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Regulated High Frequency Diathermy for Bipolar Electrocoagulation – A New Method for the Treatment of Carcinoma of the Bladder

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Summary. In the endoscopic treatment of bladder cancer, especially for stages beyond T2, transurethral resection does not seem to be sufficient. The risk of bladder wall perforation, the possibility of incomplete resection, seeding of tumor cells and high recurrence rates support the former statement [6]. Results of a multicentre prospective randomised study have exemplified that irradiation with the Neodymium-YAG Laser has been a reasonable alternative in the therapeutic approach to bladder cancer [2]. Diathermy coagulation must produce a sufficiently deep, homogenous and well demarcated tissue necrosis. The coagulation depth has to be adjustable and heat production during coagulation should not lead to bladder wall perforation and consequent damage to the bowel. These criteria were investigated using regulated bipolar high frequency diathermy. The innovation in this method is, that thermal side effects on the tissue, e.g. vaporisation and carbonisation are prevented by a protective relay with constant current flow. Animal experimental studies have shown that this method meets all postulated requirements and therefore clinical trials can proceed.

Key words: High frequency diathermy, Bipolar electrocoagulation, Bladder cancer.

Introduction

Treatment of bladder cancer up to stage T2 is by transurethral resection. The depth of resection is limited by the risk of bladderwall perforation. Damage of tumor cells without removal of bladder wall tissue would be a desireable alternative. Coagulation of deeper layers of the bladderwall has only been possible by irradiation with the Neodymium-YAG laser [2]. Monopolar diathermy is unsuitable because inhomogeneous necrosis is produced. Advantages of conventional unregulated bipolar diathermy are well known but the reported coagulation depth was not sufficient for transmural tumor destruction, in an experimental model [5].

Coagulation is a thermal effect depending on the current density within the tissue [1]. Numerous biophysical investigations at the Department of Electrial Engineering, University of the German Armed Forces, Munich, FRG, have shown, that sufficient current density for necrosis in deeper tissue layers can only be reached with constant current flow during coagulation. Peaks of current density in the superficial tissue layers are avoided. Thereby constant current input meets the requirement for transmural coagulation with bipolar diathermy.

Materials and Methods

Figure 1 shows the highfrequency generator and the electronic feedback system in a circuit diagram [1]. The innovation in this system is voltage adjustment by a feedback system depending on thermal alteration of impedance, so that current is kept at a constant within the tissue. The point of increasing impedance during coagulation is registered and a further current flow is forestalled. With this mechanism tissue is protected from the risk of perforation.

Coagulation was made by two parallel cylindrical probes (suitable for a F24 resectoscope) which were pressed onto the tissue surface (Fig. 2).

The experiments were carried out in 20 rabbits and two miniature pigs. Anaesthesia was done with a combination of

- Ketanest (Ketamine) and Rompun (Xylazin) in the rabbits and
- Stresnil (Azaperon) and Hypnodyl (Metomidat) in the pigs.

The profile of necrosis was investigated in the homogenous tissue of the liver parenchyma and the heterogeneous tissue of the bladder wall. The coagulation depth was determined in relation to current flow and to coagulation time. Complete devitalisation of cells and preservation of tissue structures of coagulated areas were judged histologically.

In endoscopic vesical thermocoagulation adjacent bowel is endangered by transmural heat conduction. Therefore temperature on the bladder serosa was measured by means of a thermocamera.

