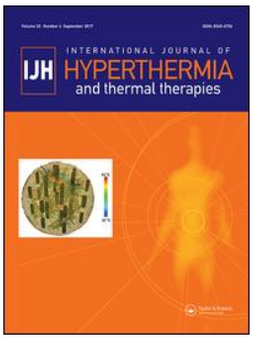

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RESEARCH ARTICLE

Does microwave interstitial hyperthermia prior to high-dose-rate brachytherapy change prostate volume or therapy plan parameters?

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Abstract

Purpose: In this prospective preliminary study we evaluated changes of prostate volume and changes of brachytherapy treatment plan parameters due to interstitial hyperthermia (IHT) applied prior to high-dose-rate brachytherapy (HDRBT), compared to our standard HDRBT procedure. *Material and methods*: In a group of 60 consecutive patients with prostate adenocarcinoma, 30 were treated with HDRBT alone and 30 with IHT preceding HDRBT. Prior to catheter implantation, a 'virtual' treatment plan (VP) was complied, a 'live' plan (LP) was prepared before patient irradiation, and a 'post' plan (PP) was drawn up after completing the irradiation procedure. In each plan, based on transrectal ultrasound images, the contours of the prostate, urethra, and rectum were delineated and the respective volumes and dose–volume histogram parameters were evaluated. These parameters, established for the LP, were then compared with those of the PP. *Results*: Changes in prostate volume and in parameters of the treatment plans were observed, but differences between the two patient groups were not statistically significant. For all 60 patients treated, the average prostate volume in the VP was 32 cm^3, in the LP 41 cm^3, and the PP 43 cm^3. Average values of relative changes in the therapy planning parameters between LP and PP were for the prostate D90 −5.7%, V100 −5.6%, V200 −13.2%, for the urethra D0, 1 cm^3 −1.6%, and for rectum D2 cm^3 0%. *Conclusion*: Hyperthermia prior to HDRBT does not significantly change the volume of the prostate and there is no need to perform the new treatment plan after the hyperthermia session.

Keywords

Dosimetry, high dose rate brachytherapy, interstitial hyperthermia, prostate cancer, volume change

History

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Introduction

High-dose-rate brachytherapy (HDRBT) delivers a highly localised dose of radiation to the prostate. Here, the rapid decrease in dose with distance is helpful in protecting the healthy tissues and organs surrounding the treated volume. HDR brachytherapy is applied in treating prostate cancer alone, as a boost therapy after external beam treatment, or as a salvage treatment after failure of first-line treatment [1,2]. In HDR brachytherapy many different fractionation schemes, in terms of dose, number of implants, or number of fractions per implant, have been described in the literature [1,2].

Hyperthermia is a very potent radiosensitiser. As shown by the results of randomised trials [3–6], hyperthermia administered in combination with radiation therapy may significantly increase the probability of local cure. From *in vitro* studies of human prostate cancer cell lines, the thermal enhancement ratio (TER) may range between 1.4 and 2.0 [7]. Several methods of heat delivery are available in the treatment of prostate adenocarcinoma, such as deep regional [8–11], interstitial [9,10,12,13] or transrectal hyperthermia [14,15]. Interstitial hyperthermia may be performed using the same guiding catheters which are later used to deliver the brachytherapy dose, or concurrently with irradiation [16,17].

Implantation of catheters causes trauma, resulting in a possible swelling of the prostate, which may affect the dose delivered to the target volume and to the surrounding healthy tissues [18–20]. Hyperthermia can also increase perfusion, further enhancing the mechanism of gland swelling [21].

Interstitial hyperthermia (IHT) in combination with HDRBT in the treatment of local recurrence of prostate cancer after radical external beam radiotherapy (EBRT) was launched at the Centre of Oncology in Krakow in 2008. In 2011 we implemented a similar protocol in patients with primary prostate cancer treated with a HDRBT boost after EBRT.

