Cognitive errors detected in anaesthesiology: a literature review and pilot study

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Editor’s key points
- This paper deals with a novel subject of cognitive errors and psychology of decision-making in anaesthesia.
- An anaesthesia-specific catalogue of cognitive errors was created using qualitative methodology.
- The errors of key importance were seen in >50% of simulated emergencies.
- The study provides deeper insight into error generation and possible strategies to prevent them.

Background. Cognitive errors are thought-process errors, or thinking mistakes, which lead to incorrect diagnoses, treatments, or both. This psychology of decision-making has received little formal attention in anaesthesiology literature, although it is widely appreciated in other safety cultures, such as aviation, and other medical specialities. We sought to identify which types of cognitive errors are most important in anaesthesiology.

Methods. This study consisted of two parts. First, we created a cognitive error catalogue specific to anaesthesiology practice using a literature review, modified Delphi method with experts, and a survey of academic faculty. In the second part, we observed for those cognitive errors during resident physician management of simulated anaesthesiology emergencies.

Results. Of >30 described cognitive errors, the modified Delphi method yielded 14 key items experts felt were most important and prevalent in anaesthesiology practice (Table 1). Faculty survey responses narrowed this to a ‘top 10’ catalogue consisting of anchoring, availability bias, premature closure, feedback bias, framing effect, confirmation bias, omission bias, commission bias, overconfidence, and sunk costs (Table 2). Nine types of cognitive errors were selected for observation during simulated emergency management. Seven of those nine types of cognitive errors occurred in >50% of observed emergencies (Table 3).

Conclusions. Cognitive errors are thought to contribute significantly to medical mishaps. We identified cognitive errors specific to anaesthesiology practice. Understanding the key types of cognitive errors specific to anaesthesiology is the first step towards training in metacognition and de-biasing strategies, which may improve patient safety.

Keywords: cognition; decision-making; diagnostic errors/prevention and control; medical mistakes; physicians/psychology

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Increasingly, attention is being focused on the prevention and management of medical errors that have been estimated to account for 44 000–98 000 deaths annually in the USA.1 Recent studies suggest that cognitive errors, a subset of medical errors involving faulty-thought processes and subconscious biases, are important contributors to missed diagnoses and patient injury.2–6 Indeed, according to Groopman,7 ‘a growing body of research shows that technical errors account for only a small fraction of incorrect diagnoses and treatments. Most errors are mistakes in thinking. And part of what causes these cognitive errors is our inner feelings, feelings we do not readily admit to and often don’t even recognize’. Thus, the psychology of decision-making is becoming increasingly appreciated in the non-medical and medical literature.

Cognitive errors have been described in safety culture industries, such as aviation and nuclear power plants,6,7 and in the literature of medical education and other medical specialities, including internal medicine, emergency medicine, family practice, radiology, neurology, and pathology.2,8–15 In the 1990s, early pioneers of the ‘Crisis Resource Management’ paradigms at Harvard and Stanford introduced this topic by including fixation error (also known as ‘anchoring’ or ‘tunnel-vision’) in their curricula.11,16,17 Numerous additional cognitive errors have been identified and this concept has been greatly expanded in other disciplines since then. A comprehensive review of cognitive errors or decision-making psychology has not yet been published in contemporary anaesthesiology literature. This manuscript sought to provide an expanded introduction to the concept of cognitive...
errors, and to identify the cognitive errors that may be most important in anaesthesiology practice.

