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Cognitive error in an academic emergency department

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Abstract

Background: Medical error is a leading cause of death nationwide. While systems issues have been closely investigated as a contributor to error, little is known about the cognitive factors that contribute to diagnostic error in an emergency department (ED) environment.
Methods: Eight months of patient revisits within 72 h where patients were admitted on their second visit were examined. Fifty-two cases of confirmed error were identified and classified using a modified version of the Australian Patient Safety Foundation classification system for medical errors by a group of trained physicians.
Results: Faulty information processing was the most frequently identified category of error (45% of cases), followed by faulty verification (31%). Faulty knowledge (6%) and faulty information gathering (18%) occurred relatively infrequently. "Misjudging the salience of a finding" and "premature closure" were the individual errors that occurred most frequently (13%).
Conclusions: Despite the complex nature of diagnostic reasoning, cognitive errors of information processing appear to occur at higher rates than other errors, and in a similar pattern to an internal medicine service despite a different clinical environment. Further research is needed to elucidate why these errors occur and how to mitigate them.

Keywords: classification; cognitive; diagnosis; diagnostic error; emergency; error; information processing.

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Introduction

Medical errors were estimated in 2016 to cause 250,000 deaths per year in the US [1]; the rate of diagnostic error overall has been estimated at 10–15% [2], although reported rates are variable depending on the method used to estimate incidence [3]. While a great deal of effort has been expended on the improvement of systems issues such as improving patient handoffs [4] and medication reconciliation [5], cognitive errors have proved more difficult to study and mitigate [6].

Previous work by Graber et al. showed that the majority of the cognitive errors identified among high-risk cases on an internal medicine service were errors of faulty synthesis (information processing and verification) and that relatively few errors were attributable to poor knowledge or data gathering [7]. Though the diagnostic errors in an emergency department (ED) are likely to occur at around a similar rate as diagnostic errors in the rest of the health system [8], ED errors may be of a different character because of the fast pace [9] and frequent interruptions [10] that can lead to incomplete or unreliable gathering or transfer of information [11]. One study identified an incomplete history and physical examination as a factor in 42% of ED malpractice claims [12].

The first step to reducing error in the ED is to understand the factors that contribute most frequently to medical error. One commonly examined source of potential medical errors are patient revisits, as a patient's return to the ED within a short time frame suggests that an error may have occurred [13]. The aim of this study was to determine the cognitive factors that contribute to error most frequently in the ED by examining revisits within 72 h.

Subjects and methods

Setting

The study was conducted at an adult ED in an urban academic public hospital in New York City with approximately 156,000 annual visits.

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Definitions

A revisit was defined for our study as two visits to the same ED within a 72 h window. Cases were excluded if the patient was under 18 or over the age of 89, the second visit was planned during the first visit (e.g. wound check follow-up), the patient was admitted on the first visit or if the patient was discharged on both visits. While it is possible that some of the excluded cases also contained instances of error, we felt that the most serious and important cases of error were likely to be found when the patient was discharged on the first visit and admitted on the second visit, as this suggests that the original disposition may have been made in error.

Cognitive error was defined as a delayed, incorrect or missed diagnosis due to an error in physician judgment as determined by information obtained later, a modification of the definition used by Graber et al. [7]. Errors were classified using a modified version of the Australian Patient Safety Foundation classification system and abbreviated from the categorization described by Graber et al. [7] to focus only on the cognitive factors contributing to error, not on systems issues. This classification system describes four broad categories of factors which can lead medical decision-making to break down: faulty knowledge, faulty data gathering, faulty information processing and faulty verification. It also defines multiple subcategories for each of the factors. See Table 1 for the classification system used with descriptions of each factor.

Data sources

As part of routine ED quality improvement measures, 72 h revisit case summaries are identified at our institution, with pertinent data included from the history, examination, laboratory results and imaging tests. If it remained unclear whether an error had occurred after review of the case summary, or further information was required to identify the type of error, the full medical record was examined and the original providers were contacted for further clarification when possible. Eight months of 72 h revisits from 2013 to 2014 were included in our analysis. Within the 8-month study period, 271 cases met the inclusion criteria and were examined.

