Principles of Electrocautery-Based Techniques

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Introduction

Electrosurgery was first described in great detail by A.J. McLean, who provided histological analysis and interpretation of the healing process in various animal tissues subjected to electrosurgery [1]. McLean also extensively studied principles regarding current density and heat transfer governing the effects of electrical current on tissue [1]. Since its initial description, electrosurgery has evolved into a widely used technology that allows surgeons to obtain a surgical effect such as cutting or coagulation by applying a high-frequency electrical current to a target tissue [1, 2]. This chapter will focus on the technical aspects of several electrosurgical techniques used in the treatment of BPH.

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Basic Principles

The core principles of electrosurgery revolve around the fact that human tissue introduced into an incomplete circuit will conduct current, therefore closing the circuit and resulting in heating of the tissue [3–5]. In an electrical circuit, current generated in an electrosurgical generator flows from a positive (active) electrode to a negative (return) electrode to form a complete circuit [4]. The amount of heat produced increases with increased current density, tissue resistance, and time as described by the following modification of Joule's Law (Eq. 2.1) [5].

$$\text{Energy} = \left(\frac{\text{current}}{\text{cross} - \text{sectional area}} \right)^2 \times \text{resistance} \times \text{time} \qquad (2.1)$$

A small surface on an active electrode leads to a current density sufficient to cause the desired tissue effect in a short amount of time, while a larger electrode would require a stronger current or more time to achieve the same degree of heating [2, 5]. In fact, the given effect on the tissue largely depends on the rate of temperature rise in tissue that can be varied by adjusting the settings of the electrosurgical generator [4, 5].

Cutting of tissue may be achieved by the application of a high-current, low-voltage continuous wave form causing a quick increase in tissue temperature [4]. Rapid rise in tissue temperature leads to the vaporization of tissue

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water and subsequent fragmentation [1, 4]. Coagulation can be achieved by using a wave form that is dampened, therefore delivered in short interrupted bursts with current-free intervals between the bursts [2, 4]. The slow temperature rise achieved by the dampened current leads to coagulation by thermal denaturizing of the tissue and with further time desiccation may subsequently occur [1, 4]. Various "blend" settings often exist on modern electrosurgical generators that can achieve a combination of cutting and coagulation by producing variations of dampened currents based on the surgeon's preference and desired outcome. Fulguration is a technique using a high-voltage interrupted current in which the active electrode is held a few millimeters away from tissue and passed over in a sweeping motion as sparks bridging the air gap lead to broad and superficial coagulation [2, 6]. As these tissue effects are a result of tissue heating, they can all be achieved with both monopolar and bipolar configurations.

Electrosurgical generators typically produce currents at a frequency ranging from 0.3 to 5 MHz for safety reasons [2]. At lower frequencies near or less than 100 kHz, electrical currents can cause neuromuscular stimulation resulting in muscle contraction and adverse effects in the patient [2]. At higher-range frequencies near 5 MHz or greater, the current can be more difficult to contain, and leak becomes a threat to the safety of both the patient and operator [2]. The output frequency of a given electrosurgical generator is typically a variable inherent to the device and manufacturer's specifications and is not adjusted by the user [7].

Fundamentals of Monopolar Endoscopic Techniques

Monopolar endoscopic techniques feature an active resection electrode typically in the form of a loop, a large dispersive pad located on the patient that acts as the return electrode and a continuous irrigating resectoscope [4]. The ideal irrigating fluid in monopolar procedures should be clear in color, chemically inert, and electrolyte free to avoid dispersion of current away from the targeted tissue, similar in osmolality to serum and able to be detected by the surgeon when absorbed into the intravascular compartment [8]. Classically, glycine has represented the irrigation fluid of choice in monopolar transurethral resection of the prostate (TURP) although mannitol, sorbitol, and glucose-based solutions are also used as alternatives [8–11]. The most commonly used irrigating fluid, 1.5 % glycine, is hypotonic to serum and has been known to cause TUR syndrome in a small portion of patients after TURP. Maintenance of body temperature is also an issue with continuous irrigation; therefore, pre-warming or continuous warming of irrigation solutions is helpful to avoid large perioperative decreases in body temperature and the potential adverse effects associated with hypothermia [12, 13].

