Human factors in anaesthetic practice: insights from a task analysis

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Background. Despite a growing recognition of the role of human error in anaesthesia, it remains unclear what should be done to mitigate its effects. We addressed this issue by using task analysis to create a systematic description of the behaviours that are involved during anaesthesia, which can be used as a framework for promoting good practice and highlight areas of concern.

Methods. The task steps involved in preparing and delivering anaesthesia were identified using hierarchical task analysis (HTA). The systematic human error reduction and prediction approach (SHERPA) was then used to identify potential human errors at each task step and suggest ways of preventing these errors.

Results. The number and type of behaviours involved vary according to the ‘phase’ of anaesthesia, with tasks in the induction room, including induction of anaesthesia itself, being the most demanding. Errors during preoperative planning and perioperative maintenance could be avoided by measures to support information handling and decision-making. Errors during machine checking, induction, and emergence could be reduced by streamlining or automating task steps, or by making changes to the physical design of the work environment.

Conclusions. We have demonstrated the value of task analysis in improving anaesthetic practice. Task analysis facilitates the identification of relevant human factors issues and suggests ways in which these issues can be addressed. The output of the task analysis will be of use in focusing future interventions and research in this area.

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The adverse effect of human error on the safe and effective delivery of anaesthesia has been widely recognized for a number of years.1–5 However, what is not clear is how and when the different types of human error have an effect, or what steps can be taken to mitigate their effects. The aim of the study described in this paper is to address this question by using task analysis to create a detailed behavioural description of the anaesthetic process. Although particular aspects of anaesthetic practice will be highlighted for illustrative purposes, the emphasis of the paper is on demonstrating the use of task analysis to identify issues of potential concern rather than making firm recommendations about how the issues raised by the illustrative examples should be addressed.

Task analysis has been described as a methodology for examining the actions or cognitive processes involved in a given work activity.6 In surgery, it has been shown to have the following benefits:7

• A human-centred description of the medical and surgical team activities, which in turn allows key skills and knowledge to be identified;
• A means of identifying potential ‘vulnerabilities’ in the work processes, for example, gaps in procedures or interference from medical technologies;
• An aid to defining suitable interventions to enhance work activity, including the specification of user and system requirements for technology-based solutions;

Task analysis has also been used to study the activities in an intensive care unit, with the data subsequently being used as a baseline measure against which to identify and quantify errors.8 Another study examined a clinical
pathway using task analysis, and in doing so identified potential ‘bottlenecks’ within the pathway; for example, a task step that involved retrieval of an electronic patient record during patient admission was prone to error due to incorrect records being retrieved. Within anaesthesia, Weinger and colleagues have used task analysis to compare the performance of novice anaesthetists with those of experts. However, although it generates useful insights into anaesthetic practice, the approach of Weinger and colleagues focused more on the tasks themselves than on task behaviour. It involved an observer recording the frequency and duration of pre-defined clinical task activities, such as ‘i.v. adjustment’ and ‘conversing with surgeon’. Although this allows relevant activities to be identified, what appears to be less well captured in this technique is the sequence and organization of behaviours that make up the task activity.

In the present study, the tasks involved in preparing and delivering anaesthesia were identified using hierarchical task analysis (HTA), as advocated by Ainsworth and Marshall. This begins with a general task goal (for example, ‘provide preoperative care’), and breaks this down, or ‘decomposes’ it, into the task steps that must be performed in order to achieve the main goal. The end result is a hierarchy of task steps that represent the behaviours that need to be performed in the conduct of a task. By way of illustration, an HTA of setting up an i.v. infusion is shown in Figure 1.

The output of an HTA can be used in its own right as a self-contained description of task activity, but given that a major objective of this study was to identify potential human errors, we have employed an extension to HTA, known as the systematic human error reduction and prediction approach (SHERPA). This facilitates the identification of errors that could occur, and of the points during the task at which they might occur, by applying a classification of potential errors to the output of an HTA. The classification scheme lists a number of error types, from which the analyst selects those that are likely to apply to the task under consideration. Using the example shown in Figure 1, the errors listed in SHERPA that could credibly occur during task step 3.2 (‘check flow switches’) might be judged to include ‘check omitted’ and ‘wrong line checked’. Having identified the potential errors, each is examined further to determine its potential for occurring, the consequence of it occurring, and what could be done to reduce its occurrence. The advantage of SHERPA is that it is relatively straightforward and has a good level of reliability. Its use has recently been demonstrated to identify potential errors in the administration of medicines and in laparoscopic surgery.

