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REVIEW ARTICLE

Non-technical skills in the intensive care unit

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In high-risk industries such as aviation, the skills not related directly to technical expertise, but crucial for maintaining safety (e.g. teamwork), have been categorized as non-technical skills. Recently, research in anaesthesia has identified and developed a taxonomy of the non-technical skills requisite for safety in the operating theatre. Although many of the principles related to performance and safety within anaesthesia are relevant to the intensive care unit (ICU), relatively little research has been done to identify the non-technical skills required for safe practice within the ICU. This review focused upon critical incident studies in the ICU, in order to examine whether the contributory factors identified as underlying the critical incidents, were associated with the skill categories (e.g. task management, teamwork, situation awareness and decision making) outlined in the Anaesthetists' Non-technical Skills (ANTS) taxonomy. We found that a large proportion of the contributory factors underlying critical incidents could be attributed to a non-technical skill category outlined in the ANTS taxonomy. This is informative both for future critical incident reporting, and also as an indication that the ANTS taxonomy may provide a good starting point for the development of a non-technical skills taxonomy for intensive care. However, the ICU presents a range of unique challenges to practitioners working within it. It is therefore necessary to conduct further non-technical skills research, using human factors techniques such as root-cause analyses, observation of behaviour, attitudinal surveys, studies of cognition, and structured interviews to develop a better understanding of the non-technical skills important for safety within the ICU. Examples of such research highlight the utility of these techniques.

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In the UK, the Department of Health's report on patient safety has encouraged healthcare providers in areas such as anaesthesia and intensive care medicine to emulate high-risk industries, for example aviation and nuclear power, in the application of human factors research to enhance safety.[9] In aviation, pilots' skills not directly related to technical expertise, but crucial for maintaining safety are called non-technical skills, and include interpersonal skills such as communication, teamwork and leadership, and cognitive skills such as task management, situation awareness and decision making.[2 16] Within the nuclear power and aviation industries, the specific non-technical skills important for protecting against errors have been empirically identified and trained through Crew Resource Management courses.[41 11 18] During the last 20 yr, the importance of non-technical skills for delivering safe and high-quality medical care has been increasingly recognized, if not explicitly addressed, in medical training.[31] More recently, research has begun to identify the specific non-technical skills important for safety in medical domains such as anaesthesia and surgery.[15 21 25 45] Each working environment has its own unique non-technical skill requirements. Although the principal skill categories may be generic and relatively transferable across domains,[19] the component behaviours that demonstrate proficiency in those skills within a particular environment (e.g. the operating room) will be specific to the needs and characteristics of a domain.[27 31] Rall and Gaba[34] have pointed out that many of the principles related to performance and safety within anaesthesia are also pertinent to the intensive care unit (ICU). The current article reflects on the relevance to the intensive care environment of the non-technical skills

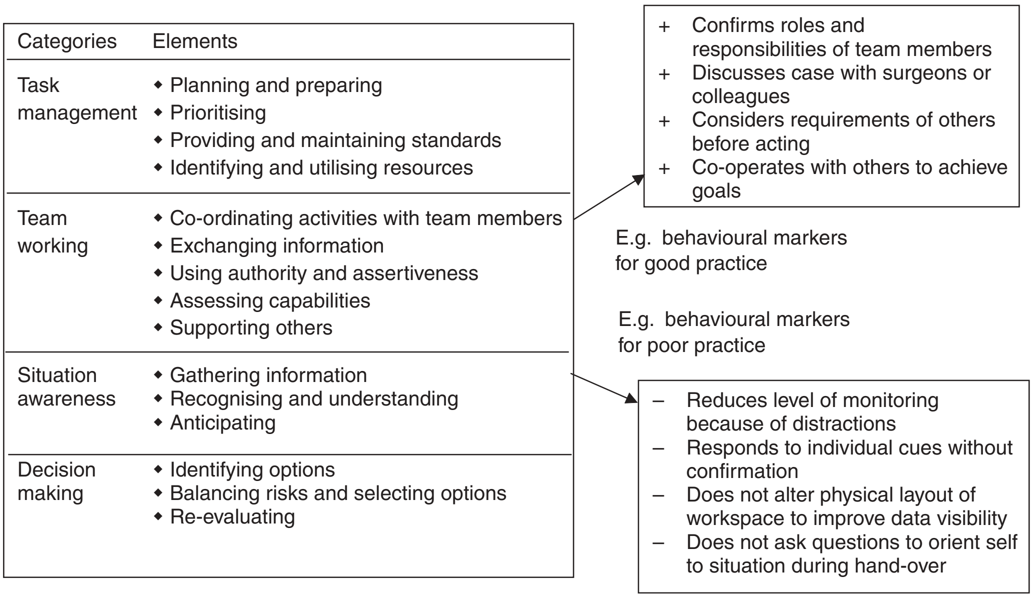

Fig 1 ANTS taxonomy.[13 14 16] For more details please see the ANTS website (www.abdn.ac.uk/iprc/ants).

