

# Pre-plan technique feasibility in multi-interstitial/endocavitary perineal gynecological brachytherapy

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## Abstract

**Purpose:** To present the implementation of a magnetic resonance imaging (MRI) pre-planning technique in multi-interstitial perineal and endocavitary gynecological brachytherapy.

**Material and methods:** We used a new fully MRI-compatible applicator that is capable to engage titanium needles, and an intrauterine tandem, developed in our department for the treatment of gynecological cervical cancer patients. This applicator is an attempt to combine the technical advantages of the Martinez universal perineal interstitial template (MUPIT) with the improvement in dose distribution by adding an intrauterine probe with the imaging advantages of MRI-based brachytherapy, thus preserving the stability, geometry, and robustness of the implant, avoiding possible errors of free-hand needle placement. A pre-brachytherapy MRI T2 acquisition is carried out with the template in place 3-5 days before the implant. On this image set, clinical target volume (CTV) is drawn. The required needles and their depths are selected accordingly to encompass the CTV (as conformal as possible). To facilitate this task, a Java based application linked to the treatment planning system has been developed. From this procedure, each needle identification and its depth are obtained previously to the implantation. With this information, the radiation oncologist proceeds with implant and then, a post-implant MRI is carried out, in which the contouring, needles, tandem reconstruction, and optimization are established.

**Results:** This pre-planning procedure has been successfully applied in 10 patients. An excellent reproduction of the virtual pre-planning has been achieved.

**Conclusions:** We describe a virtual pre-planning technique using a multi-interstitial and endocavitary perineal template. It is based on a virtual work with MRI images. This procedure has shown to be feasible and efficient in clinical practice by facilitating the work of specialists, and reducing uncertainties of the application.

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**Key words:** brachytherapy, cervical cancer, endocavitary, interstitial implants.

## Purpose

The American Brachytherapy Society (ABS) together with the Groupe Européen de Curiothérapie and the European Society for Radiotherapy and Oncology (GEC-ESTRO) have recommended magnetic resonance imaging (MRI) as the preferred image modality in image guided brachytherapy, specifically using the T2 acquisition sequence [1,2,3,4].

In locally advanced cervical carcinoma with moderate extension to the parametrium, combined endocavitary and interstitial applicators (Vienna [5] or Utrecht [6] applicators; Nucletron, Elekta AB, Stockholm, Sweden) are appropriate, although these have coverage limitations in patients with more advanced disease (distal parametrial affectation, medial or distal vaginal affectation, or extension to rectum or bowel), in which interstitial templates such as the Martinez universal perineal interstitial template (MUPIT) [7] (Nucletron, Elekta AB, Stockholm,

Sweden) or the Syed template [8] (Best Medical International, Inc., Springfield, VA, USA) have been typically used. In an attempt to circumvent these difficulties, our department has developed a new gynecological applicator (Template Benidorm, TB) [9]. The device is a fully MRI-compatible applicator that engages titanium needles and an intrauterine tandem that allows the use of MRI-based dosimetry, thus providing the advantages of MRI volume definition. The use of MRI provide smaller and better defined target volumes, with statistically significant decrease of rectal toxicity, comparing with computed tomography (CT)-based treatments, as that is made using MUPIT template [10].

Pre-planning techniques are employed in external radiotherapy (EBRT), frequently in contrast with brachytherapy. Potential reasons of this, in addition to the lack of commercial applications in clinical routine, are the possible anatomic changes that are produced after the applicator insertion (uterus straighten).

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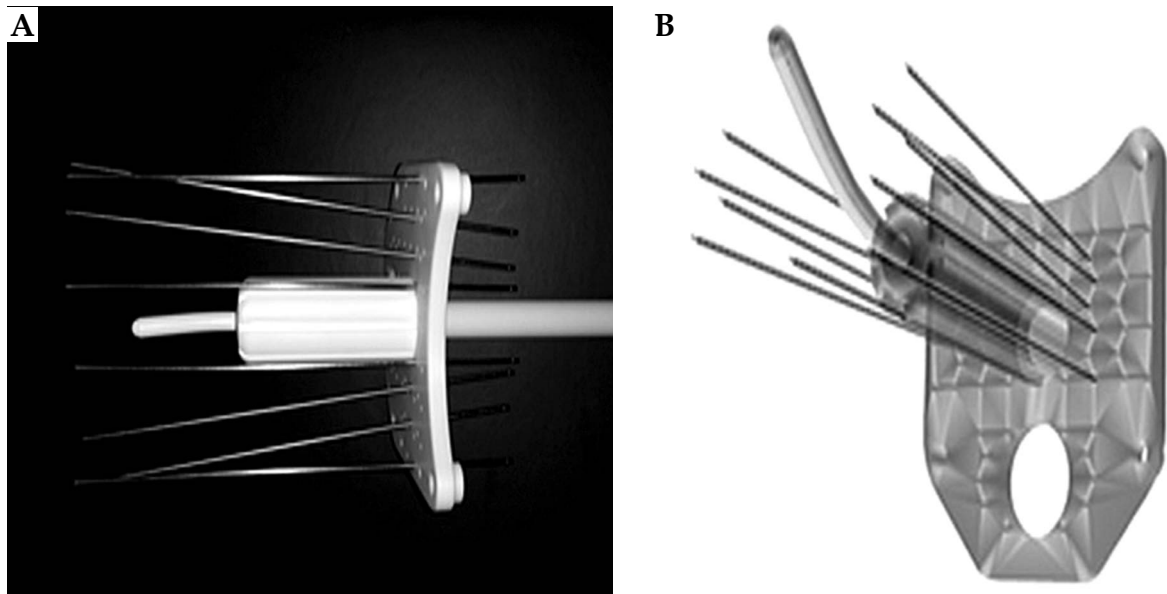


