RESEARCH ARTICLE

Analysis of critical report notification from musculoskeletal radiology in a tertiary academic medical institution with a regional trauma center

Tae Ran Ahn, Yu Mi Jeong*, So Hyun Park, Ji Young Jeon, Sheen-Woo Lee, Young Sup Shim

Department of Radiology, Gil Medical Center, Gachon University College of Medicine, Incheon, Republic of Korea

* Current address: Department of Radiology, Eunpyeong St. Mary’s Hospital, College of Medicine, The Catholic University of Korea, Seoul, Republic of Korea

* youme34@gilhospital.com

Abstract

Purpose

We aimed to analyze the prevalence, causes, and clinical settings of 4-year critical radiologic reports (CRRs) notified from the musculoskeletal section of the radiology department. Then, we investigated the communication outcomes.

Methods

This study was approved by our institutional review board. We retrospectively included 175 musculoskeletal CRRs from our database between January 2017 and December 2020. The CRRs were analyzed by two musculoskeletal radiologists, who categorized the CRRs by clinical setting (emergency department(ED) patient, outpatient, and inpatient), body part, type of image modality, reason for CRR, incidental lesion, and clinical outcome. The clinical outcome was retrieved from the electronic medical records.

Results

The 175 musculoskeletal CRRs accounted for 5.4% of the CRRs (n = 3217) available in the study period. Most CRRs (94.9%, 166/175) corresponded to the musculoskeletal system, while the remaining ones (5.1%, 9/175) corresponded to the non-musculoskeletal system. In addition, the spine, extremities, and thoracic cage accounted for 52.6%, 40.6%, and 1.7% of the musculoskeletal CRRs, respectively. Moreover, most patients presented to the ED (50.3%, 88/175), followed by inpatients (30.9%, 54/175), and outpatients (18.9%, 33/175). The CRR reasons included missed fracture (54.3%), suspected malignancy (16%), clinical emergency (10.3%), unexpected infection/inflammation (11.4%), and others (8%). Furthermore, 11 (6.3%) incidental lesions were not related to the primary imaging purpose. Referring clinicians actively acknowledged 80% of the CRRs. The loss to follow-up action was the
highest in the ED patients (35.2%, 31/88; \( p < 0.001 \)), being significantly higher than that in outpatients (6.1%, 2/33) and inpatients (3.7%, 2/54).

**Conclusion**

Missed fractures were the most common cause of musculoskeletal CRRs. ED showed prevalence in musculoskeletal CRRs and reflected the highest loss to follow-up action. ED physicians should pay more attention to CRRs to enhance patient care.

**Introduction**

Medical imaging comprises an examination, a verified report, and the report communication [1]. Currently, routine official radiologic reports are documented through the Picture Archive and Communication System (PACS). However, critical or unexpected imaging findings with clinical significance may require timely non-routine communication. Optimal communication of critical radiologic reports (CRRs) has become more prevalent, especially after the American College of Radiology released standard guidelines for non-routine communication [2]. The detailed situations of non-routine communications by ACR guideline are as follows [2]: (i) findings that suggest a need for immediate or urgent intervention, (ii) findings that are discrepant with a preceding report of the same exam and where failure to act may adversely affect patient health, (iii) findings that the interpreting radiologist reasonably believes are significant and unexpected, may have a reasonable probability of impacting the patient’s health and may not require immediate attention but, if not acted on, may worsen over time and likely result in an adverse patient outcome.

Radiologic reports with clinical significance or requiring immediate action should be promptly informed to the referring physician to ensure the continuity of patient treatment. The Joint Commission has mandated compliance with the communication of critical test results among caregivers on a timely basis as an important part of the National Patient Safety Goals [3].

Non-routine communication varies depending on the institution, and many medical centers have implemented electronic systems for non-routine communication [4–6]. Thus, radiologists can timely alert the referring physician and their team by sending a text message related to CRRs using the notifications embedded in PACS. Despite the improving documentation of CRR non-routine communication [7, 8], to our knowledge, its analysis in specific subspecialties has not been addressed. In particular, musculoskeletal CRRs may be beneficial for patients with potentially missing risk management, highlighting the importance of their analysis.

In this study, we analyzed the prevalence, reasons, clinical settings, and follow-up rate related to CRRs in the musculoskeletal section and identified the impact of electronic notification systems and communication outcomes.

