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## Original Article

# An observer study: comparison of computed radiography to electronic and film portal imaging

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## Abstract

*Introduction:* Computed radiography (CR) is an imaging facility that does not require the use of hard copy film, digital images are obtained with a photostimulable phosphor plate, which replaces film, in a cassette. As the first UK radiotherapy site to trial CR, we are collecting data to assess the feasibility of using CR in radiotherapy treatment verification.

*Method:* From 30 patients undergoing radical radiotherapy, 10 were consecutively accrued to three sites: pelvis, thorax and head and neck. Treatment verification images were taken using current protocols, but substituting standard imaging for CR images on one fraction. Four independent observers were used: two clinical oncologists and two therapy radiographers. Observers rated CR, electronic portal imaging (EPI) and enhanced contrast (EC) films of the three sites for both landmark visibility and ease of verification decision, using a numerical scoring system.

*Results:* Ratings for visibility of landmarks and for verification decision were similar for CR and film/EPI images for most landmarks. However, CR images rated poorly compared to EC film in the head and neck region with landmarks such as thyroid cartilage and cricoid cartilage rating as 'not clear'. CR images rated better than EPI images for both visibility and verification decision on the majority of landmarks in the pelvis region.

*Conclusion:* Results gathered from a relatively small sample size have provided the following conclusion. The visibility of landmarks in CR images is comparable to that in film and EPI. Verification of treatment images based on CR is comparable to that of the current imaging media in the department.

## Keywords

Computed radiography; electronic portal imaging; radiotherapy treatment; verification

## INTRODUCTION

A fundamental principle of radiotherapy is that successful treatment outcomes require the accurate alignment of radiation beam and target volume, hence the necessity for treatment verification procedures.[1–3] Verification in radiotherapy departments is performed using a number of different image acquisition devices most notably amongst those is an electronic portal imaging device (EPID) which allows for high efficiency of image acquisition along with archiving and communications capabilities.[2–5] The advantages of EPID systems over conventional film/screen combinations mean that this is the preferred imaging modality for many treatment sites. EPID allows for the adjustment of image contrast and brightness for optimum viewing and the electronic transfer and registration of images to enable an efficient verification process.[6–8]

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Advances in image planning and treatment delivery, using more complex treatment techniques with non-coplanar beams, higher doses and tighter margins around the target volume, require the optimisation of verification.[9] Whilst film/screen is still considered a reliable imaging method and in many cases a necessary alternative in place of EPID, there are limitations of contrast differentiation when taking images with high-energy photon beams. Such differences manifest themselves when observing soft tissue and bone, whereas digital images can be contrast enhanced for observation.[10,11]

Computed radiography (CR) is an imaging modality that, like EPID, does not require the use of hard copy film. Digital images are obtained with a photostimulable phosphor plate, replacing film, in a cassette. When exposed to radiation, these photostimulable phosphors act as energy traps that store this proportional energy until the plate is scanned by a laser, allowing the phosphors to release this stored energy in the form of light. The light is collected by a photo-multiplier tube that converts the light into an electrical signal and subsequently a digital number for storage.[11–13]

As the first UK radiotherapy site to trial CR, we are collecting data to assess the feasibility of using CR in radiotherapy treatment verification. The study aims to address the quality of CR images against EPID and film, which are the current accepted image acquisition devices for treatment verification in the department.[14] The study looks at the ease of identification of anatomical landmarks with the various imaging modalities from images acquired in three sites where the use of EPID and film are already established; pelvis, thorax and head and neck. The study also looks at the ease of verification for these modalities using a numerical scoring system.[5]

## METHOD

### Imaging systems

The department had the use of a CR system for a fixed period of 6 months for trial purposes. The radiotherapy solution offered by Kodak is the 2000RT CR plus reader and eraser offering a 12-bit grey scale resolution. This was used in combination with Kodak EC-L (enhanced contrast for localisation) lightweight cassettes, housing AGFA ADC Storage phosphor screens (35 × 43 cm). The department currently uses Elekta iVIEW 3.1 EPID. Images are displayed on a monitor with 768 × 576-pixel display matrix, 8-bit grey scales and image analysis algorithms were used. These included image enhancement and windowing and levelling.