Evaluators

A team of physicians, including two physicians with cognitive science experience, was trained on the modified Australian Patient Safety Foundation classification and its use over several hours prior to the start of the study. All team members assigned classifications to several example cases to ensure that all participants shared a similar understanding on how to use the classification system.

Process

Identifying cognitive errors took place in two steps. In the first step, each case that met the inclusion criteria was examined by two independent reviewers to determine whether, in their clinical judgment, the case could have contained cognitive error as defined by our study criteria. Cases where the two reviewers disagreed were adjudicated by the full group. In the second step, all cases that were identified as possibly containing a cognitive error were examined in more detail by at least three members of the study team, who analyzed the details of each case and reached a consensus as a group as to whether an error occurred and if so, what categories of error occurred.

Data recording and analysis

Cases were categorized by error class and body system, as well as screened for known high-risk conditions that could predispose patients to medical error or poor outcomes, such as substance abuse or psychiatric illness. Cases were recorded in a secure database, accessible only to the researchers. Descriptive statistics were calculated using Numbers (Apple, Cupertino, CA, USA).

Ethical statement

The study was approved by the Institutional Review Board at the participating hospital.

Results

A total of 271 cases of revisits within 72 h met our inclusion criteria. A total of 131 (48%) cases were determined by both reviewers to contain no potential cognitive error; 140 (52%) were identified by at least one reviewer as containing a potential cognitive error and flagged for further review by the study team. Of the 140 cases where potential issues were identified, 52 cases (19%) were verified to represent instances of cognitive error as determined by group consensus (see Figure 1).

Within the 52 cases identified as containing a cognitive error, there were 120 cognitive factors identified as contributing to error (each case could be assigned more than one factor which contributed to the error). Among the four general categories of cognitive error, faulty information processing was the most common, representing 45% [95% confidence interval (CI) 36–54%] of the identified errors. Faulty verification was the next most frequently identified, representing 31% (95% CI 23–40%) of factors. Finally, factors of faulty data gathering and faulty knowledge occurred least commonly, representing 18% (95% CI 12–26%) and 6% (95% CI 3–12%) of errors, respectively. Table 2 represents the relative frequency of each of the four types of cognitive factors determined to contribute to error. The mean number of factors identified per case containing error was 2.3.

Of the 25 described specific cognitive factors which can contribute to error, the most commonly occurring

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Table 1: The cognitive error classification system used in our study.

