failures in the OR irrespective of the errors and incidents directly, and to develop and evaluate interventions to reduce those failures, leading to a reduction in errors in the long term.

To assess the OR's resistance to error a comprehensive survey instrument was developed measuring the presence of systemic failures that lie dormant in the working environment of the operating room and intensive care unit - the Leiden Operating Theatre and Intensive Care Safety (LOTICS) scale. It can be used in a pre-test, intervention, post-test design to evaluate the effectiveness of changes brought about in the hospital or a specific unit [15].

Survey instrument

Latent risk factors

The approach taken to assess the state of the individual LRFs is analogous to a health check, assessing a limited number of well-chosen diagnostic vital signs. Items, presented as statements, can be indicators of either potential problems or good practice. Possessing the former or lacking the latter can both be treated as indications that there are latent failures present in a particular LRF. Failure to find indications of problems and possession of the factors that are evidence of good practice can both be treated as indications that there are no latent failures present in a particular LRF.

Latent risk factors were measured with the LOTICS-scale (Additional file 1: appendix 1) [15]. The LOTICS has been validated with respect to factor structure and reliability of the scales, as well as its content and discriminative validity, and measures 11 LRFs with a total of 51 indicator questions: Training (6 items, α = .77; e.g. "In my department, staff are well trained in the use of new equipment"), Staffing Resources (6 items, α = .81; e.g. "In my department, there are enough experienced staff"), Planning & Coordination (3 items α = .75; e.g. "In my department, only short-term plans are made"), Communication (6 items, α = .84; e.g. "Information to perform procedure is available at the time when it is needed"), Material Resources (5 items, α = .75; e.g. "In my department, material/equipment is of insufficient quality"), Maintenance (4 items, α = .81; e.g. "Maintenance inspections are carried out on time"), Design (4 items, α = .78; e.g. "Controls or displays are hard to read"), Quality of Procedures (6 items, α = .79; e.g. "In my department, procedures, rules, and guidelines are often not feasible in practice"), Teamwork (4 items, α = .74; e.g. "Members of my team work well together during the operation "), Team Instruction (3 items, α = .80; e.g. "Team members receive sufficient instructions during the operation"), and Situational Awareness (4 items, α = .77; e.g. "There is sufficient information exchange during the surgery"). Respondents indicate their agreement on a 4-point rating scale (1 = *strongly disagree*, 4 = *strongly agree*). The same scalar structure was presented throughout the questionnaire, and then adjusted post-hoc. For all LFRs, negatively formulated items were recoded so that a higher score always indicates more favorable perceptions about organizational and environmental conditions of work.

Perceived incident rate

In this study, incidents are defined as all safety-related events including accidents (with negative outcomes such as damage and injury), near misses (where an accident could have happened had there been no timely and effective recovery) and errors (no harm events). We asked respondents to report how often errors, near-misses and accidents occurred in their departments. The three items were scored on a six-point scale ranging from 1 (never) to 6 (very frequently), with a higher score indicating a greater perception of incidents.

The questionnaire has an additional demographic section where respondents fill in their department or ward, job tenure on current ward (1 = <1 year, 2 = 1-5 years, 3 = 6–10 years, and 4= > 10 years), age and gender.

Finally, participants were asked about the organizational and environmental conditions that affect patient safety in their department and the possible remediable action alternatives for addressing them.

Incident reporting

Incident data were collected and then systematically analysed using the Prevention and Recovery Information System for Monitoring and Analysis (PRISMA) - Medical method over a 12-month period before and after the intervention [16]. The PRISMA method is based on the so-called system approach to the problem of human error and therefore concentrates on the conditions under which individuals work. It was originally developed in and for the steel industry and has been applied successfully in the medical domain [16,17]. Key components are an in-depth incident analysis to detect causal factors, and the Eindhoven Classification Model to classify the root causes found into technical, organizational, human, and patient related factors.

Intervention

A multidisciplinary safety committee (surgeons, anesthetists, operating room and recovery nurses) was created to improve incident reporting and to develop a number of measures aimed at the LRFs which need improvement.

The level of reporting of incidents was considered to be an important factor of the safety program. To improve the quality and completeness of reporting incidents and to achieve a general raising of awareness of patient safety problems we developed and implemented a voluntary electronic/web based reporting system and provided feedback to demonstrate the value of reporting by showing its effects on organizational culture and patient safety. Feedback was always provided at team level. In case of serious incidents there was also feedback at the individual level. All reports were reviewed by safety committee members, and selected reports were discussed during the monthly meetings. When required, reports were further analyzed by individual committee members according to their expertise.

The results of the pre-test formed the basis for the choice of interventions. Based on these results (see Table 1) the following LRFs were considered best targets for intervention: Communication, Material Resources, Training, Planning, and Staffing Resources. Compared to the other LRFs respondents in I-OR scored less favorably

Table 1 Mean LOTICS scores and perceived incident rate at pre-test compared for the I-OR and the C-OR (t-tests)

LRFs of LOTIC-scale	I- OR N = 111 C-OR N =82	Mean	*SD*	t	df	*P*	95 %	CI
Communication	I-OR	2.43	.43	-3.00	186	**.003**	-.055	.12
	C-OR	2.61	.39					
Design	I-OR	2.95	.32	.07	182	.942	-.017	.14
	C-OR	2.94	.38					
Maintenance	I-OR	2.78	.53	-1.88	174	*.061*	-.16	.06
	C-OR	2.92	.40					
Material Resources	I-OR	2.59	.35	.33	185	.745	.09	.25
	C-OR	2.57	.39					
Planning & Coordination	I-OR	2.71	.37	-2.25	183	**.026**	-.04	.13
	C-OR	2.83	.37					
Teamwork	I-OR	2.91	.32	-.33	186	.740	.07	.19
	C-OR	2.93	.29					
Procedures	I-OR	2.72	.33	-.82	184	.415	-.04	.09
	C-OR	2.74	.33					
Situation Awareness	I-OR	2.85	.41	.96	182	.338	.12	.31
	C-OR	2.79	.44					
Team instructions	I-OR	2.84	.40	-.10	178	.924	.12	.26
	C-OR	2.84	.33					
Training	I-OR	2.67	.45	-2.36	187	**.019**	-.05	.12
	C-OR	2.82	.38					
Staffing Resources	I-OR	2.71	.46	-187	100	.793	-.02	.16
	C-OR	2.81	,30					
Perceived incident rate	I-OR	3.97	.58	-.12	178	.901	-.02	.16
	C-OR	3.98	.56					

Significant values are shown in bold.

on these LRFs. On three of these LRFs, i.e. Communication, Planning and Training, the I-OR scored even lower than the C-OR (see Table 1).

At baseline we asked participants about their concerns on patient safety in their department. A number of issues related to the LRFs studied were named. On average, three times more issues were identified for LRFs with unfavourable scores than for LRFs with favourable scores. In I-OR most problems concerned Training, Material Resources, and Staffing Resources. Given these findings and to create as much possible involvement for the intervention we decided to focus on these three LRFs. However we realized that an intervention can have effects on other LRFs beyond the three selected, because changes do not occur in isolation. Moreover, in the literature, Material Resources, Training and Staffing Resources are mentioned as important contributors to medical errors [18,19].

Material resources (1) Surgical adverse events are often attributable to technique-related procedures that occur during the operation, many of which are considered preventable [20] [21]. Variations in equipment in its use increase the likelihood of error [22]. People may be more willing to violate safety rules because the material does not function in the way it is supposed to do, either because of poor maintenance or because of faulty design.

Training (2) Lack of training and experience are also mentioned as sources of medical errors, although these causes are usually not directly documented in studies of errors and incidents. Training has, however, been shown to decrease incident rates and increase the ability to solve problems, particularly for inexperienced professionals [23-25].

Staffing resources (3). There is little published work examining the relationship between workload and either quality or safety of anaesthetic care [26]. Staff often forms the last layer of defence for error occurrence and understaffing or insufficient staffing is a threat to patient safety in the OR [27]. Adequate staffing is fundamental to quality care; evidence is mounting that increasing the number of registered nurses results in better patient safety [28]. Higher staffing levels are associated with lower mortality outcomes in UK hospitals [29].

We started the intervention with a training session to show which errors are made in the operating room and how they can be traced back to latent risk factors. In addition, sessions were held to introduce the new

Table 2 Safety program

Awareness	To create awareness about safety, a symposium about safety was organized. Topics were: the system approach to human error safety problems in the OR and incident reporting
Error reporting	A local committee of the department's anaesthesiology and surgery was set. Introduction of an electronic incident reporting management system accessible to all staff and easy to use. Providing feedback to demonstrate that reporting leads to changes. Errors were discussed in the team meetings. Every month a newsletter was distributed with information on reported errors. and measures taken promoting report of near misses and errors.
Material Resources	Inventory of all equipment and supplies of anaesthesia and surgery. Standardization of equipment and supplies in anaesthesia and surgery for all equipment development of manuals with a uniform design.
Training	Training of all OR staff in the use of equipment.
Staffing Resources	Increasing participation in decision making. Introduction of frequently held staff meeting, at least once a month. Increasing job autonomy shifting for a specific task responsibility and control from supervisor to staff. Responsibility for safety in the working environment. Intervision for registered nurses. Personal coaches assigned to trainees. Social activities to promote team building. More trainees were trained.

electronic reporting system. Subsequently, an exercise involving standardization of materials and equipment was performed. All OR staff then received training for all the equipment used during operations. Parallel to this, a program aimed at improving nurse retention was carried out focussing on work climate characteristics like participation in decision making, job autonomy and social support. The content of the safety program is described in Table 2.

Statistical analyses

The data were analysed using the statistical software package SPSS version 16. Negatively worded items were reverse scored so that their valence matched the positively worded items. T-tests were used to assess differences at pre-test between the intervention (I-OR) and control group (C-OR). Chi square analyse was used for gender and reported incidents. As a means of assessing the effects of the interventions, analyses of covariance (ANCOVA) were carried out. In the ANCOVAs, age, gender, job tenure on current ward, and pre-test scores on LRFs and perceived incident rate were used as covariates.

Participation and dropout

Baseline response rate was 59 %; 193 (I-OR 111 and C-OR 82) out of 327 questionnaires were returned. The response rate at post-test was 62 %; 205 (I-OR 108 and C-OR 97) out of 333 questionnaires were returned. Of the 111 professionals in I-OR and the 82 professionals in C-OR who filled out the questionnaire at baseline, 62 in I-OR and 40 in C-OR participated at follow-up as well. At both points of measurement there were no significant differences in demographic characteristics between respondents and non-respondents. For both I-OR and C-OR applies that there were no significant differences between subjects participating only in the first or the second measurement and those who took part in both measurements on demographic characteristics, LRF scores and perceived incident rate. There was just one exception; at the pre-test in C-OR staff who participated in both measurements reported more favorable on Team Instructions than staff who participated only in the first measurement.

Comparing I-OR with C-OR at pre-test on demographic characteristics, LRFs, and perceived error rate

Table 3 Demographic characteristics of the participants in the I-OR and C-OR at pre- and post-test

Pre-test	**I-OR N = 110**	**C-OR N = 82**	**t**	**95 %CI lower**	**upper**	***P***
Age	35.4 (10.9)	40.8 (9.4)	-3.26 (1,187)	-7.95	-1.958	.001
Employment status (hours)	31.4 (9.3)	31.1 (11.7)	.205 (1,185)	-2.70	3.32	.868
Job tenure	2.7 (99)	3.2 (1.02)	-.3.32 (1,185)	-.87	-1.88	.001
Gender	11 % male 89 % female	36 % male 72 % female	χ2 16.75			<.01
Post-test	I-OR n = 108	C-OR n = 97	t	95 %CI lower	upper	*P*
Age	36.2 (11.4)	40.3 (11.3)	-2.602- (1,202)	-7.30	-1.006	.010
Employment status (hours)	30.8 (10)	31.2 (9.93)	-.278(1, 202)	-3.16	2.38	.781
Job tenure	2.8 (94)	2.8 (.93)	.146 (1,203)	-.278	.240	.884
Gender	10 % male 90 % female	23 % male 67 % female	χ2 5.907			<.05

resulted in significant differences for years of employment and age (Table 3). Staff in the intervention group was younger, had shorter job tenure and are more often female. For this reason, age, job tenure on current ward, and gender were entered as covariates in all effect analyses for the group who took part in both measurements. At the pre-test I-OR differed from C-OR on three of the dependent variables: Communication, Planning & Coordination, and Training (Table 1). Staff in I-OR reported less favourable on each of these LRFs than staff in C-OR.

Effects of intervention

First, changes over time in the I-OR were analyzed by comparing the results of all staff who took part at baseline with those of all staff who took part at follow-up. The results of the t-tests, pre- and post-test mean scores on LRFs and perceived incident rate for I-OR and C-OR are shown in Table 4.

The I-OR rated more favorably on Staffing Resources and Material Resources at follow-up than at baseline. For the other LRFs no statistically significant changes over time were found, except for communication. This LRF scored in the I-OR less favorably at follow-up than at baseline. Finally, the I-OR scored significantly lower on perceived incident rate at follow-up than at baseline. At follow-up the C-OR rated more favorably on Design and less favorably on Staffing Resources than at baseline.

Second, separate univariate ANCOVAs were conducted, using data from staff that participated in both measurements, to test if there had been a different development in the I-OR compared to the C-OR from pre- to post-test. The intervention had focused on three LRFs: Material Resources, Training and Staffing Resources. So, we expected at follow-up higher scores on these LRFs in I-OR, indicating fewer problems, than in C-OR. Consistent with our expectations, there was a positive effect of the intervention aimed at Staffing Resources. When pre-test scores, age, gender, and job tenure were used as covariates, a significant effect over time was found between the I-OR and the C-OR. (Table 5). Staffing resources improved in the I-OR but worsened in the C-OR from pre-test to post-test measurement (Figure 1). There was also a positive effect of the intervention aimed at Material Resources. When pre-test scores, age, gender, and job tenure, were used as covariates, a significant difference was found on Material Resources to the advantage of the I-OR (Figure 2). The intervention aimed at Training was not significant. When pre-test scores, age, gender, and job tenure, were used as covariates, there was no significant difference between the I-OR and the C-OR on Training over time.

We also expected in I-OR a decrease in perceived incident rate. The results indeed support our hypothesis showing a significant difference between the I-OR and the C-OR in perceived incident rate over time when pre-test scores, age, gender, and job tenure were used as covariates. There was a decrease in perceived incident rate in the I-OR (Figure 3) while perceived incident rate did not change in the C-OR.

