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Diagnostic Error Categorization at Abdominal Imaging Peer Learning Conference

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Recognizing and preventing diagnostic errors is an increasingly emphasized topic across medicine, and abdominal imaging is no exception. Peer-learning strives for quality improvement through understanding why errors occur and identifying opportunities to prevent errors from recurring. In an effort to learn from mistakes, our abdominal imaging section initiated a Peer Learning Conference, where errors are discussed and compartmentalized into one or more of the following categories: Observation, Interpretation, Communication, and Inadequate Data Gathering. In this manuscript, the structure of our Peer Learning Conference is introduced and the components of each discrepancy category are described in detail. Images are included to highlight learning points through exemplary cases from the conference.

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Background

In response to the 2015 Institute of Medicine report on "Improving Diagnosis in Health Care," there has been a heightened emphasis on identifying and reducing diagnostic errors in medicine.[1-3] The institute's report takes a patient-centered approach and defines diagnostic error as "the failure to (a) establish an accurate and timely explanation of the patient's health problem(s) or (b) communicate that explanation to the patient."[1] The importance of health care providers collaborating as a diagnostic team is emphasized as a means to minimizing diagnostic errors, and the increasingly integral role radiologists play as members of the team is highlighted.[1] With most estimates of imaging interpretation error around 3%-4%, the potential to improve diagnostic performance and reduce patient harm by identifying and learning from these errors is substantial.[4-7]

Traditional radiology quality assurance peer review models strive to ensure patient safety and reduce errors through randomized review of cases by peers.[8] The most common method for radiology peer review in the United States is the American College of Radiology RADPEER program, which allows for peer review during the routine interpretation of current exams and utilizes a scoring system tied to the severity of the error.[8] In contrast, peer-learning quality improvement focuses on why an error occurs and on identifying learning opportunities to prevent future errors.[9,10] Errors are classified and analyzed for contributing factors, to allow for constructive and nonpunitive feedback.[9] A group peer review process is one method that allows for the dissemination of information from the errors of greatest learning potential and provides an opportunity to address topics of frequent inter-reader variation.[9,10]

To promote open discussion on diagnostic performance and attempt to reduce diagnostic errors, our abdominal section initiated a Peer Learning Conference. In this manuscript, we introduce the conference structure and share our categorization process. Our objective is not to focus on specific errors that have occurred in our group but rather to introduce the categorization and how they are incorporated into a Peer Learning Conference.

Materials and Methods: Peer Learning Conference

When our abdominal imaging section initiated a Peer Learning Conference 2 years ago, a section member was appointed the Peer Learning Director (Director). The primary role of the Director is to compile nonrandom cases referred directly via email and in person as well as through multidisciplinary conferences (such as hepatobiliary, colorectal, and genitourinary). Random cases submitted for RADPEER scoring through primordial (Nuance, Burlington, MA) are also sent to the Director by the Vice Chair of Quality for the department. Interpreting radiologists are notified immediately of any potential discrepancy, to allow for addendum and timely review if patient care may be impacted. However, only the presence or absence of a discrepancy is recorded for the purposes of the Peer Learning Conference, and the name of the involved radiologist is removed. All cases are added to an anonymized personal folder within our Picture Archiving and Communication System (PACS), and the Electronic Medical Record (EMR) is reviewed by the Director or designee for each patient, to determine if the error impacted patient management or outcome.

Select cases with the most learning potential as determined by the Director or designee are presented to the section via a combination of PowerPoint and PACS at a bi-monthly Peer Learning Conference. During the conference, section members discuss each case, assign the

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error to a category, and identify contributing factors. The focus of discussion is on why an error occurred and what steps can be taken to prevent the error from happening again, rather than who made the error and the error severity. The conference is also used as a platform to discuss interobserver variability and imaging technique quality assurance.

Each error category is described below, along with select cases to illustrate the educational and practice improvement potential of a Peer Learning Conference.

Discussion: Categorization of Errors

Rather than scoring error severity, which can create a punitive feel and introduce bias, errors in a peer-learning environment are categorized in a way that promotes analysis and identification of contributing factors. Building off of previously published classifications, we use a simplified system with 4 categories: (1) errors of observation/perception, (2) errors of interpretation/judgment, (3) errors of communication, and (4) inadequate patient data gathering.[11-14] Any given error may overlap into more than 1 category.

Finally, we include a separate set of cases for observer variability. While not considered an error in itself, observer variability reflects an area where improving consistency across radiologists within the section may positively impact patient care.

