Real Time On-line Quality Assurance System for HDR Brachytherapy

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An essential quality assurance (QA) procedure in high dose rate (HDR) remote after-loading brachytherapy is that of the verification of the Ir-192 HDR source positioning accuracy. A number of methods using mechanical rulers or autoradiograph and video cameras have been reported to check the positional error of the Ir-192 source. In this study, the feasibility of a CMOS (Complementary Metal Oxide Semiconductor) PC camera, with a fluorescent screen, was investigated. The agreement between the planned and measured dwell position was better than 1 mm and dwell times better than 0.4 sec. Our results indicate that the CMOS PC camera system could be used as a QA tool for the on-line determination of the source position and dwell time.

Key Words: High dose rate brachytherapy, QA, Source positioning accuracy

INTRODUCTION

High dose-rate (HDR) remote afterloading brachytherapy is an important component of a treatment of endobronchial obstruction of lung cancer, postoperative treatment of endometrail carcinoma, and localized prostate cancer.[1] HDR remote afterloading implants are achieved by moving a single high activity source inside the catheters or applicators, under computer control, and the Ir-192 HDR source can be precisely positioned to pre-defined positions within flexible catheters that have been placed inside the specific treatment part.

Accurate delivery of doses in HDR brachytherapy depends on the positioning accuracy of the Ir-192 HDR source at the proper dwell location inside the catheter or applicator.[2] The verification of source dwell positioning accuracy is most important in quality assurance of HDR remote afterloading brachytherapy unit and therefore suggested to perform daily.[3]

Orthogonal film and mechanical ruler method has been used in most often monitoring and verification for HDR brachytherapy unit.[4,5] However, these methods are time consuming for a routine QA program and they cannot furnish information on the actual source locations, so these are not enough to verify the accuracy of Ir-192 HDR source positions.

In this study, we investigated the design of new HDR QA system with fluoroscent screen that allows monitoring of Ir-192 HDR source position.

MATERIALS AND METHODS

1. The design of new HDR QA system

The new HDR QA system is designed for evaluating the positioning accuracy of the Ir-192 stepping source. This system consists of a commercial CMOS (Complementary Metal Oxide Semiconductor) PC camera, a fluoroscent screen (Intensifying Screens, Kodak), and a computer as shown in Fig. 1.

An Ir-192 HDR after-loader unit (Nucletron, The Netherlands) was used to derive the source. The source type used in this study was MICRO SELECTRON-HDR which has active length of 3.5 mm and 0.6 mm in diameter.

An acrylic box was constructed and a commercial CMOS

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PC camera (KMC-90, Kocom Instrument, Korea) was installed in the acrylic box and a fluoroscent screen was then located on the box. Three Lumen-cath applicators were also placed above the screen and connected to the HDR unit via transfer tubes.

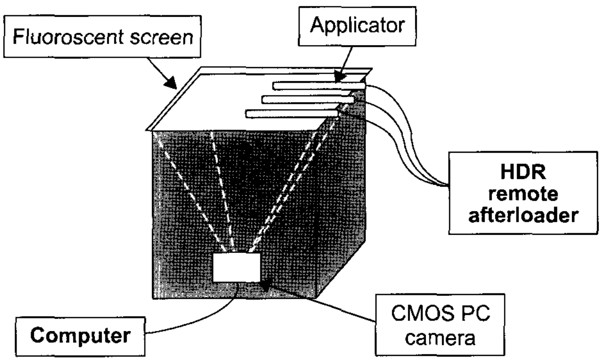

Fig. 1. The new HDR QA system consisted of a fluoroscent screen, a commercial Complementary Metal-Oxide Semiconductor (CMOS) PC camera and computer.

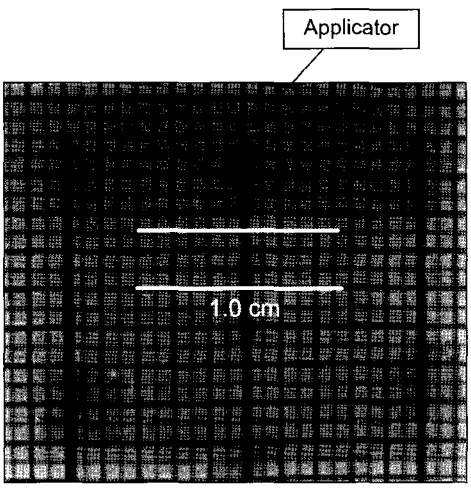

Fig. 2. 5 mm graphic paper with three applicators.

To quantify the source position, a 5 mm graphic paper was attached above the fluorescent screen, as shown in Fig. 2.

A test plan was generated for the three applicators and video images of the source at the rate of 15 frames per second were captured. The source activity was 9.33 Ci, and the dwell times and positions are shown in Table 1 and 2.

