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Simulated Surgery on CT and MR images: an Aid for Intraopertive Radiotherapy

M. Desco[a], J.Lopez[a] ,F. Calvo[b], A. Santos[b], A. Santos[c], F. del Pozo[c], P.Garcia-Barreno[a]

[a] Medicina Experimental, Hospital General Universitario "Gregorio Marañón", C/ Dr. Esquerdo 46, 28007 Madrid, Spain

[b] Servicio de Radioterapia. Hospital General Universitario "Gregorio Marañón", C/ Dr. Esquerdo 46, 28007 Madrid, Spain

[c] Grupo de Bioingeniería y Telemedicina.Universidad Politécnica de Madrid.ETSI Telecomunicación. Ciudad Universitaria s/n, 28040 Madrid.(Spain).

1. Introduction

Intraoperative radiation therapy (IORT) is a treatment technique which combines surgery and radiotherapy: A high single dose of fast electrons is delivered in a surgically defined area, while trying to protect normal tissues from the radiation beam, either by retracting the mobile structures or by shielding the fixed ones.

Before the radiation, it is necessary to define the organs and structures adjacent to the tumour that have to be protected from the radiation beam.

Special collimating devices, know as 'applicators', are used to shape the beam for optimal performance.

Almost all modern radiotherapy procedures require the planning and dose definition to be performed on tomographic studies (CT or, sometimes CT/MR).

In contrast, IORT procedures pose significant problems for dosimetry planning as the surgical pre-radiation procedure introduces significant changes in the patient geometry; therefore any pre or post-operative CT or MR images do not correspond to the actual geometry during the radiation.

There are different causes for this mismatch:

1.- Tumor excission and surgical separation of mobile structures from the beam trajectory.

2.- Insertion of collimating devices (applicator).

3.- Sometimes, global geometrical distortion due to the use of surgical instruments.

Because of these reasons, dosimetry is very difficult, frequently producing nothing better than rough approximations. Thus, any procedure able to improve the quality of the dosimetry could be extremely helpful for the radiotherapist.

In this paper we propose an approach based on an interactive computer-assisted modification of pre-operative CT or MR scans in order to make them match the situation when the radiation is applied (*surgery simulation*). The program can be used as a pre-treatment tool to better plan the intervention or in 'a posteriori' way, to allow an exact dosimetry.

2. Material and Methods

The program has been developed on a non-product version of a PHILIPS EasyVision CT/MR workstation, which allows the addition of experimental software.

CT data came either from a PHILIPS or a SIEMENS scanner. MR data were produced with a PHILIPS ACS 1.5T machine. The LINAC is a PHILIPS SL-18 and the planning system is a FOCUS.

Clinical requirements for the system stated that the program should be fully interactive, icon and mouse driven, and it should allow for a complete 3D handling of the patient images and collimator positioning.

The whole data set is displayed in the three small orthogonal views, initially representing the axial, saggital and coronal planes. The user can easily set any other orientation (for instance, the beam's point of view is sometimes useful). One of the views can be copied to a larger viewport, where it is manually edited, simulating the surgical removal of objects.

The program has three working modes: The first one ('EDITION') allows the radiotherapists to interactively modify the pre-operative CT or MR images in order to make them match the final geometry of the area. The second mode ('INSERTION') provides tools for the collimator re-positioning in 3D, until an adequate fit is achieved. Position of the collimator is continuosly displayed on the viewports (Figure 1).

In the the third mode ('RESULTS'), and once the images adequatly resemble the surgical situation, the user can display approximate isodose curves (standard curves previously obtaned in a water phantom for all the collimator types and available energies) (Figure 2).

These results may be used to redefine the planning (collimator type, energy, surgical approach).

Besides this approximate dosimetry, in order to generate the exact dose distribution, a new dataset including all the editings may be built up and exported into a standard planning system.In this case, the surgery simulation could be considered a kind of pre-processing before standard dose calculation is performed.

For both image input and output the program make use of standard image formats (ACR-NEMA, DICOM,...), though it is also necessary to deal with proprietary formats, as part of the involved equipment in our site does not comply with these standards yet.

