

Human factors in the management of the critically ill patient

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Key points

- Critical care reliability can be improved at the level of the task, healthcare worker, and organization.
- Tasks should be standardized, simplified, and based on best practice guidelines.
- Clinician teamworking and communication can be improved using checklists and reflective learning techniques.
- Supportive organizations adopt executive walkrounds, ‘adoption’ of clinical areas, and systematic learning from error.

Summary. Unreliable delivery of best practice care is a major component of medical error. Critically ill patients are particularly susceptible to error and unreliable care. Human factors analysis, widely used in industry, provides insights into how interactions between organizations, tasks, and the individual worker impact on human behaviour and affect systems reliability. We adopt a human factors approach to examine determinants of clinical reliability in the management of critically ill patients. We conducted a narrative review based on a Medline search (1950–March 2010) combining intensive/critical care (units) with medical errors, patient safety, or delivery of healthcare; keyword and Internet search ‘human factors’ or ‘ergonomics’. Critical illness represents a high-risk, complex system spanning speciality and geographical boundaries. Substantial opportunities exist for improving the safety and reliability of care of critically ill patients at the level of the task, the individual healthcare provider, and the organization or system. Task standardization (best practice guidelines) and simplification (bundling or checklists) should be implemented where scientific evidence is strong, or adopted subject to further research (‘dynamic standardization’). Technical interventions should be embedded in everyday practice by the adjunctive use of non-technical (behavioural) interventions. These include executive ‘adoption’ of clinical areas, systematic methods for identifying hazards and reflective learning from error, and a range of techniques for improving teamworking and communication. Human factors analysis provides a useful framework for understanding and rectifying the causes of error and unreliability, particularly in complex systems such as critical care.

Keywords: ergonomics; human factors; intensive/critical care; medical errors; patient safety

Human factors, or ergonomics, are the study of how interactions between organizations, tasks, and the individual worker impact on human behaviour and affect systems performance.^{1–2} This implies that systems design should be based on an understanding of human behaviour and the nature of the task, rather than necessarily adapting performance to suit the system. To do this effectively demands a multidisciplinary approach,³ involving, for example, anthropometry, ethnography, biomechanics, industrial and social psychology, architecture, education, and information technology, and also users and consumers—in the context of healthcare, patients, clinicians, and managers.⁴ This makes human factors a particularly rich area of investigation. Human factors influencing performance at the level of the task, the individual, and the organization or system are summarized in Table 1, taken from guidance on human factors provided by the UK’s Health and Safety Executive.⁵ The clinical history presented in Box 1 demonstrates some of the challenges for human factors and quality improvement research in complex systems. In this article, we explore how a human factors approach can reduce error and adverse events by improving reliability of healthcare delivery to critically ill patients.

Background

The Institute of Medicine’s (IoM) Report in 2000 ‘To Err is Human’⁶ and the UK’s ‘Organisation with a Memory’⁷ were pivotal publications in changing attitudes of individuals and whole systems to safety. The IoM report used data from retrospective case note review studies^{8–10} demonstrating high levels of adverse events (4–16% of patients) and avoidable harm, and called for concerted action¹¹ to improve patient safety. Studies in other countries^{12–16} and a systematic review¹⁷ reinforced these data. In 2005, the World Health Organisation (WHO) formed the *World Alliance for Patient Safety*¹⁸ to integrate national efforts with a series of biannual worldwide clinical challenges—first, for hand hygiene, next for operative management with the introduction of the WHO surgical safety checklist, with evidence of benefit¹⁹ across all participating countries despite very different health systems.

