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Cognitive bias and neurosurgical decision making

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COMMON neurosurgical decisions include whether to operate, what surgical approach or technique to use, how to treat complications, and how to implement risk adjustment for individual comorbidities. Neurosurgeons make these complex and high-stakes decisions by relying on individual judgment, hypothetical deductive reasoning, patient and surgeon values, and experience.[1] However, the neurosurgery decision-making process is suboptimal for several reasons. For instance, judgments are often made under time constraints due to a large clinical workload. Surgeons' information about a patient or clinical circumstances may be incomplete because of emergencies, lack of access to prior medical records, or language barriers between patients and providers. In addition, decisions are often made under duress. Because retrospective studies and low-quality clinical evidence dominate the field, high-quality, evidence-based guidelines are often absent. Furthermore, decision making is nuanced, and one does not have a published study to consult for every decision. Given this unfavorable decision-making environment with high-stakes outcomes, errors in neurosurgical judgment may occur, leading to patient harm.

Research in decision science and psychology has uncovered numerous pervasive heuristics (i.e., cognitive shortcuts or mental "rules of thumb") that are used to make decisions in complex and uncertain situations. These heuristics are highly adaptive and functional; they are used to simplify complexity in the social world and allow our bounded cognition to make efficient decisions. When overapplied, however, these cognitive tools can also lead to biases such as systematic errors in judgment and decision making. In their seminal work published in Science in 1974, which laid the foundation for the Nobel Memorial Prize in Economic Sciences, Tversky and Kahneman described a series of cognitive biases and their impact on the process of making decisions.[2] Significantly, even though cognitive biases often lead to acceptable decisions, they can produce systematic and predictable errors in judgment. In low-stakes situations, these predictable errors have minimal consequences. But in neurosurgery, these errors may have profound consequences.

Cognitive biases and their impacts on decision making have been described in the literature of medical disciplines such as general surgery,[2,3] orthodontics,[4] ophthalmology,[5] psychiatry,[6] and radiology,[7,8] among others.[9–11] Saposnik et al.[12] reported that these biases are common and pervasive in medicine. Loftus and colleagues[1] have described the influences on judgment in general surgery, which include decision complexity, patient and surgeon values, time constraints, and biases. In this opinion piece, we hope to raise awareness of circumstances that may lead surgeons to rely on mental shortcuts by describing several cognitive biases that we have observed in our neurosurgery practice and suggesting mitigation strategies that surgeons can employ to improve their decision making.

Cognitive Biases in Neurosurgery

Anchoring

Anchoring is an influential bias defined as decision making that depends too heavily on the initial information presented rather than on the appropriate weighting of subsequent information.[2] This initial piece of information is the "anchor," and bias occurs when the decision maker fails to pivot off that piece of information when new facts are presented that contradict the initial information. Anchoring bias has several fascinating features. First, the anchor may be completely irrelevant to the decision at hand yet still influence decision making. Decision makers often fail to adjust off the anchor value sufficiently even when the anchor information is irrelevant. Second, the magnitude of the anchoring effect can be measured when tested in problems that require numerical solutions.

Anchoring bias is a common cause of misdiagnosis because clinicians fail to incorporate subsequent testing results into their decision making, particularly if that new information contradicts their initial impression.[13,14] We have observed several examples of anchoring bias in neurosurgery. The first example is in the initial workup of a patient transferred for neurosurgical evaluation from an emergency department or another hospital. Once the patient arrives at the neurosurgery service, the workup proceeds on the basis of the diagnosis rendered at the transferring hospital, even if the diagnosis is clearly incorrect. For instance, if incidental calcifications in the basal ganglia are misinterpreted as intracerebral hemorrhage (the stated reason for transfer from an affiliated hospital), unnecessary vascular imaging and magnetic resonance imaging are performed. Readers are encouraged to think of examples in their own practices.