**Materials and methods**

**Study design**

This retrospective study was approved by the Gil Medical Center institutional review board and the requirement for informed consent was waived given the retrospective nature of this study.
Patients

Our institution is a tertiary-referral academic medical institution with 1700 beds and a national regional trauma center. An electronic alert notification system was embedded in PACS for CRRs in 2015. In total, 3217 consecutive CRRs were retrieved from the electronic medical record (EMR) system (BESTCare 2.0, Korea) from January 2017 to December 2020. Metadata including patient identification, patient age, referring department, and study name were automatically extracted during database search, obtaining 180 CRRs from the musculoskeletal section of the radiology department. As 5 cases showed no clinical significance (i.e., small disc herniation, mistake, or error of radiologist), we used 175 musculoskeletal CRRs for analysis (Fig 1).

CRRs

We defined musculoskeletal CRR as a significant finding detected in musculoskeletal imaging studies to primarily intend to evaluate the musculoskeletal system including spine, extremities, and pelvic bone, finally read by musculoskeletal attending radiologists. The CRR information about each alert notification (i.e., examination name, sending time of text message, and physician receiving the notification) was documented in the corresponding EMRs. During the study period of 4 years, five radiologists worked in the musculoskeletal section, and they reported CRRs for emergency findings that needed urgent management or for clinically important findings (e.g., trauma, tumor, infection) that were considered unrecognized by the referring physician.

CRR analysis

Two musculoskeletal radiologists with 12 and 4 years of experience reviewed the EMRs and magnetic resonance imaging (MRI) reports with image findings of each musculoskeletal CRR case. We categorized the data by clinical setting (emergency department(ED) patient,
inpatient, outpatient), body part (musculoskeletal, non-musculoskeletal), imaging modality (MRI, computed tomography(CT), ultrasound, X-ray), reason for CRR (e.g., clinical emergency with need of immediate management due to pseudoaneurysm, necrotizing fasciitis, or cord compression; missed fracture; suspected malignancy; unexpected infection/inflammation), and incidental lesion or not.

**Follow-up after CRR**

The CRR was considered as actively acknowledged when clinical notes were available about the radiology result notification described by physicians in the EMR or when additional management (e.g., additional imaging, biopsy, consultation to another department, and treatment) was performed after the CRR notification. The clinical outcomes of each CRR were obtained from the corresponding EMRs and classified as surgical treatment/intervention, medical treatment, conservative management, and telephonic notification to patient. On the other hand, loss to follow-up action was considered for unacknowledged CRRs.

**Statistical analysis**

Descriptive statistics were compared among the causes, clinical settings, and follow-up cases using chi-squared tests implemented in SPSS (version 26.0; IBM, Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

**Results**

The characteristics of the 175 study subjects (101 males, 74 females) are listed in Table 1. The age range of the subjects was 7–84 years with mean of 54.8 years. In the clinical setting, most patients were presented to the ED (50.3%, 88/175), followed by inpatients (30.9%, 54/175) and outpatients (18.9%, 33/175). Radiography (41.7%, 73/175) was the most frequent imaging modality followed by MRI (34.3%, 60/175), CT (22.9%, 40/175), and ultrasound (1.1%, 2/175).

The CRRs from the musculoskeletal imaging accounted for 5.4% ($n = 175$) of the available CRRs ($n = 3217$). Most musculoskeletal CRRs (94.9%, 166/175) corresponded to the musculoskeletal system, and the remaining CRRs (5.1%, 9/175) corresponded to the non-musculoskeletal system (i.e., abdomen, chest, brain). In the musculoskeletal system, the spine cases (52.6%, 92/166) outnumbered cases in the extremities (40.6%, 74/166).

Table 2 and Fig 2 show the reasons for the CRRs. Missed fractures (54.3%, 95/175; Figs 3 and 4) were the most common reasons followed by suspected malignancy (16.0%, 28/175), unexpected infection/inflammation (11.4%, 20/175), clinical emergency (10.3%, 18/175; Fig 5), and others (e.g., hardware complication, myelopathy, foreign body, dural arteriovenous fistula; 8.0%, 14/175). However, there were significant differences in the reasons according to the clinical setting. Missed fractures were significantly more numerous in the ED than in other clinical settings ($p < 0.001$). The most common reason per clinical setting was missed fractures (78/88) in ED patients, clinical emergency (14/54) in inpatients, and suspected malignancy (12/33) in outpatients.

