REVIEW ARTICLE

Medical Error Avoidance in Intraoperative Neurophysiological Monitoring: The Communication Imperative

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Summary: Error avoidance in medicine follows similar rules that apply within the design and operation of other complex systems. The error-reduction concepts that best fit the conduct of testing during intraoperative neuromonitoring are forgiving design (reversibility of signal loss to avoid/prevent injury) and system redundancy (reduction of false reports by the multiplication of the error rate of tests independently assessing the same structure). However, error reduction in intraoperative neuromonitoring is complicated by the dichotomous roles (and biases) of the neurophysiologist (test recording and interpretation) and surgeon (intervention). This "interventional cascade" can be given as follows: test → interpretation → communication → intervention → outcome. Observational and controlled trials within operating rooms demonstrate that optimized communication, collaboration, and situational awareness result in fewer errors. Well-functioning operating room collaboration depends on familiarity and trust among colleagues. Checklists represent one method to initially enhance communication and avoid obvious errors. All intraoperative neuromonitoring supervisors should strive to use sufficient means to secure situational awareness and trusted communication/collaboration. Face-to-face audiovisual teleconnections may help repair deficiencies when a particular practice model disallows personal operating room availability. All supervising intraoperative neurophysiologists need to reject an insular or deferential or distant mindset.

Key Words: Intraoperative neuromonitoring, Medical error avoidance, Interprofessional communication.

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Human errors are definitionally under human control.[1] Formal human error analysis and scholarship began in an attempt to explain and address man-made catastrophes during the exponential growth of the nuclear and commercial airline industries of the 1970 to 1980s. The examples of Chernobyl (1986) and 3-mile island (1979) nuclear accidents… the 1977 runway collision of two 747 airliners at Tenerife killing 583 people are very frequently cited. Reduction of human error within the operation, management, maintenance, and, especially, the design of complex systems suddenly became obligatory. Two general human error–reduction concepts are pertinent to intraoperative neuromonitoring (IONM): (1) error forgiving design, that is, the possibility of reversibility of an "error" (signal loss after a surgical maneuver) to prevent catastrophic injury and (2) system redundancy, which at least partly explains the injury predictive power of multimodality IONM.[1] For example, in the latter case, conus medullaris monitoring modalities (MEP, H reflex, and BCR) each assess function of the conus medullaris motor neuron pool. Let's assume (for argument's sake) a false report probability $P = 0.1$ for each test and complete independence of each test for the function of interest (of course, not true!). A combined false report/error rate of $P \times P \times P = 0.001$ could be achieved. The fact that the three tests share a degree of neural and vascular codependency reduces the improved error rate but does not change the concept.[2,3]

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Within ideally redundant and forgiving technology, the social interactions and ease of communication among collaborating well-practiced experts may uniquely determine error rates and suggest means of error avoidance.[4–6] Early on, scholarship indicated that error reduction within complex systems (like an airliner or operating room [OR]) is advanced by expert (and some nonexpert) team members vocalizing their independent judgments.[1] Recent error-reduction literature emphasizes teamwork (team cohesion, collaboration, and communication) within the highest risk areas of hospitals.[7–9] Undue deference to hierarchy, habitual "politeness," or an unaccountable aloofness may give rise to an innocent misunderstanding and harmless error at best. At worst, dysfunctional communication may result in an otherwise preventable catastrophe.[10,11] In fact, the Joint Commission has identified dysfunctional communication as the leading cause (65%) of reported "sentinel events" (medical errors) from 1995 to 2004.[12–14]

This review will summarize what is generally understood by "error avoidance" among technically proficient colleagues within the OR, especially as applied to IONM. This review and commentary is intended for physicians, doctorate-level neurophysiologists, or others who interpret and communicate the results of IONM recordings.

