Diagnostic Error in Surgery and Surgical Services

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"You're on the Island of Conclusions."
"But how did we get here?" asked Milo.
"You jumped, of course," explained Canby. "That's the way most everyone gets here. It's really quite simple: every time you decide something without having a good reason, you jump to Conclusions whether you like it or not. It's such an easy trip to make that I've been here hundreds of times."
"But this is such an unpleasant looking place," Milo remarked.
"Yes, that's true," admitted Canby; "it does look much better from a distance."

—From *The Phantom Tollbooth*, by Norton Juster

Introduction

The surgical environment contains abundant opportunities for adverse events, and patients under surgical care are at risk for harm. The monitoring of surgical safety has focused almost exclusively on treatment-related concerns, especially on complications of surgery. Diagnostic errors have received little attention. Coincident with the growing awareness about the importance of diagnostic error in general and the recently issued report from the Institute of Medicine on *Improving Diagnosis in Health Care* [1], it is appropriate to consider what is known about diagnostic error in surgery, while acknowledging that the vast majority of knowledge in this domain has evolved from internal medicine and emergency medicine.

There are currently four definitions of diagnostic error (Table 25.1) [5], some of which are based on diagnosis as the noun (the label we give to an illness), some of which are based on diagnosis as the verb (the process of arriving at the label), and the most recent, IOM definition, "The failure to establish an accurate and timely explanation of the patient's health problem(s) or to communicate that explanation to the patient," which involves both. These definitions are complementary, and the choice of which one to use depends on the purpose and the audience being addressed. There are no specific definitions of diagnostic errors in surgery, but in the surgical context the concept of diagnosis extends to all of the decisions and choices made before, during, and after surgery. These all involve clinical reasoning, and will all entail a risk of error.

The IOM report provides a comprehensive review of diagnostic error that summarizes the

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Box 25.1. A case study of diagnostic error in surgery [1]

Pat, a 43-year-old male in good health, experienced progressively severe neck pain, and a scan showed a mass on his cervical spine. While removing the mass, the neurosurgeon sent a tissue sample to a hospital pathologist, who examined the sample and called back to the operating room to report that it was an atypical spindle cell neoplasm. Assuming that this meant a benign mass, the surgical team completed the operation and declared Pat cured. Following the operation, however, the hospital pathologist performed additional stains and examinations of Pat's tissue, eventually determining that the tumor was actually a malignant synovial cell sarcoma. Twenty-one days after the surgery, the pathologist's final report of a malignant tumor was sent to the neurosurgeon's office, but it was somehow lost, misplaced, or filed without the neurosurgeon seeing it. The revised diagnosis of malignancy was not communicated to Pat or to his referring clinician. Six months later, when his neck pain recurred, Pat returned to his neurosurgeon. A scan revealed a recurrent mass that had invaded his spinal column. This mass was removed and diagnosed to be a recurrent invasive malignant synovial cell sarcoma. Despite seven additional operations and numerous rounds of chemotherapy and radiation, Pat died 2 years later at age 45 years with a 4-year-old daughter and a 6-year-old son.

available literature through 2015 and presents a series of eight recommendations for improving diagnostic performance [1]. In addition to providing the new definition of error, the report provides a helpful framework for understanding and discussing the diagnostic process (Fig. 25.1). The power of describing diagnosis as a process, using the structure-process-outcome model of Avedis Donabedian, is that healthcare organizations and departments of surgery are familiar with process improvement, opening the door for applying these same approaches to improving surgical diagnosis and outcomes [6]. Many "surgical" errors involve the very first step—timely access to surgical care. Delays in referring patients who could benefit from surgical evaluation and interventions are common in many conditions, ranging from cataracts to cancer-related surgery to aortic dissection, to name a few. For some conditions, these delays can be catastrophic: in aortic dissection, delays between presentation and diagnosis and, once diagnosed, definitive treatment leads to dramatic increase in adverse outcomes [7].

