

# Understanding Diagnostic Error

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## KEYWORDS

• Decision making • Diagnostic errors • Cognition • Overconfidence • Checklist

## HOSPITAL MEDICINE CLINICS CHECKLIST

1. Diagnostic error is an underrecognized patient safety concern.
2. Approximately 15% of patients are misdiagnosed.
3. Up to 80,000 preventable deaths occur each year in the United States as a result of diagnostic error, and many occur in hospital-based settings.
4. Diagnostic error is a leading cause of preventable deaths and malpractice claims.
5. Diagnostic errors are typically a consequence of more than 1 causal factor, and most are caused by cognitive errors and systems issues.
6. Clinicians (including hospitalists), health care systems, and patients can all take action to attempt to prevent diagnostic errors.

## BACKGROUND

Despite growing attention paid to medical errors and patient safety in general, little attention and study have been given to diagnostic errors.<sup>1-3</sup> The 1999 landmark report on medical errors by the Institute of Medicine, *To Err is Human*, mentioned diagnostic errors only twice.<sup>3</sup> Since that time, there has been growing awareness of the problem of diagnostic errors, but little progress toward a complete understanding, much less a solution.

Diagnostic errors are not uncommonly encountered during an acute episode of care, and most are related to cognitive or systems issues. Therefore, hospitalists are in a unique position: they can identify and correct, inadvertently perpetuate, or commit diagnostic errors as patients are admitted to and discharged from the hospital. For example, hospitalists recognize that initial diagnoses and therapies instituted in a busy emergency room setting are often based on preliminary impressions

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and incomplete data. By remaining aware of individual cognitive biases (eg, not considering alternative diagnostic possibilities) as well as systems issues (eg, incorrect medications or therapies being inadvertently administered during a particularly busy emergency shift), hospitalists can prevent perpetuation of such errors.

As the primary inpatient attending for a variety of patients, hospitalists also likely find themselves in the position of having to disclose diagnostic errors to patients and their caregivers. In addition, because of their unique understanding of hospital operations and potential patient safety hazards related to suboptimal care delivery (eg, hand-offs and transitions), hospitalists are in a special position to advocate for improved processes that may prevent or mitigate these errors. Hospitalists, therefore, should be well-versed in understanding the definition, epidemiology, and cause of such errors, as well as methods of preventing, reducing, and minimizing their potential adverse consequences.

## DEFINITIONS

### *What is a diagnostic error?*

Making the correct diagnosis is a complex, difficult, and arguably the most important step in patient care. The ability to provide the proper therapy to a patient depends on an accurate understanding of the disease processes affecting the patient, and a consideration of diseases the patient does not have.

A diagnostic error is typically defined in retrospect as a diagnosis that, on obtaining all necessary information, is determined to be<sup>4</sup>:

- Delayed (the necessary information to make the diagnosis was available earlier)
- Wrong (an incorrect diagnosis was made before the correct diagnosis)
- Missed (no diagnosis was made)

### *What is the difference between an error and harm?*

Not all diagnostic errors result in harm to the patient. For example, confusing one benign self-limited disease for another may have no clinically significant impact. Many diagnostic errors can result in preventable harm. A study of 100 cases of diagnostic error in internal medicine showed that 90% involved harm to the patient, including 33 deaths.<sup>4</sup> Typical harm to patients may include:

- Delay or failure to diagnose a condition and initiate appropriate treatment
- Delay in initiating treatment of a condition that was correctly diagnosed
- Inaccurate or unnecessary treatment provided to the patient for a condition that the patient did not have<sup>5</sup>

### *What are the causes of diagnostic error?*

Diagnostic errors result from a wide variety of causes. These causes include:

- Cognitive errors made by the clinician (or team of care providers)
- Systems issues related to availability and functioning of technology and communication between different practitioners within the health care system
- Various no-fault causes (**Box 1**).

