TECHNICAL REPORT

On the use of Kodak CR film for quality assurance of needle loading in I-125 seed prostate brachytherapy

L. S. Fog, R. Nicholls and T. van Doorn

Department of Medical Physics, Royal Adelaide Hospital, Adelaide, Australia

Abstract

Low dose rate brachytherapy using implanted I-125 seeds as a monotherapy for prostate cancer is now in use in many hospitals. In contrast to fractionated brachytherapy treatments, where the effect of incorrect positioning of the source in one treatment fraction can be diminished by correcting the position in subsequent fractions, the I-125 seed implant is permanent, making correct positioning of the seeds in the prostate essential. The seeds are inserted into the prostate using needles. Correct configuration of seeds in the needles is essential in order to deliver the planned treatment. A comparison of an autoradiograph obtained by exposing film to the seed-loaded needles with the patient treatment plan is a valuable quality assurance tool. However, the time required to sufficiently expose Kodak XOMAT V film, currently used in this department is significant. This technical note presents the use of Kodak CR film for acquisition of the radiograph. The digital radiograph can be acquired significantly faster, has superior signal-to-noise ratio and contrast and has the usual benefits of digital film, e.g. a processing time which is shorter than that required for non-digital film, the possibility of image manipulation, possibility of paper printing and electronic storage.

Key words brachytherapy, quality assurance, seeds, digital radiography, I-125

Introduction

In low dose rate prostate brachytherapy, radioactive seeds are positioned into the prostate through needles inserted through the perineum. Seeds are typically of 5 mm length with 5 mm of spacer material separating adjacent seeds. Additional seed separation may be achieved by inserting non-radioactive spacers between adjacent seeds. A patient treatment plan specifies the number and positioning of needles and the seed sequence in each needle. The radioactive seeds are either delivered pre-loaded in needles from the manufacturer or are loaded into needles by physicists at the hospital where the implant takes place. In contrast to fractionated brachytherapy treatments, where the effect of incorrect source positioning in one treatment fraction can be diminished by using correct positioning in subsequent fractions, the I-125 seed implant is permanent, making correct positioning of the seeds in the prostate essential[5].

Accurate treatment delivery relies on a chain of processes including correct positioning of the seeds in the needles, correct positioning of the implant template with respect to the patient and expulsion of the seeds in the correct position in the prostate. While publications by professional bodies[1,5] make recommendations on template positioning and seed positions in the prostate, they do not make specific recommendations on verification of the seed positions inside the needles. However, the need to accurately account for the positioning of the seeds is emphasised.

Other authors emphasise the need for quality assurance processes which accurately account for the number of seeds brought to the operating room[2,3] , although they do not suggest ways of accounting for the seed positions.

The acquisition and analysis of an autoradiograph to confirm the correct loading of seeds into the needles prior to implant forms an integral part of an accurate treatment delivery procedure.

When the needles are loaded by physicists at the hospital where the implant takes place, the needles are positioned in a needle loading shield. At the Royal Adelaide Hospital, a needle shield made by Standard Imaging (Standard Imaging Inc., 3120 Deming Way, Middleton. WI 53562, USA) is used (see figure 1).

Loading of a seed configuration different from that described in the treatment plan may occur if an incorrect amount of seeds is inserted into the needles, too many or too few spacers being used, or seeds or spacerds dropping out through the end of the needle. The needle loading can not be verified reliably simply by observing the retraction of the stillet in the needle as the amount of bone wax or suppository used to plug the needle will vary from needle to needle.

After loading, the seed configuration can be verified by

Corresponding author: Lotte S. Fog, Department of Medical Physics, Royal Adelaide Hospital Adelaide, SA 5000, Australia Tel: (08) 8222 5541, Fax: (08) 8222 5937, Email: Lotte.Fog@health.sa.gov.au
Received: 14 September 2006; Accepted: 4 August 2007