Hyperthermia prolongs the treatment time by about 30–55 min. The combined treatment procedure is performed

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under spinal anaesthesia. We have observed that in some patients in whom the prostate is heated, clinically significant prostate volume changes and shifts in catheter positions occur, implying a possible change in the optimum treatment plan.

The purpose of this preliminary study was to establish whether significant changes of the prostate volume and of the parameters of the treatment plan occur in patients in whom IHT was added to the brachytherapy procedure, as compared with our standard HDRBT procedure, and whether these changes require the preparation of a new brachytherapy plan post IHT.

Materials and methods

Patient characteristics

In our study we included 60 consecutive prostate cancer patients treated with transrectal ultrasound (TRUS)-guided HDRBT at the Maria Skłodowska-Curie Memorial Institute of Oncology, Cancer Centre in Krakow between September 2012 and March 2013, and between August 2014 and February 2015. Interstitial brachytherapy was performed either as a part of their first-line therapy (monotherapy or boost), or as salvage therapy (Table 1).

In all patients the prostate cancer was biopsy-proven. Initial staging involved digital rectal examination (DRE), evaluation of prostate-specific antigen (PSA) serum level, and imaging studies to determine the clinical stage of the disease (pelvic ultrasound, pelvic ± abdominal CT or MRI, chest X-ray or CT, and bone scan). No patient had any evidence of nodal or distant metastases. Based on the initial PSA value, the Gleason score and the clinical tumour stage, patients were classified into low, intermediate or high risk groups, according to National Comprehensive Cancer Network guidelines [22]. IHT was offered as an additional treatment modality to all intermediate and high risk group patients and to patients with local recurrence after previous EBRT. Informed consent was obtained from all patients.

The HDR brachytherapy patient group

Of our 30 patients treated with brachytherapy alone, 14 received it as planned monotherapy and 10 as a boost dose. In the case of the remaining six patients, their planned treatment consisting of HDRBT combined with IHT (for five of them as a brachytherapy boost following EBRT, and for one patient as salvage therapy) had to be modified by abandoning their IHT treatment due to premature termination of anaesthesia (three patients), excessive patient mobility (two patients) or at the patient's request (one patient).

Table 1. Treatment characteristics.

	All patients ($N = 60$)	No hyperthermia ($N = 30$)	Hyperthermia ($N = 30$)
HDRBT monotherapy	14	14	0
EBRT and HDRBT boost	30	15	15
HDRBT salvage	16	1	15

EBRT, external beam radiotherapy; HDRBT, high-dose-rate brachytherapy.

The HDR brachytherapy and interstitial hyperthermia patient group

In this group, 15 patients received their combined IHT + HDRBT treatment as a boost after EBRT, and 15 as salvage therapy.

Interstitial hyperthermia procedure

IHT was scheduled before every brachytherapy fraction and delivered using 915 MHz microwave antennas integrated with the BSD 500 system (BSD Medical, Salt Lake City, UT, USA), according to Radiation Therapy Oncology Group guidelines [23]. The aim of the IHT treatment was to bring the peripheral zone of the prostate and the tumour to a temperature of 41–43 °C for 60 min. The IHT procedure was shortened to 30 min or aborted in cases of premature termination of spinal anaesthesia, excessive patient mobility, or at the patient's request. Catheters implanted within the prostate volume during the implantation procedure (described below) were used to place the microwave antennas and the thermistor probes. Eight to 18 interstitial applicators (MA-251, BSD Medical, Salt Lake City, UT, USA) and four to seven temperature sensors for temperature control were used. One temperature sensor was placed in a catheter fixed to the transrectal ultrasound probe which remained in the rectum throughout the hyperthermia and brachytherapy procedures, another one or two were placed in catheters inserted closest to the urethra, and between two and four sensors were placed in the prostate tissue, preferably in areas where lowest or highest temperatures were expected, as predicted by the IHT planning tool.

