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Technical Note

Practical considerations for prostate HDR brachytherapy

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ABSTRACT

PURPOSE: A process for prostate high-dose-rate (HDR) brachytherapy was developed and implemented successfully in the community hospital setting. The practical aspects of the program are reviewed and may serve as a foundation for clinics interested in offering this clinical service.

METHODS AND MATERIALS: A generic needle distribution geometry was established to accommodate target volumes of variable size. A system to identify and assign treatment channels to each implant needle was devised. The computerized tomography (CT)−based treatment planning was used with dose constraints defined for sensitive structures and target uniformity. Implant needle stability was promoted by supporting the patient on a CT compatible padded sliding board. A process that aligns dwell position to CT imaging without the use of radiographic markers was followed. Graphical optimization of dwell times was used to generate the treatment dose distributions.

RESULTS: Prostate HDR brachytherapy as a boost or as monotherapy has been offered in a program that has evolved over the past 8 years. Practical aspects of the program promote its feasibility and precision. Collaboration with commercial entities has also led to the development of products that support the technique.

CONCLUSIONS: Prostate HDR brachytherapy offers a relatively high degree of dose distribution control in comparison with other prostate radiotherapy modalities. The practical aspects described offer assurance to achieve that goal. © 2009 American Brachytherapy Society. Published by Elsevier Inc. All rights reserved.

Keywords: Prostate; HDR; Brachytherapy

Introduction

Brachytherapy is an important radiation treatment modality for localized prostate cancer. The techniques have evolved over the past 40 years. Permanent radioactive seed implants have been extensively used (1). Temporary low-dose-rate implant techniques have also been performed (2). The availability of high-dose-rate (HDR) brachytherapy remote afterloaders provides an additional approach (3).

HDR brachytherapy offers several advantages. Treatments are administered in shielded rooms, and radiation safety is assured. The brachytherapy can be delivered in a fractionated schedule. A typical treatment fraction can be delivered within a 10- to 20-min time frame. Source transport and dwell times are computer controlled according to the parameters of the treatment plan. The ability to customize source dwell positions and dwell times allows

for planning to generate an optimal dose distribution that delivers the prescription dose while limiting the dose to sensitive critical structures, such as the urethra and rectum. It is the increased control of the dose distribution that motivated the development of the prostate HDR brachytherapy program described here.

A systematic approach was followed. A template and stepper/stabilizer system were selected, a generic needle distribution was designed, a process for needle identification established, and computerized tomography (CT) imaging was incorporated for planning. Implant stability is also critical. Once the location of the implanted catheters is finalized and imaged for planning, those positions must be maintained. To promote implant stability, patient movement was minimized using a specially designed sliding board. The practical details of this prostate HDR program may serve as a foundation for new clinical programs.

Process overview

The prostate HDR process begins similarly to that for permanent seed implant in terms of bowel prep, patient

positioning, and the use of transrectal ultrasound. Gold marker seeds are placed at the base and apex under ultrasound guidance and are referenced when delineating the extent of the target volume for planning and for radiographic evaluation of implant needle insertion depth. A generic implant needle distribution emphasizes peripheral coverage at the largest prostate cross section (approximately 1-cm needle spacing) and two to four interior needles. Fluoroscopy and flexible cystoscopy (with patient's legs lowered) are used to confirm adequate needle insertion depth.

The CT scanning is performed once the patient is released from the recovery room. Adequacy of needle depths is confirmed (adjustments made when indicated) and the CT study is exported to the treatment-planning computer. Delineation of the planning target, urethra, and rectal dose points follows, and the written directive for treatment is documented. Implant needle catheters are reconstructed, active dwell positions are selected according to the target extent, and the graphical optimization tool (Nucletron PLATO Brachytherapy Planning System; Veenendaal, Netherlands) is used to manipulate the dose distribution until an acceptable plan is completed. Maximum urethral dose is limited to 110% of the prescription dose based on the contoured volume, whereas anterior rectal dose points at the rectal contrast interface are not to exceed 75%. The prescribed isodose line should conform to the target with volume receiving 125% of prescribed dose not greater than 50% and the volume receiving 150% of prescribed dose not greater than 25% of the target volume. The total planned treatment time is verified using an independent method.

