

3D CONFORMATIONAL INTERSTITIAL BRACHYTHERAPY PLANNING FOR SOFT TISSUE SARCOMA

ALINA TĂNASE^{1,3}, M. DUMITRACHE^{2,3}, O. FLOREA¹

¹Emergency Central Military Hospital “Dr. Carol Davila” Bucharest, Romania
E-mail: alinatanasemail@yahoo.com

²Institute of Oncology “Prof. Dr. Al. Trestioreanu”, Bucharest, Romania

³University of Bucharest, Faculty of Physics, Romania

Received July 27, 2014

Abstract. Soft tissue sarcomas (STS) are malignant tumours that originate in the body soft tissues including muscles. STS are very rare, but very serious, especially if diagnosed when the disease is advanced [4]. High-dose rate brachytherapy (HDR BT) for STS is often used followed by surgery to help eradication of any cancerous cells that remains after this procedure. With HDR BT radiation is deposited inside the body, in the area of the tumour, thereby delivering a maximum dose while minimizing exposure of the surrounding healthy tissue. In this paper we present our early experience in 3D conformational interstitial brachytherapy planning with BrachyVision v.11 (Varian software) for a forearm STS. The procedure was performed in a team, involving the effort of the surgeon, radiation oncologist, pathologist, medical physicist, and radiation therapy technician. The case was a single-plan implant of 4 catheters, placed parallel to the incision. 3D treatment planning required computed tomography after recovery from surgery procedure. The clinical target volume (CTV) was defined as the volume of tissue with risk of microscopic spread, and includes the preoperative image tumour (visualized by CT – MRI fusion). Source loading was performed 7 days after catheters implant and wound closure (single ¹⁹²Ir source, GammaMed Plus iX afterloader equipment), then 3 Gy were delivered twice daily, during 5 days. We also, followed the patient response to HDR BT treatment. Concerning treatment-related complications [5], at the first medical examination after the treatment, the patient had no problem moving the fingers. However, the forearm revealed hematoma, but no infection or seroma.

Key words: soft tissue sarcoma, 3D conformational brachytherapy, interstitial brachytherapy.

1. INTRODUCTION

Brachytherapy was first introduced at the beginning of the 20th century, where the radioactive sources were manually implanted into the tumour. In the middle of last century, most brachytherapy procedures were performed using manual afterloading techniques, where needles or applicators were placed in the

tumour volume and then radioactive sources were placed remotely in the needles or applicators, minimizing the exposure of the involved medical staff. As radiation sources were used ^{60}Co , ^{137}Cs and later miniaturized ^{192}Ir .

By definition, brachytherapy brings the desired radiation dose directly to the target using sealed radioactive sources, which are positioned within or in the vicinity of the tumour. Generally speaking, brachytherapy takes advantages of the fact the sources are connected directly to the target volume and they move with the target when the target itself is moving. Another advantage, compared to the external beam techniques, is that the target receives a sufficiently high dose while the inverse square law ensures that even in the near proximity, the dose to the surrounding normal tissue (organ at risk: OAR) is reduced considerably [7].

In the last 15 years, brachytherapy has moved forward, from 2D dose distribution to 3D volumetric treatment modality. This change enable us to provide a more conformal dose delivery for a very complex target volume, with a better sparing of healthy tissues.

As equipments, HDR BT devices delivering dose rate up to 700 cGy/min at 1 cm from the source, administering discrete fractions in a temporary implant, have become common in the treatment of gynecological, breast and prostate cancer, but also for other treatment sites: head and neck, skin and soft tissue sarcomas. This last tumour site is the subject of this paper.

Soft tissue sarcomas (STS) are malignant tumours that originate in the body soft tissues (including muscle, fat, blood vessels, nerves, tendons). STS are very rare (they account for less than 1 % of all new cancer cases each year) but very serious, especially if diagnosed when the disease is more advanced.

A variety of radiotherapeutic approaches have been used in the adjuvant local management of STS. These include surgery, brachytherapy (BT), intraoperative radiation therapy, and external beam radiotherapy (EBRT) [6].

2. MATERIALS AND METHODS

In early April, a patient (70 years old, female) has been presented to Central Military Hospital "Dr. Carol Davila", Bucharest, Radiotherapy Department, with the diagnosis of STS.

After a documented tumour board, the procedure was performed in a team, involving the effort of the surgeon, radiation oncologist, pathologist, medical physicist, and radiation therapy technician.

