Surgeons’ Non-technical Skills

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Over the last decade or so there has been increasing recognition that adverse events in health care, and specifically surgery, are more likely to originate from behavioral failures than a lack of technical expertise.\(^1,2\) Analysis of worldwide literature suggests that as many as 10% to 15% of patients admitted to hospital experience an adverse event not directly related to their underlying condition, around 50% of which are classified as avoidable. Most of those patients are surgical,\(^3\) and studies indicate that approximately half of all adverse events occur in the operating room (OR).\(^4\) Much of the background information on these adverse events is covered elsewhere in this issue.

The recognition of the enormity of the scale of the problem worldwide led to the introduction of the World Health Organization (WHO) surgical checklist,\(^5\) which showed a significant reduction in mortality and morbidity in a large multicountry study. A follow-up study performed in already high-performing hospitals in the Netherlands\(^6\) confirmed the benefits of this checklist. However, data from the United States in relation to the persisting errors that still occurred after the adoption of the universal protocol\(^7\) suggest that the checklist itself is not the panacea for avoiding adverse events, even if it does help to reduce them. This situation is undoubtedly because the checklist works, not just by providing a tick-box reminder of specific points but by having the underlying ability to focus the team on the job in hand and address some of the human factor issues around patient safety. If these issues are not understood then the full value of the checklist is lost.

These findings all support the argument that although technical skills are necessary for safe surgery, taken in isolation they are not sufficient to maintain high levels of performance over time. In addition, what are now commonly termed non-technical skills,\(^8\) are as important, and sometimes more important, in ensuring the optimum outcome for the patient undergoing surgery. The problem within medicine in general,
and surgery in particular, is that these non-technical skills have never been formally recognized, taught, or assessed. However, in the past decade several studies have revealed that surgeons believe that these skills are essential for safe performance and that they have also been found to be lacking in instances of adverse events for surgical patients. For example, in a reply to an anonymous postal survey, 68 consultant surgeons from all specialties in southeast Scotland identified 70 separate skills that they considered important in a successful surgical trainee. Of these skills, only 19 (27%) were technical and 22 (31%) clinical, with 29 (41%) related to communication, teamwork, and application of knowledge. Communication was also identified as an important causal factor in 43% of errors made in surgery in a study performed in North America in 2003. Other studies have indicated that teamwork and decision making have been lacking in instances of surgical failure.

Analysis of adverse events and accidents in other high-risk industries, such as civil aviation, offshore oil exploration, and nuclear power generation, have resulted in the development of training and assessment in non-technical skills. This training is more commonly called crew resource management training, for which behavior rating systems have been developed to assess these non-technical skills in a more formal manner in the workplace. One such example is the NOTECHS (Non-technical Skills for Pilots) system, which comprises categories and elements of non-technical skills and is used to observe and rate pilots’ behavior in the cockpit during both simulated and real flight. Although there is continuing debate about the relevance of adopting methods of aviation safety to improve health care safety, the approach of developing specific behavior rating systems for use in the OR seems to be a sound one; several such systems now exist and these are discussed in the following section.

BEHAVIORAL MARKER SYSTEMS

Behavioral marker systems such as NOTECHS are methods to identify behaviors that contribute to superior or substandard performance based on a taxonomy of skills. A rating scale is also used in conjunction with the taxonomy. These marker systems are context-specific and must be developed for the situation in which they are to be used. For example, the NOTECHS system was developed and evaluated with subject matter experts from civil aviation. If a high level of validity is required, it is no use taking behavior marker systems developed to assess pilots, scoring out “pilots”, inserting “surgeons”, and then expecting that these systems are appropriate to assess surgeons. For effective non-technical skills assessment, the system needs to be explicit, transparent, reliable, and valid for the domain in which it is being used.

Observational methods of improving safety in medicine were originally pioneered in anesthesia. More recently, other observational studies have identified the individual, team, and organizational factors that seem to underlie surgical performance. These observational systems have been used to drive development and adaption of behavioral rating tools in surgery such as:

1. OTAS (Objective Teamwork Assessment System): a teamwork assessment tool for 3 subteams based on a theoretic model of teamwork
2. Oxford NOTECHS: amended aviation tool for rating surgeons
3. Surgical NOTECHS: amended aviation tool for rating surgical teams
4. NOTSS (Non-Technical Skills for Surgeons): de novo development with subject matter experts (surgeons) to observe and rate individual surgeons.