The planned dwell positions and dwell times were compared to those of measured. The captured images of the source obtained with a CMOS PC camera were overlapped in 5mm graphic paper and the distances among the source locations were measured with mechanical ruler. Source dwell time was calculated by counting the number of frames using Adobe After Effects version 5.5.

In addition, images from the Ir-192 stepping source were obtained by inserting various thicknesses of solid water phantoms between the applicator and fluorescent screen to investigate the feasibility of using this system with patient.

Table 1. Differences between the pre-defined and measured positions.

Difference		Position 1 (cm)	Position 2 (cm)	Position 3 (cm)	Position 4 (cm)
Applicator 1	Pre-defined	0.0	2.0	4.0	6.0
	Measured	0.0	2.0	4.0	6.0
Applicator 2	Pre-defined	0.0	1.5	3.5	5.5
	Measured	0.0	1.4	3.5	5.5
Applicator 3	Pre-defined	0.0	1.0	3.0	5.0
	Measured	0.0	1.0	3.0	4.9

Table 2. Measured dwell time in each dwell position (planned dwell time: 7 sec in Fig. 4. and 3, 2 and 1 sec in Fig. 5.).

Fig. 4.	Applicator 1 (sec)	Applicator 2 (sec)	Applicator 3 (sec)	Fig. 5.	Applicator 1 (sec)	Applicator 2 (sec)	Applicator 3 (sec)
Position 1	6.9	6.9	6.8	Position 1	2.8	1.7	0.8
Position 2	6.6	6.6	7.0	Position 2	2.9	1.7	0.8
Position 3	6.7	6.7	6.9	Position 3	2.6	1.7	0.6
Position 4	6.6	6.6	7.0	Position 4	2.9	1.7	0.9
Average (sec)	6.7	6.7	6.9	Average (sec)	2.8	1.7	0.8

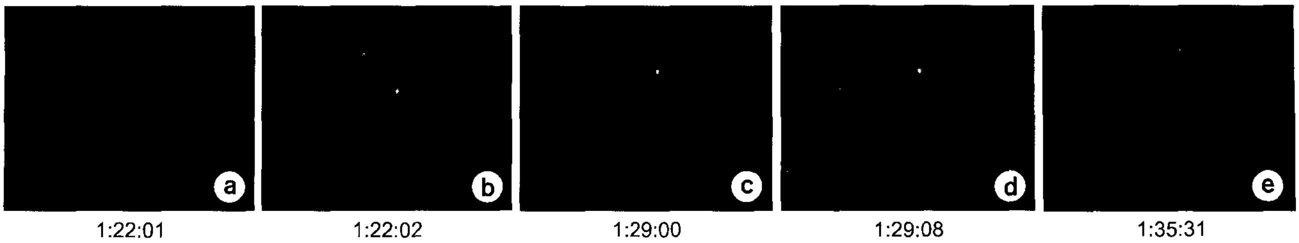

Fig. 3. Still images captured at various times (sec).

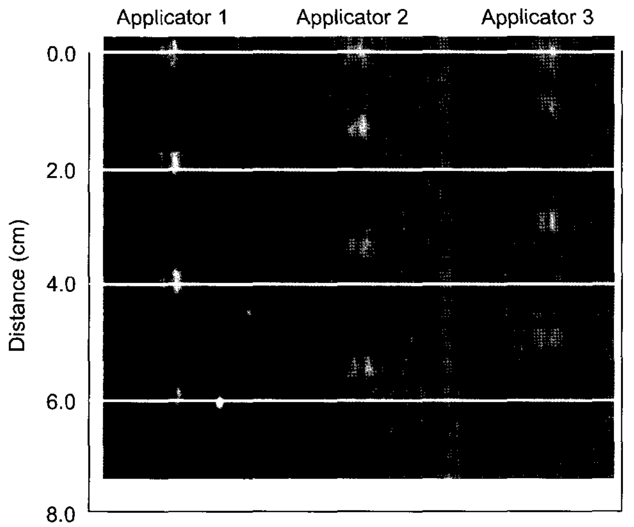

Fig. 4. Still images of the Ir-192 HDR source in various dwell positions.

RESULTS

Fig. 3 shows the still images of the source captured at various positions. As shown in the figure, it was possible to visualize the movements of the source in real time.

Fig. 4 and 5 shows the still images of the radioactive source and the planned and measured dwell positions are listed in Table 1.

Images of Ir-192 stepping source visualized through the COMS PC camera were captured at each source dwell position within the three applicators, as shown in Fig. 4. The measuring resolution was 1 mm.

The agreement between planned and measured dwell position was better than 1 mm, suggesting that the new HDR QA system provides adequate accuracy for clinical applications.

Fig. 5 shows still images of radioactive sources in the applicators at a various dwell time. As the dwell time decreased, the intensity and sharpness were decreased. However, this system was sensitive enough to capture the radioactive source when the dwell time was 1 second. The measured and planned dwell times are listed in Table 2.

Dwell time was measured as the number frames. Maximum and average difference between pre-programmed and measured source dwell time was maximum 0.4 sec and 0.2 sec.

