

Image rejects in general direct digital radiography

Bjørn Hofmann¹, Tine Blomberg Rosanowsky², Camilla Jensen²
and Kenneth Hong Ching Wah²

Acta Radiologica Open
4(10) 1–6
© The Foundation Acta Radiologica
2015
Reprints and permissions:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/2058460115604339
arr.sagepub.com



Abstract

Background: The number of rejected images is an indicator of image quality and unnecessary imaging at a radiology department. Image reject analysis was frequent in the film era, but comparably few and small studies have been published after converting to digital radiography. One reason may be a belief that rejects have been eliminated with digitalization.

Purpose: To measure the extension of deleted images in direct digital radiography (DR), in order to assess the rates of rejects and unnecessary imaging and to analyze reasons for deletions, in order to improve the radiological services.

Material and Methods: All exposed images at two direct digital laboratories at a hospital in Norway were reviewed in January 2014. Type of examination, number of exposed images, and number of deleted images were registered. Each deleted image was analyzed separately and the reason for deleting the image was recorded.

Results: Out of 5417 exposed images, 596 were deleted, giving a deletion rate of 11%. A total of 51.3% were deleted due to positioning errors and 31.0% due to error in centering. The examinations with the highest percentage of deleted images were the knee, hip, and ankle, 20.6%, 18.5%, and 13.8% respectively.

Conclusion: The reject rate is at least as high as the deletion rate and is comparable with previous film-based imaging systems. The reasons for rejection are quite different in digital systems. This falsifies the hypothesis that digitalization would eliminate rejects. A deleted image does not contribute to diagnostics, and therefore is an unnecessary image. Hence, the high rates of deleted images have implications for management, training, education, as well as for quality.

Keywords

Digital radiography, ethics, radiation safety, technology assessments

Date received: 24 December 2014; accepted: 13 August 2015

Introduction

Rejects, deletions, and subsequent retakes of diagnostic X-ray images impose professional and ethical challenges within radiological imaging (1); it occupies unnecessary processing and personnel resources (2–5), indicates suboptimal quality management (6–8), and exposes patients to unnecessary ionizing radiation and added inconveniences (9). Traditionally reject/deletion/retake rates for film-based departments have been documented to be in the range of 10–15% (8,10–17), and their main cause has been attributed incorrect exposures due to limited dynamic range of screen/film systems. Accordingly, the digitalization of medical imaging induced expectations that the problem of image rejects, deletions, and retakes would disappear (5–7,17,18). A series of research papers have reported

reject/deletion/retake rates in digital departments at around 5% (6–8,15,17,19,20), and some even at the same rate as with film systems (4). This poses the question whether the reject rates really are as high as with film systems and why the problem did not vanish with the digital revolution, as presumed.

¹Section for Health, Technology, and Society, Gjøvik University College, Gjøvik, Norway and Centre for Medical Ethics, University of Oslo, Oslo, Norway

²Department of Health, Care and Nursing, Gjøvik University College, Gjøvik, Norway

Corresponding author:

Bjørn Hofmann, Department of Health, Care and Nursing, Gjøvik University College, PO Box 1, N-2802 Gjøvik, Norway.
Email: bjoern.hofmann@hig.no



Image digitalization significantly changed the causes of rejects. While rejects for the screen/film systems mostly were exposure-related, they are now mainly reported to relate to patient positioning errors in the digital systems. Although there are some studies with reject rates for computed radiography (CR) systems (6,8,17,19,21–23), there are few studies for direct digital radiographic (DR) systems (4). Although, one would expect the reject rates of DR systems to be below film reject rates, initial studies indicate that this is not so (4,22,24,25). In order to assess whether the high reject rate with DR only are incidental findings or represent a real challenge in digital imaging more studies are needed. The reject rate in this study was defined as images deleted on modality specific work stations or in the PACS. Accordingly, the research questions of this article are: How high is the deletion rate for DR systems, and what are the reasons for deletions?

Material and Methods

This study was registered and conducted as a Quality Assurance Project of the hospital, and is as such not subject to informed consent from patients according to the Norwegian Patient Rights Act. Employees at the Radiology Department were informed about the study in advance. Access to images and systems was supervised by the Radiology Department. Confidentiality statement was valid for the data collection.