Observation/Perception

An observational or perceptual error occurs when an imaging abnormality is present but not perceived at the time of interpretation.[11,12,15] Causes can stem from factors specific to the individual radiologist or external/system-related issues. These errors may occur despite diligent review, with the pathology readily apparent in retrospect.[16]

Observational errors have been investigated utilizing eye-tracking technology and shown to occur when there is a failure to fixate on pathology with high-resolution foveal vision or a failure to fixate for a duration above a threshold needed to recognize pathology features.[17-19] In practical terms, this can occur when a radiologist's visual search pattern excludes the area of pathology or deviates from their norm, leading to an incomplete assessment of the examination. Observational errors have been shown to be more common when the workload is high and radiologists attempt to read cases at a faster than preferred pace.[17,20,21] In this environment, the challenge of balancing thorough interpretations with delays in report turnaround times (and ultimately patient care) can lead to stress and distraction.[17,22,23] Satisfaction of search, or the premature termination of a visual search after detecting 1 abnormality, is an observational error that is more likely to occur in this setting (Fig 1).[11,12]

Other psychophysiological factors that can contribute to observational errors include visual fatigue or mental/decision fatigue.[24] External distractors or interruptions, such as a phone call or being paged while interpreting a case, can lead to search pattern disruptions. Furthermore, environmental factors, such as poor lighting conditions or inadequate image window/level display, can impact the conspicuity of abnormalities (Fig 2).[24]

Practice Improvement Example

Perceptual errors discussed in the conference included findings on the edge of the scan length. For example, overlooked lower lobe

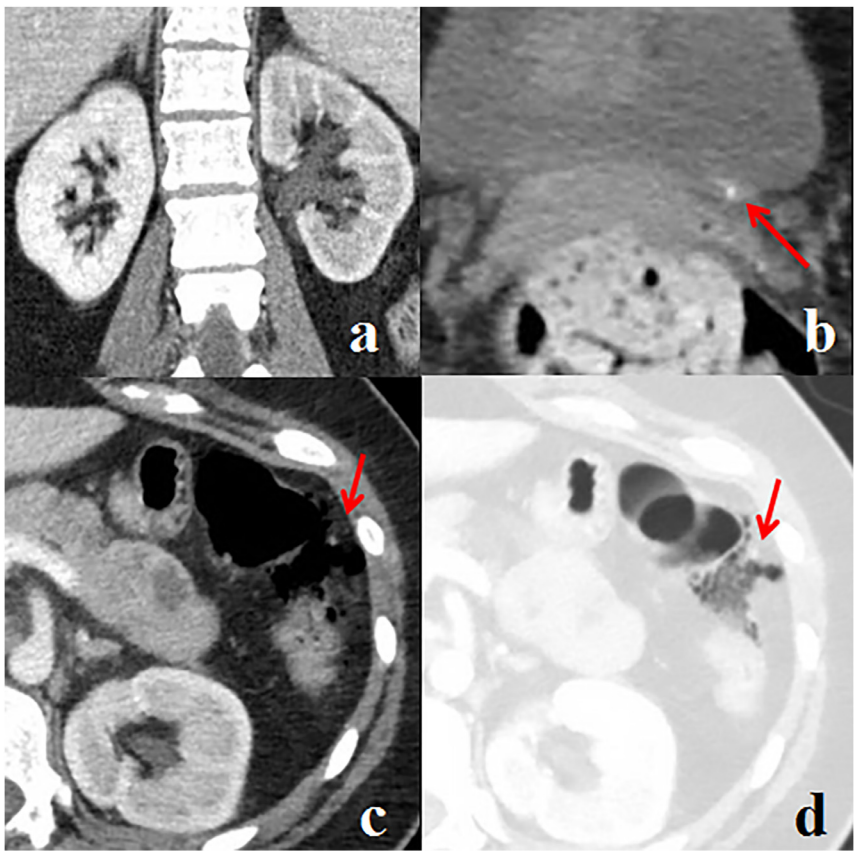

FIG 1. Error of observation due to satisfaction of search. A 28-year-old female presented with left abdominal pain. Contrast-enhanced CT demonstrates left hydronephrosis (a), secondary to obstructing calculus at the left ureterovesical junction (arrow, b). Initially, free air in the left upper quadrant (arrow, c), more conspicuous on "lung" window (arrow, d) was overlooked. Upon further review the free air was noted by the radiologist and surgery confirmed contained perforation of the splenic flexure. CT, computed tomography.

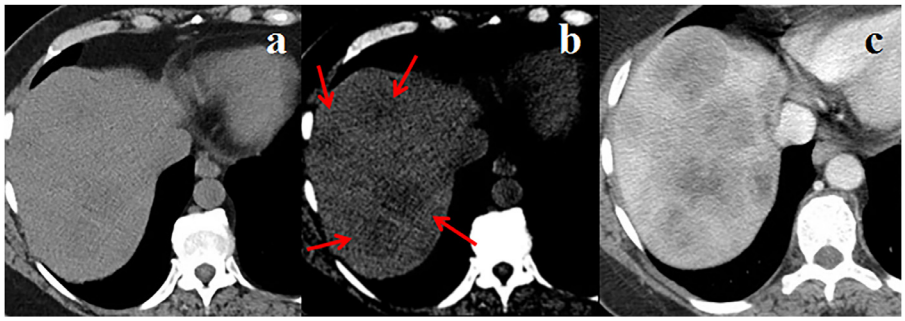

FIG 2. Error of observation due to inadequate windowing. A 64-year-old female presented to an outside hospital with generalized abdominal pain. Unenhanced CT appearance of the liver interpreted as normal (a), however, in hindsight, multiple hypodense lesions are visible, more conspicuous when a "liver" window is utilized (arrows, b). These lesions were identified on contrast-enhanced CT obtained 2 months later for unintentional weight loss (c), and the patient was subsequently diagnosed with biopsy proven metastatic colon cancer. CT, computed tomography.

