Learning from mistakes: Errors, discrepancies and underlying bias in Radiology with case examples

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Learning objectives

To describe the concepts of "Error", "Discrepancy", "Complication" and their differences.

To review 12 radiological error types and their possible consequences with case examples.

To discuss types of biases leading to radiological errors.
**Background**

Radiological imaging is an essential part of patient management. Despite significant technological developments, radiologists still suffer from "errors" and "discrepancies".

The term "error" is used, if there is no suspicion for what is "correct" and impossible to argue against while the term "discrepancy" stands for justifiable opinion differences in between colleagues.

Errors and discrepancies may cause direct or indirect, permanent or temporary harmful effects on patients due to false, missed or delayed diagnosis. However, radiological errors or discrepancies may not always alter patient management since erroneously defined radiological findings may be clinically insignificant or feed-backs from clinicians or other radiologists correct the errors or prevent discrepancies.

In the literature, classification of radiological errors and underlying bias have been discussed by different authors. Basically, radiological errors can be divided into two parts. "Perceptual errors" are more common and related to the fact that the present finding is not noticed. While "interpretative errors" are under the influence of cognitive biases that can contribute false reasoning.

According to the comprehensive classification system of Kim-Mansfield, there are 12 subgroups defined for error types. We will present cases related to those 12 types of radiological errors and underlying bias, after reviewing their classification.
Findings and procedure details

1. Definitions and differences of "error", "discrepancy" and "complication".

Diagnostic error is the condition that could inflict harm on patient, with no acceptable cause and no scientific data for defense, approved by all experts in this field (Figure-1).

The discrepancy means reasonable differences of opinions between radiologists about finding or diagnosis. It differs from error because discrepancies can be justified based on a range of scientific data, such as similar clinical, laboratory, or radiological patterns (Figure-2).

Complications are the conditions that occur during or after radiological procedures and are directly related to nature of procedure. Complications are unanticipated occurrences and they may happen even under ideal conditions (Figure-3).

2. Examples of common radiological error types.

Diagnostic errors are a large and complex issue that needs to be addressed, which prevents proper patient management, and sometimes could lead to vital consequences due to delay in diagnosis. Different classifications have been proposed at different times to classify diagnostic errors and thereby facilitate their intelligibility. The most broadly accepted classification is developed by Kim and Mansfield. According to this classification, diagnostic errors are examined in 12 groups based on the cause of error.

1. False-positive error or overreading: In this scenario, abnormality is noticed during radiological examination, however, this finding is given too much clinical value than it deserves. Consequently, it may cause unnecessary diagnostic/therapeutic effort (Figures-4,6).

2. Faulty-reasoning: In this type of error, detected abnormal radiological findings are thought to be associated with wrong clinical entity mostly due to cognitive biases such as hindsight or attributable bias (Figures-1,5,17,18).

3. Lack of knowledge: It can be mentioned when a pathological finding is noticed, but could not be interpreted correctly due to lack of adequate information or experience (Figures-6,23).
4. **Underreading**: It is the most common error type. In this type of error, an examination is reported as normal although there is undeniable detectable abnormal finding (Figures-1,19).

5. **Poor communication**: In this scenario, abnormal finding is recognized and accurately reported. However, diagnostic messages cannot be reached to clinician because of communication-related problems (Figure-7).

6. **Technique related**: This error occurs because of choosing the wrong technique or low technical quality which decreases the possibility of detecting abnormal findings, and sometimes, even, makes diagnosis impossible (Figures-8,25).

7. **Prior examination**: The main reason for this type of error is skipping the "comparison with previous exams" step which is indispensable during radiological evaluation. Each evaluation must be compared with previous examinations to increase likelihood of detecting pathological findings. But when doing this, one must be careful about 'satisfaction of report' error that will be explained later (Figure-9).

8. **History**: This error includes inaccurate reporting faults which occur when the responsible radiologist is not provided with adequate or correct information about the patient's clinical history (Figure-10).

9. **Location**: Location related error defines the inability to recognize the pathological finding which is seen within examination limits (especially in the edges of evaluated area) but falls outside the purposefully examined area (Figures-11,27).