Of the cases of diagnostic error described by Graber and colleagues, 74% involved cognitive errors, 65% involved system errors, and 7% involved only no-fault errors. Cases with cognitive or systems errors averaged 5.9 separate causal factors per patient.

**Box 1****Contributing factors in diagnostic error**

- Cognitive Errors
  - Inadequate knowledge
  - Faulty data gathering
  - Faulty information processing
  - Faulty metacognition
- System Errors
  - Technical failures
    - Faulty test or data
    - Lack of appropriate equipment
  - Organizational Failures
    - Inadequate pursuit of noncompliant patient
    - Unavailability of needed expertise
    - Inefficient processes
    - Failure to adequately supervise
    - Patient neglect
    - Policy failures
    - Inadequate training or orientation
    - Culture (eg, tolerance of error)
    - Failure to coordinate care
- No-fault errors
  - Unusual/silent presentation of disease
  - Inconsistent/confusing description from patient
  - Uncooperative patient
  - Limitations of current medical knowledge
  - Failure to arrive at correct diagnosis despite doing the right thing

*Data from* Graber M, Gordon R, Franklin N. Reducing diagnostic errors in medicine: what's the goal? *Acad Med* 2002;77(10):981–92.

Premature diagnostic closure, or the failure to consider other alternative diagnoses after arriving at the initial diagnostic hypothesis, was the most common factor, occurring in 39% of cases. Inadequate or faulty knowledge was a factor in only 11% of cases.<sup>4</sup>

## EPIDEMIOLOGY

### *How often do diagnostic errors occur?*

Diagnostic errors are difficult to systematically measure. Current estimates suggest a diagnostic error rate of 2% to 15%, and this rate may be higher for clinical specialties when compared with the perceptual specialties such as radiology and pathology. However, this rate may be an underestimate: autopsy studies, the gold standard for determining error rates, suggest a major diagnostic error rate of 23.5%, and a class I

**Box 2****Error classification in autopsy studies**

- Major diagnostic error: a diagnosis that was missed clinically and was related to the principle underlying disease or cause of death.
- Class I error: a major error that might have affected the patient's prognosis had it been corrected

*Data from* Shojania KG, Burton EC, McDonald KM, et al. Changes in rates of autopsy-detected diagnostic errors over time: a systematic review. JAMA 2003;289(21):2849–56.

error rate of 9%.<sup>6</sup> An analysis by Shojania and colleagues<sup>6</sup> showed that although error rates are decreasing over time, the United States can still expect a major error rate between 8.4% and 24.4%, and a class I error rate between 4.1% and 6.7% (**Box 2**).

### *Which diagnoses are most commonly associated with diagnostic error?*

According to a survey of more than 500 cases of diagnostic error, the most commonly missed diagnoses were<sup>7</sup>:

- Pulmonary embolism (4.5%)
- Drug reaction or overdose (4.5%)
- Lung cancer (3.9%)
- Colorectal cancer (3.3%)
- Acute coronary syndrome (3.1%)
- Breast cancer (3.1%)
- Stroke (2.6%)
- Congestive heart failure (2.2%)
- Fracture (2.2%)
- Abscess (1.9%)

### *How often are patients harmed by diagnostic errors?*

Efforts to quantify the total numbers of diagnostic errors suggest that 40,000 to 80,000 preventable deaths per year are caused by diagnostic errors.<sup>8</sup> Autopsy reviews of diagnostic error suggest that 70,000 patient deaths per year are associated with a major missed diagnosis, and approximately 50% of those patients who died may have survived to hospital discharge had the misdiagnosis not occurred.<sup>6</sup>

A review of 247 patients hospitalized with dyspnea found that 13.8% of the patients were misdiagnosed and 11.3% suffered harm.<sup>9</sup> Therefore, the typical hospitalist, who might admit and discharge 30 patients over a 7-day period, may care for 5 or 6 patients who have been misdiagnosed and 3 or 4 patients who have suffered preventable harm as a consequence of progression of the disease process, failure to institute appropriate treatment in a timely manner, or potential adverse events associated with additional workup or administration of inappropriate treatments.

