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Assessment of discordance between radiologists and emergency physicians of RADIOgraphs among discharged patients in an Emergency Department:

The RADIO-ED study

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Running title: Rereading X-ray to improve quality of care

Authors contribution: Conceptualization: Jean-Baptiste Bouillon-Minois, Julien Raconnat, Agnès Lhoste-Trouilloud and Jeannot Schmidt; Methodology: Jean-Baptiste Bouillon-Minois, Frédéric Dutheil and Jeannot Schmidt; Formal analysis: Celine Lambert; investigation: Mouna Benamor, Batiste Dalle and Maxime Laurent; Writing - original draft preparation: Jean-Baptiste Bouillon-Minois and Oluwaseun John Adeyemi; Writing - review and editing: All authors; Supervision: Jean-Baptiste Bouillon-Minois

Figure 1: Flow chart of the study. False positive: the emergency physician diagnosed something that does not exist. False negative: the EP don't diagnose something. No conclusion possible: the situation needs more exams. Incidentaloma: defined as something not related to the indication of X-ray.

Figure 2: Factors associated with discordance. Results are expressed as odds ratio and 95% confidence interval. CI: confidence interval; OR: odds ratio; REF: reference. Age is expressed in years, and the time of X-ray as follows: day is between 8:30 am and 6:29 pm, evening is between 6:30 pm and 11:59 pm, and night is between 00:00 am and 8:29 am.

Abstract

Background: The possibility to perform standard X-rays is mandatory for all French Emergency Department (ED). Initial interpretation is under the prescriber emergency physician – who continually works under extreme conditions, but a radiologist needs to describe a report as soon as possible. We decided to assess the rate of discordance between emergency physicians and radiologists among discharged patients.

Methods: We performed a monocentric study on an adult ED among discharged patients who had at least one X-ray during their consult. We used an automatic electronic system that classified interpretation as concordant or discordant. We review all discordant interpretation, which were classified as false negative, false positive or more exam needed.

Results: For one year, 8,988 patients had 12,666 X-rays. We found a total of 742 (5.9%) discordant X-ray, but only 277 (2.2%) discordance had a consequence (new consult or exam not initially scheduled). We found some factors associated with discordance such as male sex, or ankle, foot, knee, finger, wrist, ribs, and elbow locations.

Conclusions: On discharged patients, using a systematic second interpretation of X-ray by a radiologist, we found a total of 2.2% discordance that had an impact on the initial care.

Keywords: X-ray, quality, safety, Emergency Department, radiology

Introduction

The ability to perform 24/7 standard X-rays by a radiographer is mandatory to every Emergency Department (ED) in France [1]. Prescription and initial interpretation are under the attending emergency physician (EP) on call [1]. However, a radiologist needs to write a report as soon as possible [1]. X-ray is a medical investigation, which, in of itself, confers absolutely no therapeutic benefit to a patient, but with possible iatrogenic and mistake of interpretation consequences. Emergency medicine can easily be considered as perfect for errors because of uncooperative patients, inadequate histories, time-critical decisions, stress, concurrent tasks, and often junior personnel working on night shifts in overcrowded EDs [2–5]. Since more than two decades, plenty of articles are working on medical errors in EDs with recommendations such as engineering human factors and operational procedures, promoting team coordination, and standardizing care processes. While the majority of medical errors originated from communication failures, misreading of X-rays represent the majority of diagnosis errors performed in EDs [6,7]. Furthermore, such efforts should be coupled to systematic analysis of errors that occur [8]. The main indication of X-rays in emergency medicine is trauma, which could be vital adjuncts to physical exam, particularly in patients with general body trauma [9]. The main error is missed fractures that could have significant consequences for patients and physicians.

The main objective of this study is to assess the discordance rate of interpretation between EPs and radiologists. Secondary objective is to assess any risk factor or protective factor of discordance.