These tools all differ on how they were developed, for whom they were developed, the level of analysis used, and for what purpose. The following section describes the
development of the NOTSS system, which was designed as an educational framework and is being used by surgeons and researchers in Europe, Australia, Japan, and North America.

THE NOTSS PROJECT

Just as the behavioral marker system for pilots\textsuperscript{13} was systematically developed and subjected to experimental and practical evaluation for the aviation industry, a similar technique was used in the NOTSS project to develop a skills taxonomy for surgeons. The project was run by the University of Aberdeen, with a multidisciplinary steering group of surgeons, psychologists, and an anesthetist. The research drew on previous work in Scotland on surgical competence, professionalism, and the skills surgeons require to operate safely, and followed on from a similar project that developed a behavior rating system for anesthetists: the ANTS (Anaesthetists Non-Technical Skills) system.\textsuperscript{29} The aim of the NOTSS project was to develop and test an educational system for assessment and training based on observed skills in the intraoperative phase of surgery. The system was developed from the bottom up with subject matter experts (attending surgeons), instead of adapting existing frameworks used in other industries. It was considered important to recognize and understand the unique aspects of non-technical skills in surgery and not to assume that those non-technical skills identified for pilots, nuclear power controllers, or anesthetists would be exactly mirrored in, or relevant to, surgery. An adapted model of systems design\textsuperscript{30} was used to guide the iterative development of NOTSS through 3 phases of work from task analysis, through system design, to evaluation (Fig. 1). These phases related to the 3 objectives set by the NOTSS steering group in 2003:

1. To identify the relevant non-technical skills required by surgeons
2. To develop a system to allow surgeons to rate these skills, and
3. To test the system for reliability and usability.

Subject matter experts (consultant/attending surgeons) were involved at all stages of design and a steering group chaired by applied psychologists facilitated the process. This strategy ensured that the resulting system was designed by surgeons for surgeons and was written in surgical language, free of technical jargon and

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{diagram.pdf}
\caption{Development of the NOTSS system.}
\end{figure}
psychobabble. The resulting NOTSS taxonomy is broken down into 4 main categories, each with associated elements as shown in Table 1. The system is in surgical language for suitably trained surgeons to observe, rate, and provide feedback on non-technical skills in a structured manner. For each element, a judicious selection of good and poor behaviors was written; examples of these for situation awareness (SA) are shown in Table 2. This taxonomy was tested in a reliability study involving 44 consultant/attending surgeons, who were trained for 3 hours in the use of behavior markers and who then rated the lead surgeon’s behaviors in a series of simulated operation scenarios. The social skills in NOTSS were found to be reliably rated across scenarios but the cognitive skill ratings were more variable.31

Subsequent phases of work have used the NOTSS system for debriefing trainees after surgery,32 in surgical simulation, and as a central part of a master class to train surgeons to observe and rate non-technical skills.33 NOTSS has also been subject to an independent trial of workplace assessment systems along with procedure-based assessment and OSATS (Objective Structured Assessment of Technical Skill),34 with encouraging results in the OR35; it has been adopted by the Royal Austral-asian College of Surgeons as part of their competence assessment and is recommended by the Accreditation Council for General Medical Education.36 A large-scale trial in Japanese hospitals is also under way.37 A similar system has subsequently been developed for theater scrub practitioners (Surgical Practitioners’ List of Intra-operative Non-Technical Skills [SPLINTS]).38

BREAKING DOWN NOTSS

The next sections discuss the 4 NOTSS categories (SA, decision making, communication and teamwork, and leadership), some of the problems associated with carrying them out correctly, and various solutions.