BELIEF AND BIAS AMONG PEERS: SURGEON, ANESTHESIOLOGIST, NEUROPHYSIOLOGIST

An attending spine surgeon colleague has been overheard to instruct his fellows to never blurt, "Oops!" in the OR. Rather, only half-jokingly, he suggests the calming utterance, "There…"

Obviously, the idea is to preserve an intraoperative sense of decorum, routine, and control. Patient positioning is often co-managed by the surgeon and the anesthesiologist (although legal responsibility may be disputed).[15] Spine and neurosurgeons have largely (not entirely) off-loaded other routine responsibilities outside the surgical wound (anesthetic depth, blood volume/pressure, and oxygenation, for example) to the anesthesiologists. Within the wound, however, the surgeon exclusively owns the responsibility for the outcome of the operative approach and technique. Many wound-related intraoperative diagnostic tests (carotid backflow/sonography, soft tissue ultrasound, radiographic imaging, etc.) are performed, interpreted, and acted on by the surgeon in real time. The surgeon goes about the business of anatomic and physiologic de-/re-construction much as a master chess player or race car driver. Using years of training, learned/experience-driven intuition, and rules of thumb ("heuristics"), surgeons expect to achieve efficient and successful completion of the task. Interpretation of IONM data in a manner that conflicts with the surgeon's belief (expectation) may be perceived as a challenge to the surgeon's in-wound ownership. An unanticipated IONM alarm, in consequence, may create an annoying cognitive dissonance, which has the effect of transforming the surgeon's preferred "There…" to an "Oops!"

One of us has capsulized the dilemma as follows: "The idea of a different professional figure (namely a neurologist or clinical neurophysiologist) working hand in hand with the neurosurgeon in the operating room and advising him whether or not his surgical strategy was impairing the well-being of the nervous system was (and still is) something not readily acceptable to neurosurgeons."[16] This may be especially true when the surgeon first hears an alert from an unfamiliar IONM interpreter.

The surgeon's sense of wound ownership and confidence in heuristic/intuitive decision making is understandable, powerful, and usually correct. The anesthesiologist is often burdened by a similar set of learned and heuristic assumptions and beliefs. But that professional inertia or tunnel vision (cognitive bias) can create resistance when the surgeon (or anesthesiologist) is confronted by surprising data. After an alarm is given, the neurophysiologist's request/insistence that the surgeon "slow down" to consider the IONM body of knowledge and its associated probability structure competes with the surgeon's immediate ("fast") intuitive assessment. The vast literature studies on these ("fast" and "slow") modes of decision making have been eloquently summarized by Nobel laureate Daniel Kahneman.[17] Distracted by an unanticipated IONM alarm, for example, the surgeon may inwardly determine that the best in-wound option is to "keep doing what I am doing (what I have always done)" with the oft-heard response, "I haven't done anything (apart from what I have always done)"[16,18] (See Vignette). For their part, some IONM professionals may treat IONM as no more than a strictly dispassionate waveform interpretation during which meaningful relationships with their in room surgeon/anesthesiologist colleagues (or their mutual patient) are considered unnecessary.[19] Surgeon (and/or anesthesiologist) inertia and neurophysiologist insularity/deference sets the stage for dysfunctional communication. The opportunity to make a good decision may be squandered at the moment of an IONM alarm.

IONM COMMUNICATION AND THE INTERVENTIONAL CASCADE

So where does "communication" fit within the IONM paradigm? First, most of the time, the neurophysiologist's job is to actually confirm the surgeon's bias that all is well within the wound. That IONM contribution is valued because, in complex cases, the surgeon is encouraged to complete the case as intended. However, because an IONM-based intervention may be indicated, it is useful to consider the chain of events required to secure a good outcome. The diagnostic tests deployed during IONM conform to a generalized model of test–treatment pathways that affect the patient health.[20] For IONM, this model can be summarized as an interventional cascade: test → interpretation → communication → intervention → outcome.[18] With few exceptions, surgeons are imperfectly fluent with the clinical neurophysiology body of knowledge (tests and their interpretation). Neurophysiologists do not independently execute an intraoperative intervention. Therefore, in the event of signal loss, effective neurophysiologist initiated communication is crucial to the surgeon's decision to alter the course of surgery in an attempt to reverse signal loss.[21]