Brachytherapy procedure

At the Centre of Oncology in Krakow, HDRBT is used in the treatment of prostate cancer as a monotherapy, as a boost after EBRT, or as salvage therapy following histologically proven local recurrence after EBRT. In patients with primary prostate cancer classified within the low-risk group, brachytherapy is administered by delivering a dose of 36 Gy (until 2013 the total dose was 45 Gy) to the prostate volume in three fractions separated by 3 weeks. Patients with primary prostate cancer, classified within intermediate or high risk groups (PSA >10 ng/mL, Gleason score ≥7, T stage ≥2b) not amenable to radical prostatectomy or brachytherapy alone, received a combined treatment programme which included EBRT (50 Gy in 25 fractions of 2 Gy) as the first stage, followed by a boost of interstitial hyperthermia combined with HDRBT of 21 Gy in two fractions, separated by 3 weeks. Patients with only locally recurrent prostate cancer after definitive EBRT received brachytherapy combined with IHT. The total dose administered in this case is 30 Gy in three fractions, each separated by 3 weeks.

We have described the implantation procedure elsewhere [12]. Briefly, the procedure commences by subarachnoid anaesthesia, followed by the patient being placed in the lithotomy position. A Foley catheter is inserted into the bladder to better visualise the urethra. Next, the TRUS probe is introduced. Having found the appropriate position of this probe, two or three catheters are implanted to immobilise the prostate. Images of the prostate with 10–15 mm cranial and

caudal margins are then continuously imported into the treatment planning system (ONCENTRA Prostate®, Nucletron™ Veenendal, Netherlands). The prostate, urethra, and rectum (and, optionally, bladder) are delineated by one of the radiation oncologists (A.M.K. or T.D.) participating in this study. Based on the contoured structures, the medical physicist (R.K., D.N. or D.D.) prepares a 'virtual' treatment plan (VP) in which the initial distribution of catheters is planned. According to the VP, metal needle applicators are inserted transperineally under TRUS-guidance, to be subsequently replaced by plastic catheters. From the subsequent set of TRUS images, a 'live' treatment plan (LP) is elaborated which serves as the base for patient irradiation. The contours of the prostate, rectum and urethra are verified and corrected by the physician. The positions of the catheters are reconstructed and the final treatment plan is prepared by the physicist. A third set of TRUS images – with which the 'post' plan (PP) is elaborated – is gathered about 5 min prior to patient irradiation. After completion of the treatment procedure the physician re-contours the prostate, urethra and rectum volumes. The physicist then, as previously, reconstructs the catheter positions. The same dwell positions and times as those in the LP are applied to the third TRUS data set using the updated applicator positions, by manually entering the dwell times used in the LP.

Assessment of changes in prostate volume

The volumes of the prostate glands of all patients at each stage of their treatment were obtained from TRUS-based data, after their contouring by the physician. The prostate volumes were evaluated prior to catheter implantation (VP), after the implantation procedure (LP), and just before dose delivery (PP). We note that after catheter implantation, the volume of implanted catheters, V_c, will contribute to the prostate volume. The value of V_c in cm^3 can be calculated from the formula $V_c = 0.25\, n\, \pi\, r^2$, where n is the number of dwell positions, and r is the outer radius of the catheter. The step size for the iridium source is 0.25 cm for every dwell position inside the prostate contour, and the radius of the catheter is 0.095 cm.

