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Coagulating Intermittent Cutting

Improved High-Frequency Surgery in Transurethral Prostatectomy

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Key Words

Benign prostatic hyperplasia · Transurethral prostatectomy · High-frequency surgery

Abstract

Objectives: Transurethral prostatectomy (TURP) is the gold standard in surgical therapy of symptomatic bladder outlet obstruction. TURP is characterised by immediate treatment success, due to the removal of obstruction combined with a long-lasting improvement of symptoms and voiding parameters. In spite of good long-term results of TURP, intraoperative blood loss produces morbidity. We investigated a blood-sparing cut using a new high-frequency technology.

Methods: (1) A standard high frequency generator was extended in its function by additional electronics. (2) The possibility of a blood-sparing cut using 'coagulating intermittent cutting' (CIC cocut BMP) was quantified ex vivo using a blood-perfused porcine kidney. Four cuts next to each other were performed through the parenchyma using a standard resectoscope with a standard loop. This was done with a commercially available generator and CIC cocut BMP. The blood loss was determined semiqantitatively.

Results: (1) In a first step 'coagulating cutting' with coagulating and cutting periods (10/94–08/96) was developed. During each cut, phases with predominant cutting effect alternate with coagulating phases of defined duration. As a disadvantage, operation time increased due to lower cutting speed. In a second step cutting combined with coagulation effect with high voltage pulses – 'coagulating intermittent cutting' (08/96–06/97) – was developped. In this technique, the output signal consists of a pulse-modulated sinusoidal voltage with high amplitudes. But gas bubbles impaired vision. This finally resulted in the 'coagulating intermittent cutting' with constant voltage pulses and control of pulse intervals (CIC cocut BMP, since 07/97 up to now). (2) Comparing the function of the high-frequency generators in vitro, the Wilcoxon test for paired samples revealed a significant reduction of the observed bleeding with the CIC cocut BMP ($p = 0.002$).

Conclusions: 'Coagulating intermittent cutting' improves the gold standard of TURP with reduced blood loss. The procedure is feasible with a standard resection equipment. The already trained surgeon has no further learning cure, and teaching of classical TURP is maintained.

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Table 1. Advantages of TURP in the treatment of obstructive BPH

Significant improvement in subjective and objective results (flow rate, residual urine and symptom score)
Immediate removal of obstructing prostatic tissue
Possibility to remove large tissue volumes
Histopathological analysis
Early treatment results
Low failure rate
Best long time results under correct indication and treament performance

Introduction

Transurethral prostatectomy (TURP) is the gold standard in surgical therapy of symptomatic bladder outlet obstruction. TURP is characterized by immediate treatment success due to the removal of obstruction combined with a long-lasting improvement of symptoms and voiding parameters (table 1) and is the most frequently used method in patients requiring instrumental management for benign prostatic hyperplasia (BPH).

On the other hand, TURP is an invasive surgical method with the risk of increased morbidity due to the procedure (e.g. blood loss, irrigation fluid absorption) [1–3].

In order to maintain the gold standard and at the same time lower perioperative morbidity, improvement of the high-frequency technology was tried. A standard high frequency generator was extended in its function [4] and 'coagulating cutting' was developped.

Materials and Methods

Development of Coagulating Cutting and Coagulating Intermittent Cutting

Using an unmodulated sinus-shaped signal with thin wire-loop electrodes results mainly in a cutting effect. With an amplitude reduction which is just sufficient to allow cutting, the cut produces virtually no necrosis. On the other hand, if there are short pulses of high voltage (i.e. several 1,000 volts in the extreme case of spray coagulation using single pulses), the coagulating effect dominates over a wide energy range even with thin wire-loop electrodes.

To achieve a cut associated with less than usual bleeding, the electrophysical effects have to be combined to provide a clean tissue dissection with a deep coagulation zone responsible for optimal hemostasis.

Coagulating Cutting with Caogulating and Cutting Periods

During each cut, phases with predominant cutting effect alternate with coagulating phases of defined duration. The technique can be performed using standard resectoscopes together with an electronically modified standard high-frequency generator.

