

REVIEW ARTICLE

The role of non-technical skills in anaesthesia: a review of current literatureG. C. L. Fletcher^{1*}, P. McGeorge¹, R. H. Flin¹, R. J. Glavin² and N. J. Maran²¹Department of Psychology, University of Aberdeen, King's College, Aberdeen AB24 2UB, UK. ²Scottish Clinical Simulation Centre, Stirling Royal Infirmary, Livelihoods Gate, Stirling FK8 2AU, UK

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Br J Anaesth 2002; 88: 418–29

Keywords: anaesthesia; anaesthetist, non-technical skills; anaesthetist, error; education, continuing

Accepted for publication: August 30, 2001

The complexity of patient care in the modern operating environment demands a wide range of skills and attributes from anaesthetists. Conventional training has placed great emphasis on acquisition of the necessary knowledge and practical skills to ensure competent practice. However, satisfactory patient outcomes will only be realized if appropriate plans can be executed effectively. This requires a particular set of skills, such as communication, team-working, planning, resource management and decision-making, that are used integrally with medical knowledge and clinical techniques. Such skills are not new in anaesthesia; good anaesthetists have always demonstrated these competencies but they have not featured explicitly in formal anaesthetic training programmes. These skills are sometimes referred to under the general heading of 'human factors', but more specifically, as they do not relate directly to the use of medical expertise, drugs and equipment (i.e. clinical knowledge and technical skills), they can be described as non-technical skills. Non-technical skills can be divided into two subgroups: (i) cognitive or mental skills (e.g. decision making, planning, situation awareness) and (ii) social or interpersonal skills (e.g. team-working, communication, leadership). Both groups of skills are necessary for safe and effective performance in the operating theatre environment.

From an industrial psychologist's perspective, anaesthesia has much in common with the aviation, air traffic control and nuclear power generation industries. All of these high-reliability domains share safety as a prime goal and they rely on having well-designed workplaces, equipment and systems, as well as safety-focused organizational climates. Personnel must be suitably skilled to ensure they can deal with the demands of their complex work environments. This usually involves maintaining awareness of dynamic

situations involving multiple players and being able to deal with critical events in stressful, time-pressured situations characterized by ill-structured problems, shifting goals and incomplete feedback. If problems do arise in these circumstances, the limitations of human performance, combined with latent errors in the system, can potentially lead to adverse safety outcomes. In recognition of this, the other high-reliability domains have introduced special training programmes to raise awareness of problems arising from human factors and to support the development of non-technical skills.⁴² There is considerable opportunity for the cross-feeding of ideas from different domains, particularly aviation, with which anaesthesia has most often been compared.^{10 18} However, while there is a wealth of information on non-technical skills from psychological research in other work-places, the issues may not extrapolate directly and so it is important that these skills are defined carefully within the context of anaesthesia. The aim of the present paper is to review the relevant human factors literature in anaesthesia in an attempt to delineate the role of non-technical skills in anaesthetists' practice. The material is presented in four sections that are in line with the main data sources that would normally be used to identify critical behaviours: (i) incident reporting; (ii) observational studies from the real world and simulators; (iii) attitude questionnaires; and (iv) theoretical models. The final section summarizes key issues for training and assessment and discusses the limitations of current data sources that could be used to identify the non-technical skills of anaesthetists.

Incident reporting

One of the most common sources of data for revealing critical behaviours is incident reports. These take the form

of mandatory occurrence reports, detailed accident investigations, company incident reports and confidential human factors reporting systems. They can be analysed to reveal the underlying causes of the event and systemic deficiencies. Different report formats produce different types of data: some provide free text descriptions of events explaining what happened, what led up to the event, who was involved, etc., while others use more structured classifications to obtain details of technical and non-technical factors.²⁵ Incident reports have been a major source of information in the development of non-technical skills training in aviation, and they continue to be used to 'close the loop' when designing system improvements. In anaesthesia, data from incident reporting schemes have been available for 20 yr. Indeed, it was the realization that human error is implicated in as many as 80% of anaesthetic incidents^{7 27 44} (a figure comparable to findings in other industries) that prompted much of the subsequent human factors research in the field.

However, when the data from these medical incident reporting systems are scrutinized, they provide only limited insight into non-technical skills. Although many of the studies in anaesthesia have looked to the psychological literature for advice on how to analyse incidents,¹ the available human error classification systems do not appear to be used extensively to identify the underlying behavioural causes of the incidents. Analysis tends to occur at a more operational level, so that each incident has a descriptor of what happened (e.g. wrong drug administered) and a contributory factor (e.g. distraction) that helps to explain what led to the event. Unfortunately for the purposes of understanding the role of non-technical skills in anaesthesia, these technically oriented systems do not really provide the finer-grained level of information necessary to understand where the skills broke down.⁹ Furthermore, the use of human factors codes is limited (but see Runciman and colleagues⁴¹) and they are not clearly defined on reporting forms. In addition, under-reporting may affect the quantity and quality of the human factors data provided. This may be due to ambiguity in the definition of what constitutes an incident, confusion over the classification codes provided, time availability, concern over legal or disciplinary action, and a professional culture with unrealistically high expectations of human performance under stress and fatigue.^{21 43} These difficulties aside, there have been several studies describing classifications of anaesthesia incidents. Some examples and the types of non-technical skills they highlight are discussed below.

