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Image rejects in digital skeletal radiography in two public hospitals in Norway

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A B S T R A C T

Introduction: The proportion of diagnostic images not applied for diagnostic purposes is an indicator of image quality, safety, and efficiency in radiography. Despite increased awareness, image reject is still a substantial problem and needs continued observation and targeted measures. Accordingly, the objective of this study is to estimate the extent, variation, and characteristics of image rejects, in order to improve the quality, safety, and efficiency in radiography.
Methods: All skeletal images at two digital X-ray rooms at two public hospitals in Norway were reviewed for four weeks in 2020. The number of exposed images, type of examination, and number of deleted images were registered. For each deleted image the deduced reasons for deleting the image were recorded.
Results: 2183 and 1467 X-ray images were taken at Hospital 1 and 2 respectively. The corresponding reject rates were 14.2% and 9.1%. The reject rate varied greatly from day to day (from 0% to 22%), and the examinations with the highest reject rate were X-ray of extremities (knee, elbow, ankle, wrist) (12–25%) and of the spine (14–19%). The two clearly dominating reasons for image rejects were positioning and centering errors.
Conclusion: The reject rate is high and reduces quality, safety, and efficiency of imaging services. The reasons for image rejects are typical professionally reducible errors indicating great potential for improvement.
Implications for practice: Monitoring and assessing image rejects are of great importance to management, training, education, patient safety, and for quality improvement of imaging services.

Introduction

Wasteful diagnostic X-ray images impose professional and ethical challenges within radiological imaging.[1,2] In particular, rejected images absorb personnel and other resources,[3–6] indicate suboptimal quality management,[7–9] and expose patients to unnecessary risk in terms of ionizing radiation, and increased patient inconveniences.[10,11]

A wide range of studies have documented high rates of reject, deletion, or retake rates in digital imaging.[5,7–9,12–20,21–32] Reasons for[33–36] and attitudes towards[37–39] image rejects have also been studied, as well as measures to reduce image rejects.[40–42] Nonetheless, the problem prevails and warrants sustained attention. Accordingly, *the objective of this study is to investigate the extent, variation, and reasons for image rejects* in an area where image rejects have been previously studied.[2]

The corresponding research questions are:

1. How large is the proportion of rejected skeletal images in two public hospitals during four weeks in 2020?
2. How does the proportion of deleted images vary with time?
3. Which examinations have the highest rejection rate?
4. What are the main reasons for rejected images?

Answers to these questions can help us improve the quality and safety of diagnostic imaging and the efficiency of care.

Material and methods

Data were collected at two rooms for general digital X-ray[1] examinations at two radiological departments of two public hospitals in the central southern part of Norway. Together the hospitals take about 50 000 general X-ray examinations per year.

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[1] In Norway the term “general X-ray” is used for all plain X-ray examinations, elswhere also called “projectional X-ray” or “conventional X-ray.”

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All skeletal images taken during February 2020 were included in the study, and deleted images were registered in a form developed on basis of existing literature.[2,6,29,30,43,44] Piloting resulted in some minor adjustments of the form providing the following categories:

- Incorrect Positioning (other than centering errors)
- Collimation error
- Centering error
- Wrong exposure value
- Movement artifacts
- Wrong organ/extremity
- Exposure on wrong detector
- Inadequate inspiration/expiration
- Other

"Centering errors" where defined as when the object of interest was not in the center of the image, while "incorrect position" were other errors of position, such as rotation errors. Categorization was based on qualitative assessment of the images. When more than one category applied, the most prominent category sufficient for retake was registered.