A single treatment fraction of 950 cGy (4) is given when the brachytherapy is administered as a boost to supplement a teletherapy dose of 4500 cGy. After a minimum of 7 days, a second operating room (OR) procedure is performed for another 950 cGy. The patients who are treated with monotherapy receive six HDR treatment fractions (700 cGy/fraction). Again, the patient has two OR procedures, each associated with an OR day treatment and two fractions the following day, a minimum of 6 h apart.

Because the base of the prostate is against the bladder wall, the implant needles are advanced to a depth just short of penetrating that wall. For that reason, stability of the needles and a clear understanding of source dwell positions are two essential components. The practical details of the prostate HDR process are described in the sections that follow.

Needle placement

The largest prostate cross section seen on ultrasound is used as the reference view for needle distribution. Starting at the anterior aspect, off of the midsagittal plane, needles are inserted approximately 1 cm apart around the periphery

within the prostate capsule by approximately 5 mm. Depending on the prostate size, either two or four interior needles are placed equidistant between the urethra and the peripheral needles. Figure 1a shows the ideal implant needle/catheter distribution, and Fig. 2 shows an example needle/obturator system (Medical Products Incorporated, Palm Bay, FL). The template offers a 5-mm needle grid and mounts on a BK ultrasound probe stabilizer (BK Medical, Herlev, Denmark). A physicist may be present in the OR to document needle placement and to confirm adequate implant coverage for planning.

Needle identification

The pattern of ^{192}Ir source dwell positions and dwell times is usually unique for each needle. For that reason, needle identification is critical. Once the needle implantation is completed a template photograph is obtained in the OR using the cystoscope camera and printer. Referring to that photo,
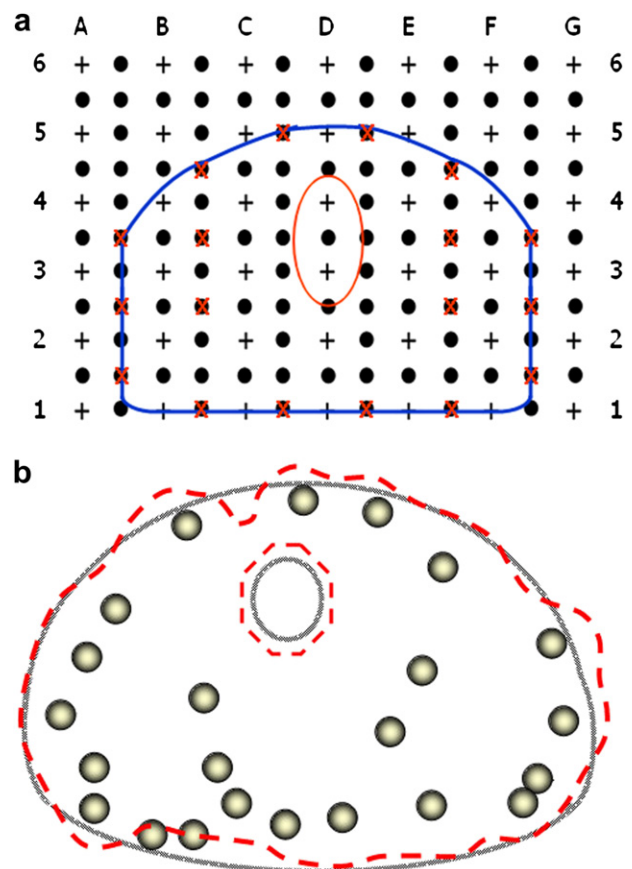