Fig. 1. Template Benidorm (left) [9] and rendering developed into the applicator's library in Oncentra (right) [12]

To have a pre-plan is always desirable, because it is an important aid for achieving optimal implant geometry that is able to obtain the best dosimetry distribution and coverage of clinical target volume (CTV) in brachytherapy treatments. This is mainly in patients with cervix tumors with irregular volumes or poor responses to EBRT and chemotherapy. The advantages of use a pre-planning are evident, and any advance in this direction will have a significant benefit in clinical practice. This article presents the implementation of a pre-planning technique using the TB in multi-interstitial perineal and endocavitary gynecological brachytherapy.

### Material and methods

The template Benidorm (Lorca Marin, Murcia, Spain), Figure 1, born out of the idea to combine technical advantages of MUPIT, intrauterine probe, and imaging advantages of MRI-based brachytherapy, while preserving the stability, geometry, and robustness of the implant. The design allows covering any desired volume in gynecological cancer from distal vagina to uterus and distal parametrium, avoiding possible errors of free-hand needle placement. This device is constructed using a template, which is fixed to the perineum, allowing the employment of titanium needles and an intrauterine component to provide a central brachytherapy dose [9,10,11]. The template consists in two perineal plates with two central holes, allowing placement of a vaginal cylinder (available in different sizes) to accommodate different vaginal lengths. These cylinders can also engage different intrauterine tubes of varying angles and lengths. Additionally, the plates are drilled with 12 rows of holes, with 1.1 cm apart, to introduce straight and angled titanium needles 1.9 mm in diameter and 200 mm length. The plates have three dimples where A-vitamin pellets are placed as a recognizable fiducial marker in MRI to be used in the reconstruction process. The number, location, and depth of the needles are decided by the physician, and they are customized for each patient.

The MRI scans of the patients were acquired with a 1.5 T MRI imager (Optima MRI 450w, software version DV24, GE Medical Systems Milwaukee, Wisconsin, USA). An eight-channel phased array receiver coil was employed, according to standard clinical MRI protocols. Following the GEC-ESTRO recommendations [1,2,3], the acquisition consists on axial T2 weighted fast recovery fast spin-echo (FRFSE) sequence, with a slice thickness reduced to 2 mm. This sequence is used for both delineating and reconstruction. Magnetic resonance imaging acquisition setting details were included in a previous publication from Richart *et al.* [11].

An applicator library has been specifically developed for this applicator, using free available software [12] (Figure 1). The anchor points are three inserted A-vitamin pellets. This library is feasible and very efficient; thus saving time, significantly reducing needle identification

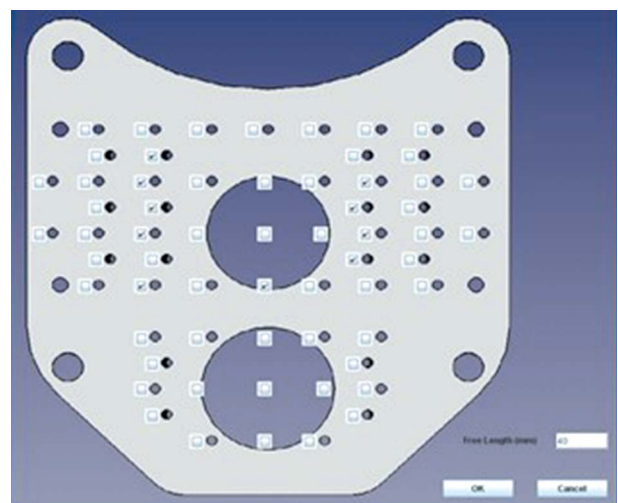


Fig. 2. Java home-made application to generate the Template Benidorm model

errors and avoiding uncertainty. It allows to solve all the steps involved in the treatment planning (contouring, reconstruction, and optimization) in just a MRI T2 sequence mainly in saving time.