In this study, a rejected image is identified as an image deleted at the workstation or in the picture archiving and communication system (PACS) system, an image not transferred for diagnostics, or an image taken to supplement a previous image because it was of poor quality. As such, rejected images have no diagnostic value as they *per se* are not used for diagnostic purposes.[2,6] Deleted images were identified by comparing images at the workstations, in the PACS, and with the radiology information system (RIS). A more detailed description of the approach is provided elsewhere.[2,45]

To avoid disturbing or influencing the workflow or the deletion rate, data were collected during evening time. Deleted images were categorized by two persons, and a third person (local radiographer) was consulted when there was disagreement between the persons, or they were uncertain about the appropriate category. Descriptive statistics and standard T-test was performed with Microsoft Excel 2016.[46]

Ethics

As this study was registered and conducted as a Quality Assurance Project of the hospitals and did not aim at "providing new knowledge about health and disease," it was exempted from approval by the Regional Ethics Committee (REC/IRB) according to the Norwegian Health Research Act. Moreover, no patient information was included, and the study did not require informed consent from patients according to the Norwegian Patient Rights Act. The employees at the Radiology department were informed about the study in advance, and access to images and image systems was supervised by the Radiology department. A confidentiality statement was valid for the data collection.

Results

The results answering the specific research questions are as follows.

How large is the proportion of rejected images in the two public hospitals?

2183 skeletal X-ray images were taken at Hospital 1 and 1467 images were taken at Hospital 2 during the study period. The number of rejected images in Hospital 1 and 2 were 311 and 133 respectively, which corresponds to reject rates of 14.2% and 9.1%. The total average rejection rate of 12.2% for both hospitals. The difference between the sites is statistically significant with respect to the number of images ($p = 0.0023$), deleted images ($p = 0.0002$), and percentage of deleted images ($p < 0.0001$).

How does the proportion of deleted images vary with time?

The reject rates vary substantially from day to day. The reject rate varied between 4.1% and 20.9% for Hospital 1 and between 0% and 18.9% for Hospital 2 as shown in Fig. 1. Fig. 2 shows the variation for the various days of the week.

Which examinations have the highest rejection rate?

The examinations having the five top rejection rates for the two hospitals are shown in Fig. 3 together with the number of examinations. There are no clear trends with respect to volume of examinations and rejection rates.

What are the main reasons for rejected images?

Positioning and centering errors are the dominant reasons for rejecting images amounting to 83.5% of the rejects. There were some differences between the hospitals as Hospital 1 had 15% more rejects due to incorrect positioning than Hospital 2. Hospital 2 on the other hand had more centering errors. Reasons for rejects are shown in Fig. 4.

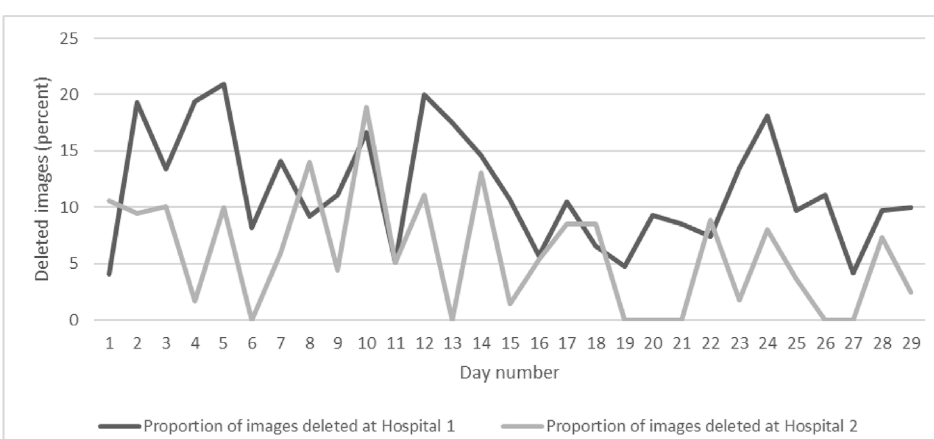

Figure 1. Temporal variation in proportion (percent) of deleted images per day.