### *How often are diagnostic errors associated with malpractice claims?*

Diagnostic errors are the first or second most common cause of malpractice claims.<sup>10</sup> According to the Harvard Medical Practice Study, errors by physicians that resulted in harm were more often related to diagnostic error than drug-related errors. Diagnostic errors were more likely to be considered negligent, more often resulted in serious disability, and often resulted in the highest payouts per claim (**Box 3**).<sup>5</sup>

**Box 3****Most common reasons for malpractice claims**

- Failure to diagnose cancer
- Injuries after trauma
- Surgical problems
- Infections
- Heart attacks
- Venous thromboembolic disease

*Data from Berner ES, Graber ML. Overconfidence as a cause of diagnostic error in medicine. Am J Med 2008;121(Suppl 5):S2–23.*

*When do most diagnostic errors occur?*

Not every phase of the diagnostic process contributes equally to the risk of diagnostic errors. Errors most often occur during the testing phase, including failure to order the proper test and failure to follow up on the results.<sup>7</sup> For hospitalists, tests pending at the time of discharge are a particularly important safety concern, because physicians are typically aware of only 35% to 40% of the results.<sup>11</sup> The next largest contribution to errors occurs during the assessment phase, and is a consequence of failure to consider all pertinent diagnoses, incorrect prioritization of items on the differential diagnosis, premature closure, and failure to recognize the urgency of the patient's clinical situation. A small percentage of errors occurred during the history taking, physical examination, and referral phases.<sup>7</sup> This finding is consistent with studies showing that most diagnostic errors were related to faulty synthesis and systems factors, rather than to a lack of knowledge (**Box 4**).<sup>4</sup>

**CONTRIBUTING FACTORS TO DIAGNOSTIC ERRORS**

A review of closed claims in Japan showed that cognitive errors were common contributing factors (compared with system-related factors) and that errors in judgment were more likely to result in compensation (**Table 1**).<sup>12</sup>

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**Box 4****Phases of care at high risk for error**

- Admission
- Discharge
- Hand-off to another physician

*Which cognitive shortcuts put physicians at risk for making diagnostic errors?*

To understand what can go wrong when making a diagnostic decision, it is important to understand how physicians make decisions. A common model for this process is dual process theory, which describes 2 separate modes of thought. Type 1 decision making is intuitive, fast, based on experience, and prone to cognitive bias, whereas type 2 decision making is analytical, slow, based on logical deduction, and systematic (**Table 2**).<sup>13</sup> Neither mode of thought is better than the other; each has its place when balancing the competing requirements of accuracy and efficiency that physicians face. A good diagnostician is able to move back and forth between the 2 modes as necessary.

Although type 1 thinking is fast, and often accurate in the hands of the experienced, it is prone to many cognitive biases<sup>14–16</sup>:

- Availability heuristic: making a diagnosis based on the diseases that most readily come to mind (eg, the most recently seen patient with a similar presentation, or an interesting zebra recently discussed in a morning report). This bias can be attenuated by paying attention to disease prevalence.
- Anchoring heuristic: settling on diagnosis too early based on one's initial impressions. To avoid this bias, one can reconsider the differential diagnosis as new evidence is gathered.
- Confirmation bias: discounting evidence that contradicts one's favored hypothesis, and paying attention only to evidence that supports it. This bias can be minimized by paying attention to evidence that does not fit.
- Representativeness heuristic: over-reliance on the typical presentation of a disease, which may cause one to misdiagnose patients with an atypical

**Table 1**  
**Contributory factors in malpractice claims**

<b>Contributory Factor</b>	<b>%</b>
<b>Cognitive Factors</b>	
Error in judgment	73
Failure of vigilance	65
Lack of technical competence	34
Lack of knowledge	31
Failure of memory	2
<b>System Factors</b>	
Poor teamwork	4
Technology failure	2
<b>Patient-related factors</b>	32

Data from Tokuda Y, Kishida N, Konishi R, et al. Cognitive error as the most frequent contributory factor in cases of medical injury: a study on verdict's judgment among closed claims in Japan. *J Hosp Med* 2011;6(3):109–14.

