Urol Res (1984) 12:257–259

Urological Research

Rectal Temperature Monitoring During Neodymion-YAG Laser Irradiation for Prostatic Carcinoma

H. O. Beisland[1] and E. Stranden[2]

[1]Department of Urology and [2]Department of Vascular Surgery, Aker Hospital, Oslo, Norway

Accepted: July 11, 1984

Summary. Neodymion-YAG laser irradiation is a new and promising method for curative treatment of localized prostatic carcinoma. The laser light energy is transformed into heat within the tissue, and there is a risk of unintended damage to neighbouring organs. In seven patients the temperature in the rectal mucosa was monitored during the laser irradiation of the prostatic capsule. The temperatures did not increase to dangerous levels. According to a standardized irradiation procedure based on experiences gained in this study 47 patients have been treated without complications.

Key words: Prostatic carcinoma, Neodymion-YAG laser irradiation, Rectal temperature monitoring.

Introduction

The application of laser for destruction of tumors is based on the principle that light energy is transformed into heat within the tissue. Tissue temperature of more than 60 °C for a few seconds causes denaturation of proteins and irreversible changes in the cells. Thus tumor tissue can be homogenously coagulated and destroyed.

Recently we have introduced the laser beam technique in the treatment of localized carcinoma of the prostate [3, 4]. The theoretical considerations were founded on the fact that even extensive transurethral resection leaves viable tumor tissue in the prostatic capsule. If the remnants of tumor are destroyed by laser irradiation of the capsule, this method may represent an alternative to radical prostatectomy.

The generation of heat is determined by beam specific parameters and optical and thermal properties of the tissue. It is therefore possible to calculate the depth of coagulation with fair precision. Nevertheless, there is a risk of damaging thermal effect to neighbouring organs. We therefore monitored the temperature in the mucosa of the anterior rectal wall during laser irradiation of the prostate.

Material and Methods

Seven patients aged 51–81 years (mean 70 years) were included in the study. Because of "prostatism" they had been treated by transurethral resection and the histological diagnosis was adenocarcinoma of the prostate. In 6 cases the tumor was well differentiated, in one case moderately differentiated. The weight of removed tissue ranged from 6 to 27 grams (mean 14 grams). Chest X-ray, pelvic and lumbar films, bone scan and blood tests did not indicate distant metastasis.

3–4 weeks after the TUR, transrectal ultrasound examination of the prostate (ATL-MK I, rectal probe prototype) was carried out to exclude tumor growth beyond the capsule, and laser irradiation of the prostatic capsule was performed.

A Neodymion-YAG laser (Messerschmidt-Bölkow-Blohm GmbH, Munich-Ottobrunn, West-Germany) was used for the irradiation under spinal anesthesia. As the prostatic cavity is spherical and the laser beam cannot be angulated more than 90°, the proximal part of the cavity was treated by transurethral approach and the distal part by suprapubic approach through a trocar cystoscope. Applying repeated pulses, the whole capsule surface was systematically irradiated by slowly rotating the beam. The laser power used for coagulation was 45–50 W and the duration of each pulse did not exceed 4 s. The amount of laser effect (Watt seconds) was automatically recorded in Joule (J). The prostatic cavity was continuously irrigated with room tempered saline (22 °C) during the procedure. A temperature sensitive probe connected to a palpating finger was introduced transrectally and pressed against the anterior wall of the rectum at the prostatic level. It was kept in position for monitoring the temperature in the rectal mucosa during the irradiation (Fig. 1). The probe (1 x 2 x 5 mm) consisted of an integrated circuit (IC) temperature transducer (AD 590) covered by an insulating sheath. Time constant of the probe (T, time to 63% of temperature span) was 0.6 s. Therefore even temperature transients were recorded, although not to their full extent.