Data were collected at two laboratories for general X-ray examinations at the radiological department of a local public hospital in the central southern part of Norway. The department makes about 25,000 general X-ray examinations per year. The two DR laboratories are part of the same department and the department's radiographers are shared between the two laboratories. Data included all exposed images during January 2014. A registration form was developed on basis of existing literature (5,10,24–26). Some adjustments resulted from a pilot study. The registered categories are given as follows:

- Positioning error (other than centering errors)
- Incorrect collimation
- Centering error
- Wrong exposure
- Artifacts
- Other reasons

Centering errors were differentiated from other positioning errors in order to be able to tailor education and improvement strategies. A “centering error” occurs when the object of interest is not in the center of the image, while other errors of position, such as rotation

errors, are categorized as “positioning error”. Images can be deleted either at the workstation of the modality or in PACS. Images deleted on the workstations can be counted directly, as these are tagged. However, in order to collect data on additional deletions in PACS, the number of images on PACS and workstations were compared for each examination. In this study, image rejects are defined as images that do not contribute with diagnostic information with regards to the relevant clinical indication due to poor image quality (5) and they are measured as deleted images, as a deleted image has no diagnostic value as it *per se* is not used for diagnostic purposes. Accordingly, a deleted image is defined as an image that is deleted from the data registry either at the workstation of the modality or from the PACS (after being transferred from the workstation). A more detailed description of the relationship between deleted images, image rejects, image retakes, and unnecessary imaging can be found in the Appendix.

Data collection was performed during evening time in order not to influence the workflow or the deletion rate. Deleted images were categorized by two persons or three persons when there was doubt. Descriptive statistics was used with Microsoft Excel 2010 to calculate deletion rate and confidence intervals. A detailed description of the X-ray equipment and PACS is given in the Appendix.

Results

In total, 1911 examinations with 5417 images were registered during January 2014. Of these 596 images were deleted during this period. Accordingly, the deletion rate was 11.0% (95% CI, 10.2–11.8).

There were 24 different types of examinations. Table 1 shows the number of examinations and deletions for the 10 most frequent examinations.

The main reason for deletion was positioning errors (51.3%) and centering errors (31.0%). The identified reasons for deletion are displayed in Table 2; Table 3 shows the distribution of identified reasons for deletion on various examination types.

Discussion

Our results show a deletion rate which is quite high compared to international studies on CR systems (6–8,11,17,19,21), but very much in line with existing Norwegian studies. Leffmann et al. found a deletion rate of 13.1% for wrist images with a CR system (27), and Andersen et al. found a reject rate of 17% for wrist images with DR (4), while we found a deletion rate of 12.4% (95% CI, 9.7–15.1). In line with both Leffmann and Andersen's findings, our study shows that the main

Table 1. The number of images and deletions for the 10 most frequent types of examinations.

	Images deleted (%)	Images (n)	Deleted images (n)
Knee	20.6% (95% CI, 17.3–23.9)	591	122
Hip	18.50%	287	53
Ankle	13.80%	507	70
Wrist	12.4% (95% CI, 9.7–15.1)	555	69
Columna	11.20%	483	54
Shoulder	9.40%	445	42
Pelvis and hip	8.20%	452	37
Thorax	6.9% (95% CI, 4.9–8.9)	622	43
Foot	6.20%	324	20
Hand	3.60%	416	15

Table 2. Distribution of identified reasons for deletion.

Category of reason for deletion	Percentage
Positioning error	51.3%
Centering error	31.0%
Other*	8.6%
Incorrect collimation	6.4%
Artefacts	2.2%
Wrong exposure	0.5%

*It was not possible to decide why the image was deleted.

Table 3. Distribution of identified reasons for deletion on various examination types.

Examination type	Positioning error	Centering error
Knee	77.9%	9.0%
Hip	3.8%	81.1%
Ankle	72.9%	12.9%
Wrist	91.3%	5.8%
Columna	27.8%	59.3%
Shoulder	59.5%	19.0%
Pelvis and hip	5.4%	62.2%
Thorax	27.9%	37.2%
Foot	35.0%	35.0%
Hand	60.0%	13.3%

reason for deletion of wrist images was positioning errors. Leffmann's study does not report whether deletions in PACS are included. If they are not, as the article indicates, their real rate may be significantly higher. This also goes for Andersen's study which does not

include deletions in PACS. Therefore, the real reject rate may be higher (4).

