ORIGINAL ARTICLE

Resolution and Contrast Sensitivity of the Radiograph after Irradiation together with Vinyl Sticker and Waistband.

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Abstract

Background: Typically, patients wear their underwear during X-ray examination, but it may be visible on the X-ray images thus affect the image quality. Therefore, the aim of this study is to investigate the effects of vinyl stickers and waistband on the contrast and resolution of radiographs.
Methods: TOR CDR (Leeds Test Object, UK) was irradiated with X-ray photons at 70kVp, 20mAs using a computerised radiography system, either directly or over the thickness of the sticker or waistband. The contrast and resolution of the X-ray image were calculated based on the manufacturer's guidelines.
Results: As the thickness of the sticker or waistband increased, the sensitivity to high and low contrast increased significantly and the resolution decreased (sticker: high contrast, p value =0.01; low contrast, p value =0.04; resolution, p value =0.22, wristband: high contrast, p value =0.01; low contrast, p value =0.02; resolution, p value =0.08)). There was a statistically significant effect on image quality after the TOR CDR was overlaid with the sticker or wristband (p-value <0.001).
Conclusion: As the thickness of the vinyl stickers and waistband increases, image contrast and resolution deteriorate. Therefore, it is important that patients remove their underwear or other clothing with vinyl stickers or waistbands for the appropriate X-ray examination.

Keywords: *Resolution; contrast; X-ray radiograph; Image quality; artifact.*

Introduction

One of the most important goals in radiography is to obtain an optimal image for reporting[1]. Optimal image quality allows an interviewing radiologist to view the image and make an accurate diagnosis. There are characteristics of an X-ray that can be assessed and used to determine image quality, such as contrast, resolution and artefacts [2].

Before the examination, the patient must remove certain clothing and change to a hospital gown. Typically, the patient can wear their underwear such as briefs, boxers, or panties under the hospital gown. However, certain types of underwear contain accessories that may appear on the X-ray. These include elasticated waistband, stickers, or lace. These unwanted images are called artefacts. An artefact is a structure or appearance that is not normally present and should not be seen on an X-ray and which could distort the image [3].[4]. Many studies have reported the presence of artefacts caused by metallic materials such as necklaces, earrings and zips on X-ray images [5-7]. This is to be expected as metal is a radiopaque material. However, the non-radiopaque material commonly used in underwear has never been studied, particularly the effects on physical imaging characteristics.

Therefore, the study aims to investigate the effects of different thicknesses of vinyl stickers and elastic waistband on image contrast and resolution.

Materials and methods

Image acquisition

Image quality phantom, TOR CDR (Leeds Test Object, UK) was placed on the center of the image receiver, size of 24 cm x 30 cm, (Carestream DirectView CR). A Computed radiography (CR) unit (Siemens Multix Top Polydorus IT) was directed so that the X-ray beam centered to the TOR CDR. Then the X-ray beam is collimated to include entire surface of the TOR CDR. The exposure parameters used on this study were 70 kVp, 20 mAs, the distance between the image and the X-ray source (SID) of 100 cm (Figure 1). The images of CDR TOR, which serve as the control image, were then acquired and processed using a printer (Carestream Dryview 5950 Laser Imaging System).

The accessories examined for this study were vinyl stickers and waistbands. Both materials were purchased from local retailers. The sticker and waistband were either cutting or bonding (without using any thread or glue) so that their size covered the entire surface area of the TOR CDR, which is 15 cm x 15 cm. Stickers and waistband were stacked, respectively, and measured using digital thickness gauze, to obtain the required thickness (thickness: sticker = 0.3 mm, 0.6 mm and 0.9 mm; waistband = 1.2 mm, 2.4 mm and 3.6 mm).

In the separate experiment, sticker and waistband for each thickness, were placed directly on center of the TOR CDR, to acquire the tested images using the same exposure parameters as for the control image. Radiation exposure for both control and tested groups was repeated twice, thus total images for this study were 16.