Table 25.1 Four definitions of diagnostic error

Definitions of diagnostic error	
Author	Definition
Mark Graber	Medical diagnoses that are wrong, missed, or delayed [2]
	A diagnosis that was unintentionally delayed (sufficient information was available earlier), wrong (another diagnosis was made before the correct one), or missed (no diagnosis was ever made), as judged from the eventual appreciation of more definitive information (LABEL)
Hardeep Singh	A breakdown in the diagnostic process and a missed opportunity to have made the diagnosis more accurately or more efficiently…regardless of whether there was patient harm [3] (PROCESS)
Gordon Schiff et al.	Any mistake or failure in the diagnostic process leading to a misdiagnosis, a missed diagnosis, or a delayed diagnosis. This could include any failure in timely access to care; elicitation or interpretation of symptoms, signs, or laboratory results; formulation and weighing of differential diagnosis; and timely follow-up and specialty referral or evaluation [4] (PROCESS)
Institute of Medicine	The failure to establish an accurate and timely explanation of the patient's health problem(s) or to communicate that explanation to the patient [1] (LABEL AND PROCESS)

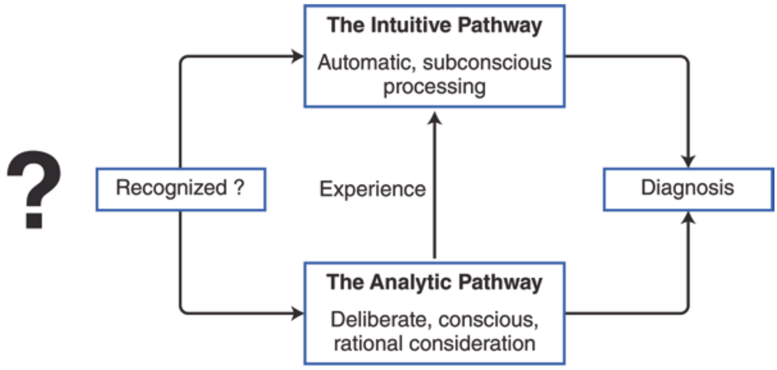

Fig. 25.1 The dual process paradigm of decision-making. Modified from Ref. [1]

The Incidence of Diagnostic Error in Surgery

Diagnostic errors are extremely common; one in every ten diagnoses is probably wrong [8]. Fortunately, the vast majority of diagnostic errors are inconsequential; the original problem resolves, the error is caught in time, the patient is resilient, or the treatment that was provided worked anyway. For some fraction of patients, however, the error results in harm and death. One estimate places the annual toll of diagnostic error in the USA at 40,000–80,000 deaths per year [9]. When timely surgical intervention is critical, misdiagnosing conditions such as spinal cord compression, necrotizing fasciitis, acute myocardial infarction, among many others, is lethal. The decision whether to operate on patients in whom these diagnoses are being considered is also a diagnostic decision, and the pressure and angst inherent in these situations is substantial and undeniable [10].

Data compiled from malpractice claims have clarified the relative incidence of surgical errors and what conditions are most commonly encountered. Diagnostic errors are the number one or two categories of claims in all of these studies. More than half of the diagnostic errors originate in ambulatory settings. In one recent study of 2531 cases of diagnostic error in ambulatory settings, 17 % were surgery related, with orthopedics, urology, and general surgery being the leading categories [11]. Most of these cases involved patients with cancer, cardiovascular conditions, and various injuries, especially orthopedic injuries. In another study, of 7438 closed claims from 2007 to 2013, 1877 were attributed to diagnostic error [12]. Of the 3963 claims involving surgeons, 524 were related to issues in diagnosis. The top five claims in each specialty are noted in Table 25.2.

While data from filed claims can help determine the relative distribution of surgery-related cases, the true incidence of diagnostic error in surgery is not known because the number of cases with good outcomes is large and not precisely known. A similar situation is encountered in internal medicine and emergency medicine—the actual incidence of diagnostic error is not known, and at the present time, no organizations report rates of diagnostic errors [13, 14]. This reflects primarily the difficulty in identifying diagnostic errors, but also the challenges physicians encounter in coming to an agreement on what comprises an error, as opposed to the normal evolution of a diagnosis over time, or the normal variability from one physician to another in diagnostic evaluation. Although healthcare has focused on patient safety for almost two decades, diagnostic errors have received relatively little attention. This has reflected cultural attitudes discouraging discussion of misdiagnosis, the challenges in finding and defining these errors, assumptions about the impracticality of potential process or outcome measures of diagnostic quality, and the belief that diagnostic errors are less amenable than

Table 25.2 The most common conditions leading to claims involving diagnostic error [12]

General surgery claims (855)		Gynecological claims (674)	
16 % Diagnosis-related (143)		15 % Diagnosis-related (98)	
15.4 %	Puncture/laceration during procedure	21.4 %	Breast CA
9.8 %	Breast CA	12.2 %	Puncture/laceration during procedure
8.4 %	Post-op infection	9.2 %	Uterine CA
6.3 %	Colorectal CA	7.1 %	Cervical CA
4.2 %	Appendicitis	5.1 %	Ectopic pregnancy
Orthopedic claims (1647)		Obstetrics claims (757)	
13 % Diagnosis-related (215)		9 % Diagnosis-related	
11.2 %	Post-op infections	17.6 %	Ectopic pregnancy
5.6 %	Bone/soft tissue CA	7.4 %	Postpartum hemorrhage
4.2 %	Compartment syndrome	4.4 %	Puncture/laceration during procedure
3.3 %	Fracture malunion	4.4 %	Appendicitis
2.3 %	Pulmonary embolism	2.9 %	Pulmonary embolism

other types of medical errors to systems-level solutions [15, 16].

