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REVIEW

Physical and Dosimetric Properties of the Applicators Used in Cervix Cancer Brachytherapy: ICRU 89 Recommendations

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SUMMARY

When radiation therapy is the primary choice of the curative treatment, brachytherapy plays a crucial role in the therapeutic management of cervix cancer. Brachytherapy techniques and the selection of suitable applicator primarily depend on the patients' anatomy and extension or location of the disease. In addition to applicator selection, technical adequacy of the brachytherapy implant and treatment conditions like simulation or treatment protocol (rectum and bladder fullness), packing, use of rectal spacer or rectal retractor significantly affect the quality of the brachytherapy treatment. This review provides an overview of the dosimetric and physical properties of the brachytherapy applicators used in treating cervix cancer with the guidance of ICRU 89.

Keywords: Applicator; cervix cancer; brachytherapy.

Introduction

Ra-226-based low-dose rate (LDR) brachytherapy (BRT) applicators used in cervix cancer treatment have evolved over many decades, and they have been modified for Cs-137 and Co-60 artificial radioactive isotopes. Nowadays, Ir-192-based pulse dose rate (PDR) and high dose rate (HDR) systems and BRT applicators compatible with these systems are widely used. The majority of these applicators are designed to be compatible with computed tomography (CT) and magnetic resonance imaging (MRI). Although there are various types of intracavitary applicators for cervix cancer BRT, most of these systems are composed of two main components including intrauterine tandem and vaginal applicator.[1,2] In addition to intracavitary system, interstitial applications are widely used in treatment of cervix cancer in selected patient group.

Quality of an Application

Technically accurate intracavitary insertions or positional accuracy of applicator significantly affects the quality of treatment. In 1994, Corn et al.[3] also showed that increased accuracy of the implants significantly correlated with improved local control and survival rates. Katz et al.[4], Perez et al.[5-6], and Viswanathan et al.[7] reported that local control and complication rates might be related with appropriate applicator selection and technical adequacy of the BRT implant. Nowadays, applicator positional accuracy or suitability of the application can be controlled using volumetric imaging methods such as CT, MRI, and ultrasonography (USG) instead of two-dimensional radiographic imaging. USG-based online imaging methods provide a great advantage in the placement of tandem in narrowed or obliterated endocervical canal, and it can be helpful in preventing perforation.[8] Furthermore, the

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USG method can be used to localize the applicator positions according to tumor topography, and it can be used to perform online interstitial needle insertion. In addition to accuracy of implantation, CT- and MRI-based imaging methods provide information about the quality of vaginal packing.

Tandem and Ovoids

Tandem-ovoids are the most commonly used applicator system in cervix cancer BRT. The HDR- and PDR-based applicators are the variations of traditional Manchester, Fletcher, and Henschke systems as shown in Fig. 1. However, existing HDR and PDR applicators are produced in thinner, lighter, and smaller sizes due to the miniaturization of radioactive source sizes with Ir-192. Ovoids can be manufactured in different diameters of 2 cm, 2.5 cm, and 3 cm. The angle and geometry of tandem-ovoids used in HDR and PDR applications may show differences with respect to classical LDR applications. Therefore, in PDR- and HDR-based treatment technique comparing the relationship between tandem and ovoid or ovoid and cervix with respect to classical LDR model can lead to various dosimetric and geometric uncertainties. In addition to standard tandem-ovoid applicators, shielded ovoid applicators may be used to reduce rectum and bladder dose. Henschke applicator was initially designed as unshielded [9,10], but these unshielded systems were modified as using shielding material in ovoids to increase the rectum and bladder protection during the treatment.[11,12]

Tandem and Ring

The ring applicator is derived from the Stockholm system.[13,14] Variable ring sizes, tandem lengths, and ring-tandem angles are available. In ICRU 89 [1], it is recommended that the ring should be always fixed perpendicular to tandem during the application. Therefore, these systems have a predictable geometry. Patients with non-bulky disease, superficial or obliterated vaginal fornix, or narrow vaginal cavity are included in the ideal patient groups. However, ring applicator can also be used in other patient groups requiring intracavitary cervix BRT. Its predictable geometry makes the ring-based applicators more advantageous in clinical

