Gynecologic and Dermatologic Electrosurgical Units: A Comparative Review

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Electrosurgery is a popular surgical technique in which high-frequency, low-voltage electrical energy produced by an electrosurgical unit is used to excise abnormal tissue with hemostasis. In this study, electrosurgical units were critically evaluated for safety, electrical specifications, design, and performance characteristics. Quantitative electrical specification and histologic thermal artifact measurements and qualitative observations were recorded for 13 electrosurgical units representing 11 manufacturers.

The Aspen Sabre 180 and Laserscope e^{10} were considered exemplary units based on safety criteria alone. Cut-mode thermal artifact was less than 10 μm for the Cooper Leep 6000, Laserscope e^{10}, and Utah Finesse. A maximum fulguration distance of greater than 0.5 mm was demonstrated by the Gyne-Tech Autolepe 2000 and 4000, Laserscope e^{10}, and the Elmed ESU 30.

For gynecologic electrosurgery, the Aspen Sabre 180 and Laserscope e^{10} were rated best, followed closely by the Utah Finesse and Finesse II and the Gyne-Tech Autolepe 4000. Dermatologic electrosurgery may be well accomplished with many of the electrosurgical units, except as noted.

Key words. Electrosurgery; surgical equipment; technology assessment, biomedical; comparative study.
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Electrosurgery is a surgical technique in which high-frequency, low-voltage electrical energy may be used to excise abnormal tissue with concomitant hemostasis.[1] The electrosurgical loop excision of the cervical transformation zone (ELECTZ) procedure for treatment of premalignant cervical disease epitomizes a contemporary gynecologic application of this technology.[2] Electrosurgery is also commonly used for dermatologic procedures. Modern monopolar electrosurgical units enable effective electrosurgery in ambulatory and hospital-based clinical settings.

The electrosurgical unit usually includes the necessary equipment to perform electrosurgery safely and effectively. A complete circuit, represented by the electrosurgical generator, an active electrode, the patient, and a return or dispersive electrode, permits the circular flow of current. The electrosurgical unit selectively generates thermal energy in tissue to cause cellular vaporization (for the purpose of cutting) or protein denaturation (for coagulation). The electrical current produced may be modified to minimize thermal damage at the margins of the excised specimen and at the base of the excision. The cutting current also may be modified or blended to alter the level of hemostatic (coagulation) effect.

Solid-state, medium- and high-powered electrosurgical units have been previously evaluated solely on electrical performance and safety testing.[3] Electrosurgical units have not been evaluated for performance on in vitro tissue. The purpose of this study was to critically evaluate commercially available electrosurgical units typically used in ambulatory primary care settings, with particular application to office dermatologic and gynecologic procedures.

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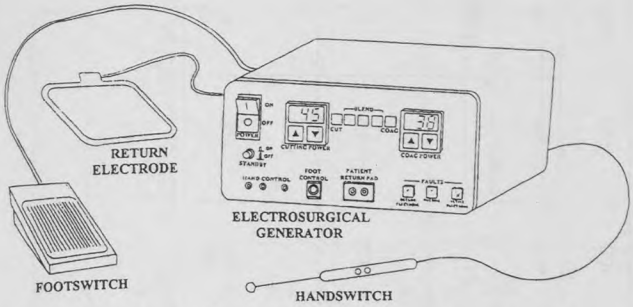

Figure. The electrosurgical unit includes a generator, active electrode and handpiece, dispersive pad or return electrode, and occasionally a foot switch.

Electrosurgical Unit Components

Electrosurgical Generator

The electrosurgical unit (ESU) contains a high-frequency oscillator that produces the desired current as distinct voltage waveforms for cutting, coagulation, or a blend of the two modes (Figure). The power output may be adjusted by altering the on/off duty cycle to accommodate the active electrode type and size, and to produce the intended surgical effect. For example, by increasing the peak-to-peak voltage, the ability of the unit to fulgurate (produce a superficial coagulum of tissue that insulates deeper tissues from injury) is increased, as clinically demonstrated by a greater spark-gap distance, ie, the distance between the electrode and tissue. Some electrosurgical generators feature microprocessor monitors to detect circuit faults, which could cause serious burns to the patient or clinician. Many units employ isolated technology that constrains the radio frequency current to the return electrode and ESU. Isolated technology is generally considered safer than ground-referenced technology.

