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Assessment of the feasibility of using transrectal ultrasound for postimplant dosimetry in low-dose-rate prostate brachytherapy

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ABSTRACT

A study was performed to establish whether transrectal ultrasound (TRUS)-based postimplant dosimetry (PID) is both practically feasible and comparable to computed tomography (CT)-based PID, recommended in current published guidelines. In total, 22 patients treated consecutively at a single cancer center with low-dose-rate (LDR) brachytherapy for early-stage prostate cancer had a transrectal ultrasound performed immediately after implant (d0-TRUS) and computed tomography scan 30 days after implant (d30-CT). Postimplant dosimetry planning was performed on both image sets and the results were compared. The interobserver reproducibility of the transrectal ultrasound postimplant dosimetry planning technique was also assessed. It was noticed that there was no significant difference in mean prostate D_{90} (136.5 Gy and 144.4 Gy, $p = 0.2197$), V_{100} (86.4% and 89.1%, $p = 0.1480$) and V_{150} (52.0% and 47.8%, $p = 0.1657$) for d30-CT and d0-TRUS, respectively. Rectal doses were significantly higher for d0-TRUS than d30-CT. Urethral doses were available with d0-TRUS only. We have shown that d0-TRUS PID is a useful tool for assessing the quality of an implant after low-dose-rate prostate brachytherapy and is comparable to d30-CT PID. There are clear advantages to its use in terms of resource and time efficiency both for the clinical team and the patient.

Introduction

Permanent low-dose-rate (LDR) prostate brachytherapy is an established treatment for localized prostate cancer. Transrectal ultrasound (TRUS) is integral to the process. Postimplant dosimetry (PID) is a quality assurance measure recommended by several international bodies, including the American Brachytherapy Society, Groupe Européen de Curiethérapie, and the European Society for Radiotherapy & Oncology (GEC-ESTRO).[1,2] In the UK, The Royal College of Radiologists (RCR) have published minimum standards for implant quality and recommend computed tomography (CT) or magnetic resonance imaging (MRI) PID to be performed for the prostate and rectum for every implant to monitor practice, to maintain quality during changes in personnel or technique, and to identify areas for improvement.[3] The RCR acknowledges there is no optimal timing for PID imaging.[3]

The imaging modalities recommended for PID in the published guidelines are CT or MRI.[1-3] Studies have looked at the use of CT, MRI, and ultrasound (US)—either alone or in combination.[4-7] The optimal timing of PID is not known. Studies looking at CT PID have shown that dosimetry based on a CT scan 30 days after implant (d30-CT) correlates better with preimplant dosimetry than PID carried out on day 1, possibly because this period allows for postprocedure prostate edema to resolve.[4,8] However, performing a CT or MRI scan for dosimetric purposes does have resource implications, including machine and radiographer time. In addition, if CT or MRI PID is performed after the patient has been discharged, a second hospital visit is needed.

Reduced CT image quality because of seed artefacts may lead to difficulties in delineation of the prostate, and uncertainties in target volume definition would be reflected in dosimetry.[6,7,9] MRI

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overcomes some of the challenges posed by CT, offering good soft tissue definition and increased accuracy when contouring the prostate. However, visualization of seeds is difficult.[10]

Although TRUS is commonly used during the planning process, its use has not been established in PID. A significant proportion of centers use live-TRUS during implantation, and acquisition of further images for PID is straightforward.[11] There are clear advantages in using TRUS in this setting. Postimplant TRUS (d0-TRUS) is performed immediately postprocedure, resulting in minimal resource and time implications, no further radiation dose to the patient, and fewer hospital visits.

It is likely that d0-TRUS allows image acquisition before the development of gross prostate edema and is better than day 1 CT (d1-CT) in this respect.[4,8] Despite this, there is likely to be a degree of prostate edema by the end of implantation that may be more pronounced than on day-30 PID imaging.[4,6,12,13]

Studies have reported that source identification and prostate delineation on postimplant TRUS can be difficult because of seed artefacts in the images.[6,14,15] In 2003, Han *et al.*[14] reported on the feasibility and reliability of using postimplant TRUS images for prostate brachytherapy seed identification. They concluded that seed identification was problematic, but accuracy might be improved with better application of TRUS technology, for example using sagittal imaging to improve visualization. The Elekta FIRST system allows acquisition of a sagittal image series. In our experience, this allows for easier seed identification than with systems that only support axial image acquisition. We conducted a study using the Elekta FIRST system to establish whether d0-TRUS–based PID is both feasible and comparable to CT-based PID, which is recommended in published guidelines.

Material and Methods

In total, 22 patients receiving LDR brachytherapy for early-stage prostate cancer between September 2008 and October 2009 at Velindre Cancer Centre were included in the study. In all, 4 consultant clinical oncologists, 1 consultant radiologist, and 2 physicists were involved.

Implant technique

The prescription dose was 144 Gy. A one-stop technique was used for prostate seed implants using the Elekta FIRST System and Isotron loose ^{125}Iodine (^{125}I) seeds. This enabled live, adaptive planning under TRUS guidance.