A second example is anchoring during intraoperative decision making. In these cases, the original operative plan designed at the time of patient consultation serves as the anchor. Surgeons may fail to adjust the intraoperative strategy to suit intraoperative findings. A classic illustration of this situation is vertebral artery injury from the placement of a cervical lateral mass screw. Proceeding with the contralateral cervical screw placement even though doing so risks injuring the other vertebral artery is a form of anchoring. Another illustration occurs in brain tumor surgery. A surgeon may have a plan to perform a gross-total removal of a skull base meningioma. Intraoperatively, the surgeon notices that the tumor is firm, calcified, and adherent to neurovascular structures. Prudence dictates that the surgeon consider performing a subtotal resection instead, but the surgeon presses on with the original plan and causes a neurological deficit.

Confirmation

Confirmation bias is a powerful bias that is related to and can amplify anchoring. Confirmation bias describes our tendency to seek and interpret information that confirms previously held beliefs while dismissing information that challenges our initial impressions, even though contradictory information can help disprove our initial theory. Confirmation bias affects where surgeons search for and collect evidence: they seek evidence that confirms their prior beliefs and expectations. Confirmation bias also affects how surgeons interpret the evidence they receive. It leads them to give too much weight to supporting information and ignore or undervalue evidence that contradicts their beliefs. One example of confirmation bias in neurosurgery is our observation that surgeons tend to seek advice from surgeons who will likely agree with their proposed management plan when faced with a challenging patient management problem.

A second example of confirmation bias is the tendency of surgeons to cite literature that supports their impression and dismiss literature that does not support their treatment plan. Neurosurgeons may criticize studies that do not support their view as being "underpowered," "retrospective," or "flawed" in some fashion. However, the same neurosurgeons may often cite studies of similar quality to support their view.

Availability

Availability bias describes how we tend to make decisions based on past events that we can recall vividly. Events that come to mind easily (i.e., are "available") seem more common, more probable, and more important than events less available in memory. Individuals are biased toward recent, novel, and highly emotional events. This conditioning may be one of the mechanisms that underlies anchoring. Certain events, such as surgical complications, trigger strong emotions and are more easily recalled than routine successes. The most striking example of availability bias at work in neurosurgery is that surgeons may change their standard practice when they have one memorable complication even though they have performed that same operation many times without that complication, and their outcomes are excellent overall.

Framing

Framing bias describes the impact on decision making of how information is presented under risk. For example, are decisions framed as gains or losses? People's risk perceptions are different in the loss domain compared to the gain domain. In prospect theory, which seeks to understand behavioral decision making under risk, subjective value is modeled by a value function that is concave for gains and convex for losses. The curve is also steeper for losses than for gains, an observation called "loss aversion." Current behavioral theory suggests that we derive less psychological value from gains than we lose from losses, even though the sizes of the gains and losses are of similar magnitude (Fig. 1).[15,16] Stated another way, similarly sized losses and gains yield markedly different perceived changes in value.

Neurosurgery has several examples of framing bias. For instance, consider the content of the informed consent discussion before surgery. Surgeons may present the risk of complications as the risk of the event occurring or not occurring. In pituitary surgery, the risk of carotid artery injury could be presented as a 0.5% risk of occurring or a 99.5% chance of it not occurring, which may influence whether a patient opts for surgery.

Another feature of framing bias is that situational context matters. We have noted that certain differential diagnoses are more likely to be considered depending on the clinical context. For example, when evaluating a patient with low-back pain, surgeons may be more likely to consider a diagnosis of infectious discitis in the emergency department than in the clinic setting, where they are more likely to consider a diagnosis of arthritic low-back pain from degenerative disc disease.