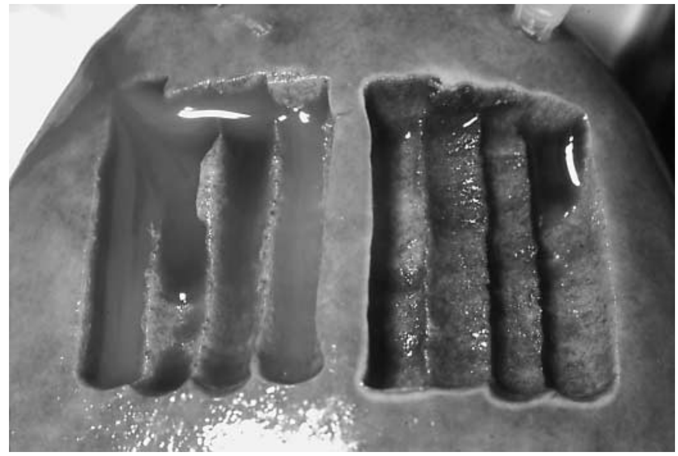

Fig. 1. In vitro experiments for 'coagulating intermittent cutting'. Bleeding of a porcine kidney during the resection with a light arc-controlled generator (left) as well as with the Storz Cocut BMP (right) at 200 W output power.

Coagulating Intermittent Cutting: Cutting Combined with Coagulation Effect with High-Voltage Pulses

To increase the cutting speed, the system was modified and a pulse modulated sinusoidal voltage with high amplitudes was developped, which allowed a higher cutting speed with constant coagulation quality.

In vitro Experiments

To validate the clinically observed improved coagulation characteristics with a constant cutting effect, 'coagulating intermittent cutting' was evaluated semiquantitatively on a perfused cadaver porcine kidney. These studies were performed in cooperation with the Department of Urology, Mannheim, Germany [5]. In these experiments, we compared the blood loss during the resection of a light are-controlled high frequency generator with our modified generator (CIC cocut BMP).

The vessels of 10 cooled porcine kidneys were dissected and freed of coagula by means of a heparin solution and perfused with porcine blood via a catheter placed in the renal artery. The perfusion pressure was adjusted to 120–140 mm Hg. The kidneys were perfused until the parenchyma showed a normal color. The kidneys were fixed, and we performed four cuts through the parenchyma next to each other of 1 cm depth and 10 cm length. This was repeated with both generator types at 200 W (fig. 1). The amount of blood loss could not be measured. Therefore, blood loss was determined semiquantitatively: The weight of six cotton swabs was determined before and after pressing them on the resection site for a total time of 2 min. For statistical analysis the Wilcoxon test for paired samples was used.

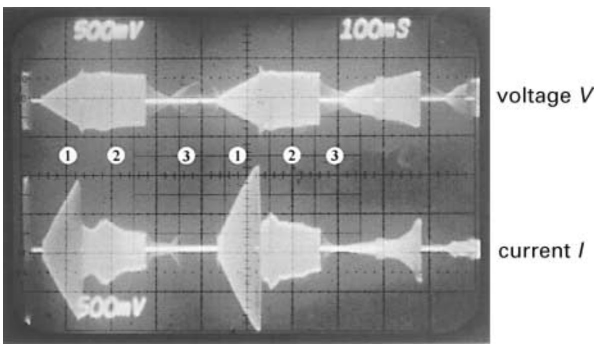

Fig. 2. 'Coagulating cutting'. Oscillogramm of a test generator with representation for voltage and electrical current Fixed time periods with cutting effects alternate with coagulating phases. 1 = Extensive and deep coagulation under low voltage and high current; 2 = cutting under electrical arc control; 3 = coagulation of the tissue surface with pulsed voltage.

Results

Development of 'Coagulating Intermittent Cutting'

The principle of the 'coagulating cutting' with coagulating and cutting periods can be described as follows: A single cut starts with a period of coagulation into the depth of the tissue (fig. 2, phase 1). The generator volate is low during this time. The current is high, due to the direct contact the whole surface of the electrode and the tissue. The optimal output voltage for this period depends on tissue and vascularization and cannot be determined in advance. Therefore, the voltage amplitude is not constant but increases slowly with time. In this way the output voltage is for sufficient time in the optimal range for producing a deep coagulation zone. The period ends when the cell fluid vaporizes and electrode and tissue are separated by insulating layer of vapor. The current is decreased at once. Till this point, the voltage is high enough to ignite an electric are bridging the insulating layer of vapor and cutting begins. During cutting, the extension of the electric arc is controlled to achieve an optimal cutting effect. The duration of the cutting period (phase 2) was experimentally determined. It should last until the coagulated area is dissected. With the end of the cutting period, the cutting effect should stop immediatelly, and coagulation should occur. This is attained by pulsing of the output signal (phase 3). At first, the voltage amplitude is decreasing, then it is increased once more up to the ignation of an electric arc and reduced a second time. If this last preiod lasts long enough, the layer of vapor has vanished at the end of period 3 and the whole cycle starts again. Period 3 cannot be shortened and therefore the cutting speed is limited and is less than in a conventional resection.

