Int. J. Radiation Oncology Biol. Phys., Vol. 43, No. 1, pp. 67–72, 1999

0360-3016/99/$–see front matter

PII S0360-3016(98)00372-1

CLINICAL INVESTIGATION **Prostate**

PROSTATE SEED IMPLANT QUALITY ASSESSMENT USING MR AND CT IMAGE FUSION

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Purpose: After a seed implant of the prostate, computerized tomography (CT) is ideal for determining seed distribution but soft tissue anatomy is frequently not well visualized. Magnetic resonance (MR) images soft tissue anatomy well but seed visualization is problematic. We describe a method of fusing CT and MR images to exploit the advantages of both of these modalities when assessing the quality of a prostate seed implant.

Methods and Materials: Eleven consecutive prostate seed implant patients were imaged with axial MR and CT scans. MR and CT images were fused in three dimensions using the Pinnacle 3.0 version of the ADAC treatment planning system. The urethra and bladder base were used to "line up" MR and CT image sets during image fusion. Alignment was accomplished using translation and rotation in the three ortho-normal planes. Accuracy of image fusion was evaluated by calculating the maximum deviation in millimeters between the center of the urethra on axial MR versus CT images. Implant quality was determined by comparing dosimetric results to previously set parameters.

Results: Image fusion was performed with a high degree of accuracy. When lining up the urethra and base of bladder, the maximum difference in axial position of the urethra between MR and CT averaged 2.5 mm (range 1.3–4.0 mm, SD 0.9 mm). By projecting CT-derived dose distributions over MR images of soft tissue structures, qualitative and quantitative evaluation of implant quality is straightforward.

Conclusions: The image-fusion process we describe provides a sophisticated way of assessing the quality of a prostate seed implant. Commercial software makes the process time-efficient and available to any clinical practice with a high-quality treatment planning system. While we use MR to image soft tissue structures, the process could be used with any imaging modality that is able to visualize the prostatic urethra (e.g., ultrasound).

Brachytherapy, Prostate, Seed implant, Image fusion.

INTRODUCTION

Radiation therapy for patients with localized prostate cancer is frequently delivered with an interstitial seed implant (1, 2). For a prostate seed implant to be effective, radioactive sources must be deposited in a pattern that results in a high radiation dose to malignant cells with relative sparing of adjacent normal tissues such as bladder, urethra, and rectum. There are now multiple studies showing a correlation between clinical outcome and implant quality (2, 3). Tumor control is less likely with a seed distribution that underdoses the prostate, and high urethra dose is associated with voiding problems (3).

Sophisticated technology has been developed to improve the planning and performance of the implant procedure, but established methods for assessing the quality of the implant after all seeds have been placed are suboptimal (4, 5). Definitive implant evaluation requires the ability to determine the location of implanted seeds relative to the bladder, urethra, rectal wall, and prostate capsule with a high degree of accuracy using imaging modalities that interface with brachytherapy dose calculation systems.

Currently the standard approach to assessing implant quality relies on a postimplant computerized tomography (CT) scan to image both implanted seeds and normal tissue structures (3). Although CT is excellent at imaging the metal seeds used for prostate brachytherapy, CT images frequently do not allow one to identify soft tissue boundaries with a high degree of confidence (5). As magnetic resonance (MR) imaging may be performed with imaging sequences that show excellent contrast between prostate and adjacent soft tissues, it may be advantageous to use MR imaging to plan and/or evaluate a prostate seed implant (4, 6).

Reports on the use of MR imaging of prostate seed implants are scarce (4, 7). A major problem with MR imaging after seed implantation is that the metal seeds currently available for prostate implantation are not well visualized on MR. Novel echo sequences are being investigated but problems with seed identification are likely to

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Accepted for publication 14 August 1998.

remain a limiting factor in the use of MR for implant evaluation (4, 7).

In this paper we describe a method of fusing CT and MR images in a way that exploits the advantages of both of these modalities for assessing the quality of a prostate seed implant. The purpose of this paper is to describe a basic technique, not to analyze the accuracy of different approaches in the hands of one group of investigators. The type of imaging that we chose to use, scan technique, timing of scans relative to the implant procedure, and ultimate quality of our implants are all peripheral issues.