Overconfidence

Kahneman has called overconfidence the most important cognitive bias because it is both pervasive and highly influential.[17] Although overconfidence is probably a requirement for being a neurosurgeon, it can profoundly influence decision making. This bias is characterized by the observation that people tend to think they are smarter

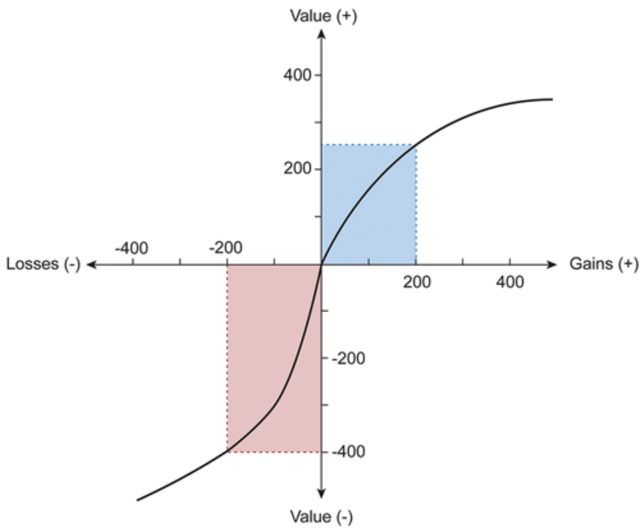

FIG. 1. Graphical illustration of the value function from prospect theory showing the change in perceived value for an incremental gain or loss. A similarly sized loss or gain yields a markedly different perceived change in value. For example, a medium-sized loss creates perceived significant destruction in value (*pink area*), whereas a medium-sized gain produces a perceived medium-sized increase in value (*blue area*). Figure is available in color online only.

and more talented than those around them, that their estimates are more accurate than those of others, and that they are above average in the context of their colleagues. Overconfidence bias is one of the major sources of diagnostic errors in medicine.[18,19] One example of overconfidence in surgeons is a false perception that "weaknesses and failures disproportionally affect their peers."[1]

We have observed overconfidence when a surgeon evaluates a patient who had prior spinal fusion surgery performed by another surgeon that resulted in a poor outcome. For example, an overconfident neurosurgeon may reason that the patient likely had either a technically flawed operation or suboptimal surgical strategy and that the patient would have had a better outcome had the overconfident neurosurgeon performed the surgery. However, patient-specific factors may have contributed to the poor outcome. Overconfidence has also been observed when surgeons decide to perform a procedure in which they have limited experience. They rely on their recollection of the one or few good outcomes they have had to justify the decision. Overconfidence is also revealed in commonly used aphorisms such as "I rely on my training" to justify performing the operation when referral to a higher-volume expert may be more appropriate.

Strategies to Limit Bias and Improve Surgical Decision Making

The techniques and strategies used to address cognitive biases and improve decision making are summarized in Table 1.

Improved Recognition of Cognitive Biases

The primary goal of this opinion piece is to raise awareness of cognitive bias in neurosurgery decision making. Sellier et al.[20] demonstrated that building awareness through debiasing training improves decision making. Strategies we employ to increase awareness of cognitive bias include educational sessions for residents and faculty and presentations at grand rounds. We hope that neurosurgeons will better understand how these hardwired mental shortcuts influence their judgments and in which circumstances these biases are particularly pervasive. Creating awareness allows neurosurgeons to recognize errors in judgment and employ strategies to improve decision making.

Build and Support Effective Teams

Effective teams can help improve decision making by limiting the effects of anchoring and confirmation biases. High-performing teams inspire creativity, facilitate information sharing, and optimize collective intelligence by harnessing the diverse skill sets of the members. The following foundational principles are associated with high-functioning teams: 1) Have team members work from evidence toward conclusions, rather than in the opposite direction (avoid confirmation bias). 2) Focus on the independent judgments of the team members rather than striving for consensus. 3) Appoint a devil's advocate to present contrary arguments (avoid confirmation bias). Effective teamwork behaviors, such as information sharing, are associated with improved patient outcomes from surgery.[21]

However, forming a team does not, in itself, necessarily address biases. Ineffective teams can amplify biases and produce extreme decisions. For example, the anchoring effect is observed in meetings when comments made early in a meeting tend to have more influence on the outcomes than suggestions made toward the end. Team leaders are especially likely to anchor, so they should let others speak first. Confirmation bias is also observed in poorly managed teams. For example, in *The Wisdom of Crowds*,[22] Surowiecki describes the powerful effect of confirmation bias on the Mission Management Team assembled to study the foam strike on the space shuttle *Columbia*'s left wing. The team started with the conclusion that the foam strike could not seriously damage the shuttle, rather than starting with the question of whether the foam strike could cause catastrophic damage. Teams should seek to widen options under consideration and test assumptions.

