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Brachytherapy ■ (2015) ■

BRACHYTHERAPY

# Simulation analysis of optimized brachytherapy for uterine cervical cancer: Can we select the best brachytherapy modality depending on tumor size?

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**ABSTRACT**

**PURPOSE:** To choose the optimal brachytherapeutic modality for uterine cervical cancer, we performed simulation analysis.

**METHODS AND MATERIALS:** For each high-risk clinical target volume (HR CTV), we compared four modalities [classical conventional intracavitary brachytherapy ($_{Conv}$ICBT), Image-guided ICBT (IGICBT), intracavitary/interstitial brachytherapy (ICISBT), and interstitial brachytherapy (ISBT) with perineal approach] using dose-volume histograms using eight sizes of HR CTV ($2 \times 2 \times 2$ cm to $7 \times 4 \times 4$ cm) and organs at risk model.

**RESULTS:** In $_{Conv}$ICBT, the doses covered 90% of the HR CTV [$D_{90}$(HR CTV)] decreased from 197% prescribed dose (PD) for the HR CTV size ($2 \times 2 \times 2$ cm) to 73% PD for $5 \times 4 \times 4$ cm, whereas the other three modalities could achieve 100% PD for all HR CTV sizes. The minimum doses received by the maximally irradiated 2-cm$^3$ volumes for organs at risks of IGICBT demonstrated lower values than those of $_{Conv}$ICBT for the HR CTV size of $4 \times 3 \times 3$ cm or smaller. ICISBT demonstrated lower values than those of IGICBT for $4 \times 3 \times 3$ cm or larger. ISBT demonstrated lowest values for $5 \times 4 \times 4$ cm or larger.

**CONCLUSIONS:** HR CTV size of $4 \times 3 \times 3$ cm seems to be a threshold volume in this simulation analysis, and IGICBT is a better choice for smaller HR CTV than the threshold volume. On larger HR CTV, ICISBT or ISBT is the better choice. 

*Keywords:* Brachytherapy; Simulation analysis; Dose-volume histograms; Uterine cervical cancer

## Introduction

Recent progress of three-dimensional (3D) image-guided brachytherapy has improved treatment outcomes of uterine cervical cancer (1−12). United States (American Brachytherapy Society Image-guided Brachytherapy Working Group) and European (Groupe Européen de Curiethérapie and the European Society for Radiotherapy and Oncology Working Group) brachytherapy groups have established guidelines and recommendations for MRI-based intracavitary brachytherapy (ICBT) (13−19). Groupe

Received 18 April 2015; received in revised form 30 September 2015; accepted 12 October 2015.

Funding: This work was supported by JSPS Grant-in-Aid for Scientific Research (KAKENHI) (C) grant number 25461931, Ministry of Health, Labor and Welfare Grant-in-Aid for Scientific Research (KAKENHI) grant number 26270801, and Japan mHDR research fund.

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1538-4721/$ - see front matter 
http://dx.doi.org/10.1016/j.brachy.2015.10.002

Européen de Curiethérapie and the European Society for Radiotherapy and Oncology defined high-risk clinical target volume (HR CTV) as gross tumor volume (GTV) at time of brachytherapy plus whole cervix plus presumed extracervical tumor extension.

They recommended that the dose-volume parameters should be reported for HR CTV and intermediate-risk CTV. However, there is no rule or consensus regarding the size or shape of HR CTV and intermediate-risk CTV that is allowable for classical conventional ICBT ($_{Conv}$ICBT), such as Manchester system. Is there any room for $_{Conv}$ICBT on image-guided planning era?

Interstitial brachytherapy (ISBT) with perineal approach is another useful treatment modality for advanced uterine cervical cancer (20–29). Because multiple treatment applicators can be implanted in and/or around CTVs without limitation by the applicator shape and number, ISBT may achieve a better CTV coverage than an intracavitary system. Hsu *et al.* performed simulation analysis and compared dose-volume histogram (DVH) results between $_{Conv}$ICBT and ISBT (30). They reported that ISBT demonstrated better coverage for paracervical and parametrial extensions than $_{Conv}$ICBT. American Brachytherapy Society recommendations for high-dose-rate brachytherapy for cervical carcinoma revealed that the eligibility criteria for undergoing ISBT were bulky lesions, narrow vagina, inability to enter the cervical os, lateral extension, and lower vaginal extension (31). In the initial phase, stainless interstitial catheters and/or template contained metallic materials that made MRI use difficult. Recently, plastic or titanium interstitial catheters have been developed along with free-hand or nonmetallic template guidance techniques (26–29). However, applicator implantation from perineal skin is invasive technique compared with ICBT technique.