Although real-time data is lacking, there is a wealth of research data that suggests diagnostic errors are quite common [8]. In internal medicine, one in every ten diagnoses is believed to be wrong, based primarily on studies involving standardized patients with classic presentations in real-world settings. A recent study using chart reviews found that one in every 20 ambulatory care patients will experience a diagnostic error every year [17]. Autopsy studies consistently show major discrepancy rates (discrepancies with a high likelihood to have changed management and treatment) in the range of 10–30 % [18, 19]. In programs providing second opinions, the likely diagnosis changes for one in seven patients, and treatment recommendations change for one in three patients [20]. The surgical specialties differ greatly, however, in how often the second opinion differs from the first. In terms of treatment recommendations, changes are less frequent in surgical oncology (19 %) and urology (28 %), and are more frequent in neurosurgery (42 %) and obstetrics (42 %) [20]. Finally, retrospective collections of cases are available for many conditions, and invariably report either bad or shocking statistics on diagnostic accuracy and timeliness. Several examples relevant to surgical care are listed in Table 25.3.

Table 25.3 Examples of case studies of specific surgical conditions and their findings relating to diagnostic accuracy and timeliness

Appendicitis	Graff et al. (2000) [21]	Retrospective study at 12 hospitals. Of 1026 patients who had surgery for suspected appendicitis, 110 patients had no appendicitis at surgery; Of 916 patients with a diagnosis of appendicitis, the diagnosis was missed or wrong in 170 (18.6 %)
Subarachnoid hemorrhage	Kowalski et al. (2004) [22]	Of 482 patients with subarrachnoid hemorrhage, the diagnosis was initially wrong in 56 (12 %) and 22 of these patients suffered neurological complications before the diagnosis was confirmed
	Edlow (2005) [23]	Review of published studies: approximately 30 % are misdiagnosed at presentation

(continued)

Table 25.3 (continued)

Ruptured aortic aneurysm	von Kodolitsch et al. [24]	In patients presenting with chest pain due to dissections of the proximal aorta, the diagnosis was missed in 35 %
	Lederle et al. (1994) [25]	Review of all cases at a single medical center over a 7-year period. Of 23 abdominal aortic dissections, the diagnosis was initially missed in 14 (61 %)
Gastric cancer	Mikulin and Hardcastle [26]	Of 83 patients with gastric cancer, the median delay in diagnosis was 7 weeks
Oral Cancer	Schnetler [27]	Of 96 cases seen in three oral surgery departments, the referring general practitioner had made the correct diagnosis in only 52 %
Breast cancer	Beam et al. (1996) [28]	50 accredited centers reviewed blinded mammograms of 79 women, 45 of whom had breast cancer. The diagnosis would have been missed in 21 %
Cancer detection	Burton et al. (1998) [29]	Autopsy study at a single hospital: Of 250 malignancies, 111 were either missed or misdiagnosed, and in 57 cases the cause of death was cancer related
Breast cancer	Burgess et al. (1998) [30]	Of 132 patients with breast cancer, referral for definitive management was delayed in 32 (17 %)
Tongue cancer	Kantola et al. (2001) [31]	Of 75 cases, referral to specialty care was delayed in 35 %
Cancer-related spinal cord compression	Levack et al. (2002) [32]	Of 319 patients, the median delay in diagnosis was 18 days
Bone cancer	Goyal et al. (2004) [33]	Of 103 patients with osteosarcoma or Ewing's sarcoma, delayed diagnosis was associated with being seen by a general practitioner (vs. ER physician) and in patients under 12 years of age
Testicular cancer	Vasudev et al. (2004) [34]	Of 180 men with testicular cancer, referral to specialty care was delayed in 60 %

(continued)

The Etiology of Diagnostic Error in Surgery

Diagnostic errors in surgical patients evolve from the same set of cognitive- and system-related factors as in other clinical settings. A very small fraction of errors derives from patient-related factors, for example patients with Munchausen's syndrome who feign symptoms [35], or patients who choose not to undergo diagnostic tests that were recommended or attend follow-up appointments. Most errors, however, reflect shortcomings of the clinician's cognitive processes, in the face of one or more breakdowns in the systems of care [2].