However, there are perceptions that progress in improving safety has been rather slow.^{20–21} This may indicate ‘systems inertia’, methodological difficulties with measurement, greater awareness of error resulting in more frequent reporting, or perhaps that the concept of safety does not directly engage the attention of clinicians and others responsible

Table 1 Factors influencing performance Health and Safety Executive: <http://www.hse.gov.uk/humanfactors/topics/pifs.pdf>

Task
Clarity of signs, signals, instructions, and other information
System/equipment interface (labelling, alarms, error avoidance/tolerance)
Difficulty/complexity of task
Routine or unusual
Divided attention
Procedures inadequate or inappropriate
Preparation for task (e.g. permits, risk assessments, checking)
Time available/required
Tools appropriate for task
Communication, with colleagues, supervision
Working environment (noise, heat, space, lighting, ventilation)
Person
Physical capability and condition
Fatigue (acute from temporary situation, or chronic)
Stress/morale
Work overload/underload
Competence
Motivation, competing priorities
Organization
Work pressures, e.g. production vs safety
Level and nature of supervision/leadership
Communication
Staffing levels
Peer pressure
Clarity of roles and responsibilities
Consequences of failure to follow rules/procedures
Effectiveness of organizational learning (learning from experiences)
Organizational or safety culture, e.g. everyone breaks the rules

for healthcare delivery. Safety means the absence of error, a negative concept. An alternative way of expressing the problem is to focus on reliability of care. Reliability means delivery of best practice care to the right people at the right time, which accords more closely with the concept of professionalism, is more positive, and provides a clear benchmark for audit: improve reliability, and safety must follow.

Box 1 Complex systems in critical illness

The ICU team was called during the 08:00 h handover to review a patient in a surgical ward.

An 81-yr-old lady had been hospitalized for 1 week for medical treatment of a colonic-cutaneous fistula. She had rheumatoid arthritis, inoperable ischaemic heart disease, and a previous nephrectomy. I.V. antimicrobials had not been administered for 24 h because the peripheral i.v. cannula had tissued and venous access was difficult. She was colonized with MRSA and faeces were positive for *Clostridium difficile*.

At 21:30 h, the previous evening she had developed progressive septic shock. Nurses documented hourly abnormal vital signs all night, at 01:00 h calling the locum resident doctor who had failed to secure venous access, substituting an s.c. infusion of dextrose-saline at 45 ml h⁻¹. No other action had been taken by any member of staff. The junior doctor coming on duty at 08:00 h immediately called the ICU. On arrival, the ICU consultant noted the absence of infection control measures, which the night nursing staff going off duty dismissed as the responsibility of the day staff. After telephone discussion with the off-site consultant surgeon, the ICU consultant applied a treatment limitation decision, the patient's husband was contacted, and comfort care was provided. She died some hours later without distress and with her husband by the bedside.

Subsequent enquiry and root cause analysis revealed multiple problems at all levels, including frontline staff competence, supervision, morale, and empowerment; prolonged night-time working patterns; lack of compassion and discipline; compliant but deeply unattractive junior staff rotas; inadequate organizational leadership; and national restrictions on working hours, funding, and accreditation of training posts.

Reliability of healthcare

We define reliability as the ability of a system to perform its desired functions under stated conditions for a specified period of time. Reliability is thus primarily a process measure, but it is often presented in terms of outcome, even though the link between process and outcome in complex systems is indistinct and non-linear. The most widely used industrial examples of high reliability include civilian aviation (rate in terms of mortalities of 10⁻⁶—less than one death per million opportunities), or nuclear power and oil exploration, though all of these industries can provide examples of catastrophic failure. Judged on this metric, emergency and critical care are highly problematic, with mortality rates of around 20%,^{22 23} which is why we correct for risk of death using increasingly sophisticated case-mix-adjustment methods. Even then we find substantial differences in case-mix-adjusted mortality rates. The problem with using outcome as a performance measure is that it does not provide insights into methods of quality improvement. Process measures by contrast are empowering, because they direct attention to those system components over which practitioners may have some control. Using this approach, unreliable healthcare—the gap between desired and actual practice expressed as the proportion of errors to total opportunities for error—is very common.^{24 25} Thus, McGlynn and colleagues²⁴ identified a failure rate of 54% in delivery of best practice interventions in the USA. Errors of omission are among the most frequent, but more difficult to detect than errors of commission, for example, in drug administration or operative procedures¹⁷

which are more frequently cited. Underlying (or root) causes are not well described, but behavioural factors, particularly communication failures (around 80% of errors),²⁶ are the most important.