pulmonary emboli on images through the lower chest or femoral vein deep venous thromboses on the inferior most images of abdominopelvic computed tomography (CT). Through group discussion, the decision was made to expand our standardized abdominal report templates to encompass the lower chest and pelvic vasculature in further detail.

Interpretation/Judgment

An error in interpretation or judgment occurs when an imaging finding is identified by the radiologist but the attributed significance is inaccurately characterized.[11,14,15] As the practice of radiology often involves interpreting imaging findings in the context of a differential diagnoses, the ground-truth is rarely available prospectively. Therefore, it is important to distinguish between interpretive error and observer variation. A true error is a discrepancy that substantially differs from the consensus of one's peers.[4,17]

Inadequate knowledge base can lead to interpretative errors. While rarely attributed as a cause for experienced radiologists,[13] knowledge base can be a factor for radiologists in training, radiologists recently completing training, and radiologists practicing outside of their subspecialty (Fig 3).[25]

Cognitive biases are important contributors to errors of interpretation and result from failed heuristics, or mental shortcuts that allow rapid problem solving based on assumptions and past experiences. Many decisions are based on the perceived likelihood of uncertain events and cognitive biases occur when these mental shortcuts fail, leading to systematic errors in interpretation.[24,26-29] Many cognitive biases exist; however, we have observed the following to be pertinent to interpretative errors in our abdominal imaging practice.

The first is *Anchoring Bias*, where an initial impression is made and not adjusted when subsequent information is discovered.[24,30] An example would be interpreting a pelvic wall mass as malignancy and not considering alternate diagnoses when the medical chart confirms a history of endometriosis. Another type of cognitive error is *Framing Bias,* or being too strongly influenced by the way the problem is presented.[24,30] For example, dismissing a nondisplaced fracture as artifact because the provided history did not mention trauma. Finally, *Availability bias* entails considering a diagnosis more likely when it readily comes to mind.[24] For example, immediately interpreting a thick-walled gallbladder as cholecystitis and failing to consider malignancy (Fig 4).

Often influenced by cognitive biases, "over-calls"—describing pathology that is not present, and "under-calls"—dismissing a clinically significant finding, are also categorized as judgment errors. The degree of pretest suspicion frequently contributes to these errors. Known as the prevalence effect, a particular abnormality is more likely to be attributed to pathology in a high-risk population (such as incorrectly interpreting a hemangioma in the liver as a metastasis in

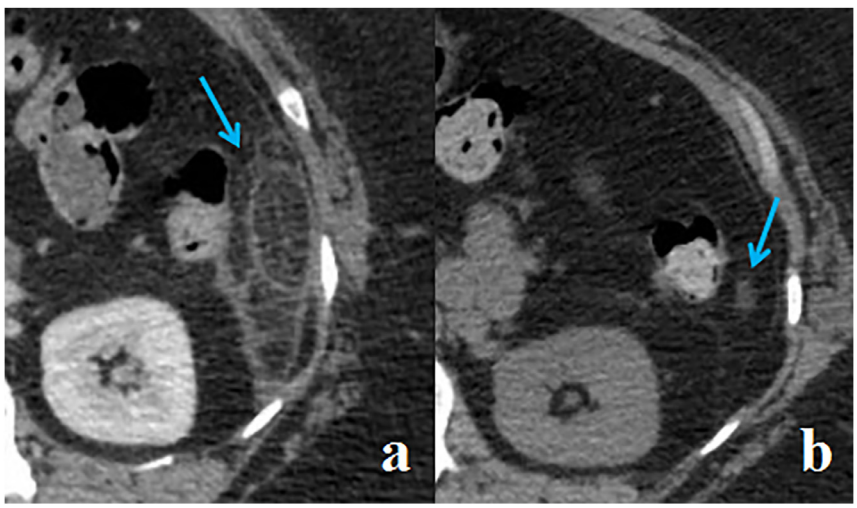

FIG 3. Error of interpretation due to inadequate knowledge base. A 47-year-old female presents with left lower quadrant pain. Contrast-enhanced CT demonstrates a focal fat-density ovoid structure with a peripheral hyperdense rim and surrounding inflammation in the greater omentum near the splenic flexure (arrow, a), interpreted as acute diverticulitis. Unenhanced CT 6 months later demonstrates scarring in the greater omentum (arrow, b) and no colonic diverticula. Therefore, findings on the initial study are most consistent with Epiploic appendagitis. CT, computed tomography.