Vincent Covello and colleagues have laid the philosophical and practical foundation for effective communication in the midst of high-risk events.[22] It may be useful to consider how the neurophysiologist's "public" (the surgeon) may respond to high-risk communication. Pertinent to IONM, the components of high-risk communication include risk perception and trust.[23] The problem of risk perception is related to Kahneman's work on decision making. The "fast" thinking system makes decisions based on experience-driven intuition; the "slow" thinking system takes into account new evidence or, especially, rationally assessed probability data. Slovic, citing the work of behavioral neurologist Antonio Damasio, makes this compelling point: "Sophisticated studies by neuroscientists have demonstrated that logical argument and analytic reasoning ('slow' thinking) cannot be effective unless it is guided by emotion and affect ('fast' thinking). Rational decision making requires proper integration of both modes of thought."[24] Therefore, and not surprisingly, the surgeon's perception of risk and willingness to alter the course of surgery may depend on both intellect and emotion. This is where trust enters. "The need to establish trust…is fundamental to the effectiveness of risk communication messages and strategies. However, trust determination theory maintains that when people are upset they commonly do not trust authority. *Trust, therefore, must be established well in advance of an actual crisis event*."[23] Covello has captured this idea with the apothegm: "They want to know that you care before they care what you know."[25,26]

Implicit in the interventional cascade schema is scholarship showing that diagnostic test accuracy/prediction (within the neurophysiologist's control) may be an insufficient basis for clinical effectiveness.[20,27] Therefore, trust-based neurophysiologist-led communication becomes an essential link within the IONM interventional cascade. Open, unapologetic, and trusted communication sets the conditions for the possibility of favorable clinical outcomes after an IONM alert.

CRITICAL LANGUAGE AND SITUATIONAL AWARENESS: AIRLINERS AND ORs

Dysfunctional communication and faulty group dynamics can be exampled by the haunting winter's day recording of an Air Florida pilot and first officer exchange. An ice encased sensor caused a false air speed reading. Insufficient power was applied by the captain at take-off from what is now Reagan National Airport:

First Officer: Ah, that's not right.

Captain: Yes, it is, there's 80 [the displayed speed].

First Officer: Nah, I don't think it's right. Ah, maybe it is.

Captain: Hundred and twenty.

First Officer: I don't know.

The first officer's muted unease and final deference to the captain resulted in the aircraft stalling. The crash into a Potomac River bridge killed 69 airliner occupants and four motorists.[28] When studies began to indicate that most airline accidents resulted from failed communication and decision making among flight crews (rather than technical/mechanical failures), the commercial aviation industry responded by "flattening" crew hierarchies.[4] Flight captains and crews were encouraged to communicate among each other with diminished regard for the crew member's "rank." In the last 35 years, the initial success of "Crew Resource Management" in aviation has evolved to a globally required training program to foster flight crew teamwork, safety, and performance.[29]

Medicine faced a similar turning point when the Institute of Medicine reported that medical errors accounted for 44,000 to 98,000 annual deaths in the United States.[30] Many of these deaths were attributed to "systems failures" similar to those previously discovered within the airline industry. Ineffective communication schemes among members of the treatment team, in particular, may account for twice as many errors as inadequate or incompetent care.[5,31] In reaction, a less steeply vertical ("flattened") communication and decision-making hierarchy has been recommended in many modern patient care settings.[32–34]