10. **Satisfaction of search**: When the radiologist detects a pathological finding during the evaluation, (s)he subconsciously lost motivation for seeking other findings. Thus, accompanying findings may be underread even if they are seen very clearly (Figures-12,13,14).

11. **Complication**: It describes undesirable situations that occur during radiological procedures and problems/misdiagnosis due to these complications. They may be caused by either incorrect selection of the patient or of the radiologic procedure (Figure-15).

12. **Satisfaction of report**: It results from having undue confidence in the patient's prior reports. As a result, if there is wrong assessment made in previous report, it will be repeated. There is a close relationship between this type of error and alliterative bias (Figure-9).
3. Common bias types underlying radiological errors.

Biases may result in misinterpretation and diagnostic errors, so being aware of certain types of biases can contribute to diagnostic accuracy. Types of biases can be classified as listed below;

1. **Attribution bias:** It defines the tendency to attribute findings of a clinical condition by looking at certain characteristics of the patient, in other words, stereotypes (Figure-7).

2. **Alliterative bias (satisfaction of report):** Alliterative bias occurs when previous interpretations about a study influence the decision-making process of the current study (Figure-9).

3. **Availability bias:** This type of bias is characterized by an increased tendency to diagnose recently seen or catchy entities (Figure-16).

4. **Regret bias:** It happens when radiologist worries about underdiagnosing a possibility so brings it forward (Figure-16).

5. **Framing bias:** This bias type reflects automatically restricting the differential diagnosis due to the referral situation and clinical framework (Figures-14,17,20).

6. **Premature closure:** It results from accepting an initial diagnosis as final diagnose without any verification. This is the most common type of bias in clinical medicine (Figure-18).

7. **Inattentional bias:** Inattentional bias, also named as tunnel vision, may result in diagnostic error due to unusual appearance or location of findings (Figure-19).

8. **Hindsight bias:** It defines when a specialist evaluates the findings retrospectively, they tend to underestimate the difficulty of making an accurate diagnosis. By contrast with other types of bias, hindsight bias is retrospective in nature (Figures-20,21).

9. **Zebra retreat:** The radiologist retreats an accurate but unusual diagnosis due to the lack of confidence, despite the presence of supportive evidence (Figure-21).
10. **Scout neglect:** Scout view is a preliminary image that is taken just before performing the imaging. Ignoring the scout view may result in a diagnostic error (Figure-22).

11. **Anchoring bias:** This type of bias occurs when radiologist fixes first-sight diagnosis, although subsequently presented findings are incompatible with the first diagnosis. Anchoring bias usually accompanied by confirmation bias, making it more dangerous (Figure-23).

12. **Confirmation bias:** Confirmation bias defines actively searching for more data to confirm the available hypothesis rather than seeking for the alternative hypothesis (Figure-23).

4. **Possible clinical consequences caused by radiological error.**

Errors in diagnosis could lead to some clinical consequences. We can also classify errors based on these clinical consequences.

The simplest and most innocent of those are errors that are noticed before affecting the patient. In this condition, the error causes no harm.

We can divide errors that reach patient into two types based on concerning the patient.

In the first type, the error reaches the patient but does not cause any harm. This error type may be clinically insignificant or may cause unnecessary further examination (Figure-24).

The second type is errors that harm the patient. These can lead either directly/indirectly, temporary/permanent clinical consequences. The consequences of harmful errors can be examined in 3 groups. The first group is related to delay in diagnosis. Thus, imaging findings that are important for patient may be missed or inadvertently interpreted as an irrelevant diagnosis (Figures-25,26). The second group is errors causing prolonged hospital-stay which leads to additional follow-up and sometimes additional treatment (Figure-15). The third group is related to the overlooking or underestimating of vital and life-threatening findings. The last one can result in serious morbidity, even mortality (Figure-27).
Case 1: Examples of “error”.

