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Use of bladder dose points for assessment of the spatial dose distribution in the posterior bladder wall in cervical cancer brachytherapy and the impact of applicator position

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ABSTRACT

PURPOSE: To validate the feasibility and use of dose points to characterize the bladder wall dose distribution and investigate potential impact of the applicator position in cervical cancer brachytherapy.

METHODS AND MATERIALS: One hundred twenty-eight optimized MRI plans were evaluated. The International Commission of Radiation Units and Measurements (ICRU-38) point doses (B_{ICRU}), surrogate for bladder base doses, were compared with D_{2cc}. Vaginal source to superior−anterior border of the symphysis distances were measured and compared within two groups, namely Group 1—$B_{ICRU}/D_{2cc} \geq 1$ and Group 2—$B_{ICRU}/D_{2cc} < 1$. Additionally, points at 1.5 and 2 cm cranial to the B_{ICRU}, parallel to the tandem and the body axis were analyzed.

RESULTS: Thirty-seven percent of the patients had the ratio B_{ICRU}/D_{2cc} of 1 or higher, with the 2cc subvolume at the bladder base (Group 1). In 63%, B_{ICRU}/D_{2cc} ratio was lower than 1 and the 2cc, cranial to the bladder base (Group 2). Median vaginal source-to-superior−anterior border of the symphysis line distance was −2 cm (range, −3.7 to +1.2 cm) in Group 1 and +1.8 cm (range, −2 to +4.8 cm) in Group 2 (+ cranial/− caudal direction). There was a high correlation between vaginal sources near the symphysis and the 2cc subvolume at the bladder base. The additional points provided no added value.

CONCLUSIONS: Location of the 2cc subvolume varies in cervical cancer brachytherapy. Maximum doses are at the bladder base if vaginal sources are also in the vicinity of the bladder base indicated by B_{ICRU}/D_{2cc} ratio of 1 or higher. Such variation should be considered in dose−effect analyses and intercomparisons, as the same D_{2cc} at different bladder locations may correlate with different morbidity profiles and severity Reporting D_{2cc} and B_{ICRU} doses together therefore remains essential.

Keywords: Brachytherapy; Cervical cancer; 3D MRI; Bladder D_{2cc}; Applicator position

Introduction

As advanced imaging technology (CT or MRI) becomes increasingly available, three-dimensional (3D) volumetric imaging is gradually being incorporated into the treatment planning process for cervical cancer brachytherapy (BT) (1−6). This enables dose−volume histogram (DVH) reporting of a defined dose received by a specified volume of an organ at risk (OAR), for example of the urinary bladder. Historically, the International Commission of Radiation Units and Measurements (ICRU) bladder point

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dose (B_{ICRU}), defined at the most posterior point of the bladder balloon, has been the most widely used parameter for recording and reporting the dose received by the urinary bladder (7). The limitations of this ICRU bladder point with regard to clinical relevance have been documented and recognized as its predictive value for urinary morbidity has been reported to be low (8–10).

In 2005, the Groupe Européen de Curiethérapie and European Society for Therapeutic Radiology and Oncology (GEC ESTRO) working group published the first recommendations on standardized contouring and dose reporting for cervical cancer image-guided BT (IGBT) (11–14). In these publications, the minimum dose to the most exposed 2cc of the bladder (D_{2cc}) was introduced as a DVH-based reporting parameter for the bladder. Most recently, in 2012, the American Brachytherapy Society also recommended the use of the D_{2cc} volume for recording and reporting of bladder doses (15).

Comparisons between bladder D_{2cc} and B_{ICRU} have shown the B_{ICRU} point dose to significantly underestimate the dose to the most exposed 2cc of the bladder wall in a significant percentage of cases (16–18). The clinical predictive value of the D_{2cc} has been demonstrated for example by Georg *et al.* (19), who reported a dose–effect relationship between the D_{2cc} and Grade 2–4 urinary morbidity represented mainly by frequency and urgency.

The D_{2cc}, like any DVH parameter, provides no information on the anatomic location of the most exposed portion within the organ. Kim *et al.* (20) reported 2cc subvolumes located cranial to the B_{ICRU} in nonoptimized treatment plans using standard source loading within a monocenter evaluation. The subvolumes, however, could be located at different bladder locations in optimized plans, with different application techniques, bladder filling protocols, packing methods applied in different centers for example in the posterior wall or in the bladder neck, and could be associated with different morbidity profiles. Varying locations of the D_{2cc} may result from varying positions of the uterovaginal applicator and the corresponding dwell position of the vaginal radiation sources in relation to the bladder. The same D_{2cc} doses at different bladder locations (neck/floor/trigone, posterior wall) may result in different adverse side effects such as frequency, urgency, continence, bleeding, ulceration, and fistula, varying in severity (grading). For correlations between bladder radiation dose and specific morbidity profiles, it seems essential that the location of the D_{2cc} subvolume be included in the analyses and linked to specific morbidity profiles and investigated for possible impact.

The aim of the present study was to therefore further assess the location of the 2cc subvolume in relation to the B_{ICRU} point, a well-defined and known point, in large patient cohort from multiple centers. The B_{ICRU} by definition is at the most posterior extent of the bladder balloon (7). If the bladder balloon is properly inserted and fixed, this point is consequently related to the bladder base (trigone/bladder neck). This study is not a repetition of previous studies analyzing the correlation between B_{ICRU} and D_{2cc} but investigates how the B_{ICRU} adds additional information for sophisticated dose reporting and dose–response studies. Although prospective treatment planning can visualize the spatial dose distribution, any kind of quantitative dose–response analyses depends on a set of clearly defined dose parameters.

Doses at the B_{ICRU} point were compared with the D_{2cc} to characterize the location of the most exposed tissue in the bladder wall. Data collected in a multicenter trial on MRI–based IGBT in locally advanced cervical cancer provided information for bladder doses and applicator positions. In parallel, the impact of the position of the vaginal applicator on the B_{ICRU} point dose, the D_{2cc}, and the location of the D_{2cc} subvolume and their ratio were investigated. An impact of the vaginal applicator position on the relation between B_{ICRU} point dose and D_{2cc} was assumed.

It still remains unclear if the B_{ICRU} point or any other dose point for the bladder should still be used for reporting in clinical practice and whether there is any added value of dose point information for retrospective dose–response analyses.

On the other hand, it is well recognized that irrespective of advances in 3D dose planning, dose points may remain relevant, especially for limited resource centers with very limited access to 3D imaging. To improve the precision for specification of dose to the bladder by point dose assessment, some institutions introduced additional dose points, which are located more cranial to the ICRU reference dose point (21). We assessed these dose points to find if they may serve as a better surrogate for the D_{2cc} subvolume compared with the single B_{ICRU} point. Such additional points may also be useful to characterize the spatial dose distribution in more detail for centers applying 3D-based dose–volume parameters.

Methods and materials

Study population

This study was an analysis performed with 3D image and dose planning data of 128 patients collected from 10 centers participating in the ongoing EMBRACE study (a study on MRI guided brachytherapy (BT) in locally advanced cervical cancer) allowing for recontouring, planning, and recalculation of the doses. All patients underwent curative radiotherapy with or without chemotherapy. They were all treated with either 3D conformal external beam radiotherapy or intensity-modulated radiation therapy followed by MRI-based IGBT. A detailed description of the EMBRACE protocol can be accessed at the EMBRACE web site (www.embracestudy.dk). Included within the EMBRACE study is a quality assurance program. Using the MR images at the time of BT, the location of the bladder balloon can be checked. The cases analyzed in this