Methods

Study location

This study was performed in the university hospital of Clermont-Ferrand, France. Two departments were involved – ED and Radiology Department. The ED is composed by three different sectors – Trauma room, diagnosis room and ambulatory care. Four attendings EPs and four residents are working 24/7. During the day (8:30 am to 6:29 pm), two other attendings and two other residents are working in the ED. Up to 60,000 visits the ED every year [3,4]. The Radiology Department has a special team responsible of non-programmed care for ED, Intensive Care Unit and other departments for urgent exams. Every day (8:30 am to 6:29 pm), one attending and three residents are working in this section and two residents during the night (6:30 pm to 8:29 am).

Study design

This study is a monocentric, retrospective, and descriptive study. Inclusion criteria were age over 16 years old, visit in the ED between July 1st 2019 and June 30th 2020, at least one standard X-ray performed during the ED visit, discharged after ED visit. Exclusion criteria were age under 16 years old, no X-ray performed during the ED visit, administrative issue in the informatic system, admission after ED visit.

Study method

Using the Maincare[®] software, the EP (attending or resident) prescribe every mandatory standard X-ray following recommendations. Secondly, X-ray are performed by a radiographer on site with a mobile AGFA DXD 100[®], or in a special room with PHILIPS DIGITAL DIAGNOST 2006[®] or SIEMENS LUMINOS 2013[®]. EPs can next read the X-ray on a film or on the computer using McKesson[®] software. After reading the X-ray, the EPs in charge of the patient write in a special box the interpretation of the X-ray as a free text. This interpretation is

automatically transferred in the Radiology Department where the attending radiologist can read the X-ray on his side. If both EP and radiologist interpretation are the same, the chart is closed but if it is not the same, a quality check is open. Each X-ray is read by an attending radiologist following the two hours of EP's interpretation between 8:30 am and 6:30 pm from Monday through Friday, the morning after the shift between 6:30 pm and 8:30 am, and the following Monday for X-ray performed between Friday 6:30 pm and Monday 8:30am. In case of concordance, the chart is closed. In case of discordance, there is four possibilities. First, it could be a false positive interpretation – for example, the EP diagnosed a fracture although it was not. Secondly, it could be a false negative – for example, the EP don't diagnose a broken bone although it was. Thirdly, no conclusion can be done, and the situation needs more exams (mainly CT-scan). Lastly, the radiologist discovered an incidentaloma defined as something not related to the indication that need to be explored – for example a pulmonary nodule.

Data extraction

Using Maincare[®] software, we extracted the following data – date of birth of the patient, sex of the patient, date and hour of admission in the ED, type of X-ray (toe, foot, ankle, knee, hip, basin, lumbar rachis, thoracic rachis, cervical rachis, face, nose, ribs, sternum, clavícula, shoulder, humerus, elbow, forearm, wrist, scaphoid, hand, finger, abdomen, chest), specialty of physician, date of physician's diploma, resident or attending, indication of X-ray, concordance or discordance, type of discordance, follow-up of discordance.

Statistical consideration

Statistical analysis was performed using Stata software (version 15; StataCorp, College Station, Texas, USA). All tests were two-sided, with an alpha level set at 5%. Categorical data are expressed as numbers and associated percentage, and the age as mean \pm standard deviation. The factors associated with discordance were studied with generalized linear mixed

models with logit link function, considering the patient as a random effect. The results are expressed as odds ratio (OR) and 95% confidence interval (CI).

Ethics

This study was approved by an Ethic committee (Comité de Protection des Personnes Sud-Est VI) and registered on number 2020 / CE 52. The local representative of the “Comité National Informatique et Liberté” registered this study on number EI 200903.