Table 3 lists the missed fractures according to the body part. Most fractures were missed in the spine (45.3%, 43/95) followed by lower extremity (26.3%, 25/95), upper extremity (23.2%, 22/95), and thoracic cage (3.2%, 3/95). The C-spine (65.1%, 28/43) was the most common site of a missed spinal fracture.

From the cases, 11 (6.3%) incidental lesions in the brain, lung, retroperitoneum, and musculoskeletal system were detected from spine MRI, spine CT, and shoulder CT (Table 4 and Fig 6).
Fig 7 shows the management and loss to follow-up action after CRR according to the clinical setting. The active acknowledgement rate of CRR was 80% (140/175), with loss to follow-up action occurring for the remaining 20% (35/175) of cases (Table 5(a)). The loss to follow-up action was higher in the ED patients (35.2%, 31/88) than in the inpatients (3.7%, 2/54) and outpatients (6.1%, 2/33) ($p < 0.001$). All the 13 telephonic notifications were identified only in the ED patients. The details about the cases of loss to follow-up action are shown in Table 5(b).

**Discussion**

We analyzed the usage of an alert notification system for CRRs in the musculoskeletal section. The analysis included prevalence, causes, clinical settings, and whether the appropriate follow-up action after CRR according to the clinical setting. The active acknowledgement rate of CRR was 80% (140/175), with loss to follow-up action occurring for the remaining 20% (35/175) of cases (Table 5(a)). The loss to follow-up action was higher in the ED patients (35.2%, 31/88) than in the inpatients (3.7%, 2/54) and outpatients (6.1%, 2/33) ($p < 0.001$). All the 13 telephonic notifications were identified only in the ED patients. The details about the cases of loss to follow-up action are shown in Table 5(b).

**Table 1. Characteristics of the study subjects.**

| Value |
|-------|
| Total number of musculoskeletal CRR | 175 |
| Mean age (year) | 54.8 |
| Clinical setting | |
| 1. ED patient | 88 (50.3) |
| 2. Inpatient | 54 (30.9) |
| 3. Outpatient | 33 (18.9) |
| Body part | |
| 1. Musculoskeletal system* | 166 (94.9) |
| (1) Spine | 92 (52.6) |
| • Cervical | 40 (22.9) |
| • Thoracic | 17 (9.7) |
| • Lumbar | 35 (20) |
| (2) Extremity | 74 (40.6) |
| • Upper extremity | 28 (16) |
| • Lower extremity | 43 (24.6) |
| (3) Thoracic cage | 3 (1.7) |
| 2. Non-musculoskeletal system ** | 9 (5.1) |
| Types of image modality | |
| 1. X-ray | 73 (41.7) |
| 2. MRI | 60 (34.3) |
| 3. CT | 40 (22.9) |
| 4. Ultrasound | 2 (1.1) |

Note. Data are presented as number (%), unless indicated otherwise.

* Musculoskeletal system includes muscles, tendons, ligaments, nerves, discs, and blood vessels.

** Non-musculoskeletal system includes abdomen, chest, and brain.

https://doi.org/10.1371/journal.pone.0262511.t001

**Table 2. The reason for critical report notification.**

| Reason for CRR | Cases No. |
|----------------|-----------|
| 1. Clinical emergency (i.e. active bleeding, necrotizing fasciitis, cord compression,) | 18 (10.3) |
| 2. Missed Fracture (refer to Table 2 for detail) | 95 (54.3) |
| 3. Concern for malignancy | 28 (16) |
| 4. Unexpected infection/Inflammation | 20 (11.4) |
| 5. Others (i.e. hardware complication, myelopathy, foreign body, dural AVF) | 14 (8) |

Note. Data are presented as number (%), unless indicated otherwise.

https://doi.org/10.1371/journal.pone.0262511.t002
up action was taken after the CRR. The results revealed that musculoskeletal CRRs accounted for 5.4% of the total CRRs. Missed fractures were the most common cause of musculoskeletal CRRs, with ED patients showing most of these cases. The active acknowledgement rate of musculoskeletal CRRs was 80%, whereas follow-up action was lost in 20% of CRRs. However, the results differed depending on the clinical setting (ED patients, inpatients, or outpatients). The rate of loss to follow-up action was the highest in the ED.