identified as being important for anaesthetists in the operating theatre.

The Anaesthetists' Non-Technical Skills behavioural marker system

Within anaesthesia, a taxonomy of the non-technical skills important for safety in the operating theatre, called the Anaesthetists' Non-Technical Skills (ANTS) behavioural marker system, has been produced. This was developed from an analysis of data from critical incident reporting systems, attitudinal surveys, theoretical models, observations and the judgements of consultant anaesthetists.[13 35] The ANTS taxonomy has 15 skill elements in four categories, with observable examples of good and poor behaviour that demonstrate non-technical skill proficiencies or deficits (Fig. 1). This can be used to structure non-technical skills training for anaesthetists,[17] and the ANTS behavioural rating form can be used to assess the non-technical skills of anaesthetists in theatre or in the simulator. For example, Yee and colleagues[44] have shown, using the ANTS rating system in Canada, that taking part in anaesthesia crisis management courses results in an improvement in the non-technical skills of anaesthesia residents. While many anaesthetists are involved in intensive care medicine, the ANTS system was specifically designed to represent their non-technical skills in an operating theatre environment. To date, relatively little research has focused upon identifying the non-technical skills important for protecting against human error in the ICU. However, studies examining human performance in the ICU have indicated the importance of non-technical skills such as teamwork and communication for safety and effective functioning.[12 22 39]

Within publications relating to intensive care, there exist a number of data sources identifying common causal factors underlying critical incidents in the ICU. Frey and colleagues[20] highlight the fact that ICU critical incident reporting systems provide a source of information that can be used for quality improvement. However, a recent patient safety report[1] points out that although lessons are learnt at a local level from UK incident monitoring systems, these improvements do not tend to be shared more widely. By using critical incident reporting data to identify behaviours that are commonly found to contribute to a critical incident, some insight can be gained into the non-technical skills important for safety in the ICU. The current article provides a summary of the non-technical skill factors commonly associated with critical incidents in published ICU studies. The emerging factors were compared with the non-technical skills categories and elements identified by the ANTS behavioural marker system to see if this provided a suitable fit. As the principles related to performance and safety within anaesthesia and the ICU are similar, the generic skill categories (e.g. teamwork) identified as being important for anaesthesia may also be important for the ICU, even though the setting and work tasks are different.

Method

The identification of research articles involved a comprehensive search of the Medline, Biomed Central and Web of Knowledge psychology databases for English language papers related to critical incidents and errors in the ICU (see Fig. 2 for a flow diagram of the review methodology).

Stage 1: Initial search

Electronic search:	Medline, biomed central and web of knowledge
Keywords:	Intensive care/critical incidents/ICU /error/adverse events/non technical skills
Limitations:	Articles in english
Results:	754 articles

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Stage 2: Screening of results

Filter:	Titles examined for relevance to the ICU, critical incidents and non-technical skills
Filter:	Relevance of abstract examined in order to assess information presented in the study
Results:	24 articles

↓

Stage 3: Inclusion criteria

Inclusion criteria 1:	Study has data collected quantative data exclusively in the ICU
Inclusion criteria 2:	Study has allowed for non-technical skill causal factors associated with critical incidents to be documented
Results:	11 articles

Fig 2 Literature review flow diagram.

Search terms were: intensive care/non-technical skills/ICU/critical incidents/errors/adverse events. The search was limited to article titles and abstracts. Articles initially found (*n*=754) were scrutinized for possible inclusion through the relevance of their titles and then abstracts. This left a total of 24 possible articles. The remaining articles were then filtered for inclusion if they met the criteria of: (i) using data collected exclusively in the ICU; and (ii) allowing for contributory factors referring to non-technical skills (as specified by the ANTS taxonomy) to be documented in the analysis of critical incidents. A total of 10 articles met these criteria, and were then analysed using the ANTS taxonomy.[13] The ANTS behavioural marker system identifies four core categories of non-technical skills (Fig. 1), each comprising several elements, and for each element, exemplar component behaviours relevant to actual practice in anaesthesia.[13 14 16] The four core non-technical skill categories include:

Task Management: Managing resources and organizing tasks to achieve goals . . .