The third imaging modality to be used was Kodak EC-L double emulsion films. These films were used in combination with Kodak EC-L dual phosphor-coated screen cassettes.

### Image acquisition

Image acquisition for this trial was in line with the department image verification protocol for radical treatment courses with standard image acquisition methods being replaced for CR images on one fraction of the patient treatment course.

*Pelvis*

Fraction one verification by EPID taking a lateral image and an anterior image. Fraction two verification by CR (lateral image and an anterior image). EPID images were acquired at treatment energies of 8 or 10 MV. Double exposures were acquired using a total of 10 monitor units (MU) for a lateral image and 8 for an anterior image. CR images were acquired at the same energies. Check film exposures of 14 MU for a lateral image and 12 MU for an anterior image were used.

*Thorax*

Fraction one verification with film/screen combination (anterior or posterior image). Fraction two verification with CR (corresponding image to fraction one). Both film/screen and CR images were acquired using treatment energies of 6 or 8 MV and double exposures of a total of 9 MU.

*Head and neck*

Fraction one left lateral film/screen combination, right lateral CR image. Again both types of image were acquired at treatment energies of 6 or 8 MV with double exposed images of 7 MU.

A total of 30 patients were consecutively accrued (10 to each site). Accrual was based on patient start date during the period allocated for trial.



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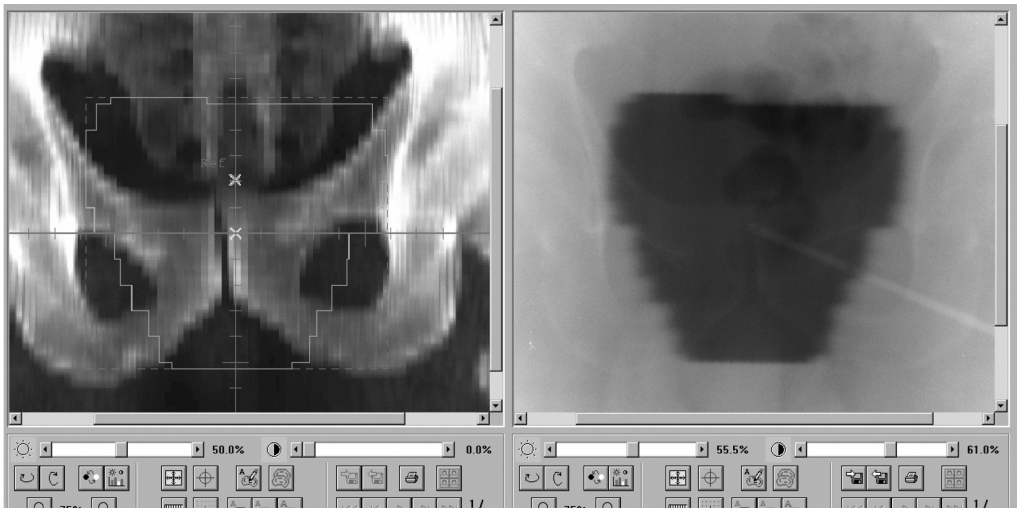


*Figure 1. Example of monitor display for observers, showing DRR on the left and treatment image on the right.*

## Image observation

The study used four independent observers to view all images, two of these were consultant oncologists and two were senior radiographers with significant experience in radiotherapy portal imaging. Observation sessions were undertaken individually and there was no time limit applied.