METHODS AND MATERIALS

Image fusion was used to evaluate the quality of prostate seed implantation in 11 consecutive patients treated over a 2-month period. All patients were evaluated with the same evaluation protocol, described in the following seven sections:

MR scan of the prostate prior to seed implantation

At our institution, prostate seed implants are performed using the basic approach described by Wallner and colleagues at Memorial Sloan-Kettering Hospital (3). With the Wallner technique the implant is planned from axial images of the pelvis that allow one to reconstruct a 3-dimensional picture of the prostate, urethra, and pubic arch. We plan the implant with MR because it is easier to identify the borders of the prostate with MR than with CT. The implant procedure is performed under fluoroscopy. Ultrasound is not used for any portion of the procedure.

The 11 patients who are the subject of this report had axial MR scans of prostate performed for planning purposes approximately 4 weeks prior to the implant procedure. Figure 1 shows selected slices from a representative case. MR scanning was done with a GE Signa 1.5 T MRI scanner. The imaging protocol involved axial images with a fast STIR (short inversion recovery) sequence, TR (repetition time) 4500 msec, TE (echo time) 32 msec, and TI (inversion time) 150 msec. We chose this pulse sequence because in most patients it results in excellent contrast between prostate and adjacent soft tissue. Interleaved 4-mm sections were obtained without an interslice gap. Intravenous contrast was not used.

A urinary catheter (16 French) was placed in the bladder for the MR scan. With our implant technique the planning scan must be done with a catheter because we need to be able to see the urethra clearly to plan and perform the implant. From the standpoint of fusing MR and CT images, the catheter is essential because the urethra is the critical structure used to align the two image sets. Without a catheter it is not possible to see the urethra on MR or CT well enough to use the urethra as a landmark for image fusion.

The bladder base is also an important landmark for image fusion. While the base of the bladder is usually well visualized on MR and contrast-enhanced CT, we find it easier to use the catheter balloon to align image sets in the craniocaudad directions. For the catheter balloon to be useful for alignment during image fusion, the balloon must be in the same position relative to the prostate on all image sets. To improve reproducibility of the position of the catheter balloon on sequential scans, the catheter is placed under mild traction so that the catheter balloon is pulled against the base of the bladder. We find the most reliable way to keep the catheter balloon against the base of the bladder during a scan is to put a rubber band under tension between the base of the catheter and the tape that secures the catheter to the patient's leg. The rubber band is tied to the catheter just above the bifurcation of the catheter and balloon ports and then the tape that secures the catheter tubing to the patient's leg is positioned low enough on the patient's thigh so that the catheter is gently pulled against the base of bladder when the rubber band and catheter tape are connected.

We use urinary catheters that are made to hold 30 cc in the balloon because smaller balloons (5 cc) tend to slip into the superior portion of the prostatic urethra when under traction. It is difficult to have the catheter balloon in the same place relative to the prostate on two different scans if the balloon slips into the urethra when the patient moves or when tension on the catheter varies.

Define target structures on axial MR images

Axial MR image sets were transferred electronically into the ADAC Pinnacle 3.0 treatment planning system (Version 3.0du6) and viewed on a work station in the radiation oncology department (Fig. 1). With the ADAC system, target structures are defined by drawing a line on diagnostic images with a hand-controlled mouse digitization system. With prostate implant patients we outline the prostate and the urethra (actually the central lumen of the catheter in the urethra) and the catheter balloon.

CT scan of the prostate after seed implantation

After seed implantation, patients underwent a CT scan to document seed position (Fig. 2). The CT was done within 24 hours of the implant procedure. Axial CT scanning was done with a GE helical scanner, with 3-mm contiguous slices from the top of the acetabulum to the bottom of the symphysis pubis. A pitch of 1:1 (slice collimation: table speed) was utilized, and standard imaging algorithm and technique. Intravenous contrast was administered before and during scanning, 110 ml of Omnipaque 350. Forty ml were instilled to opacify the bladder, and 70 ml were instilled just before initiating scanning (30-second delay). The same size catheter (and balloon) was used for both CT and MR scans with the traction system described above. The catheter balloon was filled with 30 cc of Renografin for the CT because this makes it easier to distinguish balloon from base of bladder.