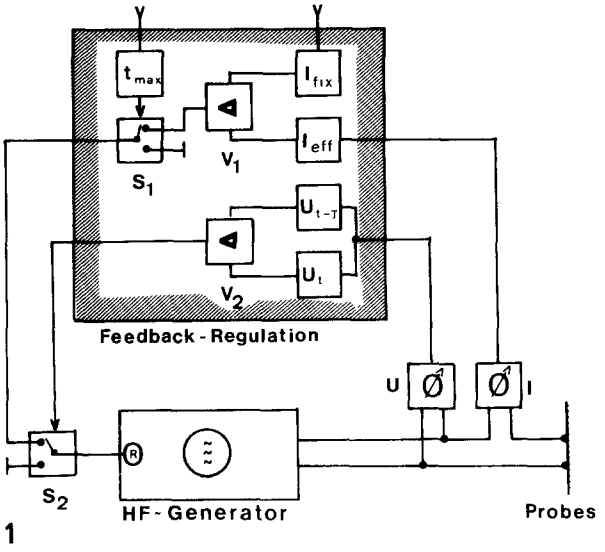

Fig. 1. Circuit diagram of regulated bipolar diathermy

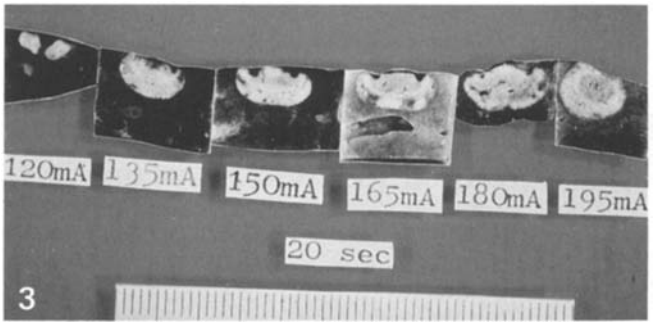

Fig. 3. Cross sections of a necrosis with equal coagulation time and different amperage in vital rabbit liver tissue (formalin fixed)

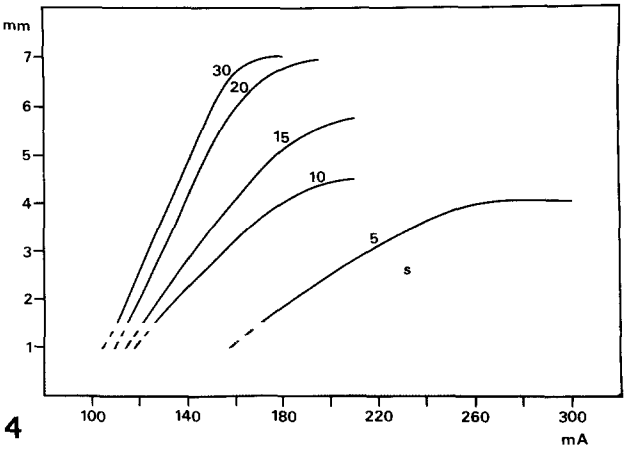

Fig. 4. Necrosis depth in relation to amperage with coagulation time as graph parameter

Results

Depth of Necrosis

For each pair of parameters consisting of amperage and coagulation time the depth of the necrosis was determined. Evaluation of numerous coagulation series (Fig. 3) led to a graph as in Fig. 4. The depth of the necrosis is shown as a function of amperage with coagulation time as the graph parameter. Coagulation time was chosen between 5 and 60 s. All graphs showed a steep linear rise and then a plateau phase. At the end of the plateau phase heat production was terminated by the feedback relay. If the necrosis was less than 1.5 mm it appeared as two cones with a bridge of vital tissue inbetween. Maximum necrosis depth of 7 mm was reached in the range of 150 mA to 190 mA. A further rise in amperage lead to a decrease in depth due to termination of coagulation by the feedback relay. Through this vaporisation or carbonisation of the tissue with consecutive affixation of the probe onto the tissue was prevented. A maximum depth of 7 mm was reached within 20