Our overall results are also in line with the overall deletion rate of 12.5% found in 2009 at one of the labs included in our study (25), and 12% found in the study by Andersen and colleagues (4). The findings show that the deletion rate is on level with the retake rate with film systems, but the reasons for deletions are different: from incorrect exposure to positioning error. This can indicate poorer quality of work among radiographers.

There are some discrepancies in the results of the reasons for deleting images in our and Andersen's study. For example, Andersen et al. found an overall positioning error of 77% while our results showed 82.3% (centering and other positioning errors) (4). This may of course be due to real differences between the sites, but can also be due to difference in interpretations of the categories and the mode of registration. In Andersen et al.'s study the radiographers registered the reason for deletion themselves, while we registered a retrospective interpretation of the radiographers' reasons for deleting the images. This weakness in our study is only relevant for the interpretation of the reasons for deletions, and not for the deletion rate, where our study is more complete than comparable studies (4). Hence, there is a tradeoff between the validity of the results on reject rate and on reasons for rejects.

The categories of reasons for deletions are quite coarse in our study. Radiographers may have more subtle reasons for deleting, which cannot be identified by the study. However, the pilot study showed that a more detailed list of reasons was not feasible with the interpretative method chosen. Nevertheless, our categories correspond well with those of other studies. In addition to registering the type of examination, it is valuable to have information on the projections of the deleted images.

This study has not measured unnecessary imaging, but only how large proportion of the images that were deleted. However, a deleted image has no diagnostic value as it *per se* is not used for diagnostic purposes. It is therefore unnecessary. The number of deleted digital images will therefore be an underestimation of image reject, of retakes, and of unnecessary imaging, simply because many original non-used images are not deleted. Nevertheless, the number of deleted images provides a useful estimate of the lowest possible rate of unnecessary imaging. If the number of deleted images is high, the number of unnecessary images is alarming. Fig. 1 illustrates the relationship between the number of rejects, retakes, and unnecessary images. There are of course many reasons why images are not deleted: abundant storing capacity; one forgets to delete them; one believes that they may be of some value in the future; the old image may in the end

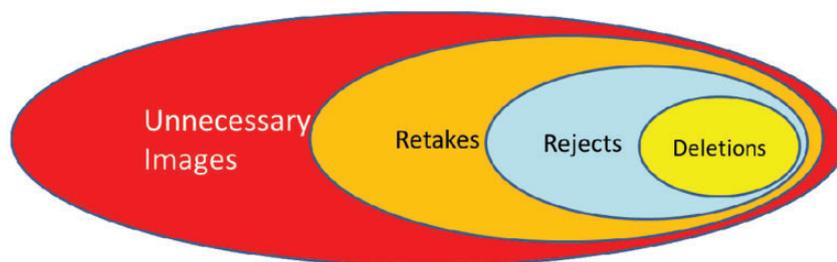


Fig. 1. The relationship between unnecessary images, retakes, rejects, and deleted images.

showed up to be better than the new one; time pressure; or because deleting too many pictures would give the impression of poor quality work.

In conclusion, we find a deletion rate of 11%. This indicates that the reject and the retake rate, as well as the rate of unnecessary images is higher than 11%. We found deletion rates comparable with reject rates of previous film based imaging systems, but that the reasons for reject rates are different. This falsifies the hypothesis that rejects and retakes would be abolished with digitalization of radiographs. For some examination types the deletion rate is over 20% and the main reasons for deletions are positioning and centering errors (together 82.3%). Monitoring unnecessary images is highly relevant to verify and improve the quality in modern radiographic imaging. It is of great importance for management, training, education, and for quality improvement.

Acknowledgements

The authors thank the employees at the hospital where the study was conducted for their facilitation and support. They also thank their colleague Dag Waaler who assisted with the statistical analysis.

