Radiography Open

ISSN: 2387-3345 Volume5, No 1(2019) DOI 10.7577/radopen.3611

The unnecessary dose behind cropped radiographs

Jónína Guðjónsdóttir and Guðlaug Arna Hannesdóttir

Health Sciences, Faculty of Medicine, University of Iceland, Reykjavik, Iceland

Abstract

Objectives: In this study it was evaluated how common image cropping, or electronic collimation, is in digital radiography, how large an area of the images is cropped and how high the radiation dose is that corresponds to the cropped area.

Methods: A sample of images were taken from three medical imaging departments. The images were reviewed; and if cropped, the extent was recorded.

Results: A total of 1.270 images were reviewed. 10.6 % of them were cropped; 19 %, 7 % and 6 % in sites A, B and C, respectively. 26 % of all chest images were cropped as well as 18 %, 13 %, 10 %, 10 %, 3 % and 2 % of lumbar spine, shoulder, hip, knee, hand and foot images, respectively. The proportion of cropped images was significantly different between sites and between examinations ($p < 0.05$). Considering only the cropped images, the average cropped fraction of each image was from 16.0 % to 36.3 % and the corresponding unnecessary dose were estimated to be from 19.0 % to 56.9 % of the dose actually needed for the final image. Averaging the cropped area over all images in the same type of examination showed that up to 4.6 % of the dose in the examinations in the study was unnecessary.

Conclusions: This study confirms that radiographs cropped, is a latent source of additional radiation dose to the patients. This needs be considered in the optimization of radiographic imaging procedures.

Keywords: Radiographic Image Enhancement, Digital Radiography, Radiation Dosage

Key points:

- Image cropping is a latent source of additional radiation dose to the patients which can easily go unnoticed
- Good collimation practices need to be reinforced

List of abbreviations

ASRT	American Society of Radiologic Technologists
DAP	Dose area product
DRL	Diagnostic reference levels
ICRP	International Commision on Radiation Protection

Introduction

The transition from film-screen radiography to digital imaging has brought about immense changes in the working environment in medical imaging departments [1]. However, this new technology has also brought with it many new features that professionals need to learn how to use appropriately.

Quality evaluation of images at the point of acquisition is now a part of the imaging workflow and sometimes images are manually processed before they are submitted for interpretation and archiving. A potential part of the image processing is cropping, or electronic collimation, of the image, which is the process of selecting and removing a portion of the image [2, 3].

When a radiograph is displayed for reporting, dark shutters cover the area of the screen corresponding to the area of the image detector outside the exposure field. These shutters improve the viewing quality but often hide the collimation borders and, thus, take away the option of using the collimation border to check for proper field size and detect unnecessary exposure. Bomer et al [4] have summarized the risks related to cropping images, including the risk of overexposure and the risk of losing important information. They also stress that the patient has the right to all information obtained during an X-ray examination and this opinion has been supported by a recent ASRT Advisory Opinion Statement on the use of post-exposure shuttering, cropping and electronic masking in radiography [2].

The purpose of this study was to evaluate the frequency of image cropping in digital radiography, the size of the cropped area and the amount of the radiation dose that corresponds to that area.

Method

The study was performed, in three imaging departments, one in a university hospital and two departments linked to different clinics. All three sites were using identical x-ray systems (Adora from NRT, Hasselager, Denmark). The systems' software allows cropping of images and it is possible to see if and how much of an image was cropped if the image is in the acquisition systems database.

A sample was taken from each site in February and March 2018. At least 100 examinations (> 400 radiographs) were evaluated from each site and, for each site, examinations taken over at least a five-day period were evaluated to minimize the effect of individual radiographers' practices. All types of adult examinations were evaluated, in the acquisition order. Within each day only the first five examinations of each type were included. Thus, all types of examinations were included, but, a maximum of 25 (five times five days) examinations of each type. This was done in order to gain a better overview of the practice in general and to include a wider range of examinations. Radiographers were not aware of the ongoing study.

Images were viewed by a radiography student at the x-ray system's workstation, since the cropped of area of the image was only visible there. For each image the type of examination was recorded, whether the image had been cropped and, if so, by how much.