**Methods**

Hierarchical task analysis

The task analysis covered the anaesthetist’s main activities from the start of the preoperative visit to the postoperative handover of the patient to the recovery staff. Data were collected for the task analysis from the following sources.

- **Literature:** In order to provide a theoretical background and ensure full coverage of anaesthetic practice, two anaesthetic textbooks and the AAGBI guidelines on preoperative machine checking were consulted and key anaesthetic tasks identified from these and organized into a timeline.

- **Observations:** Having obtained institutional and NHS REC approval [Ethical approval for conduct in the NHS was granted by the Central Manchester Research Ethics Committee and the Salford and Trafford Local Research Ethics Committee (COREC project no. 06/Q1407/16)], two members of the research team (D.P. and C.N.) observed anaesthetic teams performing pre- and perioperative tasks at an adult teaching hospital and a paediatric specialist hospital. The researchers were present for several types of list at both hospitals, as listed in Table 1. In total, approximately 200 h of anaesthetic practice was observed, from which the researchers noted the behaviours that were carried out during performance of anaesthetic tasks.

- **Subject matter expert:** Technical advice, and an initial review of the information gathered from the literature and observations, was provided by a member of the research team (G.H.M.).
The procedure adopted for carrying out the analysis followed the standard HTA process. This can be summarized as follows:

1. Identify the general task goal;
2. Identify the behavioural or cognitive steps that need to be combined in order to achieve the goal. These are known as the subordinate goals or subgoals;
3. Having identified the subgoals, define the circumstances under which each is carried out and the order in which they are conducted. This information is used to describe the plan for the overall goal;
4. Determine whether each subgoal needs to be decomposed into smaller steps;
5. If a subgoal needs to be decomposed, repeat the process from 2, with the subgoal now being treated as a goal;
6. Decomposition ends when a sufficient level of detail is reached. When this occurs is a matter of judgement, but as a rule of thumb, it is likely to be the point at which further decomposition of the subgoals is either impossible or will add little value given the objectives of the task analysis. In the current study, this was taken to be the point at which the subgoals describe specific interactive behaviours with the patient, equipment, or other staff.

SHERPA

The task steps at the lowest level of the HTA were examined in further detail using SHERPA. The procedure employed was that described by Stanton and colleagues, which is summarized as follows:

1. Classify the behaviour involved, from the following: action (e.g. pressing a button); retrieval (e.g. getting information); checking (e.g. conducting a procedural check); selection (e.g. choosing one alternative over another); information communication (e.g. talking to another party);
2. Using the classification of error types shown in Table 2, determine the errors that can credibly occur;
3. Describe the consequences of each error;
4. Determine the ‘recovery potential’ of each error, noting any steps that occur later in the HTA where the error could be ‘recovered’ (i.e. identified and corrected before it has an effect);
5. Rate the probability of each error occurring, including instances where the error occurs but is ‘recovered’. Objective estimates for these values were not available in the literature and extracting them from available critical incident reports assumes that the error in question was always explicitly identified in the reports. The research team therefore agreed bands of likelihood from their own experience. These were ‘low’ (hardly ever occurs, ≤1 in 1000), ‘medium’ (occasionally occurs, >1 in 1000 but ≤1 in 100), and ‘high’ (frequently occurs, >1 in 100);
6. Rate the ‘criticality’ of each error—i.e. the potential for the error to lead to a critical incident if unchecked. Again, in the absence of objective data, the researchers were forced to use subjective bands based on their own experience. These were ‘low’ (a barely noticeable effect), ‘medium’ (a potentially noticeable but transient effect), and ‘high’ (a potentially life-threatening or permanent effect);
7. Suggest prospective remedial strategies to prevent each error from occurring or propagating (equipment, training, procedures, or organizational).