The environment: the critical care unit as a model of complexity and acuity

Critical care is a particularly fruitful area for human factors research, since reliability is a key issue in an environment characterized by life-threatening illness, unpredictable pathways, diagnostic uncertainty, and rapidly changing physical states, with vigilance required for days or weeks, at all hours of day and night, with multiple transitions between teams and geographical areas resulting in lapses and discontinuities in communication.²⁷ Process control, absolutely essential for reliability improvement, is difficult to maintain in these circumstances.^{28 29} Given this perspective, the best analogy for critical care is military (not civilian) aviation.

While the intensive care unit (ICU) concentrates resources, knowledge, and skills to ensure high-quality process control, it also offers multiple opportunities for error. Since the first study in 1995,³⁰ errors and adverse events remain common in ICU patients. A direct observational study³¹ found that 124 of 400 (31%) consecutive patients admitted to an ICU had 316 adverse events, a rate of 2.5 complications per patient. In a review³² of the medical records of 295 consecutive patients admitted to a medical ICU, 42 (14%) had one or more adverse events during their treatment. Two studies using voluntary reporting systems found that one or more errors occurred during the care of 13–20% of patients admitted to an ICU, a rate of 26–89 errors/1000 patient days.^{33 34} Deficiencies in communication and teamworking inhibit the development of shared treatment goals.³⁵ Medical staff are more likely than their nursing colleagues to believe that teamworking is good³⁶ and overestimate the reliability with which they deliver best practice care.³⁶ Paediatric ICU shows similar rates, with 220 adverse events during 730 nursing shifts, a rate of 60 per 1000 patient days.³⁷ Adverse events in ICU patients are associated with prolonged hospital stays and higher mortality.^{31 32} Thus, even in this most secure of environments, there are significant opportunities for improvement.

Improvement: barriers and facilitators

The system: social and organizational factors

The case history presented in Box 1 demonstrates the complex interplay between systems, tasks, and people responsible for the critically ill patient. Despite numerous publications on change management in healthcare, sustained quality improvement resulting in better patient outcomes is one of the most difficult of all tasks for health systems.^{38 39} Frequent ‘top-down’ initiatives are unlikely to be adopted with enthusiasm by frontline staff confronting the daily complexities of patient care, particularly when too many organizations are involved with overlapping responsibility for hospital

accreditation, clinical practice standard development, training provision, professional education, and patient safety itself. The few examples of verifiably successful and sustained large-scale quality improvement collaborations⁴⁰ are counterbalanced by many of limited, or no, efficacy,⁴¹ stimulating demands⁴² for greater research investment and methodological rigour in quality improvement initiatives. A common weakness of many improvement efforts has been to focus improvement efforts solely on the terminal link in the error pathway (the clinician), instead of exploring failure points throughout the entire system. A human factors-based approach thus has many merits, integrating multidisciplinary improvement efforts across the entire pathway of care, from national policy formulation to frontline staff.

‘Blaming front line individuals, denying the existence of systemic error-provoking weaknesses and the blinkered pursuit of productive and financial indicators’ are described by James Reason and colleagues⁴³ as features of the vulnerable systems syndrome. The organizational structure should, therefore, reflect widely shared strategic aims involving all groups. The differing authority and power of doctors, nurses, and patients makes it difficult in some cultures to challenge and correct errors, a major problem in acute care where system tolerances may be low. In a survey of three paediatric cardiac surgical centres, 60% of respondents stated that it was difficult to discuss mistakes in their working environment, 71% had no debriefing after adverse events, 39% that guidelines were often ignored, and 27% that clinical disagreements were not effectively resolved.⁴⁴ Visible frontline leadership by executives, and interlinkages across hierarchies and professional ‘silos’ help to improve communication and transdisciplinary learning, essential for acutely ill patients whose healthcare journey crosses speciality and geographical boundaries.

Teamworking may mean some loss of professional autonomy, but this is counterbalanced by taking personal responsibility, having pride in one’s work, and leadership. Good role models and effective opinion leaders are essential in developing an organization which is patient-focused, transparent, reflective, self-critical, supportive, and forward-looking. Resources must be made available for all aspects of reliability improvement, including staff development.

