

INTERSTITIAL WATER HYPERTHERMIA: TEMPERATURE DISTRIBUTION DATA OBTAINED IN ANIMAL EXPERIMENTS COMPARED TO HUMAN APPLICATION MEASUREMENTS

Lešničar H, Budihna M, Handl-Zeller L, Schreier K

Abstract: An original circulating hot water hyperthermia system for interstitial treatment has been constructed at the University Clinic for Radiobiology and Radiotherapy in Vienna, Austria. At the Institute of Oncology in Ljubljana, Yugoslavia, animal experiments as well as a few human treatments were done. Results obtained with 4×4 metal needle implants on rabbits and/or pigs thigh showed that a good temperature distribution inside the heated volume could be obtained. The homogeneity of temperature distribution obtained in human applications using plastic tubes was also acceptable. Although somewhat lower temperatures inside the treated volume were measured in human treatments, the minimum temperatures obtained were still on the cytotoxic level (over 42.5°C). With some improvements using cooling system for the tumour surrounding zone the damage of the healthy tissue inside the treatment volume could be avoided.

UDC: 612.57-084

Key words: hyperthermia induced-methods

Orig. sci. paper

Radiol jugosl 1989; 23: 295—7

Introduction — In clinical practice with interstitial hyperthermia mostly radiofrequency or microwave applicators are used (1, 2, 3). On the other hand, in some centers the practice of nickel-copper alloy thermoseeds has been developed using conductivity as an energy transfer to the tumor tissue (4). Little is known about the possibility of using circulating hot water as a thermal source in hyperthermia treatment (5, 6). The purpose of this paper is to present interstitial measurements data obtained in animal experiments in comparison to first clinical applications using hot water hyperthermia system.

Material and methods — **The Unit:** The interstitial hyperthermia unit KHS 9—W 18 (Othmar Handl GmbH, Vienna, Austria) consists of a water reservoir, pressure and suction pump, silicone tubes for water supply into and out of the implant, and of the equipment for temperature and flow control (5). The temperature control system is installed in the thermostat, at the inflow and outflow part of the implant, as well as inside the heated tissue (Fig. 1).

The Implant: For the implant 4×4 metal needles or plastic tubes of diameter 1.6 mm with 10 mm spacing were used.

Animal Experiments: Hyperthermia was induced in thighs of rabbits (3.5—4 kg), and pigs (10—15 kg). The rabbits were anesthetized by 5 % Thiopental injected intraperitoneally, and pigs by Halothane inhalation. Temperature measurements were done with 5-point thermocouple inserted through 3 catheters placed along the central (A), paracentral (B) and peripheral (C) lines through the implant. The heated volumes ranged from $27\text{—}72\text{ cm}^3$ (Fig. 2).

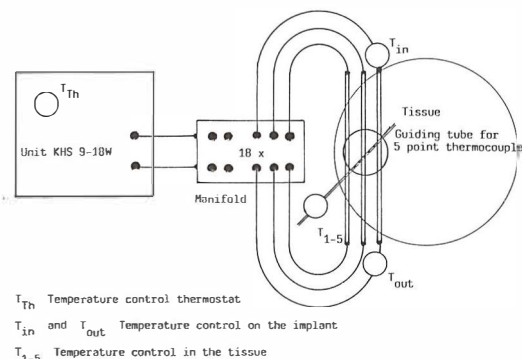


Figure 1 — Schematic presentation of KHS 9-W 18 hyperthermia unit with implanted tissue and thermoprobe

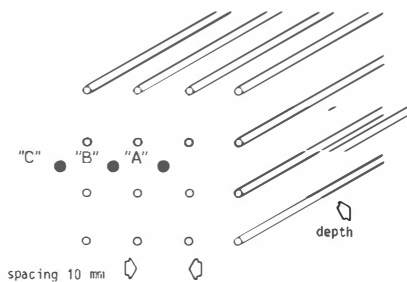


Fig. 2 — Schematic presentation of an implant. Points A, B, C show the position of the catheters for the temperature measurement

Clinical Applications: Five patients with inoperable carcinomas of the floor of the mouth and/or mobile tongue were treated with the use of interstitial hot-water hyperthermia unit. Implants of the primary tumor using plastic tubes were done under general anesthesia. A special catheter for 5-point thermocouple measurements was inserted through the implanted area. During hyperthermia, several temperature measurements were done at the points of interest, which geometrically corresponded to the measurement lines of animal experiments. At the end of hyperthermia, Ir-192 wires were inserted through the same plastic tubes in order to combine hyperthermia with brachyradiotherapy.

Standard conditions for hyperthermia treatment:

1) Water temperature in the inflow point was kept constant:

- 45.5°C and 48°C in animal experiments
- 48°C in clinical applications

2) Flow rate of the circulating hot water was 2.5 ml/sec. per tube.

3) Heating time was 60 min. after the tissue temperature had reached the »steady state« (approx. 10 min. after starting).

4) The values of heat transfer for KHS 9-W 18 calculated from previous testing were 15–20 W m⁻¹ °K⁻¹.

Results — The average tissue temperatures measured in animal and human implants are shown in Tables 1, 2 and 3. The measurement lines A, B and C, positioned constantly in animal implants, geometrically corresponded to the measurement points A', B' and C' chosen as the points of interest in human hyperthermia treatment (A, A' — central; B, B' — paracentral; C, C' — peripheral). Note that measured tissue temperatures obtained in animal metal-needle implants with an inflow water temperature of 45.5°C correspond quite well to the tissue tem-

peratures measured in human cancer treatment using plastic tube implants and inflow water temperature of 48°C (Tables 1, 2). If plastic tube implants were used in animal experiments the inflow water temperature of 48°C resulted in an increase of measured animal tissue temperatures for approx. 2°C (Table 3).

