Image guided Brachytherapy: *The paradigm of Gynecologic and Partial Breast HDR Brachytherapy*

S Diamantopoulos¹, I Kantemiris¹, A Konidari¹, P Zaverdinos¹
¹Medical Physics Department, Metropolitan Hospital, N. Faliro, Greece

E-mail: pzaverdinos@metropolitan-hospital.gr

Abstract. High dose rate (HDR) brachytherapy uses high strength radioactive sources and temporary interstitial implants to conform the dose to target and minimize the treatment time. The advances of imaging technology enable accurate reconstruction of the implant and exact delineation of high-risk CTV and the surrounding critical structures. Furthermore, with sophisticated treatment planning systems, applicator devices and stepping source afterloaders, brachytherapy evolved to a more precise, safe and individualized treatment. At the Radiation Oncology Department of Metropolitan Hospital Athens, MRI guided HDR gynecologic (GYN) brachytherapy and accelerated partial breast irradiation (APBI) with brachytherapy are performed routinely. Contouring and treatment planning are based on the recommendations of the GEC – ESTRO Working group. The task of this presentation is to reveal the advantages of 3D image guided brachytherapy over 2D brachytherapy. Thus, two patients treated at our department (one GYN and one APBI) will be presented. The advantage of having adequate dose coverage of the high risk CTV and simultaneous low doses to the OARs when using 3D image-based brachytherapy will be presented. The treatment techniques, equipment issues, as well as implantation, imaging and treatment planning procedures will be described. Quality assurance checks will be treated separately.

Keywords: HDR Brachytherapy, GYN, APBI

1. Introduction

The introduction of brachytherapy dates back to the beginning of the last century. During brachytherapy energy is derived from a radioactive source which is located in the proximity of the tumour. Therefore, radiation is deposited directly into the tumour and radiation induced side effects are minimized because of the high conformity of the procedure [1].

Modern brachytherapy exploits technological advantages such as high strength sealed radioactive sources, remotely controlled afterloading machines, sophisticated treatment planning systems and temporary implants. High doses are delivered within short treatment times. The latter is called “High Dose Rate” (HDR) brachytherapy.

Based on the technique of applicator placement HDR brachytherapy can be divided into two main subgroups: a) intracavitary and b) interstitial. During intracavitary brachytherapy specific applicators are inserted into cavities (e.g. gynecological brachytherapy). Interstitial brachytherapy is used if the tumour is not accessible through cavities. Hollow needles are then implanted into the tissue, using adequate distributions in order to cover the malignant site. Although there is a clear distinction between these two types, it is common practice to combine both techniques if this is required in order to maximize target coverage [1].
Image guidance plays a substantial role for modern brachytherapy which represents a highly conformal treatment. The doses delivered to the target are significantly higher compared to those delivered with external beam radiation therapy (EBRT). Therefore, it is of major importance to precisely reconstruct the implant, as well as to delineate the high risk clinical target volume (HR-CTV) and the surrounding healthy organs with high accuracy. Imaging innovations which were developed during the past decades were integrated into the procedure of brachytherapy (e.g. Ultrasound (US), Computed Tomography (CT), Magnetic Resonance Imaging (MRI)). MRI with its superior soft tissue depiction quality represents the gold standard for GYN brachytherapy. US is utilized mainly for prostate brachytherapy and CT for many different sides [2].

At the Radiation Oncology Department of the Metropolitan Hospital Athens, MR Image Guided Adaptive BrachyTherapy (IGABT) for GYN tumours and Accelerated Partial Breast Irradiation (APBI) with interstitial brachytherapy are performed on a routine basis. Both treatments are very demanding with regard to equipment, applicator implantation, imaging, treatment planning and quality assurance checks.

The present work provides a brief description for both techniques, focusing mainly on technical aspects.

2. Materials & Methods

At the Radiation Oncology Department of the Metropolitan Hospital MR IGABT for GYN tumours is performed on a daily basis. Applicator sets, catheters and needles which are used are provided by Elekta company (Elekta A.B. Stockholm, Sweden). For imaging purposes, a CT – SIM (Somatom CT scanner (Siemens Medical Solutions USA, Inc, Malvern, USA)) and a MRI scanner (Magnetom Avanto (Siemens Medical Solutions USA, Inc., Malvern, USA)) are utilized. Treatment planning is performed with Oncentra Brachy system, v. 4.5 (Elekta A.B. Stockholm, Sweden). Treatment is performed with a microSelectron v.2. afterloader (Elekta A.B. Stockholm, Sweden). On a scheduled basis (daily, monthly and yearly) dosimetric checks of the brachytherapy equipment are performed using Well Type Chamber, EBT films, Electa’s check ruler, Survey Meter and chronometer.

2.1. Gynecological Brachytherapy – Cervical Cancer

Cervical cancer brachytherapy can be performed either as a standalone treatment instead of surgery for small (IA) tumours, or in combination with EBRT and chemotherapy for more advanced tumours [1].

A combined intracavitary/interstitial tandem-ring applicator (Vienna applicator) [3], which is MRI compatible, is frequently used for this kind of brachytherapy. The ability to adapt to each individual anatomical and pathological situation is provided by different ring diameters (26, 30, 34 mm) and different tandem-intrauterine lengths (2, 4, 6 cm). In addition, each ring has on its periphery a set of holes, where specific Titanium needles can be added, for adequate dose coverage to the target.

