Treatment Planning Optimization in Radiotherapy Using the Bolus

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The present paper presents the results of the research regarding the bolus structure (Bio-Rad Win-IR instrument), the elasticity modulus, the bioadhesiveness properties (TA-XT2 Plus analyzer) and the clinical applications of the bolus in the adjuvant irradiation after radical mastectomy (Treatment Plan System Eclipse). The dose-volume histogram has made a comparative evaluation for with and without bolus treatment plans and confirmed the importance of bolus utilisation in selected patients. Conclusions: the thickness of the applied bolus is dependent on the skin dose required, on the treatment technique and must be equal to the depth of the build-up region for the removal of the skin-sparing effect of a high energy radiation.

Keywords: radiotherapy, planning, bioadhesive, bolus, histogram

Achieving a treatment plan that respects both the homogeneous distribution of the prescribed dose in the target volume and the dose constraints for adjacent risk organs requires choosing the appropriate irradiation technique, but in some cases, it also requires the application of a bolus to the surface of the irradiated volume.

The irradiation of the chest wall after radical mastectomy often requires the application of a bolus to obtain the optimal parameters of the treatment plan. The type and thickness of the bolus must be included in the calculation algorithm [1, 2].

The bolus allows irradiation of the skin with 100% of the prescribed dose, while without the bolus, the skin (in which almost all local relapses occur in breast cancer [3-9]) receives about 70% of the prescribed dose, and the non-target tissues (muscles, ribs) receive 100% of the dose. Similarly, the bolus is indicated for irradiation of laryngeal tumors with extension at the anterior commissure or primary vulvar tumors [6,7].

Depending on the total dose irradiation and dose fractionation, when the bolus is used, the late cutaneous atrophy may occur more frequently.

Experimental part

Materials and methods

Structure

ATR-IR spectrum was measured using a Bio-Rad Win-IR instrument with the range of 4000 to 400 cm^{-1} in the ATR mode: mono reflection device, using a diamond crystal with incidence angle of 45 °.

Elasticity modulus measurements

The texture analyzer TA-XT2 Plus (Stable micro systems UK) was used for testing the elasticity of the gel, by using a cylinder of 12 mm diameter and compression speeds of 1mm/s. The slopes from the stress-strain curves at 50% deformations were used to calculate an apparent compression modulus. Ten samples were measured; the samples height was of 9.4 mm and their area was between 95 mm^2 and 105 mm^2. An initial fast deformation of 50 % at 1 mm/s was kept constant for 60 s.

Bioadhesive properties

The same texture analyzer TA-XT2 (Stable micro systems UK) was used for testing the adhesive properties of the material. The efficiency of the gel adhesion (8 mm diameter; 2 mm height) on to a chicken fresh skin (cleaned with diluted SDS solution (0.1%, w/vol) and rinsed with distilled water, wiped with filter paper to remove the water) was evaluated at room temperature. The texture analyser has a moving arm, a cylinder probe, a heavy duty platform and a holed plate. The sample is attached to the probe which is then pressed on to the receiving surface until the trigger force is detected. The gel samples were attached to the probe in such a way that the probe was fully covered so as to avoid any errors due to interaction. The biological tissue was used as a receiver and placed between the platform and the plate. 1 ml of phosphate buffer was introduced into the formed inlet above the membrane. This was repeated eight times. The work of adhesion (TWA) and the maximum detachment force (MDF) were recorded.

The settings of the texture analyser were (table 1):

Parameters	Value
Pre-test speed	1mm/s
Post-test speed	20mm/s
Applied force	2.0kgf
Return distance	20mm
Contact time	60 seconds
Trigger force	0.1kgf

Table 1
THE SETTINGS OF THE PARAMETERS

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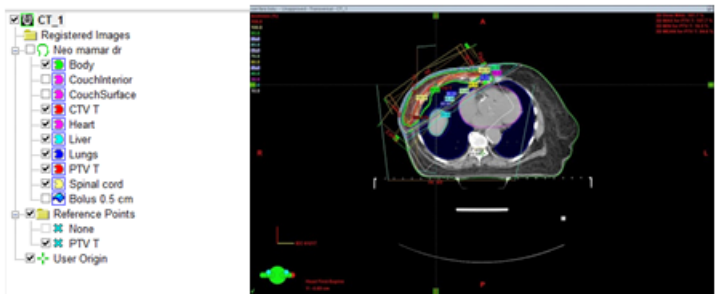