The number of reported incidents multiplied with a factor 2.4 between the pre/post intervention period. In the year before the intervention there were 250 reported errors. Of these errors 80.8 % were classified as human, 8.8 % as technical, 9.6 % as organizational, and 0.8 % as patient related. In the year after the intervention the number of reported errors increased to 629 of which were 83.9 % human, 3.7 % technical, 10.8 % organizational, and 0.95 % patient related. The increase in reported incidents was mainly due to an increase in the number of reported near misses and errors. The decrease in the contribution of technical causes, referring to physical items such as equipment, materials, instrumentation, installations, labels and forms, from 8.8 % to 3.7 % was significant ($p = .001$).

Table 4 Mean LOTICS scores and perceived incident rate at pre-test compared for the I-OR and C-OR at post-test (t-tests)

LRFs of LOTIC-scale		I-OR n = 108	C- OR n = 97	t	df	P	95 % CI	
Communication	pre	2.43	2.61					
	post	2.38	2.57	-3.42	203	**.001**	-.306	-.082
Design	pre	2.95	2.94					
	post	2.99	3.03	-.749	203	.455	-.028	.058
Maintenance	pre	2.78	2.92					
	post	2.91	2.94	-.515	193	.607	-.143	.084
Material Resources	pre	2.59	2.57					
	post	2.72	2.53	3.602	202	**.000**	.085	.290
Planning & Coordination	pre	2.71	2.83					
	post	2.78	2.83	-.911	201	.363	-.143	.052
Teamwork	pre	2.91	2.93					
	post	2.93	2.92	.160	201	.873	-.091	.107
Procedures	pre	2.72	2.74					
	post	2.69	2.70	-.392	202	.696	-.103	.69
Situation Awareness	pre	2.85	2.79					
	post	2.82	2.83	-.264	192	.792	-.143	.109
Team instructions	pre	2.84	2.84					
	post	2.84	2.81	.565	190	. 573	-.087	.157
Training	pre	2.67	2.82					
	post	2.81	2.82	-.228	203	.820	-.114	.091
Staffing Resources	pre	2.71	2.81					
	post	2.84	2.73	1.989	203	**.048**	.001	.215
Perceived incident rate	pre	3.97	3.98					
	post	3.59	3.96	-4.079	202	**.000**	-.551	-.192

Significant values are shown in bold.

Table 5 Comparison of I-OR and C-OR by separate univariate ANCOVAs (repeated measures) with pre-test scores, age, gender and job tenure as covariates

LRFs of LOTIC-scale		I-OR n = 62	C- OR n = 40	F ratio	*P*
Communication	pre	2.48	2.54	3.07	.083
	post	2.35	2.54		
Design	pre	2.94	2.96	0.26	.872
	post	2.99	2.95		
Maintenance	pre	2.81	2.98	2.43	.122
	post	2.94	2.94		
Material Resources	pre	2.60	2.51	8.38	**.005**
	post	2.73	2.50		
Planning & Coordination	pre	2.75	2.78	2.14	.147
	post	2.83	2.73		
Teamwork	pre	2.93	2.86	.167	.684
	post	2.95	2.86		
Procedures	pre	2.68	2.72	0.41	.525
	post	2.66	2.70		
Situation Awareness	pre	2.84	2.71	1.90	.171
	post	2.78	2.77		
Team Instruction	pre	2.87	2.75	0.73	.788
	post	2.84	2.74		
Training	pre	2.72	2.77	1.61	.207
	post	2.80	2.74		
Staffing Resources	pre	2.70	2.72	10.3	**.002**
	post	2.81	2.58		
Perceived Incident rate	pre	3.93	3.96	5.45	**.02**
	post	3.53	3.88		

Significant values are shown in bold.

Discussion

The study shows that our intervention aimed at Material resources, Training and Staffing resources resulted in demonstrable changes of scores on two of the relevant LOTICS scales. This type of intervention can provide direct benefits to the staff of an OR, because the changes on the working environment were both visible and resulted in improvement in task performance and are therefore likely to be accepted.

The philosophy underlying the development of the LOTICS scale is that interventions should address broad categories of error types (the underlying pathology) rather than individual symptoms. Given this approach, the intervention aimed at improving material resources was based on the concept of standardization. Standardization is a concept well understood by other safety critical industries that value the benefit of lightening the mental burden on staff and users to allow them to concentrate better on the job at hand [30]. In aviation the standardization and disciplined use of procedures, termed SOPs (Standard Operating Procedures) is widely argued to be the most critical factor distinguishing between good and poor outcomes in aviation incidents [31] and could be adapted to the OR to develop protocols that minimize the influence of competing tasks and high workload. Standardization of material and equipment further results in the reduction of costs of operation, in maintenance, repair, storage, and simplified issue procedures. As part of the process in I-OR to standardize and streamline instrumentation and equipment, including locations, old and/or less user-friendly

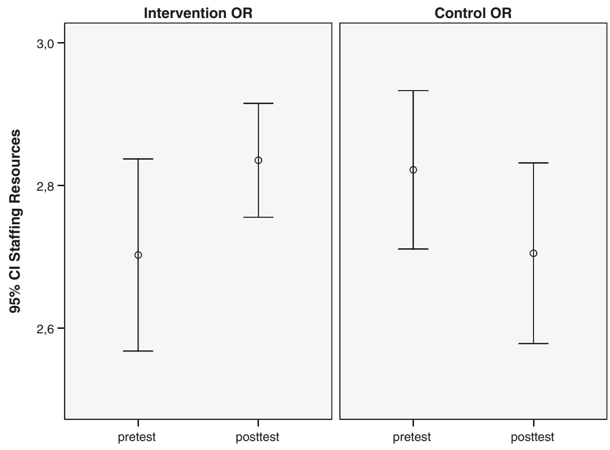


Figure 1 Significant differences between I-OR (1) and C-OR (2) on pre and post-test scores: Staffing resources.

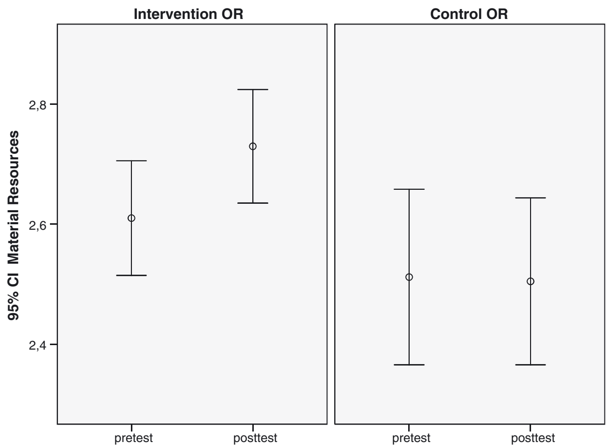


Figure 2 **Significant differences between I-OR (1) and C-OR (2) on pre and post-test scores: Material resources.**

apparatus was replaced, missing items were purchased and manuals with a uniform design were developed. This improvement (at a general level) should and did affect responses to specific test items referring to, amongst others, the availability of equipment, their quality, timely repair and replacement. Moreover, after the intervention PRISMA identified technical factors to be significantly less important as causes of incidents.

Understaffing is one of the greatest threats to patient safety. Staff are often the last layer of defence for any error occurrence and particularly the proportion of professional nursing staff has an effect on patient safety [25,32,33]. At the time of the pre-test there were shortages in OR personnel in 14 out of the 60 (23 %) Dutch hospitals investigated [33]. One of the reasons for understaffing in the Netherlands is that working in healthcare is found to be less appealing [34,35]. To limit turnover and to attract new personnel we need to enhance the attractiveness of the profession. To investigate how this can be achieved we designed and evaluated a number of intervention programs. These programs focused on the enhancement of well-studies work climate characteristics: participation in decision making, job autonomy and social support. Employee perceptions of

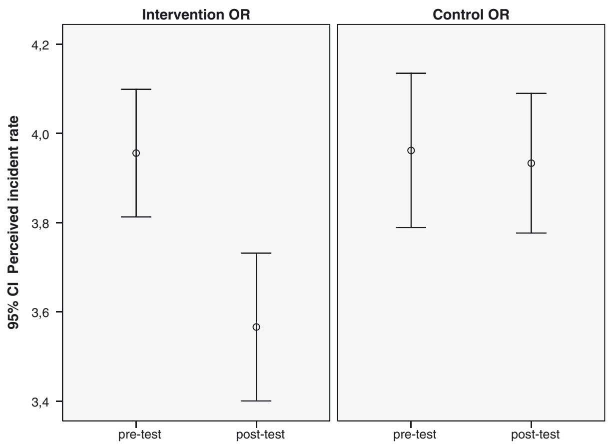


Figure 3 **Significant differences between I-OR (1) and C-OR (2) on pre and post-test on perceived incident rate.**

these characteristics have been linked to various stressors, and a number of individual and organizational outcome variables [36]. In addition to the focus on work climate characteristics more training opportunities were created so that more trainees could be qualified. As expected the interventions turned out to result in higher scores in I-OR compared to C-OR on aspects like the amount of staff to provide good care and the amount of experienced staff.

Staff turnover rate in I-OR decreased from 9.4 % in the year before the intervention to 5.1 % in the year after the intervention. Although we realize that turnover is determined by many factors, including labor market, it is likely that some of this decline can be attributed to the interventions.

Change can be a complex and drawn-out process that depends on a variety of contextual factors. The OR is a highly compartmentalized department structure which brings together members from multiple disciplines whose training and professional goals vary. Lack of communication between operating room personnel is common [37]. Most surgical errors are not attributable to an individual but involve multiple personnel and steps; approximately 43 % of errors are due to poor communication [20]. During the intervention in the OR we actually saw an increase in reported problems with communication. When communication problems do occur, they are found most often between different professional members of a team, such as between anaesthesiologist and surgeon or between nurses and doctors [38].The staff of the I-OR indicated that they needed more information to do their tasks. A tentative explanation for this result could be that having created heightened awareness about safety issues, the staff was more alert to the communication problems they experienced.

The importance of incident reporting is widely recognized [10,39]. Unfortunately, reporting is grossly incomplete. After the intervention, incident reporting rates in I-OR increased significantly compared with pre intervention rates. We realize that it is difficult to deduce from this result whether the 2.4x change in error reporting reflects a change in report behaviors with actual rates remaining constant or whether the 2.4x change in error reports reflects an increase in error rates despite the intervention. Various studies, however, showed that as an institution improves in the care it delivers and its safety culture more problems may be reported since open reporting is a tenet of safe practice [40]. Increased incident reporting rates may not be indicative of an unsafe organization, but may reflect a shift in organizational culture [41]. In this context it is important to note that the total number of reported incidents more than doubled while the contribution of technical factors to incident causation remained constant.

The propensity to report is probably further strengthened in our study by the implementation of the electronic report system. Various studies showed that an accessible and easy to use reporting system [42], the understanding that the reports will be handled in a non-punitive manner [43], and the notion that the reports are taken seriously and will lead to enhanced learning and systematic changes which will prevent it from recurring [44], positively affects the willingness to report incidents. The empirical findings in this and other studies, taken as a whole, suggest that our result, an increase in incident reporting in I-OR, reflects a change in report behaviors rather than an increase in incident rates.

We believe that this work can contribute to patient safety initiatives and research in two ways: (1) our experience provides detailed insight in the latent risk factors, (2) our findings suggest that the methodology used in the study shows promise as a method for evaluating changes in the quality and safety of care in the operating rooms. Changing culture is a new watchword in patient safety [45]. The willingness of staff to speak up about a patient-safety concern is an important part of safety in the operating room [46]. Therefore there needs to be a culture of openness [47]. We think a first step is this approach is to build a strong foundation of safety awareness among your staff and this may best be done by implementing concrete and visible improvements. We think staff perceptions of safety are a high priority issue within the OR, which will eventually motivate staff to take greater ownership of and responsibility for patient safety.

Limitation

In the present study the intervention addressing training did not result in a significant improvement. This may have been due to a failure to address the problem at a deeper level, that is, the deficiencies in the business process behind the detected indicators. It is conceivable that the intervention attacked the problem at a 'symptom curing' level the training of the use of new equipment. As a result, this intervention may not have remedied problems at a systemic level, as revealed by the responses to test items referring to various other aspects of the training procedure.

Safety questionnaires are increasingly used in healthcare for assessment of safety issues, but they differ in the scope and extent. Sexton and co-workers developed a safety attitudes questionnaire that was validated over a wide range of clinical areas (ICU, OR, inpatient settings and ambulatory clinics) and 3 countries and administered to a large study group [48]. The factors identified by their questionnaire were teamwork climate, safety climate, perception of management, job satisfaction, working conditions and stress recognition. They claim that the results could be used to benchmark organizations and to measure effectiveness of interventions. Similar safety questionnaires have been used by others to access teamwork and safety climate in hospitals and nursing units [49,50].

Compared to their study our study was limited to a smaller group of disciplines and settings. Furthermore our questionnaire was more limited in scope and more directed to a limited set of factors that we connected to latent risk factors (LRFs), as identified in incident analysis. But a major difference is that those LRFs assessed enabled a much more concrete identification of measures for intervention, as compared with abstract factors like the perception of management, job satisfaction and safety climate, while still providing a way of assessing pre- and post-intervention values. There is still much work required before we are able to understand the full value of using climate questionnaires in health care, as Pronovost and Sexton have [51] have recently pointed out.

Conclusion

The change of state of LRFs can be measured using a patient safety questionnaire aimed at these factors. The change of the relevant risk factors (material and staffing resources) concurred with a decrease in perceived and reported error rates in the relevant categories. We conclude that interventions aimed at unfavourable latent risk factors detected by a questionnaire focussed at these factors may contribute to the improvement of patient safety in the OR.

Additional file

Additional file 1: Appendix 1. LOTICS scale .

Abbreviations

ANCOVA: Analyse of covariance; C: Control; ICU: Intensive care unit; I: Intervention; LRFs: Latent risk factors; LOTS: Leiden operating theatre safety; LOTICscale: Leiden operating theatre and intensive care safety scale; OR: Operating room; PRISMA: Prevention and recovery information system for monitoring and analysis; SOP: Standard Operating Procedure.

Competing interests

The authors declare that they have no competing interests

Acknowledgements

The authors thank the employees of the operating rooms for their cooperation in the study. We are grateful for the advice from Dr. W. La Heij with whom we discussed this manuscript.

Author details

[1]OR Centre, Leiden University Medical Centre, 9600, 2300 RC Leiden, the Netherlands. [2]Department of Anaesthesiology, Leiden University Medical Centre, 9600, 2300 RC Leiden, the Netherlands. [3]Department of Psychology, Leiden University, 95555 Leiden, the Netherlands. [4]Department of Safety Science, Delft University, of Technology, Jaffalaan 5, 2628BX Delft, the Netherlands.