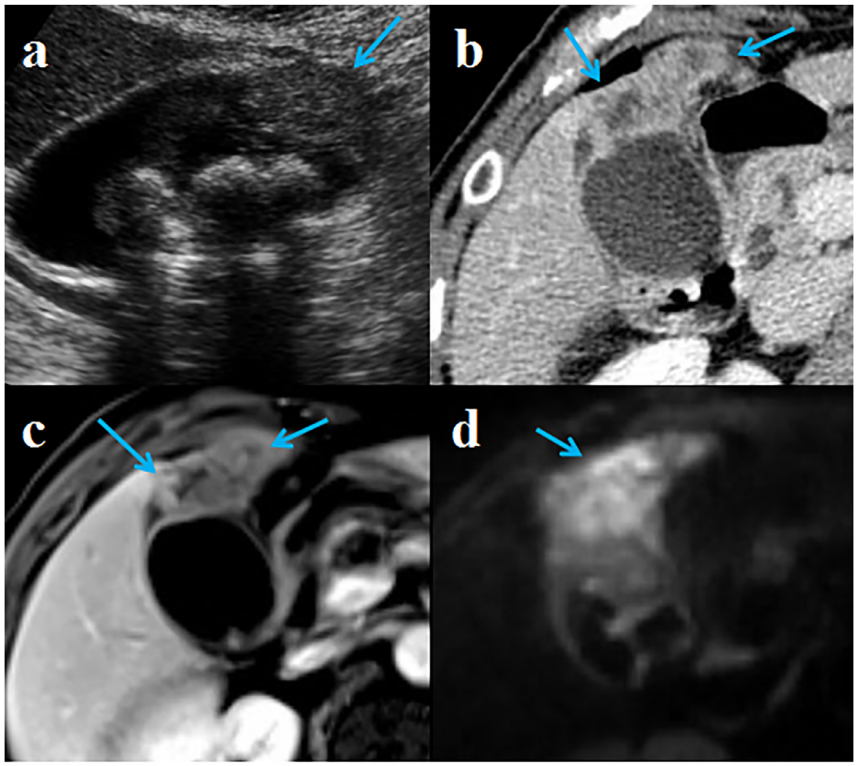

FIG 4. Error of interpretation due to availability bias. A 63-year-old female presents with abdominal pain and elevated Liver function tests (LFTs). Abdominal ultrasound demonstrates gallstones and nondependent echogenic material in the gallbladder fundus (arrow, a), which the radiologist favored to represent gallbladder sludge. The patient had an elective cholecystectomy, which was aborted secondary to gallbladder mass. Contrast-enhanced CT demonstrates a mass invading the hepatic parenchyma (arrows, b), likely gallbladder carcinoma. Contrast-enhanced MRI demonstrates an enhancing mass (arrows, c) with avid restricted diffusion (arrows, d) extending from the gallbladder fundus into hepatic segments 4A and 4B. MRI, magnetic resonance imaging.

a patient with metastases elsewhere, despite classic hemangioma imaging features) and dismissed in conditions of low prevalence (eg, not considering pancreatic cancer in a young patient, despite classic imaging features).[17]

Practice Improvement Example

An over-call can lead to unnecessary work-up and patient anxiety. At our Peer Learning Conference, over-calls are a subset under the category of errors in Interpretation and receive special discussion. In a nonjudgmental setting, the conference provides the opportunity to reiterate applicable societal guidelines and the American College of Radiology (ACR) appropriateness criteria.

Communication

Errors of communication occur when imaging findings are correctly identified and interpreted, but the relay of this information to the provider (and ultimately the patient) is delayed.[11,31] This error is of particular significance when a finding is emergent or unexpected (Fig 5). Due to increased imaging volume demands, the widespread availability of PACS, and diminished in-person radiologist-clinician interactions, it is useful to have a system-based solution in place to alert providers of emergent and unexpected findings, as well as document that the report was reviewed by the clinician. Most modern EMR will allow for notifications and provide an audit log of health care providers that have viewed the report. Calling clinicians for all critical findings remains the standard of care at our institution and appropriate documentation includes the date, time, names of the health care providers who exchanged the information, and the specific findings discussed per the American College of Radiology (ACR) practice parameters for communication of diagnostic imaging findings.[11,14]