Fig.1. The treatment plan without bolus

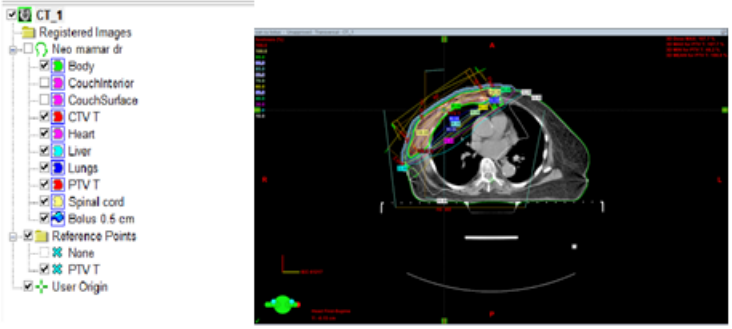

Fig.2. The treatment plan with bolus

The steps of the radiotherapy planning were: CT simulation using a SOMATOM DEFINITION scanner, delineation of target volumes and organs at risk, dosimetry and determination of treatment parameters through the Eclipse treatment plan system.

The treatment plan for irradiation of the right chest wall was initially performed without bolus (fig. 1) and subsequently with a bolus of 0.5 cm, marked with blue (fig. 2). The total dose of irradiation in the target volume (PTV) was 42.56Gy, divided in 16 fractions, 2.66Gy per fraction. The organs at risk are the lungs, the liver, the heart and the spinal cord (fig. 1, 2).

Results and discussions

The bolus material is made of non-toxic components and it usually is transparent. High dose irradiation should have no effect on the appearance and property of the gel pad.

The ATR –FTIR data registered for the studies bolus material are presented in figure 3.

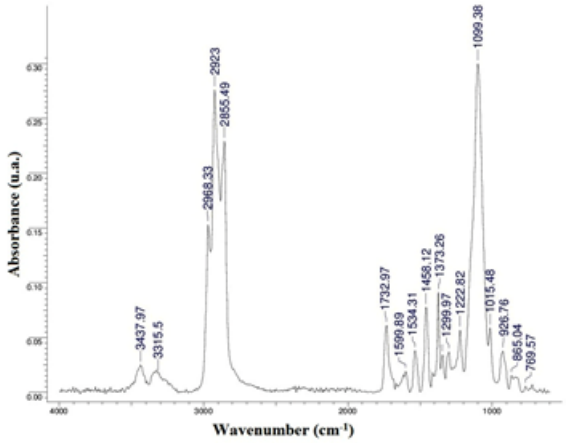

Fig.3. ATR-FTIR spectrum for the gel

The peaks at 2968, 2923 and 2855cm^{-1} respectively, are the asymmetric and symmetric stretching vibration ν(CH2), indicating an important content of the aliphatic groups. The characteristic stretching vibration, which peaks at 1732 cm^{-1}, belongs to the carbonyl groups of the polyester chains. The peaks at 1599 cm^{-1} belong to the stretching vibrations ν(C=C) of the aromatic cycles and the peaks at the 1534 and 1222 cm^{-1} respectively, 1599, 865 cm^{-1}- due to the double bonds CH=CH, 1373 cm^{-1} - due to the bending vibration ν(-CH), 1099 cm^{-1}- due to hydroxyl groups. The bolus material characteristics are presented in table 2.

Table 2
BOLUS MATERIAL CHARACTERISTICS

Bolus materials	Density [g/cm^3]	Optical characteristics	Elasticity modulus [MPa]
SuperFlab	1.07	Transparent	37

The bolus material is transparent with a density of 1.07 g/cm^3 and the elasticity modulus indicates a good flexibility. A good transparency is necessary to observe the skin surface of the patient and markings on the patient through the bolus material. Also, the material clarity provides a benefit to the radiation oncologist who uses the bolus material for radiation therapy in the skin surface treatment [8]. The Young modulus dictates the material softness and draping properties and very high values are not recommended [9,10].