Author's contribution

MvB, FB, SA were involved with study development, co-ordination and data collection and writing the article. MvB, SA were involved with data analysis. PH has been involved in drafting the manuscript, and revising it. All authors read and approved the final manuscript.

Received: 28 March 2011 Accepted: 22 June 2012
Published: 22 June 2012

References

1. To Err Is Human: *Building a Safer Health System*. Washington DC: National Academy Press; 2000.
2. Reason J: *Managing the Risks of Organizational Accidents*. Hampshire, England; 1997.
3. Cook R, Rasmussen J: "Going solid": a model of system dynamics and consequences for patient safety. *Qual Saf Health Care* 2005, **14**:130–134.
4. Amalberti R, Auroy Y, Berwick D, Barach P: Five system barriers to achieving ultrasafe health care. *Ann Intern Med* 2005, **142**:756–764.
5. van Beuzekom M, Boer F, Akerboom S, Hudson P: Patient safety: latent risk factors. *Br J Anaesth* 2010, **105**:52–59.
6. Blendon RJ, DesRoches CM, Brodie M, Benson JM, Rosen AB, Schneider E, *et al*: Views of practicing physicians and the public on medical errors. *N Engl J Med* 2002, **347**:1933–1940.
7. Christian CK, Gustafson ML, Roth EM, Sheridan TB, Gandhi TK, Dwyer K, *et al*: A prospective study of patient safety in the operating room. *Surgery* 2006, **139**:159–173.
8. Calland JF, Guerlain S, Adams RB, Tribble CG, Foley E, Chekan EG: A systems approach to surgical safety2. *Surg Endosc* 2002, **16**:1005–1014.
9. Vincent C, Moorthy K, Sarker SK, Chang A, Darzi AW: Systems approaches to surgical quality and safety: from concept to measurement. *Ann Surg* 2004, **239**:475–482.
10. Lawton R, Parker D: Barriers to incident reporting in a healthcare system. *Qual Saf Health Care* 2002, **11**:15–18.
11. Brennan TA, Leape LL, Laird NM, Hebert L, Localio AR, Lawthers AG, *et al*: Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I. *N Engl J Med* 1991, **324**:370–376.
12. Gawande AA, Thomas EJ, Zinner MJ, Brennan TA: The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery* 1999, **126**:66–75.
13. Wilson RM, Runciman WB, Gibberd RW, Harrison BT, Newby L, Hamilton JD: The Quality in Australian Health Care Study. *Med J Aust* 1995, **163**:458–471.
14. Catalano K: Knowledge is Power: Averting Safety-Compromising Events in the OR. *AORN J* 2008, **88**:987–995.
15. Van Beuzekom M, Akerboom SP, Boer F: Assessing system failures in operating rooms and intensive care units. *Qual Saf Health Care* 2007, **16**:45–50.
16. Snijders C, van der Schaaf TW, Klip H, van Lingen WPFF, Molendijk A: Feasibility and reliability of PRISMA-medical for specialty-based incident analysis. *Qual Saf Health Care* 2009, **18**:486–491.
17. Schaaf van der TW: A framework for designing near miss management systems. In *Near Miss Reporting as a Safety Tool*. Edited by Schaaf van der TW, Lucas DA, Hale AR. Oxford: Butterworth-Heinemann; 1991.
18. Wubben I, van Manen JG, van den Akker BJ, Vaartjes SR, van Harten WH: Equipment-related incidents in the operating room: an analysis of occurrence, underlying causes and consequences for the clinical process. *Qual Saf Health Care* 2010, **19**:e64.
19. Rogers AE, Hwang WT, Scott LD, Aiken LH, Dinges DF: The working hours of hospital staff nurses and patient safety. *Health Aff (Millwood)* 2004, **23**:202–212.
20. Gawande AA, Zinner MJ, Studdert DM, Brennan TA: Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 2003, **133**:614–621.
21. Wiegmann DA, ElBardissi AW, Dearani JA, Daly RC, Sundt TM III: Disruptions in surgical flow and their relationship to surgical errors: An exploratory investigation. *Surgery* 2007, **142**:658–665.
22. Arnstein F: Catalogue of human error. *Br J Anaesth* 1997, **79**:645–656.
23. Chopra V, Gesink BJ, de JJ, Bovill JG, Spierdijk J, Brand R: Does training on an anaesthesia simulator lead to improvement in performance? *Br J Anaesth* 1994, **73**:293–297.

24. Straight M: One strategy to reduce medication errors: the effect of an online continuing education module on nurses' use of the Lexi-Comp feature of the Pyxis MedStation 2000. *Comput Inform Nurs* 2008, **26**:23–30.
25. Aiken LH, Clarke SP, Cheung RB, Sloane DM, Silber JH: Educational levels of hospital nurses and surgical patient mortality. *JAMA* 2003, **290**:1617–1623.
26. Leedal JM, Smith AF: Methodological approaches to anaesthetists' workload in the operating theatre. *Br J Anaesth* 2005, **94**:702–709.
27. Alfredsdottir H, Bjornsdottir K: Nursing and patient safety in the operating room. *J Adv Nurs* 2008, **61**:29–37.
28. Needleman J, Buerhaus P: Nurse staffing and patient safety: current knowledge and implications for action. *Int J Qual Health Care* 2003, **15**:275–277.
29. Price LC, Lowe D, Hosker HS, Anstey K, Pearson MG, Roberts CM: UK National COPD Audit 2003: Impact of hospital resources and organisation of care on patient outcome following admission for acute COPD exacerbation. *Thorax* 2006, **61**:837–842.
30. Hales BM, Pronovost PJ: The checklist–a tool for error management and performance improvement. *J Crit Care* 2006, **21**:231–235.
31. Degani A, Wiener EL: Procedures in complex systems: the airline cockpit. *IEEE Trans Syst Man Cybern A Syst Hum* 1997, **27**:302–312.
32. Aiken LH, Clarke SP, Sloane DM, Sochalski J, Silber JH: Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *JAMA* 2002, **288**:1987–1993.
33. Adams A, Bond S: Staffing in acute hospital wards: part 1. The relationship between number of nurses and ward organizational environment. *J Nurs Manag* 2003, **11**:287–292.
34. Meeusen VC, van DK, Brown-Mahoney C, van Zundert AA, Knape HT: Work climate related to job satisfaction among Dutch nurse anesthetists. *AANA J* 2011, **79**:63–70.
35. Van Beuzekom M, Boer F: A comparison of US, UK, and Dutch perioperative staffing practices. *AORN J* 2006, **84**:632–641.
36. Rathert C, May DR: Health care work environments, employee satisfaction, and patient safety: Care provider perspectives. *Health Care Manage Rev* 2007, **32**:2–11.
37. Lingard L, Espin S, Whyte S, Regehr G, Baker GR, Reznick R, *et al*: Communication failures in the operating room: an observational classification of recurrent types and effects. *Qual Saf Health Care* 2004, **13**:330–334.
38. Helmreich RL: Team Performance in the Operating Room. In *Human Error in Medicine*. Edited by Bogner SM. Hillsdale: Lawrence Erlbaum Associates; 1994:225–253.
39. Mahajan RP: Critical incident reporting and learning. *Br J Anaesth* 2010, **105**:69–75.
40. Hutchinson A, Young TA, Cooper KL, McIntosh A, Karnon JD, Scobie S, *et al*: Trends in healthcare incident reporting and relationship to safety and quality data in acute hospitals: results from the National Reporting and Learning System. *Qual Saf Health Care* 2009, **18**:5–10.
41. Connolly CK: Reducing error, improving safety. Relation between reported mishaps and safety is unclear. *BMJ* 2000, **321**:505–506.
42. Benn J, Koutantji M, Wallace L, Spurgeon P, Rejman M, Healey A, *et al*: Feedback from incident reporting: information and action to improve patient safety. *Qual Saf Health Care* 2009, **18**:11–21.
43. Vincent C, Stanhope N, Crowley-Murphy M: Reasons for not reporting adverse incidents: an empirical study. *J Eval Clin Pract* 1999, **5**:13–21.
44. Wallace LM, Spurgeon P, Benn J, Koutantji M, Vincent C: Improving patient safety incident reporting systems by focusing upon feedback - lessons from English and Welsh trusts. *Health Serv Manage Res* 2009, **22**:129–135.
45. Frankel A, Gandhi TK, Bates DW: Improving patient safety across a large integrated health care delivery system. *Int J Qual Health Care* 2003, **15**(Suppl 1):i31–i40.
46. Makary MA, Sexton JB, Freischlag JA, Holzmueller CG, Millman EA, Rowen L, *et al*: Operating room teamwork among physicians and nurses: teamwork in the eye of the beholder. *J Am Coll Surg* 2006, **202**:746–752.
47. Reason JT: *Human Error*. Cambridge U.K.: Cambridge University Press; 1990.
48. Sexton JB, Helmreich RL, Neilands TB, Rowan K, Vella K, Boyden J, *et al*: The Safety Attitudes Questionnaire: psychometric properties, benchmarking data, and emerging research. *BMC Health Serv Res* 2006, **6**:44.
49. Hutchinson A, Cooper KL, Dean JE, McIntosh A, Patterson M, Stride CB, *et al*: Use of a safety climate questionnaire in UK health care: factor structure, reliability and usability. *Qual Saf Health Care* 2006, **15**:347–353.
50. Zohar D, Livne Y, Tenne-Gazit O, Admi H, Donchin Y: Healthcare climate: a framework for measuring and improving patient safety. *Crit Care Med* 2007, **35**:1312–1317.
51. Pronovost P, Sexton B: Assessing safety culture: guidelines and recommendations. *Qual Saf Health Care* 2005, **14**:231–233.

doi:10.1186/1471-2482-12-10

Cite this article as: van Beuzekom *et al.*: Patient safety in the operating room: an intervention study on latent risk factors. *BMC Surgery* 2012 **12**:10.

5

Influence of Latent Risk Factors on job satisfaction, job stress and intention to leave in anaesthesia teams: a cross-sectional survey

Martie van Beuzekom[1], Simone Akerboom[2], Fredrik Boer[1], Albert Dahan[1]

[1]Department of Anaesthesiology, Leiden University Medical Centre, P.O. Box 9600, 2300 RC Leiden the Netherlands
[2] Department of Psychology, Leiden University, P O Box 95555. Leiden the Netherlands

Eur J Anaesthesiol, submitted 2012

Introduction

Current thinking about patient safety emphasizes the causal relationship between working conditions, hereinafter referred to as Latent Risk Factors (LRFs), and the quality of patient care. Breakdown of environmental (i.e., material and equipment), social (i.e., teamwork and communication) or organizational factors (i.e., training and procedures) have been reported to relate to errors that impact performance.[1-3]

Research has shown that LRFs can also adversely affect employee health and well-being.[4-7] A plausible account for such a relationship lies in action regulation theory, postulating that conditions in the environment that tax regulation capacity can lead to regulation problems in attaining task-related goals.[8] The anticipated or experienced threat that task-related goals can not be fulfilled may generate stress, leading to strain, dissatisfaction and/or other negative outcomes.

Most studies on LRFs and worker outcomes focused on the impact of only one or a few factors, for instance either teamwork[9], work procedures[10] or communication.[11] Consequently, little is known about the relative importance of LRFs to employee health and well-being. In addition, research on this topic among anaesthesia teams is scarce, and has focused primarily on anaesthetists.[6;9] Gaining a better understanding of the extent to which LRFs impact on the well-being of anaesthesia staff is worthwhile, because the Operating Theatre is known to be a safety-critical as well as stressful environment.[2;9]

The aim of this study was to examine the relationship of various LRFs to job satisfaction, job stress and intention to leave among anaesthetists, as well as for trainees in anaesthesia and nurse anaesthetists. Considering the differences in work practices, goals, priorities and behaviours between the different professions of the anaesthesia team, we hypothesized that LRFs are perceived differently by these professions and that the LRFs predictive of the outcome variables vary depending on profession.

Methods

Sample and procedure

The study was approved by the Research Ethics Board (LUMC, Leiden, The Netherlands). Specialist anaesthetists, trainee anaesthetists and nurse anaesthetists from three university hospitals in the Netherlands were approached and invited to participate in the study.

Excluded were participants who had an internship outside their workplace. Postal questionnaires were sent to their work address. A pre-paid response envelope and a letter to explain the purpose of the study and give assurance of confidentiality were enclosed with the questionnaire.

Base-line characteristics

The respondents provided information about the following demographic variables: gender (1 = men, 2 = women), age (in years), working hours (in hours), and years in current hospital (1 < 1 year, 2 = 1 – 5 years, 3 = 6 – 10 years, 4 > 10).

Independent Variables

Latent Risk Factors were measured with the Leiden Operating Theatre and Intensive Care Safety (LOTICS) scale that captures various workplace barriers to safe work practices and safety-critical interpersonal aspects of performance. The LOTICS has been validated with respect to factor structure and reliability of the scales, as well as its content and discriminative validity.[12] In this study, the following LRFs were measured: Training, Access to Information, Planning & Coordination, Teamwork, Team Instruction, Situational Awareness, Hierarchy, Material Resources, Maintenance, and Procedures (Table 1). Items, presented as statements, were indicators of either potential problems or good practice. Respondents indicated the extent to which they agreed with each statement on a 4-point scale (*1=agree completely, 4=disagree completely)*. The same scale structure was presented throughout the questionnaire, and then adjusted post-hoc.

Table 1: Latent Risk Factors (LRFs), number of scale items, scale's alpha, and example items.

Training (6 items, α=.77)	In my department, people have sufficient knowledge of new medical technological developments
Access to Information (6 items, α=.84)	Information to perform procedure available at the time when it is needed
Planning & Coordination (4 items, α=.75)	Lack of advance planning within the department
Teamwork (4 items, α=.74)	There is an adequate exchange of information during the operative procedure
Team Instruction (4 items, α=.80)	In my department, staff have the necessary professional skills
Situational Awareness (3 items, α=.77)	There is sufficient information exchange during the operative procedure
Hierarchy (5 items, α=.82)	In my department, staff don't always dare to ask for an explanation
Material Resources (6 items, α=.75)	Material/equipment is of insufficient quality
Maintenance (4 items, α=.81)	Maintenance inspections are carried out on time
Procedures (7 items, α=.79)	In my department, procedures, rules, and guidelines are often not feasible in practice

Dependent Variables

There were three dependent variables.