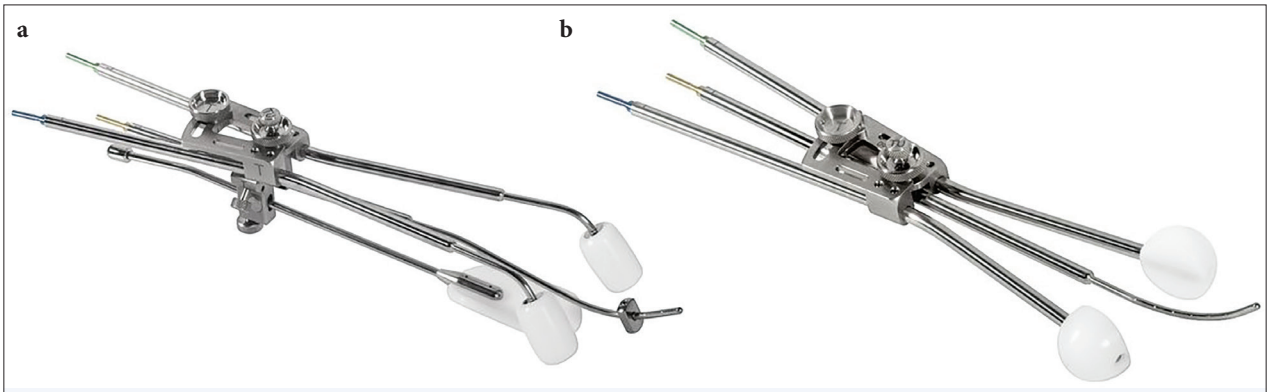

Fig. 1. Tandem-ovoids applicators (a) Fletcher and (b) Henschke.

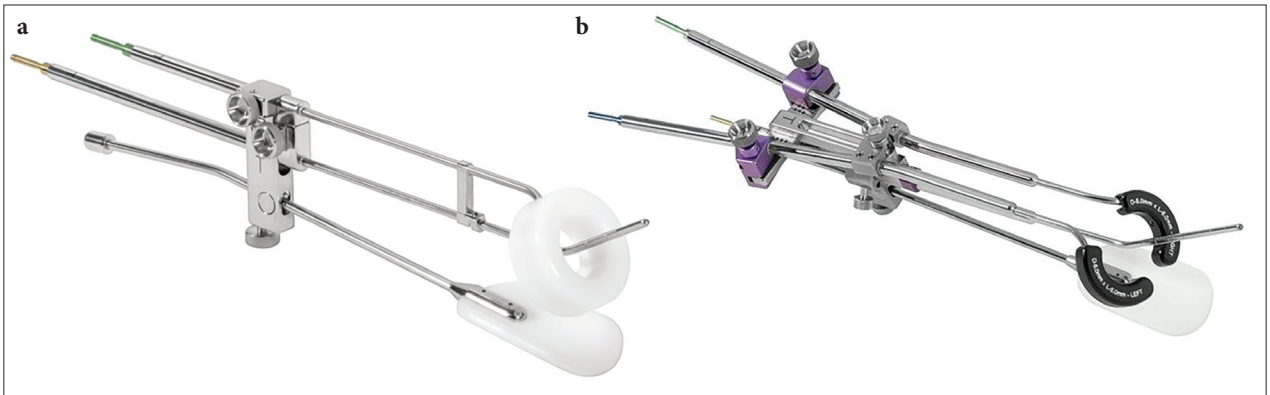

Fig. 2. Tandem-ring applicators (a) classic ring and (b) split ring.

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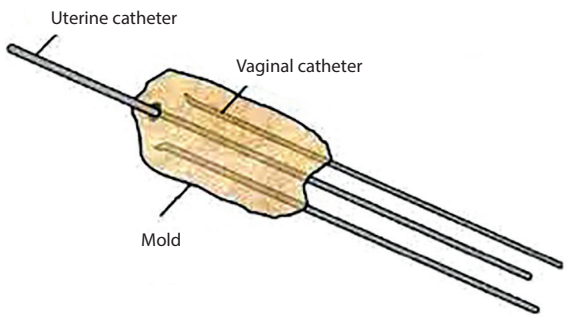

Fig. 3. Tandem-mold applicator geometry.

use. The CT and MR compatible models are commercially available. In HDR or PDR modalities, treatment can be performed by activating the dwell positions on the ring during the circular motion. In this way, the source-loading pattern of the Stockholm system can be provided with the use of ring applicator. Since selected ring-tandem angle will cause significant differences in the rectum and bladder dose, the appropriate angle should be selected according to the patient's anatomy. Since the ring is closer to the vaginal mucosa than ovoids due to the smaller thickness of the build-up material, vaginal mucosa dose in ring applicator may be higher than ovoid-based applications.[14-16] Figure 2 shows the examples of commercially available tandem-ring and tandem-split ring applicators.