Characteristic	Type 1	Type 2
Reasoning style	Intuitive Heuristic Associative Concrete	Analytical Normative Deductive Abstract
Awareness	Low	High
Verbal behavior	None to minimal	Yes
Action	Reflexive, skilled	Deliberate, rule-based
Speed	Fast	Slow
Vulnerability to bias	Yes	Less so
Reliability	Low, variable	High, consistent
Errors	Common	Few
Scientific rigor	Low	High
Context importance	High	Low

Data from Croskerry P, Nimmo GR. Better clinical decision making and reducing diagnostic error. *J R Coll Physicians Edinb* 2011;41(2):155–62.

presentation. Systemically considering each item in a differential diagnosis may help minimize this error.

- Premature closure, or satisficing: halting the search for further diagnostic possibilities once something is found that fits.
- Framing effects: how one views a problem can be influenced by the way it is described. Be sure to examine the case from alternative perspectives.
- Diagnosis momentum: a diagnosis proposed as a possibility by one person can become definite as it is passed from 1 person to the next, and it becomes accepted without being questioned by future physicians.

#### *What is the role of overconfidence in diagnostic error?*

Most individuals are not able to accurately assess their own performance relative to their peers. For example, only 1% of drivers rate their skills as less than average, and 94% of academics rank their performance in the top 50% of their profession.<sup>10</sup> Of greater concern is that the group of low performers are most susceptible to overconfidence; they are often unskilled and unaware.<sup>17–20</sup>

Clinician overconfidence plays an important role in diagnostic errors. Autopsy studies have shown that confidence does not correlate well with the accuracy of diagnoses: clinicians were wrong in 40% of cases in which they reported being completely certain.<sup>10</sup> In a study of medical students, residents, and faculty members examining the relationship between accuracy in diagnosing a clinical scenario and confidence in one's diagnosis, Friedman and colleagues<sup>21</sup> showed that although medical students (less experienced) were the least accurate in their diagnoses, the correlation between their accuracy and confidence was similar to that of faculty members. Residents (more experienced) performed more accurately in making diagnoses than students, but showed more overconfidence than faculty members when they were incorrect.

Overconfidence can lead to premature closure and a failure to pursue unanswered questions about a clinical scenario, even when resources to provide those answers are readily available.<sup>10</sup> In addition, overconfidence tends to increase without timely

feedback about the accuracy of one's performance; individuals falsely overestimate their performance and perceive less of a need to improve their skills.<sup>22</sup>

## REDUCING DIAGNOSTIC ERRORS

It is impossible to reduce diagnostic errors from practice completely. Nevertheless, hospitalists can take several steps to reduce the likelihood of their occurrence by addressing the cognitive errors and system issues associated with the diagnostic process.<sup>23</sup> For example, hospitalists can spearhead quality improvement initiatives to enhance awareness of hospital staff of common cognitive pitfalls and ways of preventing them and can lead institutional efforts to correct systems-related issues (eg, medication management, bar coding and medication reconciliation, management of noncritical but clinically significant test results, tests pending at discharge).

### *How can I avoid making diagnostic errors?*

The first step is to be aware of how frequently diagnostic errors occur. Informal surveys have shown that approximately 1% of physicians admit to having made a diagnostic error, which is not consistent with what available research suggests the true error rate to be.<sup>10</sup> Once a physician accepts that it is possible to make a diagnostic error, they can then examine the way that they make decisions in an effort to improve. Metacognitive training is an effort to understand and combat the cognitive biases that frequently occur.<sup>16,30</sup> Some strategies were described earlier along with the descriptions of common cognitive biases and heuristics.

