Diagnostic errors: understanding the concepts through spine examples.

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Learning objectives

Any man can make mistakes, but only an idiot persists in his error. *Cicero.*

*To err is human, but more so is to blame it on others.* *Baltasar Gracián.*

**Learning Objectives:**

This poster shows a spectrum of the most common errors in our experience of double-reading spine studies, trying whenever possible to determine the diagnostic error involve in each example. It aims to (1) clarify the concept of diagnostic error; (2) show a spectrum of the most common diagnostic mistakes, and (3) provide strategies to minimize them.
Background

Most of the misdiagnoses occur by a combination of factors in the radiological process. Part of our work as radiologists is to detect and analyse their causes. Our poster is focused on common diagnostic errors. A diagnostic error consists in the omission or incorrect interpretation of a radiological finding [1]. The most common radiological error in spine is the omission of fractures. It is considered the main cause of legal action against radiologists, after failing to detect breast and lung cancer [2]. Since the publication of the article “To err is human” in the year 1999 with the alarming fact that up to 100,000 people a year were dying by medical errors [3] the degree of vigilance towards errors has grown. In the United States of America a third of all radiologists are sued and at the same time a third of these are accused of medical malpractice [1]. A third of these demands are due to errors in the spine, most frequently the cervical spine (68%) with an average of nearly half a million dollars compensation [4].

Not only the patients' health, but also their sick leaves and economic compensations depend on thousands of spine reports issued every year. Therefore, it is our responsibility to know why errors occur and how to detect them to avoid making the same mistakes in the future. The reduction of errors has a positive impact on the health of the patient, healthcare costs and also the radiologist.

Concept, frequency and importance of the diagnostic error

In Radiology a diagnostic error is considered as the incorrect interpretation of the images, regardless of whether this causes harm to the patient or not [5]. The prevalence of the error ranges from 3% to 30%, depending on the series and criteria that are analysed [2, 6, 7]. Unlike a simple error, negligence occurs when an incorrect interpretation exceeds an acceptable limit (by imprudence or inexperience) and causes damage to the patient [8]. It is estimated that up to 20% of the radiological errors are clinically relevant or correspond to one greater diagnostic error [9].

It is important to convince the doctors, managers and judges that radiological errors are biased by the belief that perfection and infallibility can be required to the radiologist, when in fact the standard pattern of assistance and perfection are not synonymous [8, 10-14]. The practice of the radiologist should be judged according to whether the diagnostic process is correct, not only according to the diagnostic or therapeutic outcome [5, 8, 15].

Errors are classified as active and latent. Active errors are those committed by radiologists on their own. They happen when a diagnosis is omitted or incorrect, when follow-up or other imaging tests are not recommended, or by inefficient communication of critical or unexpected findings to the requester of the study [16]. Latent errors are
those arising from the system and involved in the whole radiological process since the moment the patient comes to the radiology department, to the point the medical requester receives the radiological report. They include for example defects in equipment, scheduling, organization issues, PACS system, workloads, work environment or internal policies of the service [2, 16, 17]. Up to 90% of medical errors stem from a combination of these factors [13,16]. Here is the importance of identifying latent errors, their correction is likely to create a greater positive impact in terms of quality of care (table 1).

To explain the errors and accidents the English psychologist Reason described a theory based on the model of the Swiss cheese (Fig. 1-3), which argues that to make an active error that causes harm, several latent errors must occur simultaneously [16].

<table>
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<th>Table 1. Latent errors or System errors</th>
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<tr>
<td>Category</td>
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<td><strong>Equipment, design, and maintenance</strong></td>
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**Fig. 1:** Reason’s Swiss cheese model of latent and active contributors to errors. A series of safeguards (slices of Swiss cheese) exist in a system or are introduced to minimize the chance of an error occurring. Within each layer of defense, latent factors exist (holes in the cheese) that predispose the system to errors. A single latent failure is unlikely to result in an error; however, with proper alignment of latent failures and in the presence of an active failure, an error is likely to manifest. When steps are introduced to prevent errors, attention should therefore focus not only on human failures but also on introducing safeguards to prevent latent failures from aligning.