The task: defining and delivering best practice

Evidence-based, best-practice standards provide the yardstick against which reliability is measured. Creating these standards is a very popular academic activity. However, the large number of best-practice guidelines in the scientific literature is at odds with the evidence of unreliability of care, as demonstrated by gap analyses. There are several reasons why physicians may be deliberately unwilling to standardize their practice. These include a belief that standardization undermines the professional fiduciary relationship between the physician and patient by prioritizing standardization over the needs of the individual patient; insufficiently convincing or absent data that an intervention

is beneficial; lack of insight into the degree of unreliability of clinical practice; failure to appreciate the downstream consequences 'random' behaviour presents in complex systems; concern that practice standards will be used for performance management, not quality improvement; and a very reasonable concern that today's wonder drug will turn out to be tomorrow's poison.⁴⁵

These tensions can be partly resolved through the use of consensus techniques in evaluating the scientific literature, and a system such as GRADE⁴⁶ to consider separately the strength of evidence and the strength of the recommendation. When evidence is weak, indirect, or conflicting, the process of arriving at a judgement to use, or not use, a particular intervention can be clarified by formal consensus techniques based on private polling of opinion within nominal groups.⁴⁷ This is necessary for established treatments with strong face validity unsupported by evidence from randomized controlled trials (e.g. timing of antibiotics for septic shock, rationing access to ICUs, or hand hygiene). Patterns of polling can show consensus, polarization, or equipoise; and give a clear measure of strength of opinion. This also provides an estimate of uncertainty and helps to identify those interventions which require further research—the concept of 'dynamic standardization'.

The relative lack of impact of guidelines on clinical practice and the difficulty of implementing large numbers of recommendations has encouraged quality improvement groups to develop care 'bundles' or 'standard order sets'. Care bundles were first proposed by the Institute for Healthcare Improvement (IHI), then adopted by the Joint Commission in the USA⁴⁸ and the National Health Service in the UK,⁴⁹ and have been used to facilitate implementation of the Surviving Sepsis Campaign guidelines.⁵⁰ Advantages of bundling include synergism, reducing complexity, and enforcing best practice, but their use has been opposed by those concerned about the science behind individual component elements, and the legal implications of non-implementation. There is little evidence that bundles *per se* improve reliability, but there is now evidence that improving the reliability of delivery of ('bundled') best practice improves patient outcomes, despite only very modest improvements in compliance.^{51 52}

The individual: determinants of behaviour

Desire for progress competes with distaste for change. All clinicians are aware of examples of promising new interventions which subsequently failed to demonstrate benefit or were found to cause harm,⁵³ and a degree of scepticism and a desire for objective verifiable evidence of benefit is appropriate and reasonable. The effort required for quality improvement is often not recognized and rewarded in the same way as other research interventions, and the research methodologies are perceived as less robust which makes it more difficult to demonstrate success.⁵⁴

Fatigue,^{55 56} burnout,⁵⁷ and depression⁵⁸ all contribute to error. Attitudinal and behavioural barriers to implementing best practice vary widely between individuals, making

generalizability difficult.^{38 59} Knowledge deficits are less common than implementation failures.^{60 61} Competence-based training is important in defining educational outcomes, but it needs to be accompanied by a strong focus on professionalism—attitudes and behaviours—to ensure that excellence becomes a habit ('normalized'). Communication failures contribute to error in around 80% of instances.^{35 36 62–74} Changing behaviour takes courage, persistence, willingness to learn from others, and leadership from in front. Patients also need to be empowered as partners in improving their own outcomes.

'Change' is more likely to result in improvement if it is approached in a systematic and integrated manner which takes into account the interrelationships between the intervention itself, the individuals who will implement it, the system in terms of social, cultural, and organizational factors, and the tools and metrics available to assess performance and outcomes. The utility of financial incentives^{75–78} does not mean that fiscal reward is the solution to unreliability; it means that quality improvement requires a systems approach to changing behaviour.⁷⁹ Understanding the reasons for failure to deliver high-reliability care is essential prior knowledge for designing improvement projects.