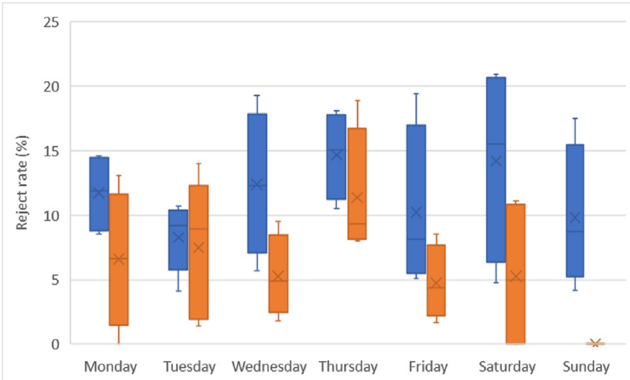

Figure 2. Box plot of variation in reject rate (%) for the seven days of the week. Hospital 1 in blue and Hospital 2 in orange. Hospital 2 had no rejects on Sundays. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

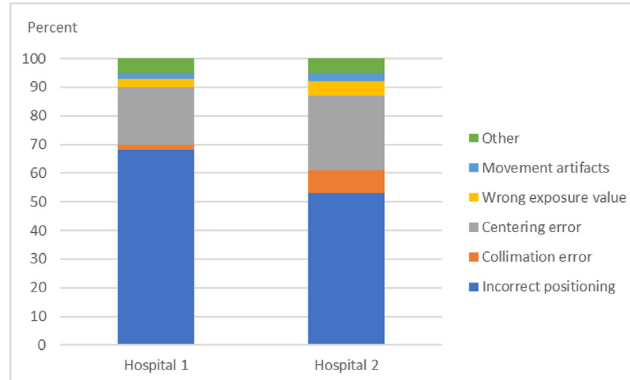

Figure 4. Classified reasons for rejecting an image in percent for Hospital 1 and 2. The class "other" includes Wrong organ/extremity, Exposure on wrong detector, Inadequate inspiration/expiration, and Undecisive.

Discussion

The results show that more than every tenth image is not used for diagnostic purposes (Research Question 1, RQ1), and thus not helpful for a number of patients. This is consistent with earlier findings in the same region in Norway (11%),[2] and in line with findings in international studies.[5,7–9,12–32,36,47–49] Despite some differences both hospitals have the potential to reduce the number of retakes substantially, and thereby to increase the quality, safety, and efficiency of imaging.[1,31,37,39,50-56] However, it is important to notice that zero retakes may not be obtainable due to patient characteristics, artefacts, and dose-image trade-off.[6]

The variation of rejection rate over time (RQ2) is substantial and may have many sources, such as case mix, variation in number and skills of professionals at work, day of week etc. Although there are some differences in reject rates between the beginning of the week and at the rest of the week, no clear pattern emerges from the data, and more research is needed to uncover the reasons for the temporal variations of image rejects.

The examinations having the highest rejection rate (RQ3) vary somewhat between the hospitals, but X-ray of the extremities and of the spine in general have high reject rates. Although the hospitals are comparable in size and tasks, the differences are not arbitrary. They may be due to number of examinations, case mix, professional profile, and staffing.

Moreover, what counts as high reject rates is of course an issue of evaluation. However, reject rates that are higher than what was commonly reported for film-based images (5%) can count as high reject rates as imaging digitalization was predicted to reduce reject rates substantially.[6]

The reasons for reject were dominantly positioning and centering errors (RQ4), which is in line with previous studies.[5,7-9,12-30,47,48,55,56] Despite these problems being well known and at the centre of professional skills, it is challenging to see that the problems of positioning and centering persist. Nevertheless, the results give good indications and directions for improving the quality, safety, and efficiency of services. In particular, training and quality assurance should focus on improving basic radiographic skills, especially positioning and centering.

The exceptionally high rejection rate for coccyx is probably due to its low volume, either due to special patient characteristics, chance (statistical error), or lack of experience of the radiographer.

It may be argued that when the wrong side is imaged, the image should not be rejected but sent to PACS, as there could be incidental findings. The main reason why this is not done in Norway (in general) is that the predictive value of findings with low pre-test probability is low.