SA

Without good SA all the other non-technical skills struggle to succeed and it is worth taking time to establish exactly what is required for good SA, the problems in achieving it, and how these might be addressed. SA can be defined as developing and maintaining a dynamic awareness of the situation in the OR, based on assembling data from the environment (patient, team, time, displays, equipment); understanding

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Non-technical skills taxonomy for surgeons</th>
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<tr>
<td>Category</td>
<td>Element</td>
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<tr>
<td>Situation awareness</td>
<td>Gathering information</td>
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<tr>
<td></td>
<td>Understanding information</td>
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<tr>
<td></td>
<td>Projecting and anticipating future state</td>
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<tr>
<td>Decision making</td>
<td>Considering options</td>
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<tr>
<td></td>
<td>Selecting and communicating option</td>
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<td></td>
<td>Implementing and reviewing decisions</td>
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<td>Leadership</td>
<td>Setting and maintaining standards</td>
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<td></td>
<td>Supporting others</td>
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<td></td>
<td>Coping with pressure</td>
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<tr>
<td>Communication and teamwork</td>
<td>Exchanging information</td>
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<tr>
<td></td>
<td>Establishing a shared understanding</td>
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<td></td>
<td>Coordinating team</td>
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what they mean, and thinking ahead about what may happen next. According to Endsley’s model, SA comprises 3 distinct elements (levels): level 1 (gathering information); level 2 (interpreting the information) (and experience clearly plays a role here); and level 3 (projecting and anticipating future states based on this information).

**Level 1**
Information coming in (to the surgeon) does so from several sources, including the patient (anatomy), colleagues (verbal cues), and instruments (patient monitors). The OR is a busy and sometimes noisy place and a great deal of activity goes on (Fig. 2). It is therefore common for the surgeon to be concentrating so intensely on what they are doing that information is either not seen or not heard, or the importance not recognized (Fig. 3). This situation is what is often called inattentional blindness or tunnel vision. This observation is not to say that the surgeon should not be concentrating hard on a specific task, but, by doing so, important information on the state of the patient or environment might go unrecognized and this should be realized.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Examples of good and poor behaviors for situation awareness</th>
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<tbody>
<tr>
<td><strong>Element</strong></td>
<td><strong>Good Behaviors</strong></td>
</tr>
<tr>
<td>Gathering information</td>
<td>Performs preoperative checks of patient notes</td>
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<tr>
<td></td>
<td>Ensures that all relevant imaging/investigations have been reviewed and are available</td>
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<tr>
<td></td>
<td>Liaises with anesthetist regarding anesthetic plan for patient</td>
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<tr>
<td></td>
<td>Identifies anatomy/disease</td>
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<tr>
<td></td>
<td>Monitors ongoing blood loss</td>
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<tr>
<td></td>
<td>Asks anesthetist for update</td>
</tr>
<tr>
<td>Understanding information</td>
<td>Changes surgical plan in light of changes in patient condition</td>
</tr>
<tr>
<td></td>
<td>Acts according to information gathered from previous investigation</td>
</tr>
<tr>
<td></td>
<td>Looks at computed tomography (CT) scan and points out relevant area</td>
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<tr>
<td></td>
<td>Reflects and discusses significance of information with team</td>
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<td></td>
<td></td>
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<tr>
<td>Projecting and anticipating future state</td>
<td>Shows evidence of having a contingency plan (plan B) by asking scrub nurse for potentially required equipment to be available in theater</td>
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<tr>
<td></td>
<td>Keeps anesthetist informed about procedure (eg, to expect bleeding)</td>
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<tr>
<td></td>
<td>Verbalizes what may be required later in operation</td>
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<tr>
<td></td>
<td>Cites contemporary literature on anticipated clinical event</td>
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Messages may need to be repeated and confirmed, background music may need to be turned off, and when things do get difficult and fraught, the principle of the sterile cockpit could be considered. This strategy, not surprisingly, comes from aviation, when, usually during takeoff and landing (e.g., less than 1524 meters [5000 ft]), no nonessential conversation should take place, thereby allowing the pilots to concentrate on the job in hand. Depending on the situation, the surgeon may ask for information to be repeated, request opinions from colleagues, or backtrack and go over previous information again to double-check comprehension.