The HTA and SHERPA were subsequently reviewed in toto by three subject matter experts who were not members of the research team. These included a surgical clinical research fellow with experience of task analysis (Mr S. K. Sarker, Royal Free Hospital, London), an academic human factors specialist (Prof. N. Stanton, Brunel...
University), and a professor of anaesthesia (Prof. J. M. Davies, University of Calgary), whose attention was drawn especially to the determination of probability and criticality of each error.

Results

An overview of the HTA output is shown in Tables 3 and 4, showing the highest-level task steps for preoperative care and perioperative care, respectively. Owing to the amount of detail generated by the HTA and SHERPA, only selected extracts, shown in Table 4, will be discussed. The extracts were chosen because they illustrate the use of task analysis, not because we judged them to be any more important from an anaesthetic point of view. They are discussed in relation to phases of giving an anaesthetic that would be recognizable to anaesthetists, namely:

- preoperative planning (Table 2);
- tasks in the induction room, including:
  - preoperative equipment check (task 1, Table 3);
  - preparation of drugs (task 2, Table 3);
  - commencing essential patient monitoring (tasks 4 and 5, Table 3);
  - induction of anaesthesia (tasks 6, 7, and 8, Table 3);
- transfer of the patient to the operating theatre (task 12, Table 3);
- maintenance of anaesthesia (task 13, Table 3);
- emergence from anaesthesia ( tasks 14 and 15, Table 3).

A complete account of the results is available from the first author.

Table 3 Extract from the HTA of preoperative care, showing the highest level task steps

<table>
<thead>
<tr>
<th>Task step</th>
<th>Description</th>
<th>Subordinate task steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Assess patient</td>
<td>Assess surgical procedure, medical history, physical examination, decide whether to give premedication.</td>
</tr>
<tr>
<td>2</td>
<td>Request investigations (if required)</td>
<td>Request full blood count, electrolytes, coagulation tests, chest radiography, ECG, sickle test, urinalysis.</td>
</tr>
<tr>
<td>3</td>
<td>Decide on anaesthetic to be used</td>
<td>Choose anaesthetic drugs, delivery method, decide on postoperative care.</td>
</tr>
<tr>
<td>4</td>
<td>Reassure patient</td>
<td>Agree choices with patient.</td>
</tr>
</tbody>
</table>

Table 4 Extract from the HTA of perioperative care, showing the highest level task steps

<table>
<thead>
<tr>
<th>Task step</th>
<th>Description</th>
<th>Subordinate task steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carry out equipment checks</td>
<td>Ensure oxygen analyser is present, check supply of medical gases, flowmeters, vaporizers, breathing system, stimulator.</td>
</tr>
<tr>
<td>2</td>
<td>Prepare drugs</td>
<td>Collect drug, determine amount required.</td>
</tr>
<tr>
<td>3</td>
<td>Identify patient</td>
<td>Confirm type of operation, patient identification.</td>
</tr>
<tr>
<td>4</td>
<td>Attach essential monitors</td>
<td>Attach pulse oximeter, arterial pressure monitor, ECG monitor, gas agent monitor.</td>
</tr>
<tr>
<td>5</td>
<td>Commence patient monitoring</td>
<td>Monitor oxygen saturation, heart rate and rhythm, monitor respiration, gas traces.</td>
</tr>
<tr>
<td>6</td>
<td>Establish i.v. access</td>
<td>Clean skin, insert cannula, establish i.v. fluid administration.</td>
</tr>
<tr>
<td>7</td>
<td>Administer anaesthetic</td>
<td>Administer oxygen, hypnotic drug, inhalation agent, analgesic drug, neuromuscular blocking agent drug.</td>
</tr>
<tr>
<td>8</td>
<td>Secure patient’s airway</td>
<td>Insert oral airway, laryngeal mask airway, tracheal tube, endotracheal tube.</td>
</tr>
<tr>
<td>9</td>
<td>Cover patient’s eyes</td>
<td>Fix airway, insert throat pack.</td>
</tr>
<tr>
<td>10</td>
<td>Attach additional monitors (if required)</td>
<td>Attach temperature probe, peripheral nerve stimulator, invasive monitoring.</td>
</tr>
<tr>
<td>11</td>
<td>Commence additional monitoring</td>
<td>Monitor temperature, degree of neuromuscular block.</td>
</tr>
<tr>
<td>12</td>
<td>Transfer to operating room</td>
<td>Remove i.v. set, disconnect monitoring lines, check lines on patient.</td>
</tr>
</tbody>
</table>
A task analysis of anaesthetic practice