**Review of cognitive errors**

Cognitive errors fall under the domain of psychology of decision-making. According to Croskerry, who has presented the most comprehensive medical catalogue of cognitive errors to date, the literature on cognitive bias in decision-making is ample, but ‘ponderously slow to enter medicine’. Perhaps this is because cognitive errors are considerably less tangible than procedural errors. They are described as ‘low-visibility’; that is, they are generally unable to be witnessed or recorded and usually occur with low awareness on the part of the thinker. Thus, they are not conducive to root-cause analysis. However, these types of thinking mistakes are thought to be potentially highly preventable. Cognitive errors are thought-process errors, usually linked to failed biases or heuristics. According to Groopman, ‘while heuristics serve as the foundation for all mature medical decision making, they can lead to grave errors. The doctor must be aware of which heuristics he is using, and how his inner feelings may influence them’. Importantly, these are errors that are made despite the availability of knowledge and data needed to make the correct decision. Thus, they are distinct from knowledge gaps. It is important to note that heuristics and biases are frequently useful in clinical medicine; they allow experts to arrive at decisions quickly and (usually) accurately. However, cognitive errors occur when these subconscious processes and mental shortcuts are relied upon excessively or under the wrong circumstances. Below, we will introduce several examples of specific cognitive errors that are commonly described in the literature and easy to understand. Table 1 lists our catalogue of 14 cognitive errors, along with definitions and examples for each.

‘Premature closure’ describes the cognitive error of accepting the first plausible diagnosis before it has been

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<th>Table 1 Cognitive error catalogue</th>
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<td><strong>Cognitive error</strong></td>
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<td>Anchoring</td>
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selecting only certain information and attempting to force errors, the fault lies in the thought process—subconsciously absence of metabolic acidosis. As with other cognitive hypercarbia, and not looking for (or discounting the malignant hyperthermia based upon hyperthermia and misdiagnosing oesophageal intubation in favour of ‘fixing’ this may occur with nearly any monitoring device, including instead of recognizing the hypotension as real. Similarly, repeating of arterial pressure measurements, changing cuff

Information does not return to the decision maker, it is impossible to shape future decisions based upon that information. As such, the absence of feedback is subconsciously noted as the positive feedback. Potential clinical examples of this abound in anaesthesiology, as we often have limited patient continuity. If a patient suffers an infection from central catheter placement, or a corneal abrasion from inadequate eye protection, or even intraoperative awareness, these issues may not be communicated back to the anaesthesiologist. The anaesthesiologist may remain ignorant of these complications indefinitely, believing the techniques used to be adequate.

‘Confirmation bias’ is an error characterized by seeking confirming evidence to support a diagnosis while subconsciously discounting contrary evidence, despite the latter often being more definitive. Sometimes this will manifest by trying to force data to fit a desired or suspected diagnosis. A simple example in anaesthesiology might be the repeating of arterial pressure measurements, changing cuff sizes and locations, in an effort to get a reassuring reading, instead of recognizing the hypotension as real. Similarly, this may occur with nearly any monitoring device, including misdiagnosing oesophageal intubation in favour of ‘fixing’ the capnograph. Another example might be diagnosing malignant hyperthermia based upon hyperthermia and hypercarbia, and not looking for (or discounting the absence of) metabolic acidosis. As with other cognitive errors, the fault lies in the thought process—subconsciously selecting only certain information and attempting to force those data to ‘satisfy’ a chosen diagnosis. Crucial to the concept of cognitive errors is the lack of deliberate thinking. Often, clinicians must sift through extraneous data that are indeed irrelevant to a diagnosis. Upon careful consideration, they may discard them. However, confirmation bias is not conscious, deliberate selection of data; it is a largely unconscionable process of (incorrect) pattern recognition.

‘Availability bias’ is an error in diagnosis due to an emotionally memorable past experience (an adverse patient outcome, or lawsuit, for example). Physicians may be subconsciously affected by these emotional experiences, causing the diagnosis to be very readily available at the forefront of the mind, which has the result of inflating the pre-test probability for that diagnosis. In the future, the physician may unintentionally ignore important differences between the current presentation and that prior experience, falling prey to the availability bias error.

Study methods

Having reviewed the literature and noting the absence of anaesthesiology-specific set of cognitive errors, we set out to perform two tasks. First, we sought to create an anaesthesiology-specific catalogue of errors. Next, we created a pilot study to observe the prevalence of those errors during simulated anaesthesia emergencies. Institutional Review Board approval was obtained before study implementation.