Fuse MR and CT images

MR and CT image sets were fused together to allow identification of seed distribution from the CT scan in the MR image space (Fig. 2). The catheter balloon and prostatic urethra are the two landmarks used to align CT and MR

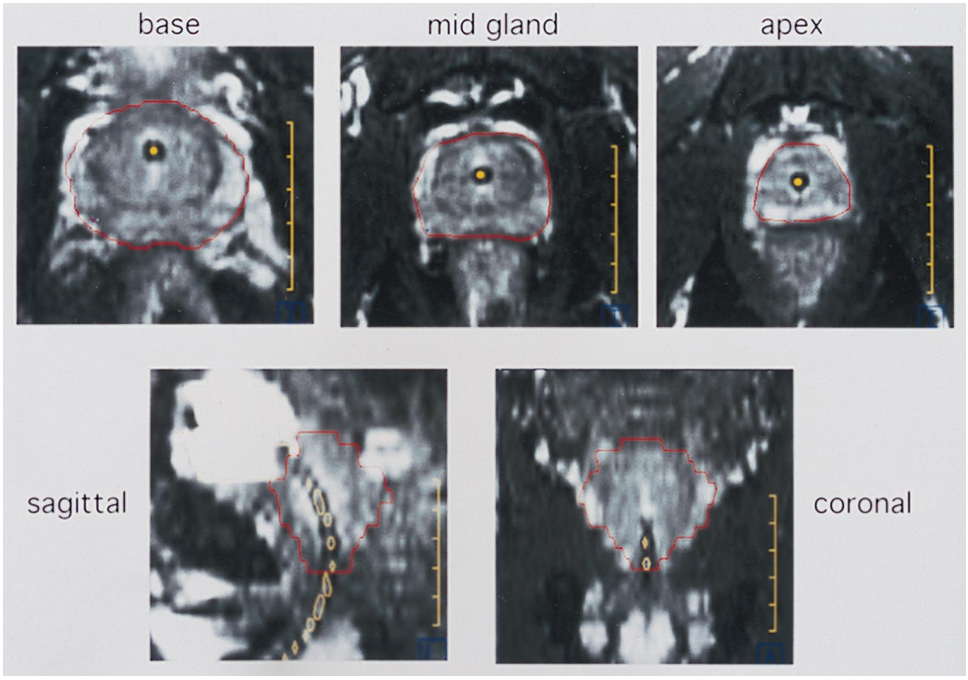

Fig. 1. MR images of the prostate performed prior to seed implant. The prostate is outlined in red and the catheter balloon and center of the prostatic urethra are outlined in yellow. Sagittal and coronal reconstructions are used to help guide target definition on the axial images and to plan needle placement relative to the pubis.

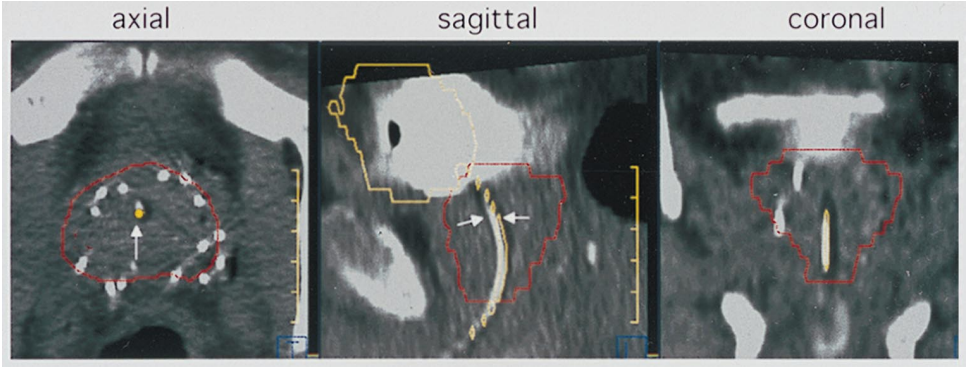

Fig. 2. CT of the prostate performed after seed implantation. MR and CT image sets are fused by aligning the prostatic urethra and bladder base in 3 dimensions. The red and yellow lines in this figure are prostate and urethra/balloon, respectively, from MR space. The accuracy of image fusion is evaluated by recording the distance between the position of the urethra on MR versus CT after image fusion. For example, there was 1.0 mm between MR and CT images of the urethra at the level shown by the two arrows on the sagittal reconstruction. Seeds and urethra (arrow) are clearly visible and localized in axial, sagittal, and coronal planes for dose calculation.