A more general approach is the consider-the-opposite strategy, in which the clinician assumes that their most likely diagnosis is incorrect and looks for alternatives.<sup>24</sup> This strategy can decrease susceptibility to premature closure, anchoring, and other biases. Another approach is to ask oneself what the worst-case scenario would be, in an effort to counteract the bias toward favoring more benign diagnoses over life-threatening ones.<sup>14</sup>

Electronic documentation, point-of-care diagnostic applications, and other information technology tools have the potential to mitigate the impact of cognitive biases in the diagnostic process. However, there is much variability in how individual clinicians and specific institutions document and use potentially useful tools in practice, because no standards or evidence-based guidelines exist (**Box 5**). Nevertheless, hospitalists should consider:

1. The routine use of problem-based assessment/plans
2. Iterative refinement of documentation to correspond with evolution of diagnostic process

#### **Box 5**

##### **Individual tips for avoiding diagnostic errors**

- Recognize and understand when diagnostic errors are most likely to occur.
- Review primary data when available. Maintain a degree of skepticism when reviewing history taking, clinical findings, documentation, and interpretation of studies and test results that are made by others.
- Identify cognitive pitfalls that you commonly make during the diagnostic decision-making process and develop checklists to mitigate the impact of these contributing factors.
- Use cognitive strategies and point-of-care diagnostic tools to improve your awareness of alternative diagnoses.

3. Use of point-of-care diagnostic applications (many of these are available on popular mobile platforms) to prompt awareness of alternative diagnoses regularly based on new undiagnosed problems or symptoms listed in the problem-based assessment/plan
4. Reconciliation of new, active, and resolved problems during hand-offs and care transitions

*How can checklists be used to avoid diagnostic errors?*

Checklists have been used to help minimize error in many industries, including health care.<sup>25,26</sup> More recently, checklists have been proposed as a tool to help avoid diagnostic error by reminding physicians to be more aware of their thought processes while making a diagnosis and to consider important alternatives once they arrive at one.<sup>27</sup> A general checklist prompts the physician to consciously review their diagnostic reasoning to look for any cognitive shortcuts that may have occurred, allowing an opportunity to correct the mistake before an error or harm occurs. A differential diagnosis checklist is based on the presenting complaint, and provides a list of common diagnoses and do-not-miss diagnoses. A forcing function checklist provides a list of common pitfalls and diagnostic tests to consider in diagnosing a specific disease to help minimize the opportunity for error (**Box 6**).

There are 6 categories of information that should be included when creating a disease-specific checklist designed to minimize diagnostic errors<sup>1</sup>:

- Essential data elements: items from the history, examination, and testing that should be obtained for every patient
- Do-not-miss diagnoses: critical diagnoses that must be considered
- Red-flag symptoms: specific findings that should raise suspicion for a do-not-miss diagnosis
- Potential drug causes: medication side effects are often missed as a cause for the patient's symptoms

**Box 6**

**Proposed general checklist for diagnosis**

- Obtain your own complete medical history
- Perform a focused and purposeful physical examination
- Generate initial hypotheses and differentiate these with additional history, physical examination, and diagnose tests
- Pause to reflect: take a diagnostic time-out
  - Was I comprehensive?
  - Did I consider the inherent flaws of heuristic thinking?
  - Was my judgment affected by any other bias?
  - Do I need to make the diagnosis now, or can I wait?
  - What is the worst-case scenario?
  - Embark on a plan, but acknowledge uncertainty and ensure a pathway for follow-up

*Adapted from Ely JW, Graber ML, Croskerry P. Checklists to reduce diagnostic errors. Acad Med 2011;86(3):307–13.*

- Required referrals: circumstances under which specialist expertise is needed to properly manage the patient
- Patient follow-up instructions and plan: the patient should be given specific symptoms that require them to return or call within a specific time frame

#### *What can patients do to prevent diagnostic errors?*

Groopman, in his book *How Doctors Think*,<sup>28</sup> includes 3 questions for patients to ask their physician to help ensure an accurate diagnosis. They are designed to help prompt the physician to rethink their diagnosis and consider alternatives that may have been overlooked. These questions are equally useful for physicians to ask themselves to help minimize their own risk of making a diagnostic error.