Data analysis

Statistical Analysis was performed using GraphPad Prism 7. The relationship between sticker and waistband thickness and image quality was analysed using the Pearson correlation test. The difference in image quality for radiographs after the TOR CDR was irradiated with and without sticker and waistband, respectively, was analyzed using two way ANOVA with Dunnett multiple comparison test. Significant level was set at p- value < 0.05.

Results

In general, stickers and wristbands have a similar effect on image quality, especially on resolution sensitivity. However, the wristband resulted in a higher threshold for high and low contrast sensitivity compared to the sticker.

From the Pearson correlation test, both high and low contrast sensitivity increased significantly with increasing thickness of the sticker (p-value: high contrast = 0.01; low contrast = 0.04). For resolution sensitivity, it decreased with increasing thickness of the sticker but not statistically significant (p-value: resolution = 0.22). A similar statistical result was found for the wristband, where both high and low contrast sensitivity increased significantly with increasing wristband thickness and resolution decreased (p-value: high contrast = 0.01; low contrast = 0.02; resolution = 0.08) (Figure 3).

A two-way analysis ANOVA showed that there was a statistically significant effect on image quality after the TOR CDR was overlapped with the sticker or wristband (p-value < 0.001). Post statistical analysis shows that the difference in high contrast sensitivity occurs when the TOR CDR is irradiated with radiation while overlaid with a 0.6 cm and 0.9 cm thick sticker (p-value). All sticker thicknesses cause a significant difference in resolution sensitivity, but not in low contrast sensitivity, between the control and tested images (Figure 4).

At the same time, all waistband thicknesses cause a significant difference in high contrast and resolution sensitivity, but not in low contrast sensitivity, between the control and the tested images (Table 1).

Discussion

The aim of this study was to investigate the effects of vinyl stickers and waistband on the contrast and resolution quality of radiographs.

A good radiograph is one with high resolution and low contrast. High resolution helps to identify small, detailed, nearby structures[8], while low contrast has more greyscale and can distinguish nearby structures with different densities[9,10]. This is important because a high quality X-ray can help the doctor to accurately assess the X-ray.

However, it was found that for the two materials tested in this study, the vinyl sticker and the waistband, the image quality decreased with increasing thickness. This indicates that the material used for the sticker and the waistband is capable of absorbing photons of X-rays. This process is called photon attenuation and occurs when the quality and quantity of photon energy from the X-ray beam passing through the material is absorbed by the material. The rate of absorption depends on the density of the material [11,12]. This suggests that both materials, particularly the waistband, have the potential to act as a material for X-ray shielding. Previous studies have reported that rubber, which is one of the components of the sticker and waistband, can reduce photon attenuation, which is reflected in the absorbed doses [13].

Both materials are mainly found in children's underwear. The associated X-ray examinations relate to the abdominal and pelvic regions. Researchers reported that the presence of unwanted signals, called artefacts, could mimic pathology [9]. For example, artifact in the pelvic image resembled a bone fracture [5]. Therefore, to avoid an artefact that mimics pathology and leads to an inaccurate diagnosis, the radiographer should specifically instruct the patient to remove underwear with vinyl stickers and a waistband.

In addition to contrast and spatial resolution, image artefacts are another factor that can affect image quality. Image artefacts create unknown features that do not represent a body structure or object. Normally, an artefact does not significantly affect the visibility of objects or

diagnostic accuracy. But artefacts can obscure part of an image or be interpreted as an anatomical feature. A variety of factors related to each imaging modality can cause image artefacts. Previous studies reported that jewellery, body adornment or tattoos may appear on the radiograph and mimic pathological conditions [14] and should be removed prior to examination if possible.