In the first phase, the surgery of the tumour bed was carried out (Fig. 1a, b). Secondly the radiation oncologist together with the surgeon introduced the guide needles and implanted the afterloading HDR BT catheters in the tumour bed (Fig. 1c, d).

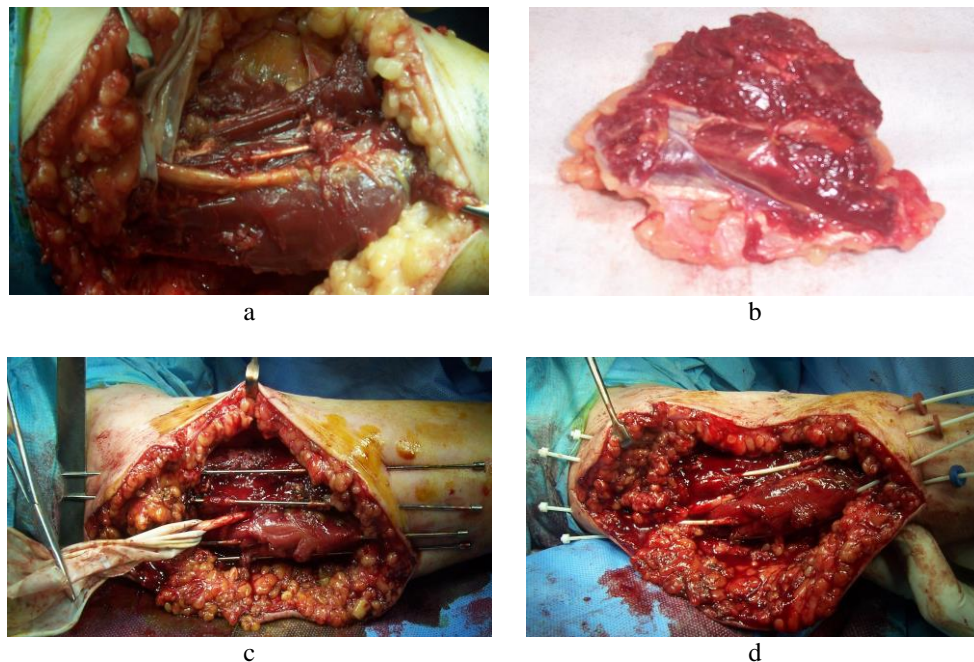


Fig. 1 – Soft tissue sarcoma surgery and applicators implant phases:

- a) tumour bed on forearm;
- b) gross tumour extracted from forearm;
- c) placement of brachytherapy guide needles;
- d) placement of brachytherapy catheters in the tumour bed after resection.

The case was a single-plan implant of 4 catheters, placed parallel to the incision (at the end of March 2014). We gave all the attention possible to the entrance of the catheters in the skin. We have tried to put them at least 1 cm past the incision (America Brachytherapy Society recommendations). Each catheter length was 20 cm, consistent with the type of transfer tubes that we used.

The space between the catheters was 1.0–1.5 cm, and they extend transversely ~ 2 cm past the CTV and longitudinally 2 cm past the CTV (Fig. 2), as ABS recommended [2]. In order to separate the catheters from neurovascular bundles and tendons, the surgeon secured them in place.

A 3D treatment planning has required computed tomography after recovery from surgery procedure. In this phase, we used a CT SIM – Somatom Spirit and for image acquisition we selected an extremities protocol: patient was lying on the CT table, in head-first-supine position, with the forearm away from the body, because the patient immobilization cannot be done in different positions due to reduced arm mobility and after surgery pain.

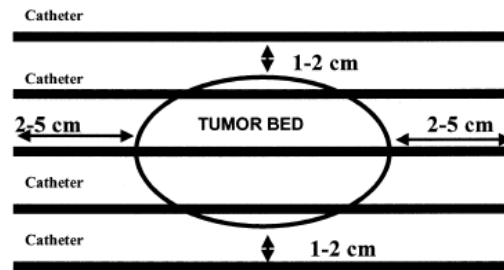


Fig. 2 – Catheters position: 1–2 cm past the CTV transversely and 2–5 cm past the CTV longitudinally, according to ABS recommendation [6].