Creation of an anaesthesiology-specific catalogue of cognitive errors

We performed a Medline literature search using the key words ‘cognitive error’, ‘cognitive psychology’, ‘diagnostic error’, ‘heuristic’, and ‘decision making’ alone and in combinations. We limited our search to articles from peer-reviewed journals written in English, screening abstracts for appropriateness. Since we were interested in the modern paradigm of thought-process errors, we limited our initial search to items published during or after 1999. We then screened all abstracts identified by Medline to be ‘related citations’ of articles we found to be relevant, and we screened relevant articles cited in the articles we reviewed, including those published before 1999. In all, we found that the concept of cognitive errors was described in 28 articles, and specific cognitive errors were identified and defined in 23 articles. From all the specific cognitive errors identified, we examined the definitions and combined items that appeared to be synonyms. For example, ‘anchoring’, ‘fixation’, and ‘tunnel vision’ are all terms that essentially describe the process of giving exclusive attention to only one problem at the expense of fully understanding the situation, and we chose to refer to this concept as ‘anchoring’. Instead of creating a new taxonomy, we chose among existing terminology options for use in this study. We listed all the separate errors, along with definitions, and we added illustrative anaesthesiology examples.
Using the expert opinion of eight faculty on the quality assurance committee (who routinely investigate errors and near-misses) and crisis simulation faculty (who have extensive experience observing the natural course of errors allowed to evolve unchecked) from the corresponding author’s academic Anaesthesiology department, we narrowed the catalogue using two rounds of a modified Delphi technique. This process consisted of interviews during which the faculty reviewed the list of errors with an investigator (M.P.S.). They were asked to comment on the relevance of each error to the practice of anaesthesiology in a hypothetical manner and also in terms of personal experience and vicarious experiences. They were also asked to comment on the likelihood of the error based upon level of clinical experience; that is, they were asked whether an error is likely to be relevant to trainees only or also to experienced anaesthesiologists. Finally, they were asked whether education about a particular error and its prevention strategy would be useful to their own practice or to that of other anaesthesiologists. After each faculty member had been interviewed once and revisions made, the same faculty were invited to comment on the proposed exclusions and the remaining catalogue. In particular, because many cognitive errors have a degree of conceptual overlap, they were asked if any items appeared to be synonymous, or if their defining features were too subtle to differentiate. They were also asked to comment on the construction of the list and whether it was self-explanatory. Based upon this information, we narrowed the catalogue to 14 items, which are listed, defined, and illustrated in Table 1. Finally, this 14-item catalogue, including error definitions and illustrative clinical examples, was presented via e-mail to all faculty members (77 in total). They were asked to identify up to five items that they believed to be most pertinent to anaesthesiology practice. Again, they were asked to consider both their own personal experiences and those they observed or were told about from colleagues or trainees. They were also invited to comment on any item they wished, and in particular, they were asked to comment if they felt a particular error did not occur in anaesthesiology. As is discussed in the Results section, this process ultimately led to a catalogue of 10 items felt to be especially relevant to anaesthesiology.

Observation of cognitive errors

We wished to observe whether the cognitive errors identified in our catalogue indeed occurred in clinical practice. As observation of errors in the operating theatre without intervening would be unethical, we elected to observe residents in an established simulation course where errors may be allowed to evolve unchecked and transpire along their natural course. We did not alter the standard simulation curriculum in any way for this study, and we recruited participants based upon availability. The following is a brief description of our standard simulation curriculum and environment. As part of standard training, anaesthesiology resident physicians at our institution practice managing simulated emergencies several times per year. Residents participated in high-fidelity scenarios, using the SimMan simulator (Laerdal Medical, Wappingers Falls, NY, USA), and actors (trained simulation centre staff) represented other team members (surgeon, nurse). Scenarios were selected from our library of 20 cases by the simulation faculty based on appropriateness for the resident level of training and prior exposure to scenarios. They contained scripted emergencies, including anaphylaxis, malignant hyperthermia, difficult airway (‘can’t intubate, can’t ventilate’), and pulmonary embolism. Before the simulation, residents were fully oriented to the simulation environment, capabilities, and limitations. Participants were instructed to act as the lead physician managing patient care, and were also informed they could ask for help, diagnostic exams, or any resource commonly available in the operating theatre. For each case, participants were given a vignette stem and the ability to ask questions, just as they would in a preoperative evaluation. Each case was 20–40 min in length and was immediately followed by a debriefing that lasted 40 min. All of this is our standard educational curriculum. It should be emphasized that we did not alter the simulated events in any way to attempt to cultivate error, nor did we study any error prevention or recovery strategies. This study was solely to confirm (or refute) whether the cognitive errors identified in our catalogue appeared during clinical decision-making exercises.