There are some limitations to this study. First, the radiation factor used is fixed at 70 kVp and 20 mAs. Although this is not an appropriate radiation factor for pediatric pelvic examinations, the setting is relevant for this study as it is an exposure factor for normal adults. Secondly, as we are using a prefabricated sticker and waistband, a detailed compositional study is not possible to determine which material has the greatest impact on image quality. Future studies could try to make a custom-made sticker or waistband and examine in detail the effects of the material used on image quality.

Image quality is highly dependent on image contrast, spatial resolution, and image noise. Although artifacts do not significantly affect the visibility of the image, the presence of artifacts can affect diagnostic accuracy. It is important to maintain image quality to reduce the repetition of examinations, which results in additional radiation doses to patients from repeat examinations and avoidable financial expenditure.

Conclusion

This study concludes that as the thickness of both the vinyl stickers and the waistband increases, image contrast and resolution deteriorate. Therefore, it is important that patients remove their underwear or other clothing with vinyl stickers or waistbands for the appropriate X-ray examination.

Conflict of Interest

The authors have no conflict of interest to declare.

Acknowledgment

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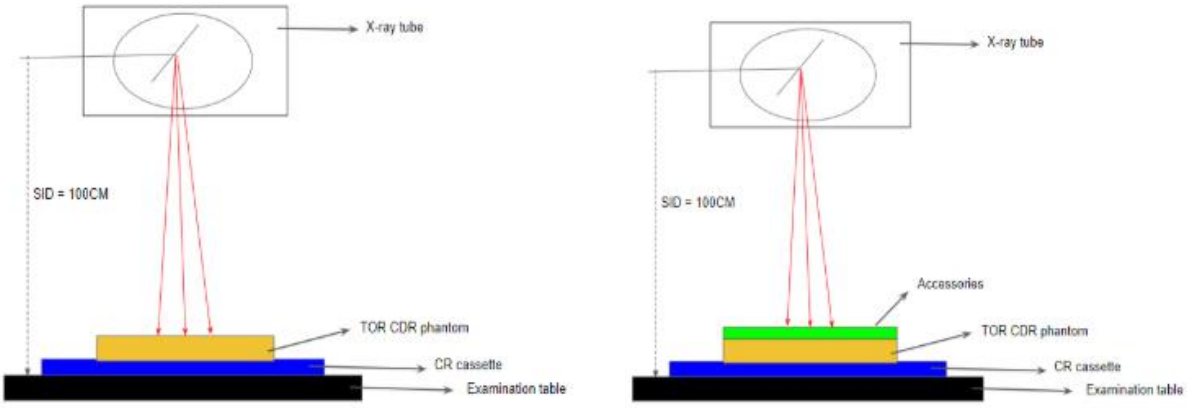
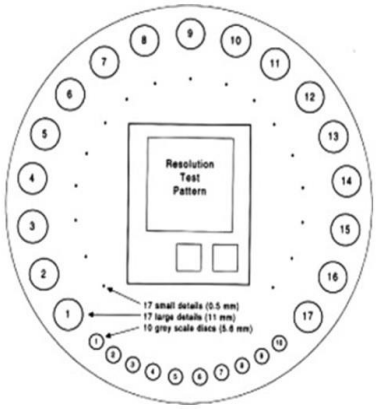
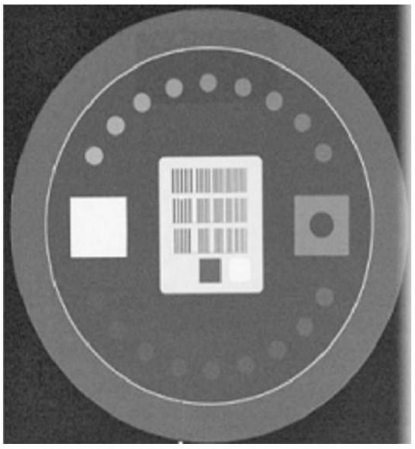


Figure 1. The schematic diagram of the study (a) without accessories and (b) with accessories

(a)



(b)