A 77 y.o. female patient with lower abdominal pain, with the history of renal stone and recurrent urinary tract infections. Patient’s symptoms did not regress under proper antibiotherapy. NECT was ordered for “evaluation of renal stones and urinary pathologies”. CT was reported as “normal, except left atrophic kidney (red arrows, A)”. However, collection (blue arrows, A, B), free air bubbles (yellow arrow, B) and mesenteric fat stranding related with inflammatory changes (green arrows, A, B) adjacent to sigmoid colon was overlooked due to misleading of clinical information.

After follow up CT, patient was diagnosed as “acute diverticulitis” with the help of radiological findings. During follow-up, symptoms persisted more than 1 month, in spite of appropriate medical treatment. Lower abdominal MRI was ordered. MRI revealed that, these falsely attributed findings for acute diverticulitis were due to “perforated sigmoid colon malignancy” (not shown).

Fig. 1: Example of "error".

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Case 2: Example of discrepancy.

13 y.o.a male patient with the history of pigeon feeding, applied to pediatrics with the complaint of dyspnea. Clinicians suspected “hypersensitivity pneumonitis” as first differential. Patient was hospitalized for further management. Serologic tests proved the presence of antibodies against specific avian proteins. Thorax CT showed **multipl ground glass nodules (red arrows, A,B).**

A radiologist, interpreted these multipl ground glass nodules in favor of “hypersensitivity pneumonia” considering opinions of clinicians, patient history and serological test result. According to another radiologist, pulmonary veno-occlusive disease is more likely, because of **accompanying interlobular septal thickening (blue arrows, A,B),** increased pulmonary artery diameter (**C**) and right ventricular dilatation (**D**).

**Fig. 2:** Example of "discrepancy".

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Case 3: Example of complication.

A 64 y.o. female patient with suspicion of sepsis, suffered from severe abdominal pain disproportionate to clinical examination findings. Abdominal CECT was ordered to rule out "mesenteric vascular disease" after explaining all the risks of procedure to the patient. After CECT, a progressive decline of GFR was observed. When periprocedural GFR values were evaluated, it was clearly understood that contrast induced nephropathy developed (A). Follow up NECT after 24-hours-later than the first examination, revealed contrast retention of kidneys due to impaired filtration functions (red arrows, B).

Fig. 3: Example of "complication".

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Case 4: Overreading (type 1) error.

22 y.o.a. patient with chest pain. Clinician suspected of pneumopericardium due to left paracardiac lineer radiolucency (blue arrows, A) in chest X-ray. Thorax CT performed for confirmation was normal and coronal reformatted images showed no abnormality involving left paracardiac area (B). Pitfall of “Mach band” effect was responsible for this overreading (type 1) error.

Fig. 4: Overreading (type 1) error.

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Case 5: Faulty reasoning (type 2) error.

Male patient with prostate cancer applied ER for head trauma. ER doctors suspected extraaxial hemorrhage (blue arrows, A) while evaluating brain CT. Radiologists did not agree with ER doctors, due to presence of prostate cancer history and absence of any finding that could be associated with head trauma. MRI was suggested for further evaluation. MRI revealed asymmetrical nodular dural thickening with contrast enhancement (red arrows, B,C) and diffusion restriction (not shown), which are consistent with dural metastasis of prostate cancer.

Fig. 5: Faulty reasoning (type2) error.

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Case 6: Lack of knowledge (type 3) and overreading (type 1) errors.

65 y.o.a female patient with newly onset dyspnea, 3 days after mitral valve replacement. Thorax CT showed intraatrial location of replaced mitral valve (red arrows, A, B). When the abnormal location and dyspnea were evaluated all together, displacement of replaced mitral valve was considered. Cardiovascular surgery department was, immediately, called to report this situation. However, it was learned that this location was an expected location in patients who had mitral valve replacement with Chimney technique. This technique is preferred in case of extensive mitral annular calcifications (blue arrows, A, B), in order to prevent calcified embolism during procedure. Lack of this knowledge resulted in overestimation of an expected finding.
Fig. 6: Lack of knowledge (type 3) and overreading (type 1) errors.