In the first study of its type, Cooper and colleagues⁷ at Harvard investigated outcomes other than death in a retrospective study in which anaesthetists were asked to describe preventable incidents that they had observed or participated in, involving either a human error or equipment malfunction. In addition, the anaesthetists were asked to describe factors that had been causal in the event. They coded 359 incidents using a specially developed branching

classification scheme. The results showed that 82% of the incidents involved human error whereas only 14% involved equipment failure. The descriptions of the events do not really give much insight into non-technical skills, but this information can be found as associated factors, which include poor communication with the team, laboratory etc., inattention/carelessness, haste, fatigue, distraction and insufficient preparation.

A second, wider study⁶ by the same group confirmed many of their earlier findings. Additional causal factors detected in this sample included excessive dependency on other personnel, failure to follow personal routine and failure to follow institutional practice. The incidents were categorized into four main types: technical, judgemental, monitoring/vigilance, and other types. Both judgemental and monitoring/vigilance could be considered as human error categories. The latter are clearly linked to non-technical behaviours, although for the judgemental category it is difficult to determine the underlying causes because of the lack of information about why or at what stage the judgement failed.

In another key study, the Australian Incident Monitoring System (AIMS)⁴¹ collected data on a comprehensive anonymous incident form that provided a large number of categories under main headings covering what happened, why it happened, the anaesthesia and procedure, where and when it happened, patient outcome, and to whom it happened. Williamson and colleagues⁴⁴ examined the human factors that either contributed to or helped minimize the incidents and suggested corrective strategies. Following Reason's work,^{39 40} they described errors as knowledge-based, rule-based, skill-based, technical or system-based. The first four categories were classified as human failures and were found in 83% of reports. The most common contributing factors included error of judgement, failure to check equipment, fault of technique, other equipment problem, inattention, haste, inexperience, and communication problems.

It is clear just from the studies of these two databases that a number of common errors that arise, e.g. inadvertent drug swaps, failure in communication, insufficient monitoring, are not related primarily to clinical knowledge or technical skills but rather to other non-technical problems. While these investigations have highlighted the types of errors that occur in anaesthesia and their associated factors, most do not provide a detailed analysis of causality and the error mechanisms leading to the incidents or recovery from them. For example, 'emergency situation' has been cited as an associated factor but it is not clear what it is about the emergency that causes the problem or what other factors are associated with this. There are some exceptions, such as the AIMS study⁴¹ and the work of Nyssen,³⁵ who investigated risks associated with failures in decision functions. Even here there is still no real explanation of the linkages between factors and descriptions of the factors (e.g. the sort of communication problem involved, and the question of

which errors are associated with which type of knowledge). It may be that this sort of information cannot be identified from incident reports as they currently exist, and so other types of investigation are needed to uncover the behaviours that break down in error situations and the skills that aid recovery. Or, to allow comprehensive understanding of the role of non-technical skills, more advanced techniques may need to be applied to the analysis of anaesthesia-critical incidents, such as the root-cause analysis being used by Busse and Johnson³ to identify the proximal and distal factors in ICU events. Accepting the current limitations on the information available from incident-reporting systems in anaesthesia, the results of the studies reviewed indicate that deficiencies in non-technical skills contribute significantly to adverse outcomes. These incident studies provide some insight into the components of these skills, but further identification and understanding of the skills is restricted because of limitations in the human factors aspects of these coding schemes.

Observational studies in anaesthesia

Another important source of data to reveal the non-technical skills in anaesthesia is the observation of performance in both real and simulated environments. While incident reports only provide information about the things that went wrong, observational studies allow behaviour to be examined under all conditions, both in the real operating environment and in the simulator. This can provide information about what is going on when things go well, what prevents everyday difficulties from leading to more serious problems, how different groups of people perform differently, etc. The use of simulators also allows experimental trials to be undertaken so that anaesthetists' behaviours and resulting performance can be measured and compared under controlled conditions.

As sources of research information, both simulators and real operating theatre observations have limitations. Collecting data within the operating theatre or emergency room can be difficult as the events of interest may not occur, it may be difficult to observe the whole environment either directly or using video, the presence of a researcher may affect normal behaviour, and also because of issues of consent and confidentiality. It is easier to set things up for observation or video recording in the simulator environment, although clearly some aspects of simulator fidelity may affect performance.²⁹ Despite these limitations, both methods have been used to study anaesthetists' practice, and the findings can be examined for evidence of non-technical skills.

Real environment studies

One of the few observational studies that has examined non-technical skills during theatre operations was carried out by Helmreich and Schaefer.²² They observed the performance

of whole operating theatre teams in Basel and categorized the behaviours using an existing aviation team skills framework. Errors were identified that included failure to complete a checklist for the anaesthesia machine; consultant distracted from a decision on the patient by problem in another operating room; failure to discuss alternatives and to advocate a course of action; and failure to debrief actions during operation.²¹ These findings are comparable with problems identified from incident reports and simulator research but provide additional insight into the real level of interaction between the anaesthetic and surgical teams. Problems observed with communication and coordination across this barrier are of particular concern as they affect the maintenance of a shared understanding of the situation.