Here, following terms are defined such that:

- *The radiation field* is the area corresponding to the beam collimation.
- *The original* image represents the whole radiation field.
- *The cropped area* is the part of the original image that was cropped of the original image.
- *The cropped image* is the original image minus the cropped area and is always smaller than the original image.
- *The final image* is the image as it was saved and used for interpretation. The final image equals the cropped image or, if the image was not cropped, the original image.
- *The unnecessary dose* is the radiation dose corresponding to the part of the image that was not used for interpretation (the cropped area).

The total proportion of cropped images was calculated for all sites. Examinations that were found more than four times in each of the three sites were considered common. For common examinations the images from all sites were pooled and the proportion of cropped images for each examination was calculated.

A Chi-square test was performed to evaluate whether the proportion of cropped images was significantly different ($p < 0.05$) between sites and between examinations.

For each cropped image the size of the original image and the size of the cropped area were simply measured on the screen with a physical ruler, since a measuring tool was not available in the workstation software. The beam collimation is generally not entirely without blurring and thus is was estimated that the measurement could not be more accurate than ± 0.5 mm. Considering the size of the screen and the size of the displayed images, a 1 mm uncertainty in the measurement can be expected to cause 1 - 2 % error margins in the calculations, depending on the size of the image.

The cropped fraction, defined as the size of the cropped area divided by the size of the original image, was recorded for every cropped image.

The dose area product (DAP) can be used as a practical dose quantity for single radiographs [5]. It includes the entire area of the radiation field and if the field is appropriately collimated to the anatomy of the patient it is proportional to the effective dose [6].

The radiation exposure needed to produce the final image was considered a necessary exposure but the radiation dose to the area that was cropped unnecessary. The cropped area was divided by the area of the final image to calculate the unnecessary dose proportion.

The cut off percentage was averaged over i) cropped images only and ii) all images of the same examination type to calculate average cut of percentage. Similarly, the average unnecessary dose percentage was calculated for the two set of images.

Microsoft Excel was used for statistical analysis.

Results

A total of 1270 images were reviewed: 413, 420, 437 in sites A, B and C respectively. In total, 10.6 % of them had been cropped, 19.4 %, 6.7 % and 6.2 % in sites A, B and C, respectively. Figure 1 shows the number and proportion of cropped images at the three sites. The proportion of cropped images was significantly different from being the same at all the sites ($p < 0.05$).