Activation Switches

Before electrosurgery begins, the generator is turned on and the proper surgical modes and power settings are selected. Electrosurgery may be initiated by either a hand switch or foot switch. Typically, two separate buttons, switches, or a single bimodal switch on the handpiece activates either the cut or coagulation mode. The handpiece insulates the clinician from the electrical current and holds the active electrode. Alternatively, foot-pedal switches placed on the floor permit the clinician to activate the ESU and active electrode by simply exerting pressure on the foot-operated device. Most foot switches have separate pedals for cutting and coagulation.

Electrodes

Although electrodes may be disposable or reusable, some experts discourage the use of reusable return electrodes.[4] Active and return electrodes are required by most units for circuit continuity during electrosurgery. The proximal end of the active electrode is inserted into the distal handpiece. Active electrodes used for cutting are shaped as a loop, square, triangle, diamond, or needle. Active electrodes have an insulated shaft and an insulated base to prevent electrical shock to the patient or clinician and thermal damage to the excised tissue. Loops are made of fine-caliber tungsten or stainless steel wire. The larger the active electrode, the greater the amount of power required for cutting.

Ball or blade electrodes, which are used to induce hemostasis by fulguration, are inserted into the handpiece after the cutting electrode is removed. Ball electrodes generally measure 3 mm or 5 mm in diameter. Ball electrodes also may be used for desiccation (drying, or the production of a coagulum of tissue by direct contact between the electrode and the tissue). Electrocoagulation is a term reserved for a lower-voltage, high-amperage modality that allows for a greater magnitude of coagulation when the patient is incorporated into the electrical circuit by means of a dispersive electrode.[5]

Return or dispersive electrodes transfer the current from the patient to the generator to complete the electrical circuit. Return electrodes or dispersive pads should be maintained in complete contact with the patient. Higher quality dispersive pads adhere to the skin. These pads have a large surface area designed to disperse the returning current exiting the patient. A partially adherent pad could concentrate the returning energy and inflict a burn to the patient. Therefore, many electrosurgical units have an electrode continuity monitor that prevents activation of the ESU if the return electrode pathway to the unit is interrupted (unplugged or broken). Safer units feature separate redundant systems or contact quality monitors (return electrode monitoring) that check, by an impedance signal, the effectiveness or quantity of the return electrode surface area contacting the patient.[3] Hence, unit activation is prevented if incomplete dispersive pad contact occurs, thus avoiding potential patient burns.

Safety Systems

Safety systems are an essential component for electrosurgery to prevent accidental electrical or thermal injury to the patient, clinician, or assistant. Most units have a circuit cable continuity monitor that detects circuit faults and de-energizes the unit power output. Contact quality monitoring provides additional safety feedback. Many

Table 1. Electrosurgical Unit Electrical and Safety Testing

Variables	ASPEN SABRE 180	CAMERON MILLER MODEL 26-2500	COOPER LEEP 6000	ELLMAN SURGITRON FFPF	ELMED ESU30	GYNE-TECH AUTOLEPE 2000	GYNE-TECH AUTOLEPE 4000	LASERSCOPE e[10]	NORDEX POWER-GYN 800-100	PREMIER 06301	UTAH FINESSE	UTAH FINESSE II	WALLACH LEAP 100
Maximum output power (W) (indicated W or setting/delivered W)	25/24 50/50 100/90	40/20 80/55 152/155	30/28 60/60 100/100	CUT 5/65 CUT 7/78 CUT HI/85	CUT5 /24 CUT 7/32 CUT 10/40	CUT/65 BLEND/73 HARD COAG/97	35/35 70/70 165/140	50/49 150/140 300/277	CUT 5/48 CUT 8/74 CUT 10/80	CUT 5/75 CUT 7/90 CUT 10/100	30/28 50/50 99/100	CUT/60 COAG/60 _____	35/25 70/65 108/120
Variable power settings	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES
Leakage current open ground, power off (μA)	14	11	12	25	14	20	18	49	___[1]	19	16	14	21
Leakage current open ground, power on (mA)	10	8	10	8	8	12	9	39	___[1]	7	20	10	6
Maximum line current (A)	1.7	1.5	1.0	0.3	1.1	1.0	2.1	1.4	___[1]	1.2	2.5	2.4	1.8
RF peak to peak voltage, pure cut (V)	250	80	250	____[2]	80	150	150	40	___[1]	____[2]	100	150	260
Maximum power generated (W)	91	155	100	85	40	65	65	300	___[1]	100	100	60	120
Activation tone range (dBA)	57-81	52-88	66	NONE	69-80	71-94	67-90	57-66	___[1]	NONE	____[3]	____[3]	NONE
Safety Alarm to signal dispersive pad unplugged	YES	YES	NO	NO	YES	YES	YES	NO	YES	NO	YES	YES	NO
No dispersive pad contact with patient indicated by: alarm light	YES YES	NO NO	NO NO	NO NO	NO NO	NO NO	NO NO	YES YES	NO NO	NO NO	NO NO	NO NO	NO NO