All images were viewed using the iVIEW 3.1 software, as detailed previously. Hardcopy images were scanned and imported to iVIEW for observation thus replicating viewing conditions for all images, Figure 1 shows the monitor screen display for observation. Observer sessions took place in the same room using the same monitor with low level room lighting for viewing. Windowing and levelling functions were used to enhance each image. Digital reference images (DRRs) were also provided from either the planning system or CT planning scan to correspond to each view to be evaluated.

Observers evaluated each image and were given two questions to answer:

*Question 1:* Based on the information from the EPID/CR/EC-L image only, the individual landmark is: (1) very clear; (2) clear; (3) visible; (4) not clear; (5) not visible.

*Question 2:* Based on the information from the EPID/CR/EC-L image only, the verification decision is: (1) very easy; (2) easy; (3) possible; (4) difficult; (5) very difficult.

Observers gave numerical ratings from 1 to 5, corresponding to these categories, against a number of identified anatomical landmarks. Eight to nine landmarks were identified for each site. The landmarks were selected that are typically used by clinicians for treatment verification. Ratings for each landmark on all images were recorded in numerical form ready for further analysis.

To summarise the data, the ratings were averaged to a mean for each structure for each modality, across all observers. This was carried out for both question 1 (the visibility of anatomical structure) and for question 2 (the ease of verification by anatomical structure).

## RESULTS

The mean ratings for landmark visibility are illustrated by treatment site in Figures 2–4. They show all anatomical landmarks used for observation. Visibility was comparable for most landmarks. The overall mean for the three sites showed that the majority of landmarks scored the same rating



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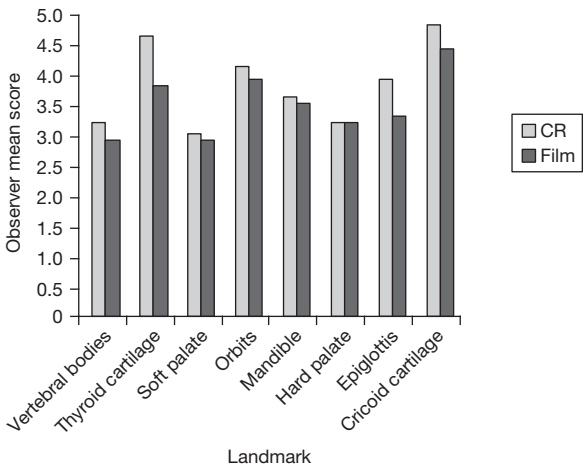


*Figure 2. Mean rating for landmark visibility of head and neck.*

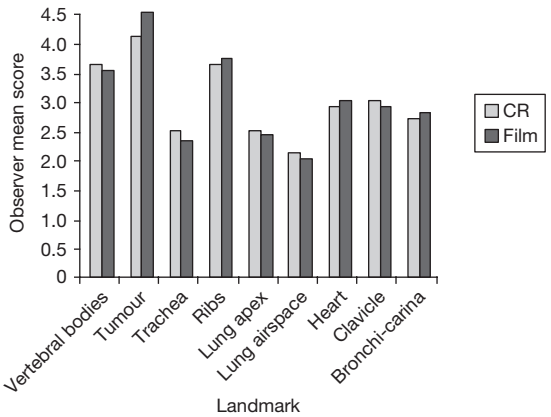


*Figure 3. Mean rating for landmark visibility of thorax.*

(visible) for both CR and film/EPID (57% of mean scores) as illustrated in Tables 1–3.

The head and neck site results are comparable between CR and EC film (Figure 2). CR scored poorly in a number of landmarks including thyroid cartilage and cricoid cartilage and so visibility of EC film is marginally superior although both media have overall visibility ratings which are not clear.

The thorax site showed equal overall mean ratings for all landmark visibilities. All structures apart from vertebral bodies, tumour and ribs rated as 'visible or better' (Figure 3).

Landmark visibility for the pelvis site proved marginally superior for CR images with all but two overall mean scores for landmarks, rating equal to or better than EPID (Figure 4).