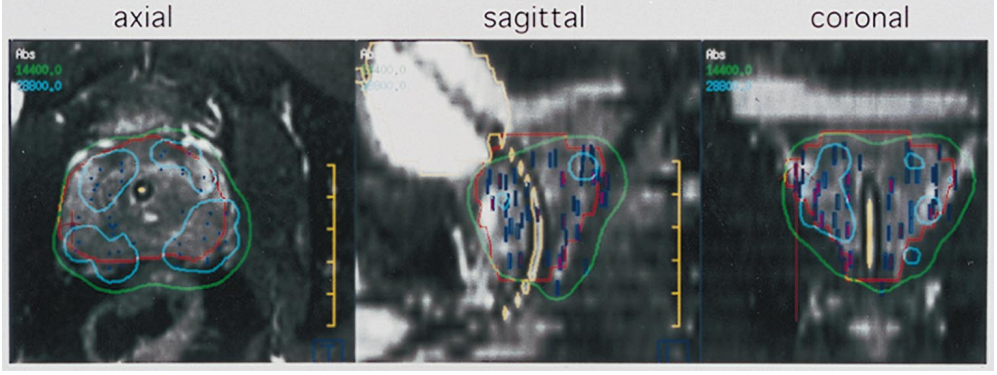

Fig. 3. Fusion images. Isodose distributions from CT localization of implanted seeds are displayed on MR images. In patients being treated with ^{125}I seeds alone our goal is to deliver a minimum of 144 Gy (green isodose line) to the prostate and to keep the dose to the urethra below 288 Gy (light blue isodose line). Implant quality is evaluated qualitatively by paging through axial, sagittal, and coronal images while looking for areas where the prostate (red line) is not covered by the prescription isodose as well as areas where the 288 Gy isodose touches the urethra. In the case shown in this figure, 95% of the prostate received at least 144 Gy and maximum urethral dose is less than 288 Gy (dose–volume histogram calculations).

image sets. These landmarks are 3-dimensional structures and therefore alignment does not require matching discrete points of interest in the two data sets. The two image sets are aligned by overlaying mid-gland sagittal reconstructions that show the catheter balloon and entire path of the prostatic urethra. Alignment requires translation and rotation in the three ortho-normal planes. Scaling of images was not performed.

The accuracy of image fusion was quantified by recording the distance between the center of the urethra on axial MR and CT images after fusion in each patient (Fig. 2). For example, if 10 axial MR and CT images are fused for a given patient, the accuracy of image fusion in this patient would be evaluated by recording the distance between the center of the urethra on MR versus CT images on each of the 10 fusion images. Maximum and average deviation values are presented in the Results section below.

Use CT images to record seed position

With each patient, CT images were downloaded into the brachytherapy program of the ADAC planning system and the CT level and window were adjusted to optimize seed visualization. Implanted seeds were localized using axial, sagittal, and coronal projections of the CT data set and the resultant dose-distribution calculated using the TG-43 dose calculation formalism.

Display CT-derived isodose lines in MR image space

The dose distribution calculated from the seed distribution recorded from CT images is displayed on MR images with prostate and urethra outlined as described previously. The result is a series of MR images that clearly show the position of the prostate, urethra, and rectum relative to the postimplant dose-distribution (Fig. 3). Sophisticated graphics tools allow one to change colors, shading, and projection as needed to better visualize dose to structures of interest.

Evaluate implant quality

Implant quality is evaluated qualitatively by paging through MR images in the axial, sagittal, and coronal planes. An area of underdosing of the prostate, or excessive dose to urethra or rectum is easy to spot because isodose lines and important normal structures are easy to distinguish from each other (Fig. 3).

Implant quality is evaluated quantitatively with a dose–volume histogram (DVH) for prostate and urethra. Because soft tissue structures have been outlined and defined in the ADAC system earlier in the process, it only takes a few seconds to calculate DVHs from fused image sets. The final step of the quality assessment process requires that one define DVH parameters that will separate implants into different quality groups.

RESULTS

The image-fusion protocol described above was used without difficulty in 11 consecutive patients. Scan time for MR and CT studies was less than 30 minutes each such that planning and evaluation scans were not difficult for patients to tolerate. The process of downloading image sets, digitizing target structures and seed distribution, fusing MR and CT images, and evaluating implant quality took approximately 1 hour per patient.