In neurosurgery, common treatment teams include tumor boards,[23] multidisciplinary spine teams,[24] skull base teams,[25] and cerebral aneurysm multidisciplinary teams.[26] The degree of interaction and care coordination are highly variable, so conclusions about the effectiveness of these teams are not possible. Advocates for the team approach emphasize the benefits of shared ideas, camaraderie, and improved patient and provider satisfaction. Blay and colleagues[27] have noted improved survival in sarcoma patients when using a multidisciplinary tumor board. In addition to having teams focused on a disease or condition, innumerable other teams are focused on healthcare delivery and administration.[28]

Physicians, often as leaders of healthcare teams, can guard against confirmation and anchoring bias by soliciting opinions from all team members (including the quiet,

TABLE 1. Examples of cognitive bias in neurosurgery decision making

Cognitive Bias	Definition	Neurosurgery Example	Techniques to Improve Decision Making
Anchoring	Decisions depend heavily on the 1st piece of information presented—the "anchor." Subsequent information is discounted	A surgeon does not change the operative plan in light of new intraoperative findings The physician does not consider alternative diagnoses when new information is revealed	Consider additional clinical information, especially when it challenges your initial impression Have a colleague review the patient's case w/o providing the anchor information Develop an awareness of the anchoring effect
Framing	How choices are presented can impact decisions; e.g., choices may be presented as gains or losses. Context impacts which options are contemplated	During informed consent discussions, surgeons may present the risk of a complication or the likelihood of the complication not occurring The care setting influences clinical decisions (i.e., a physician does not consider infectious discitis in a clinic setting but does in the emergency department)	Evaluate choices from a different perspective; i.e., reframe choices Be aware that clinical circumstances impact decision making
Confirmation	The tendency to look for & interpret information that confirms our beliefs & discard information contrary to our beliefs	A surgeon asks for advice on surgeries from partners who are likely to agree Clinicians order tests to confirm their initial impression rather than tests that challenge the diagnosis	Actively seek data & opinions that might challenge your viewpoint Appoint a devil's advocate in group settings Ask open questions that do not invite confirmation of evidence Hold multidisciplinary treatment conferences Employ decision-making support tools, such as risk calculators Employ machine learning techniques
Overconfidence	The tendency to think we are smarter & more talented than those around us, see ourselves as less biased than others, & consider our judgments & estimates as more accurate than theirs	Surgeons choose to operate on patients w/ conditions for which the surgeon is inexperienced or underqualified Surgeons perceive their colleagues as having flaws & being technically inferior to themselves Not using a standardized order set & instead relying on memory	Audit surgical outcomes Compare outcomes to national benchmarks, when available Refer patients w/ rare conditions to a high-volume surgical specialist Use checklists & standardized order sets
Availability	Events easily recalled from memory, such as novel events or those triggering strong emotions, tend to disproportionately impact decisions	A recent or dramatic surgical complication may cause changes in practice, even though overall surgical results are excellent	Recognize when surgeons are making hasty changes based on one recent complication Hunt for objective & less memorable information; rely on data when available

reserved members) and creating an environment where dissent is welcome. Team dynamics play an important role in decision making, where a few influential voices (or one) can disproportionally shape the course determined by the decisions made. The neurosurgeon, who is often one of the leaders of a clinical team, has an important role to play in limiting bias. The neurosurgeon can encourage open dialog, ensure that the objectives are clear, actively seek disconfirmatory opinions, and encourage contributions from all team members. To be sure, teams are not practical in all situations and can be inefficient decision-making bodies. However, a team approach should be considered for complex decisions when time is available to debate options.