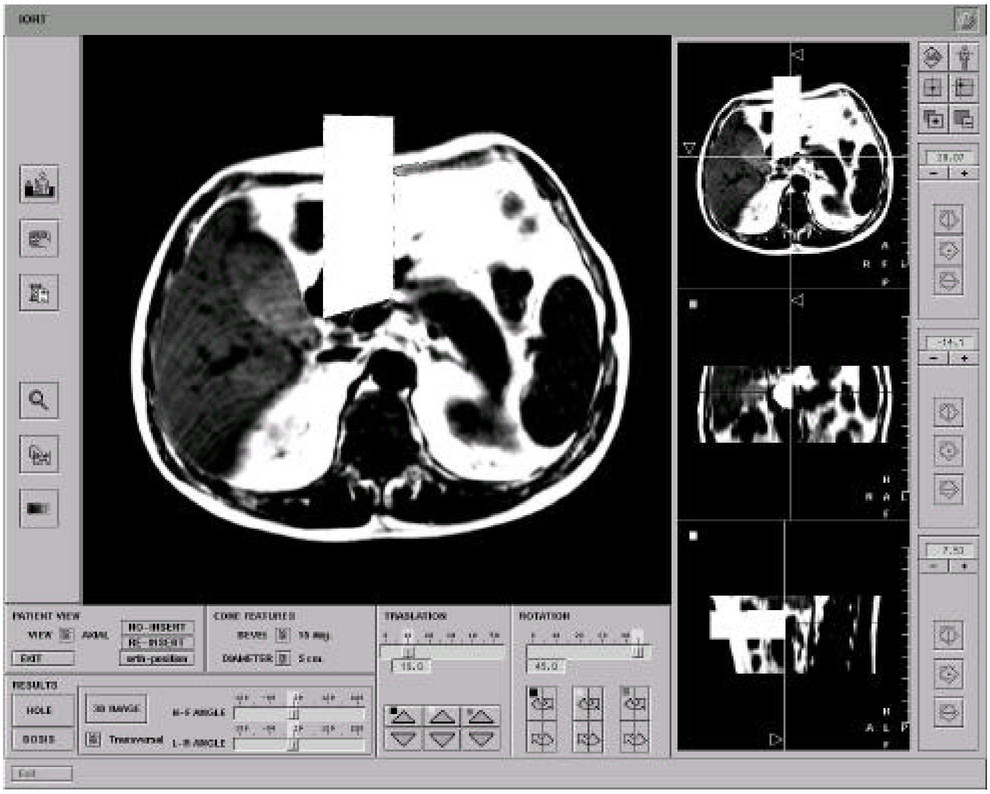

Figure 1: Program desktop arrangement

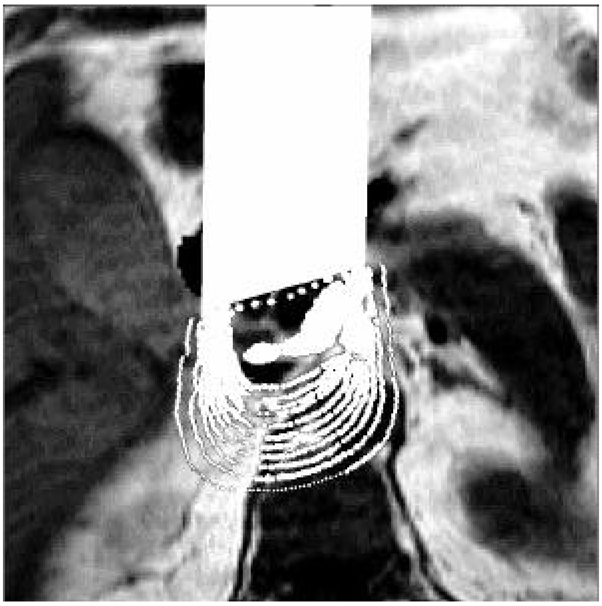

Figure 2: Approximate isodose curves as a colour overlay on the image

3. Results and Conclusions

After initial tests performed on five patients, the radiotherapists have reported the approximate dosimetry tool as a useful feature for initial planning. However, results are not reliable in certain cases where the phantom curves do not exactly fit the situation (for instance, bone structures). Results can also be inaccurate when blood collections appear in the beam trajectory, as they can substantially modify the electron isodose distribution.

Transferring data for exact dosimetry was considered very slow and, thus, only valuable for post-surgical precise dose control. The clinical trial is still on course in order to better assess all these points.

The overall impression is that the procedure may substantially improve the quality, reliability and safety of IORT treatment by allowing a more precise dosimetry.

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