The adhesive nature of the bolus material is a very important characteristic because a material such as this one shoud provide excellent skin contact without air gaps. Decreasing tackiness levels can correlate with decreased drapeability. While the bolus material should not be too tacky, the elimination of tackiness from the bolus material generally should not sacrifice drapeability.

The adhesion of polymers is the result of physical entanglement which promotes secondary chemical bonding, mainly H-bonding and van der Waals attraction. These forces are related to the chemical structure of the polymers. The types of surface chemical groups of adhesive polymers that contribute to adhesion include hydroxyl, carboxyl, amine and amide groups in the structure. Polymer characteristics which are necessary for adhesion are (a) strong H-bonding groups, (b) strong anionic charges, (c) high molecular weight, (d) sufficient chain flexibility, and (e) surface energy properties [11]. On a surface, the unsatisfied bonding potential of molecules is different from the bulk material where the interactions are uniform in the all directions. On the surface, a free energy is produced and the molecules will try to reduce this free energy by interacting with molecules in an adjacent phase, therefore the adhesion properties are manifested. The values for the maximum detachment

force (MDF) and work of adhesion (TWA) are specific for materials in contact with the skin (fig. 4).

Analysis of dose distribution in target volume and risk organs, initially performed separately for with bolus and without bolus treatment plan (fig. 5, 6, table 3, 4), then comparative (fig. 7, table 5) indicates compliance with the mandatory condition of inclusion in 95% isodose of at least 95% of PTV for bolus treatment plan only, under the conditions of conformity to dose constraints for organs at risk (similar doses to lungs, liver, heart, spinal cord).

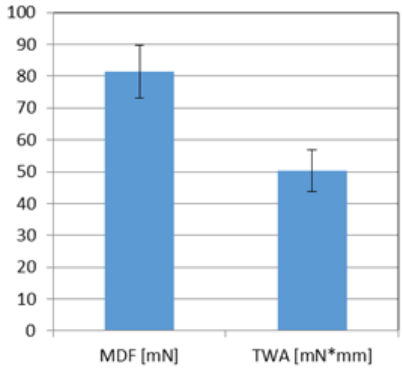

Fig.4.Maximum detachment force (MDF) and work of adhesion (TWA) for the tested bolus material

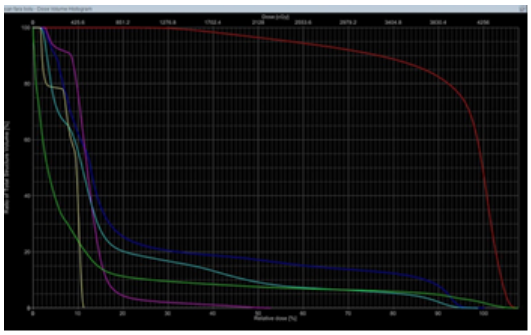

Fig.5. Dose-volume histogram without bolus

Table 3

DOSE DISTRIBUTION WITHOUT BOLUS

View	DVH Line	Structure	Volume [cm³]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
☑		Body	26337.2	0.0	107.7	11.7
☑		Lungs	2597.2	1.1	100.3	24.3
☑		Heart	477.0	2.6	52.8	12.5
☑		Spinal cord	38.5	1.6	11.4	7.9
☑		Liver	1031.4	0.8	98.9	18.0
☐		CTV T	705.8	17.6	107.7	94.6
☑		PTV T	962.8	16.5	107.7	94.6

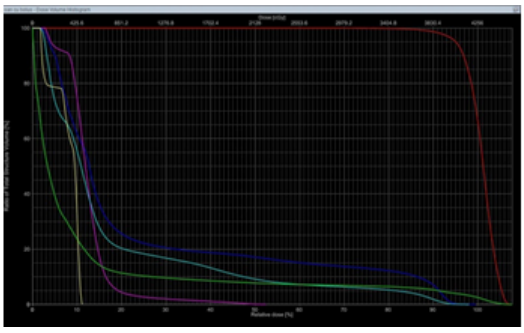

Fig.6. Dose-volume histogram with bolus

Table 4

DOSE DISTRIBUTION WITH BOLUS

View	DVH Line	Structure	Volume [cm³]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
☑		Body	26337.2	0.0	107.7	12.1
☑		Lungs	2597.2	1.1	99.6	24.1
☑		Heart	477.0	2.7	52.7	12.5
☑		Spinal cord	38.5	1.7	11.3	7.9
☑		Liver	1031.4	1.6	98.2	18.0
☐		CTV T	705.8	83.0	107.6	101.8
☑		PTV T	962.8	48.2	107.7	100.8