Team Working: Skills for working in a group context, in any role, to ensure joint task completion and team member satisfaction . . .

Situation Awareness: Developing and maintaining an overall dynamic awareness of the situation based on perceiving the elements in the environment . . . understanding what they mean and thinking ahead . . .

Decision Making: Making decisions to reach a judgement or diagnosis about a situation, or to select a course of action, based on experience or new information . . .

Each article was reviewed in order to identify the contributing factors underlying incidents that were associated with non-technical skills. This was done by examining the individual contributing factors identified in each article, and then assessing whether they could be clearly identified as belonging to a particular non-technical skill category, as outlined in the ANTS handbook.[16] Each contributory factor was classified according to the overall skill category to which it was found to refer. For example, contributory factors such as ‘inadequate assistance’ would be classified as being indicative of teamwork skills, ‘distraction or inattention’ would be classified as indicative of situation awareness skills, ‘errors of judgement’ as decision-making skills, and ‘failure to check equipment’ as task management skills. If suitable numerical data were included in the article, the total number of contributory factors associated with non-technical skills was calculated, as was the proportion that each individual factor contributed (Table 1). In addition, for all of the studies reviewed, the proportion of contributory factors that each of the four non-technical skill categories accounted for was calculated. To avoid a bias towards studies reporting large numbers of contributory factors, percentage data were used instead of raw data. This involved a two-stage process; for each study the total percentage of non-technical skill contributory factors that each skill category accounted for was calculated. These percentages were then aggregated, and the mean percentage of contributory factors identified (Fig. 3). Lastly, the percentage of contributory factors, out of all possible contributory factors, associated with non-technical skills was calculated (49%). The classification process was conducted by three applied psychologists familiar with the non-technical skills literature. The contributory factors underlying incidents were independently classified in

Table 1 Non-technical skill contributory factors (as detailed by the ANTS taxonomy) identified in ICU critical incident studies

Paper	Identification method	Non-technical skill contributory factors			
		No. of factors	%	Contributory factors	Associated ANTS category
Wright *et al.* (1991)[42]	Anonymous questionnaires (137 incidents and 97 contributory factors reported)	38	63	Inexperience with equipment	Task management
			13	Failure to check equipment	Task management
			10	Failure to perform hourly checks	Task management
			8	Poor communication	Team working
			3	Not documenting changes	Task management
			3	Forgetting	Situation awareness
Hart *et al.* (1994)[24]	Anonymous questionnaires (390 incidents)		NA	Deficiencies in communication	Team working
				Failure to accept or adhere to protocols	Task management
				Attention	Situation awareness
				Distraction	Situation awareness
				Reduced vigilance	Situation awareness
Beckmann *et al.* (1996)[3]	Incident reporting forms (610 incidents and 1896 contributory factors)	701	23	Error of recognition or anticipation	Situation awareness
			18	Failure to follow protocol	Task management
			13	Communication	Team working
			13	Error of judgement	Decision making
			13	Distraction/inattention	Situation awareness
			12	Failure to check equipment	Task management
			8	Inadequate training	Task management
Buckley *et al.* (1997)[8]	Incident reporting forms (281 incidents and 658 contributory factors)	454	19	Inadequate assistance	Team working
			17	Deviation from standard techniques	Task management
			17	Inexperience	Task management
			16	Error of judgement	Decision making
			14	Distraction	Situation awareness
			6	Inadequate communication	Team working
			6	Failure to check	Situation awareness
			2	Unfamiliar environment	Task management
			2	Unfamiliar procedure or equipment	Task management
			1	Wrong technique chosen	Decision making
Beckmann and Gillies (2001)[5]	Incident reporting forms of reintubations (143 incidents and 258 contributory factors)	165	54	Error of judgement	Decision making
			20	Problem recognition	Situation awareness
			18	Inadequate patient assessment	Situation awareness
			8	Inadequate training	Task management
Bracco *et al.* (2001)[7]	Incident reporting forms (777 incidents and 777 contributory factors)	241	37	Failure to execute plan as intended	Task management
			32	Surveillance errors	Situation awareness
			31	Application of inappropriate plan	Decision making
Beckmann *et al.* (2003)[4]	Incident reporting forms and medical chart review (211 incidents and 224 contributory factors)	83	17	Communication problem	Team working
			14	Inattention or absent mindedness	Situation awareness
			12	Failure to check equipment	Task management
			10	Poor teamwork	Team working
			10	Inexperience or inadequate training	Task management
			8	Inappropriate behaviour or action	Task management
			8	Pressure to proceed	Team working
			8	Lack of supervision	Team working
			7	Taking short cuts or breaking rules	Task management
			6	Failure to provide/enforce protocol or policy	Task man./Team wk
Beckmann *et al.* (2004)[6]	Incident reporting forms identifying cases of intra-hospital transfers (191 incidents and 900 contributory factors)	355	16	Error of problem recognition	Situation awareness
			14	Error of judgement	Decision making
			13	Communication problem	Team working
			12	Failure to follow protocol	Task management
			9	Inadequate training	Task management
			9	Patient preparation inadequate	Task management
			7	Patient assessment inadequate	Situation awareness
			7	Failure to check equipment	Task management
			6	Inexperience	Task management
			4	Lack of supervision	Team working
			3	Distraction/inattention	Situation awareness
Graf *et al.* (2005)[23]	Incident reporting forms (50 incidents and 81 contributory factors)	69	19	Disregard of standards, rules and orders	Task management
			16	Communication insufficiency, misunderstanding	Team working
			15	Drug given but not prescribed	Task management
			10	Wrong, incomplete or delayed echocardiographic assessment	Sit. aware./Task man.
			10	Delayed intervention	Task management
			10	Wrong dose	Task management
			9	Lack of experience	Task management
			4	Wrong, incomplete or delayed electrocardiographic assessment	Sit. aware./Task man.
			4	Wrong diagnosis	Situation awareness
			3	Order illegible	Team working

