© Universiti Tun Hussein Onn Malaysia Publisher's Office

JAITA

http://publisher.uthm.edu.my/ojs/index.php/jaita

e-ISSN : 2716-7097

Journal of Advanced Industrial Technology and Application

Principles and Techniques in Handling Brachytherapy - A Short Review

Nur Fatimah Zahra Mohd Khairi[1], Nurul Farhana Roszaini[1], Siti Amira Othman[1*]

[1]Faculty of Applied Sciences and Technology,
Universiti Tun Hussein Onn Malaysia, Pagoh, 84600, JOHOR

*Corresponding Author

DOI: https://doi.org/10.30880/jaita.2023.04.01.009
Received 26 April 2023; Accepted 08 June 2023; Available online 21 June 2023

Abstract: Brachytherapy is a type of radiation that involves precisely placing radioactive sources directly into or close to the tumour. This treatment is recommended for people suffering from many forms of cancer. It is an ideal tool for delivering extremely high radiation to the tumour while reducing radiation exposure and risk to the surrounding normal tissue. Physicians from a variety of disciplines may be involved in either referring to or placing brachytherapy. Brachytherapy is required for many patients as either a main treatment or as part of their oncologic care. Brachytherapy can be used to treat a wide range of tumour types, including gynaecological, urologic, rectal, cutaneous, and breast malignancies. In most brachytherapy treatments, a radiation oncologist, relies on imaging techniques such as CT scans and ultrasound during the treatment planning and delivery to accurately identify the placement of encapsulated brachytherapy sources in the patient body. By using this treatment, it is possible to deliver a higher radiation dose to a limited area than conventional external beam radiotherapy. This may be more effective at destroying cancer cells while causing minimal damage to surrounding normal tissue is placed in patients are sedated for all these procedures.

Keywords: Brachytherapy, tumour, cancer, imaging, treatment

1. Introduction

Brachytherapy is for (i) patients with locally advanced cervical cancer in combination with chemoradiation, (ii) surgically treated patients with uterine endometrial cancer to reduce the risk of vaginal vault recurrence, (iii) patients with high-risk prostate cancer to perform dose escalation and improve progression-free survival and (iv)patients with breast cancer as combination therapy. In this article, we will explain the fundamentals of brachytherapy as well as a brief overview of endoluminal brachytherapy and breast brachytherapy [1].

This interdisciplinary approach (minimize recurrence) is essential for perioperative operations when the target volume is inaccessible without endoscopic guidance (e.g., oesophageal or endobronchial tumours) or in close proximity to extremely sensitive organs [2]. During or soon after implantation, imaging is used to guide the dosimetry procedure, which involves of establishing where the sources should be positioned and/or how long those sources should stay in site to produce a high dosage to the tumour without exceeding dose limitations for organs-at-risk. In contemporary brachytherapy, several radioisotopes with distinct half-lives and energies may be used, with iridium-192, cobalt-60, iodine-125, and palladium-103 being the most common.

2. Brachytherapy Principles

Brachytherapy is the practice of delivering radiation therapy from within a very close proximity to the area needing treatment using sealed sources. The word brachytherapy may be interpreted as "near treatment." Therefore, it is

*Corresponding author: sitiamira@uthm.edu.my

commonly being use for treating tumours when a radiation source may be inserted within a bodily cavity, such as the uterus, vagina, oesophagus, or bronchus, or when the tumour is accessible to needle or catheter sources being implanted within it, such as the breast, head and neck, prostate, or skin. In fact, most tumour sites are amenable to brachytherapy treatment [3]. It can be used as primary treatment or in combination with external beam radiotherapy. Brachytherapy, commonly known as internal radiation therapy, involves the placement of radioactive material directly into or next to the tumour.

The benefits of brachytherapy over standard external beam treatment come from a better localisation of dosage to the tumour volume. Since radiation is continuously administered over time during brachytherapy, repair of sublethal and potentially fatal damage, proliferation, and other cell kinetic effects change how tumour and normal tissues respond to radiation, resulting in complex dose rate effects that also affect the therapeutic ratio for brachytherapy [4]. There are two forms of brachytherapy: intracavitary brachytherapy and interstitial brachytherapy. This approach is used, for instance, to treat prostate cancer [5]. Always impermanent, intracavitary radiation normally lasts a few days. However, interstitial brachytherapy may be either temporary or permanent. To treat cervical or endometrial cancer, for example, radiation may be delivered in the vagina.

The vast majority of brachytherapy is administered through catheter, made of a thin and elastic tube. Occasionally, brachytherapy is given with big size catheter called as applicator. The selection of applicator brachytherapy is dependent on the types of cancer being treated [6]. Once the catheter or applicator has been properly positioned, the radiation source or seed is inserted within for a given period of time. The radiation source may be kept in place for a few minutes, many days, or a whole lifetime. The amount of time it stays in place depends on the types of radiation source, the type of cancer, the location of the cancer inside the body, the patient's health, and any prior cancer treatments.