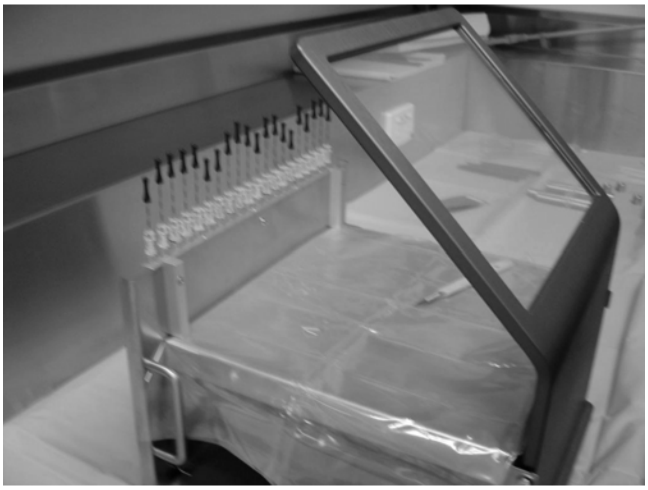

Figure 1. *Needles loaded with I-125 seeds, positioned in a needle holder.*

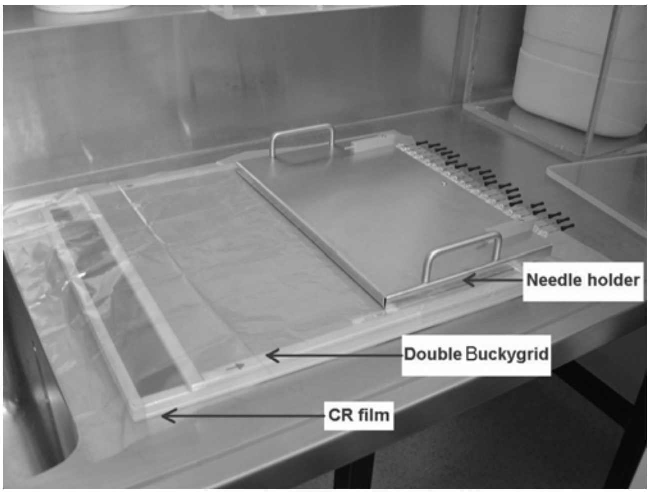

Figure 2. *Needles in needle holder, with a double Bucky grid positioned between the needle holder and a CR film cassette. A sterile plastic sheet is placed between the needle holder and the Bucky grid.*

positioning the needle loading shield on a film, thereby producing a radiographic image. The only criterion for sufficient image quality is that the seed configuration can be accurately determined.

The needle shield holds a maximum of 20 needles, and as most treatments require in excess of that, a second batch of needles must be loaded and another autoradiograph obtained.

At the Royal Adelaide Hospital, such seed configuration radiographs were initially generated using XOMAT film, as these films were in routine use for quality assurance light and radiation coincidence checks. The time required to adequately expose each sheet of Kodak (Kodak Eastman) XOMAT V film is 15 minutes, resulting in a typical total exposure time of 30 minutes.

An increase in the time for which the patient is anaesthetised is prolonged as a result of the acquisition of the seed configuration radiograph. This may result in reduced patient care and increased cost for the hospital as the anaesthetic staff and the remainder of the brachytherapy team has to wait for the quality control process to be completed. These considerations are particularly pertinent when “live planning” is carried out, in which patient ultrasound images are obtained , a plan made, needles loaded and the implant done in a single patient anaesthetics procedure , or if additional needles need loading when the patient is already anesthetised.

A significant advantage of the Kodak CR film is the possibility for digital image enhancement. The Kodak software includes analysis settings for a range of body parts specifying tone scale algorithm, spatial frequency and latitude enhancement, and also allows for the brightness and contrast settings to be modified[4].

These considerations were the primary motivation for this study which investigates other methods of obtaining an autoradiograph. To be clinically acceptable the proposed method should be faster than the current method as well as providing adequate contrast to determine the position of the seeds. At the Royal Adelaide Hospital, Computed radiography (CR) film is used clinically for patient imaging and is readily available. CR film is also known to have a much shorter processing time than Kodak XOMAT, thus the use of CR film for seed configuration radiographs was investigated.

Method

Four methods of exposure were investigated, using needles loaded for a patient treatment. In the first method, Kodak XOMAT film was used. The needle loading shield was positioned on top of the film in its paper envelope. The film-seed distance was .3 ± 0.5 mm. The exposure time was approximately 15 minutes.