Table 1 Continued

Paper	Identification method	Non-technical skill contributory factors			
		No. of factors	%	Contributory factors	Associated ANTS category
Rothschild *et al*. (2005)[37]	Observations, incident reporting forms, computerized ADE detection monitors and medical chart review (277 incidents and 329 contributory factors)	295	57	Medication error in ordering or execution of treatment	Task management
			17	Failure to take precautions or follow protocol to prevent accidental injury	Task management
			13	Inadequate reporting/communication	Team working
			4	Avoidable delays in diagnosis	Task management
			3	Inadequate patient assessment	Situation awareness
			2	Inadequate training/supervision	Task man./Team wk
			2	Inadequate reporting or communication	Team working
			1	Avoidable treatment delay	Task management
			1	Failure to check equipment or defective equipment	Task management
Total	2677 incidents (5610 contributory factors)	2401			

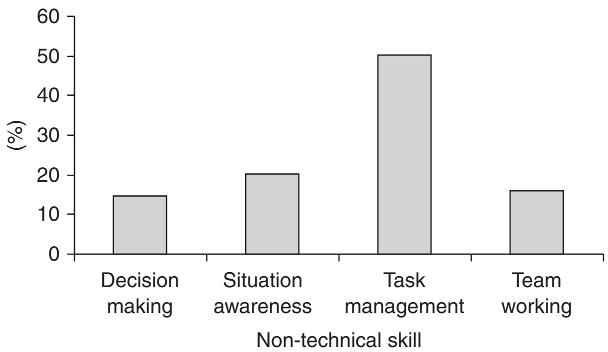

Fig 3 The proportion of contributory factors across all studies (see Table 1) that each of the four non-technical skill categories accounts for.

terms of the non-technical skills outlined in the ANTS handbook. For all of the factors in Table 1, there was a 91% level agreement by at least two assessors for the underlying ANTS category, and 71% agreement by all three assessors. For factors where there was no initial agreement, the assessors collaboratively referred to the ANTS handbook in order to reach a final agreement on the underlying ANTS category. It is notable that the contributory factors documented in the critical incident studies do not document one single practitioner role in the ICU (i.e. the role of both nurses and doctors are considered), and thus at this stage, the analysis is not role specific. Furthermore, each factor does not refer to one incident, and thus a combination of factors may be underlying any single critical incident.

