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Urethra sparing RT

Urethra sparing – potential of combined Nickel–Titanium stent and intensity modulated radiation therapy in prostate cancer

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ABSTRACT

Background and purpose: To investigate a novel method for sparing urethra in external beam radiotherapy of prostate cancer and to evaluate the efficacy of such a treatment in terms of tumour control using a mathematical model.
Materials and methods: This theoretical study includes 20 patients previously treated for prostate cancer using external beam radiotherapy. All patients had a Nickel–Titanium (Ni–Ti) stent inserted into the prostate part of urethra. The stent has been used during the treatment course as an internal marker for patient positioning prior to treatment. In this study the stent is used for delineating urethra while intensity modulated radiotherapy was used for lowering dose to urethra. Evaluation of the dose plans were performed using a tumour control probability model based on the concept of uniform equivalent dose.
Results: The feasibility of the urethra dose reduction method is validated and a reduction of about 17% is shown to be possible. Calculations suggest a nearly preserved tumour control probability.
Conclusions: A new concept for urethra dose reduction is presented. The method relies on the use of a Ni–Ti stent as a fiducial marker combined with intensity modulated radiotherapy. Theoretical calculations suggest preserved tumour control.
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Radiotherapy plays a key role in the management of prostate cancer and dose escalation studies have shown an increased biochemical control with doses up to 78 Gy [1]. Higher doses above 80 Gy have been suggested to increase the local control even further [2,3]. However, increasing the dose is complicated by the location of radiation sensitive normal tissue adjacent to the prostate, in particular the rectum and the bladder. So far, dose escalation has been possible with the introduction of intensity modulated radiotherapy (IMRT) and image guided radiotherapy resulting in higher dose conformity and making use of smaller radiation field margins possible. Further dose escalation is likely to result in higher complication rates.

Urinary side-effects are associated with radiation of the bladder and urethra and include reduced bladder capacity, urethral stricture, urethritis, bleeding and scar tissue reducing the quality of life. Urethra runs directly through the prostate and is traditionally not considered as an organ at risk (OAR) in external beam radiotherapy (EBRT) thus receiving a dose similar to the prostate. This is partly because delineation of urethra on a computed tomography (CT) scan is barely possible due to low contrast, but also because the dose currently delivered to the prostate is reasonably well tolerated by urethra. However, in brachytherapy (BT) urethral dose is a main concern to keep toxicity low [4]. A correlation between incidence of urinary toxicity and the maximum urethral dose has been demonstrated in a study using I-125 implanted seeds [5]. Because BT is highly conformal and dose to the bladder is limited this result stresses the importance of urethral dose. Combined EBRT and high dose rate BT (46 Gy/23f + 19.5 Gy/3f) reports urethral stricture rates of about 8% [6]. Furthermore, the volume of the prostatic urethra has shown to be a predictor for acute urinary toxicity while the urethral dose a predictor for late urinary toxicity [7]. Complementarily, the urethral dose has also been shown to correlate with acute urinary toxicity [8]. The importance of urethral irradiation is further emphasized by a study reporting the incidence of urethritis independent of irradiated bladder volume in EBRT [9]. Increasing dose to the prostate in EBRT could lead to higher incidence of urethra complications and it is therefore hypothesized that urethra dose reduction is necessary to keep side-effects at a reasonable level.

This study presents a method for delineation of urethra on a CT scan combined with IMRT planning incorporating urethra as an OAR. The work is purely theoretical and requires real-time tracking of the stent to implement clinically. The issue of tracking has gained a lot of interest recently and is becoming commercially available these years. Realizing the presented method is therefore possible within the nearest future.

Materials and methods

We used the planning CT scan for 20 patients previously treated for prostate cancer with EBRT. All patients were treated with a

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stent made of nickel and titanium inserted in the prostate part of urethra [10]. The stent is primarily used as a marker for positioning prior to treatment. In addition, the stent is visible on a magnetic resonance (MR) scan which is used for CT-MR co-registering making MR delineation of the prostate possible. The prostate was delineated on the MR scan and a PTV was generated by adding a 5 mm margin in all directions. Organs at risk were delineated on the CT scan. We used the previously delineated structures for this study including all together 20 patients. The Ni–Ti stent was delineated on the CT scan and used as a representation of the prostate part of urethra as shown in Fig. 1. Due to image artifacts caused by the highly absorbing stent, the diameter in the CT image is overestimated. The known diameter of the stent was therefore used in the delineation process to obtain the true physical size. The stent delineation was used as a representation of the prostate part of urethra in the following work. Dosimetric perturbations due to the presence of the stent have been shown to be less than 1% [10].