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![Image of healthcare professionals and patients](image-url)

**Case 7: Poor communication (type 5) error with attribution bias.**

A 27-year-old female patient with no prior disease referred to the emergency room with abdominal discomfort. After the first evaluation, abdominal CECT was performed (A, B). Bilateral lung bases were also partially involved in abdominal CECT (B). CT was reported as “free fluid in pelvis (red arrow), bilateral pleural effusions, interlobular septal thickenings and bilateral central ground glass opacities in lung bases” (B). Although these are well-known findings of cardiac congestion, the possibility of cardiac congestion was not emphasized in the report because of the patient’s age and irrelevant clinical history. Instead, clinicians were expected to read and evaluate the findings. 6 hours later, patient got dyspneic and tachypneic. Contrast-enhanced thorax CT (C, D) revealed enlarged left atrium (blue double-sided arrow, D) and findings compatible with pulmonary edema (C). Echocardiography, which was performed to rule out cardiac abnormality, showed severe mitral stenosis possibly due to rheumatic heart disease. Poor communication due to the lack of necessary interpretation in report, and attribution bias due to the young age, clear medical history and irrelevant symptoms of the patient caused delay in diagnosis.

Fig. 7: Poor communication (type 5) error with attribution bias.

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Case 8: Technique (type 6) error.

45 y.o.a. female patient was investigated for inflammatory bowel disease and MR enterography was ordered. Before the procedure, patient drunk gadolinum containing contrast agent by mistake. Due to the paramagnetic feature of gadolinum, the required image quality for evaluating intestinal lumen couldn’t be achieved and the study rescheduled. *(red arrow: intestinal lumen with gadolinum, blue arrow: the optimal appearance of intestinal lumen with mannitol in another patient)*

**Fig. 8**: Technique (type 6) error.

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Case 9: Prior examination (Type 7) and satisfaction of report (Type 12) errors.

Follow-up images of male patient with larynx ca history. Both of lung apices were within the imaging field in all of the control neck CTs. Bilateral apical fibrotic changes, more prominently in right apex, were present and reported consistently (A). Due to reliance on previous reports, apical areas of prior examinations were not evaluated carefully. As a consequence, nodular lesion showing gradual increase in size, located within right apical fibrotic changes was missed repeatedly, until it reached large dimensions (red arrows, B).

Fig. 9: Prior examination (type 7) and satisfaction of report (type 12) errors.
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Case 10: History (type 8) error.

75 y.o.a. female patient applied to chest clinic with progressive cough. Thorax CT was performed and reported as "bilateral residual tumoral soft tissue (blue arrows, A) and parenchymal fibroatelectatic changes due to radiotherapy (orange arrow, B)". Clinician gave feedback to the radiologist about, “negative history of malignancy and radiotherapy”. Additionally, intensive biomass exposure was mentioned. After all, CT was reevaluated by radiologist. Paramediastinal parenchymal changes (blue and orange arrows, A,B) interpreted as a result of "bronchial antracofibrosis", after combining the associated air trapping (green arrow, B,C) and bronchial narrowings (red arrows, B,C). This case is a good example of "Misdiagnosis without any harm" thanks to the feed-back of clinician.

Fig. 10: History (type 8) error.
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Case 11: Location (type 9) error.

28 y.o.a. male patient with adrenalectomy. Abdominal CECT was ordered for postoperative complications. Collection in the surgical area (blue arrow, A) and postoperative changes were reported. Although, filling defects in right pulmonary artery were involved in CT, they couldn’t be noticed due to their locations (red arrows, A,B). As in this case, the marginal areas are prone to this type of error.

Fig. 11: Location (type 9) error.

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Case 12: Satisfaction of search (type 10) error.

A 39 y.o.a male patient with history of renal stones, came to emergency department with pain in left flank and inguinal regions. Suspicion of renal colic was raised and NECT was performed. Study reported as “nephrolithiasis” (blue arrows, A, B) and patient was discharged after hydration. 6 hours later, patient suffered from severe chest pain and dyspnea at home and was brought back to ER. Retrospective analysis of NECT study showed enlarged left iliac veins (red arrows, C,D,F,G) in comparison to right ones (green arrows, C,D,F). Perivascular fat stranding (yellow arrows, C,D) and increased luminal density in left iliac veins (E) were also noted. Patient was diagnosed as PTE due to deep venous thrombosis on second arrival. Technique was not optimal for detection of deep vein thrombosis due to lack of contrast. Furthermore, “Satisfaction of search” due to presence of renal stones, resulted in decreased attention to detect these subtle findings (Red and blue arrows in G).