**Level 2**
The surgeon needs to not only receive all the information but also to understand its significance. This ability requires a degree of training and experience, so junior surgeons, not aware of the significance of certain facts, respond (or do not respond) differently from senior, more experienced surgeons. A common problem in correctly
interpreting the information is confirmation bias. Information coming in is filtered to allow the surgeon to confirm their views, discarding any information that might suggest another cause. This situation can be avoided by analyzing all the information that comes in, and if necessary, discussing the potential diagnoses with other members of the team. A common reason for ignoring some information and accepting others may be that the alternative diagnosis suggests a radical change of plan that may be difficult or unpleasant.

**Level 3**

Having received and (it is hoped) recognized the importance of the information, the surgeon must then anticipate potential future events. This situation may or may not require a change of plan. Problems with incorrect anticipation may be avoided by discussing options with colleagues and reviewing alternatives.

This is all a dynamic situation and changes as the operation progresses. Surgeons with good SA regularly step back (to avoid tunnel vision) and reassess the situation, take on board all the relevant information including nonverbal clues (anesthetic activity, scrub nurse anxiety, and monitor warnings), and reconsider the operative plan based on revised assessment.

**Decision Making**

Decision making can be defined as skills for coming to a particular course of action.\(^4^2\) There is now increasing interest in intraoperative judgment.\(^4^3\) Classic models of decision making propose that this is an analytical process: the relative features of options are compared in turn and an optimal course of action is selected; for example; in cases of large bowel obstruction the surgeon might weigh up the various pros and cons of performing a primary anastomosis against a colostomy. Decision making can be an effortful process and requires both experience and time to come to an acceptable solution. It seems that during the intraoperative phase of surgery, surgeons use analytical decision making in around 50% of cases.\(^4^4\)

Another common method of decision making applicable to intraoperative surgery is rule-based decision making. This method is used by trainee and expert surgeons alike and follows the “if X then Y” process. This process makes decision making easier, because once a situation has been detected, a relevant rule can be applied, either by consulting a manual or by referring to national guidelines or local protocols. Less formally, surgeons may remember anecdotal rules learnt during training that can be applied when certain situations arise. Deciding when to use antibiotic prophylaxis during surgery to reduce the risk of surgical site infection is 1 example.

However, experts tend to use a more heuristic-based style called recognition-primed decision making (RPD). This is a type of pattern matching that experts can use to make satisfactory decisions under times of high stress or time pressure. Studies on fire ground commanders and military decision makers\(^4^5\) found that experts could often identify the first workable solution to a problem based on their experience rather than going through the effortful process of systematically generating options and comparing the features of those options before arriving at an optimal solution. The mental efficiency that RPD brings is important, because working memory space is diminished during times of acute stress. When a trainee surgeon seems to freeze at the operating table when faced with a difficult and stressful situation, this is probably because they have inadequate working memory for analytical decision making and do not have the experience to use RPD. The causes and effects of stress are discussed later in this article.
The final method is creative decision making, which, although sounding innovative, is usually only a last resort when the other methods are not possible or have been tried and found to be unsuccessful. Making such creative decisions can sometimes be successful but usually results in failure.

**Communication and Teamwork**

Communication and teamwork can be defined as the skills required for working in a team context to ensure that the team has an acceptable shared picture of the situation and can complete tasks effectively. What is essential is that each member of the team has a shared mental model of both what is happening and what is the planned outcome (Fig. 4). There are many barriers to communication, both internal and external, and these are summarized in Box 1.

Several studies have shown that many of the adverse events that occur in surgery relate to problems with communication\(^{10-12}\) and these communication failures systematically recur.\(^{46}\) Several general remedies for improving communication within the team have been developed and are summarized in Table 3.

When communication is improved, the shared mental model is undoubtedly better and teamwork benefits. Various tools have been developed to improve and clarify communication. CUSS is one in which assertive communication uses the following escalation:\(^{47}\):

- **C** “I’m concerned and need clarification”
- **U** “I am uncomfortable and don’t understand”
- **S** “I’m seriously worried here”
- **S** “stop”

Alternatively the ISBAR system, devised by the American military for precise and succinct transmission of messages, can be used:\(^{48}\):

- **I** Identify: who, where?
- **S** Situation: what is the problem?
- **B** Background: relevant PMH, presentation
- **A** Assessment: what do you make of the problem?
- **R** Recommendation: what do you think you should do?