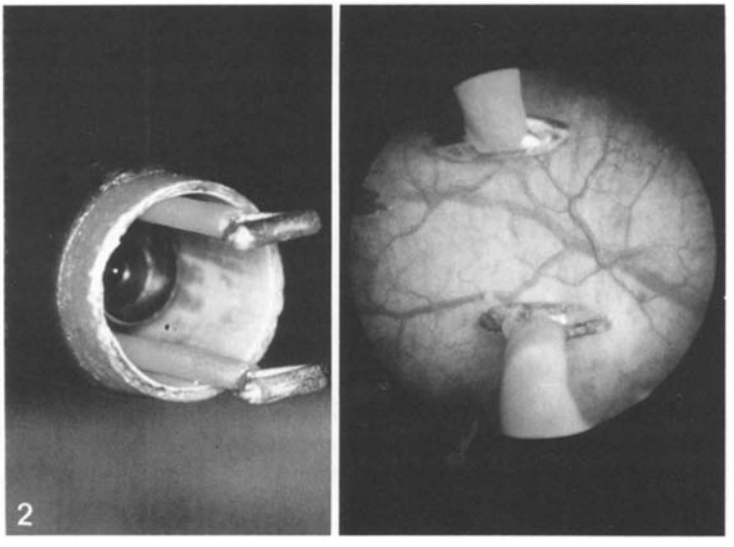

Fig. 2. Bipolar probes in a F24 resectoscope and endoscopic view of a rabbit bladder

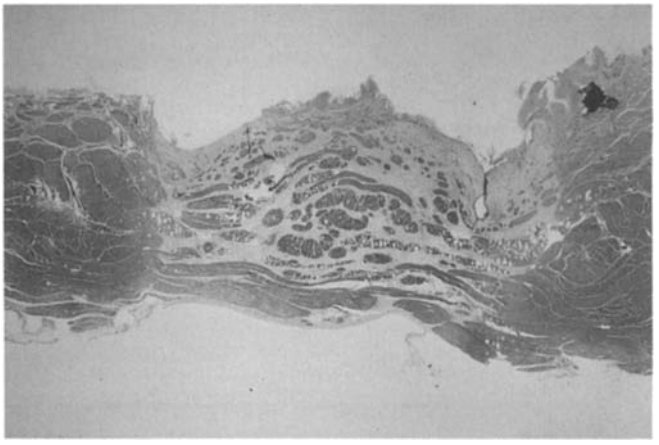

Fig. 5. Diathermy damage to the pig bladder wall

s and with an amperage of 180 mA. Definitive limitation of coagulation effect was best with coagulation times less than 15 s.

Histology

Histological examination of the coagulated areas of homogeneous liver parenchyma and the heterogeneous multilayered bladder tissue showed no fundamental difference. In each organ homogeneous necroses were produced with anatomical preservation. Within the coagulated areas a definitive and complete divitalisation of all cells occurred. The necrosis was sharply demarcated from vital tissue. In contrast to this, conventional highfrequency diathermy leads to irregular formation of the necrosis along conductive structures e.g. blood-vessels [3]. Figure 5 shows a typical transmural coagulation necrosis in the bladder wall of the pig with a wall thickness of approx. 4 mm.

Temperature Profiles

In transmural endoscopic thermocoagulation of the bladder wall, adjacent bowel can be damaged [4].

The temperature profile on the bladder serosa during coagulation was measured by a thermocamera. Coagulation was made in the 3–4 mm thick bladder wall of the pig with 180 mA and 20 s which are ideal parameters for maximum depth of necrosis. In no case of necrosis did heat production exceed 50 °C on the bladder serosa.

Discussion

In this new method of regulated bipolar diathermy the energy conveyed to the tissue is kept at a constant throughout coagulation. This is achieved by constant current input independent of varying resistance by temperature change during coagulation. By this method the well known advantages of bipolar diathermy are further improved.

The results was a homogeneous necrosis with a maximum depth of 7 mm, sharply demarcated from the vital tissue. The coagulation process was independent of the specific conductive qualities within the tissue. Necrosis can be controlled and reproduced exactly. A chosen coagulation depth cannot be exceeded with an appropriate coagulation time. Vaporisation or carbonisation of the tissue was prevented by a security feedback device. The structures of the bladder wall was maintained although the tissue was devitalized. There was no fixation of coagulated tissue to the probes and thus there was no tissue alteration and tumor cell seeding might be prevented. Mechanical cleaning of the probes was not necessary. The temperature profile during coagulation on the bladder serosa showed that heat developement was limited so that adjacent tissue e.g. bowel was not affected by coagulation. Hitherto, there has been no other conventional highfrequency method available with comparable results. On the other hand coagulation with the Neodymium YAG laser has yielded excellent results in experimental and clinical trial. In consideration of similar problems in the application of the Neodymium YAG laser it might be expected that bipolar regulated highfrequency coagulation in bladder tumours up to the T2 stage could be an alternative to transurethral resection.

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