Improvement: tools and techniques

Quality improvement research is challenging not only because it involves changing behaviour but because equipoise is often absent for interventions which have become sanctioned by custom and which do not lend themselves to analysis by prospective randomized controlled trial. A systematic approach to planning is essential, and we have presented this synoptically in Figure 1, derived from the work by Pronovost, Cook, Curtis^{80–82} and our own experiences in the NPSA's 'Matching Michigan' project.

The work starts with examining the most recent scientific evidence, auditing current practice, and surveying the local environment through pilot studies or audits. Active engagement of both organizational leaders and frontline colleagues is essential, using information from local audit and gap analyses performed (for example) as trainee or undergraduate projects. This can include surveys of attitudes and behaviours, for example, of teamworking, patient safety, and staff empowerment. Motivation for change will vary between groups, and include better clinical outcomes, resource utilization, quality targets, and client-focus. Patient and public engagement is also a powerful instrument for facilitating change.⁸³

The intervention usually requires a combination of evidence-based technical elements, and supporting 'non-technical' (behavioural) components intended to normalize and embed the intervention in routine practice at all points in the patient journey where it might be applied. Improvement tools may thus be classified as technical and non-technical. Technical interventions generally involve 'tangibles'—actions, devices, and activities which involve a specialist manual skill—whereas non-technical interventions are those focused