Fig. 1. (a) The generic distribution of needle catheters follows 1-cm spacing along the periphery and two to four interior needles. The largest cross section as seen on ultrasound is sketched onto a template grid form, and the implanted needle locations are marked on the form to assure complete coverage. A composite urethra is drawn long to emphasize the area free of needles. An actual 23-needle array is shown below (b). The 110% prescription isodose line is displayed (dashed) with prostate and urethra contoured.
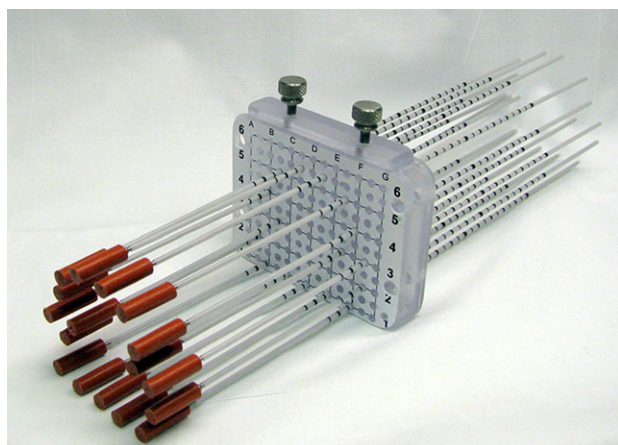
Fig. 2. An example of one of the template and needle catheter systems used (manufactured by Medical Products Incorporated of Palm Bay, FL). The disposable template was designed specifically for prostate HDR. The plastic needles have convenient depth markings (5 mm) and each has a tungsten obturator with a rubber handle for operator comfort. The needles are secured by tightening the two top screws. Four lateral holes are used to suture it to the perineum. The needles shown are 25 cm long with 6 French gauge.

the total implant needle count is confirmed and channel numbers assigned. A color code is also used to facilitate identification. The color scheme is documented on the photo and then applied to the actual needles (Fig. 3). Reference to the channel identification photo is done at the time of needle reconstruction for treatment planning and again when connecting the source transfer tubes for treatment.

Patient support

Maintaining stable needle insertion depth requires that leg movement be minimized. When the patient is transferred off the OR couch, he is positioned on a sliding board designed specifically for prostate HDR procedures. (As of this writing, the special sliding board used in this work is unavailable commercially.) The padded board elevates and separates the legs. The board is CT-scanner compatible and the patient does not need to move at all when transferred on or off the scanner, or for any other transfers that are necessary (e.g., ambulance or simulator). The leg position also affords visibility and access to the template and needles, for color coding, adjustment of the needle depth under CT guidance, and transfer tube connection for treatment. The smooth plastic bottom surface of the board eases patient transfers, thus minimizing the number of staff required and mitigating the risk of on-the-job injury. Figure 4 shows the special patient support board. If multiple fractions of HDR are given, the patient is allowed to sleep on his side overnight. This is accomplished by transferring the board onto a bed mattress and then lowering the leg supports. Before treatments, the following day, radiographic imaging is obtained. Adjustments to
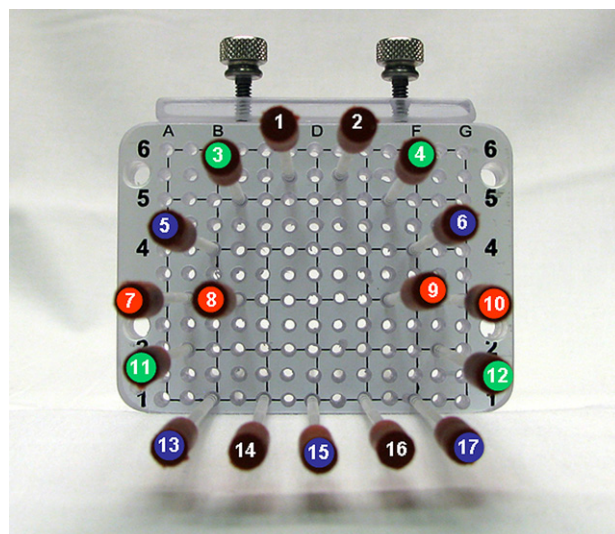

Fig. 3. A photograph of the template is obtained before the patient's transfer off the operating room table. A definitive needle count is made, and a numbering scheme assigned. The photo is subsequently referenced to assign channels to each catheter on the CT study used for treatment planning. A color code is also used to facilitate needle identification at the time of channel connection for treatment.

catheter insertion depth are made based on comparison with the baseline orthogonal film set obtained shortly after the planning CT.