Job satisfaction, indicating positive feelings that workers have regarding their job or facets of their job, which was assessed with the Job Satisfaction scale of the Leiden Quality of Work Questionnaire (3 items, ɑ=.82; e.g., "I am satisfied with my job").[13]

- Job stress, which was measured with a modified version of a stress assessment form.[14] The items tapped into a person's feelings of job-related tension and anxiety (4 items, ɑ=.89; e.g., "I regularly feel too stressed to do my work well").
- Intention to leave, which was measured with two items (ɑ=.72; e.g. "I consider getting another job outside this organisation").

Responses were given on a 4-point rating scale *(1=agree not at all, 4=agree completely)*. Higher scores indicated higher job satisfaction, higher job stress and higher intention to leave.

Statistical analysis

The returned questionnaires were analysed using SPSS® version 17 (Chicago, Illinois, USA). For all LRFs, negatively formulated items were recoded so that a higher score always indicates less favourable perceptions about working conditions. Scale scores were generated by averaging the ratings of all items that were part of the scale. The interne liability of the scales was assessed by calculating Cronbach's alpha. To calculate the percentage frequency of responses to each item, responses on *agree completely* and *agree* have been combined, as have those on *disagree completely* and *disagree*. For all LRF scales the distribution of scores was found normal. One-way analyses of variance (ANOVAs) were used to compare mean scores on LRFs, outcome variables and base-line characteristics (age, time in job, and working hours) across profession.

Post-hoc tests were conducted to examine specific differences between responses to the questionnaire scales. Chi-squared tests were used to compare mean scores across profession for gender. Bivariate correlations were calculated to examine the pattern of direct relationships between base-line characteristics, LRFs and outcome variables. In order to analyse the unique contribution that LRFs made to staff's job satisfaction, job stress, and intention to leave, regression analyses were performed. In each of these analyses base-line characteristics, which significantly correlated with the outcome variable, were included as controls in Step 1.

Results

The study group consisted of 109 specialist anaesthetists, 46 trainees in anaesthesia and 115 nurse anaesthetists. The overall response rate was 62% (270/438). Profession demographics are provided in Table 2. Compared with anaesthetists and nurses, trainees were younger and had the fewest number of years' experience in the hospital. Nurses worked fewer hours than anaesthetists and trainees. There were more female nurses and female trainees than female anaesthetists.

Table 2: Demographics and response rate by profession: Anaesthetists, Trainees in anaesthesia and Nurse Anaesthetists, Mean and SD.

	Anaesthetists N=109	**Trainees N=46**	**Nurses N=115**
	Mean (SD)	Mean (SD)	Mean (SD)
Age	44.8 (9.03) [a]	31.6 (2.96) [ab]	40.2 (10.21) [b]
Time in job	2.8 (.096) [a]	1.9 (0.90) [ab]	2.8 (.085) [ab]
Working hours	42.3 (6.10) [a]	46.3 (2.95) [b]	32.6 (8.37) [ab]
Gender			
Men N(%)	72 (69%) [ab]	23 (52%) [a]	40 (38%) [b]
Woman N(%)	37 (31%) [ab]	21 (48%) [a]	75 (62%) [b]
Response rate	67 %	56 %	72 %

Means that share an identical superscript differ significantly (p<0.05) by the Bonferroni procedure.
Note: Time in job 1= < 1 year, 2= 1-5 years, 3= 6-10 years, 4> 10 year;

Perception of job satisfaction and intention to leave differed between professions (Table 3). Post-hoc analyses showed that nurses were less satisfied with their job than anaesthetists and trainees. Trainees had a lower intention to leave their job than anaesthetists and nurses. The difference in job stress between professions was not significant. However there was a significant difference in stress between men and women anaesthetists, mean values respectively 1.64 vs.1.83 (*P*=.030), with women reporting higher stress levels than men.

Table 3: Mean job satisfaction, stress, intention to leave and Latent Risk Factors scale scores with F values of the ANOVA for each LRF by profession: Anaesthetists, Trainees in anaesthesia and Nurse anaesthesists.

	Anaesthesists	**Trainees**	**Nurses**	
	N=109	N=46	N=115	
Dependent variables	mean	mean	mean	F
Job satisfaction	2.88 [a]	2.97 [b]	2.65 [ab]	6.983 *
Stress	1.77	1.86	1.76	.350
Intention to leave	2.39 [a]	1.92 [ab]	2.35 [b]	7.748 *
Latent Risk Factors				
Training	2.16 [a]	2.23	2.29 [a]	8.61***
Access to Information	2.28 [a]	2.41 [b]	2.65 [ab]	26.14***
Planning & Coordination	2.20 [a]	2.19 [b]	2.38 [ab]	6.78**
Teamwork	1.96[a]	1.86 [b]	2.13 [ab]	8.62***
Team Instruction	2.16 [a]	2.14 [b]	2.38 [ab]	9.74***
Situational Awareness	2.08 [a]	2.22	2.32 [a]	7.69**
Hierarchy	2.16 [a]	2.15 [b]	2.36 [ab]	8.40***
Material Resources	2.02 [a]	2.00 [b]	2.23 [ab]	7.94**
Maintenance	1.81 [a]	1.89	1.99 [a]	6.64**
Procedures	2.22[a]	2.18[b]	2.38 [ab]	5.54**

p <.05; ** p <01; *** p<001.

Table 3 and 4 illustrate the perceptions of Latent Risk Factors for the three groups.

Perceptions of LRFs differed between profession, with nurses reporting more problems on every LRF than anaesthetists and/or trainees. Over 70% of nurses rated Access to information, Training, Planning & coordination and Quality of procedures as poor and perceived the Hierarchy in the operating room as strict. Access to information and Quality of procedures were perceived as poor by more than 60% of anaesthetists and trainees. In addition, over 60% of trainees reported unfavorably on the quality of Training.

Table 4: Percentages of disagreement on Latent Risk Factors by profession Anaesthetists, Trainees in anaesthesia and Nurse anaesthetists

	Anaesthesists	**Trainees**	**Nurses**
Latent Risk Factors	N=109 %	N=46 %	N=115 %
Training	48	64	73
Access to Information	61	78	90
Planning & Coordination	48	54	74
Teamwork	28	16	40
Team Instruction	42	40	64
Situational Awareness	30	46	46
Hierarchy	56	44	73
Material Resources	39	25	55
Maintenance	17	16	24
Procedures	65	62	72

Correlations

Of the demographic variables, gender correlated significantly to stress for anaesthetists (.26 $P<.005$) and working hours correlated significantly to stress for trainees (.46 $P<.001$).

As can be seen in Table 5, for each of the professions, job satisfaction was moderately to highly correlated with intention to leave. For anaesthetists and nurses, but not for trainees, job stress correlated slightly, but significantly, with job satisfaction and moderately with intention to leave. All significant correlations were in the expected direction.

For anaesthetists there was a moderate to strong relationship between the LRFs and job satisfaction (Table 5). The same pattern of relationships largely holds true for the other two groups. For nurses LRFs were generally moderately correlated with job satisfaction, except Material Resources. For trainees LRFs were generally moderately correlated with job satisfaction, except Access to Information, Team Instruction, Situational Awareness and Material Resources. In comparison with job satisfaction, of the correlations between LRFs and the other outcomes stress and intention to leave, a smaller proportion was significant, with associations ranging from weak to moderate. All significant correlations were in the expected direction.

Table 5: Correlations by profession with job satisfaction, job stress and intention to leave and LRFs

	Anaesthetists			**Trainees in anaesthesia**			**Nurse anaesthesists**		
	job sat	stress	int. to leave	job sat	stress	int. to leave	job sat	stress	int. to leave
Job satisfaction									
Job stress	**-.255***			.012			**-.328****		
Intention to leave	**-.612****	**.469****		**.419***	.069		**-.541****	**.360****	
LRFs									
Training	**-.420****	.031	**.241***	**-.529****	.040	**.455****	**-.459****	**.218***	**.278***
Access to Inform.	**-.464****	-.096	-.151	-.255	.001	.235	**-.434****	.158	**.333****
Planning & Coord.	**-.696****	.094	**.352****	**-.356***	.064	**.509****	**-.308****	.122	.195
Teamwork	**-.611****	**.265***	**.374****	**-.480****	.270	.304	**-.460****	**.219***	**.304****
Team Instruction	**-.502****	.175	.082	-.260	.128	.210	**-.490****	.133	**.225***
Sit. awareness	**-.370****	.072	.213	-.174	-.071	-.093	**-.332****	.134	**.392****
Hierarchy	**-.638****	.096	**.469****	**-.403****	.324	**.533****	**-.406****	**.409****	**.262***
Material Resources	**-.351****	**.261***	.190	-.166	**.391***	.084	-.149	-.014	.089
Maintenance	**-.278****	.130	.095	**-.397****	**.385***	.094	**-.251****	-.013	.054
Procedures	**-.397****	**.301****	**.277***	**-.337****	.223	.290	**-.355****	**.259***	**.345****

* p <.05; ** p <.01 (2-tailed), bold is statistically significant

Regression

The results of the regression analyses are presented in Table 6. Inspection of this table reveals that, generally, the LRFs account for reasonably high percentages of the variances in the outcome variables.

Anaesthetists

The LRFs accounted for a significant proportion of variance in job satisfaction, job stress and intention to leave. The equation shows that job satisfaction was most strongly related to Planning & Coordination and Hierarchy. Gender was a significant correlate of stress and remained statistically significant after controlling for the LRFs, with women reporting higher job stress than men. Procedures, Material Resources and Access to Information were most strongly related to job stress. Hierarchy and Team Instructions were most strongly related to intention to leave. Access to Information and Team Instructions both had a negative beta coefficient (but a positive zero-order correlation), indicating that these variables act to suppress variance in the equation.

Trainees in anaesthesia

The LRFs accounted for a significant proportion of variance in job satisfaction, but not in job stress and intention to leave. The equation shows that job satisfaction was most strongly related to Training, and Maintenance. Working hours was a significant correlate of stress and remained statistically significant after controlling for the LRFs, with trainees working more hours per week reporting lower job stress than trainees working fewer hours per week.

Nurse anaesthetists

The LRFs accounted for a significant proportion of variance in job satisfaction, job stress and intention to leave. Job satisfaction was most strongly related to Maintenance, Access to Information, Teamwork and Hierarchy. Hierarchy was most strongly related to job stress, while Situational Awareness was most strongly related to intention to leave.

Table 6: Multiple regression analyses predicting job satisfaction, job stress and intention to leave from demographics and LRFs for Anaesthetists, Trainees in anaesthesia and Nurse anaesthetists. The table shows the significant β and model R^2.

Anaesthetists	Model	β	R^2
Job satisfaction	Planning & Coordination	-.42***	63
	Hierarchy	-.25*	
Job-related stress	Gender	.32*	33
	Procedure quality	.36*	
	Material resources	.33*	
	Access to Information	-.31*	
Intention to leave	Team instruction	-.40**	41
	Hierarchy	.43**	
Trainees in anaesthesia			
Job satisfaction	Training	-.46 *	56
	Maintenance	-.39 *	
Job-related stress	Working hours	-.47 *	22
Nurse anaesthetists			
Job satisfaction	Teamwork	-.21*	42
	Access to Information	-.23*	
	Hierarchy	-.21*	
	Maintenance	-.25*	
Job-related stress	Hierarchy	.40**	22
Intention to leave	Situational awareness	.29*	26

* p <.05; ** p <01; *** p<001.

Discussion

In the present study, the relationships between Latent Risk Factors (LRFs) and well-being in anaesthesia teams of three university hospitals in the Netherlands were investigated. Generally, the results indicate that the outcomes of interest are predicted rather well by the LRFs. In safety research it has been argued that by controlling LRFs human error can be controlled.[1] Our results suggest that when LRFs are controlled for, they

can also positively influence anaesthesia staff job satisfaction, job stress and intention to leave.
In line with our first hypothesis we found that the different groups of anaesthesia staff have differing perceptions of the LRFs, with nurse anaesthetists reporting more unfavourably on each of the LRFs than the other professionals. Most studies on safety issues in anaesthesia have focused on anaesthetists, but the results of the present study suggest that, in addition to anaesthetists, other anaesthesia team members should be included in studies to get a valid impression of the theatre room's safety health. Despite the difference between the groups in their overall rating of the LRFs, they were rather similar regarding their relative scores on LRFs: all three professions signalled the most problems with the information flow within the hospital and the protocols and guidelines and signalled the least problems with teamwork and the maintenance system.

In line with our second hypothesis we found that the LRFs predictive of the outcomes variables differ between the members of the anaesthesia team. Poor planning & coordination had the most negative effect on anaesthetists' job satisfaction. This result is in line with earlier studies showing that perceived lack of control over work and time planning is one of anaesthetists' major sources of stress.[4;15;16] To increase anaesthetists' job satisfaction probably means finding ways of restoring a sense of control over their own time and planning. High control not only leads to positive outcomes such as job satisfaction, but also acts as an important resource, respectively regulation possibility, for countering the negative consequences of a stressful working life.[17;18] Increased control over the work environment also motivates workers to try out and master new tasks.[19;20]

For anaesthetists poor material resources emerged as an important predictor for higher job stress. Poor material resources place high demands on the performance of staff in high-performance working environments such as the theatre room. One way to facilitate material resources is to minimize the amount of variation in equipment. Higher job stress in anaesthetists was also related to poor procedures. It is important for anaesthetists in stressful situations to be able to rely on best practice.[21 22] However, poor procedures (i.e. not easily accessible, long, complex, rigid, or coming in different versions) make it hard to fulfill required tasks and may even necessitate deviation from the rules to guarantee safe and successful performance. We also found that gender was a predictor for stress in anaesthesists. Women reported more job stress symptoms than men. This result is in line with previous studies. [4;6]

A culture which makes it difficult to speak up, to voice one's opinion or to ask questions if there is something one does not understand was an important predictor of lower levels of job satisfaction in anaesthetists and nurse anaesthesists. Also higher intention to leave in anaesthetists and higher job stress in nurse anaesthetists were related to a strong hierarchy. The willingness to leave the job strongly depended on the presence of conflicts with superiors and co-workers (our hierarchy), low job control (our planning & coordination) and job dissatisfaction. [23] Our findings highlight the importance of the creation of an open and safe environment for interactions, not only for safety purposes as has been shown in previous studies [24], but also for the well-being of the anaesthesia staff.