After fusion, an average of 10 image slices were used to evaluate implant quality in each patient (range 9–11 slices/patient). The accuracy of image fusion was high. After overlaying the base of bladder (catheter balloon) and rotating image sets to superimpose MR and CT images of the prostatic urethra on midline sagittal and coronal views, the average distance between the center of the prostatic urethra on axial MR versus CT scans (value from all scan slices in all patients averaged) was 1.2 mm (range 1.8–0.8 mm, standard deviation [SD] 0.3 mm). The average of the maximum distance between the center of the urethra on axial MR versus CT in a given patient was 2.5 mm (range 1.3–4.0 mm, SD 0.9 mm). These maximum displacements were found at the base of bladder and are presumably due to buoyancy of the air-filled balloon on MR.

DISCUSSION

The image-fusion process described in this paper provides a sophisticated way of assessing the quality of a prostate seed implant. Commercial software makes the process time-efficient and available to any clinical practice with a full-service treatment planning system. While we use MR to image soft tissue structures, the process could be used with any imaging modality that is able to visualize the prostatic urethra (e.g., ultrasound [US]).

There are no other publications describing the use of image fusion for seed implant evaluation. To understand why image fusion might improve the quality assessment process, it is useful to review publications that discuss techniques of imaging the prostate for radiotherapy planning or implant evaluation:

Studies of prostate volume with US, CT, and MR imaging

US and MR: Hricak and colleagues from the University of California in San Francisco measured prostate volume with US and MR imaging in 15 patients prior to radical prostatectomy[1] (6). Ultrasound evaluations were done with both transabdominal and transrectal probes. Only sagittal views were evaluated during the transrectal study. The accuracy of US and MR was evaluated by recording the difference between prostate size by imaging and that of the actual surgical specimen. Both MR and US predicted prostate size with a high degree of accuracy. MR was better than US

[1]Hricak US and MR technique: Transabdominal US performed with 3.5 MHz transducer. Transrectal US performed with a linear array Picker LS 3000 3.5 MHz or GE RT 3000 5 MHz scanner. MR performed with a 0.35 T Diasonics MT/S unit. TR 500 and 2000 ms, TE 30 and 60 ms.

(6% versus 8% variation from surgical specimen volume, respectively) but the difference was not statistically significant.

US and CT: Narayana and colleagues compared US- and CT-derived prostate volumes in 10 consecutive patients studied prior to seed implantation (5). The US and CT were done within 1 week of each other. Prostate volume on US was outlined by a urologist and radiation oncologist working together such that the resultant outline represented a consensus of the two physicians. Prostate volume on CT was outlined independently by three different radiation oncologists such that three different CT outlines were recorded for each patient. Interobserver variation of CT-derived prostate volumes was large to the point that in half of the patients prostate volume estimates differed by approximately 100% (e.g., 35–70 cc). On average, preimplant CT prostate volumes were 47% larger and 0.6 cm longer than US prostate volumes.

CT and MR: Roach and colleagues from the University of California at San Francisco performed a prospective study using image fusion to compare CT and MR estimates of prostate volume[2] (8). They chose to compare CT to MR because MR is considered the gold standard for prostate imaging at their institution. All CT contours were done by Dr. Roach. MR contours were done by a single diagnostic radiologist expert in this area. Mean prostate volume in the 10 patients studied was 32% larger with CT than MR. The most common areas of discrepancy were posteriorly and near the apex inferiorly.

Taken together the above three groups of studies suggest that the prostate is identified with a high degree of accuracy with MR or US imaging but, at least in the hands of some investigators, CT overestimates the size of the prostate considerably and is associated with high interobserver variation.

Studies using MR for postimplant evaluation

The problem with using MR to evaluate a seed implant is that it is difficult to find an MR technique that allows one to visualize seed distribution accurately.