![Fig. 4. Shared mental model.](image)
Use of these systems in isolation or by only selected members of the team does not lead to any real improvement in communication.

**Leadership**

There is widespread recognition in organizations exposed to hazards that leadership is essential for efficient and safe team performance. In the cognitive interviews as part of phase 1 of NOTSS development, surgeons either described leadership in the OR as entirely their own responsibility, or as a shared responsibility between the surgeon, anesthetist, and nursing team leader. During the NOTSS development process, the leadership behaviors were grouped into 3 elements: setting and maintaining standards, supporting others, and coping with pressure. These social leadership skills were more reliably rated than cognitive skills in NOTSS. However, according to a recent review of the literature, there is limited empiric evidence identifying specific

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**Box 1**

**Barriers to communication**

*Internal*
- Language difference
- Culture
- Motivation
- Expectations
- Past experience
- Status
- Emotions/mood

*External*
- Noise
- Low voice
- Deafness
- Electrical interference
- Separation in space and time
- Lack of visual cues (eg, body language, eye contact, gestures, facial expressions)

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**Table 3**

**Strategies for improving communication**

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
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<tbody>
<tr>
<td>Misunderstanding information</td>
<td>Do not make assumptions</td>
</tr>
<tr>
<td>Information confusing</td>
<td>Be precise and clear</td>
</tr>
<tr>
<td>Information not heard/message ambiguous</td>
<td>Acknowledge receipt of information; verify information received; clarify any possible ambiguity</td>
</tr>
<tr>
<td>Sender uses hint-and-hope strategy</td>
<td>Say what you mean</td>
</tr>
<tr>
<td>Information given too early/too late</td>
<td>Pick your moment (especially if things are fraught)</td>
</tr>
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</table>
leadership skills and associated behaviors enacted by surgeons during operations. Despite this paucity of research, some emerging studies have shown observations about surgeons’ leadership behaviors that do not necessarily fit with traditional models from the leadership literature. In 1 recent observational study of 29 operations\textsuperscript{51} a total of 258 surgical leadership behaviors were classified. The operating surgeons most frequently showed leadership behaviors classified as guiding and supporting (33%), communicating and coordinating (20%), and task management (15%). In many instances surgeons’ leadership communications were not specifically directed to a particular team member. Accounting for operation length, surgeons engaged in leadership behaviors significantly more frequently during cases of high complexity compared with cases of lower complexity.\textsuperscript{52} Other research on surgeons’ intraoperative leadership suggests that residents move from emphasizing transactional to transformational behaviors as they progress through their training.\textsuperscript{53}

**The Surgical Checklist and NOTSS**

As mentioned earlier, to provide a final error trap before surgery, the WHO “Safer Surgery Saves Life” campaign introduced the concept of the surgical checklist and the surgical pause (http://www.who.int/features/factfiles/safe_surgery/en). In addition to providing a final check before surgery, it has undoubtedly contributed to improving the various non-technical skills required for better operative surgery. SA around the diagnosis and procedure, along with the instruments/equipment required and possible difficulties that may be encountered (projection/anticipation), are all discussed. Decision making is improved by early identification of possible difficulties, and communication throughout the team is expressed audibly and acknowledged. Teamwork has to be improved by the knowledge of all the names of people in the OR, something that has often been neglected in the past, with many OR personnel not being known by name to each other, especially across specialties. Good leadership can be encouraged, and developed, by completing the checklist in the appropriate manner, showing a commitment to patient safety and both recognizing the roles and supporting other members of the operating team.

**Stress and Fatigue**

Although fatigue and stress are not non-technical skills, it is important to recognize how they can influence non-technical skills and how their effects can be mitigated against and managed to improve performance.