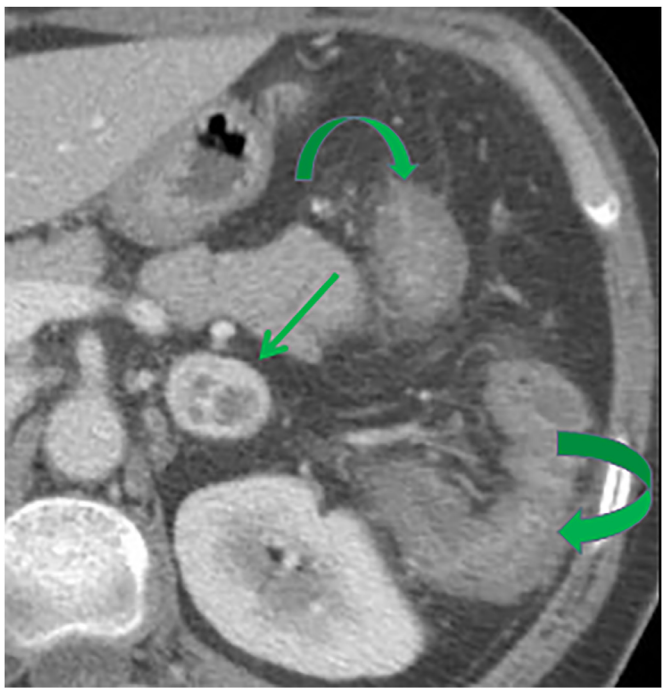

FIG 5. Error of communication due to failure to convey significance. A 51-year-old female presents with abdominal pain and rectal bleeding. Contrast-enhanced CT obtained in the emergency department. The radiologist described colitis involving the splenic flexure (curved arrows) and incidental left adrenal gland lesion measuring 2.6 cm (arrow). The conclusion did not include a differential diagnosis or recommendation for further work-up of the adrenal lesion. After revision, the radiologist noted avid enhancement was concerning for pheochromocytoma and recommended correlation with plasma-fractionated metanephrines. At surgery, pheochromocytoma was confirmed. CT, computed tomography.

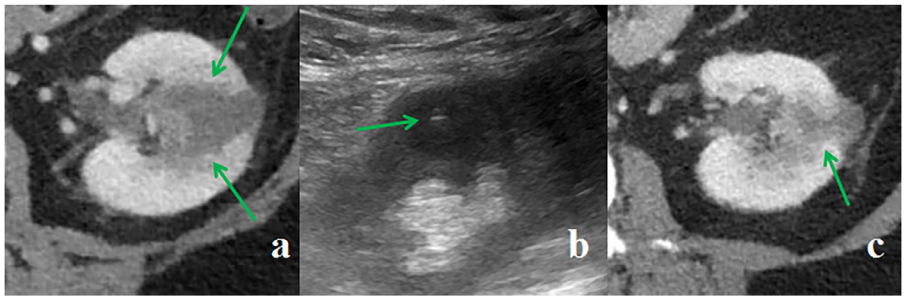

FIG 6. Error of communication due to failure to recommend next step. A 63-year-old female presents to the emergency room (ER) with fevers, chills, and abdominal pain. Contrast-enhanced CT demonstrates cystic lesion with enhancing rim in the left kidney (arrows, a). Initial report included primary renal malignancy and abscess in the differential diagnosis with no additional recommendations. After discussion with the urologist, the radiologist revised the report and recommended aspiration (arrow, b). Follow-up contrast-enhanced CT after aspiration of puss and appropriate antibiotic treatment showed resolving abscess (arrows, c). CT, computed tomography.

On occasion, a poorly structured report or over-encompassing differential may fail to adequately convey the seriousness of a finding. This can lead to delayed or inappropriate action on behalf of the provider. Similarly, the failure to recommend the next appropriate step when deemed necessary can also delay care or result in patient harm (Fig 6).[11,14,32]

Standardized report templates have been shown to improve communication between referring physicians and radiologists.[24,33] However, care must be taken to correctly modify these templates on a per-case basis. For example, an unedited abdominal ultrasound template may inadvertently state that the gallbladder is within normal limits for a patient who previously underwent cholecystectomy. Therefore, in some cases, empty fields for each organ system may be preferable, which require the dictating radiologist to actively describe findings rather than passively move through a pre-filled template.

Transcription/voice recognition software errors also fall under errors of communication and can range from inconsequential to clinically significant.[34,35] Regardless of the clinical significance, this type of error can lead to the assumption by the provider or patient that the radiologist's interpretation was rushed and therefore not trustworthy. Words that sound similar, such as “sclerosis” and “cirrhosis,” are often interchanged and short words at the beginning of a sentence may fail to register if spoken before the microphone is activated; for example, critically altering the impression “No appendicitis” to “Appendicitis.” Finally, laterality errors are communicative in nature and can be clinically significantly, including the potential for severe consequences if not discovered prior to intervention or surgical planning (Fig 7).[36]

Practice Improvement Example

When CT images are acquired with the patient prone, our technologists customarily “flip” the images horizontally and vertically so that the exam simulates conventional supine positioning prior to radiologist interpretation. On rare occasion, exams are inadvertently submitted with incomplete inversion (vertical but no horizontal flip), leading to a left-right laterality reversal. While abdominal organ anatomy tends to preclude any confusion, anatomic symmetry within the pelvis can lead to incorrect labeling of left and right (Fig 7). A laterality reversal of this nature occurred at our institution, which led to a communicative error and ultimately surgical intervention on the wrong side. The CT technologists were invited to attend the subsequent Peer Learning Conference, where the case and error were discussed in a nonjudgmental forum. The consensus was that multiple systematic failures occurred. Based on the analysis, an action plan was executed that encompassed additional CT staff and radiologist training to raise awareness and avoid this type of preventable error from recurring.