Tandem and Mold

In tandem-mold application, the shape of the vaginal cavity is taken using various template methods (Fig. 3).[2,17,18] The application of tandem-mold is still used traditionally in the Gustave–Roussy institute in France and in some brachytherapy clinics around the world. This method was previously used in LDR applications, but it is currently used in PDR and HDR BRT applications.

Tandem and Cylinder

In the literature, systematic use of tandem-cylinder applicators in cervix cancer BRT has been reported.[19,20] Cylinder applicators are commercially available in different sizes and lengths and in various tandem lengths and angles (Fig. 4).[2,21] Tandem-cylinder applicators are particularly useful in patients with extensive vaginal disease to treat cervix and vagina in a single BRT application. In addition to classical central single channel applicators, it is possible to shape the dose distribution with the use of multichannel and shielded cylinder applicators. In this way, critical organs such as rectum and bladder can be protected better than single-channel-based system.

Cylinder applicators provide ease of use for patients with narrow vaginal cavity. However, great care must be taken that absorbed dose may be lower in the lateral cervix and in the pelvic sidewall due to the lack of vaginal component like ovoid and ring. Furthermore, high rectum and bladder toxicity may become inevitable because of the increased length of treated vagina in extensive disease. In cylinder-based application, it is not recommended to perform packing since this would cause further removal of the targeted vaginal walls from the reference isodose volume.[22,23]

Interstitial Applicators

Interstitial BRT applications are commonly used in patients with anatomically unfavorable topography such as infiltrative extensive disease, asymmetrical tumor

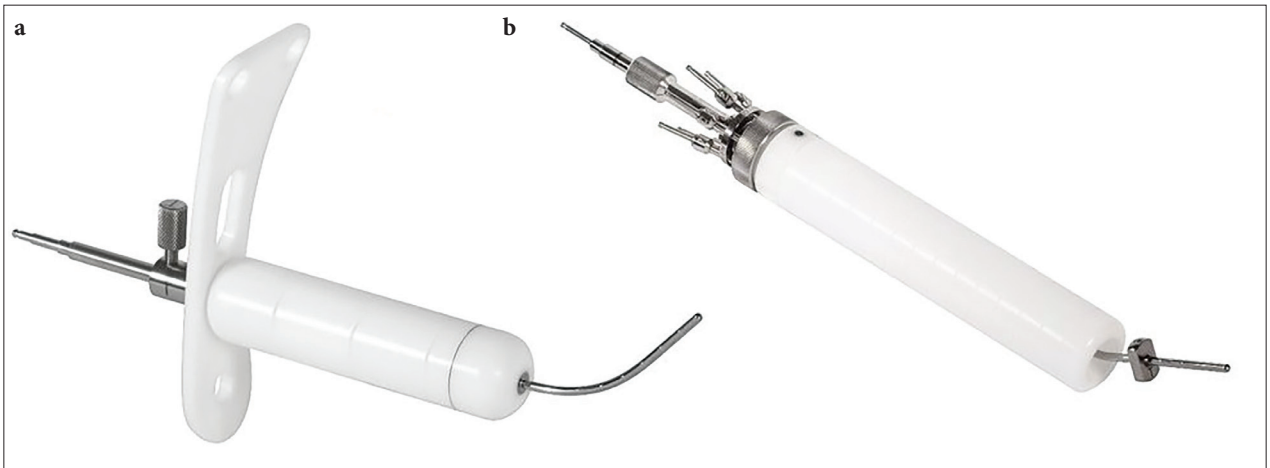

Fig. 4. Tandem-cylinder applicators (a) central single channel and (b) multichannel.