Few studies have reported that musculoskeletal imaging shows a relatively low prevalence of CRRs (4.5% [8], 19.3% [9]), requiring communication beyond the formal report. Therefore, scarce research is available on non-routine communication regarding musculoskeletal imaging. Consistent with the aforementioned studies [8, 9], we found that musculoskeletal CRRs had a low prevalence, accounting for only 5.4% of the CRRs. This low incidence may be explained by the musculoskeletal system having a low proportion of alert categories including

Fig 2. Reasons for CRR.
https://doi.org/10.1371/journal.pone.0262511.g002

Fig 3. Dorsal dislocation of fourth and fifth carpometacarpal joint (ED patient, missed fracture, telephone call). A 28-year-old man visited the ED because of hand pain after falling. Hand X-ray anteroposterior view shows no significant abnormality (A), but lateral (B) and oblique (C) views clearly show dorsal dislocation of the fourth and fifth metacarpophalangeal joint. The ED informed the patient about this lesion via telephone after obtaining the CRR.
https://doi.org/10.1371/journal.pone.0262511.g003
Missed fractures were the most common cause of musculoskeletal CRRs in our study, with the highest prevalence in the ED. Missed fractures represent up to 80% of diagnostic errors in the ED [10], and it frequently lead to legal problems in medicine [11]. Given the radiology workforce shortage and emergent clinical situations, physicians in the ED should often make management decisions before radiologic reports become available, especially considering plain radiographs [12, 13]. In our study, the cervical spine was the most common location of missed fractures, showing consistency with various studies that have reported that plain radiography may lead to miss more than 50% of cervical spine fractures for reasons including inadequate cervical spine series (e.g., lateral view only, non-visualization of C7-T1) and misreading of plain radiographies with or without adequate standard series [10, 14, 15]. In the extremities, the wrist and hand have been reported among the most common locations of missed fractures on plain radiographies [16, 17]. Wei et al. [16] showed that the wrist is the most frequent location for missed fractures, and the foot is the most frequent location expressed as percentage in the same location for extremity missed fractures. In addition, Guly [11] reported that fractures in the wrist are the second most frequently missed. In the pediatric population, Mounts et al. [17] reported that the most frequent missed fractures occur in the hand phalanges, followed by the metatarsal bone, distal radius, and tibia. Similarly, we found that the wrist and hand are the most frequent locations for missed fractures in the extremities.
Several infectious, inflammatory, and vascular emergencies also affect the musculoskeletal system [18–20], whereas medical emergencies in the musculoskeletal system are commonly secondary to trauma. However, clinical emergencies were rare in the musculoskeletal CRRs (10.3%, 18/175) considered in our study. In emergencies, such as open fracture, active bleeding, necrotizing fasciitis, and cord compression, rapid management could be performed ahead of formal radiologic reports due to the definite clinical findings, possibly decreasing the rate of CRRs in clinical practice.

Fig 5. Pseudoaneurysm of superficial femoral artery (outpatient, emergency, interventional treatment). A 69-year-old man with a history of open reduction and internal fixation of the femur for a fracture that occurred 1 month before this examination complained of a palpable mass on his thigh. The characteristic yin-yang sign is noted on Doppler ultrasonography (A). Emergent femoral angiography shows a large pseudoaneurysm (B). The patient was treated with an endovascular stent graft.

https://doi.org/10.1371/journal.pone.0262511.g005

Several infectious, inflammatory, and vascular emergencies also affect the musculoskeletal system [18–20], whereas medical emergencies in the musculoskeletal system are commonly secondary to trauma. However, clinical emergencies were rare in the musculoskeletal CRRs (10.3%, 18/175) considered in our study. In emergencies, such as open fracture, active bleeding, necrotizing fasciitis, and cord compression, rapid management could be performed ahead of formal radiologic reports due to the definite clinical findings, possibly decreasing the rate of CRRs in clinical practice.