The second question posed involved the ease of making a verification decision based on the identified landmarks for each image. The trends in ratings for each landmark were also similar to the first question. When looking at all landmarks used across the three sites it is seen that 16/30 (53%) of these had a rating of 'possible' or better in terms of verification decision on a CR image. This is in comparison to 15/30 (50%) of landmarks achieving the same minimum rating for film/EPID images.

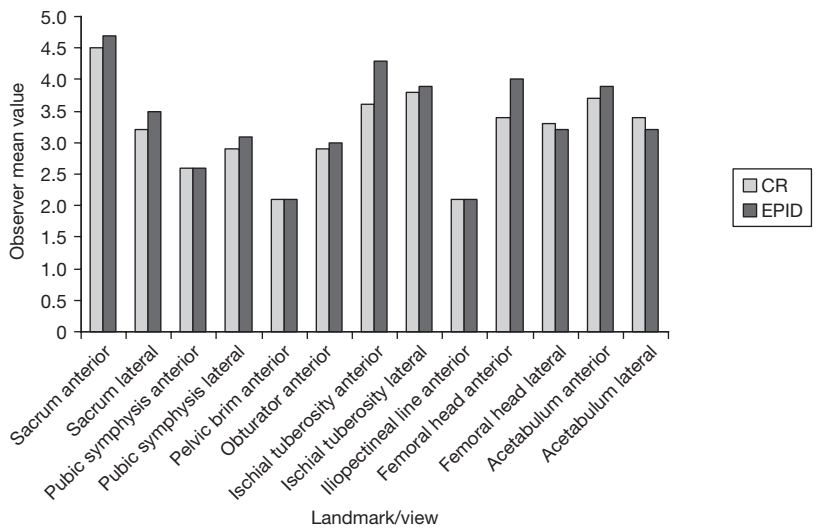


*Figure 4. Mean rating for landmark visibility of pelvis.*



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*Table 1. Overall mean ratings for head and neck*

| Structure | CR | Film |
|---|---|---|
| Vertebral bodies | 3.4 | 3.2 |
| Thyroid cartilage | 4.6 | 4.3 |
| Soft palate | 3.2 | 3.2 |
| Orbits | 4.5 | 4.2 |
| Mandible | 3.8 | 3.5 |
| Hard palate | 3.4 | 3.5 |
| Epiglottis | 3.9 | 3.4 |
| Cricoid cartilage | 4.9 | 4.3 |

*Table 2. Overall mean ratings for thorax*

| Structure | CR | Film |
|---|---|---|
| Vertebral bodies | 4.0 | 3.8 |
| Tumour | 4.5 | 4.7 |
| Trachea | 3.1 | 3.2 |
| Ribs | 4.0 | 3.9 |
| Lung apex | 2.9 | 2.8 |
| Lung airspace | 2.7 | 2.6 |
| Heart | 3.5 | 3.7 |
| Clavicle | 3.3 | 3.2 |
| Bronchi-carina | 3.4 | 3.3 |

*Table 3. Overall mean ratings for pelvis*

| Structure | CR | EPID |
|---|---|---|
| Sacrum anterior | 4.9 | 4.9 |
| Sacrum lateral | 3.4 | 3.8 |
| Pubic symphysis anterior | 2.8 | 2.7 |
| Pubic symphysis lateral | 2.8 | 3.2 |
| Pelvic brim anterior | 1.8 | 1.8 |
| Obturator anterior | 2.6 | 2.8 |
| Ischial tuberosity anterior | 3.6 | 4.3 |
| Ischial tuberosity lateral | 3.7 | 4.4 |
| Iliopectineal line anterior | 2.4 | 2.4 |
| Femoral head anterior | 3.6 | 4.3 |
| Femoral head lateral | 3.1 | 3.4 |
| Acetabulum anterior | 3.7 | 4.0 |
| Acetabulum lateral | 3.4 | 3.0 |

Tables 1–3 show the ratings by landmark for the three sites. The overall mean score per site for the imaging media (CR, film and EPID) all fall into the 'possible-to-difficult' categories for verification decision. The pelvis site provides the best average score for verification for CR and the head and neck site the worst. This is the same trend as seen with the EPID and film averages.