To provide a more systematic approach to measuring team processes, Helmreich and colleagues²³ revised an aviation line operations audit checklist to produce a detailed form that allowed the operating room teams to be scored on a rating scale using team performance indicators. The team's technical and overall performance was also scored. The key components of the operating room checklist were divided into three main sections: team concerns; the decision-making process and communication; and management of the work situation. Data collected have indicated that 20–30% of observations of briefing and team formation showed behaviour that was unsatisfactory or met only minimal expectations; for the indicator on exchange of information on decisions, 20–40% of observations were below the set standard.¹⁹ These results show that, while non-technical skills appear to have an important role, they are not always used. This can have consequences for overall clinical performance.

A major body of real life observational research has been conducted at the Shock Trauma Centre at the University of Maryland Medical Centre,^{28–33 46–49} looking at the management of patients arriving in the emergency department by trauma teams, including anaesthetists. Data were collected using video cameras located in the admitting bays and an operating room. In the first study, Mackenzie and colleagues³¹ used the video data to analyse group decision-making processes. They found that, under stressful, time-pressured situations, knowledge-based errors, such as incorrect drug administration or dosage, were observed. However, these contrasted with the anaesthetists' self-reports of primarily procedural-type errors, such as not preoxygenating the patient before intubation. This highlights one of the main problems associated with self-report: that people's accounts of their behaviour may not be related to what they actually do. The videos also showed that, while in periods of high time stress there was an increase in short cuts and task-shedding, and there was more verbal communication, particularly to convey strategies or delegate tasks. The authors point out that some of the problems associated with uncertainty, which was one of the stressors, could be reduced by increased monitoring and preparation.³¹

One particular area of interest in relation to cognitive skills was the occurrence of fixation errors.^{5 13} Xiao and colleagues⁴⁹ observed fixation errors arising from the anaesthetists moving too fast, such that they rushed past certain cues and used other, improper information, and from moving too slowly and failing to update old plans and courses of action when necessary. These fixation errors were hypothesized to be 'partly the results of the interplay between the nature of complex environments and the strategies used by practitioners in dealing with complexity',⁴⁹ and to result in a loss of situation awareness (for descriptions of this construct see Endsley⁸ or Gaba and colleagues¹⁴). Xiao and colleagues⁴⁸ investigated the dimensions of task complexity and their impact on crisis activities and team processes in the trauma room. They identified four components of task complexity which affected team coordination in different ways. Multiple, concurrent tasks led to goal conflict, task interference and competition for access to the patient. Uncertainty regarding the case led to differences in opinion when interpreting information and difficulties when trying to anticipate the actions of other team members. The use of contingency plans caused difficulty in knowing when to switch tasks and how then to reallocate activities. Finally, a high workload caused procedures to be compressed and this deviation from normal strategies further increased the complexity of the situation. To improve team coordination under these circumstances, Xiao and others⁴⁸ advocated training in explicit communication and developing work procedures that make 'certain verbalisations mandatory'.

The importance of communication was further highlighted by Xiao and Mackenzie,⁴⁶ who looked at both verbal and non-verbal task coordination. Four types of coordinating behaviour were observed: following protocol; following the leader; anticipation; and activity monitoring. When following protocols, e.g. Advanced Cardiac Life Support, all team members should know exactly what to do and what is expected, so that minimal verbal communication is required. By watching the leader, team members know what they should do and discern their instructions from the leader's activities. Similar, but based on observation of the patient's physiological status, is anticipation, e.g. a suction catheter being offered in response to a patient gagging, in anticipation of vomiting. However, problems could arise when relying on anticipation if team members interpret the situation differently. Activity monitoring describes behaviour in which one team member watches someone else complete their tasks in order to find out when they could begin the next activity. This was found to occur between the anaesthetic and surgical teams: the latter not necessarily announcing their plans to the anaesthetists. Again, this could cause problems, as it is possible to make the wrong inference about the situation from just observing other team members' activities. Information flow by explicit verbal communication was found to be relatively rare and was usually limited to sharing information about the situation

and further plans only when the team had a decision to make.

Clearly, problems can arise when so much is left unspoken. Xiao and Mackenzie⁴⁶ identified three situations when this coordination broke down: when there was pressure to seek alternative solutions; when it was necessary to initiate unexpected, non-routine procedures; and when there was a diffusion of responsibility after a change in plan and the team members had to adjust themselves to new tasks and roles. Overall, the most significant finding of this study is that it highlights the reliance of trauma teams on non-verbal cues rather than verbal communication for coordination. It would be interesting to see if these cognitive skills and task coordination strategies are used in the same way in normal elective operations and if the same difficulties arise if a crisis occurs in theatre.