The implemented pre-planning procedure is as follows: 1: Pre-brachytherapy MRI T2 acquisition is carried out with the template in place just with the vaginal cylinder (without uterine tube and needles) 3-5 days prior to

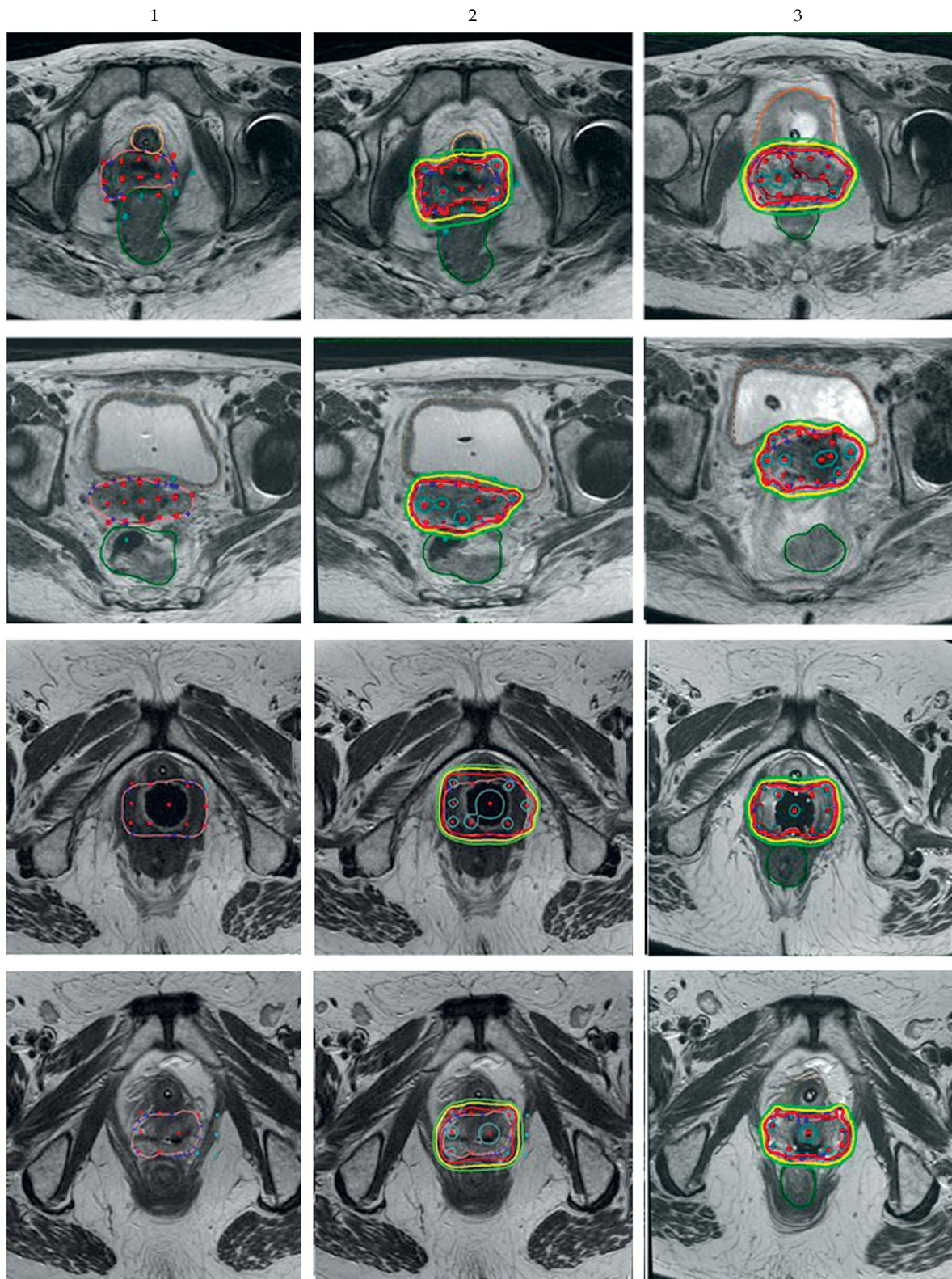


Fig. 3. Row 1 and 2: Pre-brachytherapy MRI T2. Virtual plan. Row 3: Brachytherapy MRI T2 plan after implant