Outcome Tracking

The promise of outcome tracking allows surgeons to compare their own results to those of established benchmarks as well as to those of their peers. As described above in the availability heuristic, surgeons may base judgments on vivid memories of certain patients. Those influential cases may color surgeons' perceptions of their results. Surgeons who track their outcomes have the opportunity to audit their results. By comparing their results to those of their peers, they can potentially limit availability bias and overconfidence. The disadvantages of manual outcome tracking in neurosurgery are the considerable efforts required for manual data entry, risk adjustment, and real-time analysis, and the absence of available outcome benchmarks for many neurosurgical conditions.[29]

Surgical Checklists and Standardized Pathways

Surgical checklists and standardized order sets have multiple benefits, including promoting high-functioning teams and addressing overconfidence bias.[30] Mazzocco et al.[21] demonstrated that a surgical checklist encouraged positive team behaviors and patient outcomes. Moreover, checklists mitigate overconfidence bias by reducing physicians' reliance on memory, thus avoiding material omissions in patient care orders.[31] At our center, length of stay and readmission rates in elective pituitary surgery have significantly decreased since we have implemented standardized care pathways incorporating best practices.[32]

Risk Calculators and Decision Aids

Surgical risk calculators help surgeons better quantify the particular risks of surgery for an individual patient rather than applying data from a group of patients whose specific characteristics may differ from those of the patient in question. In general surgery, Sacks and colleagues[33] demonstrated that, when presented with a series of standardized scenarios, a surgeon's perception of risk varied widely, suggesting an opportunity for a decision aid. These authors demonstrated, not surprisingly, that a surgeon's perception of risks strongly influenced the decision to operate. These findings led Sacks and colleagues to conclude that "considering these differences, surgeons appear, at least on average, to choose treatments that align with their expectations for which treatment optimizes the patient's utility by maximizing the benefits and minimizing the harms. What varies then is surgeons' judgment of the likelihood of the possible treatment outcomes."[33] In a follow-up study, Sacks et al.[34] found that using a surgical risk calculator influenced surgeon judgment and perception of risk. Interestingly, these authors noted that surgeons tended to overestimate the risk of surgery in all the case vignettes they tested.

Several neurosurgery risk calculators have been described. For example, Veeravagu et al.[35] analyzed a spinal risk assessment tool and found that it predicted which patients were more likely to have a surgical complication. Several authors have examined the American College of Surgeons National Surgical Quality Improvement Program universal surgical risk calculator in neurosurgery. Vaziri et al.[36] found that this risk assessment tool was a good predictor of mortality, but it did not predict other adverse events or clinical outcomes. One disadvantage of risk calculators as decision support tools is that input data must be entered manually, and inaccuracies can thus be introduced.[37]

Predictive Analytics and Artificial Intelligence

Predictive analytics describes the application of data science to support clinical decision making, such as risk stratifying patients before surgery, identifying patients at high risk for readmission, and predicting the likelihood of a favorable patient outcome. Data science uses vast amounts of data to draw data element associations that at first may seem implausible. These predictive models can be refined as more data become available. The use of artificial intelligence with livestreaming medical record data holds the promise of improving neurosurgical judgment by addressing some of the disadvantages of decision-making tools described above, such as laborious manual data entry.[1]

Conclusions

Cognitive biases affect neurosurgical decision making in profound ways. Surgeons use mental shortcuts that are amplified because of the high-stakes, high-stress nature of the profession. In this opinion paper, we have described several biases that may individually or in concert undermine sound reasoning. We presented observations from our practice and suggested strategies to mitigate the effect of cognitive biases on surgeon judgment. We encourage neurosurgeons to optimize their decision making by improving their recognition of biases and use of mitigation strategies to decrease the likelihood that biases will have adverse effects on patient care.

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Disclosures

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