Simulator studies

Understanding how the behaviour of experts differs from that of novices is an important means of understanding non-technical skills. Several groups have looked at the role of experience in the management of critical incidents, using the simulator to identify differences in behaviour. In the USA, Gaba and DeAnda¹² used a high-fidelity patient simulator to compare the performance of first- and second-year anaesthesia residents giving an anaesthetic during which a number of major and minor events occurred. Transcripts of the incidents were scored for factors that included time to detection, time to correction and the resolution strategy. Analysis showed that the time taken to correct the problem was related significantly to experience, the more experienced anaesthetists making a diagnosis and beginning treatment quicker. This suggests that experienced anaesthetists are better at identifying and making use of the relevant cues leading to better situation awareness and the generation of a more accurate mental model from which to recognize the appropriate problem solution. However, individual performance amongst the more experienced anaesthetists was variable and while many less experienced residents did act correctly, some with greater clinical experience did not. Drawing from findings in other areas, such as nuclear power plants, Gaba and DeAnda¹² speculated that response to acute intra-operative problems may be largely accomplished using precompiled procedures and that even inexperienced trainees can incorporate some of these procedures and retrieve them under appropriate situations. The fact that some of the less experienced residents would have had training in life-support protocols more recently may have accounted for instances when they performed as well as or better than the more experienced residents.

Byrne and Jones⁴ investigated performance in four groups of anaesthetists with experience ranging from less than 1 yr to over 5 yr, using the low-fidelity ACCESS simulator. After a brief introduction to the simulator,

participants were presented with a series of scenarios, which included problems that required interventions such as drug treatments and i.v. fluids. Times to problem recognition, treatment identification and implementation were used as measures of performance. Replicating the findings from earlier studies, speed of treatment was shown to be linked to experience, the least experienced group performing significantly worse than the other groups. However, even some very experienced participants handled the situations poorly and, regardless of years of experience, no one used relevant treatment guidelines in the scenarios for which they were available. When analysing the actual behaviours observed during the scenarios, the authors found that although trainees with less experience took longer to treat the problem, their more systematic approach to case management could actually be considered safer than the faster approaches adopted by those with more experience. Unfortunately, these results do not provide much insight into the decision processes and management strategies of anaesthetists with more experience or indeed how they might normally seek to avoid crisis situations before they occur.⁴

Nyssen and De Keyser³⁶ investigated problem-solving in novices (second and third years) and more experienced anaesthetic trainees (fourth and fifth years). Each participated in videotaped simulations of four problem scenarios that varied in complexity. Again, the results showed that, regardless of the complexity of the scenario, the more experienced anaesthetists took less time to diagnose the problem. Indeed, the majority of the novices were unable to make correct diagnoses for the two most complex scenarios. Perhaps of more interest for understanding performance were the descriptions of the different behaviours of the groups. The more experienced anaesthetists were more involved in regulating the anaesthetic (administering drugs, attending to airway and ventilation, monitoring), thus allowing them to maintain better situation awareness and anticipate future changes. While there was no overall difference in evaluation of the problem situations, the activities of the two groups did vary. The novices generated more hypotheses about the problem, whereas the more experienced group displayed more evidence of planning and set up treatment more efficiently. All of these results suggest that the more experienced group were better able to use the information provided to produce a diagnosis and hence begin treatment sooner. Moreover, if that diagnosis subsequently turned out to be incorrect they were better able to re-evaluate using other cues to produce a correct diagnosis. Thus, what appears to come with experience is the skill to focus on the important information and integrate this with existing knowledge of the situation to produce a solution. Knowing which factors to focus on allows the more experienced anaesthetists to prioritize tasks better and carry out activities flexibly.

While there are a number of methodological difficulties involved in collecting data in the real environment and in

the simulator (such as the limited availability of validated performance measures), observations of anaesthetists' performance can provide a valuable source of information regarding their non-technical skills. The studies show in particular that verbal communication, individual and team situation awareness, problem recognition, decision-making and re-evaluation appear to be key skills.

Attitude questionnaires

The final source of data on non-technical skills comes from attitude measurement studies using questionnaire-based surveys. While not providing information on the skills themselves, they do give an insight into how they are perceived and valued by anaesthetists. One of the main uses of attitude questionnaires has been for course evaluation after simulator training. The results of such surveys are usually positive and are a good source of feedback on simulator courses (for an example see Holzman and colleagues²⁴), but these data do not add much to our understanding of anaesthetists' non-technical skills.

Investigating attitudes towards production pressure amongst Californian anaesthetists, Gaba and colleagues¹⁶ found that, while the majority of anaesthetists had good working relations with their surgeons, over half did not believe the surgeons understood the risks associated with anaesthesia. Indeed, almost half the respondents had observed an anaesthetist pressured into giving an anaesthetic in an unsafe situation. Again, while these data do not give us an indication of the specific non-technical skills being used by anaesthetists, they highlight the importance of considering social and organizational factors when investigating anaesthetist performance.