In a first clinical pilot trial, 44 patients with obstructive BPH underwent TURP with this new method between 10/94 and 8/96. Compared with standard methods, there was a decrease of intraoperative blood loss. In selected cases, the transurethral catheter could be removed on the first postoperative day, resulting in a shorter hospitalization period.

The disadvantage of this method is the increase of operation time the lower cutting speed, making it too slow for larger prostates.

The following studies were aimed to increase resection speed and maintain reduction of blood loss.

Cutting Combined with Coagulation Effect with High Voltage Pulses – 'Coagulating Intermittent Cutting'

In this technique, the output signal consists of a pulse modulated sinusoidal voltage with high amplitudes (V >400 V). The pulse periods with output voltage are about 18 ms, the pause periods are about 70 ms (fig. 3a). It can be shown that a broad coagulation zone can be achieved with amplitudes of the generator voltage greater than 400 V. But with these high voltages the applied power would be too high. It could result in extensive carbonization of the tissue and in the worst case in thermic dissociation of the irrigation fluid. To reduce the mean power to a degree where no carbonization occurs, the output signal has to be pulsed. Depending on cutting speed and depth and the variation of the electric properties of the tissue a fine tuning is necessary. This can be achieved with an automatic control circuit regulating the mean extension of the electric arc between loop and tissue to a constant value. Thus, the amplitude of the voltage during the pulse periods is not constant but tuned for optimal cutting. Some pulse periods of voltage V and current I are shown in the oscillogram of figure 3a with high time resolution. Figure 3b shows the oscillogram of an entire cut. The influence of the control circuit on the amplitudes of voltage and current can be seen clearly. In case of the 'coagulating intermittent cutting', the mean power applied to the patient is of the same magnitude as in a TURP performed with a normal electrosurgical unit without any control circuit.

As a test generator, we used the Storz cocut P, which is a modification of the Storz autocon 350. In a clinical trial, we performed TURP on 108 patients with obstructive disease between 8/96 and 6/97 using the described technique of 'co-

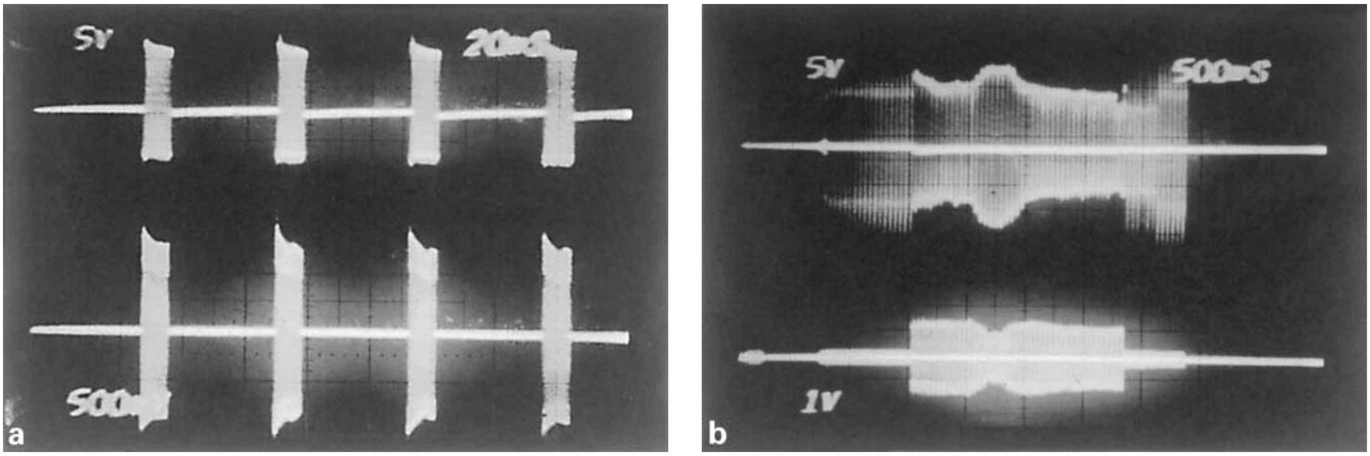

Fig. 3 a, b. Cutting combined with coagulation effect with high voltage pulses or 'coagulating intermittent cutting'. Oscillogramm of a test generator with representation for voltage (above) and electrical current (down). **a** Composition of the cutting effect through high voltage pulses regularly interruptet by voltage free periods. **b** Representation of a complete cut: The pulse amplitude is adapted to the required size.

