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Real time brachytherapy for prostate cancer – A new challenge for medical physicists

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Summary

Background

The paper present the “real time” brachytherapy for planning prostate cancer. The differences between treatment planning for “traditional” and “real time” brachytherapy, from the point of view of the medical physicist, are taken into account and each step of treatment planning is presented.

Aim

The aim of the paper was to present the difference between in “conventional” and “real time” planning treatment from the point of view of medical physicist.

Materials/Methods

Two significant aspects of treatment planning in “real time” brachytherapy are underlined. The first is connected with the place of work of the medical physicist (operating room), and the second one regarding the time (patient is under spinal anesthesia).

Results/Conclusions

Treatment planning and patient treatment, based on Ultrasound examinations, allows us to minimize topographical errors during the application of brachytherapy.

Key words

virtual plan • live plan • Real Time brachytherapy

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BACKGROUND

The purpose of this study is to present a method for brachytherapy in cases of prostate cancer, and the planning of dose delivery, done on the basis of ultrasound scans carried out during the therapeutic procedure. The participation and role of the medical physicist in such therapeutic procedures has grown significantly in current clinical practices linked to treatment planning. In this study we present a procedural algorithm for "Real Time" brachytherapy.

MATERIALS AND METHODS

The planning of dose distribution is performed on the bases of computed tomography, magnetic resonance and, in recent years, by the use of ultrasonography [1,2]. The treatment planning based on ultrasound scans, performed during therapeutic treatment, offers an improved quality situation for physicists involved in treatment planning. Until now, in radiotherapy and brachytherapy, the process of preparing a patient for (therapeutic) irradiation was spread in time. That being the case, the time of beginning brachytherapy was, and in the majority of clinical situations is, determined by the time taken to prepare the treatment plan. The plan was prepared by a physicist, usually without the presence of a medical doctor. During this time, while patient remained at home, the treatment plan could be modified several times, until it was acceptable to the responsible physician. In "traditional" brachytherapy, the time for preparing dose distribution and applicators is also time consuming. There are situations when the treatment plan can be prepared during surgical procedures (e.g. brachytherapy of pancreatic carcinoma) but these will not be described on this paper because, in such cases, treatment plans prepared by physicists are produced in a treatment planning room, using models for the positioning of implanted applicators.

The situation in the planning and execution of brachytherapy for prostate cancer, based on ultrasonography, is completely different (Figure 1).

The procedure is carried out under completely sterile conditions, in HDR bunkers, which fulfil the requirements for an operating theatre (Figure 2).

During the procedure the patient is anaesthetized – spinal or general – and remains under the care of an anaesthesiologist. Transrectal ul-

trasonography permits the designation of areas for irradiations and organs at risk areas [3]. Next the treatment plan is prepared, in which the physicist defines the number of needles to be used, their positioning, and also chooses an appropriate optimization method steps [4], thereby obtaining the arrangement of doses. Such a prepared treatment plan is called as virtual plan (VP). This is the optimal plan for the point of dose distribution spread, though at the same time it is a theoretical plan, with the assumption that the needles are positioned in parallel and their coordination is in agreement with calculations. In clinical practice, this condition is very rarely fulfilled because it is difficult, in arranging the needles to approach the prostate, to ensure their parallelism. The next stage of the procedure is to penetrate the body of the patient with the needles. This activity is carried out under ultrasound guidance, through the use of plates with openings – arranged perpendicularly to the ultrasound probe – through which the needles are arranged into the coordinates planned in the TPS calculations (Figure 3). Using the monitor screen, it is possible to position the inserted needle very exactly. Strict cooperation of the physicist and the physician at this stage of the procedure is necessary. The physicist responsible for the plan gives the physician the coordinates calculated by the TPS for each needle in turn, and these are guided into the area of the prostate gland, in line with the coordinates.

After the insertion of all of the needles, the physician verifies their positioning with a further ultrasound scan. This stage of brachytherapy may be compared with 4D radiotherapy planning, in which the positioning of organs at risk is verified before irradiation. The positioning of each needle is modified in the treatment planning system so that the TPS coordinates agree with the actual positions. It can be seen from clinical experience, that the coordinates of each needle may be approximated, because the difference between the planned positions (theoretical) and the actual positions are in the region of several millimeters. A very important element is modeling agreement between the coordinates from the ultrasonograph and those from the TPS. This calibration should be performed before every procedure [5]. After defining the actual positions of the needles, it is necessary to redefine the area to be irradiated and critical organs, because the prostate gland, after the application of needles, may be altered in its dimensions, relative to critical structures [6]. The difference in prostate vol-