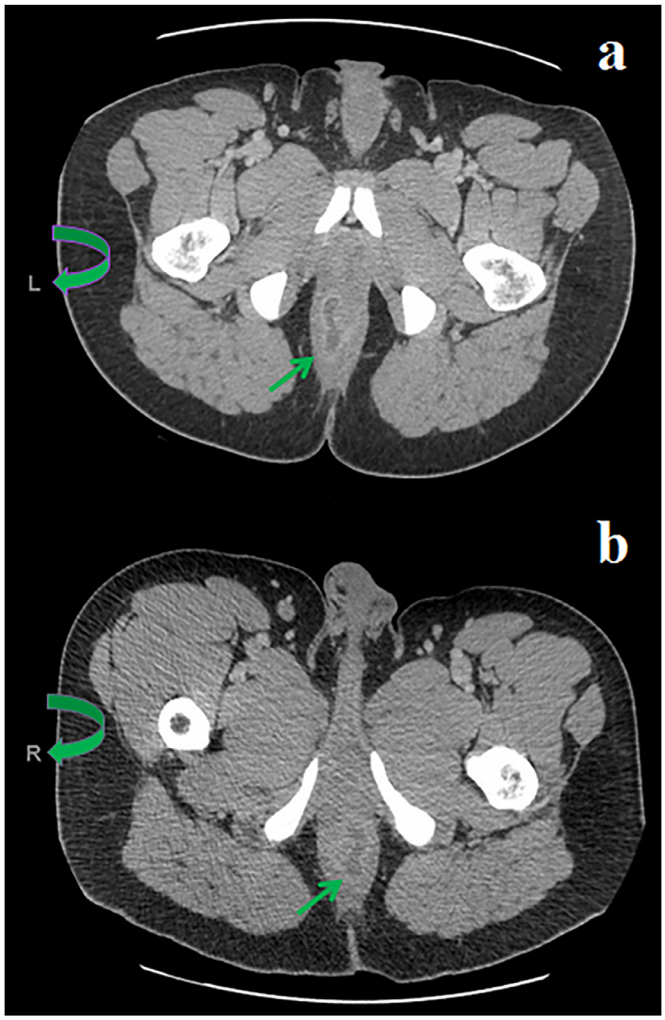

FIG 7. Error of communication due to laterality error. A 25-year-old male presents with perirectal pain. Contrast-enhanced CT was performed in the prone position with the soft tissue algorithm images inverted prior to PACS upload. Left marker is seen on the radiographic right (curved arrow, a) and the CT table can be seen anteriorly. The perirectal abscess (straight arrow, a) was described on the right side and the patient was taken to the operating room (OR) for incision and drainage where no purulent material was found. Repeat CT on the same day in the supine position demonstrates the perirectal abscess on the left (straight arrow, b). The patient was taken back to the operating room (OR) for successful incision and drainage. CT, computed tomography; PACS, Picture Archiving and Communication System.

Inadequate Patient Data Gathering

The history or indication provided with an abdominal imaging order requisition is rarely comprehensive. Therefore, this information may not be sufficient when interpreting examinations on patients

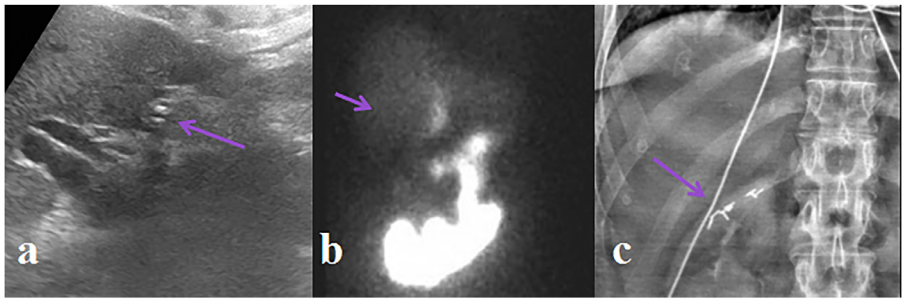

FIG 8. Inadequate patient data gathering failure to compare prior exams across modalities. A 60-year-old ICU patient with sepsis and abnormal Liver function tests (LFTs). Echogenic structures with posterior shadowing in the gallbladder fossa (arrow, a) interpreted as gallstones in a contracted gallbladder. Acute cholecystitis was included in the differential diagnosis given cholelithiasis and small volume pericholecystic fluid. Nuclear medicine hepatobiliary iminodiacetic acid (HIDA) scan showed no gallbladder filling at 4 hours (arrow, b); however, during interpretation of this exam, cholecystectomy clips were noted on prior abdominal radiograph (arrow, c). History of cholecystectomy was confirmed with the patient. ICU, intensive care unit.

with multiple comorbidities and complex medical problems. EMRs often provide additional information pertinent to the exam indication. Furthermore, with PACS, prior imaging studies can be accessible and complementary.