Fig. 4. A cushioned sliding board was designed specifically for the prostate HDR program. The patient is transferred from the operating room couch onto this board, and the legs are elevated and secured, affording access and visibility of the template and needles. The intent is also to minimize patient movement to maintain stable insertion depth of the needles. The board is CT compatible. Transfers from the stretcher for CT, simulator radiographs, or even ambulance transport can all be done with assurance of needle depth stability.

CT-based treatment plan

Preliminary CT images (with diluted contrast filling the bladder) are obtained to evaluate and adjust needle insertion depth to assure adequate coverage at the prostate base. Once adjustments are completed rectal contrast is introduced, needle obturators withdrawn, and 2.5-mm axial CT slices (using a 20 cm × 20-cm field of view) are acquired from the level of the mid Foley balloon (encompassing the cephalad extent of all needles) to the perineum. The needles contain only air, and appear as dark spots on the CT images. Immediately after the CT, ink marks are applied where the needles emerge from the template, documenting the catheter position relative to the template surface. The markings are applied directly onto the catheters to serve as indicators of any subsequent catheter displacement.

Once the CT study is transferred to the treatment planning system, the radiation oncologist contours the target volume and documents the written directive. The urethra and rectal mucosa dose points are also defined. The photograph obtained in the OR is referred to for assigning the channel numbers to each needle.

Optimization using the Plato system from Nucletron can be accomplished using one of the several options: dose points on the target surface, inverse planning, or graphical optimization. The approach used for this clinical program employed graphical optimization. The prescription dose is initially specified as a minimum peripheral dose. This results in a generous coverage of the prostate target. The graphical optimization tool is then applied to push and pull isodose lines to achieve tight conformance with the target while also satisfying the dose constraints for the urethra and rectum.

Dwell position methodology

The accuracy of the dose distribution is contingent on accurate definition of dwell positions with respect to the CT images. Radiographic markers are not used to identify dwell positions. The location of the first dwell position is determined from catheter evaluation and relies on consistent catheter length. The evaluation establishes the treatment distance to be used, the resulting deepest location of the HDR source in the implant needle and the relation to the CT slice where the cephalad aspect of the needle occurs. A source position simulator can also be used to determine treatment distance for the first dwell position. Autoradiography is used to document the location of dwell position #1 for the established treatment distance (Fig. 5). Figure 6 demonstrates how dwell position #1 is localized on the planning CT.

Verification

Independent verification of treatment time is accomplished using Patterson-Parker volume tables for radium
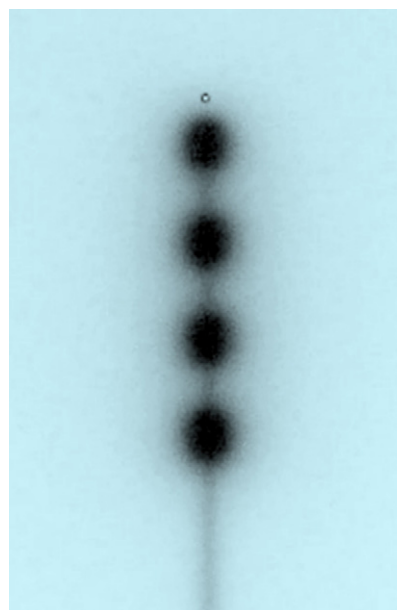

Fig. 5. The treatment distance to the deepest dwell position can be determined using a source position simulator ruler. An autoradiograph (shown above) documents the location of the resultant source dwell positions with respect to the outer pointy catheter tip. A pin hole through the film indicates the pointy tip of the catheter. The deepest dwell position center is 5 mm from the pointy tip.