Table 4 Continued

<table>
<thead>
<tr>
<th>Task step</th>
<th>Description</th>
<th>Subordinate task steps</th>
</tr>
</thead>
</table>
| 13        | Maintain anaesthesia | Move trolley into theatre  
Move patient from trolley to operating table  
Connect monitoring lines to monitors  
Recommence i.v. infusion  
Monitor condition  
Adjust anaesthetic concentration  
Review/amend postoperative requirements  
Inform recovery nurse of requirements |
| 14        | Discontinue anaesthesia | Discontinue drug administration  
Administer reversal drugs  
Administer oxygen at 100% concentration  
Uncover patient’s eyes  
Remove artificial airway |
| 15        | Transfer to recovery room | Continue oxygen administration  
Discontinue i.v. fluid administration  
Disconnect monitors  
Move patient from operating table onto trolley  
Place patient in left lateral position  
Move trolley into recovery room  
Handover to recovery nurse |
| 16        | Complete documentation | Check details on anaesthetic chart  
Check postoperative care instructions  
File documentation |

Preoperative planning

Preoperative planning is an activity consisting mainly of information gathering and decision-making, and it relies on both communication with patients and on liaison with other members of staff. For example, the anaesthetist often relies on surgeons providing accurate details about the operation, or on laboratory staff in performing tests that he or she requests. In such situations, the physical, technical, and interpersonal separation between different staff roles may hamper effective collaborative working.21 22 Given the amount of data handling during preoperative care, another issue that may be of interest is whether technological support could be of assistance during this phase, for example, by providing access to electronic patient records.

Tasks in the induction room

The equipment check is largely a process of examining and operating various parts of the anaesthetic equipment to confirm that they are serviceable. However, with 44 task steps, the equipment check is a potentially lengthy and detailed process, and it is possible that steps may be omitted, either intentionally or unintentionally. Although the process might be guided by a checklist, another option, which has become a reality on some new models of anaesthetic machine, is for the process to be partly or fully automated.

Two particular human factors problems were identified during the analysis. The first was the potential for errors to arise due to an incorrect configuration of the ventilator tubing being missed during the machine check. This appears to be especially likely when an unfamiliar machine is in use; hence, a basic precaution is for those responsible for machine checking to ensure that they are familiar with the different types of machine available at the hospital in question. Some anaesthetic departments have taken the fundamental measure of standardizing the types of machines they procure. The second problem identified was that of the common gas outlet control; on some types of anaesthetic machine, it is not immediately obvious to the operator whether this control is set to the ‘circle’ or ‘open’ mode, which can cause unexpected problems with the ventilator during anaesthesia. Although one design solution is to make the selected mode of operation more apparent, it has also been suggested that ‘multi mode’ use of the common gas outlet control should be discontinued altogether—i.e. anaesthetic machines should be operated in circle mode only.23

Previous research,24 and anecdotal evidence from anaesthetists, suggests that the most intensive phase of anaesthesia is induction. An examination of the HTA output would support this view; 73 task steps were identified between the preparation of drugs (task 2, Table 3) and transferring the anaesthetized patient to the operating room (task 12, Table 3). During this period, as well as monitoring and adjusting equipment, observing the patient and communicating with colleagues, there are also a considerable number of manual task steps, such as the insertion of canulae and airways. The anaesthetist therefore needs to attend to different aspects of patient care concurrently. Attention, though, is a limited resource25 and it is possible that a less salient task step (e.g. connecting a monitor) might be missed or performed incorrectly if the anaesthetist is distracted. There may be scope to explore how the design of equipment can further aid the anaesthetist, for example, by providing physical cues to perform certain task steps. Also, any measures that can be taken to reduce the workload experienced by anaesthetists, for example, by automating tasks or allowing them to be delegated to other staff, may be of value here.