**Stress**

There has been increasing focus on the negative effects of stress (defined as when the demands on an individual outweigh the amount of control they are able to exert) and burnout in surgery. This focus has been partly because of the recently reported results of a large survey of 7905 surgeons in the United States that reported that more than 40% felt burned out,\textsuperscript{54} a psychological term for chronic emotional exhaustion and diminished interest: a state that affects performance at work and can make surgical care less safe for patients. Burnout is one of the most serious outcomes of chronic stress, but the effects of stress manifest themselves in many other discrete and subtle ways. A systematic review of the literature on acute stress in surgery\textsuperscript{55} found 22 empiric papers in a disparate field with a mix of subjective (eg, questionnaire) and objective (eg, heart rate, salivary cortisol) measurements of stress that were used by researchers working in the real OR as well as simulated settings. This review reported that the main stressors were the act of surgery itself; patient factors such as unanticipated bleeding; and noise, visitors, and distractions. Laparoscopic surgery
was found to be more stressful than open surgery. Stress has been shown to affect technical as well as non-technical performance and although no controlled studies have been conducted in this area, experienced surgeons not surprisingly seem to be able to cope with stress better than juniors. Of particular importance are the changes in cognitive function associated with acute stress that significantly reduce available working memory and therefore have a detrimental effect on perception, decision making, and task management. As a result, decision making in acutely stressful situations may rely entirely on the RPD model; if someone lacks the experience for this, they may freeze and be unable to make a decision.

**Fatigue**

Fatigue is a factor in most commonly occurring accidents, including road traffic accidents and accidents in health care and other high-risk industries. Fatigue can be defined as a state of sleepiness characterized by feeling drowsy or tired that results in a reduced ability to maintain concentration, make decisions, and carry out skilled tasks. Lack of sleep is the most common cause of fatigue; sufferers are unable to think clearly and imaginatively, are more rigid in their thinking, and accept lower standards of performance. Motor skills are degraded and fatigued individuals are more prepared to accept their own errors, to become irritable and distracted, and are less tolerant of others. Moderate sleep loss is equivalent to moderate alcohol consumption in the way that it degrades motor performance. It has now also been shown that decreasing hours of work for doctors reduces error. Sleep is the only effective way of recovering from fatigue; after a short period of sleep deprivation it is possible to return to normal with 1 or 2 nights of good-quality sleep. It is well known that shift work disrupts normal sleep patterns by interrupting the circadian rhythm of the body and disrupting sleep cycles; however, working a single or a few night shifts can be recovered from quickly. A week of nights is probably the worst pattern of work because fatigue accumulates toward the end of the week with disrupted sleep. Increasing age is associated with longer recovery time from periods of disturbed or reduced sleep, providing more justification for the more senior surgeons to come off the on-call rota.

**SUMMARY**

The appreciation of the importance of non-technical skills to surgical performance is now gaining wider acceptance. This article describes the core cognitive and social skill categories in this area. Several tools have been developed to rate these non-technical skills in the OR, focusing on observational methods as a means of assessment. These tools are being used informally by research groups and interested clinicians, but if the increase of non-technical skills appreciation in surgery mirrors that in other high-risk industries, such as civil aviation and nuclear power generation, these skills may need to be taught and assessed in a formative manner on a larger scale. The different taxonomies developed for use in the OR differ slightly in the balance of skill categories believed to be important. There are minor differences between the varieties of NOTECHS and NOTSS, but there are larger differences in the taxonomies developed for different clinical groups in the OR. For example, the skills identified in the NOTSS taxonomy are different from the taxonomies developed for both anesthetists and scrub practitioners because each taxonomy reflects the particular role of that profession within the operating team. In the ANTS taxonomy, task management was included as a category whereas leadership (included in NOTSS) was not. The prototype SPLINTS taxonomy contains only 3 categories because that was the number of high-level themes that emerged from task analysis in that domain.
More work is needed in this area of surgery, but at present we know that good surgeons usually have good non-technical skills and most adverse events in surgery relate to poor non-technical skills. Furthermore, we now understand and recognize these non-technical skills. The challenge in the future is to incorporate them into undergraduate teaching, postgraduate training, assessment, and perhaps even selection.

REFERENCES