(c)

Disc Number	Contrast	Disc Number	Contrast
1	0.075	10	0.015
2	0.067	11	0.013
3	0.053	12	0.011
4	0.045	13	0.009
5	0.039	14	0.007
6	0.032	15	0.005
7	0.027	16	0.003
8	0.022	17	0.002
9	0.017	-	-

(d)

Disc Number	Contrast	Disc Number	Contrast
1	0.954	10	0.167
2	0.820	11	0.128
3	0.726	12	0.117
4	0.573	13	0.088
5	0.496	14	0.067
6	0.360	15	0.061
7	0.302	16	0.045
8	0.238	17	0.039
9	0.203	-	-

(e)

Group Number	Spatial Freq.	Group Number	Spatial Freq.
1	0.50	16	2.80
2	0.56	17	3.15
3	0.63	18	3.55
4	0.71	19	4.00
5	0.80	20	4.50
6	0.90	21	5.00
7	1.00	22	5.60
8	1.12	23	6.30
9	1.25	24	7.10
10	1.40	25	8.00
11	1.60	26	8.90
12	1.80	27	10.0
13	2.00	28	11.1
14	2.24	29	12.5
15	2.50	30	14.3

Figure 2. TOR CDR Images and specification tables. There are (a) 17 large details (11 mm), 17 small details (0.5 mm) and 30 groups of bar patterns on the TOR CDR test phantom. (b) The radiograph was assessed, and the number of visualized circles (disc) and bars (group) was referenced to the specification table for the threshold value of (c) low and (d) high contrast and (e) resolution specificity, respectively.

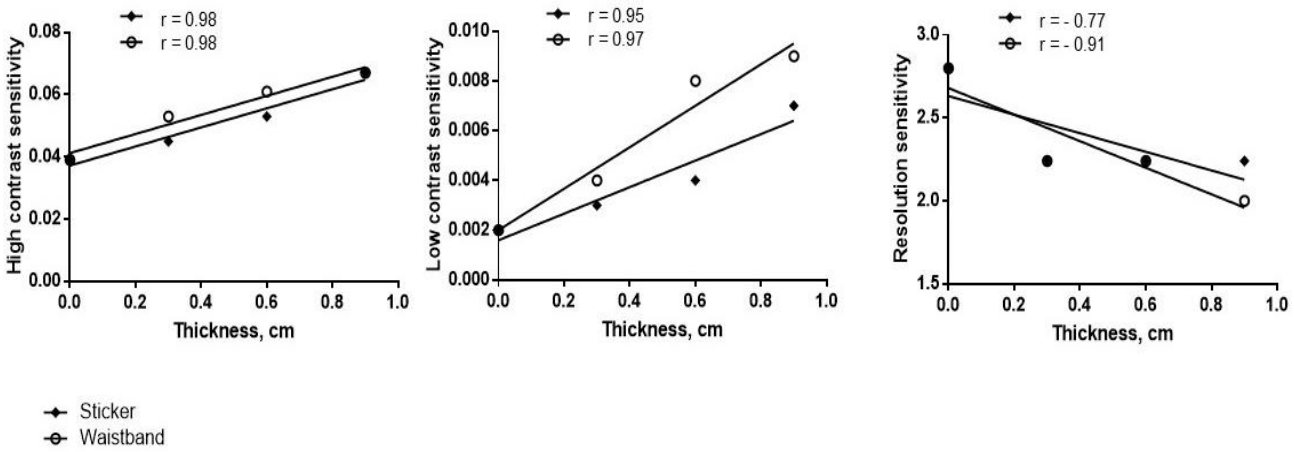


Figure 3. The Pearson correlation shows a correlation between sticker and waistband thickness and high, low contrast and resolution sensitivity, respectively.