A number of task steps associated with drug handling were identified, two of which are shown in Table 5 by way of example. One of these is step 2.2: ‘collect drug’ (before drawing up). One of the errors suggested by SHERPA for this is collecting the wrong drug. Assuming that such an error does indeed occur and is a cause for concern, one way of reducing its occurrence could be to adopt the practice of cross-checking drug selections with a
colleague or assistant, although there are arguments for and against the effectiveness of this measure in the literature.\textsuperscript{26–28} Another solution could be to use a scanner to check the barcode on a drug packet, as a way of confirming that the correct packet has been picked up.\textsuperscript{29}

The second task step shown in Table 5 is step 2.3: ‘transfer required amount of drug to syringe’. Again, applying the SHERPA led to a potential error being identified—transferring the wrong amount. However, it would appear that although some anaesthetists do indeed attempt to draw

<table>
<thead>
<tr>
<th>Task step</th>
<th>Error</th>
<th>Probability</th>
<th>Criticality</th>
<th>Remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative visit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.1 Identify type of surgery (including incorrect theatre lists or consent forms)</td>
<td>Incorrectly identified</td>
<td>Medium–low</td>
<td>Medium</td>
<td>Ensure sufficient details are provided on the operating list (e.g. ‘laparotomy/colectomy’ rather than ‘laparotomy’, if the former is meant)</td>
</tr>
<tr>
<td>1.2.4 Ask about previous anaesthetics/complications Preoperative equipment check</td>
<td>Assessment not made</td>
<td>Low</td>
<td>Low–high</td>
<td>Use preoperative checklist</td>
</tr>
<tr>
<td>1.7.1 Ensure that the vaporizer is filled to the correct level</td>
<td>Vaporizer not checked</td>
<td>Low</td>
<td>Medium–high</td>
<td>Ensure compliance with checklist. Automate this task step</td>
</tr>
<tr>
<td>1.9.1 Ensure correct configuration of the ventilator tubing</td>
<td>Incorrect configuration not identified</td>
<td>Low</td>
<td>High</td>
<td>Train operators on the machines that are being used. Standardize the machines being used</td>
</tr>
<tr>
<td>1.9.3 Select mode of operation (circle or open)</td>
<td>Controls incorrectly set</td>
<td>Medium–high</td>
<td>High</td>
<td>Make the switch setting more clearly visible. Remove the common gas outlet control</td>
</tr>
<tr>
<td>Induction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Collect drug</td>
<td>Wrong drug collected</td>
<td>Low</td>
<td>High</td>
<td>Cross-check the label. Use a bar-code checker</td>
</tr>
<tr>
<td>2.3 Transfer required amount of drug to syringe</td>
<td>Wrong amount transferred</td>
<td>Low</td>
<td>Medium–high</td>
<td>Cross-check the dose. Use pre-loaded syringes</td>
</tr>
<tr>
<td>4.2 Attach arterial pressure monitor</td>
<td>Monitor not correctly positioned</td>
<td>Low</td>
<td>High</td>
<td>Ensure there is a check of signal quality. Use a ‘signal quality’ alarm</td>
</tr>
<tr>
<td>12.3.1 Disconnect pulse oximeter</td>
<td>Monitor not disconnected</td>
<td>Low</td>
<td>Low–medium</td>
<td>Employ single port for all monitor connections. Cross-check monitor disconnections. Telemetry</td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.1.1.1 Monitor inspired agent concentration</td>
<td>Concentration not monitored</td>
<td>Low</td>
<td>High</td>
<td>Improve the display design. Encourage ‘standard checking’ by manual recording of values. Use agent level alarms</td>
</tr>
<tr>
<td>13.1.5 Monitor respiration and respiratory gas traces</td>
<td>Ventilatory frequency not monitored</td>
<td>Low</td>
<td>High</td>
<td>Set context-specific monitors and alarms. Encourage ‘standard checking’</td>
</tr>
<tr>
<td>13.1.7.2 Monitor urine output</td>
<td>Not read</td>
<td>Medium</td>
<td>Medium–high</td>
<td>Set context-specific monitors and alarms. Encourage ‘standard checking’</td>
</tr>
<tr>
<td>13.1.9 Record observations on anaesthetic chart</td>
<td>Observations recorded incorrectly</td>
<td>Low</td>
<td>High</td>
<td>Use automated recording device. Encourage ‘standard checking’</td>
</tr>
<tr>
<td>Emergence</td>
<td></td>
<td></td>
<td></td>
<td>Tie the throat pack to the LMA. Ensure end of throat pack is visible at all times. Recovery nurse to check in postoperative care unit</td>
</tr>
<tr>
<td>14.5.1 Remove throat pack</td>
<td>Throat pack not removed</td>
<td>Low</td>
<td>High</td>
<td>Manual handling training. Have a member of staff take charge of patient movement</td>
</tr>
<tr>
<td>15.4.4 Move patient using movement device</td>
<td>Patient mishandled</td>
<td>Low</td>
<td>High</td>
<td>Use a formal protocol for handover. Use an integrated care pathway. Use a perioperative care practitioner. Use a data link between theatre and postoperative care unit</td>
</tr>
<tr>
<td>15.7.7 Inform recovery nurse of postoperative care requirements</td>
<td>Nurse not given complete information</td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>
monitored value. One suggestion which was made in for example, the anaesthetist fails to observe a change in a section. This is an issue that will be explored further in the Discussion section. Secondly, there may be a relationship between the frequency and accuracy with which that monitor is read, although in the absence of empirical data such a relationship can only be surmised.

