ORIGINAL ARTICLE

Strategies for Improving the Value of the Radiology Report: A Retrospective Analysis of Errors in Formally Over-read Studies

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Abstract

Purpose: The radiology report is a critical component of the Imaging Value Chain. Unfortunately, the quality of this aspect of a radiologist's work is often heterogeneous and fails to add significant value to the referring provider and, ultimately, the patient. Gauging what defines quality can be elusive; however, we elucidate techniques that can be employed to ensure that reports are more comprehensible, actionable, and useful to our customers.

Methods: Four hundred consecutive studies (July-August 2015) submitted to our institution with request for a formal over-read were reviewed retrospectively, specifically focused on analyzing differences in language, organization, and impression between the outside reports and the formal over-reads performed at our institution. The formal over-reads were classified into one of the following categories: (1) no clinically significant change; (2) emergent clinically significant change; (3) nonemergent clinically significant change. Clinically significant changes were further classified as either perceptual or cognitive errors.

Results: A total of 12.4% of formally over-read reports had clinically significant changes. Of these, 22.2% were emergent changes. Clinically significant changes were composed of 64.4% perceptual error and 35.6% cognitive error. Four strategies were discovered specifically related to reporting techniques that helped mitigate these errors on formal over-reads: (1) synthesizing varied anatomic findings into a cohesive disease process; (2) integration of relevant electronic health record data; (3) use of structured reporting; and (4) forming actionable impressions.

Conclusions: We identify, through examples, four strategies for reporting that add value through reduction of radiologic error, helping to mitigate the 12.4% clinically significant error rate found in reinterpretation of outside studies.

Key Words: Structured report, actionable impression, clinical data, error, over-read

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INTRODUCTION

The passage of the Affordable Care Act in March of 2010 ushered in major changes to health care delivery in the United States. Although these changes have taken place in stages, one constant theme has been reducing cost and expanding access through a focus on delivering higher-quality care that is of greater value to all stakeholders. The ACR has responded to this mandate by creating a framework, known as Imaging 3.0®, to help its members meet the growing demands of patients, referring providers, and payors to deliver greater value for imaging services. The central tenet of Imaging 3.0 is to deliver imaging care that is beneficial and necessary, and avoid imaging care that is not [1]. This begins at the moment a referring provider considers requesting an imaging study and extends through to the generation of a radiology report.

Adapted from the business community, a process map for Imaging 3.0 known as the Imaging Value Chain has been established [2], in which two links of the chain are "Interpretation and Reporting" and "Communication," both of which reflect opportunities to add value through quality report generation. Yet, although there is consensus among radiology thought leaders about the necessity of providing greater value, gauging what defines value with regard to the radiology report itself can be elusive [3]. Without a thorough understanding

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of the meaning of value for radiology reporting, this aspect of a radiologist's work is difficult to improve and is often heterogeneous. Typical reports, in the eyes of our referring colleagues and, ultimately, the patient, may fail to add significant value. The purpose of our study is to better define features of a high-quality report and identify strategies and styles that could be employed to improve the value of radiology reporting.

METHODS

One reason that defining quality radiology reporting is difficult is that each imaging study is unique, and thus a "control" report for comparison is often nonexistent. Rarely are two separate reports for the same study dictated by different radiologists available for comparison. If this were the case, a side-by-side comparison could be performed to determine, in the eyes of stakeholders, which report was more valuable. Therefore, there are few examples in the existing literature of how to translate the Imaging 3.0 support columns to daily reporting practice and, in turn, improve patient care.

At our academic institution we routinely over-read a multitude of studies from outside institutions for patients who have their care transferred to our institution. These formal over-reads are requested by our referring colleagues for both inpatients and outpatients and include all modalities. Having two different reports for the same study (one from an outside institution and one generated by a radiologist at our institution) provides a framework to analyze differences in reporting to (1) establish an interobserver error rate and (2) identify factors that contribute to this error rate through direct comparison. Moreover, this analysis allows us to suggest techniques that may be employed to generate reports of higher value.

Four hundred consecutive studies that were submitted to our institution from July to August 2015 with request for a formal over-read were selected for analysis. These studies were reviewed retrospectively, specifically focused on analyzing differences in language, organization, and impression between the outside reports and the formal over-reads performed at our institution. After the two were compared, the formal over-reads were classified into one of the following categories: (1) no clinically significant change; (2) emergent clinically significant change, defined as a necessary change in clinical decision making performed within 12 hours; or (3) nonemergent clinically significant change, defined similarly, with timeframe greater than 12 hours. These determinations were derived through evaluating the longitudinal course of each patient's stay. Specifically we sought to identify how each patient's treatment plan and course was altered if there was a discrepancy in our formal over-read report versus the outside report.