[1] Technical difficulty;
[2] RF exceeds measurement;
[3] Smoke evacuator masked measurement
W denotes watts; μA, microamperes; mA, milliamperes; A, amperes; V, volts; dBA, decibels absolute; RF, radio frequency.

Table 2. Electrosurgical Unit In Vitro Performance Characteristics

Variables		ASPEN SABRE 180	CAMERON MILLER MODEL 26-2500	COOPER LEEP 6000	ELLMAN SURGITRON FFPF	ELMED ESU30	GYNE-TECH AUTOLEPE 2000	GYNE-TECH AUTOLEPE 4000	LASERSCOPE e[10]	NORDEX POWER-GYN 800-100	10 PREMIER 06301	UTAH FINESSE	UTAH FINESSE II	WALLACH LEAP 100
Cut thermal artifact (mm)														
100mm/min	30W	12	12	10	10	13	—	15	3	20	20	7	—	7
	40W	12	8	10	20	—	—	22	10	12	10	10	—	10
	50W	15	16	10	12	—	20[1]	5	8	5	7	5	20[2]	15
Cut thermal artifact 40W														
90mm/min		—	20	5	10	12	15	10	10	11	15	10	5	5
110mm/min		15	30	6	11	15	—	8	10	10	20	7	10	20
Maximum fulguration distance (mm)		0.24	0.11	0.02	0.02	0.52	0.55	0.73	0.58	0.37	0.03	0.26	0.48	0.36

1—at 65 watts; 2—at 60 watts

units also signal an audible tone, flashing light, or both when the circuit pathway is interrupted.

On many units, audible and visual (light) indicators of ESU activation signal operation. Several units feature different audible tones for cutting and coagulation. Some experts consider any ESU without an activation tone to be unacceptable.[3] Visual activation indicators are frequently color-coded to meet international safety standards. Many units allow for volume adjustment on the audible activation control, but the audible indicator should not be deactivated.

Smoke Evacuators

Smoke evacuators are an additional piece of equipment necessary in some circumstances. Smoke evacuators remove and filter the "plume" generated at the operative site to maintain visibility when operating in enclosed spaces. The evacuators filter airborne particles and microorganisms, enhancing safety for both the patient and the operative staff. Although one manufacturer combines the generator and smoke evacuator in a single unit, smoke evacuators are usually separate pieces of equipment.

Methods of Evaluation

All electrosurgical equipment manufacturers or distributors in the United States were asked by letter to provide electrosurgical units and product specification data for critical review during the summer of 1993. Eleven manufacturers agreed to participate, and 13 units were received for evaluation. The following corporations chose not to participate: Birtcher Medical Systems (Irvine, Calif), Cabot Medical (Langhorne, Pa), Leisegang Medical, Inc (Boca Raton, Fla), MDT Diagnostic Co (N Charleston, SC), Valleylab, Inc (Boulder, Col), and Zinnanti Surgical Instruments (Chatsworth, Calif).

The evaluation was divided into three phases. In phase 1, ESU electrical specification and safety testing was conducted on each unit (Table 1). Output power was measured with a Neurodyne Dempsey ESU Analyzer (model 443). With the exception of ESUs that had a single preset power, four different power settings were tested in three trials to determine if the delivered power was within 10% of the power indicated on the ESU. The 60-Hz leakage current with an open ground, power on and then off, and ground wire resistance were measured using a Biotek Digital Safety Analyzer (model 170). Maximum power-line current was measured with an Amprobe. Peak-to-peak voltage was measured in the pure cut mode and highest power setting using a 100-Ω noninductive resistor and a Tektronix 465B Oscilloscope with

a 10× probe at 50 volts per division vertical scale. The peak-to-peak amplitude of the radio frequency signal was measured for all units except for the Ellman and Premier ESUs, whose amplitudes exceeded full scale on the oscilloscope screen. Maximum power output in the pure cut mode was measured using a Neurodyne Dempsey ESU Analyzer (model 443). The volume range of the adjustable audible activation tones was measured using a Quest Electronic Impulse sound level meter (model 2700) except for the Utah Medical ESUs, in which the built-in smoke evacuator noise masked the activation tone.