Within a less steep medical hierarchy, two critical "tools and behaviors" may generate better outcomes: Critical language and situational awareness.[14] Unequivocal, attention-getting speech typifies Critical language. It is the opposite of indirect or deferential speech. Anyone involved in patient care (including within the OR) should be empowered to use critical language. Safety programs at United Airlines, for example, teach this formulation: "I'm concerned, I'm uncomfortable…this is unsafe." The prerequisite understanding that each crew member (patient caregiver) is empowered "to get everyone to stop and listen" promotes a safer environment. In general medicine, situational awareness has been defined as a "… dialogue, which keeps members of the team up to date with what is happening and how they will respond if the situation changes…a key factor in safety."[14] In IONM, this crucial ongoing "dialogue" between the monitoring team and the surgeon is ideally linked to specific knowledge of in-wound events, which may be best communicated visually rather than verbally.[35,36] When a threatening context/situation is temporally wedded to an IONM alert, causation is more likely inferred and a more urgent and pertinent communication is justified.[37–39]

Disparate disciplines (anthropology, the humanities, and rhetoric) have studied physician–physician communication. It is evident from such studies that "talk among physicians… is essential in the negotiation of professional relationships, the distribution of responsibility, the inducement of cooperation, and the assessment of competence." Such peer interaction ("talk") must be as "substantive and direct as possible" to generate the best outcome.[40] In direct communication, physicians are present together: "The full range of communication channels—including facial expression, posture, gesture, smell, proximity, and eye contact—is available to participants to help interpret and 'make sense' of the information being exchanged."[5,41] Communication by indirect means (telephone or e-mail, for example) reduces the "information channels." Each consultant must speculate about the "intent and motivation", seriousness and urgency of their patient care colleagues. Critical language is jeopardized. "… The current weaknesses in communication in the OR may derive from a lack of standardization and team integration. Team members in the OR do not commonly convene to discuss key issues before a case, decisions are often made without all relevant team members present, and much communication is consequently reactive and tension provoking."[42] In fact, poor communication among intraoperative team members has been cited as a "primary trigger" for malpractice claims.[43]

ElBardissi and Sundt[12] have attempted to address OR safety through the use of a specific model: Systems Engineering Initiative to Patient Safety. Similar to other training methods (Crew Resource Management, for example), the model's methods prominently include "teamwork and communication." This emphasis bears on data (in aviation and the OR) that superb individual practitioner skill guarantees neither optimal error avoidance nor satisfactory patient outcomes. Specifically, ElBardissi and Sundt showed that "teamwork factors" accounted for 45% of errors during cardiac cases. The group cites "miscommunication" and "lack of team familiarity" as prominent factors.[44] Lingard reported 129 communication "failures" during 48 procedures and 90 hours of observation.[42] Thirty-six percent of failures resulted in easily identifiable effects on system processes, including "team tension, resource waste, workaround, and procedural errors." After review of their work and others, ElBardissi and Sundt have advanced some possibilities for improving team collaboration and communication: team training, standardized communication, preoperative briefings, and team familiarity.[12,42,45,46]

Studies have reported that OR teams routinely matched together and familiar with each other (compared with less familiar teams) suffer significantly fewer "surgical flow disruptions" and the surgeons make significantly fewer surgical errors per case.[47,48] In the setting of laparoscopic cholecystectomy and carotid endarterectomy operations, a single-institution uncontrolled before–after study of the effects of Crew Resource Management training revealed: operative technical errors declined from 1.73 to 0.98 ($P = 0.009$) and nonoperative technical errors from 8.48 to 5.16 per operation ($P = 0.001$) after training.[7] The Veterans Health Administration (VHA) has reported the interventional effects of their formalized medical team training program for OR personnel. After the trained and nontrained groups were propensity matched, the risk adjusted surgical mortality rate was approximately 50% reduced in the trained group ($P = 0.01$). Also, a dose response correlation to surgical mortality was seen. For every additional team training quarter, a reduction of 0.5 deaths per 1,000 procedures occurred ($P = 0.001$).[49] Finally, a recently published systematic review of OR cultural domains (teamwork, communication, and safety) reported that introduction of cultural training led to improvements in at least one of the studied domains. Two studies, which looked at clinical effectiveness, suggested improved patient outcomes (reduced postoperative complications/ mortality). The authors conclude, "(Operating room) culture improvement appears to be associated with other positive effects, including better patient outcomes."[8]