Studies that were determined to have clinically significant changes were then analyzed further, specifically dividing errors into perceptual errors, defined as those that occur during image interpretation when the abnormality is not detected or appreciated, or cognitive errors, defined as those that occur during image interpretation resulting in an incorrect diagnosis being given to a detected abnormal finding. An examination of these errors was then conducted to elucidate patterns of reporting that may contribute to these errors. Finally, suggestions were generated for how to improve reporting to avoid these errors and ultimately add greater value to the radiology report.

RESULTS

Of the 400 consecutive studies reviewed, 362 studies had outside reports available for comparison at the time of formal over-read; those studies without outside reports were excluded from analysis. By modality, these 362 studies were composed of 295 CT, 54 MRI, and 13 ultrasound studies. By subspecialty, the composition of these studies was 179 neurologic, 144 abdominal, 22 cardiothoracic, 14 musculoskeletal, and 3 pediatric.

In our analysis, 12.4% (45/362) of formally over-read reports had clinically significant changes. Of these, 22.2% (10/45) were emergent changes. The other 77.8% (35/45), though not emergent, were deemed clinically impactful. The 12.4% of reports with clinically significant changes was statistically significant when compared with RADPEER-based interobserver agreement data over the same time period for studies conducted at our institution and read solely by radiologists at our institution, where there was a discrepancy rate of 4.8% (P value $< .001$). These results are summarized in Figure 1.

Further evaluation of the 45 studies with clinically significant changes revealed that 64.4% (29/45) were perceptual errors and 35.6% (16/45) were cognitive errors.

DISCUSSION

Our analysis, which identified a 12.4% error rate in the 362 formally over-read studies, is similar to interobserver agreement data in the existing literature. For example, the frequency of major disagreements between radiologists when reading emergency department plain films was

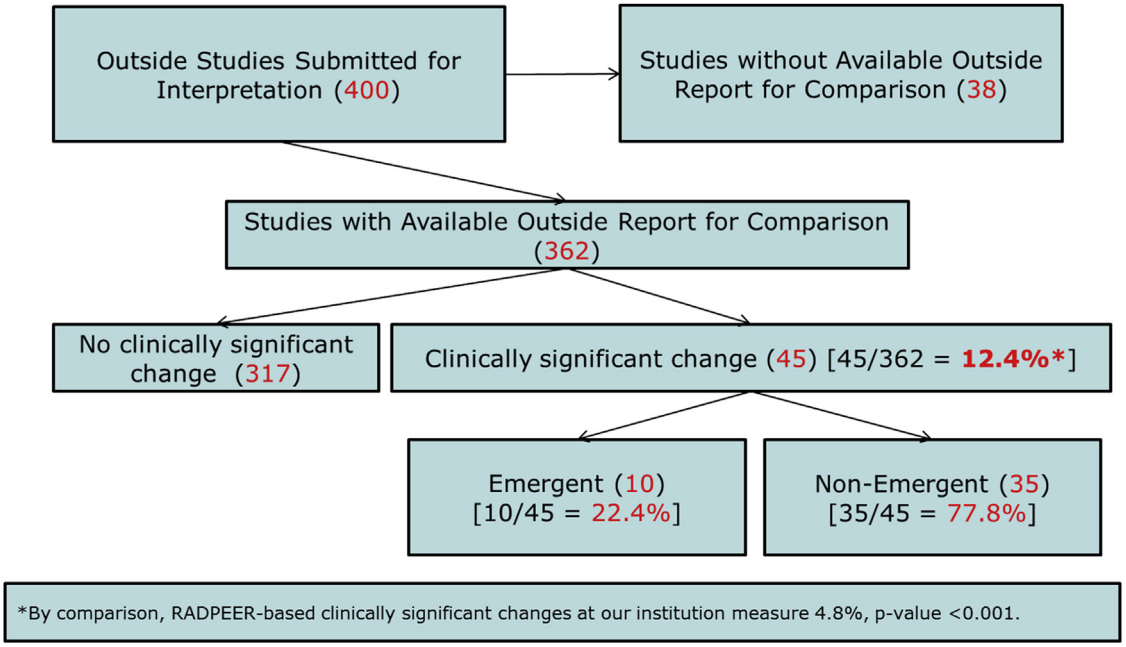

Fig 1. Summary of results of formally over-read studies.