2.1 Brachytherapy Sources

There are several radionuclides and forms and sizes of radioactive sources for brachytherapy accessible today, and there is no such thing as a 'perfect' brachytherapy source. Diverse sources have different applications based on their emission type, radiation energy, and construction. Radioactive sources utilized in brachytherapy include iridium-192 (half-life is 74.17 days), iodine-125 (half-life is 60.25 days), and palladium-103 (half-life is 16.96 days). Due to the low half-lives of these radionuclides, brachytherapy seeds can be inserted into a malignant tumour and never removed [7]. The seed's radioactivity decays, producing radiation that kills cancer cells until there is no detectable radioactivity remaining in the seeds. This is a frequent procedure for treating prostate cancer in which the seeds remain harmlessly in the prostate for the remainder of the patient's life.

Alternatively, high-dose-rate (HDR) radioactive sources have been created, in which the physician inserts a very small plastic catheter into the patient's prostate gland. Then administers a series of HDR radiation treatments to the patient by introducing a radioactive source through the catheter. After a regulated dose is provided, the catheter and radiation source are withdrawn, and no radioactive material is left in the tumour [8]. Other tumours involve radioactive sources with longer half-lives in brachytherapy, but the radioactive source is removed from the tumour after the cancer cells get the specified amount of radiation. Brachytherapy may be used to treat tumours other than prostate cancer, such as cervical, oesophageal, breast, and skin cancers [9].

3. Endoluminal Brachytherapy Techniques: Bronchus and Oesophagus

3.1 Bronchus

Endobronchial brachytherapy is a method that includes placing a catheter in close proximity to an endoluminal tumour in order to give local irradiation. During a regular flexible bronchoscopy, the catheter is inserted and then attached to the remote after loading device carrying the irradiation source [10]. Typically, 5 mm steps are employed. The treated length might be 8 to 10 cm. The dose is given 1 cm distant from the source, covering both the bronchial mucosa and the bronchus wall. The goal volume is typically defined by 2 cm margins around visible tumours. The entire treatment can be done as an outpatient.

3.2 Oesophagus

Here are the techniques:

1. Before insertion, an HDR afterloading catheter is inserted into a 16-gauge nasogastric tube and secured by tape at the open end
2. A nasogastric tube is inserted into the stomach through the recognised tumour region.
3. Anteroposterior and lateral X-rays are obtained, as well as computed tomography scans, if necessary, to augment this information.
4. In the case of plain X-rays, it may be advantageous to repeat the films after the initial X-ray with the patient having consumed oral contrast to define the level of the tumour
5. The treatment period may then be determined on the plain film.

6. Calculate the dwell periods necessary for the prescription dosage.
7. This is often defined as 1 cm from the source.
8. The HDR catheter is inserted into the afterloading machine to give treatment.
9. After therapy, the nasogastric tube is removed, and the patient is returned to the ward for recuperation and discharge.

Catheters can be put intraluminally in the bronchus or oesophagus with mild sedation during bronchoscopy or the entrance of a nasogastric tube. Because most therapies are administered in single doses, a one-day or one-night hospital stay is necessary. The disadvantages including:

1. Bronchoscopy endobronchial catheter passage is a professional technique requiring well-trained group.
2. Dose penetration is restricted, with the normal prescription point being 1 cm from the source, which may not be enough to cover the whole tumour in many bronchial tumours.
3. Unless efforts are taken to centre the catheter inside the lumen of the bronchus or oesophagus, the dosage is likely to be skewed to one side or the other.
4. Tumours near the cardia and extending into the stomach fundus may not be adequately covered by a central catheter.
5. Carina or bilateral bronchial tumours necessitate the introduction of two catheters and more difficult dosimetry.

4. Breast

Breast brachytherapy is an important aspect of every radiotherapy centre’s activity. The vast majority of patients will have external beam treatment, with just a small percentage being evaluated for brachytherapy. This is due in part to the availability of brachytherapy knowledge and resources, as well as the effectiveness and effectiveness of breast boost treatments using electron beams. There are, however, specific indications for brachytherapy, most prominently when a high dosage of radiation to an underlying breast tumour is necessary, which may exceed skin tolerance.

4.1 Techniques

1. Low dose rate (LDR) employs iridium wire that has been cut to particular lengths and then placed into either flexible plastic tubes or stiff steel needles.
2. Pulsed dose rate (PDR) or high dose rate (HDR) afterloading is accomplished using a normal commercial afterloading equipment equipped with an iridium source. Typically, a bridge-type template with stiff needles is used, which is available from conventional suppliers.