Type	Definition	Example
Faulty knowledge		
Knowledge base inadequate or defective	Insufficient knowledge of relevant condition	Providers not aware of Fournier gangrene
Skills inadequate or defective	Insufficient diagnostic skill for relevant condition	Missed diagnosis of complete heart block, clinician misread electrocardiogram
Faulty data gathering		
Ineffective, incomplete or faulty workup	Problems in organizing or coordinating patient's tests and consultations	Delayed diagnosis of drug-related lupus: failure to consult patient's old medical records
Ineffective, incomplete or faulty history and physical examination	Failure to collect appropriate information from the initial interview and examination	Delayed diagnosis of abdominal aortic aneurysm: incomplete past history questioning
Faulty test or procedure techniques	Standard test/procedure is conducted incorrectly	Wrong diagnosis of myocardial infarction: electrocardio-graphic leads reversed
Failure to screen (pre-hypothesis)	Failure to perform indicated screening procedures	Missed prostate cancer: rectal examination and PSA testing never performed in a 55-year-old man
Poor etiquette leading to poor data quality	Failure to collect required information owing to poor interaction with patient	Missed CNS contusion after very abbreviated history, pejorative questioning
Faulty synthesis: faulty information processing		
Faulty context generation	Lack of awareness/consideration of aspects of patient's situation that are relevant to diagnosis	Missed perforated ulcer in a patient presenting with chest pain and laboratory evidence of myocardial infarction
Overestimating or underestimating usefulness or salience of a finding	Clinician is aware of symptom, but either focuses too closely on it to the exclusion of others or fails to appreciate its relevance	Wrong diagnosis of sepsis in a patient with stable leukocytosis in the setting of myelodysplastic syndrome
Faulty detection or perception	Symptom, sign or finding should be noticeable, but clinician misses it	Missed pneumothorax on chest radiograph
Failed heuristics	Failure to apply appropriate rule of thumb, or overapplication of such a rule under inappropriate/atypical circumstances	Wrong diagnosis of bronchitis in a patient later found to have pulmonary embolism
Failure to act sooner	Delay in appropriate data analysis activity	Missed diagnosis of ischemic bowel in a patient with a 12-week history of bloody diarrhea
Faulty triggering	Clinician considers inappropriate conclusion based on current data, or fails to consider conclusion reasonable from data	Wrong diagnosis of pneumonia in a patient with hemoptysis: never considered the eventual diagnosis of vasculitis
Misidentification of a symptom or sign	One symptom is mistaken for another	Missed cancer of the pancreas in a patient with pain, radiating to the back, attributed to GERD
Distraction by other goals or issues	Other aspects of patient treatment (e.g. dealing with an earlier condition) are allowed to obscure diagnostic process for current condition	Wrong diagnosis of panic disorder: patient with a history of schizophrenia presenting with abnormal mental status, found to have CNS metastases
Faulty interpretation of a test result	Test results are read correctly, but incorrect conclusions are drawn	Missed diagnosis of *Clostridium difficile* enteritis in a patient with a negative stool test result
Reporting or remembering findings not gathered	Symptoms or signs reported that do not exist, often findings that are typically present in the suspected illness	None encountered
Faulty synthesis: faulty verification		
Premature closure	Failure to consider other possibilities once an initial diagnosis has been reached	Wrong diagnosis of musculoskeletal pain after a car crash: ruptured spleen ultimately found
Failure to order or follow-up on appropriate test	Clinician does not use an appropriate test to confirm a diagnosis, or does not take appropriate next step after test	Wrong diagnosis of urosepsis in a patient: bedside urinalysis never performed
Failure to consult	Appropriate expert is not contacted	Hyponatremia inappropriately ascribed to diuretics in a patient later found to have lung cancer; no consults requested
Failure to periodically review the situation	Failure to gather new data in order to determine whether situation has changed since initial diagnosis	Missed colon cancer in a patient with progressively declining hematocrit attributed to gastritis

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Table 1 (continued)

Type	Definition	Example
Failure to gather other useful information to verify diagnosis	Appropriate steps to verify diagnosis are not taken	Wrong diagnosis of osteoarthritis in a patient found to have drug-induced lupus after ANA testing
Overreliance on someone else's findings or opinion	Failure to check previous clinician's diagnosis against current findings	Outpatient followed with diagnosis of CHF, admitted with increased shortness of breath, later found to have lung cancer as the cause
Failure to validate findings with patient	Clinician does not check with patient concerning additional symptoms that might confirm/disconfirm diagnosis	Wrong diagnosis of bone metastases in a patient with many prior broken ribs
Confirmation bias	Tendency to interpret new results in a way that supports one's previous diagnosis	Wrong diagnosis of pulmonary embolism: positive test for D-dimer taken to support this diagnosis in a patient with respiratory failure due to ARDS and Gram-negative sepsis

ANA, antinuclear antibody; ARDS, adult respiratory distress syndrome; CHF, congestive heart failure; CNS, central nervous system; GERD, gastroesophageal reflux disease; PSA, prostate-specific antigen. From Graber [3]; used with permission.

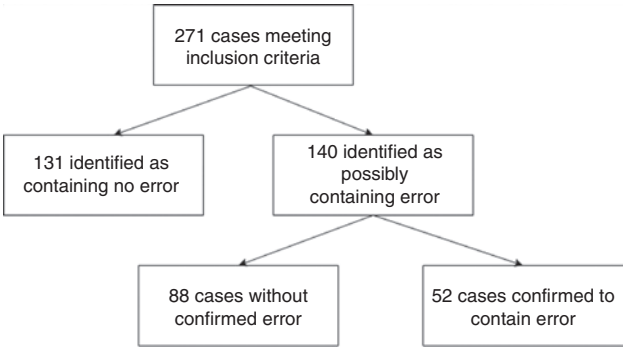

Figure 1: Flow diagram for cases reviewed in this study.

were "misjudging the salience of a finding" and "premature closure", which each represented 13% (95% CI 8–20%) of the identified types of error. In cases with confirmed error, the most common body system involved was hepatobiliary (e.g. missed cholecystitis), representing 19% of the cases, followed by pulmonary (e.g. pneumonia too sick to discharge), representing 13% of the cases; see Table 3 for the percentage of errors by body system. We also noted that a significant portion of the cases involved patients with a history of substance abuse (12% of cases) and patients with psychiatric illness and congestive heart failure (each 8% of cases); Table 4 shows the incidence of errors associated with risk factors identified in our study.