The procedure was conducted with the patient in the dorsal lithotomy position under general anesthesia. A urethral catheter was inserted and the balloon was filled with aerated gel to allow easier identification on TRUS images. A sagittal TRUS image series (pre-TRUS) was obtained with the transducer performing a 120° sweep of the region of interest. This image set was reconstructed in the axial, sagittal, and coronal planes. The prostate and organ-at-risk (OAR) volumes were contoured by one consultant and reviewed by a second consultant. A preplan was calculated using the Inverse Planning by Simulated Annealing software available in the FIRST System. This was reviewed and modified if required, ensuring that the prostate coverage and OAR doses met recommendations.[2,3]

Needles were placed using live-TRUS imaging; final positions were updated and dose coverage on the live image was continuously reviewed during needle placement, as prostate swelling or movement can result in the original contours being unrepresentative of the true prostate size or position. The preplan was updated if needed and coverage was based on the final, true needle positions; this modified plan is referred to as the "liveplan."^{125}I loose seeds and spacers were delivered from shielded cartridges using a Seed Selectron (Elekta, Stockholm, Sweden).

d0-TRUS

A TRUS scan was acquired immediately after removal of all needles with the patient in the treatment position and urethral catheter *in situ*. This added less than a minute to procedure time. The prostate and OAR volumes were outlined on the d0-TRUS images by 1 of 2 consultant clinical oncologists performing the implant. The implanting oncologist was present in the brachytherapy suite when the preimplant prostate volumes are outlined. This oncologist was also responsible for outlining immediately after the implant, and therefore did so with detailed knowledge of the case. The source trains were identified visually on the image series as no automatic seed detection software tool is available for use with US images. Seed identification was performed using sagittal US images with the aid of axial reconstructions, supported by knowledge of the position, length, and construction of the implanted source trains as it is not possible to distinguish between active seeds and spacers on the TRUS images (Fig. 1).

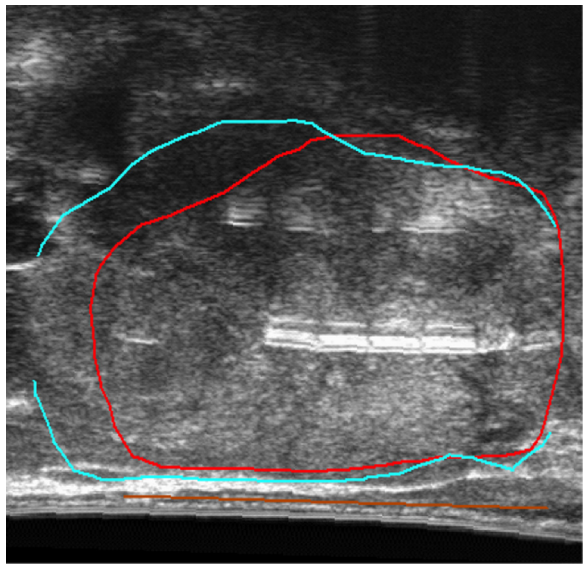

Fig. 1. TRUS image. *Prostate*: preimplant (red), postimplant (blue), and rectum (brown). Central seed/spacer train visible (white). (Color version of figure is available online.)

d30-CT

Each patient had a noncontrast pelvic CT scan 1 month postimplant (d30-CT), as recommended by the RCR.[3] The FIRST system planning software automatically identified seed location within a defined region of interest on the CT (Fig. 2). The prostate and rectum were outlined on the CT images by one of the brachytherapy clinical oncology consultants.

Postimplant dosimetry

PID for the 22 patients in this study was evaluated using both d0-TRUS and d30-CT images. The planning software used in this study does not have a margin expansion tool. This means a consistent 3-mm margin to create a clinical target volume prostate as recommended by the RCR is not easily achievable. An individualized margin is applied at the discretion of the oncologist based on knowledge of the patient being treated. Inevitably, there would be variations in the margins applied between patients. To ensure dosimetry is of a consistently high standard, the RCR guidelines have been adapted locally to take account of this—we report a D_{90}, V_{100} and V_{150} to the outlined prostate rather than the prostate clinical target volume. Rectal and urethral dose-volume recommendations are as per RCR and GEC-ESTRO guidelines respectively, as shown below.

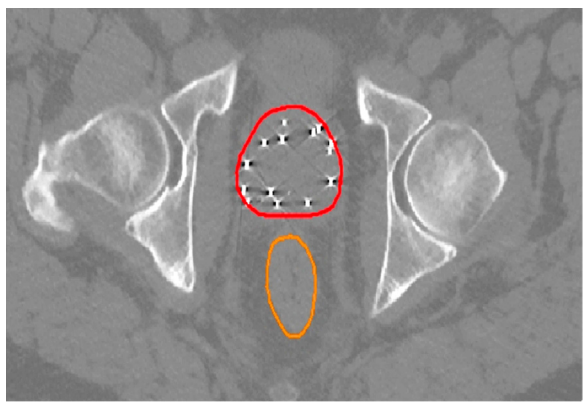

Fig. 2. d30-CT. Prostate (red) and rectum (orange), with seed artefacts. (Color version of figure is available online.)