TURP, initially developed as a monopolar technique, utilizes monopolar current to resect hypertrophied prostatic tissue through a variety of resection strategies. Monopolar transurethral electrovaporization of the prostate (TUVP) is a modification of the standard TURP; the first peer-reviewed study demonstrating its safety and efficacy was published by Kaplan and Te in 1994. A separate prospective, randomized controlled trial which compared TUVP to TURP in 150 men demonstrated improvements in the international prostate symptom score (IPSS), quality of life questionnaire (QoL), symptom problem index (SPI), and BPH impact index (BII) after TUVP which were comparable with TURP and endured at 10 years of follow-up [14]. With adjustment in the power and equipment, TUVP enables a surgeon to achieve a combination of vaporization, desiccation, and coagulation of prostate tissue using standard TURP equipment fitted with a grooved roller electrode [9, 15]. Electrovaporization is generally accomplished at a cutting current that is approximately 25 % higher power and a slower resection speed than the standard TURP [15]. As the roller electrode is moved along the surface of the prostate, cutting is achieved at the leading edge by the high current density that rapidly heats tissue leading to vaporization, while coagulation is produced at the trailing edge by a more diffuse current [15]. The difference in current density is

based on the principle that electricity flows via the path of least resistance, and as the tissue is vaporized, the underlying tissue experiences a certain degree of desiccation and therefore has a reduced conductance to current. Advantages to the simultaneous vaporization and coagulation include reduced blood loss, less fluid absorption, and reduced incidence of TUR syndrome [16, 17]. Monopolar transurethral electrovapor resection of the prostate (TUVRP) is similar to TUVP with the exception of using a thick loop to perform the vaporization at depth, which allows for the resection of "prostate chips" which may be sent for histological analysis, if desired.

Fundamentals of Bipolar Techniques

In contrast to monopolar techniques, bipolar electrosurgery features both active and return electrodes built into the instrument a small distance apart from each other [18]. This allows current to pass through the target tissue and return to the return electrode in the resectoscope, negating the need for a dispersive pad on the patient [4, 5, 18]. Additionally, resection can be carried out in a saline medium, which removes the risk of TUR syndrome and dilutional hyponatremia [7, 18, 19]. While the risk for TUR syndrome is theoretically reduced, one must still be cautious in patients with cardiac comorbidities, as the risk for fluid overload does exist with isotonic saline use [7].

The estimated depth of penetration for bipolar techniques is 0.5–1 mm, compared to an estimated 3–5 mm for monopolar techniques [20, 21]. The lower voltage and reduced depth of penetration result in reduced damage to surrounding tissues, which in principle reduces the risk of postoperative erectile dysfunction or adjacent organ damage [7, 20]. Bipolar setups have been used to perform bipolar TURP (B-TURP) which has shown to be an effective method of prostate resection and also can achieve vaporization of prostatic tissue while providing favorable hemostatic results [18, 22, 23]. Table 2.1 provides a detailed comparison of the differences between bipolar and monopolar technology.

Table 2.1 Side-by-side comparison of features of monopolar and bipolar transurethral resection of the prostate

	Monopolar TURP	Bipolar TURP
Irrigation solutions	Glycine, mannitol, sorbitol, glucose	Normal saline
Requires return pad on patient?	Yes	No
Approximate depth of coagulative necrosis	3–5 mm	0.5–1 mm
Can obtain prostate chips for histologic analysis?	Yes	Yes

Plasma kinetic vaporization of the prostate (PKVP) is an additional bipolar modality that utilizes radiofrequency energy in an electroconductive irrigation medium to create an ionized plasma layer to vaporize prostate adenoma [18, 19, 24]. A bipolar configuration may also be used to perform a TUVP or TUVRP.

Conclusion

Advancements in electrosurgical techniques have certainly had a significant impact on the practice of surgery. To achieve desired outcomes and protect patient safety, the operator must be aware of the technology and its appropriate use. In the electrosurgical management of BPH, the surgeon must choose from a wide range of techniques with the same goal in mind. Selection of the desired technique and technology may depend on several factors including patient characteristics, availability of equipment, operator experience, and preference. It is important to keep up to date with the body of available technologies to ensure that the chosen method will allow for the best possible outcome and patient safety profile.

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