Some European institutes have introduced intracavitary/interstitial brachytherapy (ICISBT), which uses additional needle implantation from vaginal wall or uterine cervix that was less invasive than that of ISBT (32, 33). They inserted a few interstitial catheters on the side of the intracavitary applicators using image-based technique although such a technique had been used before the 3D era (34). These applicators are made of nonmagnetic materials, which enable MRI use during applicator implantation. Implantation of many applicators from perineal skin may become a cause of inaccurate and low reproducibility because it is relatively longer distance between skin and tumor (35). Because template (Syed template, Martinez Universal Perineal Interstitial Template [MUPIT], and so forth) and image-guidance technique was developed, the problem of parallelism and reproducibility was considerably improved. However, pubic interference is still a problem when we try to implant to lateral side although MUPIT has holes for oblique implantation. In addition, MRI cannot be used during applicator implantation because these templates are made of magnetic materials.

However, at present, there is still no rule whether ICISBT or ISBT should be indicated for each tumor size.

Because many modalities were developed for 3D image-guided brachytherapy, we often hesitated which modality was the best for each patient. And so, we considered that it is necessary to make an ideal decision tree system for choosing the optimal brachytherapeutic modality. In this study, we performed simulation analysis using tumor models to clarify the indication for each brachytherapeutic modalities. We simulated a variety of sizes of HR CTV models using three types of applicator positions (ICBT, ICISBT, and ISBT). We calculated four treatment plans ($_{Conv}$ICBT, IGICBT, ICISBT, and ISBT) and compared DVH.

## Methods and materials

### *Tumor model*

Eight types of HR CTV models were digitized into the Oncentra Brachy software version 4.3 (Nucletron an Elekta Company, Veenendaal, The Netherlands) (Fig. 1). The smallest HR CTV was 2 × 2 × 2 cm (mediolateral × ventrodorsal × craniocaudal) of rectangular shape, and the largest HR CTV was 7 × 4 × 4 cm. We digitized a bladder model and a rectum model as organs at risk (OARs). The bladder model was 7 × 3 × 4 cm, and the gap between HR CTV and the bladder was 5 mm. The rectum model was 3 × 3 × 4 cm, and the gap between HR CTV and the rectum was 5 mm.

### *Application of each brachytherapeutic modality*

The Utrecht interstitial CT/MR applicator (33) was digitized using the applicator modeling function (Fig. 2). To simplify the comparison, the tandem was positioned at the center of HR CTV. Tandem length was 6 cm, and its angle was 15°. The distance between both ovoid source

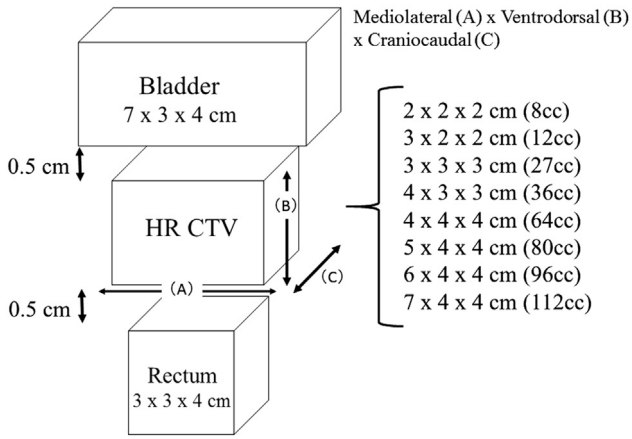


Fig. 1. Schema of high-risk clinical target volume (HR CTV) in bladder and rectum models. The smallest HR CTV was 2 × 2 × 2 cm (mediolateral × ventrodorsal × craniocaudal) of rectangular shape, and the largest HR CTV was 7 × 4 × 4 cm. The bladder model was 7 × 3 × 4 cm, and the gap between HR CTV and the bladder was 5 mm. The rectum model was 3 × 3 × 4 cm, and the gap between HR CTV and the rectum was 5 mm.