The Kodak XOMAT film was processed using an Agfa CP1000 (Agfa-Gevaert Group, PO Box 150 Burwood VIC 3125) processor.

In the remaining methods, Kodak CR film was used.

In the second method, the needle loading shield was positioned on top of the Kodak CR film cassette; the film-seed distance was 9.0 ± 2.1 mm. The exposure time was 30 seconds. The default processing algorithm "Pattern" was used.

In the third and fourth methods, a double Bucky grid was positioned between the needle loading shield and the CR cassette to collimate the radiation. The Bucky grids were mounted together in a frame with their collimating structures orientated orthogonally (Figure 2). The thickness of the double Bucky grid was 8.5 ± 0.2 mm. In the third and fourth methods, the processing algorithms "Pattern" and "Head and neck portal" were used, respectively. The "Head and neck portal" algorithm was used as a visual inspection suggested it resulted in the image with the best contrast.

I-125 RAPIDstrand (RAPIDstrand, Oncura, Plymouth Meeting, PA, USA) seeds with an activity of 0.415 mCi per seed were loaded into Medtec (Medtec, P O Box 320, Orange City, IA 51041, USA) needles in preparation for a patient treatment.

Table 1. *Quality parameters for the three films.*

	XOMAT film	CR film (Body part: pattern) (Collimated)	CR film (Body part: HN Portal) (Collimated)
Average signal value	31.41	57.24	76.50
Average noise value	15.69	44.67	13.05
Standard deviation of signal value	1.28	6.52	3.40
Standard deviation of noise	6.44	1.21	0.73
Contrast	0.33	0.12	0.71
SNR	4.10	1.64	35.03
Exposure time	Approximately 15 minutes	Approximately 1 minute	Approximately 1 minute
Processing time	Approximately 1 minute	Approximately 1 minute	Approximately 1 minute

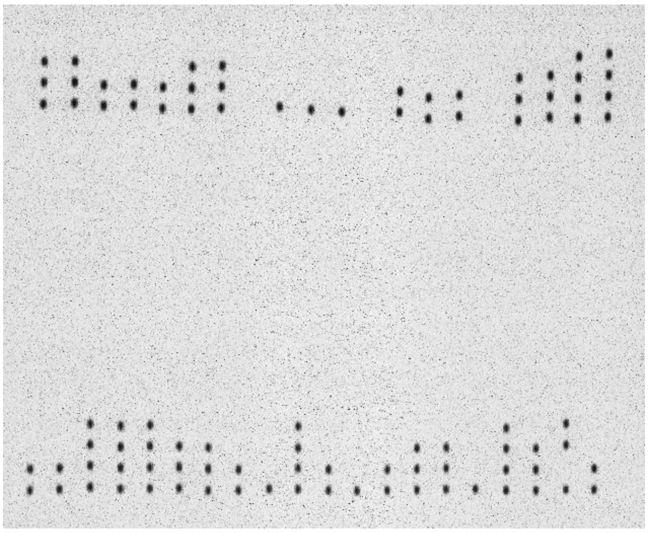

Figure 3. *CR autoradiograph (Body part: HN portal) image of 27 loaded needles for a planned implant and 10 available as spares.*

The CR images were printed on Direct Vista GrayScale Clearbase film using a Codonics printer (Codonics, Middleburg Heights, OH, USA). The exposure time was 1.0 minute.

All four films were scanned using a Vidar VXR-16 Dosimetry Pro film scanner (Vidar, Herndon, VA) and Wellhöfer Dosimetrie (Scanditronix Wellhöfer GmbH Bahnhofstraße 5 90592 Schwarzenbruck, Germany) software, using settings of 150 DPI and OD.

Averages and standard deviations of noise values were averaged over 30 data points, signal values were averaged over 11 values, obtained from single films.

The Michelson contrast C and signal-to-noise ratio SNR, were determined by the following equations, and are listed in Table 1.

$$C = \frac{I_{signal} - I_{noise}}{I_{signal} + I_{noise}}$$

$$SNR = \left(\frac{I_{signal}}{I_{noise}}\right)^2$$

Where I is the intensity. The criteria according to which the radiographic images were assessed were whether the seed loading configuration could be clearly identified and the time required for the radiographic exposure.