Electrosurgery cutting and fulguration techniques were performed using in vitro media in phase 2 (Table 2). A Crusader II milling machine was used to accurately standardize cutting speed and depth of incision. The ESU handpiece and closely standardized loop electrodes provided by the respective manufacturers were clamped to the arbor of the machine. After determining a zero reference point on the surface of a ½-in.-thick slice of pork (water content 74%), the programmed machine lowered the activated loop electrode 8 mm deep, traversed 15 mm in a horizontal plane, and then raised the loop to a resting position.

In the first evaluation, the speed of pure cut was constant at 100 mm per minute, and two cuts were made by each ESU at 30, 40, and 50 W. In the second evaluation, the power of each ESU was held constant at 40 W and cuts were made at 90 mm per minute and 110 mm per minute. Return electrode pads were appropriately positioned beneath the tissue. Between each cut, specific manufacturer-supplied loop electrodes were cleaned of all carbon deposits. A smoke evacuator filtered the generated plume at the operative site. Formalin-fixed, paraffin-embedded sections of pork skeletal muscle were cut at 5 μm, and stained with hematoxylin-eosin, and thermal artifact was measured microscopically with a stage micrometer.

Maximum fulguration distance was evaluated using the Crusader II milling machine. The activated 5-mm ball electrode was positioned precisely 1 mm from the surface of the tissue and then was lowered in 0.1-mm increments until two of five attempts to produce a spark from the ball to the tissue were successful. Then the ball was lowered in 0.01-mm increments until three of five attempts at fulguration were successful.

In phase 3, three authors independently evaluated each unit's features and performance in a simulation of clinical performance using animal tissue models. Summation of the independent scores determined the final unit rankings. Only mutually similar observations were considered valid and reportable.

The Electrosurgical Units

Aspen Saber 180

The Aspen Saber 180 (ConMed/Aspen Labs, Utica, NY) is well designed for electrosurgery. Useful, concise operation instructions are written on the top of the unit housing for quick reference. The sloped display panel is state-of-the-art and user-friendly. All ports are easily identified by both written and pictorial labels. The operator's manual is easy to read but poorly illustrated. The Saber 180 does not include a set of electrodes useful for office dermatologic surgery.

The performance characteristics of the Saber 180 are notable. The cut was excellent, and fulguration was very good. The unit has two blend modes. Power variability is adjustable by the user.

The Saber 180 was considered one of the safest electrosurgical units evaluated. The unit features a return monitoring system. The system or contact quality monitor graphically depicts impedance by an illuminated bar graph on the control panel. The manufacturer provides a "hold harmless agreement" that protects the clinician legally in the event of an accidental electrosurgical burn.

The Saber 180 is easy to use and incorporates a superb safety system. It is marketed primarily for endoscopic, gynecologic, and laparoscopic use.

Cameron Miller Model 26–2500

The Cameron Miller Model 26–2500 (Cameron Miller Inc, Chicago, Ill) is a moderately priced, small, portable electrosurgical unit designed for ambulatory care use.

The cutting performance of the Model 26–2500 was characterized as fair. The unit has a single blend mode (60% cut, 40% coagulation). The fulguration was rated as average. Power variability was adjustable by user. The operator's manual was well written but poorly illustrated.

The Model 26–2500 has no return electrode monitoring system, but the unit will not cut if the dispersive pad is off the patient. However, the coagulation mode can be activated when the dispersive pad is removed from the patient, and there is no warning alarm or light to indicate this situation. When the dispersive pad plug was removed from the unit, an alarm and light were activated. The operation modes are color-coordinated throughout the unit, with yellow indicating cutting and blue indicating coagulation.

The Cameron Miller Model 26–2500 is a good office-based electrosurgical unit with average performance characteristics. Electrodes are available for cutaneous surgery.