Discussion

To the best of our knowledge, this is the first study to categorize and quantify the cognitive factors that contribute to errors in the ED. Our study shows that, similar to an inpatient internal medicine environment, the cognitive factors that contribute to error most often in 72 h revisits are faulty information processing and faulty verification of data.

Previously published literature from other medical disciplines shows mixed results regarding what types of cognitive errors are most common in diagnosis. An analysis of admitted patients found that errors of knowledge application were most frequent [14], similar to the results of this study. However, a study of primary care visits found a large number of errors involving history taking and examination of the patient [15] and a study of intensive care unit patients found that "failure to carry out the intended treatment" was the most frequent type of error [16]. While some of these differences may be accounted for by the differences in clinical environments, the lack of an effective, comprehensive and agreed-upon methodology for measuring cognitive error is likely a significant contributing factor to these discrepancies [3]. The presence of trainees in an academic ED theoretically increases the likelihood that inadequate knowledge is contributing to error [17]; over half of the residents in one survey acknowledged that insufficient knowledge may have contributed to a recent error in their care [18]. Despite trainees' limited clinical experience, errors of data gathering and knowledge do not appear in our study to occur more frequently in the ED setting.

Past literature is also mixed on the question of what types of cardinal presentations are most likely to be prone to error and revisits. One study in Taiwan found that patients with abdominal symptoms were at highest risk to return [19], similar to the high prevalence of errors

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Table 2: Incidence of each type of error identified, grouped by error type.

Type of error	Error type	Number of times error identified
Knowledge	Knowledge base defective/inadequate	3
	Skills inadequate or defective	4
Data gathering	Ineffective, incomplete or faulty workup	13
	Ineffective, incomplete or faulty history and physical examination	9
	Faulty test or procedure techniques	0
	Failure to screen	0
	Poor etiquette leading to poor data quality	0
Information processing	Faulty context generation	13
	Overestimating or underestimating usefulness or salience of a finding	15
	Faulty detection or perception	0
	Failed heuristics	3
	Failure to act sooner	0
	Faulty triggering	10
	Misidentification of a symptom or sign	1
	Distraction by other goals or issues	3
	Faulty interpretation of a test result	9
	Reporting or remembering findings not gathered	0
Verification	Premature closure	15
	Failure to order or follow-up on appropriate test	6
	Failure to consult	4
	Failure to periodically review the situation	5
	Failure to gather other useful information to verify diagnosis	1
	Overreliance on someone else's findings or opinion	4
	Failure to validate findings with patient	0
	Confirmation bias	2

Table 3: Incidence of each type of error, grouped by system.

Primary system involved	Number of cases	Percentage of total cases, %
Cardiac	6	12
Pulmonary	7	13
Hepatobiliary	10	19
Gastrointestinal	5	10
Genitourinary	3	6
Obstetrics/gynecologic	3	6
Metabolic	6	12
Neurologic	4	8
Otolaryngology	1	2
Dermatologic	4	8
Orthopedic	1	2
Psychiatric	1	2
Hematologic	1	2

Table 4: Incidence of errors associated with each risk factor.

Risk factor	Number of cases	Percentage of total cases, %
Substance abuse	6	12
Psychiatric illness	4	8
Congestive heart failure	4	8
Human immunodeficiency virus (HIV)	3	6

in return visits categorized as 'hepatobiliary' or 'gastrointestinal' in our study. A Dutch study found a similarly high rate of returns for abdominal pathology, but also a high rate of returns for patients with urinary symptoms [20], which our study did not find. Upper respiratory tract infections were the most common reason for a revisit in a Hong Kong ED study [21], and a study of physician-recalled errors found that the most frequently reported errors involved pulmonary problems [22]. Our study did not calculate the distribution of complaints by system for all visits to the ED at our study site, but the rates of error found in our study for hepatobiliary complaints (19% of cases) and gastrointestinal complaints (10%) were significantly higher than the rate of ED visits nationally for all gastrointestinal complaints (6% of all visits) [23], suggesting that intra-abdominal complaints may be more vulnerable to diagnostic and cognitive error. While the poor localization of visceral pain lends biologic plausibility to this idea, cultural and health care delivery system differences may also play a role and more study is needed in this area.