Helmreich and Schaefer²² adapted a questionnaire that had been designed to survey pilots' attitudes towards leadership, team-working and safety issues to produce the Operating Room Management Attitudes Questionnaire (ORMAQ). Results from surveys of operating theatre teams in the USA and Switzerland showed anaesthetists agreeing that 'communications and coordination are as important as technical proficiency in the operating room'. They also disagreed with the statement 'team members should not question senior staff' and endorsed 'consultative management styles in the operating room', even though they encountered more autocratic styles in reality.²² Attitudes towards the effects of stress and fatigue were of more concern,^{21 43} many anaesthetists agreeing that their performance was unaffected by fatigue and that their decision-making was as good in an emergency as in normal situations. While this unrealistically high expectation of human performance has also been documented for airline pilots and surgeons, it does not encourage anaesthetists to accept error as a normal occurrence or to realize that critical incidents may occur because of stress or non-technical factors. A recent Scottish survey by Aberdeen University using the same questionnaire has

found similar attitude patterns (R. Flin, G. Fletcher, P. McGeorge and A. Sutherland, in preparation).

Theoretical models

In spite of the difficulties in collecting information on anaesthetists' performance and the factors that influence it, there has been some valuable research conducted in this area, mainly in the USA. While there are many questions still to be answered, the literature reviewed above highlights a range of non-technical skills that are critical in supporting anaesthetists' performance. Several models describing anaesthetists' non-technical skills have now been developed on the basis of generic models of error mechanisms, decision-making, situation awareness, team performance and other human factors research. The models fall into two complementary categories, aligned with the focus of the underpinning research. First there are *cognitive models*, such as Gaba's process model of anaesthetists' decision-making/problem solving behaviour.¹³ These models concentrate on the individual's mental processes. Secondly, there are *team models*, such as Helmreich's model of operating room performance,²² which focus on team and organizational factors.

Cognitive models

On the basis of findings from simulator studies, incident reports and using cognitive psychology theories^{38 40 45} as a framework, Gaba¹¹ developed a model to describe anaesthetists' decision-making processes. The initial model was based on what he called four levels of human information processing: (i) processing sensory data from the environment and controlling actions (sensorimotor level); (ii) following rules for solving problems (procedural level); (iii) solving problems through reasoning (abstract level); and (iv) coordinating attention and interactions (supervisory level). The model describes how anaesthetists become aware of a problem and how they would then act to resolve the situation. In later versions of this model, which incorporate ideas from aviation,⁴² a resource management level has been added to produce 'a comprehensive model of dynamic decision making and crisis management'.¹³ This final model is used as a framework for Gaba's simulator training programme in Anesthesia Crisis Resource Management (ACRM), which particularly emphasizes non-technical skills. The activities associated with each processing level are summarized in Table 1. Investigating performance in ACRM, Gaba and colleagues¹⁵ conducted a set of studies using both technical and behavioural (or non-technical) assessments and found that crisis management scores were strongly correlated with leadership, communication and distribution of workload. However, there was more variability between raters' scores of anaesthetists' behavioural performance than for technical performance,

highlighting the difficulties associated with identifying and measuring non-technical skills.

The first part of the model is the sensorimotor level. At this level the anaesthetist is engaged in basic observation and verification activities: checking the patient, monitoring the displays (heart rate, blood pressure, etc.), observing the activity of the surgical team, and combining these to maintain a good level of situation awareness. The anaesthetist then carries out separate actions to confirm and cross-check that the information is accurate and reliable. For example, if the non-invasive blood pressure monitor showed a low value that was not expected, the anaesthetist would confirm that the reading was accurate by checking the patient's pulse, repeating the measurement, noting any changes in monitored signals. Although closely linked to observation, this verification activity is considered to be a separate task, which if omitted may contribute to incidents occurring. The supervisory level of control allocates the mental resources for the task. The anaesthetist will determine whether he or she needs to pay particularly close attention to surgical activities, for example during certain activities such as insertion of laparoscopic trochars, or whether attention can also be widened to activities such as completing the anaesthetic record.

The next stage of the decision-making process occurs at the procedural level, where the anaesthetist uses the information collected about the patient to identify and anticipate problems. The first task is to assess the situation and decide what course of action is necessary. It may be that the only action necessary is to continue monitoring the situation. Or the cues that are detected may suggest a problem; this must be identified, its consequences for the patient anticipated and a solution selected. One of the difficulties Gaba and colleagues¹³ associate with this activity is that there may be an absence of definitive cues for a specific problem, and so heuristics, or rules of thumb, may be used to assist in identifying the problem. Depending on the urgency of the problem and the familiarity of the situation, the model then divides activities into continuing on the procedural level or moving to the abstract level. In the former case, the anaesthetist is able to use precompiled responses, for example Advanced Life Support protocols or the experts' own preplanned strategies, to dictate a course of action. In cases where the problem is novel or the patient does not respond to an initial solution, the model moves into the abstract level, where the anaesthetist may have to return to basic principles of medical knowledge and use reasoning to identify the appropriate course of treatment. This reasoning activity is more time-consuming and would be less favoured in emergency situations. Gaba and colleagues¹³ noted that this type of reasoning seemed to occur alongside the use of the precompiled responses, linking actions back to medical concepts, perhaps to cross-check on their validity.