**Fig. 12:** Satisfaction of search (type 10) error.

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Case 13: Satisfaction of search (type 10) error.

Patient with gastric cardia tumor, underwent gastrectomy and distal esophagectomy. On the first postoperative day, dyspnea and abdominal pain developed. Anastomosis leakage was suspected and thoracoabdominal CT with oral opaque was performed. On-call radiologist noticed apparent contrast extravasation from esophagojejunostomy to the posterior mediastinum. Study was reported as “consistent with anastomosis leakage from esophagojejunostomy” (red arrows, A, B). Due to the “satisfaction of search” effect of this major finding, the remainder of the examination was reported as normal. Despite the normal reporting of abdominal CT findings, the patient’s abdominal complaints progressed, so the patient was re-operated and additional jeunojejunostomy leakage was detected. When preoperative CT was retrospectively evaluated, obvious signs of leakage in the jeunojejunostomy area were noticed. Linear hyperdensity consistent with leakage extending inferiorly from the jeunojejunostomy anastomosis (blue arrows, C), extraluminal contrast material between jejunal loops (blue arrows, D) and pelvic fluid with relatively high density (red ROI mark, E) were overlooked findings.

Fig. 13: Satisfaction of search (type 10) error.

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Case 14: Satisfaction of search (type 10) error with framing bias.

The patient admitted to the emergency department with the right flank pain. With the suspicion of urinary tract stone, the patient underwent a non-contrast abdominal CT scan with renal stone protocol. During the radiological evaluation, the stone located at the right ureteropelvic junction (red arrows, A), and dilatation of the right renal collecting system secondary to stone (green arrows, B, C) were seen, which supported the provided clinical information. The rest of the examination was reported as normal. 6 months later, the patient admitted to the emergency department with the complaints of progressive jaundice, and a periampullary mass was detected. Retrospective analysis of abdominal CT that performed 6 months ago revealed "double duct sign (blue arrows, B, C), and subtle dilatation of intrahepatic biliary ducts (purple arrows, D)", which pointed out periampullary tumour. Because of the framing of clinical information, the radiologist examined the study with the preliminary diagnosis of stone and ignored other possible pathological findings. Moreover, after finding the stone, the radiologist was convinced that (s)he had found the finding that may cause right lower quadrant pain. And (s)he did not carefully examine the rest of the study with the deceptive effect of “satisfaction of search”.

Fig. 14: Satisfaction of search (type 10) error with framing bias.

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Case 15: Complication (Type 11) error.

Thorax CT with pulmonary thromboemboli protocol was performed for a dyspneic patient with known history of malignancy. Just after the study, patient complained of pain and swelling in his forearm. The AP X-ray of upper extremity showed spreading of extravasated contrast agent to the wrist region (blue arrow, A). It was noted that, amount of intravascular contrast media was not sufficient for evaluation of this protocol (red arrow, B). Medical treatment was given and procedure was repeated. This case is a good example of “Acute and temporary harm” due to a procedural error/complication.

Fig. 15: Complication (type 11) error.

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Case 16: Availability and regret bias.

The patient admitted to the emergency department with complaints that were suggestive for intestinal obstruction. In order to evaluate bowel obstruction, contrast-enhanced abdominal CT was ordered. Radiological evaluation showed "dilated small bowel loops with air-fluid level, and interloop free fluid", which were consistent with mechanical bowel obstruction (red arrows, A). At the same time, intrahepatic linear air densities extending from the hepatic hilus to the periphery and running parallel to the portal vein branches were observed (blue arrows-circles, B,C). Although the distribution of air seemed to be intrabiliary; patient’s poor condition, accompanying mechanical obstruction, and presence of air in the peripheral hepatic regions forced the radiologist to report it as in favor of portal venous gas. In control abdomen CT, hepaticoenteric anastomosis was noticed (purple arrow, D). It was clearly understood that, intrahepatic air was formed by the intraluminal air that passes from this anastomosis into the bile ducts and spreads, even, to the most peripheral regions (green arrows, D), due to the significantly increased intraluminal pressure secondary to the ongoing bowel obstruction (red arrow, D). Because coexistence of intestinal obstruction and portal venous gas is a well-known association, and radiologist had lots of experience about this coexistence, availability bias resulted in misjudgement. Moreover, regret bias ended up reporting of the worst-case scenario which eliminated the possibility of a major overlooking.