Cognitive errors involve one of three problems:

1. *A knowledge deficit*. For example, the physician does not know or recognize the disease at hand. There are over 8000 diseases listed in the National Library of Medicine's MESH catalogue, and over 100 new diseases are entered every year.

2. *A problem collecting or interpreting diagnostic data*. For example, the physician fails to appreciate the auscultatory findings of a pneumothorax, or doesn't recognize that a patient's hyperkalemia is from hemolysis, noted at the bottom of the laboratory slip.
3. *An error in "putting it all together," synthesizing the facts at hand* with the physician's knowledge base to arrive at the correct diagnosis or differential diagnosis. This is the process of clinical reasoning.

There is no data on the relative frequency of these error types in surgery, but in internal medicine, the vast majority of cognitive errors are in the third category, which entails synthesizing the available information [2]. The current paradigm of clinical reasoning involves the use of two very different cognitive pathways [36] (Fig. 25.2). Except for early trainees, most new problems are recognized immediately, and using a subconscious, intuitive pathway, the diagnosis is evident within milliseconds. If the problem is not recognized, we resort to deliberate, rational consideration of the situation, a process that takes longer and involves cognitive "work." Humans and probably all animals have evolved to take advantage of the intuitive pathway whenever we can, and indeed almost all everyday actions and thoughts derive from this system. In practice, both systems may come into play in diagnosing a new patient problem, and in theory, the rational system has the opportunity and responsibility to be constantly monitoring intuitive processing. If some discrepancy is noted or something just "doesn't fit," the rational pathway takes over and we sense the need to slow down, or look for additional data or input to affirm our hunches or heuristics. If there are no such flags, we assume our assessment is correct and proceed. Unfortunately, the "feeling of right" in these situations is exactly the same whether our diagnosis is correct or not, until that unpleasant point that we realize that the diagnosis may be wrong [37]. Physicians, like all decision-makers, are generally not accurate in predicting which of our diagnoses are correct or not, a problem of calibration [38–40].

Both systems are error prone but for different reasons. The *rational pathway* for understanding a clinical dilemma in surgery can be degraded by insufficient knowledge or experience, or by flaws in logical thinking, or reasoning. *Intuitive decision-making* can be degraded by a large range of innate cognitive "biases," of which over 150 have been described, (See Wikepedia's ever expanding "List of Cognitive Bias") and commonly encountered examples are shown in

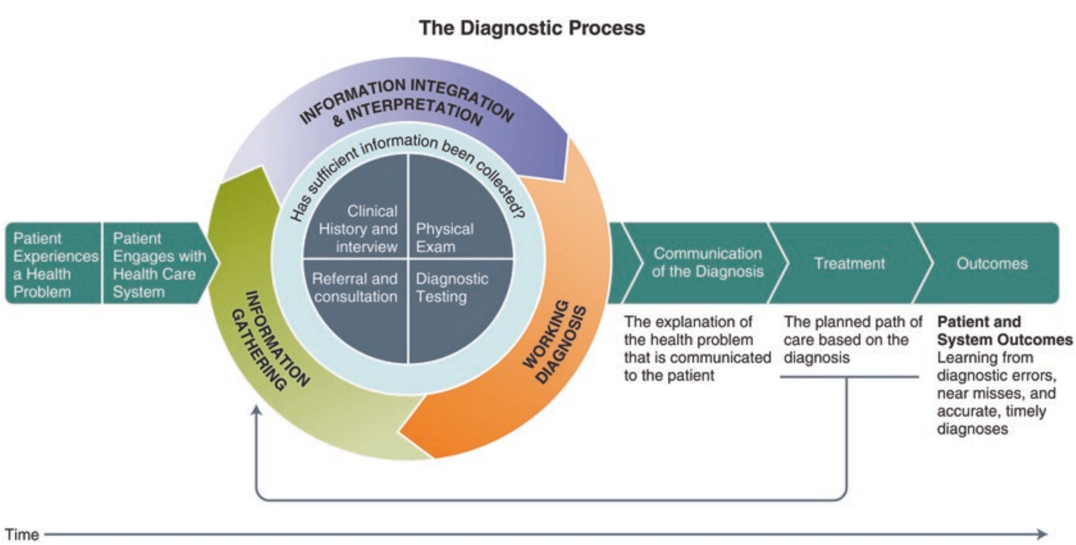

Fig. 25.2 The current dual-process paradigm for "how doctors think"