Measurement line	Tissue temp. — rabbit °C ± SD*	Tissue temp. — pig °C ± SD
A	43.6 ± 0.5	43.7 ± 0.6
B	43.5 ± 0.5	43.7 ± 0.6
C	42.3 ± 0.6	41.8 ± 0.5

* SD — standard deviation

Table 1 — Average tissue temperatures in °C as measured in lines A, B and C using metal needle implants on rabbits and pigs thigh with inflow water temperature of 45.5°C

Measurement point	Tissue temp. °C ± SD
A'	43.4 ± 0.5
B'	42.7 ± 0.3
C'	41.4 ± 0.4

Table 2 — Average tissue temperature measured in human treatment — plastic tube implant at inflow water temp. 48°C

Measurement point	Tissue temp. °C ± SD
A	45.3 ± 0.5
B	44.4 ± 0.6
C	43.3 ± 0.5

Table 3 — Average tissue temperature measured in rabbits thigh — plastic tube implant at inflow water temp. 48°C

Discussion — In previously published data on animal experiments with interstitial water hyperthermia (6) it was pointed out that the use of plastic tube implants instead of steel needle implants resulted in approximately 1–2°C lower average tissue temperatures. For some technical reasons (afterloading with Ir-192 wires) we were not able to use steel needle implants. Based on our results, it could be concluded that higher tissue temperatures in normal animal tissue are easier to achieve in comparison with human tumor tissue. The cooling effect of arterial system inside the implanted area in rather small experimental areas (rabbits and piglets) having somewhat lower influence on the heating ability

as compared to the human tissue could serve as a possible explanation of that. These difficulties could easily be overcome by using somewhat higher inflow water temperatures. Nevertheless, the average tissue temperature measured in our human hyperthermia treatment was still on cytotoxic level, and homogeneity of temperature distribution expressed as standard deviation of approximately 0.5°C is highly acceptable. It appears that formerly designed counter-flow needles and tubes with the possibility of cooling one part of the implanted volume are the most promising novelty in our hyperthermia system (6). This improvement should enable us to heat the tumor zone properly without causing any thermal damage to the surrounding healthy tissue.

Povzetek

INTERSTICIALNA HIPERTERMIJA Z VODO: PRIMER-JAVA TEMPERATURENE PORAZDELITVE NA POSKUSNIH ŽIVALIH Z MERITVAMI PRI ČLOVEKU.

Na univerzitetni kliniki za radiobiologijo in radioterapijo (Dunaj, Avstrija) so zasnovali in izdelali originalno hipertermično napravo za intersticialno zdravljenje s pomočjo ogrevane vode. Avtorji so nato na Onkološkem inštitutu v Ljubljani skupaj izvedli poskusno študijo na živalskem modelu in nekaj kliničnih aplikacij pri bolnikih. Rezultati implantacije stegna s pomočjo 4×4 kovinskih igel pri zajcih in/ali prašičih kažejo, da ta način omogoča dobro razporeditev temperature v ogrevanem volumnu. Dobljena razporeditev temperature je bila dovolj homogena tudi pri kliničnih aplikacijah, kjer so uporabili plastične cevke. Čeprav so pri

le-teh v pregrevanem volumnu namerili nekoliko nižje temperature, so bile tudi dobljene minimalne temperature dovolj visoke, da so dosegale citotoksično raven (preko $42,5^{\circ}\text{C}$). Z nekaj izboljšavami, ki bi omogočale hlajenje področja v okolici tumorja, bi se lahko izognili poškodbam zdravega tkiva znotraj implantiranega volumna.

References:

1. Bolmsjö M. Commercially available equipment for hyperthermia. In: Watmough DJ and Ross WM ed. *Hyperthermia*. Glasgow, 1986; 224—42.
2. Cosset JM, Dutreix J, Haide C, Gerbaulet A. Interstitial thermoradiotherapy: a technical and clinical study of 29 implantations performed at the Institute Gustave-Roussy. *Int J Hyperthermia* 1985; 1: 3—13.
3. Coughlin TC, Douple EB, Strohbehn JW, et al. Interstitial hyperthermia in combination with brachytherapy. *Radiology* 1983; 148: 285—8.
4. Brezovich I, Atkinson W. Temperature distribution in tumor models heated by self-regulating nickel-copper alloy thermoseeds. 1984; *Med Phys* 11 (2): 145—52.
5. Handl-Zeller L, Kärcher KH, Schreier K, Handl O. Optimierung interstitieller Hyperthermie Systeme. *Strahlentherapie* 1986; 1963: 460—3.
6. Lešničar H, Budihna M, Handl-Zeller L, Schreier K. Interstitial hyperthermia with circulating water — results of animal experiments. In: Kärcher K. H. ed. *Proceedings of the 4th meeting on progress in radiooncology*. Vienna, 1988; 263—6.
7. Handl-Zeller L, Kärcher KH, Schreier K, Budihna M, Lešničar H. The interstitial Viennese system KHS 9-W 18: homogeneous hyperthermia with simultaneous radiation in deep-seated tumors with integrated heat protection of normal tissue. In: Kärcher K. H. ed. *Proceedings of the IVth meeting on progress in radiooncology*. Vienna, 1988; 267—9.

Author's adress: Hotimir Lešničar, MD, The Institute of Oncology, Zaloška 2, 61000 Ljubljana