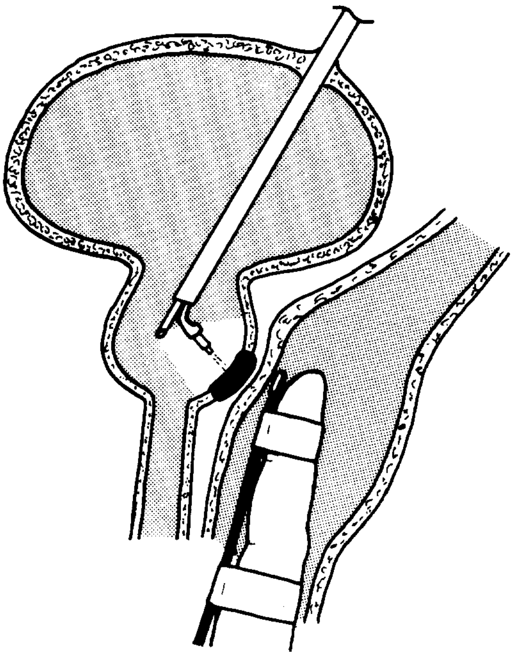

Fig. 1. Suprapubic approach to the prostatic cavity through a trocar cystoscope. The temperature probe connected to a palpating finger is kept in position against the anterior rectal wall during laser irradiation of the posterior wall of the prostatic cavity

Table 1. The maximal temperatures recorded in the rectal mucosa during laser irradiation of the posterior prostatic capsule related to laser parameters

Patient	Maximal temperature	Laser parameters		
		No of pulses	Maximal power	Laser energy
1	39 °C	13	50 W	1,880 J
2	52 °C	20	49 W	2,676 J
3	43 °C	13	45 W	1,912 J
4	38 °C	35	49 W	2,483 J
5	38 °C	28	47 W	4,417 J
6	46 °C	25	50 W	4,463 J
7	47 °C	18	45 W	1,927 J

Results

The maximal temperatures measured in the mucosa of the anterior rectal wall during irradiation of the posterior wall of the prostatic cavity are given in Table 1. The rise in temperature was not correlated to the number of pulses or to the amount of laser energy given.

The temperature increased successively with each pulse application until reaching an individual maximum level. Interruption of irradiation caused immediate decrease in the temperature, at first rapidly, then more slowly and within 2–3 min the original temperature level was reached

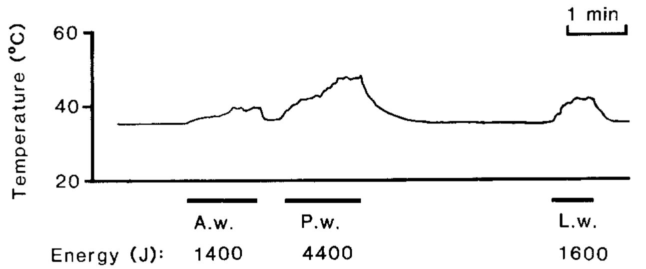

Fig. 2. Laser irradiation of the prostatic cavity with continuous fluid irrigation. The rectal temperature decreased to original level by interruption of the irradiation. Irradiation of the anterior wall (*A.w.*) and the lateral walls (*L.w.*) increased the temperature a few degrees of Celsius whereas irradiation of the posterior wall (*P.w.*) increased the temperature more, but not to dangerous levels. —— Irradiation periods

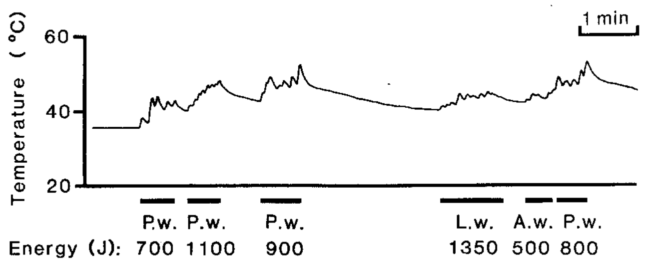

Fig. 3. Laser irradiation of the prostatic cavity with fluid irrigation synchronous to the irradiation periods ——. The rectal temperature did not decrease to original level at interruption of irradiation. With each series of pulses against the posterior wall (*P.w.*) the temperature increased to higher levels. Irradiation of the anterior wall (*A.w.*) and the lateral walls (*L.w.*) increased the rectal temperature only a few degrees of Celsius

(Fig. 2). New series of pulses produced the same temperature changes.