Table 3. Distribution of missed fractures.

| Location         | n (95) |
|------------------|--------|
| Axial skeleton   |        |
| Spine            | 43     |
| • Cervical       | 28     |
| • Thoracic       | 6      |
| • Lumbar         | 9      |
| Sacrum           | 2      |
| Upper extremity  |        |
| Shoulder         | 3      |
| Elbow            | 8      |
| Wrist and hand   | 11     |
| Lower extremity  |        |
| Hip              | 9      |
| Knee             | 7      |
| Lower leg        | 1      |
| Foot & Ankle     | 8      |
| Thoracic cage    |        |
| Rib              | 2      |
| Sternum          | 1      |

Note. Data are presented as number (%), unless indicated otherwise.

https://doi.org/10.1371/journal.pone.0262511.t003
We also found that 6.3% (11/175) of incidental lesions in the brain, lung, retroperitoneum, and bone and joint were detected on spine MRI, CT, and shoulder CT. In approximately half of these cases, CRRs were generated by suspected malignancy. To prevent unexpected radiologic findings deriving in mortality or morbidity, CRRs due to incidentally suspected malignancy are important for patient safety. With the development of imaging techniques, the diagnostic performance has improved, and the frequency of incidental findings that are unrelated to the primary purpose of examination has increased [21]. In whole-body MRI of the general adult population, up to 36% of potentially relevant incidental findings have been reported [22]. As musculoskeletal imaging covers various body parts, many unexpected incidental lesions may be revealed [23–25]. One meta-analysis provided a mean frequency of incidental findings in imaging diagnostic tests of 23.6%, mean frequency of clinical follow-up of 64.5%, and mean frequency of clinical confirmation of 45.6% [26]. Clinicians who order imaging studies in the trauma setting usually pay attention to detect bone or soft tissue injuries. This study can help clinicians to learn specific missed traumatic and non-traumatic lesions in musculoskeletal imaging, which will improve patient care as well as reduce the follow up loss rate.

We found a 20% loss to follow-up action, possibly due to ineffective communication between the radiologists and referring physicians or to the patient’s disagreement to subsequent work-up or treatment. Roy et al. [27] reported that when patients were discharged from hospitals with pending examination results, physician unawareness of actionable results could reach up to 62%, potentially leading to adverse outcomes. Non-routine communication of clinically significant findings may ensure the review of reports by a clinician [6]. Sahraian et al. [28] assessed the utilization of reports and images in musculoskeletal radiology, with only 0.8% of referring physicians reviewing images without radiologic reports. However, in the ED, viewing images before the formal radiologic reports was much more frequent, accounting for 9.7% of the cases [28]. Consistently, the rate of active acknowledgement was significantly lower in ED patients (64.8%, 57/88; p < 0.001) than in inpatients or outpatients. Therefore, clinicians being acquainted with missed lesions during emergencies can help to reduce the loss to follow-up action rate. Telephonic follow-up is being increasingly focused on patient management, particularly in the ED [29, 30]. In our study, 7.2% of the CRRs initially undetected by the clinicians were provided to the patients by telephone. Such efforts will likely help improving patient safety and reducing delayed treatment.

Table 4. Clinically unexpected incidental lesions.

| Age/Sex | Location | Specific site | Final diagnosis | Radiologic examination |
|---------|----------|--------------|-----------------|------------------------|
| 28/F    | Brain    | Pituitary gland | Macroadenoma | Cervical spine MRI |
| 47/M    | Brain    | Cerebellum | Metastasis | Cervical spine MRI |
| 71/M    | Brain    | Cerebrum | Metastasis | Cervical spine MRI |
| 47/M    | Thorax   | Lung | Tuberculosis | Shoulder CT |
| 60/F    | Thorax   | Lung | Tuberculosis | Cervical spine MRI |
| 31/M    | Thorax   | Lung | * | Thoracic spine CT |
| 81/M    | Hip & Pelvis | Femoral head | Avascular necrosis | Lumbar spine MRI |
| 26/M    | Hip & Pelvis | Sacroiliac joint | Sacroilitis | Lumbar spine MRI |
| 38/F    | Retroperitoneal space | Kidney | Angiomyolipoma | Lumbar spine MRI |
| 57/F    | Retroperitoneal space | Paraortic space | Indeterminate lymph node | Lumbar spine CT |
| 62/F    | Retroperitoneal space | Paraortic space | Metastatic lymph node from cervical cancer | Lumbar spine MRI |

*Follow up loss.