agulating intermittent cutting'. The mean age of the patients was 72 years (range 59–84), the mean weight of the resected tissue was 40 g (15–120 g). The postoperative hemoglobin reduction was less than 2 g/dl in 100 patients and less than 4 g/dl in 8 patients. In 1 patients with 100 g of resected tissue, a postoperative blood transfusion was necessary. The determination of irrigation fluid absorption using the ethanol dilution method [7] showed no absorption in 106 patients. Only in 2 patients was a significant absorption of irrigation fluid observed with no clinical signs of a TURP syndrome. In 21 patients, the transurethral catheter could be removed on the first postoperative day. The mean hospitalization time was 5 days (range 4–9 days).

'Coagulating Intermittent Cutting' with Constant Voltage Pulses and Control of Pulse Intervals

The pulsing of the output voltage of the generator described above has some severe disadvantages: When high power is needed, to start cutting, the output power of the generator is limited to a value much lower than the maximum output power of a normal generator for high frequency surgery. On the other hand, if only low power is needed for cutting, the control circuit reduces the output voltage to values where the desired broad coagulation zone no longer can be achieved. Due the high voltage pulses and the resulting spark, the vision was impaired by the appearance of a significantly higher amount of gas bubbles in the irrigation fluid.

Thus, another coagulating cutting had to be developed which had to maintain the cutting speed as well as the coagulation effect. Again, in this generator, the coagulating effect is achieved by a pulsed output signal using voltages with high amplitudes. But with this generator the pause between two pulses is not fixed but controlled. Once more the mean extension of the electric arc between tissue and cutting loop should be constant. With only a short lag between the pulses the output power is almost as high as the maximum power of an unmodified generator. If the necessary power decreases the lag between two pulses increases and less power is delivered to the patient. The different time periods between the single pulse are shown in figure 4a.

Considering the signals of an entire cut, a virtually constant voltage amplitude can be seen (fig. 4b).

In vitro Experiments

Using the described model of autologous perfused porcine kidneys a blood sparing cut using CIC could be observed. The coagulation zone of the resected tissue was deeper than using a standard high-frequency generator. Nevertheless, there was no carbonisation as is well known from the vaporisation. The comparison of the modified generator (CIC cocut BMP) with a standard light arc controlled generator revealed a significant reduction of the observed bleeding with the 'coagulating intermittent cutting' ($p = 0.002$). These results confirm the clinically observed reduction of blood loss.