The importance of 'non-technical' skills for safety, like teamwork and situational awareness, has been well recognized and received more attention on anaesthesia in recent years.[11;25] We found that the importance of 'non-technical' skills for well-being is most evident in nurse anaesthetists. Poor teamwork lowered their job satisfaction while lower levels of situational awareness increased their intention to leave. Active involvement of these members in the progress of the operation helps them to develop knowledge, insight, and experience that enhance their understanding and control of the situation and their opportunity for learning. Lack of development opportunities can lead to disengagement because it undermines employee motivation and learning.[26] Lower levels of job satisfaction in nurse anaesthetists were also related to poor access of information. Obtaining timely and adequate information from others is crucial for nurse anaesthetists to carry out job demands. When the environment does not provide access to information needed to carry out job demands workers feel powerless. One way to boost nurses' job satisfaction is a clear structure for the transmission of information[27] Poor maintenance emerged as another important predictor of lower job satisfaction in nurse anaesthesists. The perception that the maintenance system is working in a way that material and equipment is being maintained before it fails, and thus the system reduces unexpected failures and increases safety, builds employees' trust in management and their confidence about their abilities to handle their work environment and job tasks.

Hours worked per week turned out to be crucial for trainee's anaesthetists job stress. The fewer hours' trainees reported working per week, the greater the job stress they experienced. One possible explanation for this finding is that working fewer hours compromises clinical exposure. Studies showed that reduced working hours potentially reduce teaching and supervision for interns.[28 29] To reduce the stress levels of trainees with fewer working hours, a supportive environment and various stress management strategies may help. An important factor for trainees' job satisfaction actually is receiving training. Trainee anaesthetist felt less satisfied with their job when training opportunities were not fully utilised, e.g., poor clinical supervision, few task specific training activities, and reduced time for specialty training. Training has been shown to increase the ability to solve problems, particularly for inexperienced professionals.[30] Poor maintenance emerged as another important predictor of lower job satisfaction in trainees. This is possibly due to the fact that in a training situation, employees must have confidence in the structure of the environment.

This study has some limitations. A point of concern is that the sample only included anaesthesia staff working in three university hospitals in the Netherlands. The experience of participants in these hospitals may differ from those in other hospitals or indeed in other countries. Future research needs to test the hypotheses across a wider sample, including peripheral hospitals, to see if the present findings can be confirmed.
The sample size is also small, particularly for trainees. Therefore, research studies with much larger size would be required to ensure appropriate generalization of the findings of the study. Although the response rate (62%) is acceptable for a postal survey, future research also needs to aim for a higher response rate.
In this research we included a substantial number of LRFs. However, it is conceivable that in addition to the studied set of LRFs other factors may contribute to the outcomes under investigation, such as staffing [5]

housekeeping [31] and financial rewards [32] Future research may consider incorporating these factors.

Finally, due to the study's cross-sectional design, the analyses cannot provide a definite answer concerning the directions of the relationships. The results of this study are therefore suggestive in nature and are meant to give first indications. Longitudinal research is clearly needed to identify causal links in the relations between LRFs and well-being.

Notwithstanding these limitations, the findings of this study suggest that unfavourable LRFs can act as stressful triggers at the workplace. If anaesthesia staff cannot control such stress this may negatively affect their well-being. The key to a healthy workplace seems to be to control the deficiencies in the structure of the work environment. Therefore, we call for intervention studies to test whether or not improving LRFs does affect job satisfaction, job stress and intention to leave of anaesthesia team members positively.

References

1. Reason J. *Managing the Risks of Organizational Accidents*. Hampshire, England: 1997.

2. Catchpole KR, Giddings AE, Wilkinson M *et al*. Improving patient safety by identifying latent failures in successful operations. *Surgery* 2007; **142**: 102-10.

3. Flin R, Patey R. Non-technical skills for anaesthetists: developing and applying ANTS. *Best Pract Res Clin Anaesthesiol* 2011; **25**: 215-27.

4. Kluger MT, Townend K, Laidlaw T. Job satisfaction, stress and burnout in Australian specialist anaesthetists. *Anaesthesia* 2003; **58**: 339-45.

5. Akerboom S, Maes S. Beyond demand and control: The contribution of organizational risk factors in assessing the psychological well-being of health care employees. *Work and Stress* 2006; **20**: 21-36.

6. Lindfors PM, Nurmi KE, Meretoja OA *et al*. On-call stress among Finnish anaesthetists. *Anaesthesia* 2006; **61**: 856-66.

7. Kivimaki M, Sutinen R, Elovainio M *et al*. Sickness absence in hospital physicians: 2 year follow up study on determinants. *Occupational and Environmental Medicine* 2001; **58**: 361-6.

8. Frese M, Zapf D. Action as the core of work psychology: A German approach. In: *Handbook of industrial and organizational psychology* Palo Alto, CA: Consulting Psychologists, 1994: 271-340.

9. Sexton JB, Thomas EJ, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. *BMJ* 2000; **320**: 745-9.

10. Amalberti R, Vincent C, Auroy Y *et al*. Violations and migrations in health care: a framework for understanding and management. *Qual Saf Health Care* 2006; **15** Suppl 1: i66-i71.

11. Lingard L, Reznick R, Espin S *et al*. Team communications in the operating room: Talk patterns, sites of tension, and implications for novices. *Academic -Medicine 2002 Mar* 2002; **77**: 232-7.

12. Van Beuzekom M, Akerboom SP, Boer F. Assessing system failures in operating rooms and intensive care units. *Qual Saf Health Care* 2007; **16**: 45-50.

13. van der Doef M, Maes S. The Leiden Quality of Work Questionnaire: its construction, factor structure, and psychometric qualities. *Psychol Rep* 1999; **85**: 954-62.

14. Heus Pd, Diekstra R. Development of the Work Stress Screening Inventory (WSSI). *Gedrag en Organisatie* 1999; **12**: 3-15.

15. Kinzl JF, Knotzer H, Traweger C *et al*. Influence of working conditions on job satisfaction in anaesthetists. *Br J Anaesth* 2005; **94**: 211-5.

16. Cooper C, Dewe P, O'Driscoll M. *Organizational stress. A review and critique of theory, research, and applications*. 2001; 1-288.

17. Lederer W, Kinzl JF, Trefalt E *et al*. Significance of working conditions on burnout in anesthetists. *Acta Anaesthesiol Scand* 2006; **50**: 58-63.

18. Karasek RA, Russell RS, Theorell T. Physiology of Stress and Regeneration in Job Related Cardiovascular Illness. *Journal of Human Stress* 1982; **8**: 29-42.

19. Morgeson FP, Delaney-Klinger K, Hemingway MA. The importance of job autonomy, cognitive ability, and job-related skill for predicting role breadth and job performance. *J Appl Psychol* 2005; **90**: 399-406.

20. Rama-Maceiras P, Parente S, Kranke P. Job satisfaction, stress and burnout in anaesthesia: relevant topics for anaesthesiologists and healthcare managers? *Eur J Anaesthesiol* 2012; **19**: 311-319.

21. de Saint MG, Auroy Y, Vincent C *et al*. The natural lifespan of a safety policy: violations and system migration in anaesthesia. *Qual Saf Health Care* 2010; **19**: 327-31.

22. Perel A, Berkenstadt H, Ziv A *et al*. Anaesthesiologists' views on the need for point-of-care information system in the operating room: a survey of the European Society of Anaesthesiologists. *Eur J Anaesthesiol* 2004; **21**: 898-901.

23. Lindfors PM, Meretoja OA, Luukkonen RA *et al*. Attitudes to job turnover among Finnish anaesthetists. *Occup Med (Lond)* 2009; **59**: 126-9.

24. Firth-Cozens J. Organisational trust: the keystone to patient safety. *Qual Saf Health Care* 2004; **13**: 56-61.

25. Flin R, Fletcher G, McGeorge P *et al*. Anaesthetists' attitudes to teamwork and safety. *Anaesthesia* 2003; **58**: 233-42.

26. Bakker AB, Demerouti E, de Boer E *et al*. Job demands and job resources as predictors of absence duration and frequency. *Journal of Vocational Behavior* 2003; **62**: 341-56.

27. Smith AF, Mishra K. Interaction between anaesthetists, their patients, and the anaesthesia team. *Br J Anaesth* 2010; **105**: 60-8.

28. Bowhay AR. An investigation into how the European Working Time Directive has affected anaesthetic training. *BMC Med Educ* 2008; **8**: 41.

29. Fernandez E, Williams DG. Training and the European Working Time Directive: a 7 year review of paediatric anaesthetic trainee caseload data. *Br J Anaesth* 2009; **103**: 566-9.

30. Chopra V, Gesink BJ, de JJ *et al*. Does training on an anaesthesia simulator lead to improvement in performance? *Br J Anaesth* 1994; **73**: 293-7.

31. van Beuzekom M., Boer F, Akerboom S *et al*. Patient safety: latent risk factors. *Br J Anaesth* 2010; **105**: 52-9.

32. Misra-Hebert AD, Kay R, Stoller JK. A review of physician turnover: rates, causes, and consequences. *Am J Med Qual* 2004; **19**: 56-66.

6

Perception of patient safety differs by clinical area and disciplines

M. van Beuzekom [1], F. Boer [1], S. Akerboom [2], A. Dahan [1]

[1] Department of Anaesthesiology, Leiden University Medical Centre, P.O. Box 9600, 2300 RC Leiden, the Netherlands
[2] Department of Psychology, Leiden University, P O Box 95555. Leiden, The Netherlands

Br J Anaesth accepted 2012

Introduction

Safety in hospitals and complex environments such as the Operating Theatre and the Intensive Care Unit rely on multiple system defences such as the organizational structure, protocols, the training received by the professionals and the quality of equipment or technology. Of particular interest are how medical errors occur, how they can be addressed within the health care system and how the work environment affects medical errors and near misses. There is increasing acceptance of the idea that adverse outcomes are often due to system failures, whereby deficiencies at many different levels create the context in which human error can have a negative impact.[1-3] Organizational factors, which may contribute to errors and to safety, can be grouped together into a limited number of general failure classes or Latent Risk Factors (LRFs). LRFs are error-producing conditions such as poor design, maintenance failures, unworkable procedures, deficiencies in training, equipment design and use as well as poor team coordination.[4] Safety experts argue that proactively reducing such LRFs will result in the delivery of safer care more quickly than taking measures directed, often reactively, at specific providers of care.

Patient safety varies across institutions, within institutions and between disciplines.[5-8] [9] One dimension along which it can vary is the clinical area, such as the Operating Theatre (OT) or Intensive Care Unit (ICU). A proactive system approach to patient safety suggests that it is necessary to study all aspects of the system that comprises an operation or ICU hospitalization.[10;11] Most studies focus on the impact of a limited set of factors, for instance either teamwork[6], work procedures[12] or communication.[13] Consequently, little is known about the relative importance of each of them, if studied simultaneously.

Anaesthetists do not work independently from others. Their performance is embedded in organizational factors. Different disciplines in the Operating Theatre may have different work norms and the pace of their work may vary.[14] Surgeons, anaesthetists and critical care physicians seem more satisfied with physician–nurse collaboration than nurses.[15;16] Nurses are less likely to agree that they were provided with adequate training to do the job than surgeons.[17] Physicians' views of the contribution of guidelines to safety and to clinical practice differ from those of nurses.[17-20] Thus it would be likely that interdisciplinary differences may exist in the perception of patient safety.

The aim of the present study is to test for differences in perceptions of Latent Risk Factors and to explore the contribution of disciplines and clinical area (Operating Theatre and Intensive Care Unit). Identification of differences between clinical area and disciplines allow the measures aimed at LRFs that are below standard to be specifically tailored. Tailoring is necessary because correction of the various LRFs would require entirely different preventive actions.[21] The advantage of identifying these differences would be the ability to address these issues in a safety management program.

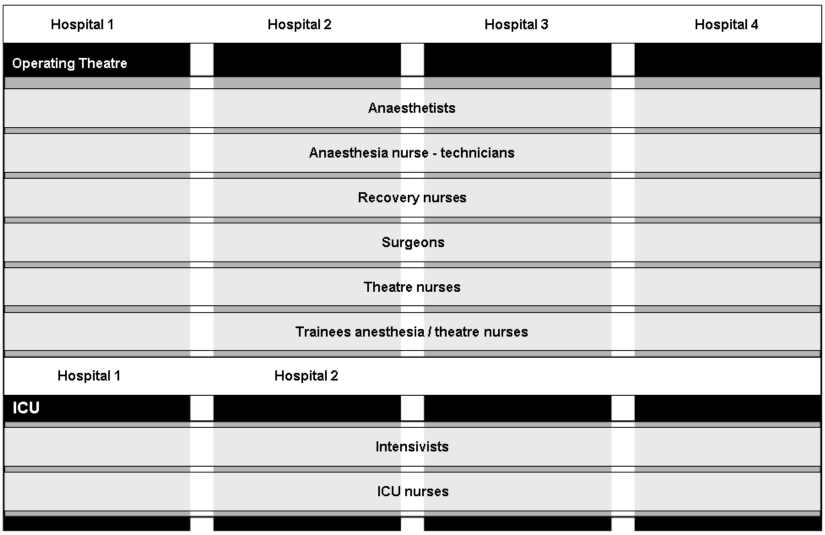
Methods

Sample and procedure

The study was approved by the Research Ethics Board. We chose to investigate the clinical area of the Operating Theatre (OT) and Intensive Care Unit (ICU). Both the OT and the ICU are dynamic environments, where there is a wide variety of high-technology equipment, constant change and time stress. There is a considerable risk of error in these departments. The study was performed at four university hospitals in the

Netherlands. We asked hospitals, where another safety program was currently implemented, to participate in a safety program. That is why 2 ICUs were incorporated in the study. The study design is presented in Figure 1. Clinicians, trainees and nursing staff were included in the study, if they had been in their job for more than three months. Disciplines included anaesthetists, anaesthesia nurse-technicians*, recovery nurses, surgeons, theatre nurses*, intensivists, intensive care nurses (IC nurses), and trainees anaesthesia nurse-technicians /theatre nurses (Trainees A-T nurses).

Figure 1: design of the study



Base-line characteristics

The following four demographic variables were used as control variables: gender (1 = *male*, 2 = *female*), age (in years), working hours (contractual hours per week), and length of service in the job (1 = < *1 year*, 2 = *1 – 5 years*, 3 = *6 – 10 years*, 4 = > *10).*

Survey instrument

The approach taken to assessing the state of the individual LRFs is analogous to a health check, which measures a limited number of well-chosen diagnostic vital signs. Items, presented as statements, can be indicators of either potential problems or good practice.