Fig. 2: Safeguards and defenses. A series of five safeguards and defenses have been introduced to minimize the chances of latent failures aligning to produce an error. By undertaking regular safety audits, introducing standardized work flow in procedure areas, instilling a culture of safety throughout a department, training and orienting all new hires, and ensuring that all procedures are properly supervised, the effects or complications related to latent contributors residing within a system can be minimized or even prevented.

**Fig. 3:** Insufficient safeguards. If insufficient safeguards or defenses exist, an error is likely to ultimately occur. In this example, despite the demonstration that some defenses effectively minimize or prevent errors from occurring, a situation will arise when a series of latent contributors align and an error will occur. Here, poor ergonomics and ambient light, frequent telephone disturbances, working with an inexperienced resident, and other factors listed on the left side align to enable an error to occur. A lesion detected during a readout session was not mentioned in the report, possibly with important consequences for the patient’s care. Such contributors should be identified through the root cause analysis process, and steps should be put in place to prevent this error from occurring again.

Findings and procedure details

Spectrum of diagnostic errors in the vertebral spine

Radiology depends essentially on the identification and interpretation of visual findings, thus perception biases and cognitive have a more important role than in other areas [11]. While the training can improve the diagnostic radiologist threshold, some of these processes are not always subject to conscious control by the human mind [7].

Errors of perception:

They consist of the omission of a finding that is present in the image [2, 8, 18]. They are the most common (80%) and constitute the first cause of lawsuit in Radiology [2]. In general, they are triggered off by other factors, e.g. the poor quality of the images, equivocal or insufficient clinical information, the level of alert of the observer, eyestrain, distracting factors, the degree of visibility (evidence) of the alteration, lack of review of previous studies, etc. Retrospective error is frequent in these situations (Fig. 4) or tendency to wrongly believe after knowing the diagnosis that the injury would have identified [8, 10].

Omission error:

It is to ignore a finding despite having kept the eyes on this anatomical area [2]. Some common spine omissions are sacral fractures, hernias, spondylolysis, and transverse process fractures (Figs. 5-11). Injuries located in peripheral areas or outside the field of interest, injuries visible in few slices or unexpected incidental findings can explain these errors.

Satisfaction of search error (SOS)

It occurs when once detected an injury the radiologist prematurely ends the search, omitting other relevant findings (Figs. 12-14) [2, 11, 16].

To avoid these errors the radiologist should always perform a systematic analysis of the study and a secondary search. It should also be aware of lesions that often arise in association and do a conscious search for both these findings, and any other incidental ones.

Cognitive errors

In these cases the anomaly is detected but interpreted in the wrong way. Cognitive errors include a misperception, failed heuristic or biases of cognition. Cognition biases relate to psychological distortions that lead to a poor critical judgment [7] patterns.
**Framing bias (Induction error or bias of conditioning)**

This error occurs when the radiologist is influenced by the way a clinical problem is outlined (Fig. 15) [11]. It can be prevented by analysing the study before reading the clinical information or by requesting additional clinical information in the face of unexpected image findings.

**Availability bias**

It is the tendency to consider first a diagnosis that is familiar and prevailing in the mind for any particular reason. For example, a radiologist who is sued for having omitted a pathological fracture is likely that tends to consider a possible tumoral origin more frequently in his diagnoses [5] than other colleagues. To avoid them you can get objective information about the real prevalence and likelihood of the diagnosis and compare the rate of similar diagnoses in the team of radiologists of your health centre [7].

**False positive error or over-reading**

It happens when non-pathological radiological findings are wrongly interpreted as disease. It can occur with anatomic variants, normal post-surgical findings or image artifacts [7, 19-22]. They are usually due to insufficient academic knowledge and indicate lack of experience. They are most frequent in young residents or radiologists. (Figs. 16-20). Continuing medical education and the consultation with other colleagues have been shown to reduce these errors [17].

**False negative error or underreading**

It is the tendency to not associate a pathologic significance with the radiological images. They might be caused by fear to overdiagnose simple or incidental findings or pressure from the administration to reduce expenses by false positives [2].