found to be between 10% and 12% [4]. Similarly, an analysis comparing subspecialty neuroradiology "second opinion" reads of neurologic CT and MRI studies with the original interpretations revealed 13% major and 21% minor discrepancy rates [5]. Moreover, rates of perceptual and cognitive error in our study are also similar to existing literature regarding radiologic error. According to previously published literature, 60% to 80% of radiologic error is perceptual; that is, most error occurs as a result of the radiologist not observing the finding itself rather than a misinterpretation of the finding [6,7]. Our analysis classified 64.4% of errors as perceptual.

In addition to identifying error rates, we sought to help explain why these errors occur. Specifically in our study, we attempted to answer why certain errors were not repeated in formal over-reads. We hypothesize a link between reporting and thought process, proposing that the way radiologists frame how a report is generated influences how a study is interpreted, whether directly or indirectly. In this context, direct comparison of original interpretations and formal over-reads revealed patterns of reporting that helped identify solutions for reducing or avoiding error. Four strategies/styles of reporting emerged that we believe add value to the radiology report, specifically by mitigating error.

1. *Synthesizing varied anatomic findings into a cohesive disease process (a.k.a. We are not just anatomists)*

Suboptimal radiology reports often lack synthesis of the abnormal findings into a cohesive disease process. Too often, radiology reports are merely descriptions of anatomy, noting what looks abnormal in each organ and reporting these findings without the effort of trying to convey an understanding of the underlying disease process to give a more accurate impression, or in the worst case, missing an important finding or complication because of this lack of understanding. More than leading to error, this sort of practice leads referring providers, and patients, to see the radiologist as just an anatomist, ie, someone who can point out what is abnormal on the images but who has limited value in interpreting the findings in a clinical context.

It is more valuable for a radiologist to use his or her understanding of underlying disease processes for two primary reasons. First, an understanding of the disease process helps the radiologist avoid misses of common complications that he or she should be looking for related to the primary diagnosis, thus reducing perceptual error.

Example #1: Multiple nonocclusive splenic vein thrombi were not identified in a case of acute interstitial edematous pancreatitis on an outside interpretation. This is a common complication that the radiologist should be aware of, as are splenic artery or gastroduodenal artery pseudoaneurysms, peripancreatic fluid collections, etc. Missing splenic vein thrombus in a pancreatitis case can lead the referring provider to lose confidence in the radiologist and devalues the radiologist's role in the care of the patient.

Example #2: Multiple acute segmental lower lobe pulmonary emboli were not identified on the most superior images of a CT Abdomen/Pelvis done routinely for restaging of ovarian cancer on an outside interpretation. Certainly, the "edges" of studies are often blind spots for the radiologist, particularly when the indication calls focus to the task of comparing and measuring sizes of liver metastases, peritoneal implants, lymph nodes, etc. However, an understanding of the inherent hypercoagulable state of a cancer patient should prompt the radiologist to include in his or her search pattern an attempt to identify a deep vein thrombosis/pulmonary embolism, a finding for which this patient was at high risk.

Second, incorporating understanding of the disease process helps the radiologist form a more accurate and actionable impression rather than having to hedge, thus reducing cognitive error.

Example #3: There were several cases of outside reports where "indeterminate lymph nodes" were described in patients with intrathoracic or intra-abdominal sources of infection, with the caveat "malignant adenopathy not excluded" in the impression. The phrase "cannot exclude" does not add value to patient care and can harm the referring physician's perceptions of the radiologist's report, and thus should be avoided in radiology reporting [8]. A more favorable impression, as over-read at our institution, reads "Multiple enlarged lymph nodes are favored to be reactive in the context of an identified infectious source," which better demonstrates the radiologist's understanding of how infection commonly causes reactive adenopathy, without raising red flags about possible malignancy that could lead to unnecessary additional imaging, unnecessary treatment or consultation, and, most importantly, unnecessary worry for the patient.

2. *Integration of relevant electronic health record data (a.k.a. Dig into the patient's chart)*

Being cognizant of patient clinical data, ideally through the use of real-time integration with an electronic health record, allows for report generation that can take into account the clinical context. This clinical information is indispensable when generating a radiology report if used appropriately, as the short histories provided by ordering providers as a "clinical indication" are often insufficient in providing the most appropriate clinical history for the radiologist to make an accurate and actionable impression. Indeed, prior studies have shown that clinical information, when accurate, improves radiology reporting [9,10]. In addition to clinical history, integration with an electronic medical record also allows the radiologist access to laboratory values, operative notes, and pathology reports, all of which can play a significant role in improving the accuracy of interpretation, and thus avoid cognitive error. Examples of integration of clinical data to avoid error are provided in Table 1.