Results

Characteristics of the population

Between July 1st 2019 and June 30th 2020, 51,552 consults were recorded on the ED of Clermont-Ferrand. 42,403 consults were excluded because of admission after ED consult, or no X-ray performed during the consult. On 12,666 X-ray (for a total of 8,988 consults), 11,819 were concordant and 847 discordant (Figure 1). Among the 8,988 consults, 4,914 patients (54.7%) were males, and the mean age was 45 ± 23 years old. More precisely, 7,035 (78.3%) were less than 65 years old, and 1,953 (21.7%) up to 65 years old, containing 336 (3.7%) up to 90 years old. Furthermore, 2,246 patients were under the care of non-emergency medicine residents, 1,709 of emergency medicine residents, 354 of attending non-emergency physicians, and 4,679 of attending EPs.

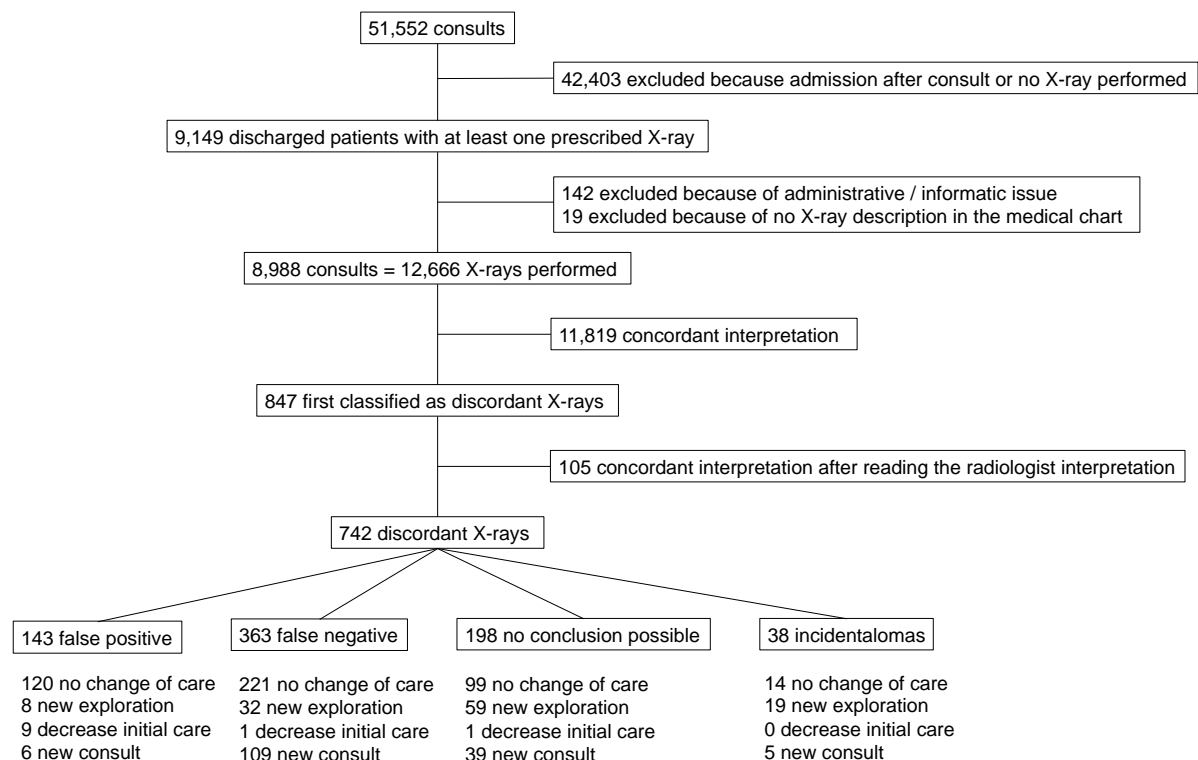


Figure 1: Flow chart of the study. False positive: the emergency physician diagnosed something that does not exist. False negative: the EP don't diagnose something. No conclusion possible: the situation needs more exams. Incidentaloma: defined as something not related to

the indication of X-ray. When the EP did not write any interpretation in the dedicated box, the radiologist did the interpretation and classified it as “discordant”. Another EP reviewed all the chart to find the initial interpretation (mainly in the text).