4.2 Advantages

1. Clinically confirmed to be extremely effective in preventing cancer from returning after surgery in early breast cancer.
2. Typically conducted as an outpatient procedure.
3. When administered as an Accelerated partial breast irradiation (APBI), treatment periods are as short as 5-7 days
4. Allows for a high tumour dosage with the possibility of designing dosimetry into the implant, skin sparing, and lung and rib sparing.

4.3 Disadvantages

1. Can only treat a limited volume and is impractical for tumours larger than 5 cm in maximum size.
2. Requires general anaesthesia and inpatient care.
3. Requires operator knowledge.

5. Proper Techniques in Handling Brachytherapy

A type of radiation therapy known as brachytherapy is used to treat a variety of cancers. Radioactive seeds, capsules, or other implants can be surgically placed inside or near a cancerous tumor as part of the treatment. A brief amount of radiation is released by the implants. Brachytherapy can use a lot of radiation to shrink or kill tumors without harming the healthy tissue around them. Internal radiation therapy is another name for brachytherapy. Brachytherapy is a treatment that only treats a specific area of your body and is considered local. It is frequently used to treat eye, breast, cervix, prostate, and head and neck cancers [11].

Brachytherapy can be either short-term or long-term. In temporary brachytherapy, radioactive material is injected into a catheter for a predetermined amount of time before being removed. It is given at a low-portion rate (LDR) or high-portion rate (HDR). Seed implantation is another name for permanent brachytherapy. It permanently deposits radioactive seeds the size of a grain of rice near or inside the tumor. Following a while, the seeds lose their radioactivity. Now and then, dynamic seeds might set off radiation finders at security designated spots. Rarely do inactive seeds cause metal detectors to activate.

There are three different types of brachytherapy. The method you use, the type of brachytherapy (LDR, HDR, or permanent), and where the implants are placed all play a role in the outcome. Intracavity brachytherapy uses implants that are inserted into a body cavity, like vagina, close to the tumor [12]. An implant is used in interstitial brachytherapy and is inserted directly into the tumor. Patient will be provided with medications to help stay relax, regardless of the procedure. To alleviate pain and discomfort, patient may receive anesthesia and a sedative. For some types of cancer, brachytherapy is a highly effective treatment. It is most effective against cancers that have not metastasized or spread. As the radiation leaves the body, the majority of side effects improve.

5.1 Types of Brachytherapy

Brachytherapy can be given for a long time or for a short time. Seeds containing the radioactive material are implanted inside or nearby the tumor in permanent brachytherapy. After six months, low dose radiation eventually fades and is gradually absorbed. A catheter or applicator is used to deliver the radioactive material to a target site in temporary treatment brachytherapy. This material is typically placed in the delivery device for 12 to 24 hours prior to removal in cases of low dose radiotherapy, whereas high dose radiation may only be administered for a few minutes. Brachytherapy treatment makes use of a wide range of different radioactive sources.

There are three kinds of brachytherapy, among them is low dose rate (LDR) inserts. The radiation source stays in place for anywhere from one to seven days in this kind of brachytherapy. You will probably spend this time in the hospital. The radiation source and the catheter or applicator will be removed by your doctor after your treatment is finished [13]. The radiation source in these High-dose rate (HDR) implants is only left in place for 10 to 20 minutes at a time before being removed. Treatment may be provided twice daily for two to five days or once weekly for two to five weeks. The schedule depends on the kind of cancer. The catheter or applicator may remain in place throughout treatment, or it may be inserted prior to each treatment. During this time, a patient might be in the hospital, or might go to the hospital every day to get the radiation source set up. After the treatment complete, the doctor will remove the catheter or applicator, just like with LDR implants.

Permanent implants come next, which require the catheter to be removed following the installation of the radiation source. Although the radiation gets weaker with each day, the implants remain in body for the rest of life. Most of the radiation will dissipate over time. The patient may need to limit the time with other people and take other safety precautions when the radiation is first introduced. Take extra care not to spend time with young children or women who are pregnant.

5.2 Brachytherapy Treatment

The type of treatment determines the radioactive material used, which can be iodine, palladium, cesium, or iridium. The radiation source is encased in all of them. This indicates that it is contained within a metallic, non-radioactive capsule that is frequently referred to as a "seed." This keeps the material from moving to different pieces of the patient's body. Using a special delivery device, radioactive seeds are injected directly into the tumor by permanent implants. In most cases, ultrasound or x-ray imaging is used to ensure precise placement. Needles, catheters, or specialized applicators are used for temporary implants. The radiation sources are inserted after the precise position of the device has been confirmed. This is designated "after loading." After placing the delivery device, the oncologist may manually insert and remove the material. Alternately, the material may be inserted by the oncologist using a remote after loading machine controlled by a computer. Clinical imaging helps position the material to treat the cancer in the best manner. The position of the source and the duration of time required to deliver the desired radiation dose are calculated by computers [14].