Results and discussion

A wide range of contributory factors associated with critical incidents can be accounted for by the non-technical skill categories outlined in the ANTS taxonomy (Table 1). Overall, out of 2677 incidents and 5610 total contributory factors, 50% can be attributed to some form of non-technical skill deficit. These figures do not include one study[24] which did not provide numerical data on the contributory factors underlying incidents. Across all of the studies, task management was found to account for the largest proportion of non-technical skill contributory factors (Fig. 3), followed by situation awareness, team working, and finally decision making. However, this breakdown is entirely constrained by the type of data the reviewed critical incident studies were designed to capture. For example, critical incident studies tend to vary in the different categories and types of data they collect, with some studies collecting minimal non-technical skills related data. This may explain the high proportion of incidents associated with task management, as critical incidents' studies tend to show a bias for capturing technical contributory factors related to task management skills, for example checking equipment, following protocols, inadequate preparation of patients. However, less provision may exist for capturing contributory factors associated with non-technical skills such as decision making, for example failing to consider options, not asking others for suggestions, or being unwilling to revise courses of action in the light of new information.

A further limitation of critical incident studies is that they lack a fine-grained analysis of the non-technical factors underlying incidents. In the current review, although contributory factors such as 'errors of judgement' and 'failure to follow protocol' may show face validity with skills such as 'decision making' and 'task management', the precise details underlying those factors cannot be ascertained. For example, 'errors of judgement' may arise as a result of deficiencies in recognizing and understanding information (i.e. situation awareness), 'and failure to follow protocol' might arise because of a lack of supervision (i.e. teamwork/leadership). Also, it was not possible to classify a considerable number of contributory factors identified in the study, as a result of the underlying non-technical skill not being obvious. For example, factors such as 'insufficient staff' might be associated with task management, or may be indicative of staffing policies. Lastly, it can be seen that, although the study by Hart and colleagues[24] does not include numerical data, it does provide some supporting evidence for the relevance to the ICU of the non-technical skills described in the ANTS taxonomy, and highlights the utility of including numerical data when analysing accident causation.

Despite the above issues, the current review does demonstrate that even though a variety of different contributory factors are captured by ICU critical incident studies, a large proportion of these can be attributed to the non-technical skill categories outlined in the ANTS taxonomy. This is both informative for the future development and use of data from critical incident reporting systems, and is indicative that the ANTS taxonomy may provide a good starting point for the development of a non-technical skills taxonomy for intensive care. However, it is also apparent that further research, using a range of techniques, is required to allow better identification of the non-technical skills necessary for maintaining safety in the ICU. The ANTS system used several techniques to collect data regarding practice in anaesthesia in order to generate a non-technical skills taxonomy tailored for the anaesthetists' role in the operating room.[14]

The techniques for gathering the basic skill set can include root-cause analyses, observations of behaviours in real-time and simulated environments, attitudinal surveys, studies of cognition and structured interviews.[2 15 26 36] Each technique provides different forms of data. For example, root-cause analysis describes in detail the precise factors underlying critical incidents. However, the data retrieved from root-cause analysis are limited by the scenario being investigated, and the technique used to assess the incident. Observational approaches record behaviour as it occurs in a variety of conditions, for example, during an emergency procedure. However, it is difficult in real-life studies for observers to capture all the events that occur within an environment and there is potential for participant behaviour to be altered by the presence of a researcher. Attitudinal surveys highlight opinions on the importance of skills such as teamwork and are informative about the social and organizational factors that affect perceptions of error and rule compliance. However, these generally do not provide specific information about the non-technical skills underlying good performance. Studies of cognition use experimental methods to model and understand the factors that affect cognitive processes (e.g. decision making) within a particular environment, but are also susceptible to participant behaviour being altered by the experimental paradigm, for example the use of a low fidelity simulator. Structured interviews utilize the knowledge and experience of domain experts in ascertaining the non-technical skills required for coping with emergency and routine situations, although perceptions of confidentiality, and the relationship between the interviewer and interviewee, can affect the data obtained.

The techniques described above could provide a rich source of non-technical skills information for the ICU, and may provide useful examples for developing training materials. Although research focusing on non-technical skills in the ICU is still very much in its infancy, there are examples of research within both the critical care and psychology literatures that have used the human factors techniques described above. Examples of such studies were found during the earlier literature search, and whilst not containing suitable data for inclusion in the critical incident review, are potentially informative and are discussed below.