Description of X-ray

Among 12,666 X-rays, 2,756 were performed on chest, 1,059 on ankle, 898 on knee, 878 on shoulder, 875 on hand, 721 on foot, 695 on wrist, 638 on cervical rachis, 581 on ribs, 543 on lumbar rachis, 536 on basin, 406 on hip, 395 on elbow, 310 on thoracic rachis, 306 on finger, 190 on humerus, 169 on leg, 142 on clavicle, 132 on nose, 92 on forearm, 80 on scaphoid, 73 on femur, 67 on toe, 42 on sternum, 42 on abdomen and 40 on face.

Discordance analysis

Among 8,988 patients, 742 (8.3%, 95%CI: 7.7 to 8.8%) had one X-ray considered as discordant. None had more than one discordance. Among 12,666 X-rays, 742 (5.9%, 95%CI: 5.4 to 6.3%) were classified as discordant: 143 (19.3%) false positive, 363 (48.9%) false negative, and 198 (26.7%) with a doubt on the interpretation, so no conclusion can be done, and further exams are needed. Lastly, 38 (5.1%) were incidentalomas. Among the 742 discordant X-rays, 454 (61.2%) had no consequences, 118 (15.9%) needed more exploration, 11 (1.5%) induced a decrease of care, and 159 (21.4%) patients were sent to a physician again – 25 (3.4%) to their general practitioner, 72 (9.7%) to a specialist, and 62 (8.4%) were asked to come back in the ED (Figure 1).

Factors associated with discordance

Males have a higher risk of discordance compared to female (OR: 1.27, 95%CI: 1.06 to 1.52) (Figure 2). When patients were in charge of emergency medicine resident, there was a higher risk of discordance (OR: 1.26, 95%CI: 1.01 to 1.57) compared to emergency medicine

attending. Period of the shift was not associated with a higher or lower risk of discordance. Regarding locations of X-ray, ankle (OR: 1.36, 95%CI: 1.06 to 1.75), foot (OR: 1.49, 95%CI: 1.12 to 1.98), knee (OR: 1.50, 95%CI: 1.15 to 1.95), finger (OR: 1.54, 95%CI: 1.01 to 2.35), ribs (OR: 1.55, 95%CI: 1.13 to 2.12), wrist (OR: 1.96, 95%CI: 1.46 to 2.63), and elbow (OR: 2.03, 95%CI: 1.41 to 2.93) were significantly associated with discordance, whereas chest X-ray was protector (OR: 0.57, 95%CI: 0.47 to 0.71).