Figure 5 illustrates the linear trend in answers to question 2, in this illustration both film and

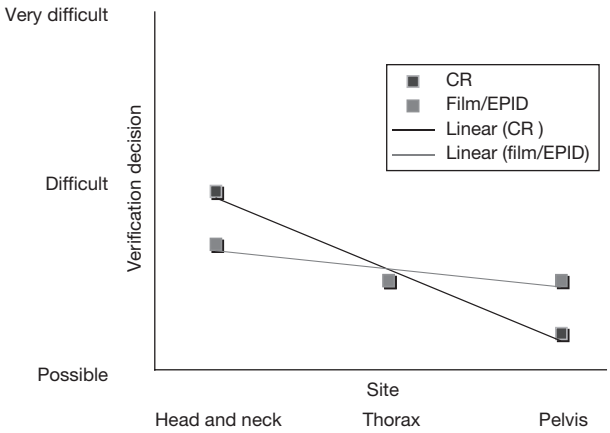


*Figure 5. Overall observers mean answers to 'ease of verification decision'.*

*Table 4. Number of landmarks that failed question 2*

| Image type | Observers | |
|---|---|---|
| | Radiographer | Oncologist |
| Film and EPID | 296/532 (*56%*) | 240/517 (*46%*) |
| CR | 291/538 (*54%*) | 235/531 (*44%*) |

EPID have been combined as the current departmental verification modalities for analysis against CR. The trend for CR and for film/EPID is very similar as previously shown, but it can be seen that all mean scores fit into the 'possible-to-difficult' increments. If a cut-off point is set for the acceptable quality of landmarks for verification, then a slightly more favourable outcome is seen for CR. If value 3 is used as the cut for acceptable image quality, i.e. 'possible' then values 4 and 5 (difficult and very difficult) count as failed. Table 4 illustrates the numbers of landmarks failing question 2. If the results for all observers are taken from Table 4 and then combined, it can be seen that the number of landmarks failing question 2 for film/EPID is 51% compared to 49% CR landmarks failing the same question.

## DISCUSSION AND CONCLUSION

An observer study was carried out to compare the clinical efficacy of CR images to film and electronic portal images in radiotherapy treatment verification. The average scores were generally



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similar for CR, film and EPID images. The trends illustrated across the three sites are comparable between the three forms of imaging media. Observers rated the majority of anatomical landmarks as visible across CR, film and EPID. The results highlight observer differences between radiographers and oncologists, with oncologist observers finding verification 'easier' on a greater number of anatomical landmarks for both film/EPID and CR images. Radiographer observers 'failed' more landmarks on verification ease.

Of the three treatment sites, the results showed that head and neck images rated poorly for landmark visibility and this is for both forms of imaging media. Noticeable differences between imaging media were seen in overall mean ratings for two landmarks: thyroid and cricoid cartilage rated as 'not clear' for film and 'not visible' for CR. Thorax and pelvis results highlighted a more favourable outcome with the majority of anatomical landmarks rating as 'visible' or better. Soft tissue landmarks such as tumour and pelvis structures such as anterior sacrum and anterior ischial tuberosity were the exception with overall mean ratings of 'not clear' or 'not visible'. A noticeable difference in mean ratings for the pelvis site is seen with anterior femoral head, rating as 'visible' for CR but 'not clear' for EPID.

From the breakdown in analysis of results small differences have been highlighted between the quality of CR to that of current department imaging methods, with CR being marginally superior for pelvis verification but marginally inferior for head and neck verification. Overall it can be concluded that the quality of CR is comparable to that of current imaging methods for treatment verification.

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