Results and discussion

The CR image, obtained using the “HN portal film” setting, is shown in figure 3.

Film profiles showing optical density for the XOMAT film and image intensity for the CR films are shown in figure 4. These profiles were extracted in a direction along the film which was perpendicular to the lengths of the needles, and chosen to be through points which had the greatest optical density or image intensity.

The seed loading configuration could be clearly identified through methods 1, 3 and 4.

When the needle loading shield is positioned on the XOMAT film, the seed-film -distance (3.3 ± 0.5 mm) is significantly smaller than the distance between the active ends of the seeds (5.0 mm) and the contributions to the image from individual, adjacent seeds can be clearly identified.

When positioning the needle shield on the CR cassette, however, where the needle-film distance (9.0 ± 2.1 mm) is greater than the distance between the active ends of the seeds, the contributions to the radiographic image from adjacent seeds could not be clearly distinguished (see figure 4b). Thus method two was not acceptable, and in the subsequent procedures with CR film, collimation was used.

While the default setting (Pattern), method 3 produced images on which the seeds could be counted, the setting HN Portal, method 4, greatly improved the image parameters. However, either method 3 or 4 is acceptable as the needle configuration is easily identifiable in both.

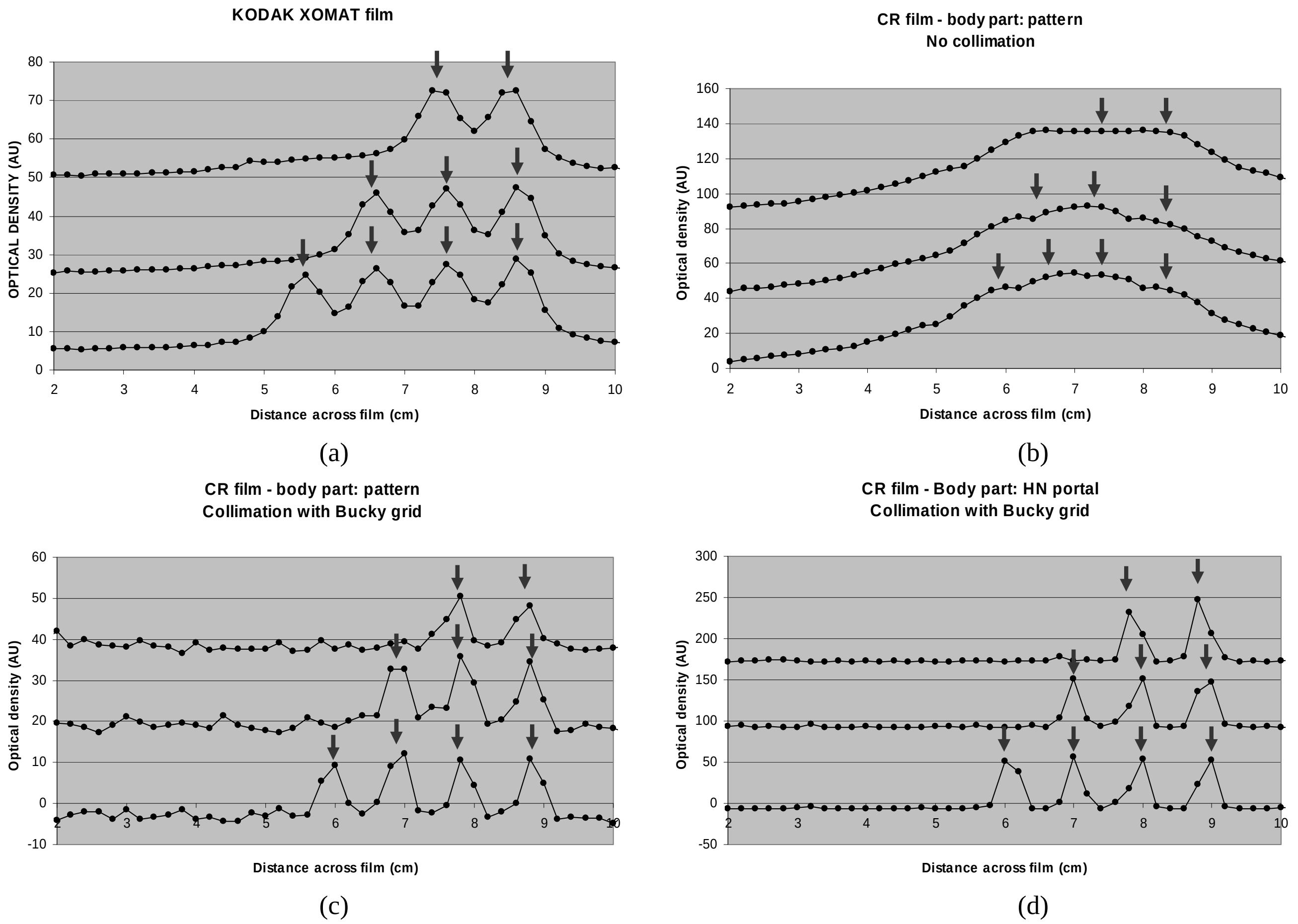

Figure 4. *Optical density or image intensity profiles across the films. Seed locations are shown with arrows. (a) Kodak XOMAT film, (b) Kodak CR film, using the setting "Body part: Pattern", without collimation, (c) Kodak CR film, using the setting "Body part: Pattern", using a double Bucky grid for collimation, (d) Kodak CR film, using the setting "Body part: HN portal" , using a double Bucky grid for collimation. Off-sets have been added to the graphs to make them more easily visible.*

Non-negligible noise away from the film areas irradiated directly by the seeds is present on all film scans. A gradual fall-off in dose over several centimetres with increasing distance from the seeds is evident on the XOMAT film – its absence on the CR films is due to the collimation.

The average signal and noise values vary by up to a factor of four between the three films (see table 1). The variations in contrast and SNR are, however, significantly greater.