In an era of value-driven care, the onus lies on the radiologist to leverage all available resources to acquire more information than that listed in the "Indication," to avoid incorrect interpretation and provide the most effective service to the referring provider and, ultimately, to the patient. Moreover, if imaging is suspicious but does not fit the provided clinical history, particularly in the context of the emergency department, the radiologist can directly communicate with the referring provider to elicit more history to provide the best interpretation.

It should be noted, however, that clinical history does not always lead to a more accurate interpretation. In a prospective blinded study where radiologists interpreted studies before and after clinical information, the clinical history resulted in a more accurate report 67% of the time; however, 33% of the time, the report was less accurate [9]. Therefore, although using clinical history during interpretation is certainly advantageous, it can lead to bias, and a radiologist must use his or her clinical judgment to determine which parts of the history are relevant and actionable and which are not so as to optimize the reduction of cognitive error.

3. *Use of structured reporting (a.k.a. Structured reporting is better for everyone)*

Numerous prior studies have found that the use of structured radiology reporting is preferred by referring providers [11]. We advocate for its consistent use. Structured reporting permits radiologists' findings and thinking to be displayed in a predictable, reproducible, succinct, organized, and precise format [12]. Furthermore, among referring physicians, there is a statistically significant increase in mean content satisfaction and mean clarity satisfaction ratings for structured reports versus conventional reports [13]. More than just the preferences of referring providers, however, structured reporting is generally the preference of most radiologists as well, owing to the report appearance, completeness, and legibility [14].

One advantage of structured reporting is the checklist function a structured report can have, guiding a radiologist's search pattern, and thus reducing perceptual error. Radiologists may as a whole believe that a systematic

Table 1. Examples of reducing error through integration of electronic health record data

Clinical History	Outside Interpretation	Over-read Interpretation	Comments
89-year-old male with clinical indication of abdominal pain. Right upper quadrant ultrasound performed.	"IMPRESSION: … - Hepatic steatosis with markedly diminished flow within the main portal vein, query thrombus…"	"IMPRESSION: … Given heterogeneity of the liver and T3 colon cancer, consider MRI for metastases. This will provide better assessment of the portal vein patency which demonstrates questionable reversal of flow and potentially thrombus."	Looking closely at the patient's chart, **a history of T3 colon cancer was noted,** which resulted in a very different impression. Subsequently an MRI of the abdomen revealed **diffuse hepatic metastases** and not steatosis. The portal vein was patent.
40-year-old female with clinical indication of "right flank pain." Non-contrast CT abdomen/pelvis performed.	"IMPRESSION: … 1. Cause of right flank pain not identified. 2. Possible fibroid."	"IMPRESSION: 1. Right adnexal mass measuring 5.7 × 7.8 cm, difficult to characterize without the use of IV contrast. In the setting of acute right lower quadrant pain, this is concerning for ovarian torsion. Recommend pelvic ultrasound for further evaluation."	Reading the patient's **ED note** during reinterpretation (with **physical examination** actually localizing pain to the right lower quadrant) allowed a more accurate interpretation of the pelvic lesion and avoided an *emergent error*. Subsequent pelvic ultrasound confirmed **right ovarian torsion.**

search pattern is employed for each study, but our findings suggest that this is not always the case. Numerous potentially avoidable errors of perception may have been avoided if a reminder to follow a systematic approach were available. Structured reports help to address these types of errors by providing a virtual checklist promoting systematic identification of abnormalities by region, including potential blind spots. Structured reports, in essence, are an element of human factors engineering in the radiology workflow, providing a forcing function to avoid human lapses in search patterns. An example of this in an emergency encounter is provided in Table 2.

Moreover, structured reporting helps the radiologist avoid perceptual error that occurs as a result of inevitable interruptions to daily workflow. Routine interruptions in daily workflow, owing to phone calls, an emergent protocol that must be completed, or a referring provider coming to the reading room to consult on a different case, will often cause the radiologist to suspend reading of the current study, to be resumed later. With free-form reporting, when returning to the study the radiologist can be left questioning where exactly he or she left off, which could lead to an inefficient use of time if anatomic regions or structures are repeatedly evaluated, or in the worst case could lead to missed findings if an anatomic region or structure is not evaluated at all, with the radiologist having incorrectly believed it was addressed before interruption. With structured reporting, the radiologist will instead know exactly where he or she left off in the case, based upon which parts of the structured template are still empty, and thus ensure examination of previously unaddressed regions.