The next stage in Gaba's model involves the implementation of the plan developed during the problem-solving

Table 1 Processing levels and activities described by Gaba's model of decision-making by anaesthetists^{11 13 14}

Cognitive level (lowest to highest)	Mental activity	Activities
Sensorimotor level	Processing sensory data and managing routine tasks	Observation, verification, problem recognition and assessment. Routine physical activities such as drug administration
Procedural level	Solving problems by applying rules	Identify and solve problems by applying precompiled responses
Abstract level	Solving problems by reasoning	Uses mental resources to create mental model of problem and to work out solution from first principles
Supervisor level	Supervisory control	Allocates attention and mental resources
Resource management level	Resource management	Uses available resources, information, equipment and personnel to manage perioperative care of patient

stage. As this usually involves the execution of a physical task, such as administering drugs or adjusting the anaesthetic machine, this part of the model is included at the sensorimotor level. It is not described in detail other than to identify the types of errors that can occur, namely slips of action such as using the wrong syringe.

The supervisory control level is responsible for the coordination of tasks through allocation of attention. This determines how much time and how much attention is given to making observations, problem recognition, selecting a response and ensuring that actions are implemented. While it is not clear how much of this supervisory control is under conscious control and how much is automatic, particularly in experts, it is clear that this is a vital process and problems can result in overload and potential failure to execute important steps, such as re-evaluation. As with other parts of the model, situation awareness is an integral part of the supervisory control process.¹⁴

The highest level of processing in the model is that of resource management. At this level, the anaesthetist identifies and attempts to utilize all available resources. Activities necessary for leadership, monitoring and cross-checking and communication are all coordinated from this top level. All of the higher-level perioperative aspects of case management are controlled from here, as are interactions between the individual anaesthetist and the rest of the team. While it is not stated in descriptions of the model, it is assumed that this level of control is under conscious and deliberate control. It is also something that can hopefully be addressed by training, as this feature of anaesthetists' performance has been found to be lacking, particularly in crisis situations.

The Belgian researchers Nyssen and De Keyser³⁶ have identified a simple model of problem-solving that is similar to Gaba's phases of problem recognition, action and re-evaluation. This model shows two problem-solving strat-

egies identified in novice and more experienced trainees, where cues and information are detected and hypotheses are tested against corrective action. On the basis of a re-evaluation of the situation, the diagnosis is verified and new hypotheses are identified if necessary. In the first strategy, when the initial corrective action does not seem to be correct, re-evaluation is based on the original cues that led to the incorrect diagnosis. Thus, new hypotheses must continue to be generated and tested while the situation is not resolved. Essentially, the anaesthetist is fixated on a limited set of cues and does not look for any alternative information. For example, concentrating on the patient's blood pressure recording but not using other information, such as the heart rate, end-tidal carbon dioxide concentration and state of the surgical field. In the second strategy, when the first diagnosis does not seem to be correct, the anaesthetist looks for other cues and, through the collection and integration of more detailed information, is able to make the correct diagnosis. The key components of the effective strategy (associated with greater experience) were identified as effective monitoring strategies, anticipation, flexible allocation of attention, a knowledge of different situations, and the need to re-evaluate after each intervention. Thus, the model highlights the need for anaesthetists to have good situation awareness, to know and understand which cues are important when assessing the situation, and to anticipate the outcome of events given the available data, and for planned intervention. These elements of problem-solving are again common to the models of decision-making identified in other work domains. This model is useful because it starts to identify where experience has an influence and so is able to suggest simulator training that might be used to facilitate the development of problem-solving skills.

In Finland, Klemola and Norros²⁶ developed a conceptual framework that addresses the specific features of anaesthetists' thought processes. They started from the assump-

Table 2 Summary of factors in Helmreich's model of operating room performance^{19 22}

Inputs	Team performance function	Outcomes
Organizational factors Resources, organization and practices Cultural issues Patient	Interaction with colleagues Same specialty Different specialties	Team Patient safety Team performance
Team factors Composition Familiarity Group and intergroup norms	Task type Case management Technical Cognitive Social/interpersonal	Individual and organizational Attitudes Job satisfaction Personal development
Individual factors Attitudes, personality and motivation Knowledge and training Stress and fatigue		

tion that the way anaesthetists perceive their patients will affect their behaviour. Using interviews, asking about the anaesthetist's various tasks and decisions, use of monitors and equipment, and means for dealing with uncertainty, they identified two types of orientation taken to the patient. The 'realistic orientation', described anaesthetists who focused on the uniqueness of each individual patient, communicating with them as being involved in a joint process, and recognizing the uncertainty present in the anaesthetic process. The 'objectivistic orientation' described anaesthetists who had an authoritative relationship with the patient, viewed the patient in terms of their disease and who did not recognize or acknowledge the uncertainty in the anaesthetic process. The latter type of orientation towards patients was found to be more common in their sample.