CAPTAINS, CREWS, AND CHECKLISTS

The surgeon is often cited as the "captain of the (operating room) ship." Although this concept has been challenged, acceptance of this probably appropriate hierarchical formulation need not compromise patient safety. It may be possible to adjust and amend a surgeon's/"captain's" strong cognitive bias to "keep doing what I am doing (what I have always done)" after an IONM alert[50] (See Vignette). Using the Systems Engineering Initiative to Patient Safety model, ElBardissi and Sundt have captured the essentials of a surgeon mindset best suited to error avoidance: cognitive flexibility, adaptability, and resiliency. And, very apropos an IONM alert: "Cognitive flexibility refers to the ability to consider multiple (alternate) hypotheses when attempting to generate potential causes of a patient's unstable condition. Cognitive adaptability is also an important factor that can affect problem solving during surgical cases. For example, threats to patient safety decrease when surgeons are able to change their technique or strategy in light of unexpected patient anatomy, disruptions to surgical flow, or other unanticipated changes in work system events."[12] This cognitive adaptability fits well with the psychological formulations of Kahneman, Slovic, and Covello: we would like surgeons to integrate "slow" evidential, probabilistic thinking into their "fast" intuitive/heuristic decision-making during high-risk communications. Trusted neurophysiologists can help to effect this change before and during IONM.

The published arguments suggesting an ethos of elaborated collegial communication and collaboration within high-stakes patient care settings are increasingly conclusive and inescapable. Within the IONM "interventional cascade" paradigm, the interpreting neurophysiologist (crew member) executes accurate tests, and, in the event of an alarm, communicates the results with sufficient cogency, urgency, and passion so that an alteration of the anesthetic or surgical plan is seriously considered. The literature strongly suggests that this critical language more reliably occurs within OR teams (crews) that are familiar with each other and have formed trusting relationships. The ElBardissi and Sundt group often refer to "stable" and "familiar" intraoperative teams. However, we can easily link back to the role of trust in risk communication scholarship when the group sums up: "In stable teams, *trust* develops among team members."[12,22,48]

In recognition of intraoperative stress and time pressure, there is evidence that checklists may reduce errors by assuring open lines of communication and enhance situational awareness by requiring team member acknowledgment/agreement on crucial decisions and events.[51,52] A group of spine surgeons and one neurologist/neurophysiologist have, therefore, created a checklist for IONM during deformity correction of the "stable spine."[53] The checklist contains much to recommend it. In the event of an alarm: (1) a formal pause in the case is enforced (2) personnel and equipment needs are optimized, and (3) an orderly, coordinated, and standardized approach is followed. Embedded within the checklist is a call to "summon" the "senior neurologist or neurophysiologist" in the event of an IONM alarm. Because all or nearly all the surgeon authors work in major teaching hospitals around the United States, each very likely enjoys routine access to a trusted neurologist/neurophysiologist colleague who can actually be summoned to their OR. This advantage is far from universally available throughout the United States, where offsite IONM supervision is not uncommon.

CHALLENGES TO EFFECTIVE IONM PRACTICE WITHIN THE OR TEAM

The Vitale IONM checklist forms the infrastructure for collaboration among expert peers: a surgeon/anesthesiologist/neurophysiologist copractice. Nevertheless, the issue of communication and trust in IONM is complicated by the diverse models of IONM care delivery. In the variety of settings worldwide, the neuromonitorist is not necessarily a physician or PhD level neurophysiologist. Unsupervised (or surgeon supervised) IONM technologists or others (even vendor representatives) may be expected or obligated to fill the role of the "responsible neuromonitorist." Surgeon-directed neuromonitoring devices are available. These are mainly geared to mapping techniques (pedicle screw testing, for example). However, naive application of these devices during complex multimodality neuromonitoring may invite disaster.[54–56]