The insertion of the implant is performed with the patient in lithotomy position under spinal anaesthesia. A Foley catheter is inserted into the bladder and is filled with a radiation-opaque fluid. A transrectal US probe assists for the correct insertion of the entire implant. Following implantation, CT and MR images are acquired. T2 weighted images in three planes are acquired for target and organ delineation purposes. T1 weighted images are obtained for applicator reconstruction. Images are imported into the treatment planning system in DICOM format. The delineation of the OARs (bladder, rectum, sigmoid) and the definition of the HR CTV is completed by the radiation oncologist. Subsequently, the medical physicist reproduces “in silico” the exact implant, either by using vendor provided libraries of applicator models or by using manual reconstruction (Figure 1).

Although in an APBI implant, Paris system is followed, sometimes the needles are curved and are not equidistant as it is shown in Fig. 2. In 3D brachytherapy these “imperfections” of the implant can be corrected – in contrary to the 2D brachytherapy – by dwell time optimization.
Figure 1. Isodose levels on a T2 weighted MR image and model based reconstructed implant (tandem-ring and peripheral catheters) for cervical brachytherapy.

The goal of the planning procedure is to shape the dose distribution of the implant to the target volume, using source position and dwell time optimization. The prescription dose is 7 Gy per fraction, four fractions in total. Dosimetric goals for this treatment are D90 (The dose that encompass at least the 90% of the high-risk CTV [1]) \(\geq 7\) Gy, D2cc of bladder (the dose that at least receive the 2 cm\(^3\) of the bladder [1]) \(< 5.1\) Gy, D2cc of rectum (the dose that at least receive the 2 cm\(^3\) of the rectum [1]) \(\leq 4.8\) Gy and D2cc of sigmoid (the dose that at least receive the 2 cm\(^3\) of the sigmoid [1]) \(\leq 4.8\) Gy. Fig. 1 demonstrates conformity of MR IGABT: Invasion of the tumour into the left parametria was covered with the insertium of titanium needles which were appropriately optimized.

2.2. Accelerated Partial Breast Irradiation using Interstitial Brachytherapy

Accelerated partial breast brachytherapy is offered to patients as an alternate treatment option to EBRT [4, 5]. Patient selection criteria are age (> 50 years), histology (grade 1-3) and tumour size (< 3 cm). Needle implantation procedure is performed either in an intraoperative or postoperative manner. The needles are placed into the tumour bed aiming at parallel and equidistant distributions according to the Paris system [1] (Figure 2).

Figure 2. Typical catheter arrangement and isodose levels of APBI brachytherapy. Light blue lines indicate the reconstructed catheters.

After surgery a CT scan is performed. DICOM images are imported into the treatment planning system. The radiation oncologist delineates the target and the organs at risks (skin, underlying ribs, lung and remaining breast).

Treatment planning is based on the rules of Paris system for interstitial brachytherapy. Planning target volume (PTV) should be covered by the 85% isodose level of the mean central dose. Prescription dose is 32 Gy in 8 fractions of 4 Gy twice daily. Dosimetric goals are presented in Table 1.
Table 1. Minimum quality requirements for plan acceptance in an APBI treatment.

| Dosimetric Indexes | Minimum Values                      |
|--------------------|-------------------------------------|
| D90                | ≥ 90%                               |
| V100               | > 90%                               |
| DNR\(^a\)          | ≤ 0.30                              |
| D_{skin}           | < Prescribed dose                    |
| D_{lung}           | < 70% Prescribed dose               |

\(^a\) Dose nonconformity ratio-DNR is the ratio of the volume of 150% isodose to the 100% isodose

3. QA protocol for HDR brachytherapy

Prior to each brachytherapy treatment several safety Quality Assurance (QA) checks are carried out. The list of QA checks includes daily routine tests for verification of the impeccable performance of the equipment, as well as patient specific measurements for precise implant reconstruction and reproducibility between fractions.

On a daily basis, the current activity of the Iridium 192 source is calculated and compared with treatment planning and afterloader values. Source position checks and time checks are also performed, along with numerous equipment safety checks: communication, catheter attachment lock, door interlock, warning lights, room monitor, emergency stop buttons, catheter obstruction, treatment timer and contamination tests [6].

Some of the patient specific checks are: measurement of the free length of the implanted catheters, comparison of the active dwell times derived from plan to the actual that are going to be delivered, test for possible source obstruction in the catheters.

4. Conclusions

Modern image based adaptive HDR brachytherapy is a highly demanding procedure. It represents a high end technique which utilizes sophisticated equipment and imaging, while expertise plays a pivotal role. Finally, it is of major importance, that the medical physics team of the department enables safe and accurate dose delivery.

5. References

[1] V. Strnad, R. Potter and G. Kovacs, Practical Handbook of Brachytherapy (2014).
[2] J.C. Dimopoulos, G. Schirl, A. Baldinger, T.H. Helbich and R. Potter, MRI assessment of cervical cancer for adaptive radiotherapy, Strahlenther Onkol 185 (2009), pp. 282-287.
[3] C. Kirisits, S. Lang, J. Dimopoulos, D. Berger, D. Georg and R. Potter, The Vienna applicator for combined intracavitary and interstitial brachytherapy of cervical cancer: design, application, treatment planning, and dosimetric results, Int J Radiat Oncol Biol Phys 65 (2006), pp. 624-630.
[4] P. Karlsson, Accelerated partial breast cancer irradiation (APBI)--the future breast cancer radiotherapy?, Acta Oncol 48 (2009), pp. 485-486.
[5] F. Wenz, W. Budach, J. Dunst, P. Feyer, W. Haase, W. Harms, et al., Accelerated partial breast irradiation (APBI)--ready for prime time?, Strahlenther Onkol 185 (2009), pp. 653-655.
[6] J. Venselaar and P.-C. J, A practical guide to quality control of brachytherapy equipment (2004).