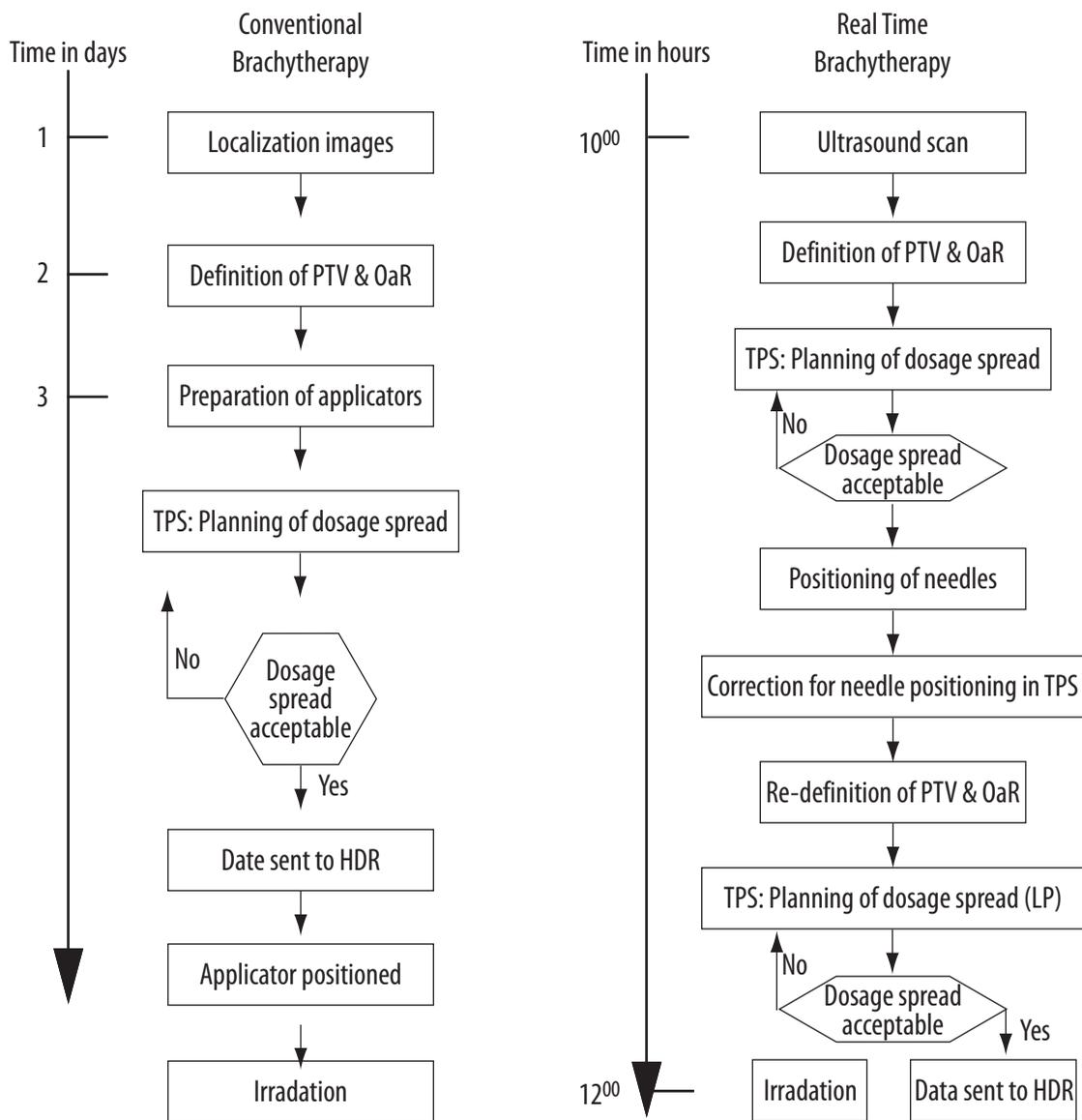


Figure 1. Basic algorithms (procedural) for planning and treatment in radio and brachytherapy by classic and real time techniques. VP – The virtual plan is the treatment plan as it stands after definition of PTV and OaR. LP – the live plan is that which is finalized after insertion of the needles.

ume, before and after application of the needles, is in the region of several percent. The next step of the procedure is the calculation of dose distribution spread. It is necessary to perform optimization. This planning stage may be very time-consuming because, as the physicist can not change the position of the needle, only the parameters may be optimized in order that the dose distribution spread in PTV and OaR (Organ at Risk) remain as accepted by the physician. Such a prepared treatment plan is known as the Live Plan (LP). The plan is assumed to be acceptable if

90% of the therapeutic dose will be delivered to 95% of the volume of the prostate gland and if no more than 10% of the volume of the ureters (one of the organs at risk) receives a dose higher than 125% of the planned dose.

One must remember that, at the time of dose calculation, the patient is to be found several meters from the planning physicist. This is a completely new situation for physicists. The quiet office in which treatment plans are prepared is replaced by an operating theatre. After acceptance of the



Figure 2. Group: anesthesiologist, radiotherapist, medical physicist, nurse, technicians work under operating theatre conditions. The time for completion of the procedure is determined by the time the patient’s anesthesia will last.