In the United States, baseline and intraoperative data are commonly (but certainly not always) recorded by a certified technologist, who is supervised by either an in-house or offsite physician. It is not uncommon for technologists, especially those who are well known and respected by the surgeon, to effectively communicate the supervising neurophysiologist's interpretation of results. However, technologists generally "lack the medical knowledge to advise the surgeon about clinical options when changes do occur."[57] Some alerts demanding urgent action may be initially unacknowledged or dismissed by the surgeon. At that point, the supervising neurophysiologist, irrespective of location, should be prepared to engage the surgeon in a discussion of the applicable body of knowledge and probability analysis to secure an intervention (if possible) and the best outcome (See Vignette).

We now have evidence that unimpeded OR team communication and situational awareness deliver better patient outcomes.[7,49] Intercollegial collaboration may be compromised when the supervising professional, perhaps overseeing several cases, is offsite. Despite good intentions in the current practice environment, the offsite IONM professional may be frustrated by barriers to critical medical information, inadequate bandwidth, the burden of multiple case supervision, and technology insufficient to the necessity for situational awareness and collaboration.

Thirty years ago, the offsite model of IONM enjoyed a modest beginning.[58] Initially, "The system was developed to support intraoperative neurophysiological monitoring for a large health center and the surrounding medical community (which looks to the center for consultation)."[59] The original vision also included robust audio and video connections that permitted views of the wound ordinarily available only to the surgeon.[35] The actualization of situational awareness and the possibility of collaboration between the neurophysiologist and surgeon were emphasized ("collaboration" appears seven times in this seminal publication). Senior author Robert Sclabassi and the group also commented on questions that remain pertinent today…like the meaning of telepresence:

> The term "telepresence" does not yet have a firm definition, and people use it in different ways. There is a need for a word to precisely denote remote human presence, as opposed to virtual reality or remote shared task space. It is in the sense of human presence that we use telepresence. Used in this way, telepresence resonates with terms in common usage such as "social presence," "stage presence" and simply "presence." *Webster's defines the latter as "a quality of poise and effectiveness that enables a performer to achieve a close relationship with his audience," which is very much like what we are trying to achieve via technology for remotely located participants*.[35]

However, offsite neuromonitoring rapidly increased in an environment of (1) relative scarcity of trained/credentialed IONM professionals when demand was great, (2) an almost unbounded web-based connectivity and (3) equipment that initially limited the available data streams to waveforms only. Unfortunately, the anticipated culture of intraoperative collaboration between providers was left undone. Therefore, the resulting insular and/or deferential posture of "distanced" supervising neurophysiologists must be held unsurprising, or even expected given circumstances.

Two of us were among the co-authors of "Practice guidelines for the supervising professional: IONM."[60] The IONM supervision guidelines also help create the basis for copractice by emphasizing an ethos of patient-centered care. IONM supervising neurophysiologists are encouraged to preoperatively make themselves known to patients (personally or by e-mail/website), actively collaborate with their intraoperative colleagues, and begin the attempt to establish better situational awareness through audiovisual intraoperative connectivity for offsite practitioners. In retrospect, the guideline is not nearly strong enough on the last point. Since 2010 to 2013, when the guideline was being written, the literature on intraoperative collaboration and situational awareness to reduce errors and improve intraoperative outcomes has become increasingly abundant and compelling.[7,8,48,49] In addition, randomized trials in tele-stroke suggest that the offsite communication imbalance among physicians and staff can be significantly repaired by face-to-face audiovisual teleconnections.[61–65] A future IONM guideline revision should reflect these lines of evidence.

The challenge for health care systems, hospitals, equipment manufacturers, and IONM practitioners is to provide the tools necessary to establish truly collaborative error-avoiding teams during IONM. And… do this while improving IONM value (quality/cost).