(5). The ^{192}Ir source activity is converted to milligrams that would be equivalent to radium, and the prescription dose volume is approximated by measuring the cylindrical implant volume on CT or from dose−volume histogram computation. Product of milligrams of radium and hours used for that volume is scaled based on the prescribed dose. Treatment time is calculated from the ratio of scaled product of milligrams of radium and hours used and milligrams that would be equivalent to radium. Agreement between planned and calculated treatment time is typically within 5%.

Treatment

Flexible needle transfer tubes are inserted into the corresponding treatment channels at the treatment unit indexer. The photo obtained during the OR procedure is referenced to ensure that each channel is correctly connected to the assigned catheter. Correct channel and catheter connections are verified independently at the template and at the channel indexer of the HDR unit before treatment. Total treatment time is calculated to include the time between treatment channels so that a stopwatch can be used to confirm correct treatment duration. Although treatment time errors are unlikely, this independent monitoring serves as real-time treatment surveillance in the event of timer or source retraction failure. On completion of each treatment session, the patient is surveyed with a calibrated radiation instrument to confirm that the HDR source is safely stored
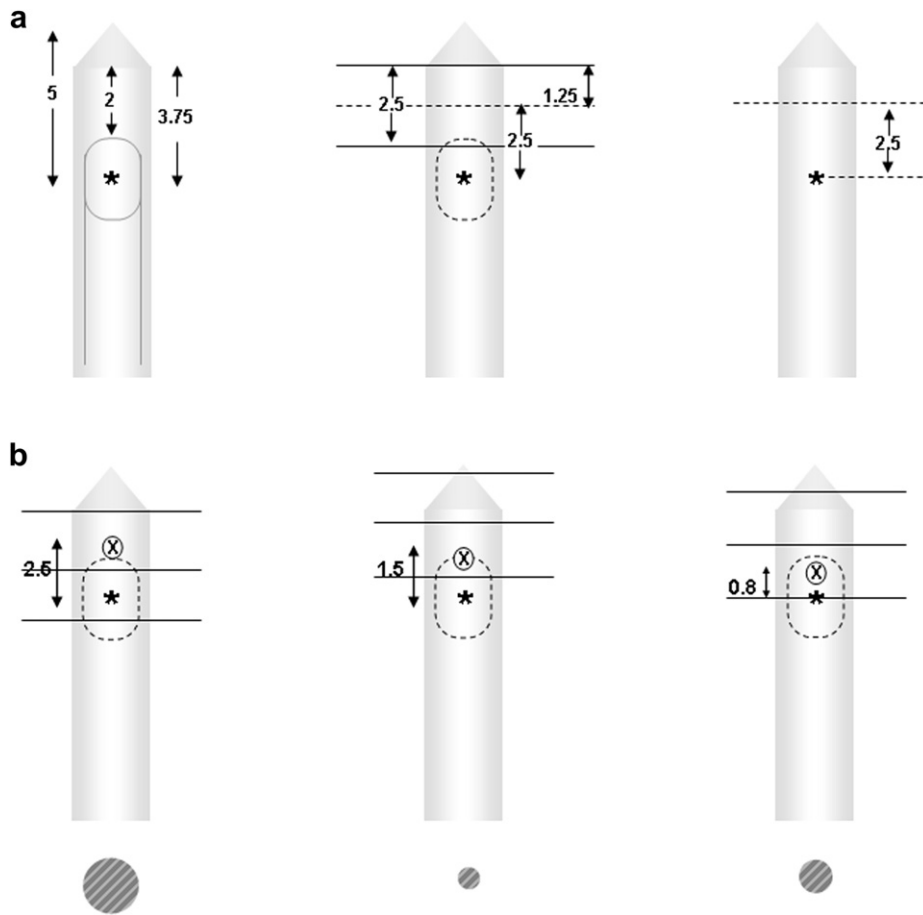
Fig. 6. Localization of the deepest dwell position on the planning CT takes into account the data from Fig. 5 and the thickness of the solid portion of the needle tip. The relation is diagrammed in (a) such that a 2.5-mm CT slice that coincides with the most cephalad 2.5 mm of air in the catheter is centered 2.5 mm superior to the deepest dwell position. This finding is applied in (b). At the highest CT slice of each catheter, the degree of partial volume effect (PVE) of the air is evaluated to assign an offset to the deepest dwell position. If the first catheter reconstruction point is placed at the first CT slice without PVE (indicated as ⊗) then offsets in the three examples above are applied based on the corresponding PVE appearance (shown as round gray areas). Assigning -2, -1, and 0 mm as offsets to the deepest dwell position assures accuracy within 1 mm.