4. *Forming actionable impressions (a.k.a. Make your impression an impression)*

A key function of the radiology interpretation, as defined in the Imaging Value Chain, is to deliver an actionable report [15]. "Actionable" in this setting does not necessarily mean making recommendations, but instead means answering the clinical question in a precise manner with language that steers the referring provider toward a clear course of action. Ideally, the radiologist should produce an accurate, concise, and meaningful report that gives the referring provider a diagnosis, or differential diagnosis if required, and further imaging recommendations when appropriate. We discovered, through our analysis, that many impressions did not synthesize the salient findings or produce an actionable conclusion. Cognitive error resulting from these suboptimal impressions occurred in three primary ways. First, suboptimal impressions restate the findings and do not synthesize the findings into a unified diagnosis when one is present. Second, suboptimal impressions that are not concise endlessly

Table 2. Example of reducing error through the use of structured reporting

Clinical History	Outside Interpretation	Over-read Interpretation	Comments
82-year-old female with MVC. CTA Chest performed.	"IMPRESSION: 1. Minimally displaced fractures of the posterior left 9th through 12th ribs. 2. Very tiny right pneumothorax…"	"IMPRESSION: Vascular: Nonopacification of the left vertebral artery from its origin to the superior field-of-view on this examination (approximately the C3 vertebral body), where it reconstitutes. Given the presence of significant left supraclavicular soft tissue swelling, this is highly suspicious for traumatic injury to the left vertebral artery. Recommend CTA neck for further evaluation. Chest: 1. Mildly displaced left posterior ninth through twelfth rib fractures. …"	At our institution, our Chest CTA Trauma templates are structurally divided into **"Vascular"** and **"Non-vascular"** components. Within the "Vascular" component is a field labeled **"Supra-aortic Vessels."** This virtual checkbox addresses a common **blind spot** on chest CTs and, in this case, saved this patient from an emergent missed finding, as subsequent CTA Neck confirmed a **traumatic dissection of the left vertebral artery** at its origin.

Note: CTA = CT angiography; MVC = motor vehicle collision.

ramble about differential possibilities without favoring any of them. The length of an impression in radiology reports varies inversely with the confidence of the radiologist [16]. Third, suboptimal impressions are often so vague that not only do they not provide the referring provider with an answer to the specific question asked, but they raise other "cannot exclude" diagnoses that can lead to unnecessary additional imaging and delays in diagnosis. Each of these scenarios ends up leaving the referring provider without a clear plan of action, leads to cognitive error through either misdiagnosis or delays in diagnosis, and ultimately devalues the radiology report and the role of the radiologist as a whole. There are important legal implications regarding the creation of actionable reports as well, as most medical legal actions against radiologists stem from delay in diagnosis rather than inaccurate reports [17].

In an era of value-based health delivery, it is paramount that radiology report impressions avoid the vagueness and non-interpretations that have earned us the reputation of being "hedgers," and should instead (1) read as concise, synthesized conclusions that favor a diagnosis; (2) offer reasoned alternative diagnoses when appropriate; (3) leave out the blanket "cannot exclude" diagnoses when they are so unlikely in the clinical context that they need not be mentioned; and (4) give explicit recommendations when appropriate so as to be actionable and not just suggestive. Examples of actionable reports and how they can avoid cognitive errors are given in Table 3.

Our study had a few notable limitations. First, the imaging studies being analyzed may have been subject to selection bias. Specifically, studies submitted to our institution for formal over-read are generally considered more difficult to interpret than the average study, as the inherent complexity of the patient's condition is usually what necessitates the patient's transfer to our institution. Therefore, one could argue that the error rate found in our analysis is exaggerated owing to study complexity. However, the error rate found in our study is still statistically significant when compared with interobserver agreement data from our own institution, which should have similar study complexity and thus control for this bias. In the context of this comparison, the claim that the reporting strategies presented mitigate error still holds.

A second limitation to consider is the role of subspecialty over-reads in our analysis. All of the over-reads at our institution are performed by subspecialty-trained radiologists, whereas it is unknown whether the original interpretations were provided by fellowship-trained or non-fellowship-trained radiologists. Although an error is an error regardless of training, it is unclear what role subspecialty training, in addition to the reporting techniques provided, may have had in reducing error on formal over-reads.