Table 3. Electrosurgical Unit Features and Performance

Variables	ASPEN SABRE 180	CAMERON MILLER MODEL 26-2500	COOPER LEEP 6000	ELLMAN SURGITRON FFPF	ELMED ESU30	GYNE-TECH AUTOLEPE 2000	GYNE-TECH AUTOLEPE 4000	LASERSCOPE e[10]	NORDEX POWER-GYN 800-100	PREMIER 06301	UTAH FINESSE	UTAH FINESSE II	WALLACH LEAP 100
Maximum cutting power (W)	100	150	100	140	55	300	15 0	3 00	1 00	100	100	65[1]	100
Maximum coagulation power (W)	80	75	80	90	55	125	1 00	12 0	6 0	7 0	75	60[1]	65
Blend mode- % cut/coag[6]	65/35 40/60	55/45	80/20	50/50	70/30	80/20	82/18 75/25 65/35 60/40	4 MODES Continuous Voltage	80/20	70/3 0	70/30 50/50 30/70	70/30	65/35
Output frequency (kHz)	417	500	550	3 8 00	1700	400	4 00	3 50	45 0	2 9 00	400	400	500
Rated load (ohms)	500	500	400	4 00	5 00	500	4 00	5 00	2 00	4 00	500	500	500
Maximum voltage - cut	1,000	1,300	700	600	9 00	580	8 70	566	1,100	1,600	1,000	1,200	1,000
peak to peak (V) coag	6,500	1,600	2,500	600	1,700	5,000	5,000	4000	1,600	1,600	5,000	5,000	1,500
Digital output indicator	YES	YES	YES	NO	NO	NO	YES	YES	NO	NO	YES	NO[1]	YES
Hand switch	YES	YES	NO	YES	NO	YES	YES	YES	YES	NO	YES	YES	NO
Foot switch	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controlled output circuitry	YES	YES	NO	NO	NO	YES	NO	YES	?	NO	YES	YES	NO
Ground reference technology	NO	NO	NO	YES	YES	NO	NO	NO	NO	YES	NO	NO	NO
Isolated technology	YES	YES	YES	NO	NO	YES	YES	YES	YES	NO	YES	YES	YES
Patient electrode continuity monitor	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	NO
Return electrode monitor REM (Quality contact)	YES	NO	NO	NO[4]	NO	NO[5]	NO[5]	YES[2]	NO	NO	NO	NO	NO
Activation tone	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	NO
Adjustable tone volume	YES	YES	YES	NO	YES	YES	YES	YES	NO	NO	YES	YES	NO
Hold harmless agreement	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Safety	●	◔	◕	◔	◑	◑	◑	●	◔	◔	◕	◕	◔
Cut	◕	◔	◑	◑	◑	◕	◕	●	◕	◔	◕	◑	◑
Fulguration	◕	◑	◑	◔	◑	◑	◑	◕	◔	◔	◔	◔	◑
Dimension (H/W/L in inches)	6/12/16	5/12/11	45/8/111/210	4 3/4/8/6 3/4	5/13/12	5/10 1/2/103/4	5/10.5/10.75	16/6/14 1/2	5/12/11	31/4/8/111/2	7/14.2/14.1	6.2/12.8/13	5/61/2/91/2
Weight (lbs.)	20	10.5	14	9.5	8	8.5	9	26	16	7	25[3]	20[3]	5
Warranty (Parts/Labor)	2 YR.	1 YR	1 YR	2 YR	1 YR	2 YR	2 YR	1 YR	1 YR	2 YR	2 YR	2 YR	1 YR
Price	$3995	$2495	$3,000	$1995	$1295	$3995	$3995	$7500	$2695	$1535	$5200	$3200	$2295
Recommendation	◕	◔	◕	◔	◔	◕	◕	●	◑	◔	◕	◕	◔
Crest factor													
peak voltage: cut	1.8	1.6	1.7	1.5	1.7	1.4	1.4	1.4	1.9	2.0	2.0	2.8	1.6
RMS voltage coag	7.0	3.8	7.0	2.1	4.0	8.2	8.2	6-14[7]	3. 0	2.8	6.5	6.5	3.7

[1] Preset (blend mode)
[2] Neutral electrical safety system
[3] Includes smoke evacuator
[4] Antenna plate
[5] Quality of contact with split pad
[6] Burst duty cycle
[7] Dependent on power setting

RATING SCALE

● Superior ◕ Excellent ◕ Very Good ◕ Good ◑ Fair ◔ Average ◔ Below Average ◔ Poor ○ Unacceptable

Cooper LEEP System 6000

The LEEP 6000 electrosurgical unit (Cooper Surgical Inc, Shelton, Conn) is designed specifically for gynecologic-based electrosurgery, as evidenced by the simplified and basic display panel and by the selection of active electrodes. The compact unit, however, has no capability for handpiece activation. The manufacturer provides an array of equipment and supplies for this unit. The operating manual is lavishly illustrated and easy to follow. There is an insufficient manufacturer-supplied selection of electrodes available for cutaneous surgery.