- What else can it be?
- Is there anything that does not fit?
- Is it possible that I have more than 1 problem?<sup>28</sup>

Hospitalists can encourage patients and caretakers to ask these questions during their hospitalization.

#### *Which systems approaches can be used to reduce diagnostic error?*

Many systems level changes to improve diagnostic error rates have been proposed, but there has been little research testing these ideas.<sup>29-31</sup> Because hospitalists are heavily involved with inpatient medical care, it is important that they take a leadership role in working on systems solutions to help reduce diagnostic error rates.

- Improve supervision of trainees
- Ensure that test results are reported in a timely manner
- Improve the ability of practitioners to communicate with each other directly and through an electronic medical record
- Reduce detractors from good decision making (eg, fatigue, distractions, stress)
- Promote a culture of safety that seeks to improve quality and avoids placing blame on individuals
- Provide tools that offer diagnostic decision support at the point of care
- Enhance the ability to provide feedback to clinicians about the accuracy of their diagnoses

#### *What electronic tools are available to minimize diagnostic error?*

A growing number of decision support tools are available on the Internet and optimized for mobile devices, providing a point-of-care resource for busy hospitalists. Some of these tools have been critically evaluated, but some have not. None of them is a replacement for professional judgment, but they may provide useful prompts to expand the range of diagnostic considerations. A partial list of resources on the Internet includes<sup>27</sup>:

- DXplain (<http://dxplain.net/>)
- Isabel (<http://www.isabelhealthcare.com/>)
- VisualDx (<http://www.visualdx.com/>)
- PEPID (<http://www.pepid.com/>)
- Diagnosaurus (<http://accessmedicine.com/diag.aspx>)

*What are the potential pitfalls of trying to minimize diagnostic error?*

Attempts to introduce change into a complex health care environment likely have unintended consequences. Well-intentioned improvements may inadvertently cause new sources of error, making it impossible to eliminate error altogether:

- System improvements may weaken over time as the initial reason for the change is forgotten
- As health care systems evolve, it takes time to identify new sources of error and generate solutions
- Many solutions are a trade-off between different contributing factors to diagnostic error (eg, the increase in hand-offs after resident duty-hour changes, which were implemented to combat fatigue)<sup>23</sup>

Another potential problem is checklist fatigue: as more checklists are introduced, clinicians may skip them altogether.<sup>25</sup> In addition, an unintended consequence of type 2 decision making may include an increase in the number of diagnostic tests ordered, thereby increasing health care costs, decreasing efficiency, and possibly increasing workloads of individual clinicians (another potential cause of diagnostic error).