Between October 2009 and February 2010, 32 resident physicians consented to participate in the study. As cognitive errors are thought to be ubiquitous processes and not situation-specific, we did not control for the simulated vignette subject matter or script, nor did we ask the faculty instructors to deviate from their usual practices. As is standard in our curriculum, resident physicians were asked to manage the emergency as if in real life. While observing the live scenarios, investigators made note of error behaviours. Those behaviours were subsequently explored during the debriefing, so that the thought processes could be elicited. The investigators recorded all cognitive errors that were identified; a resident physician could make any number of defined cognitive errors, including none or all, in a given scenario.

Expert rating

Two expert investigators evaluated each participant after the simulated case and debriefing, using a five-point Likert-style survey that queried performance of cognitive errors and non-technical skills, such as communication and teamwork behaviours. This instrument was developed using the cognitive errors in the first part of this study, was demonstrated to be reliable (Cronbach’s $\alpha=0.81$), and is described in detail elsewhere. Each expert rater received instructions and a calibration session with the principal investigator. Experts completed the cognitive error survey after the debriefing process, so that they could ascertain both the degree of medical knowledge possessed by the resident physician...
and the thought process by which decisions were made. Scores were given after debriefing because a defining feature of cognitive errors is the absence of a knowledge deficit; thus, it was essential to gain insight into the decision-making thought process before scoring. As previously discussed, cognitive errors cannot be detected by observation alone.

Statistical analysis
Expert raters indicated whether or not a particular cognitive error was made by a given resident physician using a five-point Likert scale (1, strongly disagree that error occurred; 2, disagree that error occurred; 3, neutral or unsure; 4, agree that error occurred; 5, strongly agree that error occurred). For our analyses, we averaged investigator scores for each error and created a binary variable as follows: an average of >3 indicated an error occurred; whereas an average of ≤3 indicated no error occurred. Then, using SPSS version 17 (SPSS Inc., Chicago, IL, USA), we performed frequency analysis for each error.

Results
Cognitive error catalogue
Thirty-two of the 77 faculty physicians (41.5% response rate) queried responded. Our faculty consensus identified the following 10 cognitive errors as being highly relevant to the practice of anaesthesiology: anchoring, availability bias, omission bias, commission bias, premature closure, confirmation bias, framing effect, overconfidence, feedback bias, and sunk cost. The percentage of responders who identified a given error as being among the five most important is given in Table 2. Throughout the modified Delphi process, the faculty overwhelmingly affirmed their perception that these kinds of thought-process error occur frequently and are likely to contribute to actual error behaviours and ultimately, adverse outcomes. Certain items were noted to be less likely, and they involved patient behaviours. Psych-out error and visceral bias both depend largely on dynamic interactions with awake patients, so it is not surprising that they figured less prominently in the final catalogue, yet were identified by our faculty members who specialize in obstetric anaesthesiology or critical care environments, including the post-anaesthesia recovery unit.

Cognitive errors chosen by more than 25% of respondents, for a total of 10 items, were selected for the pilot study. However, specifically for our simulation-based portion of the study, we omitted feedback bias, since this kind of error requires a prolonged amount of time lapse. Thus, nine of the errors from Table 2 were assessed in the second part of the study: anchoring, availability bias, omission bias, commission bias, premature closure, confirmation bias, framing effect, overconfidence, and sunk cost.