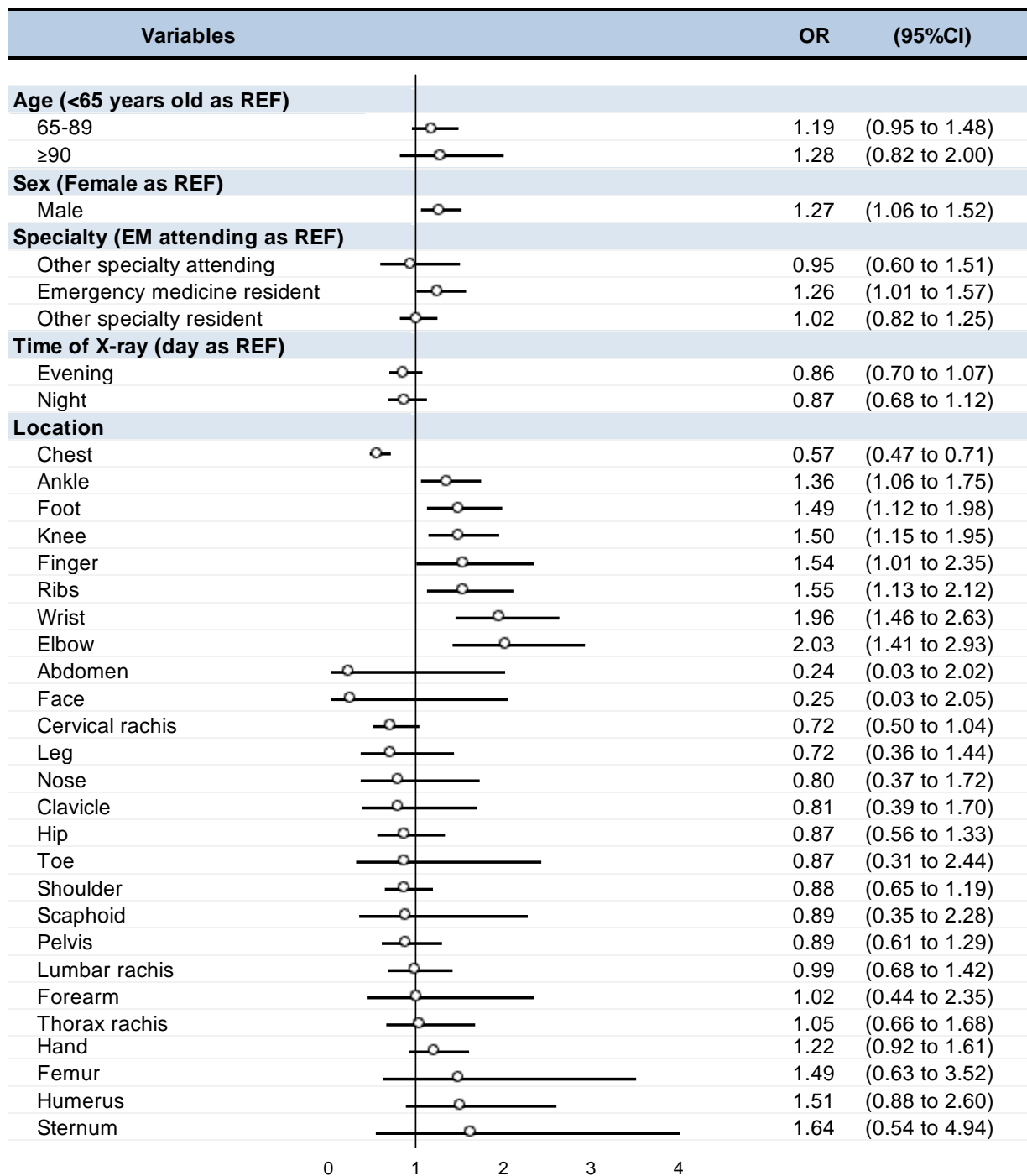


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Discussion

We found, among 12,666 X-rays performed in an ED, a high initial rate of 5.9 % charts with a discordance between EPs and radiologists among discharged patients. However, only 288 (2.3%) had a consequence on the care of the patient. Thus, we need to discuss those results.

This rate is probably higher than the “real rate” because we studied only discharged patients. Indeed, we can suppose that patients with a fracture that need a surgery, or a pneumonia that need to be admitted would decrease this rate. The double check in those cases are not EP and radiologist but EP and orthopedic surgeon or EP and internal medicine physician. On the other hand, it is possible that EPs missed fractures because of not performing X-ray first. Indeed, Mattijssen-Horstink et al. found that 14.7% of missed fractures were due to not performing a radiograph during initial ED visit, even if in the majority of these cases there was no clinical indication for radiography at initial visit [10]. In 2010, Petinaux et al. found a discordance rate at 3.5% (false positive and false negative but there was not the “doubt” possibility) over 151,693 X-rays [11], and Espinosa et al. found also a 3.0% rate [12], but both considered discordance only if patients must consult again. Wei et al. found an overall percentage of missed fractures in the extremities at 3.7% [13]. In our study, only 2.2% of X-ray performed induced a change in the care previously scheduled by the EP. We are so in accordance with the literature. Regarding the proportion between false negative and false positive, we found a significant higher rate of false negative compared to false positive in accordance with literature [11–13].