The clinical performance of the LEEP 6000 was rated average for both cut and fulguration. Power output is adjustable by user.

The LEEP 6000 does not feature a return electrode monitoring system; however, several other noteworthy safety features are included. The unit has a test-mode system. Failure to plug in the dispersive pad plug will activate an alarm and indicate "fail" on the digital display. If the pad is off the patient, the unit will cut and fulgurate mildly, but it emits an intermittent audible alarm. All plug receptacles are unique to avoid improper placement.

The Leep 6000 unit is well designed with many noteworthy features appropriate for office-based electrosurgery.

The Ellman Surgitron FFPF

The Ellman Surgitron FFPF electrosurgical unit (Ellman International, Hewlett, NY) is a relatively high-frequency electrosurgical generator. As such, the manufacturer claims that an "antenna pad" precludes the need for a dispersive pad. The unit operated slightly better when the antenna was in contact with the patient. The operating manual is simple and easy to read but has minimal illustrations and does not adequately explain the proper use of its features. This unit includes a wide range of reusable and disposable electrodes, including those suited for dermatologic applications.

The performance of the Surgitron was characterized as average for cutting and fair for fulguration. At the highest setting for fulguration, only minimal spray or arcing distance was noted. Power output is adjustable by the user.

The Surgitron features no return electrode monitoring system. There is a light but no auditory signal to indicate unit activation. There is neither a light nor an alarm to signal breach of circuit continuity. The screws surrounding the output knob appear to conduct electricity, posing a possible electrical hazard.

The Surgitron is a basic, average-performing, high-frequency electrosurgical generator with few safety features.

Elmed ESU 30

The Elmed ESU 30 (Elmed Inc, Addison, Ill) is the lowest powered unit evaluated. The unit operates by an unstable foot switch only. The handpiece and electrode are quite long, which could hinder procedures viewed through a colposcope. The operating manual is detailed and well illustrated.

The performance of the ESU 30 was rated average for cutting and below average for fulguration. A variety of electrode tips, including a few that are useful for dermatologic lesions, are available. Power output can be varied by the user.

The ESU 30 has no return electrode monitoring system. An alarm signals when the dispersive pad is unplugged; however, there is no alarm or any lights to indicate when the dispersive pad is not in contact with the patient. The dispersive pad, which is connected to the ESU by two alligator clips, is considered minimally secure. In our tests, there was little difference in the frequency tone during activation and patient alarm. The unit also was noted to cut and desiccate when the dispersive pad was removed from the patient.

The ESU 30 is a basic electrosurgical unit that is priced inexpensively.

Gyne-Tech Autolepe 2000

The Autolepe 2000 (Gyne-Tech, Burbank, Calif) is a simplified electrosurgical unit that incorporates "dynamic tissue energy control." This system senses tissue impedance and electrode contact resistance to control proper current to tissues. The power selection is set at 60 W and is not adjustable. There is one blend mode and a switch to select desiccation or fulguration. It is a unit clearly marketed exclusively for use in ELECTZ procedures.

The performance of the Autolepe 2000 was rated excellent for cutting and average for fulguration.

The unit has no return electrode monitoring capability; therefore, there is no light or alarm to indicate when the dispersive pad is not in contact with the patient. An alarm does indicate when the dispersive pad is unplugged from the generator. The unit features an audible feedback when an adequate cut is being performed. There is no tone feedback during fulguration, yet there is feedback present during the desiccation mode. The unit is also able to fulgurate if a patient is not in contact with the dispersive pad.

The Autolepe 2000 is a simplified, preprogrammed

electrosurgical generator designed for use in ambulatory care settings. Its automatic internal power adjustment capability is characteristic of a contemporary ESU.

GyneTech Autolepe 4000

The Gyne-Tech Autolepe 4000 (Gyne-Tech, Burbank, Calif) is similar to the Autolepe 2000, except that unit power is adjustable by the operator. The range of electrodes supplied is consistent with its marketed indication for use in gynecologic electrosurgery.

The performance of the unit was judged as very good in the cutting mode and average for fulguration.