In the current study, LRFs were measured using the Leiden Operating Theatre & Intensive Care Safety (LOTICS) scale, which has been validated with respect to factorial structure and reliability of the scales, as well as its content and discriminative validity. [22] It measures 12 LRFs with a total of 55 indicator questions: training, task related communication, planning & coordination, design, maintenance, equipment resources, teamwork, team instruction, housekeeping, situational awareness, hierarchy and procedures. Items, presented as statements, were indicators of either potential problems or good practice (Appendix 1). Respondents indicated the extent to which they agreed with each statement on a 4-point scale *(1=disagree completely, 4=agree completely)*. Higher scores indicated more favourable perceptions about working conditions.

Statistical analyses

The returned questionnaires were analysed using SPSS® version 17 (Chicago, Illinois, USA). For all LRFs, negatively formulated items were recoded so that a higher score always indicates more favourable perceptions on that LRF. Scale scores were generated by averaging the ratings of all items that were part of the scale. To calculate the percentage frequency of responses to each item, responses on *agree completely* and *agree* were combined, as were those on *disagree completely* and *disagree*.

The study sample was divided according to clinical area: OT vs. ICU and according to disciplines. One-way analyses of variance (ANOVAs) were used to compare mean scores and base-line characteristics (age, working hours and current years in the job). Chi-squared tests were used to compare mean scores across discipline for gender.
To test for differences in perceptions of LRFs by clinical area and discipline, we used ANOVA, as there were differences in age, working hours, and length of service in the job, they were used as covariates. Pearson correlation coefficients were calculated to examine the pattern of direct relationships between LRFs and clinical area and discipline.

Results

The overall response rate was 64% (768 out of 1260 questionnaires). The response rate ranged by hospital (62%- 65%) by clinical area (62 % - 68%) and by disciplines (62-69%). Respondents were predominantly female 71% with a mean age of 40.32 ($F_{(3,760)}$ =8.71 p=.000). Respondents had been in their job an average for more than 8 years (mean 2.77, $F_{(3,760)}$ =2.97 p=.019). Respondents worked on average 33.14 hours a week ($F_{(3,760}$=8.97 p=.000). Significant differences between disciplines were found in age, working hours, length of service in the job and gender (Table 1).

Table 1: Descriptive statistics: demographics by disciplines mean and percentage (%)

	Response Rate %	N	Age mean	Working hours mean	Length in the job * mean	Male %	Female %
Anaesthetists	66%	121	41.40	43.50	2.66	63	27
Anaesthesia nurse-technicians	64%	114	40.23	32.00	2.82	35	65
Recovery nurses	66%	99	46.06	26.99	2.78	19	81
Intensivists	69%	26	41.81	42.88	2.23	62	28
I.C. nurses	62%	111	41.10	30.73	2.84	27	73
Surgeons	62%	26	46.08	44.38	3.36	80	20
Theatre nurses	66%	216	40.20	28.90	2.97	1	99
Trainees AT nurses	65%	56	23.71	35.53	1.89	1	99

* length of service in the job 1 < *1 year*, 2 = *1 – 5 years*, 3 = *6 – 10 years*, 4 > *10 years*

Demographics and LRFs

We compared demographic variables with LRFs. There was a significant differences for age with design of equipment ($F_{(3,760)}$ =7.60 p=.04). Younger staff had a somewhat more favourable perception of design. In the 18-25 age group the mean was 3.09 (sd.36) compared with the age group> 55 mean 2.95 (sd. 41).

Staff with more working hours had also more favourable perceptions of design ($F_{3,\ 761=}$6.08, p=. <001) and material resources ($F_{3,\ 761=}$7.19 p=<.001). Staff who have worked in the hospital for 5-10 years have less favourable perception of communication ($F_{3,\ 761=}$ 4.75 p=.003).

Clinical area: OT and ICU and LRFs

Over 40-50% of the staff of the OT and ICU rated communication as poor. The ICU also rated equipment and housekeeping as poor (Table 2). Comparing OT and ICU, significant differences were found on training ($F_{(1,750)}$ =8.96 p=.003), communication ($F_{(1,749)}$ =5.37 p=.021), teamwork ($F_{(1,750)}$ =6.33 p=.012), team instruction ($F_{(1,750)}$ =7.88 p=.005) and hierarchy ($F_{(1,750)}$ =1610 p=.000). The OT had more favourable perception of design ($F_{(1,750)}$ =4.60 p=.032) and equipment ($F_{(1,750)}$ =22.05 p=.000).

Table 2: Descriptive statistics of LRFs between clinical areas: Percentage (%) agreement and mean (sd)

LRFs	OT		IC	
	%	mean (sd)	%	mean (sd)
Training	70	2.75 (.38)	88	2.86 (.33)
Communication	44	2.76 (.33)	53	2.97 (.32)
Planning & Coordination	76	2.48 (.43)	87	2.58 (.38)
Design	91	3.00 (.38)	85	2.93 (.39)
Equipment	75	2.86 (.42)	53	2.61 (.44)
Maintenance	83	2.96 (.42)	83	2.92 (.34)
Teamwork	90	2.99 (.36)	91	3.05 (.35)
Team instruction	68	2.75 (.39)	75	2.83 (.34)
Housekeeping	60	2.61 (.45)	56	2.60 (.33)
Sit. awareness	84	2.85 (.40)	87	2.85 (.37)
Hierarchy	79	2.75 (.42)	93	2.90 (.32)
Procedures	72	2.73 (.35)	68	2.70 (.32)

Mean score on a 1–4 scale, where 4 means agree strongly

Disciplines and LRFs

Anaesthetists, intensivists and surgeons had more favourable perceptions of all LRFs, with exception of the anaesthetists for team instruction (49%

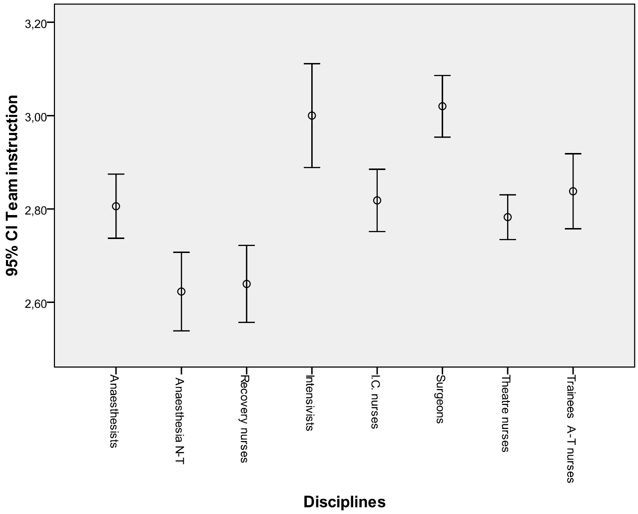
of agreement) and communication (54% of agreement). Over 70% of the anaesthesia technicians rated communication and housekeeping as poor (Table 3).

Table 3: Descriptive statistics: percentage (%) agreement on LRFs between disciplines

LRFs	Anaesthetist	Anaesthesia N-T	Recovery nurses	Intensivists	IC nurses	Surgeons	Theatre nurses	Trainees A-T nurses
Training	72	54	72	92	83	92	64	82
Communication	49	30	46	92	46	68	37	49
Planning & Co.	74	67	67	81	67	96	80	70
Design	91	82	88	88	88	98	90	95
Equipment	86	69	69	98	69	72	72	82
Maintenance	93	82	81	98	80	68	81	81
Housekeeping	79	33	61	75	61	92	59	68
Teamwork	93	80	78	92	87	98	95	91
Team instruct.	54	54	59	96	78	98	71	79
Sit. awareness	79	71	72	77	72	75	95	80
Hierarchy	76	74	64	92	64	96	85	67
Procedures	90	72	66	69	66	84	78	79

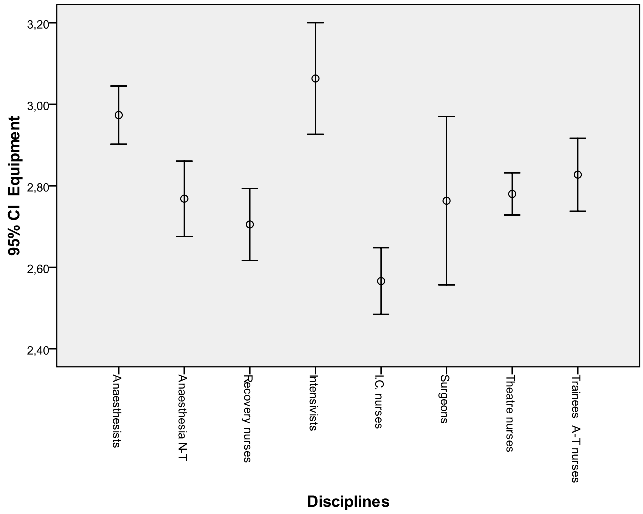
Significant differences on all LRFs were found for all disciplines. Surgeons, intensivists had more favourable perceptions than anaesthesia technicians and recovery nurses on instructions ($F_{(7,757)}$ =7.93 p=.000, Figure 1a). The same pattern was found for communication ($F_{(7,756)}$ =11. 03 p=.000), planning & organisation ($F_{(7,756)}$ =9.72 p=.000), teamwork ($F_{(7,757)}$ =8.46 p=.000) and hierarchy ($F_{(7,756)}$ =9.28 p=.000).

Figure 1a: Mean values and 95 CI of disciplines for: Team instruction



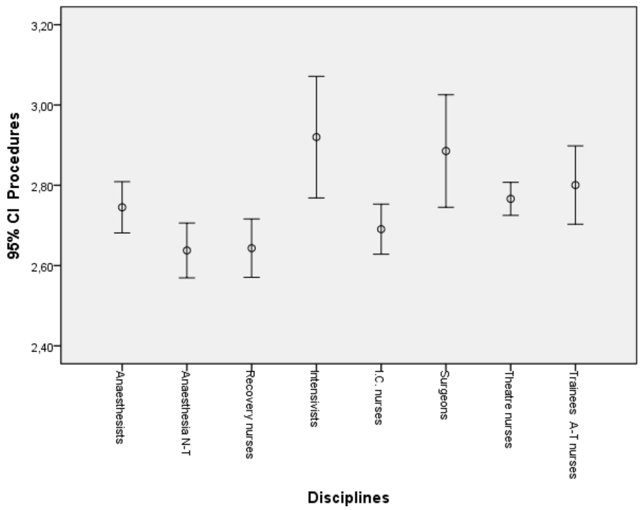
Intensivists and anesthetists had more favorable perceptions than IC nurses of equipment ($F_{(7,749)}$ =10.04 p=.000, Figure 1b) design ($F_{(7,756)}$ =3.54 p=.001) and maintenance of equipment ($F_{(7,756)}$ =7.76 p=.000)

Figure 1b: Mean values and 95 CI of disciplines for: Equipment



Intensivists and surgeons had more favourable perceptions than nurses of procedures ($F_{(7,756)}$ = 4.86 p=.000 figure 1c). The same pattern was seen for situational awareness ($F_{(7,756)}$ =8.24 p=.000) and housekeeping ($F_{(7,756)}$ =14.39 p=.000).

Figure 1c: Mean values and 95 CI of disciplines for: Procedures



Correlations

Bivariate correlations were calculated to examine the pattern of relationships between clinical area, disciplines and LRFs.

Correlations between clinical area and LRFs were significant and positive for material resources, design and situational awareness (Table 5). The strongest association was found with design (.148 p= <.01), hierarchy (.146 p= <.01) and equipment (.133 p=<.05).

For disciplines, significant correlations were found for communication, planning & coordination, housekeeping, teamwork and team instruction. The strongest associations with disciplines were found for communication (.148 p= <.01) and housekeeping (.145 p= <.01).

Table 4: Correlations Latent Risk Factors between clinical are and disciplines

LRFs	Clinical area	Disciplines
Training	.074*	.144**
Communication	.037	.148**
Planning & Coordination	-.001	.132**
Design	.148**	.001
Maintenance	.094*	-.035
Equipment	.133**	-.047
Teamwork	.028	.097**
Team instruction	.110	.135**
Housekeeping	.017	.145**
Situational awareness	.113**	.034
Hierarchy	.146**	.078
Procedures	.010	.057

*p <.05; ** p <01 (2-tailed).

Discussion

In this study we focused on the influence of the clinical area (OT vs. ICU) and disciplines on reported scores in an inquiry on patient safety. We examined the clinical areas of OT and ICU because these are areas where adverse events frequently occur. We observed that the ICU staff reported fewer problems for training, communication, team instruction and hierarchy. This could be the result of the process, which is entirely different to OT or ward work. The OT had more favourable perceptions of design and equipment. Poor equipment places high demands on the performance of staff in high-performance working environments. For instance, good design reduces the need for extensive training in the use of equipment, whereas poor design may be only partially compensated for by extensive training. One way to facilitate equipment resources is to minimize the amount of variation in equipment. An explanation could be that the OT is a more standardized environment than the ICU.

We found differences between disciplines on all Latent Risk Factors, which shed some light on differences between disciplines in their perception of patient safety. We speculate that this is the result of differences in work organization, content and professional training. One might expect that the perceptions of physicians and nurses are different because of their different expertise and work responsibilities.

Three profiles between disciplines and LRFs were found. The 1st profile: Anaesthetists, anaesthesia nurse-technicians and recovery nurses had lower perceptions of communication, team instruction, teamwork and planning & organisation and hierarchy (non-technical skills). Teamwork issues generally cluster around issues of miscommunication, lack of coordination, failures in monitoring, and lack of team familiarity.[23] Communication and interaction between members of the anaesthesia team specifically have received less attention than communication in the Operating Theatre during surgery. In the Netherlands an anaesthesia team consists of an anaesthetist, frequently a trainee anaesthetist and an anaesthesia technician.[24] In general, it is a challenge within the Operating Theatre to build functional teams.[25] Usually these teams are just co-incidentally formed, similar to airline crews. The teams consist of members of several different disciplines that work together for that particular operation or the whole operating day. This task-oriented team model with high levels of specialization has historically focused on technical expertise and performance of members with little emphasis on interpersonal behaviour and teamwork. In this model, communication is informally learned and developed with experience.[26] This places a substantial demand on the non-clinical skills of the team members, especially in high-demand situations like crises.