brachytherapy implant. A vaginal obturator of a known length (40, 60, 100, or 130 mm according to the vaginal length) is introduced and the bladder is filled with 50 cc of saline solution. 2: On this image set, the CTV is drawn. Clinical and image gross target volume (GTV) at diagnosis and the GTV at the time of the brachytherapy were unified in a single CTV (including GTV, high-risk CTV [CTV<sub>HR</sub>] and intermediate-risk CTV [CTV<sub>IR</sub>]), based on GEC ESTRO recommendations [13,14,15]. The required needles and their depths are selected to encompass CTV (as conformal as possible). To facilitate this task, a Java based application linked to the treatment planning system (TPS) (Oncentra Prostate version 4.3, Elekta AB, Stockholm, Sweden) has been developed. From this procedure, each needle identification and its depth is obtained previously to the implant. 3: With this information, radiation oncologist proceeds with implantation and then, a post-implant MRI is performed, in which the contouring, needles plus tandem reconstruction, and optimization are established.

## Results and discussion

The developed Java application presents a friendly user interface, as is showed in Figure 2. The user can select the needles efficiently (both straight and divergent) to be included together with the free length, and then their depth. This information is incorporated automatically into the applicator library. The pre-brachytherapy MRI is performed in T2 mode, which is recommended for contouring. Once the specific virtual number of needles and depths have been selected, a virtual plan is made in Oncentra TPS and optimizing according to the required dosimetry and CTV coverage, the needles "density" (distance within needles) and extension. Figure 3 shows a case of MRI virtual pre-plan and MRI planning for dosimetry. In the virtual plan, the template is reconstructed using the library according to Otal *et al.* [12]. A rendering view of a virtual plan example is shown in Figure 4, in which the A-vitamin pellets (A1-A3), the needles, and uterine tandem are illustrated.

The virtual pre-plan procedure has significant advantages: needle depth estimation, needle positions and number, the coverage of the CTV being optimized while minimizing doses in organ at risk. "A suboptimal implant can never be transformed into a satisfactory application by any form of treatment planning optimization" [16]. The corrections are limited in cases of a suboptimal dosimetry due to an uncovered treatment volume. Treatment planning, based exclusively on MRI is preferred to other traditionally employed image modalities, like CT or methods combining both MRI and CT. Uncertainties are reduced with exclusive MRI because of the inaccuracies derived from CT-MRI registration procedures [17]. There has been a consequent growing interest in developing fully MRI compatible devices that allow the real-time insertion and guidance of the brachytherapy applicators [18]. Another option is MRI pre-plan. The primary limitation of the pre-plan is the lack of an intrauterine/intracavitary component and the likelihood of divergence of the needles, partic-

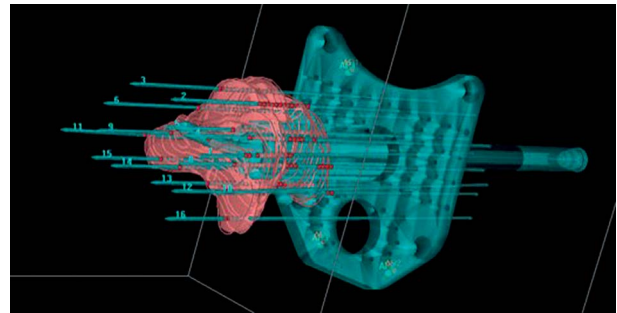


Fig. 4. 3D view of the virtual plan

ularly when rigid needles are not used. The position of the uterus varies in the majority of the patients, being straight after the insertion of the intrauterine tube. The pre-plan can be done with IC component under general [19] or paravaginal [20,21] anesthesia. In spite of a virtual pre-plan, these authors describe one sixth of all needles planned, and implanted as free needles due to the geometrical limitation of tandem/ring and needle applicator [19]. Perineal templates like TB avoids previous limitations due to the use of rigid needles, can add an intrauterine component and can cover all the directions of tumor extension.

This pre-planning procedure has been successfully applied in 10 consecutive patients. An excellent reproduction of the virtual pre-planning has been achieved. When hysterectomized patients are treated, there is only a small change from pre-plan to post-plan. From our experience, in patients without surgery, the needles changes are also small, both in number and position after the insertion (within 5 mm at the tip for a typical depth of 160 mm). The same experienced radiation oncologist (SR) has completed the contouring in both pre-brachytherapy MRI and post-implant MRI. In our opinion, this virtual pre-plan technique can be extended easily to others multi-interstitial applicators like MUPIT or Syed, with an optimized number of needles and appropriate depth. Pre-planning and library allows an easy implant and quick reconstruction that is safe and time saving.

## Conclusions

A virtual pre-planning technique using multi-interstitial and endocavitary TB has been introduced for use in gynecological brachytherapy. With the data presented, this pre-planning MRI-based system has demonstrated reliability, efficiency, and usefulness in clinical practice by facilitating the work of specialists, and reducing uncertainties of the application.

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## Disclosure

Authors report no conflict of interest.

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