Our study concurred with previous findings that patient factors can be a significant contributor to diagnostic and cognitive error [24]. Specifically, patients with psychiatric disease [25], substance abuse [26] and

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congestive heart failure [27] are known to have a high frequency of ED revisits; diagnosis and ideal management may be difficult in these populations. In our study, errors in each of these at-risk populations appeared more frequently than the rate of ED visits nationally for these issues. Substance abuse was the source of 12% of errors identified but represented only 7% of ED visits nationally. Psychiatric disease was tied to 8% of errors in our study but represented only 4% of ED visits nationally. Congestive heart failure was related to 8% of errors but was the source of 3% of national ED visits, and patients with human immunodeficiency virus (HIV) were tied to 6% of errors, while making up only 0.4% of ED visits [23]. However, the overall number of cases analyzed in this study is small, which may limit the generalizability of these conclusions.

A variety of techniques have been explored to attempt to reduce errors of information processing. Classically, two types of diagnostic thinking have been described, with System 1, or rapid pattern recognition, being vulnerable to error and System 2, or effortful logical reasoning, being a safety net which can catch errors [28]. Consequently, some efforts at error reduction have focused on cognitive forcing strategies, designed to reorient clinicians to alternative diagnostic possibilities at pre-specified points in the workup (such as pop-up reminders in the electronic medical record). Unfortunately, while these interventions succeed in making physicians more deliberate, they may not reduce cognitive error [29–31], suggesting that System 2 may not be as effective as suggested at eliminating information synthesis problems. Additionally, experienced physicians may be able to effectively use System 1 thinking to make their workflow more efficient by rapidly categorizing patients without making errors [32]. While some research shows that only additional clinical knowledge and experience reduces cognitive error [33], other evidence has suggested promise for guided reflection and cognitive forcing strategies [34, 35]. Ultimately, the effectiveness of interventions to reduce error may be context dependent; checklists have been shown to be effective in some contexts but not others [36]. More research is still needed to determine what strategies may be most effective for reducing cognitive errors in the clinical environment.

Limitations

There are several potential sources of bias for this study. Though many of our errors were attributed to either premature closure or misjudging the salience of a finding, managing patients is a complex and dynamic interaction between knowledge and interpretation and it is possible that knowledge issues may affect information processing and verification. Additionally, while Croskerry and others have described many of the types of cognitive errors that occur [37] as well as the clinical situations in which they are most likely to be found, in practice, it can be difficult to categorize real errors that occur in the clinical setting as descriptions overlap and the error types lack strict criteria; we did not categorize distal causes of error in this analysis [38]. Our definition of a revisit may have also systematically affected our results, as a missed important finding such fracture would be unlikely to have been admitted on their second visit.

The results of this study are also based on a retrospective review, which may have overestimated the incidence of errors, as the reviewers have the benefit of hindsight. In an effort to reduce hindsight bias and give maximum deference to providers, we attempted to include only cases of clear cognitive error. Our study is also limited by its single center nature, as patients may have returned and been admitted at other hospitals, as well as our documentation, as what was documented in the original medical record and the quality review case summaries may not fully reflect potential issues. As there is no gold standard for determining whether an error occurred or what cognitive factors may have contributed, we relied on group consensus, which can be subject to bias. Finally, as the classification system we used for cognitive factors contained more factors categorized as information processing and verification factors than those categorized as knowledge or data gathering factors, this may have contributed to the increased frequency that these factors were seen in our study.

Conclusions

Errors of information processing and verification were the most commonly identified errors in a study of patients with 72 h revisits to an academic ED. Patients with abdominal complaints were at highest risk for cognitive errors in diagnosis. Further standardization around describing and quantifying cognitive errors is needed to further elucidate how these errors impact care in the ED environment.

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