A treatment team is required for brachytherapy. A radiation oncologist, a radiation therapist, a dosimetrist, a medical physicist, a nurse, and occasionally a surgeon makes up this team. The radiation oncologist is a doctor with extensive training who focuses on using radiotherapy to treat cancer. The oncologist examines the patient, identifies the accurate treatment needed, and chooses the right amount of radiation and therapy [15]. At times, a specialist will help by putting treatment gadgets in the patient. The oncologist, medical physicist, and dosimetrist all decide how much radiation to give the patient and how much they can handle. The dosimetrist and physicist then conduct in-depth treatment calculations. Treatment may be delivered with assistance from the radiation therapist, a specially trained technologist. The nurse explains the treatment and any potential side effects. Treatment catheter care is also being managed by the nurse.

6. Conclusion

Brachytherapy is suggested as an independent treatment or in combination with other treatment options (external radiation or surgery) in a wide range of clinical conditions, and it has a significant role in the worldwide oncological landscape. Physicians from a variety of disciplines are engaged in the brachytherapy process via patient referral, brachytherapy implantation, and post treatment care (follow-up and treatment of problems, if present). Numerous attempts have been undertaken to bring brachytherapy to the maximum degree of modernity and enhance its therapeutic index via a series of incremental advancements. Brachytherapy's patients could have short-term and long-term effects that affect physical and emotional well-being. Some side effects could occur during or shortly after treatment and usually improve after about two weeks.

Acknowledgment

The authors fully acknowledged Universiti Tun Hussein Onn Malaysia for supporting this work.

References

[1] Sahithi Madireddy, Amit Verma, Bilikere S. Dwarakanath, Rao VL. Papineni. (2022) Technological advancements in brachytherapy of cancer, Physics Open, Volume 11.
[2] Sophie J. Otter, Alexandra J. Stewart, Phillip M. Devlin. (2019). Modern Brachytherapy, Hematology/Oncology Clinics of North America, Volume 33, Issue 6, Pages 1011-1025.
[3] Hoskin, Peter, and Catherine Coyle (eds). (2011). Radiotherapy in Practice - Brachytherapy, 2 edn, Radiotherapy in Practice, online edn, Oxford Academic, 1 May 2013).
[4] C. Hennequin, S. Guillerm, S. Wong, L. Quéro. (2018). Endoluminal brachytherapy: Bronchus and oesophagus, Cancer/Radiothérapie, Volume 22, Issue 4, Pages 367-371.
[5] Cozzi, S., Augugliaro, M., Ciammella, P., Botti, A., Trojani, V., Najafi, M., Blandino, G., et al. (2022). The Role of Interstitial Brachytherapy for Breast Cancer Treatment: An Overview of Indications, Applications, and Technical Notes. Cancers, 14(10), 2564. MDPI AG.
[6] Ning Jeff Yue. (2006). Principles and practice of brachytherapy dosimetry, Radiation Measurements, Volume 41, Supplement 1.
[7] Michael F. L'Annunziata. (2016). Chapter 1 - Radioactivity and Our Well-Being, Editor(s): Michael F. L'Annunziata, Radioactivity (Second Edition), Elsevier, Pages 1-66.
[8] Chargari, C., Deutsch, E., Blanchard, P., Gouy, S., Martelli, H., Guérin, F., Dumas, I., Bossi, A., Morice, P., Viswanathan, A. N., & Haie-Meder, C. (2019). Brachytherapy: An overview for clinicians. CA: A Cancer Journal for Clinicians, 69(5), 386-401.
[9] Brachytherapy. (2022). Radiologyinfo.org. Retrieved from https://www.radiologyinfo.org.
[10] Kanaev SV, Turkevich VG, Baranov SB, Savel'eva VV. (2014). Basic principles and results of brachytherapy in gynecological oncology. Vopr Onkol. 2014;60(4):422-8.
[11] Radiological Society of North America, (2021), Brachytherapy, Retrieved from https://www.radiologyinfo.org/en.
[12] Ananya Mandy, (2019) Brachytherapy Procedure, Retrieved from https://www.news-medical.net/health.
[13] National Cancer Institute, (January 2019), Brachytherapy to Treat Cancer, Retrieved from https://www.cancer.gov.
[14] Jo's Cervical Cancer Trust. (2020). Risk and Side Effects of Brachytherapy, Retrieved from https://www.jostrust.org.uk.
[15] Mayer C, Gasalberti DP, Kumar A. (2023). Brachytherapy. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing