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Review article

Electrosurgical technology: Quintessence of the laparoscopic armamentarium

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A B S T R A C T

One of the biggest enemies of minimally invasive surgery is bleeding. The ongoing desire to improve hemostasis and thus its efficacy has led to the rapid evolution of electrosurgical technology. In this review we discuss the yet evolving science of electrosurgery. For the optimal use of available tools, it is of utmost importance for the laparoscopic surgeon to understand that different electrosurgical instruments have different properties and thus their use has to be tailored. To understand the concept well, we review the important landmarks in the evolution of electrosurgery related to gynecological laparoscopy, revisit the basic principles, and then proceed on to discuss the modern tools in the electrosurgical armamentarium.

Introduction

Use of laparoscopic surgery in gynecological practice is increasing worldwide. A recent review exploring surgical trends in Taiwan over the past 2 decades,[1] confirmed that operative laparoscopy is widely accepted as an efficacious technique in the treatment of gynecological lesions. According to a nationwide population-based data in Taiwan, use of laparoscopic approach for hysterectomy increased dramatically from 5.2% to 40.4%, with a simultaneous decrease in the open approach from 77.3% to 45.7% in a span of 10 years.[2] It is noteworthy to say that this aggrandizement in laparoscopy was possible owing to the advancement of technology and human desire to explore and exploit the possibilities.[3] One of the biggest enemies of minimally invasive surgery is bleeding. The ongoing desire to improve hemostasis and thus its efficacy has led to rapid evolution of electrosurgical technology. Indispensability of electrosurgical technology in a laparoscopic armamentarium is well known to surgeons. In a recent publication, the incidence of electrosurgical injuries, mechanisms of injury, and recognition and management of electrosurgical complications were discussed.[4] In this review we discuss the evolving science of electrosurgery. The main aim is to focus on various energy sources available today.

Methodology

This review includes a search of electronic resources, namely Medline, PubMed, CINAHL, the Cochrane Library, Current Contents, and EMBASE. The Medical Subject Headings (MeSH) including all subheadings and keywords used included *Electrosurgery*, *Electrosurgery in laparoscopy*, *Electrocoagulation*, *Monopolar electrosurgery*, *Bipolar electrosurgery*, *Vessel sealing system*, and *Ultrasonic electrosurgery*. Articles were screened for historical facts as well as recent advances about electrosurgery. Web searches were performed using educational sources if appropriate.

Results and discussion

Electrosurgery was incorporated in the armamentarium of gynecological laparoscopic surgeries around 8 decades ago and has exponentially evolved with time. Indeed electrical energy is the most common form of energy used in gynecological laparoscopies

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today; unfortunately it still remains one of the least understood sciences among the users.[5]

Historical overview

In 1911 Jacobaeus[6] of Stockholm introduced the concept of diagnostic visualization of the peritoneal cavity and termed this new procedure *laparoscopy*. However, the first reported use of laparoscopy in conjunction with electrosurgery was by Fervers,[7] a general surgeon, way back in 1933 when he attempted laparoscopic adhesiolysis. Power and Barnes[8] in 1941, reported the first ever human performance of laparoscopic electrosurgical female sterilization using a monopolar instrument. The concerns related to the considerable morbidity due to thermal injuries on using monopolar energy contributed to the evolution of bipolar devices in around 1970 by Frangenheim[9] in Germany and Rioux and Cloutier[10] in North America. The same technique was further refined by Kleppinger[11] in 1977 and thus originated the still famous Kleppinger bipolar forceps. These designs were used mostly unchanged until the early 21st century, when a number of proprietary bipolar systems emerged based on the recognition that high radiofrequency–electrosurgical coagulation and desiccation could be used to seal vessels of substantial size predictably, and with much reduced lateral thermal injury. In 1993, Amaral[12] first described the ultrasonic scalpel for laparoscopy as having the ability to provide both vessel sealing and tissue transection. However it gained practical popularity only from 2010 onwards. A hybrid of advance bipolar and ultrasonic technology to maximize the efficacy of electrosurgery has currently brought hopes to herald a new era in the electrosurgical armamentarium; it has yet to prove itself efficiently in the surgical battlefield (Fig. 1).

Mini revisit to electrosurgical biophysics and basic principles

In simple terms, the source of electrical energy in the operating room actually originates from surrounding power generation facilities and is delivered to the operating room through wires. In the operation room, this energy is modulated by the electrosurgical unit (ESU) or power generator in order to imbue current with appropriate and specific characteristics to produce the desired tissue effects during surgical procedures.

Electrosurgical procedures basically depend on a circuit that involves: an ESU (or power generator), an active electrode, target tissue (of the patient), and a return electrode. The flow of electricity or electrons in this circuit is alternating current (AC), which means that, in the ESU, anode and cathode are continuously interchanged. For safe application to the human body, a key characteristic that must be altered is the frequency of the AC. As with normal frequency of AC (i.e., 60 Hz) muscles and nerves are stimulated to produce muscle spasms and abnormal movements during surgery. However, the dreaded hazard of the 60-Hz frequency is interference with conductivity of heart muscle, resulting in cardiac arrest and death by electrocution.[5]

It has been observed that these adverse effects of AC can be overcome by the increasing the frequency exponentially. Modern-day ESUs use frequency ranges of 200 kHz to 50 MHz as this allows for desired thermal effects without muscle fasciculation or nerve stimulation.[13] This tissue effect is achieved by the conversion of flowing electric energy to thermal energy when it encounters resistance (target body tissue). Thermal energy can cause cutting, coagulation, desiccation, and fulguration, depending upon the electrodes and how they are manipulated. These varied effects can be achieved by adjusting the voltage and active time of the electrode that energy is applied to target tissues.

Evolution of technology

As the surgery becomes less invasive, and the technical difficulty increases, the demand for a reliable energy device becomes stronger.[14–17] The evolution of the ESU has been briefly discussed previously. This section basically deals with four generations of electrosurgical systems to maximize desired tissue effects while minimizing adverse effects.

Conventional monopolar electrosurgery

Monopolar electrosurgery refers to the arrangement of a single small electrode at the tip of the surgical instrument that delivers focused alternating electrical current to the target tissue for the desired surgical effect. The second electrode is placed on the patient at a site remote from the surgical site to complete the electrical circuit (conventionally referred to as cautery plate). Conventional monopolar electrosurgery remains a popular

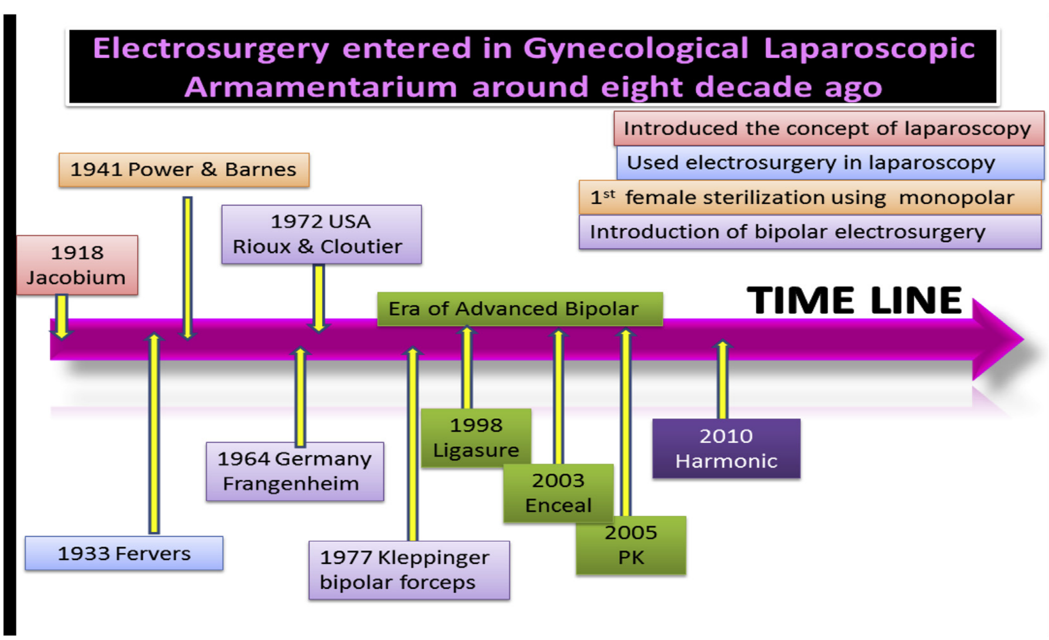

Fig. 1. Important landmarks in the evolution of electrosurgery in gynecological laparoscopy.