Selection of an appropriate data analysis algorithm for the CR image results in a significant reduction in the average noise and its standard deviation. While selection of an appropriate algorithm improved the contrast by a factor of six, the SNR was improved by more than an order of magnitude. The greater improvement in the SNR is due to the magnitude of the noise level being non-negligible compared with the signal.

The contrast and SNR of the XOMAT film fall in-between the values of the two CR data sets.

The radiographic image must be said to be of adequate quality if the dark spots produced by the individual seeds can be clearly distinguished, and it should be emphasised that this is the case for all three films. The implementation of several algorithms for the CR image was simply undertaken to demonstrate the ease with which image enhancement is achievable.

The exposure time and processing time used in the data collection the for XOMAT and CR film is shown in table 1 The exposure times listed are also those used in clinical practice at the Royal Adelaide Hospital. While the processing times for CR and XOMAT film are similar, the exposure time is far greater for XOMAT than for CR film.

Conclusion

Both Kodak XOMAT and Kodak CR films can be used as a quality assurance tool for verification of correct needle loading in seed brachytherapy, however a bucky grid must be used with the CR film.

The use of CR film has a significant advantage over XOMAT film as its use significantly shortens the time required for the quality assurance procedure. Thus the use of CR film in quality assurance on needle configurations in I-125 seed implants is recommended.

References

1. A Practical Guide to Quality Control of Brachytherapy Equipment, European Guidelines for Quality Assurance in Radiotherapy, Booklet No. 8, ESTRO, 2004.
2. Nag, S. et al., *Intraoperative planning and evaluation of permanent prostate brachytherapy: Report of the American Brachytherapy Society*, Int. J. Rad. Oncol. Biol. Phys., 51:1422-1430, 2001.
3. *Code of practice for brachytherapy physics: Report of the AAPM Radiation Therapy Committee Task Group No. 56,* Med. Phys., 24:1557-1598, 1997.
4. *Kodak DirectView Total Quality Tool – Theory of operation*, Publication No. 3E4043 Rev C, 2003, Kodak Health Imaging.
5. Yu, Y. et al: Permanent prostate seed implamnt brachytherapy: Report of the American Association of Physicists Task Group No. 64, Med. Phys. 26 (10), 2054-2076, 1999.