Safety features of this unit are similar to those of the Autolepe 2000. The Autolepe 4000 is well suited for office-based electrosurgery.

Laserscope e^{10}

The Laserscope e^{10} (Laserscope Surgical Systems, San Jose, Calif) features state-of-the-art electrosurgery systems. The e^{10} is more likely to be found in hospital operating rooms than in outpatient settings. The control panel is self-explanatory and color-coordinated for cut and coagulation. The operating manual is well illustrated and technical in detail. Electrodes available reflect its hospital-based use and do not include a range of tips suitable for cutaneous surgery.

The performance of the e^{10} was rated as excellent for both cutting and fulguration. The system features a microprocessor, which continually monitors and adjusts power levels (constant-voltage electrosurgery) for optimal tissue performance. The ESU also indicates an error and deactivates if it detects a stall speed. This function minimizes thermal artifact.

The e^{10} features the "Nessy" neuroelectrode safety system, a return electrode monitoring system that is considered to be one "gold standard" for safety design.

The e^{10} is a well-designed and extremely safe electrosurgical unit that is used more commonly in the operating room than in outpatient settings.

Nordex Model 800–100 PowerGyn

The Nordex PowerGyn (Nordex Medical Corporation, Grand Rapids, Mich) is a basic electrosurgical unit designed for use in the ambulatory care setting. The operating manual is detailed but has no illustrations. The range of active electrodes includes those useful for cutaneous surgery.

The performance of the Nordex was rated good in the cutting mode and below average for fulguration.

The PowerGyn does not feature a return electrode monitoring safety system. A light is displayed and an alarm activated if the dispersive pad plug is removed from the unit. However, no alarm or lights indicate when the dispersive pad is not in contact with the patient. This unit uses a fan for cooling purposes.

The PowerGyn electrosurgical unit is a good basic electrosurgical generator for use in office settings.

Premier 06301

The Premier 06301 (Premier Medical, Norristown, Pa) electrosurgical generator is a relatively high-frequency electrosurgical generator developed for use in ambulatory care settings. The unit is basic in design. It features one blend mode, no hand switch, and individual plug receptacles for coagulation, cut, blend, and fulguration. There is a wide selection of active electrodes available for use, including those needed for cutaneous surgery. The operator's manual is too brief and poorly illustrated.

The performance of the 06301 unit was rated fair for cutting and fulguration. The power selection dial is not uniformly linear.

The Premier 06301 has no return electrode monitoring system. When the dispersive pad was off the patient, the unit was noted to cut and fulgurate without alarms or visual indicators on the display. The unit also cut if the dispersive pad was not plugged into the control panel.

The Premier electrosurgical generator is a basic high-frequency unit with few safety features.

Utah Finesse

The Utah Finesse (Utah Medical Products, Inc, Midvale, Utah) is a unique and well-designed electrosurgical system. Electrosurgical units manufactured by Utah are the only ESUs that combine a generator and smoke evacuation system into one unit. Such an arrangement is ideal when storage space is a consideration. The smoke evacuator operates whenever the ESU is activated and continues for a short time after the cutting electrode is deactivated. The control panel is user-friendly in design and features three blend modes. It has a well-written and well-illustrated operator's manual. No electrodes for cutaneous surgery are supplied with the ESU.

The performance of the Finesse unit was excellent for cutting and good for fulguration.

The Finesse electrosurgical unit includes controlled output circuitry, a negative feedback system that adjusts output to an optimal range to maximize clinical performance and minimize thermal artifact. The Finesse unit

does not include a separate return electrode monitoring system. However, the system utilizes a patient electrode-continuity monitor that deactivates the unit when a breach in the circuitry is indicated.

The Finesse is a well-designed electrosurgical unit system that incorporates a smoke evacuator.

Utah Finesse II

The Finesse II (Utah Medical Products, Inc, Midvale, Utah) is a preprogrammed, user-friendly version of the Finesse ESU. The cut, coagulation, and blend modes are preset. The only adjustable feature is the on/off switch. The Finesse II includes a built-in smoke evacuation system.

The performance of the Finesse II was rated good for both cut and coagulation modes.

The safety system is similar to that employed by the Finesse unit. The alarm tone is not adjustable and a safety light is present.

The Finesse II electrosurgical generator is a user-friendly system with a built-in smoke evacuator. The lack of adjustable power settings limits its use to gynecologic electrosurgery, for which it is specifically designed.