Limitations

The reasons for deletions are registered in quite coarse categories in this and other studies. Clearly, radiographers may have other and more subtle reasons for rejecting an image. However, the applied categories covered the most relevant reasons in this study and correspond well with those of other studies.[33,34,37,38] Moreover, it would be interesting to study the rejected images with respect to

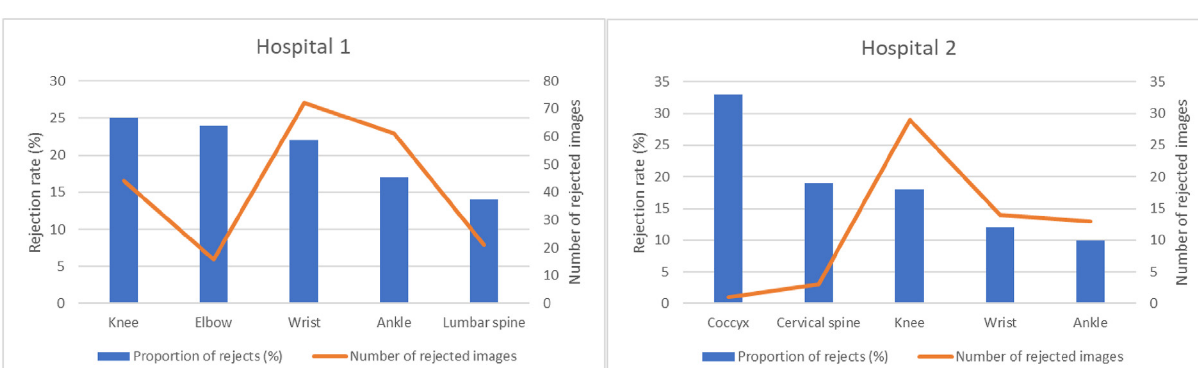

Figure 3. Examinations of the five top rejection rates for the two hospitals with the number of examinations for Hospital 1 (left) and Hospital 2 (right). Percentages are estimated for each examination type.

their specific projections. Unfortunately, this was not possible in this study, but is clearly recommended for further high-volume studies.

This study has only investigated how large proportion of the images that were deleted or not transferred for diagnostic purposes. However, many transferred images may not be used for diagnostics either, resulting in underestimating unnecessary imaging. There are many reasons for this, such as abundant storing capacity, forgetting to delete non-used images, believing that they may be of some value in the future or that the image may in the end turn out to be better than the new one, time pressure, and because extensive deleting gives the impression of poor-quality work. However, a deleted image is a clear case of image reject and of unnecessary imaging as it has no diagnostic value. The relationship between the number of deletions, rejects, retakes, and unnecessary images is discussed in more detail elsewhere.[2]

Moreover, many PACS have reject (or retake) analysis modules providing information about reject rates. However, these may not register deleted or rejected images at the workstations and therefore underestimate the number of deleted or retaken images. The laborious manual registration performed in this study may therefore still be required to provide more accurate results.

As mentioned, one of the reasons for the high rate of image rejects can be case mix. Some patients may be demanding in terms of providing high quality image, e.g., due to obesity. This may result in several retakes. This indicates that further studies should investigate not only type of examination and technical reasons for image reject, but also patient characteristics and radiographers' competency.

Moreover, it may be argued that the data (from 2020) are old. However, it is crucial to note that the data are collected just before the disruption of the healthcare by the SARS-COV-2 pandemic, and the scarcity of reject studies indicate the importance of the results.

As the employees at the Radiology department were informed about the study in advance, this may have biased the results, as they were aware that they were audited. This bias would most likely reduce the reject rate as the employees would be more conscious. However, as the investigators analysed the registers after the images were taken and after working hours (they were not visible to the staff), the effect may be moderate.

This study may be criticized for not including advanced statistical tests. However, there are only two Hospitals and many types of examinations and reasons for rejects. Hence, advanced statistical tests may lead to false inferences.[57]

Conclusion

This study demonstrates an average rejection rate of 12% and shows that the rate varies with time and place. Positioning and centering errors amounted to more than 80% of the reasons for image rejects. This indicates that image rejects are largely professionally reducible and that there is a substantial potential to improve the quality, safety, and efficiency of imaging services. Hence, the results are of great importance to management, training, education, patient safety, and for quality improvement of imaging services.

Conflict of interest

None.

Contributions

Bjørn Hofmann designed the study and supervised four students who performed data acquisition. Bjørn Hofmann drafted, revised, and approved the final manuscript. Students were invited as co-authors.

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