**Premature closure error**

It is the tendency to assume a diagnosis without a full verification. This error is illustrated in Figure 21, which corresponds to a 25 year old patient with a cervical trauma and a wrong diagnosis of epidural hematoma instead of cervical disc herniation [20]. It is advisable to assess differential diagnoses with reasonable alternatives; never convert an inconclusive diagnosis into a definitive one without clinical correlation and/or complementary additional tests if they were necessary [7]. The radiologist should express the degree of certainty of the diagnosis in the radiology report.
Alliterative Error

This type of error results from the influence of a former diagnosis made by another radiologist [2]. The probability that the second radiologist perpetuates this error in following reports of the same patient is high if he is not aware of the error (Figs. 13 and 21) [7, 23].

They can be avoided by analysing images, both the present and the previous, before reading the reports. It is useful to search for evidence that could refute the initial diagnosis, not only the one that can confirm it [7], and always avoid the "copy and paste" of previous reports.

Communication errors

They are a frequent cause of lawsuit against the radiologist. It is important to remember that the responsibility of the radiologist includes not only to make a correct diagnosis, but also to communicate in a direct and effective way the critical, serious and unexpected findings or modifications to reports that change the patient management [2]. Also the radiologist should suggest additional radiological procedures (Fig. 9) or follow-ups where appropriate [24, 25, 26].

Finally, errors in the numbering of the vertebral levels, because of anatomic variants that include transition vertebrae (Fig. 22), floating ribs, absent or hypoplastic vertebral bodies, variability in the level where the medullary cone ends or inconstant insertion of ligaments in the transverse processes of L5 should be stated in the radiological report [20, 21], due to implications in upcoming therapeutic or surgical procedures, since misidentification would bring about an intervention in the wrong spine level. Strategies to prevent them are simple. Radiologist should describe the numbering scheme adopted in those cases in which the anatomy deviates from the standard pattern or use sagittal imaging of the adjacent spinal segments to get more anatomical references [24].
Images for this section:

**Fig. 4:** Omission error: Subtle fracture of the superior endplate of L2 visible in the coronal (a) and sagittal (b) CT reformats, which was initially missed and posteriorly confirmed in the sagittal MR-STIR sequence where bone edema was found.

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Fig. 5: Perception error: Bilateral sacral insufficiency fractures with prominent bone edema in 94-year-old patient with low back pain. They were initially omitted in the sagittal MR-STIR lumbar sequence (a) and later detected in the axial MR-STIR of the pelvis.

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**Fig. 6:** Omission error: 44 year-old patient with chronic low back pain. Sagital T1WI show a pars interarticularis lysis of L5 (arrows), that was omitted due to its peripheral location (a). The patient required surgery, and a CT was performed after it (b).

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**Fig. 7:** Omission error: Axial CT (a) and sagittal reformat (b) show a fracture of the left superior articular process of C7 that was detected in double reading.

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**Fig. 8:** Perception error: Axial NECT (bone window) shows a small left sacral wing cortical defect (arrow) after a gluteal contusion in a 76 year-old patient, finding omitted in the
initial report (a). The coronal T1WI (b) shows a hypointense line consistent with a vertical sacral fracture.

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Fig. 9: Omission and comunication error: Axial NECT (bone window) shows a fracture of the transverse foramen of C3 (arrow) in a patient with neurologic symptoms (a). It is not only important to detect it but also to suggest a vascular study to exclude injury of the vertebral artery.

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Fig. 10: Perception error: Axial NECT (a) and sagittal reconstruction (b) show a fracture of the left transverse process of L1 (arrows). It is not uncommon that these lesions go inadverted. They are often associated to renal lesions.