Assessment of changes in parameters of the treatment plan

The treatment plan parameters were taken from dose–volume histograms (DVH), calculated by the ONCENTRA Prostate® system, for the PP and LP, which may differ due to possible changes in organ volumes and catheter positions. Selected parameters for the prostate, urethra and rectum volumes were compared. For the treated prostate volume, these were D_{90} (the dose covering 90% of the treated volume), D_{mean} (the average dose value in the prostate), and V_{100}, V_{150} and V_{200} (prostate volumes receiving 100%, 150% and 200% of the prescribed dose, respectively) for the urethra, D_{max} and D_{mean} (the maximum and average values of dose in the urethra, respectively), and $D_{0.1cm3}$ (the highest dose in 0.1 cm^3 of the urethra volume) for the rectum, D_{max} and D_{mean} (the maximum and average values of dose in the rectum volume, respectively), and D_{2cm3} (the highest dose in 2 cm^3 of the rectum volume). The aim in plan optimisation was to achieve at least 95% of the prescribed dose in 90% of the prostate volume (PTV), i.e. $D_{90} > 95\%$, an acceptable level being 90%. The PTV volume receiving 200% of the prescribed dose should not exceed 15%. The maximum dose values, D_{max}, in the urethra and rectum should not exceed 125% and 80% of the prescribed dose, respectively. Since 2013 we have used $D_{0.1cm3} < 115\%$ as the dose constraint for the urethra, and $D_{2cm3} < 65\%$ of the prescribed dose for the rectum. The treatment plan parameters of the PP were established by introducing exactly the same dwell times, in the same positions, in the same catheters, as those which had been used earlier in the LP.

Statistical analysis

Changes in prostate volumes in groups of patients with or without hyperthermia were evaluated in absolute terms, separately for each group, using the Mann Whitney U test and Student's *t*-tests. To analyse changes in parameters of the treatment plan analysis of variance for multiple measurements was used to evaluate the differences, separately for the prostate (PTV), urethra and rectum volumes, the level of significance being set at $p < 0.05$.

Results

In Supplementary Table S1, for each patient undergoing BT alone, or preceded by IHT (IHT + BT), the volume of prostate in the VP, the number and total volume of catheters implanted, the duration of hyperthermia (if applied), the volume of prostate in LP and PP, and the differences (absolute and relative to the virtual volume) between live and virtual prostate volumes (after correction for the volume of implanted catheters) and between PP and LP prostate volumes (absolute and relative to LP prostate volume) are listed. Over all 60 patients the median number of catheters implanted was 18 (range 14–23). The mean volume of implanted catheters was 1.8 cm^3 (range 1.2–2.6 cm^3). The median duration of the brachytherapy procedure (time between applying anaesthesia to the patient until the post-plan was elaborated) was 130 min (range 90–215 min) in the HDR alone group and 180 min (range 150–220 min) in the BT and hyperthermia treatment group. The median time between TRUS for LP and TRUS imaging for PP was 65 min (range 35–130 min) in the HDRBT alone group, and 111 min (range 90–135 min) in the IHT + BT treatment group.

Hyperthermia and thermometry parameters

The median time of the hyperthermia was 58 min (range 50–60 min). The median values of maximum and minimum temperatures in the prostate were 42.8 °C (range 40.4–43.7 °C) and 38.6 °C (range 37–40.5 °C) respectively. The median for the maximum 'thermal dose' which is equivalent to the time that the tissue remained at the temperature of 43 °C was 31 min (range 1–81 min). The values of the 'thermal dose' parameter were obtained from the BSD 500 system which calculates them assuming stationary thermometry.

Volume change

Due to the relatively small number of patients, no attempt was made to separate the patient groups with respect to their

prostate volumes (i.e. small, medium or large). The median volume of all 60 patients was $32.3 \pm 11.0\,cm^3$ in their VP, and $41.4 \pm 12.4\,cm^3$, and $43.0 \pm 12.5\,cm^3$ in their LP and PP, respectively.

By comparing the V_{VP}, V_c and V_{LP} volumes in Supplementary Table S1 for each patient, a systematic increase of prostate volume between VP and LP may be noticed. Indeed, the difference $V_{LP} - (V_{VP} + V_c)$ yields a mean value of $+7.3\,cm^3$ with a standard deviation of $3.7\,cm^3$ ($N = 60$). This would indicate that in the case of our patients, the swelling of their prostate volume with respect to the VP, due to mechanical trauma, after correction for the volume of catheters, is by about $+7.3\,cm^3$ (mean value for all 60 patients), with a standard deviation of $3.7\,cm^3$. This value of standard deviation, of about $3.5\,cm^3$, could be indicative of the absolute error of determining the prostate volume by the physician.