Free text responses by faculty overwhelmingly affirmed the importance of cognitive errors in anaesthesiology practice. Almost all responders indicated that listing only five was difficult because they all occur with significant frequency. Several responders suggested that the most important errors might vary based upon experience, with some more likely to occur among trainees and others more likely among experienced clinicians. As an example, availability bias was suggested to be more likely among experienced anaesthesiologists, since they would have more emotionally memorable experiences from which to draw. Overconfidence was also suggested to be more likely among experienced anaesthesiologists, while omission bias was suggested to be more likely among less experienced clinicians. No responder indicated that cognitive errors were unimportant or did not significantly contribute to medical errors.

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<thead>
<tr>
<th>Cognitive error</th>
<th>Faculty selection [% (n)]</th>
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<tbody>
<tr>
<td>Anchoring</td>
<td>84.4 (27)</td>
</tr>
<tr>
<td>Availability bias</td>
<td>53.1 (17)</td>
</tr>
<tr>
<td>Premature closure</td>
<td>46.9 (15)</td>
</tr>
<tr>
<td>Feedback bias</td>
<td>46.9 (15)</td>
</tr>
<tr>
<td>Confirmation bias</td>
<td>40.6 (13)</td>
</tr>
<tr>
<td>Framing effect</td>
<td>40.6 (13)</td>
</tr>
<tr>
<td>Commission bias</td>
<td>32 (10)</td>
</tr>
<tr>
<td>Overconfidence bias</td>
<td>32 (10)</td>
</tr>
<tr>
<td>Omission bias</td>
<td>28.1 (9)</td>
</tr>
<tr>
<td>Sunk costs</td>
<td>25 (8)</td>
</tr>
<tr>
<td>Visceral bias</td>
<td>12.5 (4)</td>
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<tr>
<td>Zebra retreat</td>
<td>12.5 (4)</td>
</tr>
<tr>
<td>Unpacking principle</td>
<td>6.25 (2)</td>
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<tr>
<td>Psych-out error</td>
<td>6.25 (2)</td>
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Observation of cognitive errors
Thirty-two resident physicians (PGY 2–16, PGY 3–8, PGY 4–8) consented to participate in this pilot study. Over a period of 5 months, 38 simulated encounters were observed in real time. As is our standard practice, these encounters are also recorded; these recordings were available to study personnel if needed. Six resident physicians participated in simulation training twice over the course of the data collection, and one resident physician was scheduled three times. However, no resident physician participated in the same scenario more than once, and no education about cognitive errors was presented; thus, repeat participants had neither an advantage nor disadvantage compared with other participants.

Table 3 lists the nine cognitive errors observed during the 38 simulation encounters, along with the corresponding prevalence data. By far, our faculty felt that anchoring was the most common error, followed by availability bias, premature closure, and feedback bias. These are errors that have been frequently identified in other fields of medicine. Seven
of the nine errors we studied occurred in at least half of the simulation sessions.

**Discussion**

The observations during our pilot study were consistent with the high ratings of our faculty; premature closure and confirmation bias were the most commonly observed cognitive errors in simulated scenarios. Framing effect and availability bias were observed the least. In fact, errors perceived by faculty to be important to anaesthesiology were indeed observed frequently among trainees in a simulated environment.

Some items that were scored very highly by anaesthetists were observed relatively infrequently in simulation, and vice versa. As a general phenomenon, there are a few possible explanations for this. First, faculty were asked which errors they believed were most pertinent or important, not necessarily which were most frequent. Next, the Delphi process involved perceptions of errors, but those perceptions are likely based upon observational experience alone, without the benefit of cognitive mechanism debriefing. In contrast, during the simulated exercises, our raters were able to inquire as to thought process and identify errors with the added insight into cognitive mechanisms. Another possible explanation is that our faculty were asked to reflect on their past experience and identify the errors they thought were most important, while the investigators in the simulation portion were looking prospectively and had the assistance of prompts from the cognitive error survey. Additionally, it is possible that our faculty strongly identified with errors they felt were easier to understand and relate, and this unfamiliarity itself may have biased their responses. However, since most errors in our catalogue were observed in simulation, results from both parts of the study are likely to represent an important first look at cognitive errors in anaesthesiology practice.