In 1997 two groups published papers describing the use of MR after seed implantation (4, 7). Dubois and colleagues from Wilford Hall Medical Center and the University of Texas Health Sciences Center compared CT- and MR-derived DVHs in 20 patients who had undergone seed implantation with ^{125}I or ^{103}Pd for localized prostate cancer. Prior to the study they investigated multiple different MR techniques before settling on the one used for comparison to CT[3]. Because prostate volume is not the same on CT and MR, the DVH to the volume of tissue that received a specific dose (they use the term "calculation volume") was used to compare source localization on CT versus MR. The DVHs from the CT scans were used as the standard. The authors conclude that their results show that: "The differences in isodose volumes, of the calculation volumes, for all implants at all dose levels were not statistically significant. . . . This study presents the first evidence that MRI may be reliably used to identify permanently implanted ^{125}Iodine and ^{103}Palladium sources."

Before working out the details of the image-fusion protocol we describe in this report, we read the Dubois paper and tried to use MR for postimplant evaluations. Under the direction of a diagnostic radiologist expert in prostate MR (R.A.H.) we tried multiple different MR techniques, including the one described by Dubois and colleagues. Although we did find techniques that allowed us to locate most of the seeds, most of the time, we elected to look for another approach because: 1) meticulous comparison of MR and plain film radiographs showed that on three consecutive cases we could not use MR to locate all the seeds accurately (data not shown) and 2) uncertainty in seed localization on MR made the process of seed registration complex to the point that the process was both frustrating and time-consuming.

Difficulty with seed localization on MR images has been reported by the other group to publish on this subject: Moerland and colleagues from the Netherlands report a study of MR imaging to evaluate seed distribution following prostate implantation in 21 patients (7). A variety of MR techniques were used to optimize visualization of the prostate and the seeds. Multiple problems with seed identification using MR alone are described, including a 2-mm error in seed position due to spatial distortion of the MR image. Because of these problems the authors do not use MR alone to evaluate prostate seed implants. They use plain radiographs to reconstruct seed distribution using conventional methods of seed registration from sets of orthogonal radiographs. MR imaging is done postimplant to visualize soft tissue anatomy. The dose-distribution calculated from plain film registration of seed distribution is projected over MR images by matching up as many seed coordinates as can be seen clearly on the MR images.

The approach described by Moerland and colleagues is similar to ours in that MR is used to visualize soft tissue anatomy and an x-ray based approach is used to determine seed distribution. In our experience, registering seed positions from plain radiographs is more tedious than registering seed location from axial CT images. With a treatment planning system designed for brachytherapy implant evaluation and image fusion, the image-fusion approach we describe allows one to register seed position and calculate dose DVHs at a single terminal in a time-efficient manner.

We chose not to perform a comparison study (CT alone versus MR/CT image fusion) because the lack of a definitive gold standard and high interobserver variation in this

[2] Roach MR technique: 5-mm-thick axial images with TR 600 ms, TE 12 ms, matrix 256 × 192, NEX 2 as well as axial and sagittal images with TR 4000 ms, TE 104 ms echo train 8, matrix 256 × 192, NEX 2.

[3] Dubois MR technique: GE 1.5 Tesla Signa MRI scanner. TR 3000 ms, TE 27 ms, 256 × 256 matrix, NEX 2, 8 kHz bandwidth, 3-mm-thick axial slices interleaved, 16 cm FOV, anterior–posterior phase direction, superior saturation band, flow compensation, no phase wrap.

setting are such that results would not be convincing or generalizable beyond our implant group (5). People who are confident that they can accurately contour the prostate, urethra, and rectum on a postimplant CT scan will be reluctant to add complexity to the evaluation process by fusing CT with another image set. Implant teams that feel more confident identifying soft tissue anatomy with MR or ultrasound will likely find the image-fusion procedure we describe helpful when looking for ways to improve their implant program.

Two other groups have fused CT and MR images to study the planning of external beam therapy for prostate cancer (8, 9). Both of these studies used bony landmarks (e.g., pubic arch, femurs) to align CT and MR image sets. The problem with using bony landmarks to fuse images of the prostate is that prostate position relative to bony structures is sensitive to changes in bladder and rectal volume (10).

Prostate movement between scans was documented by Roach and colleagues in the previously mentioned study that used image fusion to evaluate target volume definition for conformal radiotherapy for prostate cancer (8). In this prospective study MR and CT scans were performed specifically to define the prostate for radiotherapy planning. The time interval between MR and CT scans was 0–10 days (average 3.6 days). Because the authors were aware of the problem of prostate motion, efforts were taken to minimize differences in bladder and rectal volume between scans. CT and MR image sets were fused using bony landmarks to define regions of discrepancy in prostate volume. Prostate alignment was evaluated in 3 dimensions. In 6 of the 10 patients studied, prostate movement contributed to a volume discrepancy (range −5–63%) between CT and MR scans.