The effect of solid water between the screen and applicators is shown in Fig. 6. As the thickness of solid water decreased, the source image was clearer. When the thickness of water phantom is more than 5 mm, it is not possible to visualize the source image.

CONCLUSIONS

We have investigated the design of the new HDR QA system with fluorescent screen for monitoring HDR source position and dwell time.

Using the CMOS PC camera system, radioactive source images at each dwell position along the applicator were visualized well. The maximum uncertainty in measuring the dwell positions was 2 mm in this study. For more precise positioning test, however, some improvements of resolution are required and it may be possible to obtain the resolution up-to 1 mm which would be enough for the HDR QA purpose. Thus the CMOS PC camera with the fluoroscent screen can serve as a real-time record for measuring source dwell positioning accurately.

This system can be also used as a timer for dwell time measurement. Our experiments using the new HDR QA system have shown that this is a very fast and easy way to

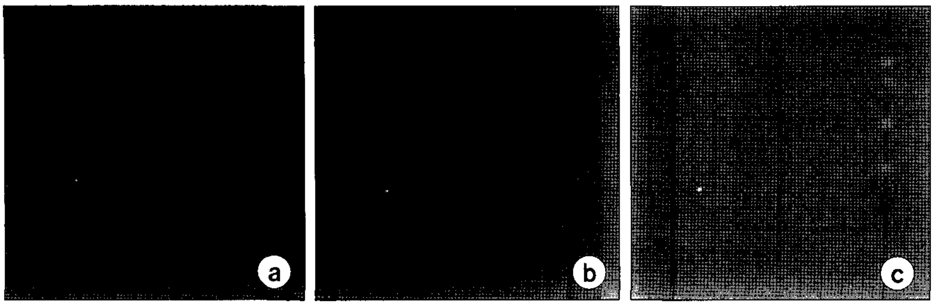

Fig. 5. Still images of the Ir-192 HDR source at various source dwell times: (a) 3sec, (b) 2sec and (c) 1sec.

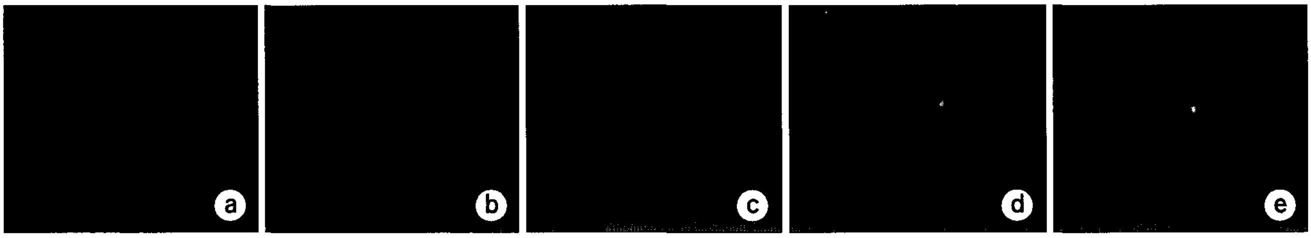

Fig. 6. Captured images of the Ir-192 HDR source when solid water phantoms with thicknesses of: (a) 5 mm, (b)3 mm, (c) 2 mm, (d) 1 mm and (e) 0 mm were inserted between the applicator and screen. The source dwell time was 5sec in all cases.

check timing accuracy errors.

In summary, the new quality assurance system with a fluoroscent screen and CMOS PC camera enables us to monitor Ir-192 HDR source position and dwell time in real-time. However, further study is necessary to use the system with patient.

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고선량률 근접 방사선 치료를 위한 실시간 온-라인 정도 관리(QA) 시스템 개발

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고선량률 후 장착 근접치료 과정에서의 필수적인 정도 관리(QA) 과정은 Ir-192 선원 위치의 정확성을 검증하는 것이다. 눈금자나 방사선 사진(autoradiograph), 비디오 모니터(video monitor) 등을 이용한 여러 방법들이 Ir-192 선원의 위치적인 오차를 점검하기 위해 사용됨이 보고되고 있다. 본 논문에서는, Fluoroscent screen 과 CMOS (Complementary Metal Oxide Semiconductor) PC 카메라를 이용하는 방법을 새로운 고선량률 근접치료의 정도 관리 (QA) 도구로 사용할 수 있는 가능성에 대해 연구하였다. 계획된 dwell position과 그 측정값은 1 mm 이내에서 일치함을 보였고, dwell time의 정확성은 0.4초 이내였다. 이번 연구의 결과는 CMOS PC 카메라를 사용하여 새롭게 제작된 정도 관리(QA) 시스템이 선원의 위치와 dwell time점검이 실시간으로 가능한 정도 관리(QA) 도구로 사용될 수 있음을 보여준다.

중심단어: 고선량률 근접 방사선 치료, 정도 관리(QA), 선원 위치의 정확성