Fig. 16: Availability and regret bias.

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Case 17: Framing bias with faulty reasoning error.

35 y.o.a. female patient with headache, nasal congestion and weakness. Symptoms persisted more than 3 weeks despite medical therapy, and periorbital erythema developed. She was diagnosed as sinusitis by clinicians. Parasal CT was ordered to evaluate the presence of "pneumococcal cellulitis". Previous pneumonia history was not mentioned in clinical information. Diffuse opacities involving nasal cavity and ethmoid sinuses (A,B) were reported as "compatible with sinusitis". Increased densities in periorbital subcutaneous areas (A,B) were falsely attributed to accompanying "pneumococcal cellulitis", due to framing of clinical information. After progression of symptoms, biopsies from periorbital subcutaneous tissue and nasal cavity revealed lymphomatous infiltration. MRI showed sinonasal lymphoma involvement (C). After appropriate chemotherapy, follow-up CT showed complete resolution of disease (D). Minimal homogenous contrast enhancement of sinonasal opacities was also noted, during retrospective evaluation of first parasal CT (upper part, B) and head-neck CTA obtained at the same time with parasal CT (lower part, B).

Fig. 17: Framing bias with faulty reasoning error.

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52 y.o.a. male patient with metastatic gastric cancer was brought to emergency room due to the abdominal pain, distention and discomfort. The diagnosis was prematurely closed as “peritoneal carcinomatosis” because of both the cancer history and CT findings (thickened and enhancing peritoneal layers (red arrows, A,B) and accompanying pelvic free fluid/mesenteric congestion). On following period, it is understood that jejunostomy catheter (blue arrow, A,B) displaced into peritoneal space, and its tip was seen in pelvic region. After removal of the misplaced catheter and appropriate treatment of peritonitis induced by nutrients given through jejunostomy, patient’s complaints vanished away.

Fig. 18: Premature closure bias causing faulty reasoning error.

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Case 19: Inattentional bias (Gorilla effect) with underreading error.

Female patient admitted to ER with bilateral hip pain, after falling from stairs. X-ray and pelvic CT was interpreted as “normal” by on-call radiologist. However, shortening of femoral neck (red arrow, A) and hyperdense line due to impacted fracture (red arrows, B,C) were missed. Prejudice of “Fractures are seen as hypodense lines” caused inattentional blindness in this case; just like the famous case of “gorilla”, inserted in a CT by researchers and overlooked by %83 of radiologists that are busy with searching lung nodules. Hyperdense fracture line, like “gorilla”, is an atypical finding for radiologist. Due to its unexpected nature, it may lead to underreading error.

Fig. 19: Inattentional bias (Gorilla effect) with underreading error.

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Case 20: Framing and hindsight bias.

40 y.o.a female patient with no history of known disease applied to the ER with complaints of chest pain, dyspnea and confusion. Due to the severe back and neck pain lasting for 2 days, dissection was suspected. Triple rule out CT was performed. CT showed bilateral massive pleural effusion (A,D), and severe contrast reflux into the inferior vena cava, right renal vein (red arrows, B) and peripheral branches of hepatic veins (blue arrows, B). These findings were suggestive for hemodynamic compromise. Pleural effusions were drained, and significant amount of pus was observed. Patient was accepted as septic, and proper treatment was started. Microbiologic evaluation of pleural fluid sample was consistent with *Streptococcus pyogenes*, which is an unexpected bacteria for pleura. After feed-back from microbiologist, an ecchymotic area spreading from the neck to the anterior chest wall was noticed. Soft tissue infection was suspected. CT was retrospectively re-evaluated. It was understood that, increased densities in subcutaneous fat tissues of neck and anterior chest wall (red circles, C,D) were not noticed by on-call radiologist due to the framing of preliminary diagnosis of dissection (purple arrows, C). Lymphadeopithes within the affected areas (green arrows, C) and obliteration of upper mediastinal fat tissues (yellow circle, D) were other considerable findings. Moreover, enlargement of upper mediastinum suggesting mediastinitis was detected retrospectively in chest X-ray obtained after thoracentesis (E, yellow arrows).