SUMMARY

The scholarship on medical error avoidance consistently emphasizes a central theme: open communication. Given technical proficiency of an intraoperative team (including IONM), medical error avoidance is strongly dependent on critical language, collaboration, and situational awareness. Increasing evidence suggests that surgical outcomes depend on these nontechnical factors. Training programs (Crew Resource Management, for example) are available to hospitals to improve communication and reduce medical errors. Checklists may help. Flexible, adaptable surgeons will make the best decisions when confronted with unexpected events. Supervising intraoperative neurophysiologists need to reject an insular or deferential or distant mindset. Rather, they should become familiar and trusted colleagues of the anesthesiologist and surgeon.

Appendix 1.

Vignette: Conflict, Resolution, and Trust

How Cognitive Bias and Heuristics May Confound Decisions in the OR?

Case 1: A well-credentialed neurophysiologist (N) very recently joined the staff of an academic hospital known for its orthopedic spine surgery excellence. During case 1 (adolescent idiopathic scoliosis), N's young technologist reported several consecutive MEP results below the surgeon-preferred alert level (>50% amplitude reduction). Anesthetic and perfusion conditions were ideal. The surgeon (S), an internationally recognized spine surgeon, questioned the alert because "no correction yet." N and S engage in a brief, tense discussion of possible pathophysiology, troubleshooting needs, and likelihood data using this very sensitive alert criterion. BP and blood volume were optimized; no in-wound changes were made. The MEP remained just below 50% of baseline amplitude level through wound closure. Postoperatively, the patient was intact.

Case 2: It is one week later. N monitors a cervical laminoplasty for S. Preoperatively, the patient complains of "numb" hands and a "wobbly" gait. After prep/drape and just before muscle relaxant and posterior exposure, N's technologist reports >90% loss of "hands and feet" MEP and >50% amplitude loss of the bilateral tibial SEP scalp potential. S, regarding the technologist doubtfully, summons N.

What Are the Heuristics and Cognitive Biases That May Interfere With the Best Decision in These Cases?

Case 1

Decision/alert criterion bias: In signal detection theory, the observer of test results decides the alert criterion. The cognitive bias of S is to identify all reasonable positive results to never miss a catastrophic spinal cord injury. The selection of a very sensitive alert criterion implies the acceptance of excess false-positive reports, something S may not acknowledge despite N's explanations. Note: N is also susceptible to and should be aware of this bias.

Case 2

Availability heuristic: The recent case of one week ago comes more easily to mind than other less well remembered cases. The recent "false report" may receive undue weight at the moment of decision.

Similarity heuristic: The similarity (representativeness) heuristic could as easily occur if the recalled "false report" had arisen from an inaccurate radiologic spine marking… In the view of S, "similar" false reports from any source "represent" the fact that experts he relies upon may mislead him.

Affect heuristic: An emotional reaction, rather than a risk and benefit analysis, may color or determine the decision.

Confirmation/expectation bias: The tendency to interpret data (especially experimental) in a way that affirms preconceived notions. As far as S can recall, an IONM alert at this early stage of a laminoplasty has never happened before and should not happen now. There is a tendency to disbelieve or downgrade data that conflicts with "normal" expectations.

Avoidance of a medical error: *S takes a deep breath. N carefully explains the high likelihood of an incipient catastrophic spinal cord injury here (as opposed to the last case). Together, as a team, S and N conclude that the signal loss must be malpositioning. After adjustment of the patient's head/neck alignment, MEP and SEP return to baseline and remain robust. Postoperatively, the patient is intact. S asks N to present both cases at the next ortho-spine M&M conference.

*Kahneman would refer to this moment as "slowed down" thinking, permitting probabilistic notions to ultimately direct decision making; ElBardissi and Sundt use the terms cognitive flexibility, adaptability, and resiliency.

Vignette: A problem common to heuristics is the neglect of probability of competing alternatives; that is, improperly judging all alternatives as equally likely when making a decision under conditions of uncertainty.[12,17,41,66–72]

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