Contributions: All authors designed the study. TBR, CJ and KHCW did data collection and primary analysis. BH supervised the study and drafted the article.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. World Health Organization. Quality assurance workbook for radiographers and radiological technologists. Geneva: WHO, 2001. Available from: <http://whqlibdoc.who.int/publications/2001/9241546425.pdf?ua=1>
2. Pitcher EM, Wells PN. Quality assurance and radiologic audit. *Curr Opin Radiol* 1992;4:9–14.
3. McKinney W. Repeat exposures: our little secret. *Radiol Technol* 1994;65:319–320.
4. Andersen ER, Jorde J, Taoussi N, et al. Reject analysis in direct digital radiography. *Acta Radiol* 2012;53:174–178.
5. Waaler D, Hofmann B. Image rejects/retakes—radiographic challenges. *Radiat Prot Dosimetry* 2010;139:375–379.
6. Foos DH, Sehnert WJ, Reiner B, et al. Digital radiography reject analysis: data collection methodology, results, and recommendations from an in-depth investigation at two hospitals. *J Digit Imaging* 2009;22:89–98.
7. Nol J, Isouard G, Mirecki J. Digital repeat analysis; setup and operation. *J Digit Imaging* 2006;19:159–166.
8. Peer S, Peer R, Giacomuzzi SM, et al. Comparative reject analysis in conventional film-screen and digital storage phosphor radiography. *Radiat Prot Dosimetry* 2001;94:69–71.
9. Jacobson AF, Sceelee RV, Nalley EA. A methodology for the study of retakes in medical radiography. *Phys Med Biol* 1972;17:871–872.
10. Akhtar W, Aslam M, Ali A, et al. Film retakes in digital and conventional radiography. *J Coll Physicians Surg Pak* 2008;18:151–153.
11. Eze CU, Olajide BO, Ohagwu CC, et al. Analysis of film reject rate in the diagnostic x-ray facility of a tertiary health institution in Benin, Nigeria. *Nig Q J Hosp Med* 2013;23:54–57.
12. Eze KC, Omodia N, Okegbunam B, et al. An audit of rejected repeated x-ray films as a quality assurance element in a radiology department. *Niger J Clin Pract* 2008;11:355–358.
13. Heddson B, Ronnow K, Olsson M, et al. Digital versus screen-film mammography: a retrospective comparison in a population-based screening program. *Eur J Radiol* 2007;64:419–425.
14. Lewentat G, Bohndorf K. [Analysis of reject x-ray films as a quality assurance element in diagnostic radiology]. *RoFo* 1997;166:376–381.
15. Peer S, Peer R, Giacomuzzi SM, W J. Comparative reject analysis in conventional film-screen and digital storage phosphor radiography. *Eur Radiol* 1999;9:1693–1696.
16. Roohi Shalemaei R. Films reject analysis for conventional radiography in Iranian main hospitals. *Radiat Prot Dosimetry* 2011;147:220–222.
17. Weatherburn GC, Bryan S, West M. A comparison of image reject rates when using film, hard copy computed radiography and soft copy images on picture archiving

- and communication systems (PACS) workstations. *Br J Radiol* 1999;72:653–660.
18. Busch HP, Faulkner K. Image quality and dose management in digital radiography: a new paradigm for optimisation. *Radiat Prot Dosimetry* 2005;117:143–147.
 19. Honea R, Elissa Blado M, Ma Y. Is reject analysis necessary after converting to computed radiography. *J Digit Imaging* 2002;15 (Suppl. 1):41–52.
 20. Jones AK, Polman R, Willis CE, et al. One year's results from a server-based system for performing reject analysis and exposure analysis in computed radiography. *J Digit Imaging* 2011;24:243–255.
 21. Prieto C, Vano E, Ten JI, et al. Image retake analysis in digital radiography using DICOM header information. *J Digit Imaging* 2009;22:393–399.
 22. Døssland M, Jensen I, Hofvind S. Omtak av røntgen thorax-undersøkelser ved Oslo Universitetssykehus, Ullevål [in Norwegian]. *Hold Pusten* 2009;7:12–15.
 23. Willis C. Strategies for dose reduction in ordinary radiographic examinations using CR and DR. *Pediatr Radiol* 2009;34:196–200.
 24. Bakke L, Egeberg K. Reasons for retakes in CR and DR systems - a comparison [in Norwegian]. Gjøvik: University College of Gjøvik, 2011.
 25. Sunden A, Skailand M, Plassen T. Retake analysis as part of quality assurance of digital radiography [in Norwegian]. Gjøvik: University College of Gjøvik, 2009.
 26. Hofmann B, Waaler D. Retake of radiological images: the problem that could not be digitally abolished [in Norwegian]. *Hold Pusten* 2008;7:12–15.
 27. Leffmann B, Henriksen I, Kaur M, et al. Reject analysis of wrist images [in Norwegian]. *Hold Pusten* 2013;6:18–22.
 28. Villforth JC. The X raying of America. *FDA Consumer* 1979;13:13–17.
 29. Hofmann B. Too much of a good thing is wonderful? A conceptual analysis of excessive examinations and diagnostic futility in diagnostic radiology. *Med Health Care Philos* 2010;13:139–148.