Later on, clinical situation rapidly deteriorated, patient became hypotensive, myoglobin increase suggesting myonecrosis was observed, acute kidney failure, acute respiratory distress and thrombocytopenia developed. After evaluation of clinical, radiological and microbiological findings all together, the diagnosis of "streptococcal toxic shock" was made. The patient died 3 days after the onset of the complaints and 1 day after her ER admission.

With the knowledges of *S.pyogenes* presence in pleura, history of neck pain and location of ecchymotic area, it seems to be impossible to overlook changes in soft tissues and upper mediastinum, during retrospective evaluation (hindsight bias).

Fig. 20: Framing and hindsight bias.

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Case 21: Zebra retreat and hindsight bias

75 years old male patient with known tracheoesophageal fistula (green arrows) suddenly lost his consciousness. Brain CT and CT angiography revealed edematous brain tissue, diffuse air within brain vasculature (B) and contrast filling limited to just proximal segments of left middle cerebral artery and anterior cerebral artery (red arrows, A). His recent studies were reevaluated to detect etiology of air in brain vessels. In thorax CT, which was performed for hemothysis 3 days ago, parenchymal ground-glass opacities suggesting hemorrhage were seen (C). In mediastinal window, next to the fistula, there was an outpouching of pulmonary vein (blue arrow, D), that had not been present in previous study (E). This newly developed outpouching had been, also, noticed by on-call radiologist. However, it had not been emphasized adequately due to the absence of apparent contrast extravasation into the tracheal lumen. Moreover, hemothysis originating from pulmonary vein was a quite unexpected situation. This phenomenon is called as zebra retreat. Though, due to the hindsight bias, it is impossible to overlook or underrate that outpouching with the knowledge of diffuse air embolism, during retrospective evaluation.

Fig. 21: Zebra retreat and hindsight bias.

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Case 22: Scout neglect bias.

Abdominal CECT of male patient, for evaluation of solid organ injury after motor-vehicle accident. **Right pubic fracture (blue arrows)** is masked in routine abdominal CT images with 3mm slice thickness and soft filter (A). However, it is easily seen in scout image without any suspicion (B).

**Fig. 22:** Scout neglect bias.

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Case 23: Anchoring and confirmation bias due to the lack of knowledge.

A 45 y.o.a. male patient with complaints of fever, weight loss and lymphadenopathy. Blood tests revealed anemia and marked eosinophilia. Further investigations were carried out to exclude malignancy. Extremely dense (3047 HU) material levelling in gastric lumen, and similar millimetric densities scattered through bowel loops (red arrows, A,B) were seen in abdominal CT. The radiologist interpreted these densities as heavy metal due to their extremely high density. Mercury was suspected because of its liquid state. Then, the radiologist searched the literature for mercury toxicity to find whether there is any similarity or not. While the radiologist immediately accepted the findings and symptoms that are compatible with mercury poisoning (C, green underlines/box), the other findings of mercury toxicity that are incompatible with patient’s findings were ignored (C, red underlines) due to the anchoring and confirmation biases. After a while, a clinic feed-backed about a long-time usage of ‘lanthanum’, which is a phosphate binder metal used for compensasion of hyperphosphatemia in chronic kidney disease.