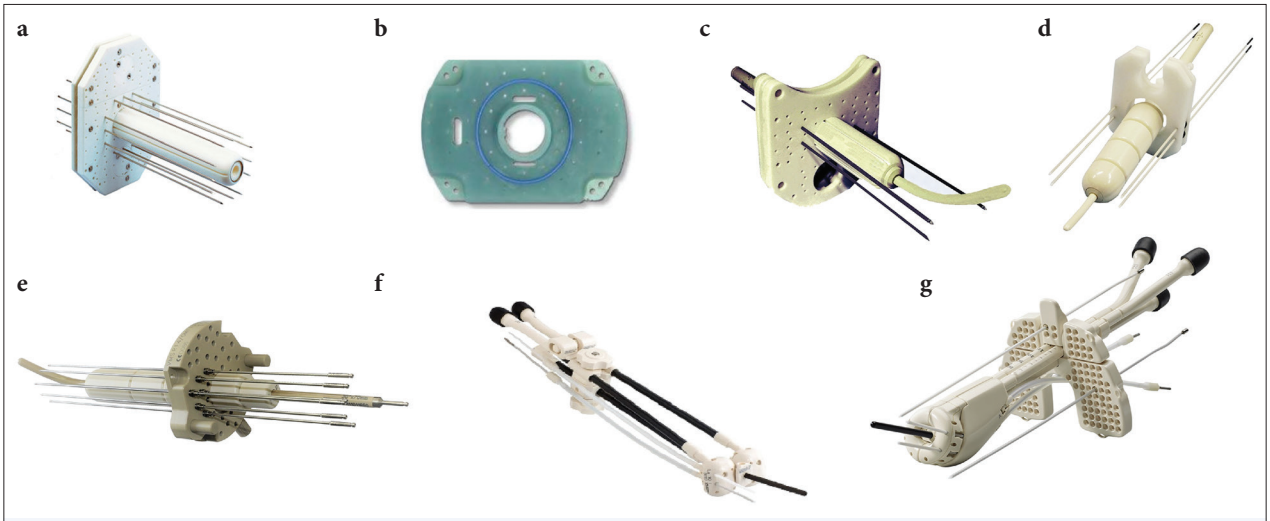

Fig. 5. Interstitial templates (a) MUPIT template, (b) Syed-Neblett template and hybrid applicators (c) Benidorm applicator, (d) Pamplona applicator, (e) Kelowna applicator, (f) Utrecht applicator and (g) Venezia applicator.

localization, narrow vaginal cavity, or recurrent disease. Tumor volume and patient anatomy play a key role in the selection of intracavitary or interstitial BRT applications. In the literature, it has been shown that appropriate applicator selection significantly affects the quality of BRT planning to encompass the disease.[24-27]

Development of perineal template used in afterloading BRT unit was an important turning point in the advancing of interstitial BRT applications. The template guide allows the placement of interstitial needles across the entire perineum according to a selected pattern. In this way, the desired dose distribution can be achieved in the target region and the critical organs can be protected at maximum level. In the literature, there are various examples of perineal templates that are commercially available or developed by the institutes (Fig. 5). MUPIT (Martinez Universal Perineal Interstitial Template, Beaumont Hospital, Royal Oak, Detroit, MI, USA) is one of the widely used perineal template in LDR and HDR BRT applications to treat multiple pelvic perineal lesions.[28] The Syed-Neblett (Best Industries, Spring el eld, VA, USA) is another well-known interstitial template system.[29] The Syed-Neblett template is commercially produced in three different shapes and sizes for LDR BRT applications: GYN 1-36 needles, GYN 2-44 needles, and GYN 3-53 needles. Additionally, free-hand implantation can be performed in small-volume vaginal lesions or in parametrial and periurethral diseases without using any perineal template system.[30] In addition to interstitial template, intracavitary and interstitial BRT applications can be performed together with hybrid applicator using the advantage of both systems (Fig. 5). The Vieanna applicator (Nucletron, Veenendaal, The Netherlands; Varian, Palo Alto, USA) is an example of commercially available hybrid system with rings and interstitial needles. It has been shown that the Vieanna applicators can be effectively used to treat residual disease located in the parametrium after radio-chemotherapy.[24,27] The Vienna II applicator has holes in which the oblique interstitial needles can be placed on the ring to treat the distal parametrium. Another commercially available form of the ring-based interstitial applicators is Venezia applicators, which are the developed form of the Vienna applicators where the perineal template and ring-interstitial needles can be combined (Elekta AB, Stockholm, Sweden). In addition to ring-based hybrid applicators, combination of ovoid and interstitial needles with modified holes in the ovoid for needle guidance is commercially available to treat extensive disease in cervix carcinoma (Utrecht applicator, Nucletron). Jurgenliemk-Schulz et al. also reported that ovoid-based hybrid applicators enable better coverage in the treatment of parametrial diseases.[31]

Conclusion

The patient's anatomy and extension or location of the disease plays a crucial role in the selection of a suitable BRT applicator to treat cervix cancer. In addition to applicator selection, treatment conditions like simulation or treatment protocol (rectum and bladder fullness), packing, use of rectal spacer or rectal retractor significantly affect the quality of the BRT treatment.

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