https://doi.org/10.1371/journal.pone.0262511.t004
Fig 6. Pulmonary tuberculosis (outpatient, incidental lesion, medical treatment). A 60-year-old woman visited our outpatient clinic with bilateral numbness. C-spine MRI (A) allowed to determine a herniated disc at C6-7 (not shown) and incidentally noted consolidation in the right upper lung. Chest CT after CRR shows a large cavitary lesion in the right upper lobe (B). The patient underwent the QuantiFERON test, which was positive for tuberculosis infection and was treated with four-drug therapy.

https://doi.org/10.1371/journal.pone.0262511.g006

Fig 7. Management and follow-up after CRR.

https://doi.org/10.1371/journal.pone.0262511.g007

Table 5. Clinical outcome of musculoskeletal CRR (a) and follow-up loss (b) cases characteristics.

(a)

| Clinical outcome                                      | Patient No. |
|-------------------------------------------------------|-------------|
| 1. Actively acknowledgement                           | 140 (80)    |
| (1) Surgical treatment/intervention                    | 31          |
| (2) Medical treatment                                  | 12          |
| (3) Conservative treatment                            | 49          |
| (4) Further work up ([lab test, image exam, PET CT, biopsy]) | 35          |
| (5) Telephone notification to patient                  | 13          |

2. Loss of follow-up                                    

35 (20)

(b)

| Follow-up loss cases: Reason of CRR | Total patients (n = 35) | ED patient (n = 31) | Inpatient (n = 1) | Outpatient (n = 3) |
|-------------------------------------|------------------------|--------------------|------------------|-------------------|
| 1. Clinical emergency               | 0                      | 0                  | 0                | 0                 |
| 2. Missed fracture                  | 31                     | 31                 | 0                | 0                 |
| 3. Concern for malignancy           | 1                      | 0                  | 0                | 1                 |
| 4. Unexpected infection/inflammation| 1                      | 0                  | 0                | 1                 |
| 5. Others*                          | 2                      | 0                  | 1                | 1                 |

Note. Data are presented as number (%), unless indicated otherwise.

*Include large herniated disc on cervical trauma CT, Dural AVF, and myelopathy on MRI.

This study has some limitations to be considered. First, since this study targeted the CRRs generated in musculoskeletal imaging studies read by musculoskeletal attending radiologists, we did not include critical musculoskeletal lesions detected on non-musculoskeletal imaging (e.g., compression fracture detected on chest CT, musculoskeletal active bleeding detected on abdomen CT). Therefore, our study likely substantially underestimates the proportion of all CRRs that are missed fractures. Second, telephonic and direct communications between
radiologists and referring physicians were not included for the CRRs owing to problem solving and lack of electronic records. Third, as no detailed manual with specific examples of radiologic CRR is available in our institution, the CRR frequency may have been different depending on the radiologist. Fourth, as radiologists are usually not informed about the clinical outcome of their CRRs, we estimated it from the EMRs. Finally, this study was performed in a single institution with regional trauma center, the incidence of traumatic injury is relatively high. Hence, the results of this study may not reflect the reality of institutions without a trauma center. Nevertheless, the findings allowed us to learn about traumatic lesions that clinicians often miss.

In conclusion, missed fractures were the most common cause of musculoskeletal CRRs. In addition, the ED had the highest prevalence and rate of loss to follow-up action in patients with musculoskeletal CRRs. Physicians in the ED must pay more attention to CRRs, and radiologists should effectively communicate with the referring physicians and provide accurate and timely radiologic reports. A reliable standardized CRR manual is needed, and deployment is necessary across clinical practice.

Author Contributions

Conceptualization: Yu Mi Jeong.

Data curation: Tae Ran Ahn, Yu Mi Jeong, Ji Young Jeon, Sheen-Woo Lee, Young Sup Shim.

Formal analysis: Tae Ran Ahn, So Hyun Park.

Methodology: So Hyun Park.

Resources: Ji Young Jeon.

Supervision: Yu Mi Jeong.

Writing – original draft: Tae Ran Ahn, Yu Mi Jeong.

Writing – review & editing: Yu Mi Jeong, So Hyun Park.