Identification of the most common cognitive errors is crucial to developing appropriate training strategies for management and prevention. With this catalogue as a starting point, more research should be performed to confirm the importance of these errors and test error prevention and recovery methods. Although a thorough treatment of metacognition and strategies for cognitive error prevention and recovery is beyond the scope of this manuscript, it deserves some brief mention here. Put simply, metacognition is thinking about thinking, and studies of metacognitive training have demonstrated improved decision-making processes and decision outcomes. Basic features of metacognitive practice include: recognition of limitations of memory, ability to reflect on and appreciate a broader perspective, good capacity for self-critique and harnessing overconfidence, and the ability to select specific strategies for best decision-making. Practitioners should do deliberate self-checks, asking the questions: ‘Am I using the best decision-making strategy right now?’ and ‘Am I relying too heavily on pattern-recognition or bias?’. While some urgent situations require immediate action, more accurate diagnosis and appropriate therapy may result from active generation of alternative interpretations of evidence and identification of hidden assumptions when time permits. Physicians should be deliberate in deciding when it is appropriate to think more or think differently.

A limitation of this consensus is that it was based on the practice of faculty at a single large academic centre involving supervision of trainees. It is possible that perceived frequencies and relative importance of various errors would vary with type of practice and level of experience. Further, regarding the simulation portion of the study, due to our relatively small sample size and the diversity of simulated encounters, we cannot comment on the potential relationships between years of training, types or prevalence of error, and clinical ‘outcome’ of simulated emergencies. Finally, it is not known whether these same errors occur at similar rates among experienced anaesthesiologists, nor is it known whether these errors occur at similar rates during real clinical emergencies. These are all areas that warrant further study.

The concept of cognitive errors is relatively new to the medical literature, and relatively novel to the anaesthesiology literature. As such, there is a large amount of work still to be done. A larger study of anaesthesiologists’ opinions on cognitive errors should be done to include those in other practice models. Further, studies that seek to stratify by novice, intermediate, and experienced anaesthesiologists would help identify whether certain errors are more prevalent among certain groups. Additionally, the observation of these errors in real clinical events should be attempted, although this would present several challenges (self-reporting is generally poor, and it would be unethical to observe errors without intervening). As noted, we did not study any error prevention or recovery strategies, but simply observed for the occurrence of these errors. However, the applied psychology concepts of metacognition and ‘de-biasing’ strategies have been demonstrated in other fields to be effective in cognitive error prevention and recovery. With common cognitive errors in anaesthesiology identified, specific strategies to minimize them can be developed and disseminated. Ultimately, studies addressing the effectiveness of metacognitive training and debiasing strategies in preventing these errors among anaesthesiologists must be performed.
To our knowledge, this is the first study to identify cognitive errors specific to anaesthesiology practice and to observe them prospectively. We were able to identify 10 key errors perceived to be especially pertinent to anaesthesiology practice, and were then able to observe their occurrence consistently and frequently in simulated anaesthesia scenarios. We believe that these are likely to occur in real clinical anaesthesia scenarios as well, as they do in other fields of medicine. This application of cognitive psychology is important because it follows logically that errors of thought lead to errors of behaviour, and consequently contribute to morbidity and mortality.

We advocate that anaesthesiologists must have insight into their own decision-making processes and deliberately abandon intuitive reasoning for an analytic approach when necessary. To achieve this, educational training in cognitive errors, metacognition, and debiasing strategies is needed. However, there are still many questions regarding which errors are most important to address and which metacognitive strategies are most appropriate and effective in anaesthesiology. Further research in this area is needed to reduce decision-making errors and improve patient safety.

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**Declaration of interest**

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