We can see right solitary atrophic kidney (blue arrows, D), and Rugger-Jersey spine like appearance (multiple vertebral endplate hyperdensities (green arrows, E) with relatively spared middle parts (purple arrow, E), which may represent hyperparathyroidism secondary to kidney failure. **Lack of enough knowledge** about differential diagnoses of intraluminal hyperdensities, and anchoring/confirmation bias about preliminary diagnosis of heavy metal poisoning resulted in diagnostic error in this case.

**Fig. 23:** Anchoring and confirmation bias due to the lack of knowledge.

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**Case 24: Error causing unnecessary effort.**

A female patient with tracheostomy was brought to ER with symptoms of myocardial infarction. During routine examination, a hard mass palpated by clinician in right lower quadrant. Detailed history couldn’t be taken from patient and sonography was ordered. Bed-side sonography revealed nothing but acoustic shadowing (not shown). Abdominal radiography demonstrated an **oval radiopaque structure (Red arrows, A)**. Afterwards, it was understood that there was a parietal bone graft, based on the history taken from patient’s relatives.

**Fig. 24:** Error causing unnecessary effort.

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Case 25: Delay in diagnosis with no apparent harm.

45 y.o.a male patient with transplant liver and recurrent history of cholangitis after transplantation. Due to persistent itching and progressive jaundice, percutaneous transhepatic cholangiography (PTC) was performed for biliary drainage. PTC showed multisegmental involvement with dilated and stenotic biliary ducts (red arrows, A).

Contrast enhanced upper abdominal MRI and MRCP for evaluation of biliary tree were reported as “Chronic cholangiopathic changes due to recurrent episodes of cholangitis” . Clinicians suspected of “ischemic cholangiopathy” due to liver transplant history, and ordered Abdominal CTA to rule out ischemic etiology.

CTA performed one month after MRI, revealed hepatic artery occlusion (blue arrows, C,E) and arterial collateralisation (yellow arrows, C,D). After confirmation of “ischemic bilipathy”, previous MRI was evaluated retrospectively. MRI images (B) taken from the same slice levels of CTA (C), was less obvious to diagnose, due to artifacts secondary to inadequate breath-holding. Higher spatial resolution with lesser imaging time of CTA enabled accurate diagnosis in this case.

Fig. 25: Delay in diagnosis with no apparent harm.

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Case 26: Delay in diagnosis with indirect harm.

Cardiac MRI of a 71 y.o.a. male patient for evaluation of angina and left ventricle hypertrophy showed a hyperintense lesion in the right lung, which was seen in only one slice of black blood sequence with 8 mm slice thickness (red arrow, A). This lesion was not reported. Three years later, a growing lung mass is detected in the superior segment of the right lower lobe (red arrows, B, C). Due to the major fissure invasion (blue arrow, C), right pneumonectomy was done instead of lobectomy.

Fig. 26: Delay in diagnosis with indirect harm.

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Case 27: Delay in diagnosis with life threatening complication.

47 y.o.a. male patient with chest pain and abdominal discomfort. History and clinical examination suggested cardiovascular etiology as possible underlying cause. Coronary CT was ordered to evaluate presence of coronary artery disease. Coronary arteries were reported as normal. However, well-defined splenic hypervascular lesion was present and missed due to “edge effect”. The lesion was seen only at the last few slices of “images with large field of view” (red arrow, A). One week later, patient admitted to ER with severe left upper quadrant pain. Abdominal CECT shows ruptured lesion (red arrows, B,C), subcapsular splenic hematoma (blue arrows, B,C) with active extravasation (not shown).

Fig. 27: Delay in diagnosis with life threatening complication.

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Conclusion

Errors, discrepancies and confounding biases are inseparable parts of daily routine for radiologists, and can cause various unexpected clinical consequences. In this study, we explained certain types of errors and biases with case-based examples. By doing so, we aimed to increase awareness about radiological diagnostic errors and related biases. Being familiar with errors and underlying biases is essential for radiologists to cope with them, to avoid false interpretations and try to develop countermeasures.
Personal information and conflict of interest

Ö.Önder-Ankara/TR-nothing to disclose//A.Azizova-Ankara/TR-nothing to disclose//
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disclose.
References

References are shown in Figure-28.
REFERENCES


Fig. 28: The reference list.

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