References

1. Waite S, Scott JM, Drexlser I, Martino J, Legasto A, Gale B, et al. Communication errors in radiology–Pitfalls and how to avoid them. Clinical Imaging. 2018; 51: 266–272. https://doi.org/10.1016/j.clinimag.2018.05.025 PMID: 29906784

2. American College of Radiology. ACR practice parameter for communication of diagnostic imaging findings (Resolution 11). Reston, VA: American College of Radiology. 2014:1–8.

3. 2021 National Patient Safety Goals. [Internet]. Available from: www.jointcommission.org/standards/national-patient-safety-goals/hospital-national-patient-safety-goals/.

4. Lacson R, Prevedello LM, Andriele KP, O’Connor SD, Roy C, Gandhi T, et al. Four-year impact of an alert notification system on closed-loop communication of critical test results. American Journal of Roentgenology. 2014; 203(5): 933–938. https://doi.org/10.2214/AJR.14.13064 PMID: 25341129

5. Harvey HB, Alkasab TK, Pandharipande PV, Zhao J, Halpern EF, Salazar GM, et al. Radiologist compliance with institutional guidelines for use of nonroutine communication of diagnostic imaging results. Journal of the American College of Radiology. 2015; 12(4): 376–384. https://doi.org/10.1016/j.jacr.2014.08.013 PMID: 25441481

6. Larson PA, Berland LL, Griffith B, Kahn CE Jr, Liebscher LA. Actionable findings and the role of IT support: report of the ACR Actionable Reporting Work Group. Journal of the American College of Radiology. 2014; 11(6): 552–558. https://doi.org/10.1016/j.jacr.2013.10.016 PMID: 24485759

7. Lakhani P, Langlotz CP. Documentation of nonroutine communications of critical or significant radiology results: a multyear experience at a tertiary hospital. Journal of the American College of Radiology. 2010; 7(10): 782–790. https://doi.org/10.1016/j.jacr.2010.05.025 PMID: 20889108
8. Anthony SG, Prevedello LM, Damiano MM, Gandhi TK, Doublet PM, Seltzer SE, et al. Impact of a 4-year quality improvement initiative to improve communication of critical imaging test results. Radiology. 2011; 259(3):802–807. https://doi.org/10.1148/radiol.11101396 PMID: 21467253

9. Visser JJ, de Vries M, Kors JA. Assessment of actionable findings in radiology reports. European Journal of Radiology. 2020; 129:109109. https://doi.org/10.1016/j.ejrad.2020.109109 PMID: 32521309

10. Pinto A, Berritto D, Russo A, Ricciutiello F, Caruso M, Belfiore MP, et al. Traumatic fractures in adults: missed diagnosis on plain radiographs in the Emergency Department. Acta Bio Medica: Atenei Parmensis. 2018; 89(Suppl 1):111. https://doi.org/10.23750/abm.v89i1-S.7015 PMID: 29350641

11. Guly H. Diagnostic errors in an accident and emergency department. Emergency Medicine Journal. 2001; 18(4):263–269. https://doi.org/10.1136/emj.18.4.263 PMID: 11435359

12. Tranovich MJ, Gooch CM, Dougherty JM. Radiograph Interpretation Discrepancies in a Community Hospital Emergency Department. Western Journal of Emergency Medicine. 2019; 20(4):626.

13. Scepi M, Rouffineau J, Faure J-P, Richer J-P, Van Der Marcq P. Discordant results in x-ray interpretations between ED physicians and radiologists. A prospective investigation of 30000 trauma patients. The American Journal of Emergency Medicine. 2005; 23(7):918–920. https://doi.org/10.1016/j.ajem.2005.07.003 PMID: 16291460

14. Woodring JH, Lee C. The role and limitations of computed tomographic scanning in the evaluation of cervical trauma. The Journal of Trauma. 1992; 33(5):698–708. https://doi.org/10.1097/00005373-199211000-00019 PMID: 1464919

15. Davis JW, Phreaner DL, Hoyt DB, Mackersie RC. The etiology of missed cervical spine injuries. The Journal of Trauma. 1993; 34(3):342–346. https://doi.org/10.1097/00005373-199303000-00006 PMID: 8483172

16. Wei C-J, Tsai W-C, Tiu C-M, Wu H-T, Chiou H-J, Chang C-Y. Systematic analysis of missed extremity fractures in emergency radiology. Acta Radiologica. 2006; 47(7):710–717. https://doi.org/10.1080/028418506006340 PMID: 16950710