within the tungsten shield of the treatment unit. A radiation survey before treatment can also document exposure resulting from a prior nuclear medicine procedure. Transfer tubes are disconnected after the final survey. Once the last treatment fraction has been delivered, the sutures holding the template in place are removed and the entire template/catheter system is explanted in one step.

Discussion

The HDR brachytherapy plays a significant role in the management of localized prostate cancer. When compared with permanent seed brachytherapy, HDR offers the potential for greater control of the dose distribution. It is also amenable to fractionated treatment schedules. Very promising clinical results have been reported (6, 7).

This brief technical note has summarized a process for prostate HDR that has worked very well in a community hospital setting. The approach that was taken can serve as a basis for those interested to start a prostate HDR clinical

service. The practical approach begins with a generic needle distribution and a template system that is amenable to different size targets. This provides a simple yet adaptable solution for achieving good geometric coverage. The importance of optimal patient positioning during needle placement cannot be over emphasized. This includes straightening and centering the patient, and elevating the patient's legs to allow needle targeting within the bony constraints of the pelvis. Despite that, techniques for manipulating needle path direction are sometimes necessary to reach the lateral and anterior aspects of the target. The use of a slightly bent obturator or directional force from the tip of a narrow instrument can direct the needle at an angle that can often circumvent bony obstruction. Special attention is also made for needle placement relative to the urethra. The use of fluoroscopy and a radio-opaque Foley catheter can ensure that the anterior-medial needles are placed parallel to the urethra. Lateral proximity of those needles to the Foley catheter as appreciated from the anterior fluoroscopy view is not a large concern because the treatment planning allows for dwell time reduction adjacent

to sensitive structures and also because the path of the urethra is variable with respect to the anterior aspect of the prostate.

The control of dose delivery with HDR is dependent upon controlling the insertion depth of the needle catheters with regard to the prostate base. The template system is relied upon to prevent displacement of the implant needles. In addition, maintaining the patient in a stable position that avoids leg movement offers additional assurance of needle stability. The special sliding board affords this stability while maintaining optimal leg elevation, access to and visualization of the implant system.

The localization process of the deepest dwell position of each needle is another important factor. The systematic use of the offsets to locate the center of the deepest dwell position in relation to the CT slices accurately aligns the dose distribution to the anatomy. At the initiation of this clinical program, a suitable radiographic marker was not commercially available. However, even when radiographic markers are used, a similar process is necessary to achieve alignment accuracy of 1 mm.

With growing interest in this treatment, further refinements are being developed. Inverse treatment planning is now commercially available and is less operator reliant (8). It may also shorten the planning time. The possibility of housing an HDR unit in a room equipped with cone beam CT capability is also very interesting. Conceivably, the patient could remain on the CT couch while planning is done and then receive treatment. This would also provide convenient positional verification when multiple fractions are delivered. The special sliding board described in this article was developed to offer assurance of needle stability in a more conventionally equipped facility. Real-time ultrasound-guided needle placement and planning have also been developed (4). Magnetic resonance-guided imaging for planning is also under investigation and may provide for improved target definition (9). Ultrasound fusion with CT is also under investigation (10).

Conclusion

The HDR brachytherapy for prostate cancer is feasible in the community hospital setting. The technology and treatment planning tools are readily available. It is important to establish a process that achieves good implant catheter geometry that enables the generation of an optimal treatment plan. Systems must also be established to assure stability of the implanted catheters, to understand the precise location of dwell positions and the means to easily identify each needle and channel for correct implementation of the treatment plan. The approach presented here has proven to be clinically successful and feasible.

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