Maintenance of anaesthesia

Compared with the induction phase, there are fewer (16) task steps during the maintenance phase. Apart from adjusting the dose of anaesthetic, it might appear that there is little to do under normal circumstances. Taken in isolation, this observation suggests that the scope for error is relatively limited. However as reported earlier, there is evidence that a relatively high proportion of critical incidents occur during the maintenance phase.\textsuperscript{1} This is an issue that will be explored further in the Discussion section.

According to SHERPA, one type of error that could arise during maintenance is that data are not monitored; for example, the anaesthetist fails to observe a change in a monitored value. One suggestion which was made in response to this problem was to create ‘context-specific’ monitors for use in anaesthetic machines. These would automatically adjust alarm limits to take into account the nature of activity being undertaken at the time of monitoring (e.g. during extended electrocautery or the administration of drugs). A second suggestion was to encourage the practice of making ‘standard checks’—that is, a routine check of monitors that is initiated by the anaesthetist on a periodic basis. Human factors literature suggests that the use of standard checks is a characteristic of an individual’s problem-solving technique rather than of the situation itself.\textsuperscript{31, 32} This suggests that standard checking may need to be prompted; one way of doing this may be by maintaining the common practice of manually recording values from monitors. However, a later task step is ‘record observations on anaesthetic chart’, and here a potential error is that values are recorded incorrectly, for which automatic recording of values has been suggested as a preventative measure. This begs the question: which type of recording is preferable? The foregoing discussion suggests an argument for using both types of transcription where practicable. This, though, could create confusion should there be a discrepancy between the manually recorded and the automatically recorded values. Should a ‘dual system’ be preferred, then the circumstances under which such discrepancies would occur, and the impact they would have on the way anaesthetic records are created and interpreted, may need to be examined in more detail.

During the current study, the researchers rated many of the monitor readings as having a low probability of error (either not being read or being read incorrectly) and a high criticality should an error occur—these were typically connected with respiration, for example, oxygen saturation and agent concentration. Others were given ratings of low error probability and medium-to-high criticality depending on the case; these included heart rate and arterial pressure. Some were given medium or high probabilities of not being monitored, with a criticality rating that was varied between low and high—these were urinary output and neuromuscular block. There are two related issues here. First, and more generally, the probability and criticality of an error may depend on the nature of the anaesthetic case; this is an issue that will be revisited in the Discussion section. Secondly, there may be a relationship between the importance given to a monitor and the frequency and accuracy with which that monitor is read, although in the absence of empirical data such a relationship can only be surmised.