The following four sections include examples of human factors research using root-cause analysis, observational studies, studies of cognition, and attitudinal surveys, that have been found to yield information regarding the non-technical skills required for safe practice in the ICU. Although the findings of such research does not describe in detail the non-technical skills required for the intensive care environment, and are insufficient for developing a taxonomy of non-technical skills in the ICU, they do provide informative data with respect to validating and describing the relevance to the ICU of the non-technical skill categories outlined in the ANTS taxonomy.

Root-cause analysis of ICU adverse events

Root-cause analysis identifies the fundamental causes of more serious critical incidents, and distinguishes the technical and non-technical contributory factors that originated from both the local and organizational environment. In particular, root-cause analyses of adverse events in the ICUs in the USA[32 33] underlined the importance of the non-technical skill category of team working, and specifically communication processes that support good team working, in the prevention of incidents. For example, in a case where a patient with hospital-acquired pneumonia was accidentally given an undiluted medication,[32] a lack of communication and understanding between an ICU doctor and trainee nurse regarding the medication handover procedure was identified as one of the main contributory factors. In another case, a patient being treated for heart and renal failure had an air embolism after a large central venous catheter was removed whilst the patient was sitting up.[33] One of the main contributory factors identified as underlying the incident was the reluctance of a nurse, who recognized that the catheter removal was being done incorrectly, to speak up and correct the trainee doctor conducting the procedure. Thus, root-cause analyses can provide non-technical skills information relating to both a particular situation, such as a lack of shared understanding for team member roles in a specific procedure, or a more general aspect of teamwork, such as the need for open communication between doctors and nurses.

Observational studies of ICU teams in real-life and simulators

Non-technical skill competencies in the ICU can be further investigated through observational studies. This involves either observation of real-life environments, or videotaped ICU scenarios in medical simulators. Lighthall and colleagues[28] observed the performance of ICU staff on a training course, which realistically simulated the intensive care environment, and presented cases that challenged both medical and non-technical skills. Their analysis identified commonly occurring errors relating to the non-technical skill categories of situation awareness, decision making, teamwork and task management, and their specific impact upon the provision of care. Vigilance and fixation errors such as failing to recognize changes on monitors, not responding to ventilator alarms, and failing to periodically check patient status whilst placing a line, resulted in unrecognized deterioration in the simulated patient's condition. Judgement errors, such as placing a catheter in a deteriorating patient, and being complacent with abnormal vital signs, resulted in inappropriate delays of therapy and clinical deterioration. Communication and task management errors, such as failing to communicate priorities, overloading nurses with requests, and not following up inquiries on lab results, resulted in insignificant tasks being done instead of key tasks, tasks not being done in a timely manner, and forgotten requests not being identified.

A real-life observational study conducted by Donchin and colleagues[12] has also underlined the importance of detailing team competencies required for safe practice in the ICU. The study investigated the nature and causes of errors in an Israeli ICU collected data over a period of 4 months, and involved observers noting all activities, interactions and errors that occurred at the patients' bedside. Out of the 8178 activities recorded, approximately 1% were erroneous, with doctors being found to commit around half of all errors despite being involved in just 4.7% of activities. In particular, team working problems were highlighted as being an important factor in the occurrence of errors, with verbal communication between nurses and doctors being reported in 37% of errors, despite being observed in only 2% of activities. Donchin and colleagues[12] hypothesized that this may have occurred as a result of informal communication exchanges, and misunderstandings and misperceptions during communication. Therefore, observational studies in real-life and simulators can associate certain non-technical skills (e.g. team working) with measurable outcomes (e.g. errors), and understanding the causes and environments in which behaviours and errors occur.

Attitudes towards non-technical skills in the ICU

Attitudinal studies in the ICU have also focused upon non-technical skills, with surveys in the USA examining the attitudes of ICU staff with respect to teamwork and error. These studies have shown that the majority of both nurses and doctors feel that junior team members should be able to question senior members, and that decision making should include more team member input.[38] However, it has also been found that more nurses than doctors report finding it difficult to speak up in the ICU. In addition, fewer nurses than doctors report feeling that their input about patient care is well received, that disagreements in the ICU are properly resolved, and that teamwork between nurses and doctors is well coordinated.[40] Furthermore, whilst the majority of ICU staff acknowledge the importance of medical errors, they also report difficulty in openly discussing mistakes, because of factors such as the expectations of other staff members and negative personal implications.[38] Thus, attitudinal studies can be useful in that they highlight a number of organizational factors that may influence the use of non-technical skills such as teamworking in the ICU. For example, a lack of perceived openness of communication between nurses and doctors may make nurses reticent to become involved in patient care decisions, and the negative personal implications associated with discussing errors may result in the root causes behind errors not being identified and addressed.