Table 25.4 Common cognitive biases associated with diagnostic error

Common cognitive biases in medical diagnosis		
Cognitive bias	Definition	Predisposing factors, examples
Premature closure	Accepting a diagnosis that "fits" without considering other possibilities	The physician is rushed; failure to recognize two conditions happening at once (e.g., second or third fractures after identifying the first one)
Representativeness bias	Missing the correct diagnosis because of excessive reliance on the presence/absence of classic characteristics	Atypical presentations: an elderly woman with fatigue and shortness of breath but no chest pain is not worked up for MI
Availability bias	Judging a diagnosis to be more likely if it readily comes to mind, particularly because of recent experience	A patient with vomiting and fever from gangrenous bowel is diagnosed with gastrointestinal flu because it is "going around"
Framing error	Accepting a diagnosis suggested by the patient or another MD	Referrals, handoffs. The consulting surgeon may too easily accept the diagnostic impression of the ER physician who first sees the patient
Context errors	Misunderstanding the true context of the problem at hand, a failure of sense-making	A patient with vomiting and fever is assumed to have a GI problem, but the real issue is sepsis and diabetic ketoacidosis
Affective bias	Negative or positive emotions and feelings that subconsciously detract from optimal decision-making	*Positive*—we fail to consider a more serious diagnosis in someone we are close to or admire or identify with
		Negative—we fail to investigate further in a patient who we subjectively dislike

Table 25.4 [41]. The IOM report emphasized the importance of the environment and the work system in determining the quality and outcome of diagnosis and clinical decisions. The local culture of safety is critical, along with human factors that can influence the immediate situation, such as stress, distractions, fatigue, and team support.

Surgeons face a number of unique cognitive challenges that may predispose to diagnostic errors. First, patients undergoing surgery have typically been seen by a number of physicians leading up to the surgical event, creating the unavoidable assumptions that all of the requisite diagnostic thinking has already been completed, and that the diagnostic conclusions can be trusted (see Box 25.2).

Conversely, patients presenting with conditions that are considered primarily surgical, such as patients with an "acute abdomen," may not be seen by other internists or emergency medicine staff, thus losing the opportunity to be assessed from a different perspective. Secondly, the large amount of task-oriented activities surrounding preoperative preparation and the mental rehearsal a surgeon or anesthesiologist must go through may not leave sufficient cognitive capacity to avoid diagnostic errors or prevent biases [42]. It is generally acknowledged that cognitive overload directs cognition away from the rational, deliberate pathway and toward the more error-prone intuitive approach. Finally, surgeons require a high level of confidence to lead a team through high-risk operations, raising the question of whether this may sometimes engender overconfidence and a tendency to disregard other opinions or novel information. This requires training surgeons on becoming team leaders and being aware of how these factors can shape their actions and the actions and outcomes of others [43].

System-related errors that contribute to diagnostic error include breakdowns in communica-

Box 25.2. Cognitive Challenges of Diagnostic Error in Surgery

A patient is being evaluated for upper GI bleeding in the Emergency Department. The patient has a remote history of an abdominal aortic aneurysm repair and a more recent history of peptic ulcer disease. The diagnosis by the patient's primary care provider, the ED staff, and a consulting gastroenterologist is a bleeding ulcer. When the surgeon is called for persisting bleeding and proceeds with plans for an emergency gastrectomy, the assumption is made that the diagnosis is correct. In the OR, the patient is found to have an aorto-enteric fistula and the patient exsanguinates on the table before a vascular surgeon can be called in to assist.

What factors might have contributed to the cognitive errors in this case?

- Knowledge by the surgeon about the prior history of aortic aneurysm repair
- Deliberation about the speed of the bleeding ulcer diagnosis
- Cognitive challenges of preparing for the technical aspects of the procedure
- Accepting a diagnosis without due consideration of other possibilities leading to assuming the diagnosis is correct

tion or coordinating care, reliably transmitting test results and consults, erroneous laboratory or imaging interpretations, difficulties associated with using an electronic health record, supervising trainees, and a host of other issues [2]. Cognitive load contributions are identified as the lead cause for most cases of diagnostic error [2].