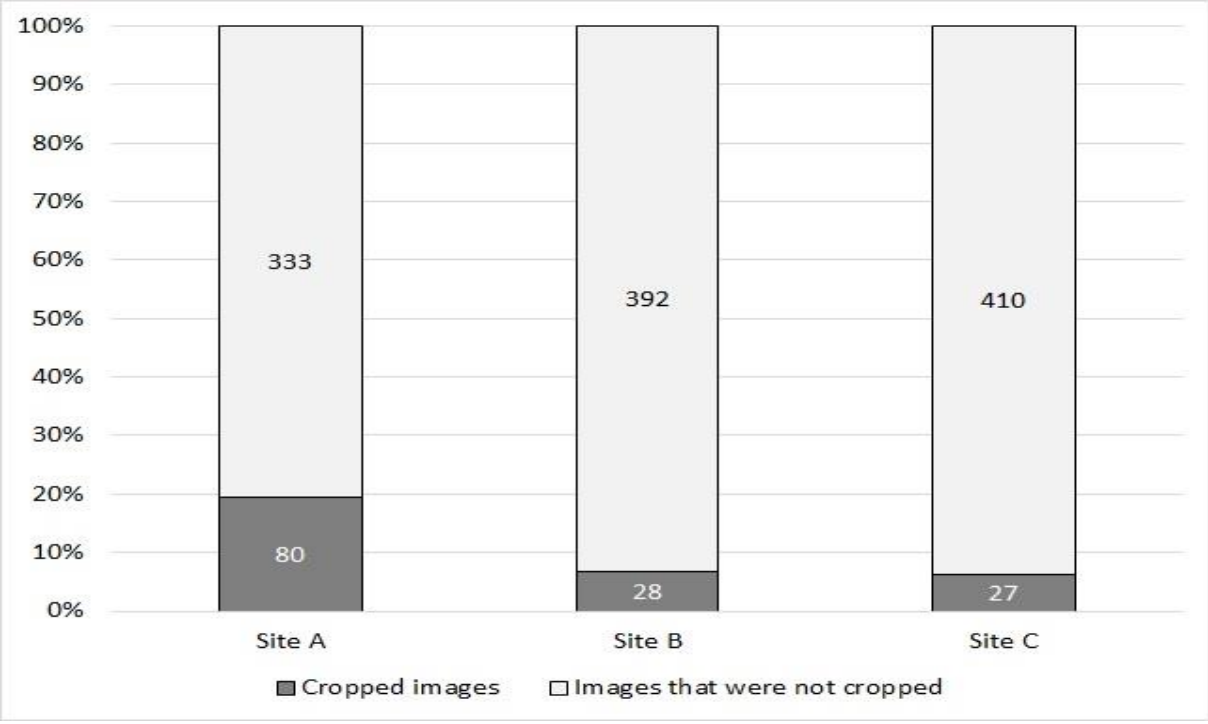

Fig. 1 The number (in columns) and proportion (y-axis) of cropped images found at each site

Common examinations (> 4 examinations at each site) were: Chest, Shoulder, Lumbar spine, Hip, Knee, Hand and Foot, which included a total of 1072 images. 83.8 % of cropped images fell in the common examinations category at site A, 64.3 % at site B and 100 % at site C.

Figure 2 shows the number and proportion of cropped images for the seven common types of examinations. Numbers from all the three sites are summed up for each examination type. The proportion of cropped images was significantly different between examinations ($p < 0.05$). The proportion was largest in Chest examinations, 26 %, then Lumbar spine (18 %), Shoulder (13 %), Hip (10 %), Knee (10 %), Hand (3 %). The lowest proportion of Foot images was cropped, only 2 %.