## REFERENCES

1. Schiff GD. Finding and fixing diagnosis errors: can triggers help? *BMJ Qual Saf* 2012;21(2):89–92.
2. Winters BD, Aswani MS, Pronovost PJ. Commentary: reducing diagnostic errors: another role for checklists? *Acad Med* 2011;86(3):279–81.
3. Wachter RM. Why diagnostic errors don't get any respect—and what can be done about them. *Health Aff (Millwood)* 2010;29(9):1605–10.
4. Graber ML, Franklin N, Gordon R. Diagnostic error in internal medicine. *Arch Intern Med* 2005;165(13):1493–9.
5. Newman-Toker DE, Pronovost PJ. Diagnostic errors—the next frontier for patient safety. *JAMA* 2009;301(10):1060–2.
6. Shojania KG, Burton EC, McDonald KM, et al. Changes in rates of autopsy-detected diagnostic errors over time: a systematic review. *JAMA* 2003;289(21):2849–56.
7. Schiff GD, Hasan O, Kim S, et al. Diagnostic error in medicine: analysis of 583 physician-reported errors. *Arch Intern Med* 2009;169(20):1881–7.
8. Leape LL, Berwick DM, Bates DW. Reply to letter of Rodney A. Hayward. *JAMA* 2002;288(19):2405.
9. Zwaan L, Thijs A, Wagner C, et al. Relating faults in diagnostic reasoning with diagnostic errors and patient harm. *Acad Med* 2012;87(2):149–56.
10. Berner ES, Graber ML. Overconfidence as a cause of diagnostic error in medicine. *Am J Med* 2008;121(Suppl 5):S2–23.
11. Roy CL, Poon EG, Karson AS, et al. Patient safety concerns arising from test results that return after hospital discharge. *Ann Intern Med* 2005;143(2):121–8.
12. Tokuda Y, Kishida N, Konishi R, et al. Cognitive error as the most frequent contributory factor in cases of medical injury: a study on verdict's judgment among closed claims in Japan. *J Hosp Med* 2011;6(3):109–14.
13. Croskerry P. A universal model of diagnostic reasoning. *Acad Med* 2009;84(8):1022–8.
14. Trowbridge RL. Twelve tips for teaching avoidance of diagnostic errors. *Med Teach* 2008;30(5):496–500.

15. Redelmeier DA. Improving patient care. The cognitive psychology of missed diagnoses. *Ann Intern Med* 2005;142(2):115–20.
16. Croskerry P. The importance of cognitive errors in diagnosis and strategies to minimize them. *Acad Med* 2003;78(8):775–80.
17. Ehlringer J, Johnson K, Banner M, et al. Why the unskilled are unaware: further explorations of (absent) self-insight among the incompetent. *Organ Behav Hum Decis Process* 2008;105(1):98–121.
18. Krueger J, Mueller RA. Unskilled, unaware, or both? The better-than-average heuristic and statistical regression predict errors in estimates of own performance. *J Pers Soc Psychol* 2002;82(2):180–8.
19. Kruger J, Dunning D. Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *J Pers Soc Psychol* 1999;77(6):1121–34.
20. Kruger J, Dunning D. Unskilled and unaware—but why? A reply to Krueger and Mueller (2002). *J Pers Soc Psychol* 2002;82(2):189–92.
21. Friedman CP, Gatti GG, Franz TM, et al. Do physicians know when their diagnoses are correct? Implications for decision support and error reduction. *J Gen Intern Med* 2005;20(4):334–9.
22. Rudolph JW, Morrison JB. Sidestepping superstitious learning, ambiguity, and other roadblocks: a feedback model of diagnostic problem solving. *Am J Med* 2008;121(Suppl 5):S34–7.
23. Graber M. Metacognitive training to reduce diagnostic errors: ready for prime time? *Acad Med* 2003;78(8):781.
24. Croskerry P, Norman G. Overconfidence in clinical decision making. *Am J Med* 2008;121(Suppl 5):S24–9.
25. Gawande A. The checklist: if something so simple can transform intensive care, what else can it do? *New Yorker* 2007;83(39):86–101.
26. Ely JW, Graber ML, Croskerry P. Checklists to reduce diagnostic errors. *Acad Med* 2011;86(3):307–13.
27. Groopman JE. *How doctors think*. Boston: Houghton Mifflin; 2007.
28. Hales BM, Pronovost PJ. The checklist—a tool for error management and performance improvement. *J Crit Care* 2006;21(3):231–5.
29. Graber M, Gordon R, Franklin N. Reducing diagnostic errors in medicine: what's the goal? *Acad Med* 2002;77(10):981–92.
30. Graber ML. Taking steps towards a safer future: measures to promote timely and accurate medical diagnosis. *Am J Med* 2008;121(Suppl 5):S43–6.
31. Singh H, Graber ML, Kissam SM, et al. System-related interventions to reduce diagnostic errors: a narrative review. *BMJ Qual Saf* 2012;21(2):160–70.