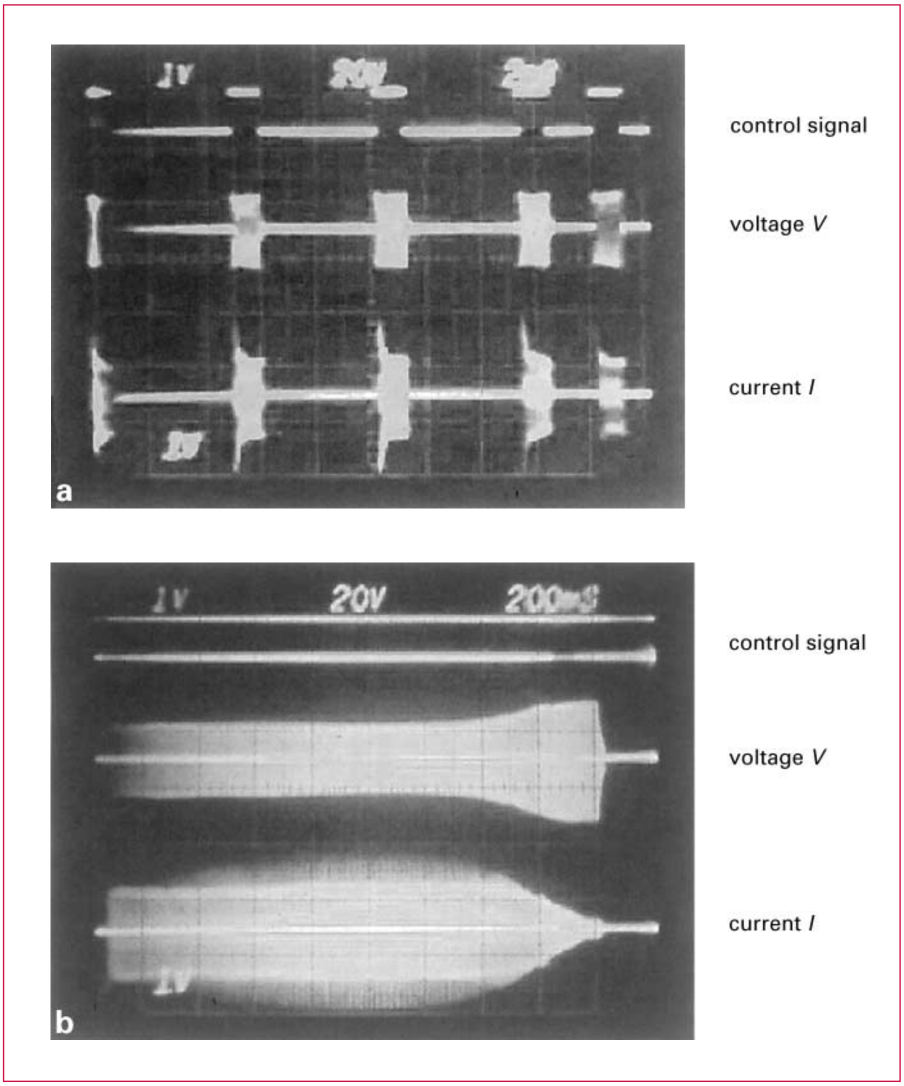

Fig. 4 a, b. 'Coagulating intermittent cutting' with constant voltage pulses and control of pulse intervals. Oscillogramm of a test generator with representation for voltage and electrical current. **a** Composition of a single cut: The interval between the pulses is determined by electrical arc control. **b** Representation of a complete cut: The voltage amplitude is considerably maintained.

Discussion

TURP is characterised by immediate treatment success due to objective removal of obstruction combined with a long improvement of symptoms and voiding parameters [3, 6, 7]. Even old men (older than 80 years of age) benefit from TUR-P [8–10]. The intraoperative and early postoperative mortality rate has decreased from 2.5% in 1962 and 1.3% in 1974 to less than 0.2% today [11–15]. An analysis of the last consecutive 1,000 patients of our institution with bladder outlet obstruction and TURP with a standard high-frequency generator, showed a perioperative mortality rate of 0% [2].

However, the overall rate of complications with TURP has remained constant at 18% during the last years. The most frequent complications are intraoperative and postoperative arterial and venous bleeding which make blood transfusion necessary. Blood transfusions during the intra- and postoperative period are necessary in 0–32% of all cases [1, 2, 15–19].

In the last years, these problems led to the development of instrumental alternative technics and of alternative ablative treatment options, also aimed for immediate desobstruction but associated with less morbidity than TURP. Modification of the shape of the electrode (i.e. 'thick loop electrode' [20], modifications of the high frequency unit with vaporisation of tissue (TUVP) [21, 22], improvement of laser technic (HoLR/EP) [23, 24], or additional mechanical effects for tissue ablation (Rotoresect) [5] is used.

The described new high-frequency technology is a step in reducing the perioperative morbidity of TURP. In vitro experiments proved the blood sparing cut of 'coagulating intermittent cutting'. This confirmed first clinical observations due to reduction of blood loss. In a retrospective analysis our own data (1,000 consecutive patients after classifcal TURP versus 343 patients after 'coagulating intermittent cutting') demonstrate a reduction of the transfusion rate to one fourth, whereas these two groups are comparable to each other.

Also, an advantage is the feasibility of the procedure with a standard resection equipment. It is possible to use a combination of different high-frequency techniques with the same instrument and generator. The technical realization of the resection requires no adaption of the surgeon.

Conclusion

The efficiency of TURP as gold standard in obstructive BPH is superior to all other treatment modalities today. In spite of possible complications, TURP is the best therapy to achieve excellent long-term results. Before recommending alternative therapeutic options, the high success rate of TURP should be considered, keeping in mind a reduction of perioperative morbidity using the so called 'coagulating intermittent cutting'.

The presented concept of a new high-frequency technology allows a blood sparing cut maintaining the classical surgical techniques and advantages of TURP. The latest development of the 'coagulating intermittent cutting' with pulses of constant voltage and control pulse intervals is a technique which allows highest cutting speed at optimal coagulation.

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