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Fig. 11: Perception error: Bulging disk depicted at the left neural foranima of L4-L5 (arrows) in axial (a) and sagital T2WI (b) of a patient with incapacitating sciatic pain. The lesion was detected at double reading.
Fig. 12: Satisfaction of search error (SOS): Sagittal T1WI (a) and T2WI-STIR (b) of the thoracic vertebral spine show a dorsal epidural hematoma with cord compression after a trauma. In the first radiological report only the post-traumatic herniation was reported, and the large dorsal epidural hematoma was omitted.
Fig. 13: SOS and alliterative error: (a, b) 36 year-old woman with paresthesia was diagnosed with herniated disk on consecutive years by another radiologist, omitting a medullary lesion (arrows). (c) Two months later sagittal brain MR-FLAIR images showed signs of multiple sclerosis.

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Fig. 14: SOS error: Spondylolisthesis of the L4-L5 drifted the attention of the radiologist omitting the periaortic adenopathy (arrow) visible in the sagittal T1WI of the spine.

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Fig. 15: Cognitive error (Framing Bias): L4 limbus vertebra seen in a sagittal TC reformat (bone window) was interpreted as an acute fracture in a trauma patient. Limbus vertebrae can cause chronic low back pain, but can be differentiated from acute fractures due to their sclerotic cortical border.

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Fig. 16: Cognitive error: Sagittal TC reformats in a patient with cervical trauma were interpreted as a fracture dislocation of C4 (arrow) (a). Movement artefact was suspected during review of the study; a second study was performed and confirmed the absence of fracture (b).

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Fig. 17: Cognitive error: (a) The cortical irregularity of C6 body was misinterpreted as fractures causing an overdiagnosis error (b) These artefacts related to movement can be easily recognised on axial planes, where air-soft tissue interface is visible.

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Fig. 18: Cognitive error: A hyperintensity of the T11 body in STIR T2WI was interpreted as bone marrow edema, instead of a gradient warping artifact produced by distortion of the gradient at the edges of this large field of view.

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Fig. 19: Cognitive error: Patient diagnosed with a vascular malformation instead of the CSF flow artifact. CSF flow-related phenomenon is due to time of flight (TOF) effects and turbulent flow, these artifacts can simulate a wide variety of pathologies.

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Fig. 20: Cognitive error: Axial CT shows a basivertebral vein as a hypodense line across the vertebral body of T10 which was misinterpreted as a fracture line.

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Fig. 21: Premature closure and alliterative error: Axial CT and sagittal reformat of trauma patient (a, b) were interpreted as an epidural haematoma. At T1WI (c, d) another radiologist made the same diagnosis, without considering any differential option, such as herniated disk which was the final diagnosis after the double reading.

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Fig. 22: Cognitive and communication error: Coronal (a) and sagittal CT reformats show a Castellvi type IIIa lumbosacral transitional vertebra, with an enlarged right transverse process fused to sacrum (arrow). This anatomical configuration has a double importance. It must be noted in the radiological report as a reference on numbering the spine levels and the implications in the event of interventional treatment or surgery. The second reason is that it may lead to Bertolotti Syndrome (chronic lower back pain due to the reduced and asymmetrical motion at lumbosacral junction).

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Conclusion

Approach to errors and culture of the error

Active errors or diagnostic errors committed by the radiologist are subject to mental traps or psychological biases, and are difficult to control. It is part of our job to use strategies to minimize them, implement training sessions on errors, double reading, lifelong learning, and seek consultation with other colleagues or feedback (feedback) from the requester on the final diagnosis.

Our culture and education has tended to stigmatize the error and the people who commit it. This favours fear, shame and therefore its concealment. The best way to approach an error is to analyse the entire system rather than focus individually on the person who committed it [16, 19]. It is not easy, nor quick, and requires to establish a positive culture of error understood as an opportunity for all [26]. We are not required infallibility, but we are expected not to make mistakes beyond "the acceptable standard". One of the possible strategies to know our error rates is to make double reading of the cases [27, 28]. To uncover and measure our mistakes does not mean to "open Pandora’s box" with catastrophic consequences for the radiologist, but on the contrary, it is the mandatory way to improve and be competitive in a globalised digital world.

Finally, in the spinal column we must remember that we should be meticulous in the radiological reading of the study as we are in other anatomical areas, and let us not forget that a third of negligence lawsuits to radiologists are related to the omission of spine fractures.
References