The 2nd profile: We found that anaesthetists and intensivists had more favourable perceptions than surgeons of the technical LRFs (equipment, design and maintenance). IC nurses had the lowest perception of these LRFs. A low rate of equipment problems was found during anaesthesia, indicating that their procedures for checking and maintenance of equipment was adequate.[27] Human error and lack of familiarity with equipment have been shown to be more common than 'true' equipment failure. [28]Anaesthetists and intensivists work more with equipment, design and maintenance, which would explain why they are more familiar with these issues. In their training they are therefore more exposed to deficiencies, which may be an explanation of why they perceived the technical skills more favourably. The low perception of IC nurses has to do with performance obstacles related to misplacement of equipment related to inadequate workspace. Also the current devices at the ICU bedside do not adequately support a nurse's information-gathering activities.[29] The performance obstacles related to misplacement of equipment may be eliminated by creating and reinforcing a protocol or by establishing a tracking system, the performance obstacle of inadequate workspace may require a major redesign of the physical layout of the ICU.[30]

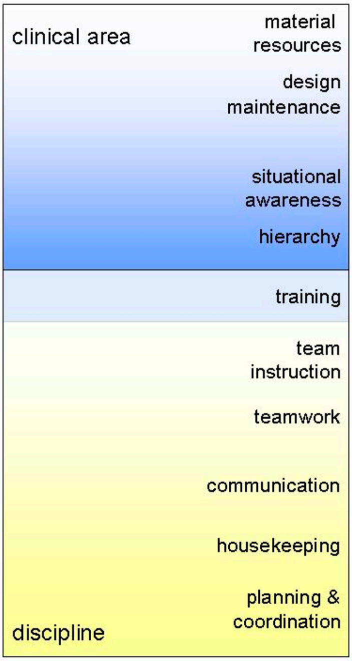
The 3rd profile: We found that nurses, especially anaesthesia nurse-technicians and recovery nurses are more sensitive to procedures, housekeeping and situation awareness. Physicians and nurses hold divergent views regarding adherence to rules and clinical guidelines.[18-20] Nurses appear to hold more systematized and less individualistic conceptions of clinical work than physicians and appear to be more fastidious in adhering to documented procedures.[17]Anaesthesia nurse-technicians often serve as controllers for the anaesthesia team by getting supplies and equipment ready for the anaesthetic procedure. They are confronted with non-availability of equipment, what explains why they perceived housekeeping as poor.

The attitudes of healthcare disciplines towards the working conditions are a component of an organization's safety culture. An important and perhaps glaring gap in our knowledge of cultural assessment of safety relates to the sources of variation in the safety culture. We do not understand whether the variation in culture is explained by the clinical area or staff.

We found a correlation between clinical areas, hierarchy and situation awareness (Figure 2). Hierarchy is more prevalent in high-intensity areas as the theatre room, intensive care and emergency department.[31] This may explain why hierarchy plays a role at the clinical level.

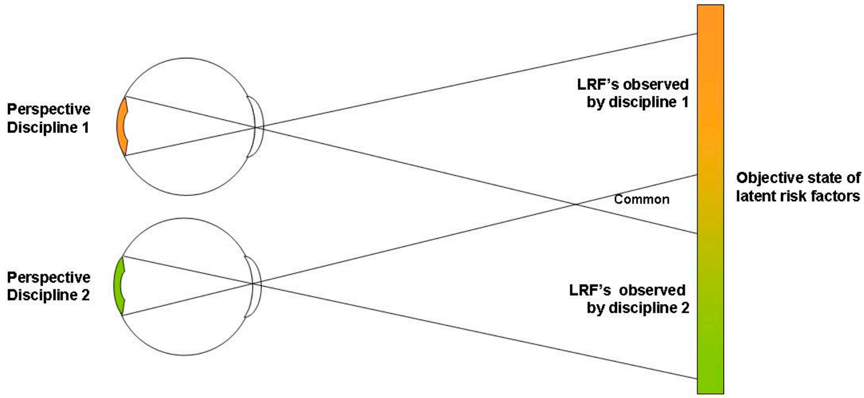
Within hospitals technology use is steadily. In our study we found a correlation between the quality and availability of equipment and the clinical area. While technology has the potential to improve care, it is not without risks. It can cause significant harm if not adequately designed, regulated and maintained. Technology has been described as both part of the problem and part of the solution for safer health care. Organization of workflow around equipment and process is also vital. Given our findings it would be advisable that hospital procurement services apply a risk assessment and a risk management analysis prior to decisions involving new equipment in order to tailor measures to be taken for individual groups to minimize the risks of latent errors. Correlations with disciplines and LRFs were found on non- technical skills (Figure 2). Our study supports the current view as to why much attention is paid to non-technical skills training. [32;33]

Figure 2: Overview of the significant correlations presented by clinical area, discipline and Latent Risk Factors



Division of labour among multiple professions can provoke different views on safety. In our study we not only found differences between physicians and nurses but also differences within clinician and nursing specialties. Compared with other disciplines, the anaesthesia team also feels the safety deficiencies in the organizational infrastructure more acutely. The different tasks performed by the various disciplines could be an explanation of why they see only a certain aspect but not the whole picture (Figure 3). We therefore recommend that in the context of safety programs, all disciplines should be involved, not just single disciplines. Identification of differences between disciplines would allow the measures to be tailored. Identification of separate underperforming latent factors is warranted, because their correction requires entirely different preventive actions.

Figure 3: Perspective of different disciplines on Latent Risk Factors



Practical application of the findings

The results of this study led to specific interventions on the OT and ICU. Anaesthetists, anaesthesia nurse-technician and recovery nurses had significant different results on communication and team instructions. Interviews with staff revealed that the results on these LRFs were based on a lack of information causing ambiguity in responsibility. One OT started with an intervention based on the introduction of a standardized handover protocol through the perioperatieve process and other OT started an intervention to promote the availability of procedures. The ICU had less favourable perception on equipment and design. Interviews with staff revealed that this was based on the different prototypes of equipment. Therefore, one ICU started an intervention to standardize equipment and supplies for all equipment development of manuals with a uniform design.

There are limitations to our study. All data were cross-sectional, however a sampling bias remains possible, and some caution must be exercised in generalizing our study findings. Nurses comprise 79% of the study population, as they are the bulk of an ICU's and OR's staff. Thus it is likely that nurses' perceptions of LRFs contribute most. Moreover, we have attributed differences in LRFs by disciplines, when they could also be explained by gender, age or length of service. That was the reason for including the demographics as covariate in the analyses. Another point of concern is that the sample only included staff working in university hospitals in the Netherlands. The experience of participants in these hospitals may differ from those in other hospitals or indeed in other countries. Future research needs to test the hypotheses across a wider sample, including peripheral hospitals, to see if the present findings can be confirmed.

As health care has focused its safety efforts toward the system rather than towards the individual provider of care, organizational factors have emerged, known as Latent Risk Factors. Understanding how LRFs affect safety should enable us to design more effective control measures that will impact on the overall safety condition. We would argue that systematic analyses and step-by-step improvements are feasible and can impact directly on the culture. Strategies for improving patient safety should be tailored specifically for clinical areas and disciplines.

References

1. Reason J. Managing the Risks of Organizational Accidents. Hampshire, England: 1997.

2. Cook R, Rasmussen J. "Going solid": a model of system dynamics and consequences for patient safety. *Qual Saf Health Care* 2005; **14**: 130-134.

3. Amalberti R, Auroy Y, Berwick D *et al.*Five system barriers to achieving ultrasafe health care. *Ann Intern Med* 2005; **142**: 756-764.

4. van Beuzekom M., Boer F, Akerboom S *et al.* Patient safety: latent risk factors. *Br J Anaesth* 2010; **105**: 52-59.

5. Huang DT, Clermont G, Sexton *et al.* Perceptions of safety culture vary across the intensive care units of a single institution. *Crit Care Med* 2007; **35**: 165-176.

6. Sexton JB, Thomas EJ, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. *BMJ* 2000; **320**: 745-749.

7. Cooper JB, Blum RH, Carroll JS *et al.* Differences in safety climate among hospital anesthesia departments and the effect of a realistic simulation-based training program. *Anesth Analg* 2008; **106**: 574-84.

8. Singer SJ, Gaba DM, Geppert JJ *et al.* The culture of safety: results of an organization-wide survey in 15 California hospitals. *Qual Saf Health Care* 2003; **12**: 112-118.

9. Gaba DM, Singer SJ, Sinaiko AD *et al.* Differences in safety climate between hospital personnel and naval aviators. *Hum Factors* 2003; **45**: 173-185.

10. Calland JF, Guerlain S, Adams RB *et al.* A systems approach to surgical safety 2. *Surg Endosc* 2002; **16**: 1005-1014.

11. Vincent C, Moorthy K, Sarker SK *et al.* Systems approaches to surgical quality and safety: from concept to measurement. *Ann Surg* 2004; **239**: 475-482.

12. Amalberti R, Vincent C, Auroy Y *et al.* Violations and migrations in health care: a framework for understanding and management. *Qual Saf Health Care* 2006; **15** Suppl 1: i66-i71.

13. Lingard L, Reznick R, Espin S *et al.*Team communications in the operating room: Talk patterns, sites of tension, and implications for novices. *Academic -Medicine 2002 Mar* 2002; **77**: 232-237.

14. Helmreich RL. Team Performance in the Operating Room. In: Bogner S.M., editor. Human Error in Medicine. Hillsdale: Lawrence Erlbaum Associates; 1994. 225-253.

15. Thomas EJ, Sexton JB, Helmreich RL. Discrepant attitudes about teamwork among critical care nurses and physicians. *Crit Care Med* 2003; **31**: 956-959.

16. Sexton JB, Makary MA, Tersigni AR *et al.* Teamwork in the operating room: frontline perspectives among hospitals and operating room personnel. *Anesthesiology* 2006; **105**: 877-884.

17. Flin R, Yule S, McKenzie L *et al.*Attitudes to teamwork and safety in the operating theatre. *Surgeon* 2006; **4**: 145-151.

18. McDonald R, Waring J, Harrison S *et al.* Rules and guidelines in clinical practice: a qualitative study in operating theatres of doctors' and nurses' views. *Qual Saf Health Care* 2005; **14**: 290-294.

19. Espin S, Lingard L, Baker GR *et al.* Persistence of unsafe practice in everyday work: an exploration of organizational and psychological factors constraining safety in the operating room. *Qual Saf Health Care* 2006; **15**: 165-170.

20. Phipps DL, Beatty PC, Parker D *et al.* Motivational influences on anaesthetists' use of practice guidelines. *Br J Anaesth* 2009; **102**: 768-774.

21. Wagenaar WA, Groeneweg J, Hudson PTW *et al.* Promoting Safety in the Oil Industry - the Ergonomics Society Lecture Presented at the Ergonomics Society Annual Conference, Edinburgh, 13-16 April 1993. *Ergonomics* 1994; **37**: 1999-2013.

22. Van Beuzekom M, Akerboom SP, Boer F. Assessing system failures in operating rooms and intensive care units. *Qual Saf Health Care* 2007; **16**: 45-50.

23. Elbardissi AW, Wiegmann DA, Dearani JA *et al.* Application of the human factors analysis and classification system methodology to the cardiovascular surgery operating room. *Ann Thorac Surg* 2007; **83**: 1412-1418.

24. Van Beuzekom M, Boer F. A comparison of US, UK, and Dutch perioperative staffing practices. *AORN J* 2006; **84**: 632-641.

25. Hamman WR. The complexity of team training: what we have learned from aviation and its applications to medicine. *Qual Saf Health Care* 2004; **13** Suppl 1: i72-i79.

26. Smith AF, Mishra K. Interaction between anaesthetists, their patients, and the anaesthesia team. *Br J Anaesth* 2010; **105**: 60-68.

27. Fasting S, Gisvold SE. Equipment problems during anaesthesia are they a quality problem? *Br J Anaesth* 2002; **89**: 825-831.

28. Cassidy CJ, Smith A, Arnot-Smith J. Critical incident reports concerning anaesthetic equipment: analysis of the UK National Reporting and Learning System (NRLS) data from 2006-2008*. *Anaesthesia* 2011; **66**: 879-888.

29. Koch SH, Weir C, Haar M *et al.* Intensive care unit nurses' information needs and recommendations for integrated displays to improve nurses' situation awareness. *J Am Med Inform Assoc* 2012; **19:** 583-590.

30. Gurses AP, Carayon P. Performance obstacles of intensive care nurses. *Nurs Res* 2007; **56**: 185-194.

31. Rosenstein AH, O'Daniel M. Impact and implications of disruptive behavior in the perioperative arena. *J Am Coll Surg* 2006; **203**: 96-105.

32. Fletcher GC, McGeorge P, Flin RH *et al.* The role of non-technical skills in anaesthesia: a review of current literature. *Br J Anaesth* 2002; **88**: 418-429.

33. Flin R, Patey R, Glavin R *et al.*Anaesthetists' non-technical skills. *Br J Anaesth* 2010; **105:** 38-44.

*In the Netherlands anaesthesia technicians and theatre nurses train for three years; a nursing degree is not a prerequisite.

Appendix 1: LOTICS scale

Training	Adequate coaching of new personnel Keeping employees informed about new medical / technological developments Training employees in the operation of new equipment Adequate supervision of trainees in their practical period Co-workers on my department have the necessary qualifications In OR combination of staff junior / junior are avoided / on the ICU an adequate mix of seniority is applied
Communication	Information about changes in OR program / planned procedure timely provided Information about changes in OR program / planned procedure are communicated through the right channels Adequate communication about patients with other disciplines Information to perform procedure available at the time when it is needed Adequate communication about patients between teams Information to perform procedure not properly communicated
Planning & Coordination	Organizational changes not adequately supported within the department Lack of advance planning within the department Sufficiency of planning
Design	Equipment operation is difficult Controls or displays are hard to read Controls of displays are unclear and / or lacking Too much information on controls or display
Equipment	Following new technologies when procuring new equipment Availability of materials & equipment at the time it is needed Insufficient quality of materials & equipment Worn-out or faulty equipment replaced in a timely way Equipment frequently repaired Instruments often incomplete
Maintenance	Maintenance carried out on a regular basis Maintenance inspection performed timely OR / ICU equipment badly maintained Maintenance schedule is lagging

Teamwork	I really feel I am a part of my team Team's ability to deal with unexpected events Members of my team work together as a well coordinated team Clear view of who is doing what and when
Team Instructions	Team members debriefed on what they can expect during operation / shift Team members sufficiently instructed during operation / shift I have confidence in my other team members
Situation Awareness	Team members alert each other to problems Members of my team know what one another is doing Members of my team monitor each others performance Adequate exchange of information during the operation / shift
Housekeeping	Materials are often stored haphazardly The working environment is always clean An optimal arrangement of equipment is often not possible
Hierarchy	In my department we listen to each others' opinion In my department, you can freely blessing that you disagree with anything In my department will be open to criticism that the work is concerned In my department employees do not always dare to ask for explanations In my department can openly something is not right to raise
Procedures	Accessibility of procedures / regulations / rules Violations of procedures / regulations / rules Procedures / regulations / rules frequently not clear Procedures / regulations / rules frequently not applicable in practice Procedures / regulations / rules applied correctly Procedures taken a bit less seriously to do a better job

7

Summary and conclusions

Summary

There is no "best" measure of safety. Safety is too multidimensional to be represented in a single score. It is also clear that measures taken to improve safety, when performed without due regard for the total context, are often ineffective and can even be detrimental. One man's improvement may be another's latent condition. Ideally safety should be embodied throughout the institution, minimizing possible latent causes that might combine to produce injury. This continuing search to improve safety with small incremental measures is very similar to the quality concept of continuous quality improvements.