As with other diagnostic error categories, inadequate patient data gathering is often a consequence of the radiologist's need to balance thorough interpretations with rapid report turnaround times. To avoid serious errors and unnecessary workups, an important component to daily workflow must include investigating patient clinical information and reviewing prior studies, including across imaging modalities (Fig 8). While additional patient information or prior imaging is not always available, this

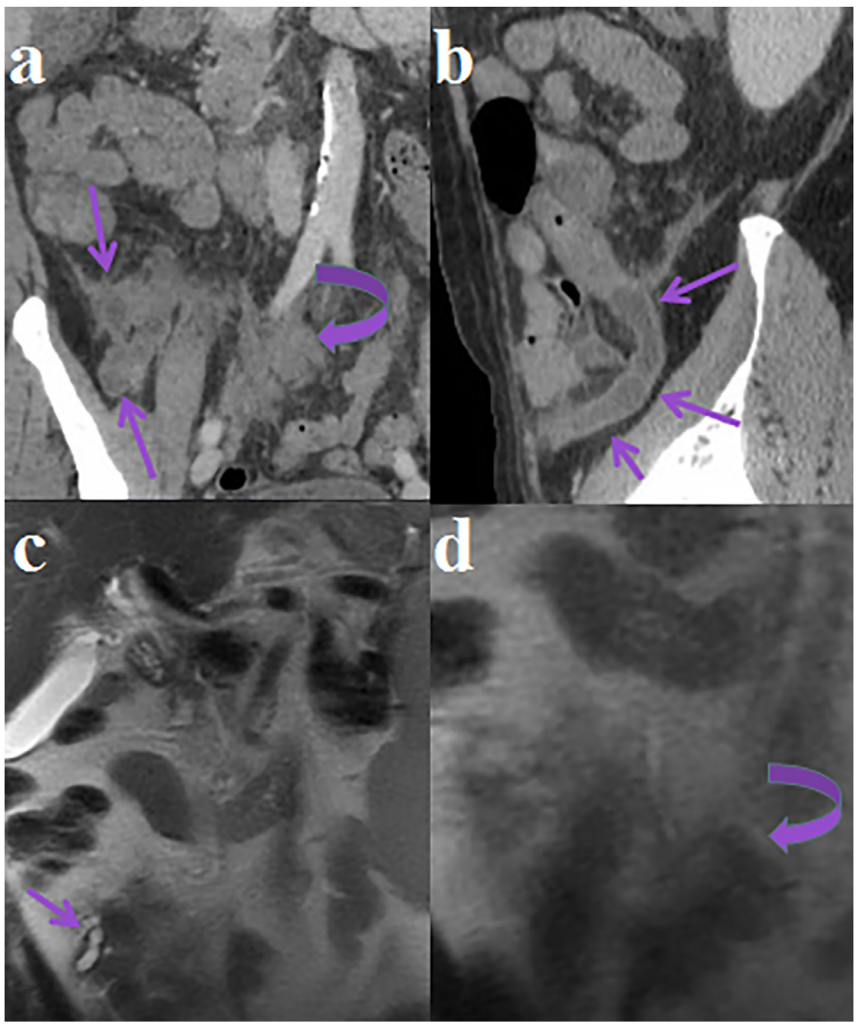

FIG 9. Combination of errors-inadequate patient data gathering and interpretive error due to availability bias. A 66-year-old male with myelofibrosis and pancytopenia presented with fever. Contrast-enhanced CT demonstrates a dilated appendix (straight arrows, a, b) with adjacent soft tissue density (curved arrow, a), concerning for appendicitis with adjacent phlegmon. Follow-up CT 6 days later (not shown) showed no change and further review of an MRI performed 8 months prior revealed a dilated appendix in retrospect (straight arrow, c) and similar adjacent soft tissue mass (curved arrow, d). Therefore, mucocele of the appendix with adjacent sclerosing extramedullary hematopoiesis was favored. CT, computed tomography; MRI, magnetic resonance imaging.