In a subsequent study, Norros and Klemola³⁴ also identified differences in the way the anaesthetists used the information available to them. One group of anaesthetists was found to use situational information only to confirm that the anaesthetic was running according to plan and responded on the basis of the type of patient and surgery. This 'habit of action' was described as 'reactive', and success was based on keeping the course of the anaesthetic on plan. A second group of anaesthetists was found to use situational information from a variety of different sources to build up an understanding of how the patient might respond. Thus, the anaesthetic plan was used only as a baseline from which to develop a fuller understanding of the patient as more information about the situation became available. This was described as an 'interpretative' habit of action. Perhaps not surprisingly, the reactive habit of action was associated with an objectivistic orientation towards the patient and the interpretative habit of action was associated with a realistic orientation.

What all these models have in common is a focus on the cognitive processes associated with the anaesthetist's tasks, particularly those necessary for dealing with multiple data

sources, uncertainty about the patient and sometimes limited resources. Most of them, with the exception of the framework of Klemola and Norros²⁶ (which in effect describes the need for good situational assessment), have been derived from more generic human information processing models. However, it is important that the particular social and environmental context of the anaesthetic task is taken into consideration, such as interactions with team members, limitations imposed by the layout of the workspace, and the organizational culture of the medical system. It is also essential that the current models continue to be enhanced and evaluated in line with growing understanding, and experience from other high-reliability industries which face similar types of safety challenges.

Team models

Helmreich and Schaefer²² have proposed a model of operating room performance that takes as its focus the whole operating team rather than an individual anaesthetist's mental processes. It is based on a simple framework previously used to describe teamwork on flight decks²⁰ and was adapted for medical teams as a result of observations of theatre staff in Switzerland and the USA. The main components of the model consist of team input factors, team performance function, team outcomes and individual and organizational outcomes, in a feedback loop. These are summarized in Table 2.

The first part of the model relates to the team input factors. These are divided into organizational factors, team factors and individual factors, all of which have been found to affect team performance. Organizational factors are those that could be considered to produce system errors. The following are all examples of organizational factors. How the anaesthetics department and operating theatre suites are organized and how efficiently they run and communicate with each other will affect the availability of resources and

the motivation with which people will work. Conflict between groups within the operating theatre can cause particular problems, as noted previously regarding anaesthetic and surgical teams. Different groups in the operating room may have different work norms and the pace of their work may vary. Cultural issues come into play here at professional, organizational and national levels. This is why it is very important to take care when generalizing from research from other countries with regard to UK hospitals. As these input factors affect overall team performance, different attitudes and expectations about roles and activities as a result of cultural norms could have an effect on performance. Finally, the performance of the team will be affected by the task demands, i.e. patient factors, including the type of surgery, which Helmreich and Schaefer²² include as an organizational factor.

Helmreich and Schaefer²² identify a number of team input factors, including the composition of the team. They note that the usual mix seems to be separate medical and nursing groups for both surgery and anaesthesia (their writing suggests that the nursing staff groups are fixed, whereas in the UK the nursing staff usually do not belong to either discipline specifically). Given that there are several distinct groups making up the team, the model suggests that group and intergroup norms need to be considered. For example, difficulties may arise because different parts of the team may expect different types of communication. Not mentioned, but clearly important, is the familiarity of the team. Groups that work together regularly may have more (or less) understanding of the group's expectations, capabilities and ways of practice.

Finally, individual factors include the attitudes, aptitudes, personality and motivation, knowledge and training, emotional state, and level of physical condition and fatigue. Therefore, the team may be more or less effective if members are tired and stressed or have less training or experience. Unfortunately, results from the ORMAQ survey^{21 43} suggest that medical teams are very poor at acknowledging this fact. Together, organizational, team and individual factors combine to form the team's input for a procedure.

Team performance functions are divided into two types. The first describes the interaction either with colleagues from the same specialization (e.g. anaesthetists) or between specializations (e.g. anaesthetists and surgeons). The second describes the different types of tasks: cognitive and interpersonal issues, and technical aspects and case management. This is essentially a division into non-technical and technical tasks. Breaking the non-technical tasks down further, they describe activities involved in forming and maintaining the team, including leadership; those of communication and decision-making, including maintaining shared situation awareness and option generation; and those for maintaining workload and managing situation awareness through monitoring. The focus of this model is more on the identification of these factors and how they are maintained

rather than complex descriptions of their construction. For a more detailed description of the processes at play in this central part of Helmreich and Schaefer's model, one can refer back to the cognitive models described previously.

The final component of the model relates to outcomes. Here, Helmreich and Davies¹⁹ highlight the multiple outcomes of operating room performance. The most obvious is the patient's safety, but equally important for team performance are individuals' job outcomes. Helmreich and Schaefer believe that 'team processes that are perceived by participants as having been effective in maintaining patient safety should impact on morale and job satisfaction favorably'²² and are likely to be used as feedback to the input and process stages of the model. It is at this stage in the model that debriefing and discussion of reported incidents can be used to support performance. In their final discussion of the model, the authors discuss how organizational interventions can be used to support team performance through training and safety reporting systems.