Appendix

Rejects, retakes, and unnecessary examinations

Unnecessary images do not “provide any useful diagnostic information to the physician” (28). Professionally and ethically these are the most pertinent measure. However, for practical and conceptual reasons they are difficult to assess. Practically, it may be demanding to assess whether a specific image provides useful information for a physician, as the judgement is subjective (5), and it may be difficult retrospectively to assess a previous judgement of necessity and usefulness. Moreover, an initial image may be “necessary” in order to make a subsequent high quality image of great benefit for the patient. On the conceptual side, it is far from obvious what is necessary (29), as necessity can be defined from many perspectives. Moreover, incidentalomas can be of great value. Nonetheless, in the setting

of this study, only those images being unnecessary because of poor image quality are relevant.

Due to conceptual and practical challenges, unnecessary images have been estimated in terms of retakes, i.e. where a new image (of the same structure, with the same intention) is taken because the old one is believed not to provide useful information to the physician, e.g. due to poor image quality. Although helpful, this may not solve the problems, as it may be equally difficult to measure how many images are retaken, as images can be taken as part of a series, as supplements, and for less specific reasons. Again, a genuine and proper measurement of retakes would demand access to the (subjective) mind of the radiographer/technician.

From a methodological point of view, therefore, it may be easier to measure the number of images that are rejected, e.g. by measuring the number of deleted images. A deleted image has no diagnostic value as it *per se* is not used for diagnostic purposes. Accordingly, rejects can be defined as images that do not contribute with diagnostic information with regards to the relevant clinical indication due to poor image quality (17,26). In this study a deleted image is defined as an image that is deleted from the image registry either at the workstation of the modality or that is deleted from the PACS (after being transferred from the workstation).

The number of deleted digital images will be less than the number of rejects (and correspondingly, less than the number of retakes and unnecessary images). This is because the original images, which are taken in order to obtain better results and which are not used in the diagnostics, in fact are not deleted. As pointed out in the article, there are many reasons why images are not deleted, e.g. because there is abundant storing capacity, because one forgets to delete them, because one believes that they may eventually be of some value in the future, that the old image in the end showed up to be better than the new one, or because deleting too many pictures would give the impression of poor quality work.

Hence, although the number of unnecessary images is the most interesting measure both professionally and ethically, it can be hard to assess. Measuring unnecessary images, retakes, and rejects to some extent presuppose that we know the context and the intentions of the person assessing the image at the time of assessment. This is difficult. Software modules forcing people to give reasons for deleting images may be helpful, but the categories they provide may not capture the nuances in why professionals consider an image to be useless, and the requisite registration may restrict deletions. Therefore, sometimes it may be most appropriate to the measure number of deleted images and the reasons for deletion of images. As Fig. 1 illustrates, the

number of deleted images may grossly underestimate the number of unnecessary images, but if the number of deleted images is high, this indicates that the number of unnecessary images is alarming. Not all unnecessary images may be eliminated, as some are due to the apparatus or the patient.

Equipment

The X-ray laboratories that were included in this study had the following equipment:

Lab A: Installed 2011. X-ray tube by Varian, model A-292, and with Canon detectors CXDI-70C wireless

(35 × 43 cm), CXDI-80C wireless (27.4 × 35 cm), and CXDI-401C (43 × 42 cm). Eizo workstation with 1 k screen.

Lab B: Installed 2005. X-ray tube by Varian, model A-196, and with Canon detectors CXDI-40G (43 × 43 cm), CXDI-50G (35 × 43 cm), and CXDI-31 (23 × 29 cm). Fujitsu-Siemens workstation with 1k screen.

Picture Archiving and Communication System (PACS) is Siemens, i.e. Sienet MagicView W50 which is connected to a Syngo Workflow RIS-system (installed 2003).