The safety of an organization can be improved by investigating and correcting the many processes that shape performance at the "sharp end". Errors do not occur of themselves, but arise within the context of the work environment. Where the environment is one that makes errors by individuals more likely, we can identify the underlying problems that will have been present in the system, often recognized but long tolerated. The factors that make errors more likely, or more dangerous, can be characterized as Latent Risk Factors (LRFs). LRFs, that is, staffing, training, communication, planning & coordination, design, maintenance, equipment, teamwork, team instructions, housekeeping, situational awareness, hierarchy and procedures. Understanding how LRFs affect safety should enable us to design more effective control measures. Improving the recognized LRFs will tilt the safety balance in the advantageous direction. Recognition of their importance and acting to improve these factors will likely be more effective in improving safety than personally directed approaches.

In chapter 2 a general overview of LRFs is given. Each one of these LRFs is the responsibility of the organization rather than of individuals, which is

why they form an appropriate level of description for the system-based approach, as opposed to the person approach that refers to individual performance factors such as skill or vigilance.

In chapter 3 the development of the Leiden Operating Theatre Intensive Care Scale (LOTICS) is describes as an instrument to detect the underlying causes of medical errors proactively by measuring LRFs. In the prospective survey, items can be either indicators of either potential problems or good practice. It shows the strengths and weakness of an organization, allowing the possibility of data-driven interventions. Changes in patient safety performance can then be monitored and the effects of interventions to improve the level of patient safety can be evaluated. Similarly, LOTICS can be used for comparison of different hospital, clinical areas and disciplines within the medical system.

In chapter 4 an approach to a successful implementation of a patient safety program is described in the Operating Theatre. The favourable change of the LRFs: material and staffing resources concurred with a decrease in perceived and reported error rates in the relevant categories. This type of intervention can provide direct benefits to the staff of an OT, because the changes on the working environment were both visible and resulted in improvement in task performance and are therefore likely to be accepted.

In chapter 5 the relationships between Latent Risk Factors (LRFs) and well-being in anaesthesia teams of three university hospitals in the Netherlands were investigated. The results indicate that the job satisfaction, stress and intention to leave are predicted rather well by the LRFs. Importantly, this finding shows that unfavorable working conditions not only result in potential hazards for patient safety, but also negatively affect employees' job satisfaction, job stress and increase intention to leave the job. Most studies on safety issues in anaesthesia have focused on anesthetists, but the results of this study show that, in addition to anaesthetists, other anaesthesia team members should be included in studies to get a valid impression of the theatre room's safety health.

In chapter 6 we focused on the influence of the clinical area (Operating Theatre vs. Intensive Care Unit) and disciplines on reported scores in an inquiry on patient safety. We observed that the ICU staff reported fewer problems for training, communication, team instruction and hierarchy than the OT staff. This could be the result of the entirely different process, compared to OT or ward work. The OT had more favorable perception, on design and equipment resources. We found differences between disciplines on all Latent Risk Factors. We speculate that this is the result of differences in work organization content and professional training.

Conclusions

The prospective identification of Latent Risk Factors (LRFs) can lead to removal of error-inducing conditions before they can contribute to patient injury. Identifying LRFs will improve patient safety by improving the conditions that set the working environment for the occurrence of errors. Interventions aimed at unfavorable LRFs detected by the LOTICS, may contribute to the improvement of patient safety in the OT. This thesis has shown that staff from OT and ICU is able to detect these shortcomings but differ in their scope of the present risks. Unfavorable LRFs can act as stressful triggers at the workplace. If staff cannot control such stress this may negatively affect their well-being. The key to a healthy workplace is to control the deficiencies in the structure of the working environment.

The willingness of staff to speak up about a patient-safety concern is an important part of safety in the Operating Theatre and Intensive Care Unit. Therefore there needs to be a culture of openness. We think a first step in this approach is to build a strong foundation of safety awareness among staff. This may best be done by implementing concrete and visible improvements. We think staff perceptions of safety are a high priority issue within the Operating Theatre and Intensive Care Unit, which will eventually motivate staff to take greater ownership of and responsibility for patient safety.

8

Samenvatting en conclusies

Samenvatting

Een goede maat voor patiëntveiligheid is moeilijk te geven. Patiëntveiligheid hangt van zoveel factoren af, dat het niet mogelijk is om deze in één getal te vangen. Het is duidelijk dat wanneer maatregelen om de veiligheid te verbeteren zonder inachtneming van de totale context worden ingevoerd, deze vaak niet effectief en zelfs schadelijk kunnen zijn. Idealiter moet veiligheid verbeterd worden op de werkvloer door het minimaliseren van latente oorzaken die in combinatie schade kunnen veroorzaken. De voortdurende zoektocht om met kleine stapsgewijze maatregelen de veiligheid te verbeteren, is vergelijkbaar met het kwaliteitsconcept van voortdurende kwaliteitsverbetering.

De veiligheid van een organisatie kan worden verbeterd door het onderzoeken en corrigeren van processen die het gedrag op de werkvloer ("the sharp end") bepalen. Fouten komen niet van zelf, maar ontstaan binnen de context van de werkomgeving. In deze werkomgeving zijn een aantal risico factoren aanwezig die aanleiding kunnen geven tot fouten maar die niet meteen in het oog springen. Daarom worden ze Latente Risico Factoren (LRFs) genoemd. LRFs dat zijn personeel, opleiding, communicatie, planning & coördinatie, ontwerp, onderhoud en beschikbaarheid van apparatuur, teamwork, team instructies, hygiëne, situationele awareness, hiërarchie en procedures. Onderzoek maakt duidelijk dat verborgen gebreken in het systeem de werkende mens in een positie kan brengen waarin ze fouten maken of 'onveilig gedrag' vertonen. Om de patiëntveiligheid te optimaliseren is inzicht in de kans op fouten en incidenten een belangrijke voorwaarde. Inzicht in de onderliggende oorzaken van onveiligheid maakt dat er gericht maatregelen getroffen kunnen worden om de veiligheid structureel te

verbeteren. Verbeteren van deze onderliggende factoren is meer effectief dan verbeteringen gericht op de directe oorzaken van fouten.

In hoofdstuk 2 wordt een overzicht van LRFs gegeven. De controle van elk van deze LRFs valt onder de verantwoordelijkheid van de organisatie en niet onder die van het individu. Daarom passen ze in een systeemgerichte benadering. Deze benadering staat in tegenstelling tot de persoonsgerichte benadering, waarin individuele prestatiematen, zoals vaardigheden of oplettendheid, centraal staan.

In hoofdstuk 3 wordt de ontwikkeling van de Leidse Operatie en Intensive Care schaal (LOTICS) beschreven als een instrument om proactief de onderliggende oorzaken van fouten te detecteren door het meten van LRFs. De schaal toont de sterke en zwakke punten van een organisatie, waardoor de mogelijkheid ontstaat van data gestuurde interventies. Veranderingen in de veiligheid kunnen daardoor worden gecontroleerd en de effecten van interventies worden geëvalueerd. Op dezelfde manier kan de LOTICS worden gebruikt voor vergelijking tussen ziekenhuizen, werkunits en disciplines.

In hoofdstuk 4 wordt een succesvolle implementatie van een veiligheidsprogramma in de operatiekamer beschreven. De gunstige verandering in LRFs: apparatuur/materiaal en personele bezetting, gingen gepaard met een daling van het totale aantal waargenomen (bijna)fouten en een daling van fouten in de betreffende categorieën. Dit type interventie heeft voordelen voor het personeel van een OK, omdat de veranderingen in de werkomgeving zichtbaar zijn en resulteerden in verbetering van de taakuitvoering en daarom waarschijnlijk worden geaccepteerd.

In hoofdstuk 5 worden de relaties tussen de Latente Risico Factoren (LRFs) en welzijn in anesthesieteams onderzocht. De resultaten geven aan dat arbeidssatisfactie, stress en intentie om te vertrekken vrij goed voorspeld worden door de LRFs. Belangrijk is dat deze bevinding aantoont dat ongunstige arbeidsomstandigheden niet alleen leiden tot mogelijke gevaren voor de patiëntveiligheid, maar ook een negatieve invloed hebben op stress gerelateerde uitkomstmaten. De meeste studies over veiligheidskwesties in de anesthesie hebben zich geconcentreerd op anesthesiologen, maar de resultaten van deze studie tonen aan dat om een valide beeld van de veiligheid te krijgen het hele anesthesie team hierbij betrokken moet worden.

In hoofdstuk 6 hebben we ons gericht op de invloed van de klinische omgeving (Operatiekamer vs. Intensive Care Unit) en disciplines op de scores op de LRFs. We zagen dat IC personeel (staf en verpleegkundigen) minder problemen waarneemt voor training, communicatie, team instructie en hiërarchie. Dit kan het gevolg zijn van een ander werkproces, in vergelijking met de operatiekamer. Anesthesisten en personeel van de OK hadden een gunstigere perceptie over ontwerp en beschikbaarheid van apparatuur dan die van de ICU. We vonden verschillen tussen disciplines op alle LRFs. We suggereren dat dit het gevolg is van verschillen in organisatie van werk en professionele training. De taken van de verschillende disciplines kunnen een verklaring zijn dat ze slechts een aantal aspecten, maar niet het gehele plaatje overzien. Daarom adviseren wij in het kader van veiligheidsprogramma's, alle disciplines erbij te betrekken.

Conclusies

De proactieve identificatie van LRFs helpt bij het ontwikkelen van maatregelen om foutinducerende omstandigheden te voorkomen, voordat zij een bijdrage kunnen leveren aan letsel bij de patiënt. Interventies gericht op ongunstige LRFs zoals gemeten met de LOTICS kunnen patiëntveiligheid verbeteren. Dit proefschrift heeft aangetoond dat staf en medewerkers van afdelingen anesthesiologie, OK en ICU in staat zijn om deze tekortkomingen te signaleren, hoewel ze in waardering over de risico's verschillen. Ongunstige LRFs kunnen fungeren als stressoren op de werkplek en een negatieve invloed hebben op het welzijn van het personeel. De sleutel tot een gezonde werkplek is het beheersen van de tekortkomingen in de structuur van de werkomgeving.

De bereidheid van het personeel te spreken over patiëntveiligheid is een belangrijk onderdeel van de veiligheid in de OK en ICU. Daarom is een cultuur van openheid van belang. We denken dat het versterken van het veiligheidsbewustzijn onder medewerkers een begin is om dit te realiseren. Dit kan het beste worden gedaan door de uitvoering van concrete en zichtbare verbeteringen. We denken dat indien personeel en staf de patiëntveiligheid binnen de OK en ICU een hoge prioriteit geeft dit uiteindelijk hen zal motiveren tot een grotere betrokkenheid bij en verantwoordelijkheid voor de veiligheid van de patiënt.

Curriculum Vitae

Martie van Beuzekom was born on the 13th of June, 1955 in Sliedrecht. After completing secondary school (Merwerode, Dordrecht, HAVO), she went to the Nursery School (1974-1978) of the Free University in Amsterdam. Initially she was employed at the emergency department. From 1982 on she combined her work with the Masters study Psychology of the University of Amsterdam. She performed graduation projects at the Onze Lieve Vrouwe Gasthuis on emotional and cognitive aspects of cardiac surgery and at the GGD with a comparative study of HIV negative and HIV positive gay men on their Cognitive and Emotional Functioning. She attained her degree of Master of Arts in Psychology in 1988. She finished a higher management education at the institute of business administration (1991). In 1999 she was registered as Health Psychologist. In 2002 she obtained a master's degree strategic management at the business school of University at Utrecht.

Between 1988 and 1989, she was employed at the Academic Medical Centre on a research project on AIDS care. Between 1990 and 1992 she was project coordinator AIDS for the Dutch Association of Out-Patient Mental Health Care (NVAGG). After 1992 she worked in succession at the RIAGG in Amsterdam ZNW on several projects on mental AIDS care and the last years also on quality of care. From 1993 she was also employed at the Flevohuis, particularly for the AIDS-unit. Between 1997 and 1998 she was employed at the Hospital of Hilversum as Manager of the Operating Room. In the same year she started as manager OR-center in the Leiden University Medical Center. In 2012 she started to work on several projects on patient safety management.

In 2005 she started with F. Boer and S. Akerboom (Cognitive Sciences, Leiden University) a research project on safety in the Operating Department and Intensive Care Unit, on the supervision of A. Dahan from 2010.

List of Publications

Boer F, Beuzekom M, v: Continu to train OR nurses. *Medisch Contact* 2005; **60**: 1646-1647.

Van Beuzekom M, Boer F: A comparison of US, UK, and Dutch perioperative staffing practices. *AORN J* 2006; **84**: 632-641.

Vuyk J, Van Den BJ, Terhell K, De Bos R, Vletter A, Valk P *et al.*: Acetazolamide improves cerebral oxygenation during exercise at high altitude. *High Alt Med Biol* 2006; **7**: 290-301.

Van Beuzekom M, Akerboom SP, Boer F: Assessing system failures in operating rooms and intensive care units. *Qual Saf Health Care* 2007; **16**: 45-50.

Caljouw MA, van Beuzekom M, Boer F: Patient's satisfaction with perioperative care: development, validation, and application of a questionnaire. *Br J Anaesth* 2008; **100**: 637-644.

Van Beuzekom M, Boer F, Akerboom S, Hudson P: Patient safety: latent risk factors. *Br J Anaesth* 2010; **105**: 52-59.

Van Beuzekom M, Boer F, Akerboom S *et al*. Patient safety in the operating room: an intervention study on latent risk factors. *BMC Surg* 2012; **12**: 10.

Van Beuzekom M, Akerboom SP, Boer F, Dahan, A: Influence of Latent Risk Factors on job satisfaction, job stress and intention to leave in anaesthesia teams. *submitted Eur.J.Anaesthesiol.*

Van Beuzekom M, Akerboom SP, Boer F, Dahan, A: Perception of patient safety differs by clinical area and disciplines. *accepted Br J Anaesth.*