Addressing Diagnostic Error in Surgery

As the old saying goes, the first step in addressing any problem is recognizing that you have one. This is particularly relevant in the case of diagnostic error, because physicians generally believe that they are practicing at a very high level, and tend to attribute diagnostic errors to other clinicians who aren't as experienced or careful. All humans and, perhaps, physicians in particular are overconfident in their abilities and in the correctness of their clinical decisions [44] The cognitive errors made in clinical diagnoses are the same errors people make in their everyday lives; we jump to conclusions, we trust information given to us without verifying it, we accept an assigned diagnosis without rethinking it, and our emotions get in the way of good judgment. All physicians can improve the quality of their practice by accepting the universal predisposition to error, understanding the causes of diagnostic error, and addressing these problems transparently.

Addressing Interpretive Diagnostic Error in Surgical Pathology and Cytology

Optimal surgical diagnosis and care relies heavily on accurate cyto-pathological diagnosis, and errors deriving from the interpretation of cytology, biopsy, or surgical specimens are important to recognize and address. Errors may arise at any point in the "total testing cycle" [45], which begins with specimen acquisition, labeling, and delivery to the laboratory, where the specimen is prepared for the analytic phase. The post-analytic phase begins with a report generation and ends with delivery of the report to the clinician, and the clinician acting on it appropriately. Unlike the other phases of the total testing cycle, the analytic phase is substantially different in surgical pathology and cytology (vs. clinical pathology and automated lab testing) in that it involves visual interpretation and the judgment of the pathologist to arrive at the correct interpretation [33, 46, 47]. Compared to automated lab testing, which operates at error rates in the range of 0.01–0.001 %, the error rate in surgical pathology is orders of magnitude higher, in the range of 2–5 % [34, 48, 49]. Errors in the post-analytical phases of testing are also especially common [50, 51], and many involve failures to reliably communicate test results [52], as illustrated in the case vignette above.

There are many factors that contribute to an accurate interpretive diagnosis, including: (1) the pathologist's knowledge and experience, (2) clinical correlation, (3) standardized diagnostic criteria and taxonomy, (4) confirmatory ancillary studies when available, and (5) secondary review of cases.

Studies have shown the additive value of clinical correlation, standardization of diagnostic criteria, and taxonomy and confirmatory ancillary testing to the accuracy of surgical pathology and cytology diagnoses [53–55]. Several of these factors contribute to establishing a precise diagnosis, but the pathologist's knowledge and experience remain the essential factors in interpretive diagnosis such as in neuropathology tissue ambiguity. Although numerous studies have shown that second opinions help detect interpretive diagnostic errors [56], there have been only scattered efforts to formalize and adopt this practice as a clinical standard. Targeted case reviews could be an integral component of a quality assurance plan that is aimed proactively at preventing errors before they have a potential adverse impact on patients. The College of American Pathologist has issued a recent guideline on the use of second opinions in surgical pathology [49], (see Table 25.5) and a much more detailed and specific set of guidance on second opinions in cancer diagnosis is available in the 11-part series from Cancer Care Ontario [57].

Table 25.5 Guidelines College of American Pathologists Guidelines for Interpretive Diagnostic Error Reduction in Surgical Pathology and Cytology [48]

• Anatomic pathologists should develop procedures for review of pathology cases in order to detect disagreements and potential interpretive errors, and to improve patient care
• Anatomic pathologists should perform case reviews in a timely manner to have a positive impact on patient care
• Anatomic pathologists should have documented case review procedures that are relevant to their practice setting
• Anatomic pathologists should continuously monitor and document the results of case review
• If pathology case reviews show poor agreement within a defined area, anatomic pathologists should take steps to improve agreement

Addressing Cognitive Errors

Experience and meaningful feedback are the cardinal requirements to acquire expertise, and expertise is probably the most important factor in determining the ultimate quality of the diagnostic process. It is generally accepted that experts make the fewest errors, possibly because they've made them all before [58, 59]. Think-aloud verbal protocols, both concurrent and retrospective, have been used to reveal the refined knowledge and reasoning strategies underpinning superior performance [60]. These techniques are useful to identify the domain-specific knowledge that experts utilize to perform the task. For example, Lesgold et al. reported that expert radiologists demonstrate longer reasoning chains with more of their comments being interlinked and interconnected to at least one other chain. These findings highlight how experts store and organize knowledge in a more coherent manner, enabling them to better access and retrieve this information to solve simple tasks [61].