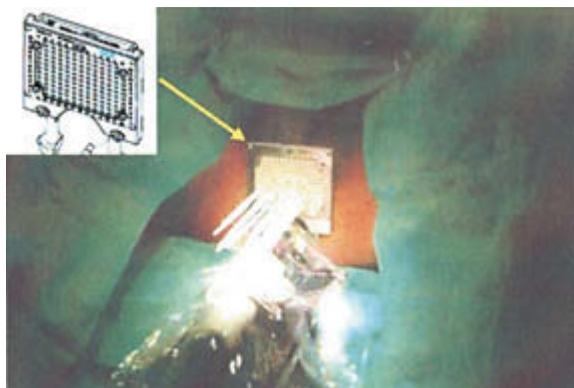


Figure 3. Arrangement of coordinates in agreement with the treatment planning system. This system cannot ensure the even spacing of needles inserted into the body of the patient. Coordinates from ultrasonography must be in agreement with coordinates from the treatment planning system.

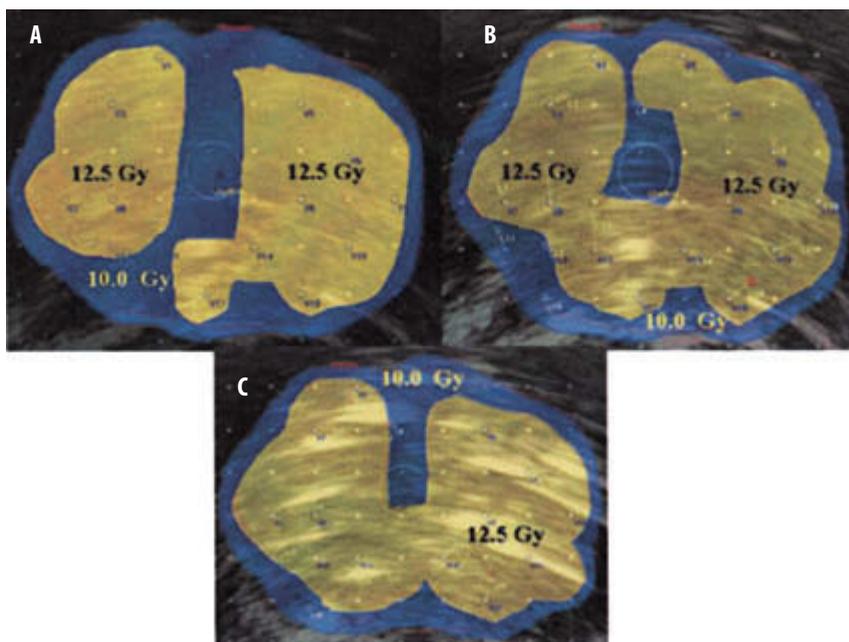


Figure 4. The virtual plan (VP) A – This plan is accepted for use in treatment if it fulfils all the planned optimal conditions (at least 90% of the therapeutic dose is delivered to 95% of the volume of the prostate gland while no more than 10% of the volume of the ureters receives a dose in excess of 125% of the planned dosage). B – Dose distribution for proper needle locations but with “virtual” positioning and source stoppage times. C – Dose distribution after optimization for actual needle positioning. The purpose of this process is not to correct the theoretical dose distribution but to minimize the likelihood of ‘geographical’ errors.

live plan, it is sent to the HDR therapy device. Figure 4 shows the live plan (LP) and the theoretical or virtual plan (VP).

At this point it is necessary to point out that the purpose of the live plan is not to correct the virtual plan, which was accepted and formed the basis for the insertion of needles into the patients’ body, but to minimize the likelihood of making a ‘geographical’ error in the positioning of the nee-

dles, relative to the planned positions. In practice it may be that, after re-optimization, the dose distribution spread of the live plan is more useful, from the therapeutic point of view, than that of the virtual plan. Such situations are very helpful but are “accidental” because the planning physicist, optimizing the treatment plan at this stage, can only choose factors and optimization methods, such as geometry and volume, and cannot change the positioning of the needles.

CONCLUSIONS

Real Time brachytherapy procedures have been carried out in the Oncology Institute in Gliwice since March, 2003. During this time 50 such procedures have been performed. Patients qualifying for brachytherapy were in stage T1-3, NxMo. Planned are one-time doses for the whole of the gland, 10 Gy, 100% isodose, according to the planning conditions described above [7]. Equipment and software applied is produced by the firm, Nucletron. The irradiation device is an HDR microselectron v: 1.0.X (Nucletron) and the treatment planning system is a SWIFT v: 2.0 applicator system (Nucletron). Ultrasound scans were performed using a model 2101 ultrasonograph, produced by the firm Falcon. All the above equipment was connected to the information system and data is automatically sent for acceptance. All information about the patient, the planned dose distribution spread in both the live and virtual plans, and the ultrasound images are recorded in a database. The group carrying out the procedures consists of a radiotherapist, an anaesthesiologist, a medical physicist, a nurse and a radiographer. The entire procedure lasts for a maximum of 2 hours.

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