Dose plans were generated using Varian Eclipse version 8.8 treatment planning system (TPS). We applied a 9-field technique with uniformly distributed fields (gantry angle = 0, 40, 80, 120, 160, 200, 240, 280, 320°) and a total dose of 78 Gy delivered in 39 fractions. A pilot study showed that 9 fields in general lowered the global hot spots (located in the PTV for all 20 patients) compared to a more conventional 5-field technique. We used the following absolute constraints for the organs at risk with successive lowering of the maximum urethra dose:

- Max 65 Gy for the dorsal part of the rectum wall.
- Max 25% of the rectal volume receiving 70 Gy.
- Max 50% of the bladder volume receiving 60 Gy.
- Max 2% of the urethra volume receiving X Gy, with X = {79, 75, 73, 71, 69, 67, 65} Gy.

The urethra constraint means that 7 IMRT plans were generated in total for each patient. The 2% criteria did not originate from urethra tolerance, but was simply employed for convenience in the planning process. Constraints for the other organs at risk are similar to the daily practice in our institution. To ensure that the

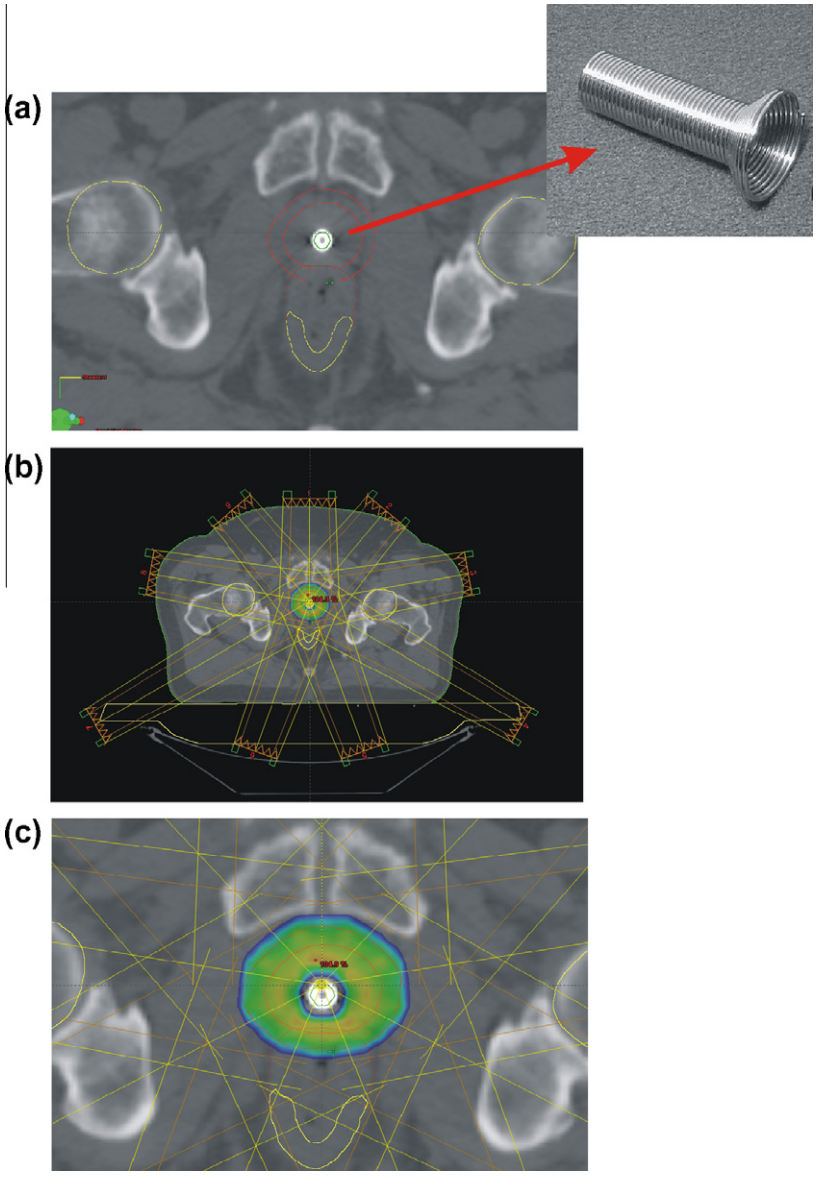

Fig. 1. Delineation of the stent on the CT scan and IMRT planning. (a) Due to partial volume effects the true size of the stent is smaller than the appearance on the scan. The known physical size was used to correct for this effect (b) the 9-field treatment geometry (c) a urethra sparing dose distribution. The coloured regions indicate areas covered by more than 95% of the prescribed dose.