Studies of cognition in the ICU

Studies of cognition in the ICU have described the processes underlying decision making by ICU staff during their provision of care to patients. Decision making is a non-technical skill that has been researched by a number of psychologists, with studies examining whether expert decision making in the ICU relies on similar cognitive processes to other complex work domains. Patel and Arocha[29] have studied decision-making processes by consultants in surgical and medical ICUs, in the USA, where caregivers face different problems. An analysis of audiotape transcripts from the morning rounds revealed that in the medical ICU (where it is necessary to diagnose patient conditions and then make treatment decisions) there was a tendency for decisions to be made using 'backwards driven reasoning'. This involved developing a hypothesis about a situation and then testing and refining it against the available data before coming to a solution. By contrast, the findings in the surgical ICU (where patients were recovering from a surgical procedure, and thus their diagnosis was better understood), showed decisions to be made through 'forwards driven reasoning'. This involved first gathering information about a situation and then recognizing the solution from the perceived data. In a similar decision-making study, Cesna and Mosier[10] asked nurses how they would react to an emergency situation in the ICU. Expert nurses tended to immediately recognize the best solution for the situation. In contrast, less experienced nurses were shown to have a tendency to generate several options, with the best option not being generated first. In both studies, decision making was found to be consistent with recognition primed decision making,[30] a form of naturalistic decision making where an expert relies on their experience and knowledge to 'pattern match' or recognize a situation, and then recall a viable course of action without having to consider all the alternatives.

Studies of cognition can be useful for understanding the processes underlying non-technical skills such as decision making, and whilst not providing a direct relationship between non-technical skills and safety, insight can be gained with regard to training and enhancing non-technical skills. For example, as expert decision makers are found to focus their attention on identifying situational features rather than choosing between options, training could focus on situation awareness skills such as altering scanning behaviours in accordance with patient conditions, and improving communication and cross-checking amongst team members so that information necessary for decision making is shared immediately. Alternatively, less experienced decision makers could be trained to develop the mental models and patterns they require for recognizing situations and associated solutions.[43]

Conclusion

This review of contributory factors underlying critical incidents demonstrates an overlap between the non-technical skills requirements for the ICU and anaesthesia, with both domains having a need for good teamwork, situation awareness, task management and decision-making skills. This is consistent with other high-risk domains, such as aviation, where non-technical skill competencies for the same skills are recognized as being crucial for safe practice, and are taught through tailored training packages. To teach and reliably assess non-technical skills within a particular domain it is necessary to identify the component behaviours that demonstrate proficiencies of these skills within the domain.[31] Each work environment has its own particular needs and characteristics, and the behaviours that demonstrate non-technical skill competencies within the ICU will be specific to the demands of intensive care medicine, and the roles and responsibilities of caregivers.

It can be concluded that further research is necessary on the non-technical skill proficiencies required for safe practice in the ICU, and to describe them in sufficient detail so that they can be taught and reliably assessed. Ideally, as non-technical skill training programmes are integrated with the technical aspects of a domain, training packages will be implemented when professionals have an adequate level of technical competence. This also reduces the cognitive load of having to learn both technical and non-technical skills simultaneously. The current review demonstrates that the framework of non-technical skill categories identified in the ANTS taxonomy is also pertinent to the ICU, and thus provides a useful foundation for future investigations. Research using other human factors including root-cause analysis, attitudinal surveys, structured interviews, observational studies, and studies of cognition, could facilitate a greater understanding of the non-technical skills required for supporting safety in the ICU. Although research focusing specifically on non-technical skill competencies for the ICU is limited, examples of research in the ICU using human factors techniques can be found to both support the importance of the non-technical skill categories outlined in the ANTS taxonomy, and also provides examples of how such research can aid in identifying the non-technical skill competencies required for intensive care. Through a combination of the research techniques described, future work can give us a better understanding of the nature and key challenges of the ICU environment, its non-technical skill requirements, the behaviours that demonstrate non-technical skill proficiencies, and the organizational factors that affect the quality of non-technical skills demonstrated by nurses and doctors in the ICU.

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