In common with their applied research programme, Helmreich's model considers anaesthetists' performance only as part of the wider team and the external factors that could influence it. This is very important, as the anaesthetist does not work independently of others, and the cognitive processes of the type described by Gaba and colleagues¹³ should not only function at the individual level. Xiao and Mackenzie^{46 47} also observed that organizational factors played a significant role in increasing uncertainty and task complexity. The description of Helmreich's team model is less detailed than that of the earlier cognitive models, mainly because the concepts are not described in such great depth. Factors relating to team function and management, decision processes and situational awareness are described but the underlying processes are not discussed as this is not the focus of their research. Therefore, to obtain a full understanding of the anaesthetists' performance it is necessary to integrate the two types (cognitive and team) to produce a single model. This should encompass a higher-level component describing interactions with the external environment and team process factors, as well as a lower-level component describing individual cognitive activities and task process factors. The model can be used to analyse incidents in terms of active failures (human errors) and latent conditions (safety of organizational systems)³⁹ and to ensure that all necessary skill areas are addressed in training programmes. The development of a taxonomy of anaesthetist non-technical skills will help provide a framework for further development of such a model.

Concluding remarks

What is clear from this review is that non-technical skills play a central role in good anaesthetic practice and that a wide range of behaviours are important. These include: monitoring, allocation of attention, planning and preparation, situation awareness, prioritization, applying prede-

finer strategies/protocols, flexibility in decision-making, communication, and team-working. However, it is apparent that these skills and their roles are not discussed in the literature at an appropriate level of specification to allow complete understanding to be achieved. For example, prioritization is an elemental skill that is difficult to subdivide further, whereas team-working is a general category that requires further decomposition into its component element skills. It is at the more detailed element level that a taxonomy of such skills becomes useful for training and research^{2 9 37}, as it is then that the full range of skills and their roles can be investigated and the factors that influence them identified. While the purpose of this paper has been to review the role of non-technical skills in anaesthesia, this is only possible to a certain degree because of the limited definition of these skills in the literature. Thus, the research reviewed here highlights the main types of non-technical skills important in anaesthesia and describes some aspects of their role—how they are used and the consequences of non-use. But it is not possible from the extant literature to provide a full list of non-technical skills and their function, as each study tends to highlight a specific aspect of anaesthetists' performance rather than providing a comprehensive skills analysis. It is also worth noting that the majority of existing research has occurred outside the UK and, given the comments in the previous sections on the potential impact of cultural differences, it is important that more research is conducted in the UK.

Nevertheless, this review clearly shows that non-technical skills have a considerable influence on anaesthetists' performance and hence on patient safety. Therefore, there is a strong requirement to provide training at the knowledge and skills level that will teach and reinforce safe behaviours and attitudes. As a corollary, there is a need for more research to specify the key non-technical skills and to develop measures for assessing this component of anaesthetists' performance.

Indeed, one of the most important lessons learned from research in aviation is that, to maximize the understanding of non-technical skills, appropriate performance measures are essential.⁴² Once available, these would allow the possibility of more systematic and empirical investigations into anaesthetists' non-technical skills and would provide a structured assessment tool that could be used in education and training (for a discussion of current observational assessment in anaesthesia, see Greaves and Grant¹⁹). One way to do this is to follow the example of aviation and supplement the limited data from the existing literature by using training needs analysis techniques, such as observations, interviews, surveys and reviews of incident reports, for the specific purpose of identifying the non-technical skills needed to underpin good practice in anaesthesia. From this, a behavioural marker system for anaesthetists' non-technical skills could be developed. Behavioural markers provide observable exemplars of good and poor behaviour for each element of a skill. The process of using behavioural

markers is more objective than unguided forms of expert assessment, as the marker systems can be tested for reliability and validity. Inter-rater reliability is particularly important, and the observers making the assessments must be trained to ensure they are properly calibrated to use the measurement tool. A research project at the University of Aberdeen and the Scottish Clinical Simulation Centre, funded by the Scottish Council for Postgraduate Medical and Dental Education, is currently conducting a training needs analysis to develop such a behavioural marker system for use in the training of anaesthetists^{8a} and other similar initiatives are also taking place elsewhere in Europe.

As Gaba says in a recent comparison of the health care system with other high-hazard industries, 'the issue of patient safety is no longer a hidden epidemic'.¹⁰ Indeed, it is of increasing concern and efforts are starting to be made to resolve this at both the organizational and the specialty level. Considerable challenges remain for the profession, including a need to rapidly enhance our understanding of the role of non-technical skills in anaesthesia and their impact on patient safety.

Acknowledgements

The research for this literature review was conducted as part of collaborative project between the Industrial Psychology Group at the University of Aberdeen and the Scottish Clinical Simulation Centre and was funded by the Scottish Council for Postgraduate Medical and Dental Education (SCPMDE), reference RDNES/990/C: The Identification and Measurement of Anaesthetists' Non-Technical Skills. The authors would like to thank the other members of the project steering group, Dr Rona Patey and Professor Nigel Webster, for their help with the original literature survey. The views presented are those of the authors and should not be taken to represent the position or policy of the funding body.

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