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An evaluation of our experience in position verification of catheters used for interstitial high-dose-rate brachytherapy of solitary bladder tumors

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ABSTRACT

PURPOSE: The goal of this study was to verify the position of catheters used over 4 days for brachytherapy of solitary bladder tumors.

METHODS AND MATERIALS: The study covered three phases. Shifting of catheters was studied using daily position verification CT scans of 20 patients. The possibility to omit the CT scan on Day 2 by adding a loading margin of 4 mm on each side was studied using data of 5 patients. Whether the Day 4 verification CT scan could be omitted if this margin was used, was studied for another group of 10 patients, comparing the Day 3 treatment plan to the Day 4 CT scan.

RESULTS: An average catheter shift on Days 2, 3, and 4 of, respectively, −0.3 mm (−8 to 10 mm), −0.5 mm (−14 to 10 mm), and −0.1 mm (−16 to 28 mm) was found over the measurements at both sites of the catheter. Including only shifts causing underdosing of the clinical target volume (CTV), the average shift on Days 2, 3, and 4 was, respectively, −3.6 mm (−1 to −8 mm), −5.4 mm (−1 to −14 mm), and −5.3 mm (−1 to −16 mm). After adding a loading margin, the CTV was covered on Day 2; however, the margin was not sufficient for Days 3 and 4. On Day 4, in 2/10 patients, the CTV was not completely covered. In 5/10 patients, an increased 200% isodose volume was found.

CONCLUSIONS: Position verification is necessary in bladder brachytherapy. If a 4-mm margin on each side of the loading pattern was added, position verification on Day 2 could be omitted. The verification CT scan of Days 3 and 4 is still necessary.

Keywords: Catheter displacement; Position verification; High-dose-rate; Bladder cancer; Radiation therapy; Brachytherapy

Introduction

Organ sparing treatment of bladder cancer including brachytherapy has been performed in the Netherlands, Belgium, and France since the 1950s, having roots in the United States. In our institute, transurethral resection of bladder tissue followed by external beam radiotherapy combined with brachytherapy has been performed in patients with solitary muscle invasive bladder cancer since 1973, initially with ^{226}Ra and ^{137}Cs needles, and later with afterloading catheters using an ^{192}Ir source (1, 2). Traditionally, the brachytherapy catheters were implanted in the bladder wall using an open surgery procedure where the catheters were kept at a specified distance using spacers in the cavity of the bladder. Brachytherapy was performed using low dose rate and since 1998 using a pulsed dose rate afterloader. In 2009, the surgical technique was modernized to a laparoscopic technique, which has since 2010 been Da Vinci robot assisted. Spacers could therefore no longer be used. In addition, a high-dose-rate (HDR) treatment schedule was introduced, in which the brachytherapy was given in 10 fractions during 4 days (2), allowing patients to be nursed on a regular hospital ward.

The next step in improving comfort for the patient might be limited mobilization between fractions. Before answering this question, we decided to investigate whether the catheters and therefore the source dwell positions remain exactly in the same place during the whole interstitial brachytherapy treatment, while the patient remains in

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supine position. For this purpose, a study was designed to investigate position verification of catheters.

Methods and materials

Study population

From September 2009 to November 2016, 91 patients were treated with interstitial brachytherapy using laparoscopy, in which 84 patients Da Vinci robot (Intuitive Surgical, Sunnyvale, USA) assisted. CT scans for position verification were made since January 2014 (43 patients). This study was performed in three phases:

1. To investigate shifting of the catheters, CT data and treatment plans of 20 patients (January 2014 to September 2015) were used.
2. To find out whether it was possible to eliminate the verification CT scan of the second day, the data of 5 patients of the group of 20 patients was used with 4 mm extra active dwell position length at both sides of the loading as a margin.
3. After that, a third phase (10 patients, July 2014 to October 2016) was completed to find out whether the Day 4 verification CT scan would still be necessary if the margin of 4 mm was used. The Day 3 treatment plan was compared to the Day 4 verification CT scan. The initial treatment plans and treatment adjustments were made including the 4-mm margin.

Patients with a T2 muscle invasive bladder cancer $\leq$5 cm were treated by transurethral resection of bladder tissue followed by external beam irradiation of 40 Gy in 20 fractions applied to the bladder and the iliac lymph nodes. This was followed by an HDR brachytherapy boost to the tumor bed of 25 Gy in 10 fractions in 4 consecutive days. A Flexitron PDR afterloader (Elekta AB, Stockholm, Sweden) with a source activity between 18.5 and 37 GBq was used to deliver the brachytherapy treatment.

The first brachytherapy fraction was given on the day of the planning CT and initial treatment planning (Day 1). On Days 2−4, three fractions per day were given with an interval of at least 4 h. Instructions were given to the patient and the nursing department to minimize movements of the patient. During the hospitalization, the patient had to remain in the supine position. The upper body was allowed to be elevated, but not higher than 45°. During nursing, the patient was moved using log roll. On the ward, this was usually done before the first fraction of the day was given. After completing the treatment, the catheters were removed (2, 3).

Implantation procedure

Using the robot, Luneray catheters (needle-catheter combination, Elekta AB, Stockholm, Sweden) are placed interstitially in the bladder wall. The urologist uses both abdominal laparoscope and cystoscope views to ensure intramural positioning of the catheters within the bladder wall. Using the attached needles, the catheters are inserted through the abdominal skin and are then positioned in the bladder wall after which they exit at the other side of the abdomen. The catheters are positioned parallel to each other with a spacing of 7−10 mm. The clinical target volume (CTV) covers the initial tumor area with a maximum margin of 1 cm. The number of catheters is chosen depending on the size of the tumor area. The CTV is marked by titanium clips, placed on the outside of the bladder wall at the exit and entry positions of the first and last catheters. Finally, the catheters are fixed with buttons to the skin of the abdomen, and a transurethral catheter with a Foley balloon is placed.

Imaging and planning

A planning CT scan with 1 mm slice thickness and a reconstruction interval of 1 mm is made with breathing instructions to prevent breathing artifacts. Thin copper wires are placed in the catheters to visualize the catheters and to mark the first possible active dwell position on the CT. If necessary, the length of the catheters is reduced so that the most distal dwell position reaches beyond the distal clip.

The catheters and the clips are reconstructed in the treatment planning system (Flexiplan, Oncentra Brachy, Elekta AB, Stockholm, Sweden), and active dwell positions are chosen between the clips. A step size of 2 mm between source positions is chosen. An average dose of 2.5 Gy is prescribed to dose points which are located at 5 mm distance from every active dwell position on the inner side of the bladder. Optimization is used when cold spots are seen between the catheters and to reduce high-dose areas (4).

Because CTV and organs at risk were not entered, target-specific parameters to evaluate the quality of the implant could not be assessed. Instead, the quality of the implant is evaluated using the implant-specific parameters: homogeneity index (HI) and overdose index (OI). $HI = (V_{100}-V_{150})/V_{100} \times 100\%$ indicates the size of that part of the volume that receives 100% to 150% of the prescribed dose (5). $OI = V_{200}/V_{100} \times 100\%$ indicates the size of that part of the volume that receives more than 200% of the prescribed dose (6). The following objectives of HI and OI were used: HI should reach 60% with a minimum of 50%, whereas OI should stay below 25%.

Position verification CT scan

Depending on available time, verification CT scans were made of patients on Days 2, 3, and 4.

Catheters and clips were reconstructed on the verification CT scan, and the active dwell positions were copied from the original treatment plan (Fig. 1). A three-dimensional view was used to determine shifts of the active