Table 3. Examples of reducing error through the formation of actionable impressions

Clinical History	Outside Interpretation	Over-read Interpretation	Comments
75-year-old female with abdominal pain and diarrhea. CT Abdomen/Pelvis performed.	"IMPRESSION: "1. Stable colonic bowel wall thickening. This likely relates to resolving pancolitis."	"IMPRESSION: 1. Ahaustral colon consistent with long-standing ulcerative colitis. Pancolonic inflammation with mucosal hyperemia is more suggestive of ulcerative colitis flare rather than *C. difficile* colitis…"	By noticing the ahaustral nature of the colon in addition to wall thickening, value was added by suggesting a more **unified diagnosis** (rather than a nonspecific term of "pancolitis"). This led to a new **biopsy-proven diagnosis of ulcerative colitis.**
56-year-old male with history of pancreatic cancer and vomiting. CT abdomen/pelvis performed.	"IMPRESSION: 1. Patient is status post gastrojejunostomy. There is now gastric outlet obstruction and dilated afferent limb. 2. Extensive carcinomatosis. 3. Small amount of ascites."	"IMPRESSION: 1. Severe distention of the stomach, as well as marked dilatation of the pancreaticobiliary limb. Extensive peritoneal carcinomatosis in the left anterior abdomen, with omental caking abutting the gastrojejunostomy. **This constellation of findings is concerning for tumor involvement of the gastrojejunostomy resulting in gastric outlet and afferent limb obstruction."**	The outside interpretation lacks a synthesized conclusion, and rather just restates findings. After reading this outside impression, the referring provider was left asking the same **clinical question**: What is causing the gastric outlet obstruction and dilated afferent limb? The over-read interpretation synthesizes the findings into a **meaningful, coherent and actionable report that answers the clinical question.**
66-year-old female with history of radical cystectomy and ileal conduit with sepsis. CT abdomen/pelvis performed.	"FINDINGS: …Bilateral ureteral stents are unchanged in position… IMPRESSION: 1. Moderate left hydronephrosis, new since August 20."	"IMPRESSION: 1. There is interval development of left-sided hydronephrosis. The bilateral ureteral stents are unchanged in position, though with the proximal left ureteral stent again noted to be located at the UPJ rather than within the renal pelvis. Findings are suggestive of proximal left ureteral stent dysfunction.…"	This is another example of restating findings without providing an explanation when there is one present. Although the existing ureteral stent was indeed unchanged in position, it was actually malpositioned. Simply calling the stent unchanged **missed the opportunity to provide a meaningful and actionable report**, one that **identified a cause** of new hydronephrosis and gave the referring provider **a clear course of action** requiring intervention. The patient indeed underwent stent replacement, and subsequently resolution of left hydronephrosis.

Note: UPJ = ureteropelvic junction.

Finally, it should be noted that although we believe the reporting strategies presented mitigate error, they may not eliminate all errors, particularly perceptive error. Furthermore, although not quantified, using the techniques provided during interpretation likely adds to the overall time to interpret the study, owing to time spent sifting through a patient's electronic health record, completing "normal" fields in a structured report, and providing a clinical context as reasoning for favoring a diagnosis. Ultimately, we believe using these strategies improves patient care, which should be the primary objective of every study we read. Yet, the value-adding steps and strategies we propose do present a tradeoff with

study throughput, which must be considered in a high-volume setting.

TAKE-HOME POINTS

- The radiology report comprises a discrete link in the Imaging Value Chain, though the quality of this aspect of a radiologist's work is often heterogeneous and fails to add significant value to the referring provider and, ultimately, to the patient.
- A 12.4% clinically significant error rate was found in formally reinterpreted studies from outside institutions. Of these, 64.4% were perceptual errors and 35.6% cognitive errors.
- Four techniques were identified in reporting that helped to avoid these errors on formal over-reads: (1) synthesizing varied anatomic findings into a cohesive disease process, specifically targeting perceptual error; (2) integration of relevant EHR data, specifically targeting cognitive error; (3) use of structured reporting, specifically targeting perceptual error; and (4) forming actionable impressions, specifically targeting cognitive error.
- We advocate for the use of the above four strategies in all radiology reports when applicable as methods for avoiding error, and ultimately increasing the value of the radiology report for both the referring provider and the patient.

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