17. Mounts J, Clingenpeel J, McGuire E, Byers E, Kreeva Y. Most frequently missed fractures in the emergency department. Clinical Pediatrics. 2011; 50(3):183–186. https://doi.org/10.1177/0099228X10384725 PMID: 21127081

18. Mehta P, Morrow M, Russell J, Madhuripan N, Habeeb M. Magnetic resonance imaging of musculoskeletal emergencies. Seminars in Ultrasound, CT and MRI; 2017; 38(4):439–452. https://doi.org/10.1053/j.sult.2017.04.001 PMID: 28865532

19. Baker JC, Hillen TJ, Demertzis JL. The role of imaging in musculoskeletal emergencies. Seminars in Roentgenology; 2014; 49(2):169–185. https://doi.org/10.1053/j.ro.2014.01.001 PMID: 24836492

20. Fayad LM, Carrino JA, Fishman EK. Musculoskeletal infection: role of CT in the emergency department. Radiographics. 2007; 27(6):1723–1736. https://doi.org/10.1148/rg.276075033 PMID: 18025514

21. Booth TC, Najim R, Petkova H. Incidental findings discovered during imaging: implications for general practice. British Journal of General Practice; 2016; 66(648):346–347. https://doi.org/10.3399/bjgp16X685777 PMID: 27364655

22. Hegenscheid K, Seipel R, Schmidt CC, Völzke H, Kühn J-P, Biffar R, et al. Potentially relevant incidental findings on research whole-body MRI in the general adult population: frequencies and management. European Radiology. 2013; 23(3):816–826. https://doi.org/10.1007/s00330-012-2636-6 PMID: 22911290

23. Gaetke-Udager K, Girish G, Kaza RK, Jacobson J, Fessell D, Morag Y, et al. MR imaging of the pelvis: a guide to incidental musculoskeletal findings for abdominal radiologists. Abdominal Imaging. 2014; 39(4):776–796. https://doi.org/10.1007/s00261-014-0108-y PMID: 24682526

24. Tuncel SA, Çağlı B, Tekataş A, Kınç MY, Ünlü E, GençHELLAC H. Extraspinall incidental findings on routine MRI of lumbar spine: prevalence and reporting rates in 1278 patients. Korean Journal of Radiology. 2015; 16(4):866. https://doi.org/10.3348/kjr.2015.16.4.866 PMID: 26175587

25. Quattrocchi CC, Giona A, Di Martino AC, Errante Y, Scarchiola L, Mallio CA, et al. Extra-spinal incidental findings at lumbar spine MRI in the general population: a large cohort study. Insights into Imaging. 2013; 4(3):301–308. https://doi.org/10.1007/s13244-013-0234-z PMID: 23456750

26. Lumbreras B, Donat L, Hernández-Aguado I. Incidental findings in imaging diagnostic tests: a systematic review. The British Journal of Radiology. 2010; 83(988):276–289. https://doi.org/10.1259/bjr/98067945 PMID: 20335439

27. Roy CL, Poon EG, Karson AS, Ladak-Merchant Z, Johnson RE, Maviglia SM, et al. Patient safety concerns arising from test results that return after hospital discharge. Annals of Internal Medicine. 2005; 143(2):121–128. https://doi.org/10.7326/0003-4819-143-2-20050719-00011 PMID: 16027454
28. Sahraian S, Alvin MD, Haj-Mirzaian A, Jalilianhasanpour R, Beheshtian E, Honig E, et al. Musculoskeletal Radiology Reports: Overlooked or Valuable? Journal of Digital Imaging. 2020; 33(2): 348–354. https://doi.org/10.1007/s10278-019-00286-0 PMID: 31659589

29. Melnick V, Raptis C, McWilliams S, Picus D, Wahl R. On-call radiology resident discrepancies: categorization by patient location and severity. Journal of the American College of Radiology. 2016; 13(10): 1233–1238. https://doi.org/10.1016/j.jacr.2016.04.020 PMID: 27319372

30. Guss DA, Gray S, Castillo EM. The impact of patient telephone call after discharge on likelihood to recommend in an academic emergency department. The Journal of Emergency Medicine. 2014; 46(4): 560–566. https://doi.org/10.1016/j.jemermed.2013.11.067 PMID: 24484625