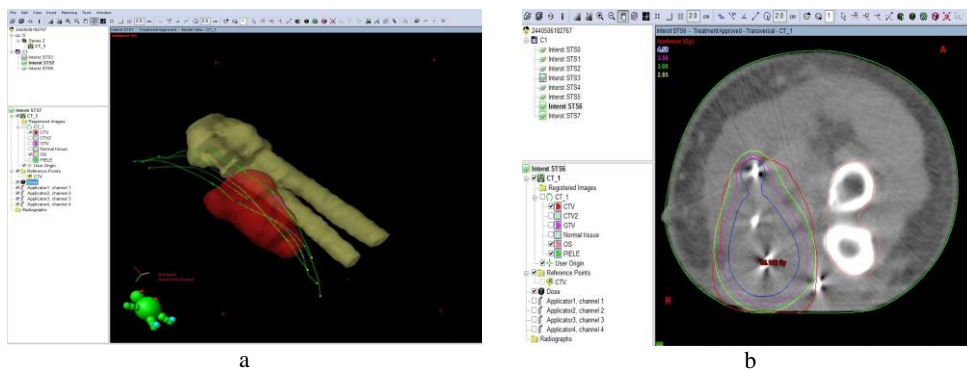


Fig. 3 – 3D conformational treatment planning: a) CTV, OAR and catheters reconstruction with virtual sources positions; b) dose distribution.

For catheter identification, we used dummy source markers that have been inserted through each catheter. The CT image acquisition allows a 3D reconstruction of catheter position and sources within. This approach minimizes errors and furthermore permits 3D dose distribution [6].

The CTV was defined by the radiation oncologist, as the volume of tissue with risk of microscopic spread, and includes the preoperative image tumour (gross tumor volume, GTV, visualized by CT-MRI-fusion). Also, OAR have been outlined (bone, healthy tissue and skin for the region of interest) (Fig. 3a).

3. RESULTS AND DISCUSSIONS

The treatment planning was performed using a BrachyVision v.11 Varian software with a cost function optimization algorithm (Fig. 4).

Each catheter was reconstructed and virtual sources were configured (Fig. 3a), inside CTV structure. For BT treatment the radiation oncologist

prescribed a total dose of 35 Gy (3.5 Gy/fraction) delivered twice daily, during 5 days/weeks.

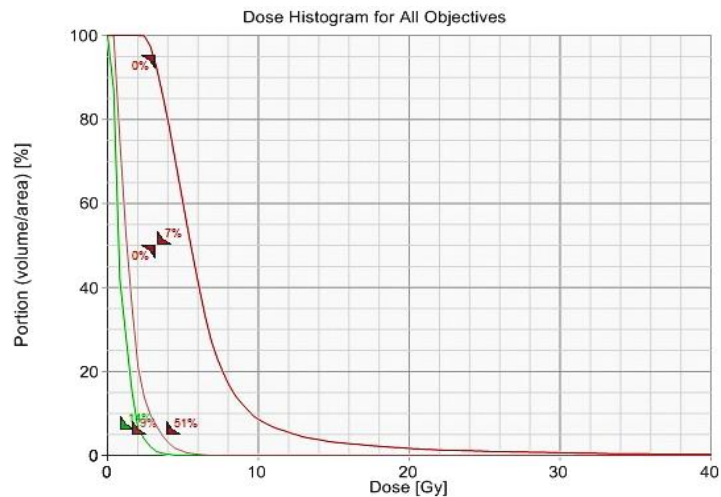


Fig. 4 – Dose histogram of optimization process, in order to obtain a better coverage of CTV.

Optimizer						
Structures and reference lines						
	ID	Resol...	Points	Surface		
	PIELE	5.5	2442	<input checked="" type="checkbox"/>		
	CTV	2.5	5450	<input type="checkbox"/>		
	OS	2.5	4326	<input checked="" type="checkbox"/>		
	GTV	2.5	1424	<input checked="" type="checkbox"/>		
	CTV2	2.5	5828	<input checked="" type="checkbox"/>		
	Normal tissue	2.5	5828	<input checked="" type="checkbox"/>		
Objectives for CTV						
	U..	Volume [%]	Volume [cm ³]	Dose [Gy]	Dose [%]	Priority
	L	95.00	81.09	3.20	91.43	100.0
	U	5.00	4.27	4.00	114.29	200.0
	L	49.70	42.43	3.21	91.70	100.0
	U	50.30	42.93	3.32	94.92	100.0

Fig. 5 – Optimization objectives for CTV: D95 % and D5 %.

As volume optimization objective for CTV, we set D95 % (dose to 95 % of the CTV) no less than 3.2 Gy and D5 % (dose to 5 % of the CTV) no more than 4.0 Gy (Fig. 5).

In order to obtain a better coverage, we placed virtual source positions outside the CTV and we set the dwell time large enough to bring a necessary contribution to CTV, but small enough to not create dose complications at OAR.