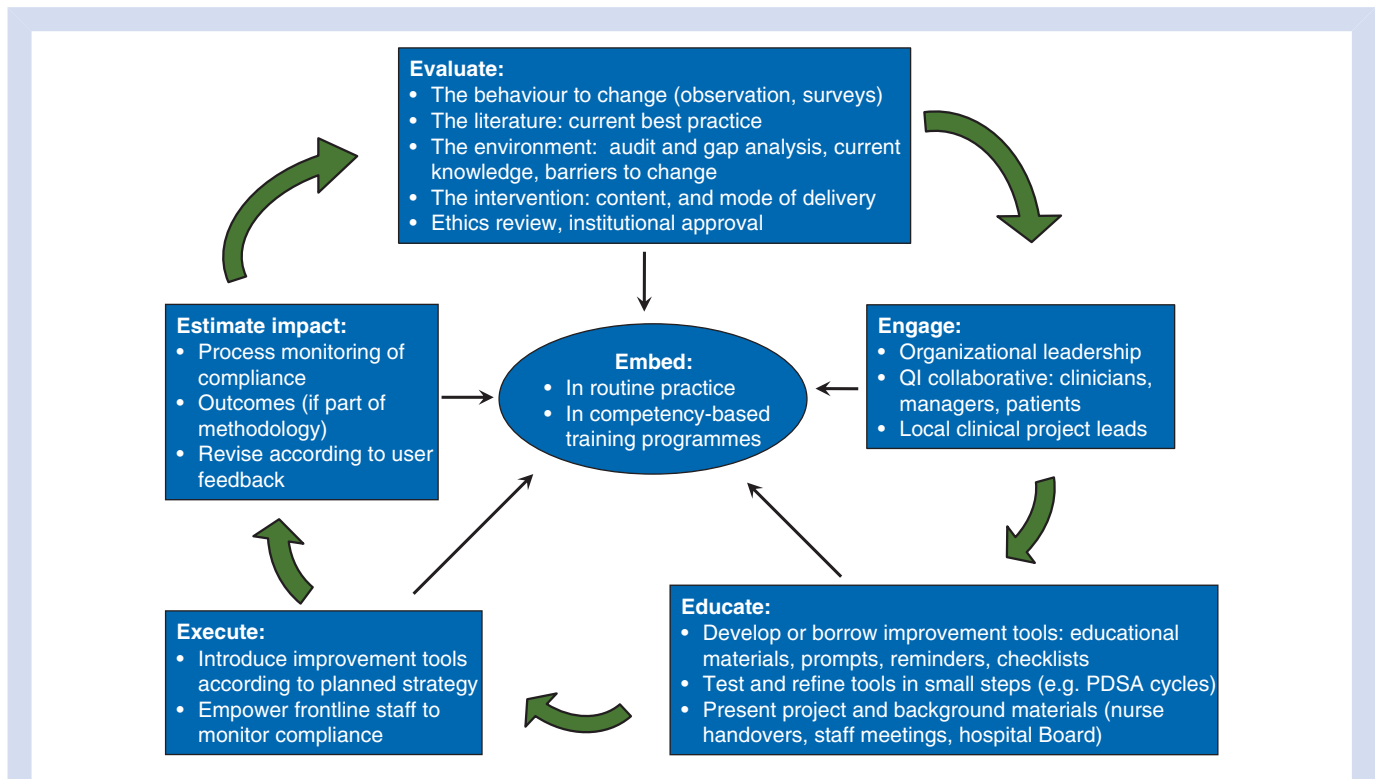


Fig 1 Planning a quality improvement project.

Table 2 Examples of improvement tools developed to minimize central venous catheter bloodstream infections (CVC-BSIs)

	Intervention	Aim or activity	Tool
Technical	Evidence-based best practice	Educational resources, guidelines, care bundles	DH CVC insertion and continuing care guidelines and bundles ⁸⁴
	Equipment	Inventories, easy access and availability	CVC trolley or cart
	Standardization and staff buy-in	Unit policies	CVC management standard operating procedures
Non-technical and reflective learning	Forcing functions	Electronic prescribing	Computerized prescribing system includes CVC insertion and maintenance
	Clinical decision support	Checklists, prompts, reminders	CVC insertion checklist
	Staff attitudes to unit safety, teamworking, and empowerment	'Diagnostic' tool to assess safety culture and empower discussions about improving patient safety	Agency for Healthcare Research and Quality (AHRQ) Safety Culture Survey ⁸⁵
	Information about current lapses in safety	Critical Incident monitoring	Incident reports Staff safety assessment
	Shared understanding of treatment pathways	Facilitates communication between all members of the multidisciplinary team	Daily goals chart
	Observation of team behaviours	Structured observation and feedback to team members	Observing patient rounds
	Observation of individual behaviour	Understanding roles and responsibilities of other team members	Shadowing another professional
Reflective learning	Insight into views of others about performance, role model	Multisource feedback	
Engagement and sustainability	Executive engagement	Member of hospital board meets regularly with ICU staff, joins unit safety group, participates in unit safety meetings	Executive walk-rounds. Executive-clinician partnerships, including shadowing
	Reliability of care at local level	Audit, gap analyses, feedback	Feedback of CVC-BSI data
	Training and education	Competency-based training programmes linked to educational resources	www.CoBaTrICE.org ⁸⁶

on behaviours. The former ensures delivery of the right care to the right patient, and the latter ensures that this happens every time, that it becomes sustainable. To some extent, the distinction is blurred, since many interventions (e.g. checklists) look like technical devices but require behavioural change to be effective.⁸⁷ We have listed in Table 2 examples of those interventions that we have developed for the UK's National Patient Safety Agency 'Matching Michigan' project, based on the work by Pronovost and Goeschel and colleagues in the USA, to reduce bloodstream infections linked to the use of central venous catheters.

There is no single, ideal method or tool for implementing and sustaining changes in clinical practice. Multifaceted interventions may be no more effective than properly applied single interventions.²² Some interventions are, of necessity, multifaceted (e.g. rapid response–medical emergency or outreach–teams), in which case the content of the intervention should be made explicit. It is also important to distinguish between the intervention (e.g. earlier antimicrobials for sepsis) and the vehicle for delivery (e.g. outreach care, education).

Improvement tools should be as simple as possible, locally adaptable, and designed with the active involvement of those who will use them. Each step should contribute to understanding of long-term change, best achieved through training programmes—at national and international level when based on strong scientific evidence and systematic reviews, but also at the local level in seminars and tutorials.

Conclusions

Human factors analysis provides a useful framework for examining facilitators and barriers of reliable delivery of best practice care, promoting patient safety, and minimizing error. A systematic approach to implementing technical and non-technical interventions is essential. Standardized care reduces opportunities for error, but challenges clinicians to make judgements about what constitutes best practice without inhibiting continued research and further refinement of clinical guidelines. Engagement in, and ownership of, quality improvement initiatives by frontline staff with the involvement of patients is central to success.

Conflict of interest

None declared.

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