Regardless of one's level of expertise, there are several strategies to improve clinical reasoning that have good potential to reduce the likelihood of cognitive errors [62, 63]:

1. *Practice Reflectively*. Active reflection allows clinicians the rational, deliberate pathway to review intuitive decisions, opening the door to considering alternative ideas or approaches. Although both intuitive and rational cognition are error prone, it is widely believed that most diagnostic errors involve the intuitive pathway, and that these errors can either be avoided, or recognized more reliably by reflective practice and knowing the common biases that arise. "De-biasing" refers to formal training on the common cognitive error types, and has been shown to reduce diagnostic errors in research settings [64–66]. Because the most common cognitive errors are prema-

ture closure (accepting a diagnosis without due consideration of other possibilities) and context-related errors, it is valuable to be as comprehensive as possible in considering different diagnostic possibilities. Always construct a differential diagnosis. In a recent study of diagnostic error, there was no differential diagnosis listed in 80 % of the cases [67]. *"What else can this be?"* is the universal antidote in these situations and that question should be commonly asked by both patients and their surgeons [68].

2. *Work in Teams*. The power of the team to improve decision-making and performance in general is well recognized and amply documented [69, 70]. The Institute of Medicine strongly endorsed the recommendation to work in teams as a strategy to reduce diagnostic error, and specifically called for patients and nurses to be consistently and effectively included and empowered as team members [1]. The patient can act as a safety net to detect diagnostic errors, and as the party most intimately affected has both the knowledge and the incentive to monitor the diagnostic process and its outcomes [71, 72].

   The concept of the surgical team is well established in the operating room, where team behaviors have been shown to correlate with outcomes and complications [73], especially in cases of high complexity [74]. The leadership style of the surgeon has received increasing attention as a determinant of surgical outcomes; surgeons who score poorly in transformational leadership styles have worse outcomes [75], thought to reflect in part a climate in the surgical theater where there is limited psychological safety for others to speak up [76]. The "captain of the ship" approach discourages members of the team from pointing out findings which may be inconsistent with the presumptive diagnosis out of fear of censure [77].

   Surgical team training, such as using TeamSTEPPS, teaches the communication and coordination processes that are required to bring together the individual knowledge, skills, and attitudes of the team members in the service of a common and valued team goal [78]. At its core, TeamSTEPPS™ aims to teach four fundamental competencies that constitute teamwork (leadership, situation monitoring, mutual support, and communication) with the aid of patient scenarios, case studies, multimedia, and simulation [79, 80]. Individual surgical team members are highly specialized and have their own functional task-work (e.g., anesthesia, nursing, surgery, and perfusion), yet come together as a team towards the common goal of treating the patient. Interventions focusing on teamwork have shown a relationship with improved teamwork and safety climate [81]. The "working together" of a clinical microsystem is accomplished by a complex suite of "nontechnical skills" coming together to grow the situational awareness and interconnectedness [82, 83]. Teams that score low on independently observed nontechnical skills make more technical errors and in cases where teams infrequently display team behaviors, patients are more likely to die or experience major complications [84]. There is a significant correlation between subjective assessment of teamwork by team members and postoperative morbidity. Good teamwork (in terms of both quality and quantity) is associated with shorter duration of operations, fewer adverse events, and lower postoperative morbidity [85].

3. *Get Help—Second Opinions*. Second opinions are a particularly effective method of detecting diagnostic errors, and should be encouraged at every opportunity. This should begin by requesting a second review of all important surgical biopsies, whereas, the diagnosis will change in a small but important fraction of these cases [49, 86]. Interdisciplinary case conferences and "tumor boards" are the role model for effective ways to obtain second opinions and learn from others in critical manner [87]. Working in teams is a very effective way to obtain second opinions. Second opinions may be helpful intraoperatively from other surgeons or other types of specialists in ensuring a correct diagnosis or operative decision.

A second key area where second opinions may be helpful is when the decision to proceed with elective surgery is being considered. Second opinions were once required by insurance carriers; of 4555 patients who participated in the Cornell Elective Surgery Second Opinion Program, the second surgeon often disagreed with the need for elective surgery, and disagreement was highest in gynecology and orthopedic cases [88]. Disagreement, of course, does not imply that the initial decision was wrong, as we lack studies with detailed and long-term follow-up of patients.

An interesting variant of this approach involves the addition of a nurse practitioner to a pediatric trauma service to specifically review and follow all cases. Missed injuries in trauma care average 4–5 % [89], and the involvement of this second pair of eyes was effective in uncovering many surgical misdiagnosis cases that would have otherwise been missed [90].