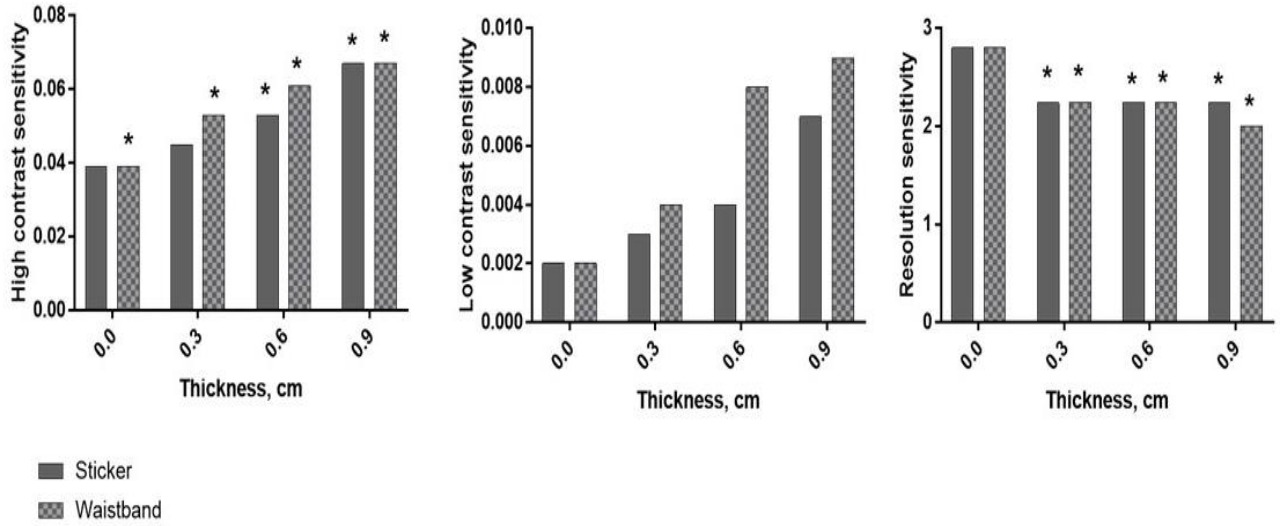


Figure 4. The two-way ANOVA with Dunnet multiple comparison test shows the difference between high, low contrast and resolution sensitivity for TOR CDR after irradiation without accessories (0.0 cm) and together with accessories. (*) represents for a significant difference to the control group (0.0 cm).

Table 1. Comparison of high, low contrast and resolution sensitivity between TOR CDR without accessories (0.0 cm) and with accessories thickness. The bold p-value represents a significant value.

Dunnett's multiple comparisons test		p value
	High contrast sensitivity, Threshold value	
	0.0 cm vs 0.3 cm	0.21
	0.0 cm vs 0.6 cm	**<0.01**
	0.0 cm vs 0.9 cm	**<0.001**
	Low contrast sensitivity, Threshold value	
	0.0 cm vs 0.3 cm	0.98
	0.0 cm vs 0.6 cm	0.88
Sticker	0.0 cm vs 0.9 cm	0.34
	Resolution sensitivity, Threshold value	
	0.0 cm vs 0.3 cm	**<0.001**
	0.0 cm vs 0.6 cm	**<0.001**
	0.0 cm vs 0.9 cm	**<0.001**
	High contrast sensitivity, Threshold value	
	0.0 cm vs 1.2 cm	**<0.01**
	0.0 cm vs 2.4 cm	**<.001**
	0.0 cm vs 3.6 cm	**<.001**
	Low contrast sensitivity, Threshold value	
	0.0 cm vs 1.2 cm	0.88
	0.0 cm vs 2.4 cm	0.22
Waistband	0.0 cm vs 3.6 cm	0.13
	Resolution sensitivity, Threshold value	
	0.0 cm vs 1.2 cm	**<0.01**
	0.0 cm vs 2.4 cm	**<.001**
	0.0 cm vs 3.6 cm	**<.001**

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