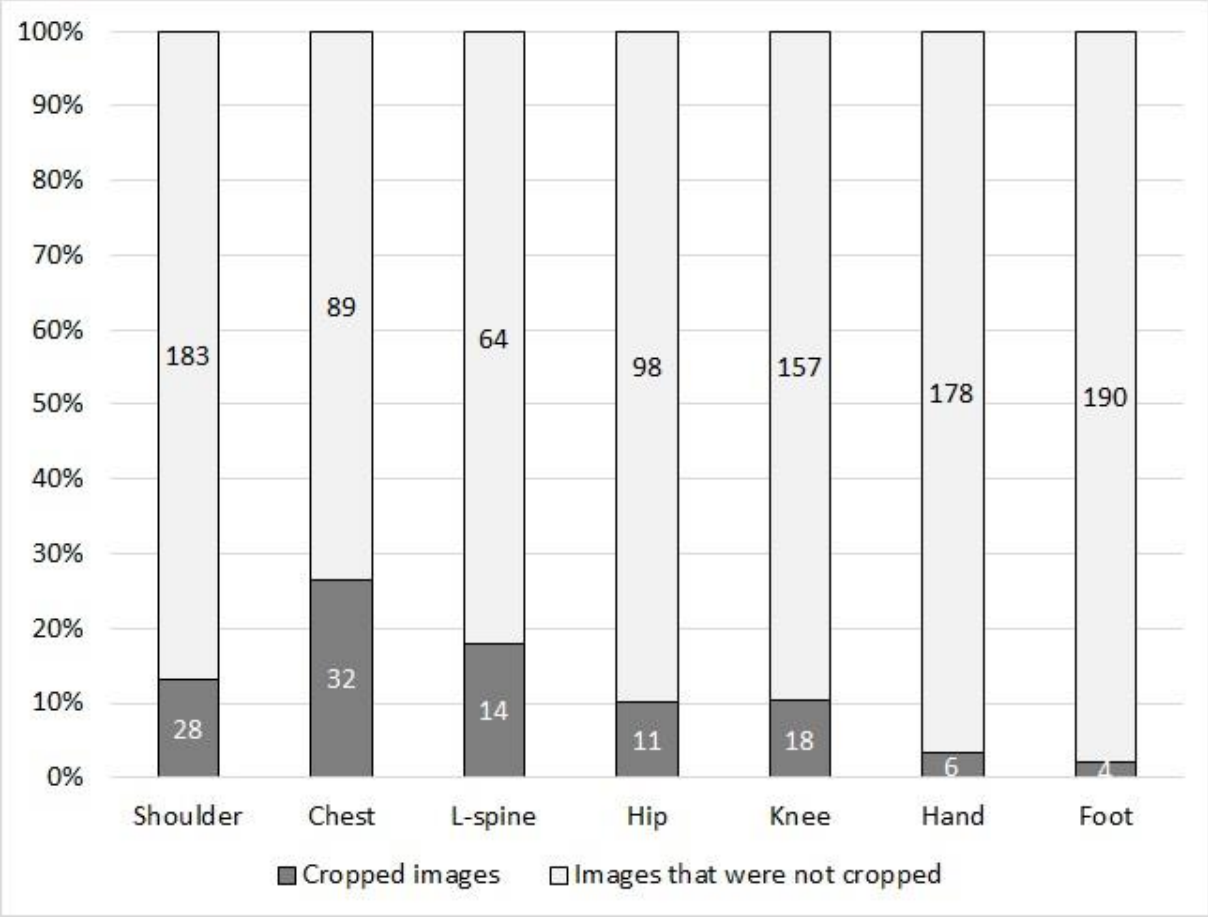

Fig. 2 The number (in columns) and proportion (y-axis) of cropped images in each type of examinations. L-spine = lumbar-spine

Considering only the cropped images, the average cropped fraction of each image was from 16.0 % (Hand) to 36.3 % (Foot) as shown in Table 1. The corresponding unnecessary dose was estimated to be from 19.0 % to 56.9 %, i.e. the dose used was up to 56.9 % more than needed to produce the final image.

	N	**Cropped fraction (%)**			**Unnecessary dose (%)**
	(cropped)	Max	Min	Avg	Average
Shoulder	28	60	9	27.4	37.8
Chest	32	39	2	16.5	19.7
Lumbar spine	14	48	10	24.3	32.1
Hip	11	41	11	20.7	26.2
Knee	18	64	6	28.7	40.2[a]
Hand	6	28	11	16.0	19.0[a]
Foot	4	55	25	36.3	56.9[a]

Table 1 Average unnecessary dose for cropped images

The number of cropped images (N) in each type of examination, the maximum (Max), minimum (Min) and average (Avg) cropped fraction of each image and the corresponding average unnecessary dose. The average is calculated from cropped images only.

Averaging the cropped area over all images in the same type of examination gave an average cropped fraction from 0.5 % (Hand) to 4.4 % (Chest and Lumbar spine) and an estimated unnecessary dose in the range of 0.5 % to 4.6 % as shown in Table 2.

	N	**Cropped fraction**	**Unnecessary dose**
	(all)	Average (%)	Average (%)
Shoulder	211	3.1	3.2
Chest	121	4.4	4.6
Lumbar spine	78	4.4	4.6
Hip	109	2.1	2.1
Knee	175	3.0	3.0[a]
Hand	184	0.5	0.5[a]
Foot	194	0.8	0.8[a]

Table 2 Average unnecessary dose for all images

The number of images (N) in this study from each type of examination and the average cropped fraction if all images (both cropped and un-cropped images) are included. The last column shows the corresponding average unnecessary dose in each examination type.

There were a few cases in which the cropped fraction was very large, as shown in Figure 3 and the median cropped fraction of images was lower than the average for Shoulder, Lumbar spine and Knee examinations.

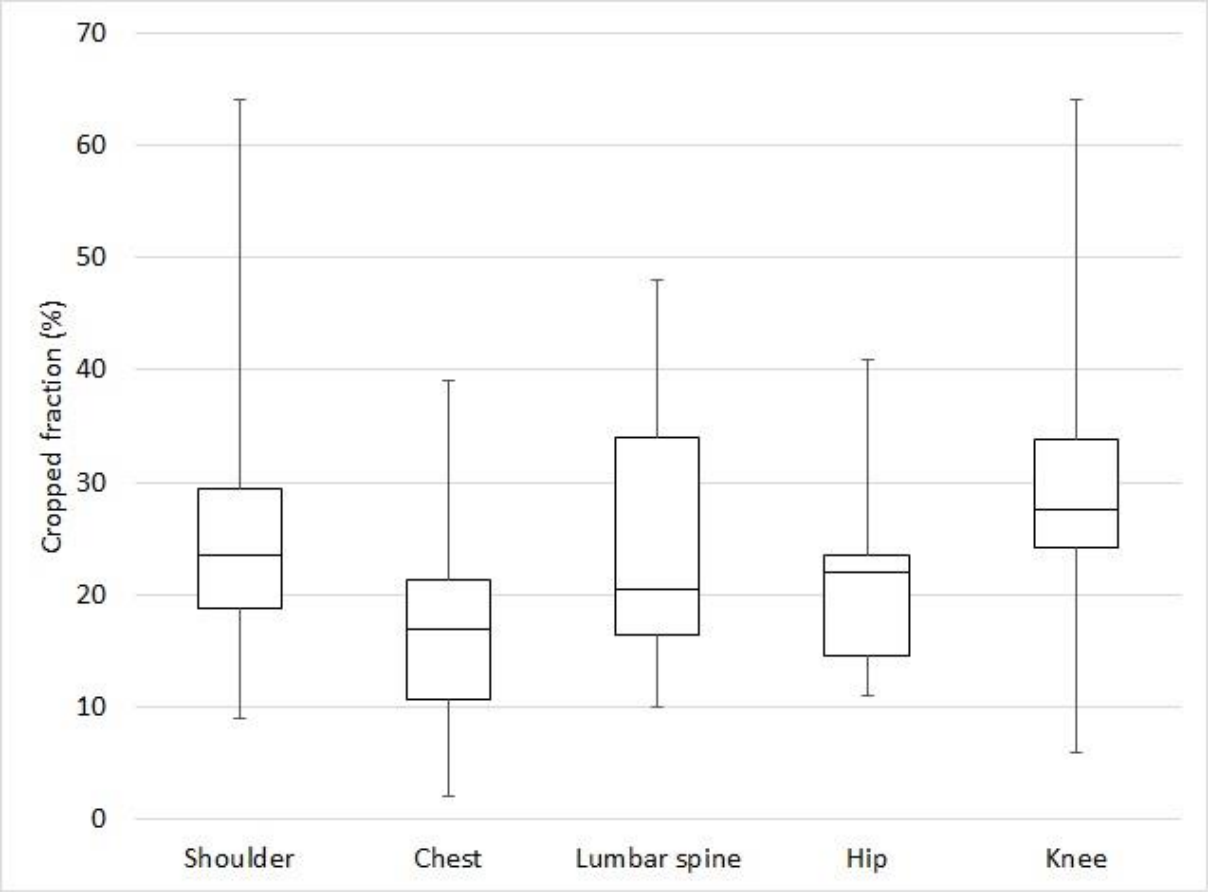

Fig. 3 The range of the cropped fraction of each image. For each type of examination, the figure shows the interquartile range (the box), the median (the line in the center of the box), the minimum and the maximum (upper and lower ends of the lines) cropped fraction

Discussion

This study shows that radiographs are cropped and that the reasons and consequences need to be discussed. The radiation dose in lumbar spine examinations was, on average, 4.6 % more than needed at the sites included in this study. For lumbar spine examinations it is safe to assume that the larger radiation field leads to a directly proportional increase in the effective dose. For examinations of the hip, shoulder and chest the radiation field was on average 2.1 – 4.6 % larger than the final image but, in those examinations, it is likely that the collimated area was partially outside the margins of the patient, thus not adding to the effective dose. However, population doses based on DAP values [5] contain the same error.

Images were cropped at all three sites in the study, but the proportion of cropped images varied from 6 – 19 %. This difference, due to the design of the study, does not necessarily

reflect the actual proportion of cropped images at each site. Some variation was expected as the use of the option to crop images may rely heavily on professional conduct and local guidelines. There was no obvious explanation for the high proportion of cropped images in one of the sites. All three sites are different from each other in terms of size, examination types and patient population but the aim of the study design was to include a large variety of examinations and radiographers' practices to minimize the influence from individual practices and examination types on the results. As shown by Tsalafoutas [7], the equipment can affect collimation practices but, in this study, all three sites had identical equipment.