From the values of LP and PP volumes, and their percentage differences listed for each of the 60 patients in Supplementary Table S1, the mean relative change in prostate volume between PP and LP was found to be 4.1% (range −6.8–17.6%) this difference being statistically significant ($p < 0.05$). For patients without hyperthermia this mean value is +3.9% (SD 3.9%, $N = 30$) and for patients with hyperthermia it is +5.2% (SD 5.3%, $N = 30$). In patients with hyperthermia the relative change in prostate volume is somewhat larger, but this difference is not statistically significant ($p = 0.51$), whereas the absolute change in prostate volume is slightly lower compared to the brachytherapy alone group ($6.9\,cm^3$, SD $4\,cm^3$ vs. $7.7\,cm^3$, SD $3.5\,cm^3$, $p = 0.41$). We found no statistically significant difference between the two groups of patients ($p = 0.000047$ for 30 patients without hyperthermia and $p = 0.000108$ for 30 patients with hyperthermia), thus we conclude that hyperthermia does not significantly change the volume of the prostate. We have also found no differences in prostate volume or volume changes between the groups of patients treated with radical or salvage intent (Table 2).

DVH parameter changes

The average values of DVH parameters calculated for all 60 patients and for the two groups of 30 patients each (BT alone or IHT + BT), are listed in Table 3.

We justify this form of presentation in terms of mean values by having earlier established that no statistically significant changes of prostate volumes (in LP vs. VP, corrected for V_c) after HDRBT were stated. While some changes in the values of DVH parameters between LP and PP are observed, no differences between the two groups of patients were statistically significant ($p > 0.07$).

The changes between LP and PP in the mean values of the parameter D_{90} for the prostate volume are −5.7% (range −24.1–2.4%), for V_{100} −5.6% (range −34.3–2.0%), and for V_{200} −13.2% (range −67.8–7.1%). For the urethra and rectum volumes respectively, the mean values of parameters $D_{0,1cm3}$, and D_{2cm3} change by −1.6% (range −20.7–8.1%) and 0.0% (range −27.1–37.8%) when calculated for all 60 patients.

Discussion

Changes in prostate volume play an important role in prostate cancer therapy using low dose rate brachytherapy (iodine-125 or palladium-103 seeds) [19,20], because of the extended

Table 2. Mean values of prostate volume parameters for patients treated with radical intent ($N = 44$) and patients treated with salvage intent ($N = 16$). All errors are standard deviations (SD) around the mean.

	Radical treatment ($N = 44$)	Salvage treatment ($N = 16$)	p Value
VP volume (cm^3)	33.12 ± 11.8	29.89 ± 8.5	0.32
LP volume (cm^3)	42.50 ± 12.8	38.21 ± 10.9	0.24
PP volume (cm^3)	43.93 ± 12.9	40.31 ± 11.4	0.33
volume change (%)	3.63 ± 4.8	5.55 ± 5.4	0.19
volume change (cm^3)	7.58 ± 3.4	6.54 ± 4.7	0.34

LP, live plan; PP, post plan; VP, virtual plan.

Table 3. Mean values of treatment plan parameters, based on live plan and post plan dose–volume histograms (DVH) for all patients ($N = 60$), for patients treated without-hyperthermia ($N = 30$), and for patients treated with hyperthermia ($N = 30$). All errors are standard deviations (SD) around the mean.