In one patient the flow of irrigation fluid was turned on and off synchronously to the irradiation. In this case the temperature did not decrease to original level between the series of irradiation pulses. Repeated series of irradiation caused increasing maximal temperature levels (Fig. 3). Irradiation of the lateral walls and the anterior wall of the cavity did not increase the temperature in the rectal mucosa more than a few degrees of Celsius irrespective of the number of pulses or the amount of laser energy given.

Damage to the rectum was not clinically observed neither peroperatively nor postoperatively. The operating time ranged from 25 to 40 min and the total amount of laser energy used for the irradiation of the whole cavity ranged from 8,200–18,000 J. A catheter was left in the bladder for 24 h and the hospital stay was one or two days.

Discussion

The Neodymion-YAG laser ($\lambda = 1{,}064$ nm) is well suited for deep homogenous coagulation because of low absorption and considerable scattering of infra-red radiation in biological tissue at this particular wavelength. The rise in temperature and temperature distribution depend on the absorbed energy and thermal properties such as density, specific heat, thermal conductivity and local blood circulation through the tissue. The optical scattering is mainly a back-scattering, but a forwardscattering through the wall of a holeorgan is possible. Due to denaturation of proteins, the back-scattering increases whereas the forward-scattering decreases. Consequently, the increased back-scattering in collaboration with thermal conduction away from the irradiation site limits the depth of necrosis attainable on continued irradiation.

From theoretical considerations and experimental results on urinary bladder tissue the depth of necrosis is found to be 4–5 mm when a fixed spot is irradiated with a power of 40–45 W for 2–3 s [1]. Corresponding experiments on the prostatic capsule do not exist, but we suggest to attain the same depth of necrosis when scanning the capsule area by slowly rotating the beam in a meander pattern with a laser power of 45–50 W.

It is known that the intestines are more sensitive to heat and thus more vulnerable than the urinary bladder wall [2]. Probably they also are more sensitive to heat than the prostatic capsule. The retroprostatic space, the fascia of Denonvillier and the prerectal space divide the prostatic capsule from the rectum. The good blood circulation in this region is favourable for an effective heat disposal, but irrigation with room temperated saline seems essential to reduce the heat conduction. It is important to continue the irrigation also when the irradiation is interrupted. Otherwise the temperature will increase to ever higher levels and not decrease sufficiently within 2–3 min interruption. In preheated tissue less beam energy is needed for coagulation. To prevent unintended damage it is therefore necessary to establish sufficient cooling or to reduce the laser power successively. The later procedure is not practical.

It may be objected that the temperature is monitored on the mucosal surface and not in the rectal wall. Attempts have been made to introduce temperature sensitive needle electrodes transperineally into the prerectal space. Due to difficulties with standardization of the electrode position and the drawback of only having a single point registration, this method was abandoned in favour of the mucosal surface registration.

As a consequence of the experiences obtained in this study the irradiation procedure is standardized as follows: By transurethral and suprapubic approach the entire prostatic capsule is irradiated with a laser power of 45–50 W. With a pulse duration of 4 s the surface of the capsule is scanned systematically by slowly rotating the beam. The irradiation of the posterior part of the capsule is interrupted for 2–3 min at 10-pulses intervals. Irrigation of the prostatic cavity with room temperated saline is continuous even during the interruptions. Irradiation anteriorly and laterally is carried out without interruptions.

So far 47 patients have been treated with this procedure without complications.

References

1. Halldorsson T (1981) Biophysical fundamentals and instrumentation for the endovesical Nd:YAG laser application. Urologe A 20:293
2. Kronester A, Staehler G, Weinberg W, Keiditsch E (1981) Risk of intestinal damage from endoscopic Neodymion-YAG laser irradiation of bladder tumors. Urologe A 20:305
3. Sander S, Beisland HO, Fossberg E (1982) Neodymion-YAG laser in the treatment of prostatic cancer. Urol Res 10:85
4. Sander S, Beisland HO (1984) Laser in the treatment of prostatic carcinoma. J Urol (accepted for publication)

Dr. H. O. Beisland
Department of Surgery and Urology
Aker Hospital
Oslo 5
Norway