Source loading was performed 7 days after catheters implant and wound closure (single ^{192}Ir source, GammaMed Plus iX afterloader equipment). Each catheter has been connected to the planned channel, through a transfer tube (Fig. 6a, b).

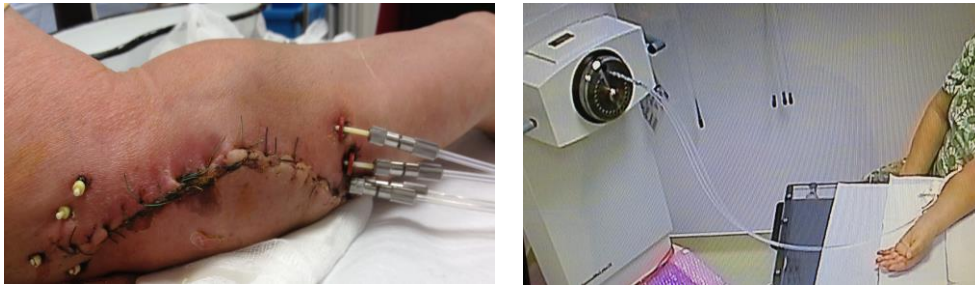


Fig. 6 – a) Catheters-transfer tubes connection;
b) STS treatment configuration.

We followed the response to BT treatment. At the first medical examination after treatment (at the end of May 2014), the patient had no problem moving her fingers. The forearm revealed hematoma, but no infection or seroma were noticed.

As this was our early experience on STS treatment using 3D conformational HDR BT, for the next similar case, we intend to optimize this procedure using a non coplanar catheter placement, that have to lead to better results in terms of volume coverage and dose distribution.

4. CONCLUSION

Brachytherapy represents an effective mean of enhancing the therapeutic ratio, offering both biological and dosimetric advantages in the treatment of patients with STS.

As a STS treatment procedure, 3D conformational HDR BT enables delivery of precise dose radiation to CTV. Because of the rapid dose fall-off outside treatment volume, the surrounding normal tissues are relatively spared. Minimizing dose to normal tissues is essential to optimizing functional outcome, which is one of the primary goals in STS BT.

This type of brachytherapy treatment has to be performed by a complex team. This treatment approach depends upon the institution, clinical situation, and medical staff skills and expertise.

In this case also, it is absolutely necessary to monitor the evolution of the treatment in terms of complications (infection, seroma, hematoma, chronic edema, fibrosis, and chronic radiation dermatitis) [2].

REFERENCES

1. K. M. Alektiar, M. J. Zelefsky, M. F. Brennan, *Morbidity of adjuvant brachytherapy in soft tissue sarcoma of the extremity and superficial trunk*, *Int. J. Radiat. Oncol. Biol. Phys.* **47**, 1273–1279 (2000).
2. L. C. Emory, C. O. Momtgomery, B. K. Potter, M. E. Keisch, S. A. Conway, *Early Complication of High-Dose-Rate Brachytherapy in Soft Tissue*, *Clin. Orthop. Relat. Res.* **470**, 751–758, 2012.
3. C. H. Gerrand, R. S. Bell, S. Wunder, R. A. Kandel, B. O’Sullivan, C. N. Catton, A. M. Griffin, A. M. Davis, *The influence of anatomic location on outcome in patients with soft tissue sarcoma of the extremity*, *Cancer* **97**, 485–492 (2003).
4. N. F. Gilbert, C. P. Cannon, P. P. Lin, V. O. Lewis, *Soft-tissue sarcoma*, *J. Am. Acad. Orthop. Surg.* **17**, 40–47 (2009).
5. L. Livi, R. Santoni, F. Paiar, P. Bastiani, G. Beltrami, P. Caldora, R. Capanna, P. De Biase, B. Detti, S. Fondelli, E. Maldolesi, P. Pertici, C. Polli, Simontacchi, G. Biti, *Late treatment-related complications in 214 patients with extremity soft-tissue sarcoma treated by surgery and postoperative radiation therapy*, *Am. J. Surg.* **191**, 230–234 (2006).
6. S. Nag, D. Shasha, N. Janjan, Y. Petersen, M. Zaider, *The American Brachytherapy Society Recommendations for Brachytherapy of Soft Tissue Sarcomas*, *Int. J. Radiat. Oncol. Biol. Phys.* **49**, 1033–1043 (2001).
7. J. L. M. Venselaar, D. Baltas. A. S. Meigooni, P. J. Hoskin, *Comprehensive Brachytherapy*, CRS Press, Boca Raton, FL, 2013.