Up to 64 % of the radiation field was cropped off from of a single image, which is alarming; nevertheless, similar results have been reported by others [6]. It is important to note that if images are cropped at all the cropped fraction is rarely small, e.g. never less than 10 % for lumbar spine images reviewed in this study. A habit of cropping images rapidly leads to an accumulation of unnecessary radiation dose and, worryingly, collimation practices seem to have worsened after the implementation of digital technology [8]. The results of this study support arguments that have been made about the widespread need for comprehensive and practical education in digital image technology [9]. In addition to the over-exposure inherent in cropping radiographic images and the risk of losing important information, image quality is degraded by using image cropping rather than proper collimation, due to increased scatter radiation [10]. If collimation borders are not generally visible on the displayed image due to shuttering, cropping of images can go undetected. Thus, it is necessary to verify that images are not cropped and to ensure awareness of this important aspect in the optimization of radiographic procedures. Collimation practices should be evaluated when investigating DAP values above set diagnostic reference levels (DRL), as recommended by the ICRP [6]. However, DAP values below DRL do not ensure good collimation practices, e.g. if image detectors with high dose efficiency are used and radiation doses lowered accordingly, the optimization of other dose contributing factors might be neglected. It is important that all factors, both equipment and practice related, are optimized.

This study has some limitations. It is inherent in the design that the infrequent examinations are overrepresented. It was considered more important to obtain data for wider range of examinations and to reduce potential bias from individual practice. In the study the collimation of the radiation field was assumed to include the anatomy of the patient only. It should be noted that this is not always the case; in extremity examinations a part of the beam may not fall on the patient at all and does thus not contribute to the patient dose. The unnecessary dose cannot be directly translated into added risk of exposure induced cancer because neither age nor gender information was gathered.

In conclusion 10.6 % of images had been cropped and the largest fraction cropped of an image was 64 %. The radiation dose to the patient that did not contribute to the image, as a result of cropping, was as much as 4.6 % of the total dose in some types of examinations. It can be assumed, based on this study, that available options to crop images are used and that

the radiation field is not truly represented by the image used for reporting in all cases. Image cropping is a latent source of additional radiation dose to the patients which can easily go unnoticed. This needs to be considered in the optimization of radiographic imaging procedures.

Compliance with Ethical Standards

The study was performed with a license from The National Bioethics Committee (VSN-17-233).

References

1. International Atomic Energy Agency (2015) Worldwide Implementation of Digital Imaging in Radiology, IAEA Human Health Series No. 28. International Atomic Energy Agency, Vienna.

2. American Society of Radiologic Technologists (2018) The Practice Standards for Medical Imaging and Radiation Therapy. Advisory Opinion Statement. Use of Post-Exposure Shuttering, Cropping and Electronic Masking in Radiography. American Society of Radiologic Technologists, Albuquerque.

3. Seeram E, Brennan PC (2017) Radiation Protection in Diagnostic X-Ray Imaging. Jones & Bartlett Learning, Burlington.

4. Bomer J, Wiersma-Deijl L, Holscher HC (2013) Electronic collimation and radiation protection in paediatric digital radiography: revival of the silver lining. Insights Imaging. 4 (5):723-7. https://doi.org/10.1007/s13244-013-0281-5

5. European Commission (2008) European guidance on estimating population doses from medical x-ray procedures. Radiation protection 154. European Union, Luxembourg.

6. International Commision on Radiation Protection (2017) Diagnostic reference levels in medical imaging. ICRP Publication 135. Ann. ICRP 46(1). https://doi.org/10.1177/0146645317717209

7. Tsalafoutas IA (2018) Electronic collimation of radiographic images: does it comprise an overexposure risk? Br J Radiol 91(1086):20170958 https://doi.org/10.1259/bjr.20170958

8. Zetterberg LG, Espeland A (2011) Lumbar spine radiography - poor collimation practices after implementation of digital technology. Br J Radiol. 84(2011):566-9. https://doi.org/10.1259/bjr/74571469

9. Morrison G, John SD, Goske MJ, et al. (2011) Pediatric digital radiography education for radiologic technologists: current state. Pediatr Radiol. 41(5):602-10.

https://doi.org/10.1007/s00247-010-1904-3

10. Carlton RC, Adler AM (2013) Radiographic Imaging, Concepts and Principles. Delmar, New York.