The researchers also identified among the maintenance task steps a behaviour that appears to be outside maintenance—communicating requirements for postoperative care to the recovery nurse ahead of the patient’s arrival in the recovery room. Although this does not happen formally until the actual handover, it appears to be common practice for a ‘pre-warning’ to be sent just before the patient is extubated; this minimizes the chance of the anaesthetist’s
workflow being disrupted by a delay in arranging the patient’s aftercare. Should there be a need to establish this as a formal practice, it could be made the responsibility of a member of staff (for example, a perioperative care practitioner) acting as a ‘runner’; alternatively it could be facilitated using information technology. For example, a data link between theatres and the recovery room could both allow anaesthetists to transmit patient data to the recovery nurse and facilitate the organization of patient movement from theatres to the recovery room.

**Emergence from anaesthesia**

With 40 task steps to carry out in a relatively short space of time, the discontinuation of anaesthesia and subsequent transfer of the patient to recovery is fairly busy. The human factors issues involved are largely similar to those discussed in the previous phases. As with induction, the emergence phase involves the manual handling of the patient and equipment as the patient is moved from the theatre to the recovery room. There is, of course, no possibility that these task steps can be eliminated, and hence the only options available for making them safer are to ensure ergonomic design of the trolley and the path between the operating room and recovery (e.g. installing doors that open mechanically when activated by a member of staff) and to ensure adherence to manual handling protocols.

**Discussion**

*The problem of setting values of criticality and probability of given errors in SHERPA*

A major weakness of the study was the way in which the probability of an error occurring and the criticality of such an error were subjectively set. The method employed was to use the experience of the team, particularly the subject matter expert (G.H.M.), and to audit this against the opinion of an external subject matter expert as described in the Methods section. One alternative approach to this subjective assessment could have been to administer a questionnaire to a larger group of anaesthetists. However, there were more than 200 different task steps and associated error modes identified; this would have made for a very lengthy questionnaire. Furthermore, the questionnaire would have been difficult to understand without considerable background information, and the scores obtained would still be subjective and affected by the variations in practice between the respondents.

An alternative strategy is to use the information obtained from the task analysis to interrogate available critical incident, closed case, or other sources of objective data, in order to derive probability and criticality data. This seems to us to be a more practicable way of obtaining an objective assessment. However, this does require considerable further research to be conducted. In the light of this, the estimates as presented in this paper should be seen as initial estimates to illustrate the use of HTA and SHERPA.

*Is maintenance of anaesthesia really more dangerous than induction or emergence?*

The question of why more errors might occur during maintenance of anaesthesia than at the far more intensive stages (induction of anaesthesia and emergence from anaesthesia) is very interesting. One explanation might be that errors made earlier, say during patient induction or during the equipment checks, become apparent during maintenance, either because it takes until this phase for the error to manifest itself or because the anaesthetist has fewer attentional demands during maintenance and so is better able to detect them. However, given that maintenance is usually longer than other phases, an alternative explanation could be that the probability of making an error within a specified time frame remains the same regardless of the number and nature of the task steps being carried out and therefore more errors are made during maintenance since it is longer. This is an issue that would need to be examined in a further empirical study.

Frequency aside, where new errors are made during monitoring, they are likely to be related to a loss of concentration which causes the anaesthetist to miss indicators of change in the patient’s condition. It has long been recognized that people have difficulty in maintaining an optimal level of performance in monitoring for an extended period of time, and a number of suggestions have been made about how the so-called ‘vigilance decrement’ can be combated. As with preoperative care, there is a considerable element of data handling involved during monitoring, and Sanderson draws attention to the need to take into account anaesthetists’ information requirements when considering how future monitoring technology should be designed. It is highly likely that further research in this area would rely heavily on the task analysis presented.

*The utility of task analysis in anaesthesia*

The main aim of this study has been to provide a systematic description of anaesthesia delivery and consider the human factors issues associated with each step. The use of HTA as the analytical method gives emphasis to the behaviours performed by the anaesthetist; in doing so, it complements other studies that focus on the task itself. This, in turn, facilitates a discussion of human factors issues in anaesthesia by allowing these issues to be mapped onto specific parts of the task. SHERPA extends HTA by applying a human error taxonomy to each task step, allowing a more detailed examination of the types of errors that could take place. This in turn provides further suggestions about
how quality and safety can be improved, either by training or by work design.

In common with previous research, the current study illustrates the ability of HTA to elucidate the task steps required to deliver anaesthesia, which could be of value in determining what trainees need to be taught during training. Although much of this may already be obvious to experienced anaesthetists, it is possible that their implicit understanding of how to carry out anaesthesia is difficult to articulate fully to trainees. Sarker and colleagues have explored the further use of HTA in surgeons’ self-appraisal of laparoscopic procedures; they found that a task analysis created by a sample of surgeons was able to provide the basis for a reliable performance assessment tool. For the purposes of training and assessment, the output of HTA is quite similar to a clinical protocol. However, although the focus of a protocol is on the task itself, the focus of HTA is on the behaviours involved in executing the task. Because of this, it can either complement existing approaches to protocol generation or provide insight into how these protocols would be carried out in practice. An additional benefit of HTA in this regard is that it leads to a consideration of which task steps are most likely to be performed incorrectly and why, and of the relationship between different steps.

Although the HTA and SHERPA analyses we have described contribute to the understanding of anaesthesia practice and can be linked to practical applications, three main caveats should be indicated. The first is that this analysis describes a ‘generic’ anaesthetic delivery; although it captures much of what takes place during most cases, it is probable that the description would change for specialized procedures such as cardiac or neurosurgical operations.

A second, related, issue is that anaesthesia practice depends to some extent on the circumstances of each case. This means that it is possible to conceive of situations where the content of the SHERPA analysis would be different. For example, although in many situations monitoring the temperature of the patient is of low or medium importance, it becomes highly important if the patient is being cooled for a heart bypass. Similarly, monitoring inhalation agents is of highest importance when anaesthetizing neonates or the elderly who are more sensitive to volatile agents. For some task steps, the importance of an error can vary across the patient population. For example, picking up the wrong drug in the induction room could potentially lead to a critical incident with patients who are allergic to the drug being used, but for most patients a critical incident is less likely to arise. At this point, some comments about the validity of SHERPA should be made. The technique has been found to predict with some degree of accuracy the errors that actually occur during a task, with data coming from laboratory experiments of equipment use and from field studies of pilot interaction with a flight deck. However, although SHERPA has been shown to be generally valid, the accuracy of prediction achieved during a given analysis is somewhat dependent on the analysts’ understanding of the task at hand, as it is the analyst who decides which errors are credible enough to be included.

As mentioned earlier, the analysts in this study included both human factors specialists and a consultant anaesthetist and the output was reviewed by other experts in both domains. Therefore, it is expected that the analysis will be a reasonable reflection of what does and could occur under most circumstances. However, it would be of interest to determine through empirical data the frequency of these errors in practice. Although such a study has not yet been carried out in anaesthesia, a derivative of SHERPA has been used retrospectively to identify errors during surgical procedures, suggesting at least some level of validity in this domain.

Finally, although HTA aims to provide a comprehensive description of task-related behaviour, it is often considered to be more representative of physical actions than of the cognitive aspects of a task. HTA does go some way to describing the cognitions involved in carrying out a task (e.g. in the current study, the HTA indicated the information that an anaesthetist requires during patient monitoring) and attempts have been made more recently to extend HTA to take better account of information demands. However, many analysts turn to cognitive task analysis (CTA) to address such issues in more detail than HTA commonly provides. A full consideration of CTA methods is beyond the scope of this paper; however, examples of its use in medicine are provided by Velmahos and colleagues, Lyons and colleagues, and Sullivan and colleagues. It is worth mentioning that HTA remains a useful starting point for task analysis even if CTA is ultimately employed, because the former tends to provide a more rigorous description of the task’s structure.

To conclude, this paper has demonstrated the value of task analysis in general, and a combination of HTA and SHERPA in particular, in the examination of anaesthetic practice. A number of potential applications have been indicated, some of which we intend to explore in future studies. The current study serves to increase understanding of how anaesthesia is carried out, and to facilitate further discussion and research on relevant human factors issues.

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