	All patients ($N = 60$)				No hyperthermia ($N = 30$)				Hyperthermia ($N = 30$)			
DVH parameter	Live plan	Post plan	Mean change	p Value	Live plan	Post plan	Mean change	p Value	Live plan	Post plan	Mean change	p Value
Prostate volume (cm^3)	41.4 ± 12.4	43 ± 12.5	1.6	<0.05	41.6 ± 8.5	43.1 ± 8.8	1.5	<0.05	41.1 ± 15.5	42.8 ± 15.5	1.7	<0.05
PTV/prostate												
D_{mean} (%)	141.6 ± 3.6	136.2 ± 6.1	−3.8	<0.05	140.1 ± 3.4	136.2 ± 3.7	−2.8	<0.05	143.1 ± 3.1	136.2 ± 7.9	−4.8	<0.05
D_{90} (%)	102.6 ± 2.6	96.7 ± 6.1	−5.7	<0.05	103.0 ± 2.2	98.0 ± 5.6	−4.8	<0.05	102.2 ± 2.9	95.3 ± 6.3	−6.6	<0.05
V100 (%)	92.1 ± 2.1	86.9 ± 6.5	−5.6	<0.05	92.5 ± 1.7	88.7 ± 4.1	−4.1	<0.05	91.7 ± 2.3	85.0 ± 7.8	−7.2	<0.05
V150 (%)	29.4 ± 4.3	25.4 ± 5.1	−13.0	<0.05	27.3 ± 3.9	24.6 ± 3.6	−9.7	<0.05	31.5 ± 3.7	26.3 ± 6.2	−16.3	<0.05
V200 (%)	8.1 ± 1.7	7.0 ± 1.8	−13.2	<0.05	7.3 ± 1.9	6.6 ± 1.4	−10.0	<0.05	8.8 ± 1.6	7.4 ± 2.1	−16.5	<0.05
Urethra												
D_{max} (%)	116.8 ± 2.4	120.8 ± 17.2	3.5	0.07	116.5 ± 2.5	118.3 ± 14.2	1.6	0.49	117.1 ± 2.4	123.3 ± 19.6	5.3	0.09
D_{mean} (%)	96.0 ± 6.5	94.1 ± 7.5	−1.8	<0.05	95.3 ± 6.6	94.0 ± 6.5	−1.3	<0.05	96.6 ± 6.4	94.3 ± 8.5	−2.4	<0.05
$D_{0.1cm3}$	113.4 ± 2.0	111.6 ± 5.8	−1.6	<0.05	112.7 ± 1.9	111.8 ± 3.3	−0.8	0.11	114.1 ± 1.8	111.4 ± 7.7	−2.3	0.06
Rectum												
D_{max} (%)	82.3 ± 4.7	85.2 ± 10.1	3.6	<0.05	81.4 ± 2.5	84.9 ± 8.9	4.4	<0.05	83.1 ± 6.0	85.4 ± 11.4	2.8	0.21
D_{mean} (%)	46.4 ± 4.3	46.7 ± 4.4	0.8	0.64	46.0 ± 3.8	46.7 ± 3.2	1.9	0.20	46.9 ± 4.8	46.6 ± 5.4	−0.2	0.75
D_{2cm3}	59.1 ± 4.1	59.0 ± 5.9	0.0	0.93	59.2 ± 4.1	59.3 ± 4.8	0.3	0.79	59.0 ± 4.1	58.8 ± 6.9	−0.3	0.82

DVH, dose–volume histogram; PTV, Planning Target Volume.

period of dose delivery involving weeks or even months. In the case of HDR brachytherapy where multiple fractions per implant are applied there is also a possibility that catheters will move between fractions, thus changing implant geometry [18,24,25]. Such movement can affect the optimised conditions of treatment plans, leading to clinical implications due to, for example, reduction of dose delivered to the PTV or increase of dose to critical organs.