Web-based decision support tools are readily available to assist in differential diagnosis [91–93], but these resources are generally underutilized by clinicians [94]. Although not yet evaluated in surgical settings, these tools can improve the accuracy of medical diagnosis, in addition to being an excellent teaching tool for trainees. Checklists and "time out" procedures have proven to be an important aid in regard to surgical safety, and comparable interventions could be potentially helpful in preventing diagnostic error by surgeons if used to engage surgical providers in meaningful way [95]. The tertiary trauma survey, for example, provides a systematized and reproducible approach to the diagnosis of injuries in these patients, and can reduce diagnostic errors [89].

Addressing System-Related Errors

All system-related errors are considered preventable, and the original IOM report *To Err is Human* concluded that the repair of system-related flaws would be the most effective approach to improving safety in healthcare [96]. A recent systematic review of system-related diagnostic errors identified several opportunities to close the system-loopholes that can become the key factors in producing an error [97]. Communication breakdowns are the most commonly identified problems in cases of diagnostic error, as they are in all other types of adverse events. Surgical care is particularly susceptible to communication challenges, given the large number of players involved in a typical case, involving the patient, family members, the referring physicians or ER staff, the anesthesiologists, the surgical team, and pathologists, just to name a few [98]. Communication breakdowns, for example, are almost always cited in cases of wrong-site surgery [99], and in patient handoffs where vital information is lost or degraded [100].

The electronic medical record can improve communication if used appropriately, by making tests, notes, consults, impressions, and plans readable, and accessible. They can also degrade communication to the extent that the team members no longer interact verbally, as illustrated by the "Texas Ebola" case where the ER triage nurse knew that the febrile patient in the ER had been exposed to Ebola, but the treating clinician failed to read her note in the electronic record [101]. Copy-paste notes seriously degrade the reliability of the medical record [102], as do many features that were designed more for billing than to optimize clinical care [103, 104]. The case study presented in this chapter illustrates a communication breakdown, the failure of an amended pathology report to be effectively communicated to the cancer surgeon in a timely manner.

Other addressable system-related human factors problems include workload stress, fatigue, and the constant distractions that are commonplace in surgical environments [105, 106]. Surgical units should also promote a culture of safety at every opportunity, eliminating blame and focusing on learning from cases of diagnostic error. Encouraging feedback from patients, autopsies, and clinical follow-up on discharged patients back to discharging clinical staff offer enormous learning opportunities both to validate the accuracy of diagnosis and to unmask process deficiencies. Most training programs, both undergraduate and postgraduate, offer little or no training on patient safety in general, or diagnostic error specifically [107]. Lectures, case studies, and morbidity/mortality conferences are all appropriate vehicles to expose surgical trainees and students to the basic concepts relevant to diagnostic error: Human factors, the cognitive psychology of decision-making, practice-based improvement, communication optimization, teamwork, and many other topics would provide both a foundation and a vocabulary for improving the reliability of clinical reasoning in practice [108].

One of the major recommendations in the IOM report on *Improving Diagnosis in Health Care* was to make the patient an effective partner in the diagnostic process (see Chaps. 4–13). There is growing evidence that engaged patients have better health outcomes [109]. Involving patients in decisions on their elective surgery illustrates that patients welcome being involved in shared decision-making. An instructive example is a patient-focused decision aid regarding hip and knee replacement surgery that reduced the number of operations by 26 and 38 %, respectively [110].

The Future Reliability and Assurance of Surgical Diagnosis

In the long run, the quality and safety of diagnosis in surgery will inevitably improve, thanks to innovations in diagnostic testing. There is no better example than the problem of diagnosing appendicitis, originally based on the careful integration of the clinical story with observations of the patient's abdomen, and inevitably the critical presence or absence of discomfort at McBurney's point. The diagnosis was missed in 20 % of patients, and of those patients who went to surgery, about the same percentage had something else. Abdominal imaging has led to dramatic improvements in diagnostic reliability, with sensitivity and specificity now exceeding 90 % [111]. This represents a real improvement in the reliability of diagnosis, but possibly at the expense of some degradation in the ability of physicians to conduct a thorough and accurate physical examination [112].

The more relevant question is whether we can improve the timeliness and accuracy of diagnosis in the short term. The recent advances in understanding the system-based and cognitive factors that contribute to these errors are important, and they create an opportunity to redesign the training and feedback to surgeons and consider what interventions might be helpful [62, 63, 97]. Surgeons and surgical programs should be encouraged to consider which of these interventions would have the greatest impact on improving diagnostic performance in their own situations and participate in research programs to evaluate the outcomes of these projects. Surgical programs should strive for patient-centered approaches that incorporate the benefits of working in teams, practicing reflectively, taking advantage of second opinions, and efforts to address the many other system-related and cognitive factors that underlie diagnostic errors.

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