Contrary to literature, we did not find any diurnal variation of discordance. We expect to have a higher rate of discordance during the evening because of overcrowded EDs or during the night after midnight because of physician’s tiredness. It is also during those periods that no attending radiologist are available to double check any EP’s doubt. However, some studies

have also found and described diagnosis errors from radiologists. Indeed, radiologic interpretation is a human enterprise based on complex psychophysiologic and cognitive processes. Thus, most missed radiologic diagnoses are attributable to image interpretation errors by radiologists, including perceptual and cognitive errors [14]. In 2006, Hallas et al. found a significant peak from 8 pm to 2 am [15]. We also did not find any difference regarding the specialty of the physician first interpreting the X-ray. This could be easily explained by the fact that all charts are supervised by an attending EP who is also available to help non-EP attending. In the literature, Guly showed that most fractures are missed by junior doctor, but the author concedes that EDs are often staffed by very junior doctors [6]. In case of a doubt, any physician can ask a specialist to proofread the X-ray. Pamuk showed that orthopedists can safely perform tele consult using their own smartphone in the radiological evaluation of proximal humerus fractures. Although it will never replace a consult in person, this “smartphone approach” is highly reliable for diagnostic and treatment-related decision [16].

Regarding location, we found a significant risk factor of discordance in ankle, knee, wrist, ribs, and elbow. Those location are in accordance with literature which showed that elbow, hands, fingers, ankle, wrist and foot are most frequently missed fracture’s locations [17,18]. Some ameliorations can be proposed. First, it has been proofed that even one hour of training can improve the quality of interpretation in pediatric musculoskeletal radiograph interpretation [19]. Regarding hip, proximal femur, pelvis, and sacrum, studies showed that CT-scan are mandatory in case of clinical doubt even if X-ray seems to be normal [20,21]. It is even more recommended in elderly patients because of difficulty of interpretation due to osteoporosis, arthrosis, and overhaul of bone composition [22,23]. Lastly, artificial intelligence has showed benefit in radiology with deep learning, as well as thoracic imagery, breast imagery, dental and maxillofacial surgery [24]. Its use in emergency radiology is still confidential but will probably increase in the next decade.

Limitations

Our study has some limitations. First, we have excluded 161 patients, including putative missing data. However, it represents less than 2% of patients, which could probably not change our results. However, the full informatic process was able to decrease the rate of missing data below other studies. Second, this study is monocentric, so our results are not generalizable. However, because of the high number of X-ray performed (up to 12,000), we were able to conclude with simple statistics tests, that increase internal validity. Furthermore, those tests were in accordance with literature, increasing external validity. Third, only X-rays performed among discharged patients benefit of a review by an attending radiologist. This could induce some discordance among admitted patients (e.g.: a patient admitted for a fall at home because of sepsis, had a chest X-ray that found a pneumonia, is admit in internal medicine, but none of the musculoskeletal X-rays have a review and the delay of diagnosis a wrist fracture can have consequences). However, even if internal medicine physicians are not the best to interpret musculoskeletal X-ray, they are able to perform physical exam and in case of doubt, they can ask for a second look on radiologists. Lastly, radiologists had the EP's interpretation when they performed their own interpretation. This could induce anchoring bias. It could be more accurate to blind the radiologist and ask a third physician to review both interpretations. After this study we created staff between radiologists and EPs. Further studies are needed to assess putative benefit of those staff or artificial intelligence available 24/7 in the ED to reduce the rate of discordance.

Conclusion

We found a 5.9% rate of discordance between EP and radiologist interpretation among discharged patients. However, only 2.2% had an impact on the initial care. Factors associated with discordance are male sex, and ankle, foot, knee, finger, ribs, wrist and elbow locations.

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