In our treatment protocol we use one fraction per implant, so we avoid interfraction catheter migration which negatively affects the quality of dose delivery in brachytherapy [24]. The hyperthermia session precedes the brachytherapy procedure and takes place at a time at which the PTV and organs at risk are re-contoured, the catheter positions are decided upon and the treatment plan is prepared and optimised. As the hyperthermia procedure extends the overall period of treatment by about 30–50 min, increasing the risk of excessive mobility of the patient, we are considering the replacement of subarachnoid by epidural anaesthesia.

We note that due to the relatively small number of patients (30 in each group) our results are preliminary in character. In our material we found statistically significant changes in the PTV therapy planning parameters, all tending to decrease in the PP with respect to the LP. This observation is consistent with other reports concerning prostate cancer brachytherapy [18–20,24–26]. The decrease in the delivered dose in our material is slighter than that reported by Foster et al. [24]. This may be related to our implanting procedure (one fraction per implant vs. multifraction) and to our different set-up errors (intrafraction vs. interfraction). The mean PTV V100 decrease in our patients was about 5%, while Foster et al. report a decrease of some 20%. We also found no statistically significant changes of therapy planning parameters in the critical organs, except for an increase in the average dose in the urethra (D_{mean}), maximum dose in the rectum (D_{max}), and the highest dose in 0.1 cm^3 of the urethra ($D_{0.1cm3}$). The most important result of our preliminary study is that we found only a slight increase of the prostate volume due to mechanical trauma (on average 7.3 cm^3, i.e. 17.9% per 60 patients) and no statistically significant differences with respect to prostate volume and therapy plan parameters in patients treated with interstitial brachytherapy alone and with interstitial brachytherapy preceded by hyperthermia.

One of the effects of hyperthermia is increased perfusion. Van Vulpen et al. [21] consider that interstitial hyperthermia – as compared to deep hyperthermia – causes a particularly large increase in blood flow through the prostate, which may be associated with trauma after catheter insertion. High perfusion may increase the prostate extravasation of blood from damaged vessels by the catheters [21]. The implanted needles may induce a severe inflammatory response to mechanical tissue damage. An important role is played by vascular mechanisms such as vasodilatation (which enhances perfusion) and vascular leakage (causing swelling) [19]. Perhaps the response to vascular injury has a higher impact on the perfusion of the prostate than heat alone, which appears to support our observation of no significant differences in changes in prostate volumes between groups of patients with brachytherapy alone and brachytherapy preceded by hyperthermia. Foster et al. reported a significant decrease of the mean prostate volume 24 h after implantation (by 3.89 cm^3, or by −11%) [22], as do Kim et al. [18] in eight of 13 patients after an average period of 20 h post implantation.

Various mathematical methods of assessing changes in prostate volume have been described [18–20]. These models typically do not account for changes in the shape of the prostate as a result of catheter implantation. Intra-observer variability in prostate contour delineation should also be considered, as it may affect the values of therapy planning parameters. To minimise this effect, the contours of the prostate in the LP and PP planning were verified by another radiation oncologist who did not perform the implantation procedure. Corrections of the prostate contours after catheter insertion may be uncertain due to possible misinterpretation of ultrasound images, caused by artefacts resulting from the presence of several applicators [27]. Similar difficulties may arise in the reconstruction of the catheter positions. In brachytherapy, dose decreases rapidly with distance from the source, so even a small error in the reconstruction of the position of the catheters may significantly affect the values of therapy planning parameters.

Conclusion

In our study we found that the addition of interstitial hyperthermia to HDR brachytherapy of the prostate incurs no significant changes in the volume of the prostate, nor in the values of parameters of the treatment plan. However, we observed changes in volume and therapy plan parameters of the PTV (i.e. of the prostate) in the LP and PP therapy. As seen from the comparison between prostate volumes in VP and LP, after correction for the volume of catheters implanted, some increase of the prostate volume (on average, by 7.3 cm^3 or by 17.9% in our group of 60 patients) may be expected due to mechanical trauma.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Supplementary material available online
Supplementary Table S1