In our program, image fusion is based on alignment of the prostatic urethra and bladder base. The assumption behind this approach is that prostate position relative to the urethra will be reproducible, or at least more reproducible than if alignment is based on the pelvic bones. As would be predicted from studies of prostate motion, most of the 11 patients reported in this paper had some degree of misalignment of the pelvic bones after 3-dimensional alignment of the urethra on CT and MR image sets (8, 10).

In our report, seed implantation was done between the CT and MR scans used for image fusion. In view of the edema that results from the implant procedure, it may be that this approach introduces inaccuracy into the evaluation process that would be avoided by performing CT and MR scans back-to-back after the implant (11). A detailed discussion of the postimplant edema issue is beyond the scope of this paper, but the bottom line is that at this point in time we do not know the optimal time for postimplant evaluation (2). However, the purpose of this paper is to describe a technique of image fusion. The timing of imaging relative to the implant procedure is a peripheral issue.

CONCLUSION

We describe a method of fusing CT and MR images that exploits the advantages of both of these modalities when assessing the quality of a prostate seed implant. Commercial software makes the process time-efficient and available to any clinical practice with a full-service treatment planning system. While we use MR to image soft tissue structures, the process could be used with any imaging modality that is able to visualize the prostatic urethra (e.g., ultrasound).

REFERENCES

1. Blasko JC, Wallner KE, Grimm PD, Ragde H. PSA-based disease control following ultrasound-guided I-125 implantation for stage T1/T2 prostatic carcinoma. *J Urol* 1995;154:1096–1099.
2. Willins J, Wallner K. CT-Based dosimetry for transperineal I-125 prostate brachytherapy. *Int J Radiat Oncol Biol Phys* 1997;39(2):347–353.
3. Wallner K, Roy J, Harrison L. Dosimetry guidelines to minimize urethral and rectal morbidity following transperineal I-125 prostate brachytherapy. *Int J Radiat Oncol Biol Phys* 1995;32(2):465–471.
4. Dubois DF, Prestidge BR, Hotchkiss LA, Bice Jr WS, Prete JJ. Source localization following permanent transperineal prostate interstitial brachytherapy using magnetic resonance imaging. *Int J Radiat Oncol Biol Phys* 1997;39(5):1037–1041.
5. Narayana V, Roberson PL, Pu AT, Sandler H, Winfield RH, McLaughlin PW. Impact of differences in ultrasound and computed tomography volumes on treatment planning of permanent prostate implants. *Int J Radiat Oncol Biol Phys* 1997; 37(5):1181–1185.
6. Hricak H, Jeffery RB, Dooms GC, Tanagho EA. Evaluation of prostate size: A comparison of ultrasound and magnetic resonance imaging. *Urol Radiol* 1987;9:1–8.
7. Moerland MA, Wijrdeman HK, Beersma R, Bakker CJG, Battermann JJ. Evaluation of permanent I-125 prostate implants using radiography and magnetic resonance imaging. *Int J Radiat Oncol Biol Phys* 1997;37(4):927–933.
8. Roach M, Faillace-Akazawa P, Malfatti C, Holland J, Hricak H. Prostate volumes defined by magnetic resonance imaging and computerized tomographic scans for three-dimensional conformal radiotherapy. *Int J Radiat Oncol Biol Phys* 1996; 35(5):1011–1018.
9. Rasch C, Remeijer P, Barillot I, van Herk M, Lebesque J. Observer and imaging modality (CT, MRI) related definition of the prostate. *Int J Radiat Oncol Biol Phys* 1997;39:(2).
10. Haken RKT, Forman JD, Heimburger DK, Gerhardsson A, McShan DL, Perez-Tamayo C, Schoeppel SL, Lichter AS. Treatment planning issues related to prostate movement in response to differential filling of the rectum and bladder. *Int J Radiat Oncol Biol Phys* 20:1317–1324.
11. Waterman FM, Yue N, Reisinger S, Dicker A, Corn BW. Effect of edema on the post-implant dosimetry of an I-125 prostate implant: A case study. *Int J Radiat Oncol Biol Phys* 1997;38:(2)335–339.