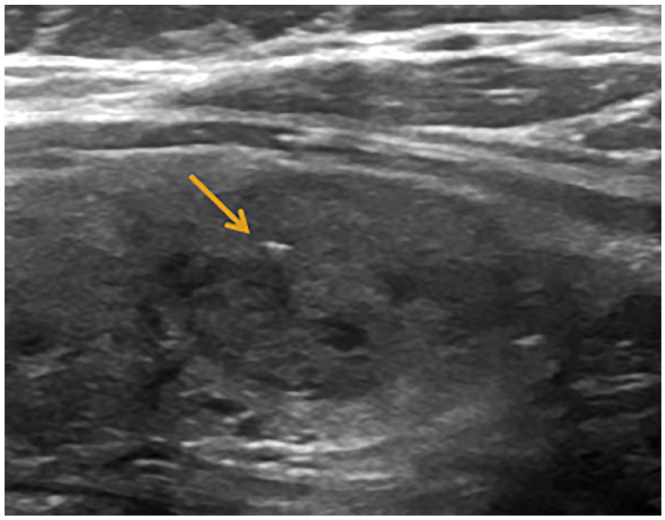

FIG 10. Observer variability. A 58-year-old female with multiple incidental thyroid nodules on chest CT presented for follow-up thyroid ultrasound. A 2.0 cm mixed solid and cystic hypoechoic nodule is seen in the right thyroid lobe with an echogenic focus (arrow), interpreted as TIRADS 4—moderately suspicious, and fine-needle aspiration was recommended. A second radiologist noted comet tail artifact associated with the echogenic focus, classifying the lesion TIRADS 3—mildly suspicious. Therefore, according ACR TIRADS, this nodule does not meet criteria for fine needle aspiration (FNA) could be followed with surveillance imaging. CT, computed tomography; TIRADS, Thyroid Imaging Reporting and Data System.

data should be incorporated whenever possible prior to formulating a diagnosis.[11,37]

Practice Improvement Example

Through conference discussion, inadequate data gathering in our practice was often attributed to the pressures of timely report turnaround. Accessing the EMR was cumbersome and slowing down workflow. In response, requests were made to the department and institution for an integrated EMR-PACS solution, which has since been incorporated and allows for more expeditious review.

Combination of Contributing Factors

Errors are inherent to any organizational system. An effective system attempts to reduce harm from these errors by having multiple barriers in place. In 1990, James Reason presented what is referred to as the "Swiss Cheese Model" of system failure.[38] Every step in the process is analogous to a slice of Swiss cheese, with the holes reflecting varying potentials for failure. For a single slice, the likelihood to pass through a hole may be high. However, with a stack of slices, the likelihood that holes overlap for all of the slices is much lower.[38] In other words, an error may breech 1 barrier but should be captured by subsequent levels of defense within the system. Returning to health care, when barriers fail, patient harm may occur. However, more levels of defense (slices of cheese) increase the opportunity to stop an error. In radiology practice, many system failures are the result of a combination of the aforementioned diagnostic errors (Fig 9).

Observer Variability

In contrast to an error, observer variability occurs in situations where a gold standard or consensus does not necessarily exist.[11,39] Variability in radiology reporting overlaps with categories where errors are encountered, including perception, interpretation, and communication.[11,39] Further, variations can be interobserver or intraobserver (variations in reporting by the different radiologists or the same radiologist, respectively). As an interobserver example, a thyroid nodule may be interpreted by 1 radiologist as warranting tissue sampling. However, when the patient returns for ultrasound-guided fine-needle aspiration, the radiologist tasked with performing the intervention may feel the imaging characteristics fail to warrant intervention (Fig 10).

Practice Improvement Example

Incorporating standardized reporting systems into our practice have led to more consistent reporting and reduced observer variability. However, despite the use of the ACR Thyroid Imaging Reporting and Data System,[40] our section continued to see variability in thyroid nodule reporting. Therefore, the topic was presented at Peer Learning Conference, with imaging examples to highlight the various features mentioned in the template. A follow-up presentation showed specific cases of interobserver variability within our section. We discussed ways to utilize Thyroid Imaging Reporting and Data System to promote consistency across the section.

Future Objectives

As our conference continues to evolve, some future objectives include automating the process of collecting cases, including community radiologists by teleconference, and broadening the discussion to include select resident errors.

Conclusions

Diagnostic errors are a significant issue in abdominal imaging and can be categorized as errors of Observation, Interpretation, Communication, and Inadequate Patient Data Gathering. A Peer Learning Conference allows abdominal radiologists an opportunity to reflect on errors in a nonpunitive environment and identify contributing factors. Classifying errors and understanding factors that contribute to each type of error may assist in making necessary adjustments, with the ultimate goal being improved patient care.

Disclosure of Potential Conflicts of Interest

Andrew James Del Gaizo, Category of Disclosure
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Employee of the Department of Veterans Affairs National Teleradiology Program.
Jason N. Itri, Thomas Pendergrast, and Rafel R. Touppani declare that they have no conflict of interest.

Compliance With Ethical Standards

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Ethical approval: All images in this manuscript were of studies performed for clinical purposes and incorporated into the manuscript via retrospective review. All patient identification information has been removed. Otherwise, this article does not contain any studies with human participants or animals performed by any of the authors.

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