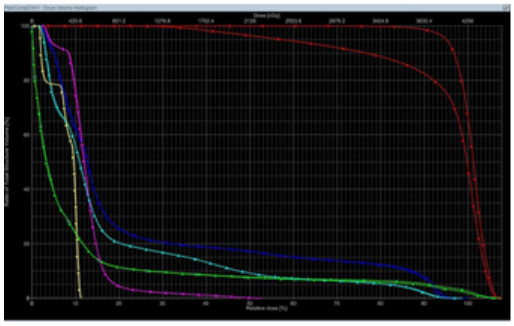

Fig.7. Comparative dose-volume histogram

Table 5

COMPARATIVE DOSE DISTRIBUTION

View	DVH Line	Structure	Volume [cm³]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
☑		Body	26337.2	0.0	107.7	12.1
☑		Lungs	2597.2	1.1	99.6	24.1
☑		Heart	477.0	2.7	52.7	12.5
☑		Spinal cord	38.5	1.7	11.3	7.9
☑		Liver	1031.4	1.6	98.2	18.0
☐		CTV T	705.8	83.0	107.6	101.8
☑		PTV T	962.8	48.2	107.7	100.8
☑		Body	26337.2	0.0	107.7	11.7
☑		Lungs	2597.2	1.1	100.3	24.3
☑		Heart	477.0	2.6	52.8	12.5
☑		Spinal cord	38.5	1.6	11.4	7.9
☑		Liver	1031.4	0.8	98.9	18.0
☐		CTV T	705.8	17.6	107.7	94.6
☑		PTV T	962.8	16.5	107.7	94.6

Following the analysis of the two treatment plans, the approved plan was the plan with the bolus. Figure 8 shows the position of the bolus on the right part of the treated patient's chest.

Checking the patient's treatment position and the bolus position on the skin (avoiding air gaps and for good reproductibility) was performed imagistically in the treatment room prior to irradiation (fig. 9).

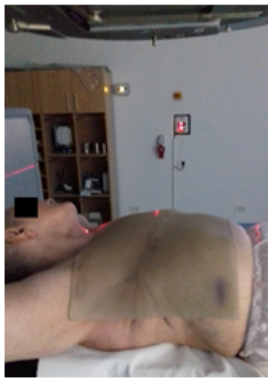

Fig.8. Pacient with bolus on the right chest wall

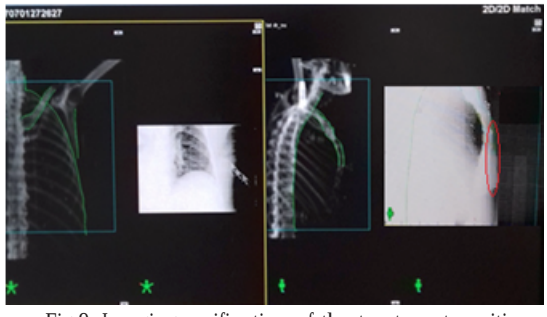

Fig.9. Imaging verification of the treatment position

Conclusions

Bolus materials are used during the high energy photon and electron radiation treatments of the different body areas (head and neck, chest wall, vulva) in order to deliver the full prescribed dose to the skin surface. Because of the risc from late atrophy associated with the bolus use, some radiation oncologists do not use the bolus or use it for only half of the number of fractions. Even if this late toxicity is

possible, the benefit regarding PTV covering is higher and the use of bolus is recommended in the selected patients. The thickness of the applied bolus is dependent on the skin dose required, on the treatment technique and must be equal to the depth of the build-up region for the removal of the skin-sparing effect of a high energy radiation.

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