Wallach Leap 100

The Leap 100 (Wallach Surgical Devices, Inc, Milford, Conn) is a basic electrosurgical unit. The unit has one blend mode. The Leap 100 also has no hand switch. Its operator's manual is written understandably but is not illustrated. A variety of electrodes, including those for cutaneous surgery, are available.

The performance of the Leap 100 was rated good for cut and average for fulguration. Power output is adjustable by the operator.

The Leap 100 has no return electrode monitoring system and no audible tones or alarms. There is no alarm to signal when the dispersive pad is unplugged and no alarm or lights to indicate when the pad is not in contact with the patient.

The Leap 100 electrosurgical generator is a basic, simplified electrosurgical unit designed for use in the ambulatory care setting.

Discussion

Safety is the most important priority when considering the purchase and operation of electrosurgery equipment. Optimal safety systems protect the patient, staff, and clinician from accidental injury and potential financial repercussions. Available safety monitoring systems, such as return electrode monitoring or contact quality monitoring, minimize the possibility of a mishap. Circuit continuity monitors and isolated outpatient circuitry are other examples of basic safety features expected of a quality generator. Actual historical data documenting outpatient electrosurgical injuries are incomplete and unreliable. Therefore, the safety ratings in this study are based on the presence of features that are designed to limit electrical accidents. The Aspen Sabre 180 and Laserscope e[10] are considered exemplary electrosurgical units based on safety criteria alone.

Unit clinical function is the next most significant consideration. Units should be capable of effective cutting with minimal thermal damage to excisional tissue. The output power of most electrosurgical units can be adjusted within a specified range to accommodate varied impedance encountered by differences in tissue conductivity and loop electrode size. Some generators monitor the impedance and self-adjust the power according to demand. Several units demonstrated noteworthy excision modes while maintaining minimal thermal artifact. The Aspen Sabre 180, Gyne-Tech Autolepe 2000 and 4000, Laserscope e[10], and the Utah Finesse were judged to be the overall best units based on these criteria.

Fulguration to achieve adequate hemostasis is the second important function of electrosurgical units. Once an effective excision is accomplished, the clinician encounters active hemorrhage at the excisional site. Fulguration produces superficial thermal injury to tissue when compared with desiccation. When fulgurating, the active ball electrode is held off the tissue, whereas with desiccation, tissue contact is maintained. The spark-gap distance, or distance between the electrode and tissue, must be sufficiently great to accommodate the clinician's depth perception. Several factors, including peak-to-peak voltage of the unit in the coagulation mode, determine the maximal spark gap permitted; ie, the greater the peak-to-peak voltage (crest factor), the more likely the spark will traverse the air gap to the tissue. Units with very small spark gaps challenge the clinician's ability to maintain this proper distance. If the spark-gap distance increases too much, no energy transmits to the tissue and no hemostasis results. Desiccation and deep thermal injury occur if the electrode touches the tissue. Therefore, the greater the spark gap, the easier the fulguration becomes for the clinician and the less likely inadvertent excessive thermal damage is to occur. However, an excessive spark-gap distance requires greater voltage, which could also result in tissue damage if used inappropriately. When excessive bleeding occurs, as with the ELECTZ procedure, for example, a highly efficient fulguration mode minimizes hemorrhage and the clinician's anxiety.

Several electrosurgical units demonstrated com-

mendable fulguration. The Aspen Sabre 180, Laserscope e[10], Gyne-Tech Autolepe 2000 and 4000, Utah Finesse and Finesse II, and Wallach Leap 100 were exemplary. However, no unit with a ball electrode achieved a 1-mm spark gap thought to be a necessary minimal threshold to permit depth-perception distinction. The clinical implication of this limitation equates to actual frequent desiccation when attempting fulguration. It has been hypothesized that units with greater spark-gap intervals produce better clinical outcomes, but this issue remains uncertain. Generally, however, fulguration results in less scarring and more rapid healing as compared with dessication.[5]

Tissue response to initial desiccation is another observation that bears important clinical significance. When the ball electrode is activated briefly on the tissue, the initial thermal effects are noted at the periphery of the ball and not at the center. This produces a ring of thermal damage that spares the centrally located tissue. The significance of this distribution is that if the clinician is attempting to desiccate a bleeding site, a brief activation directly centered on the bleeding site may not be effective. A bleeding site may be desiccated either by prolonging the activation period, which further damages normal adjoining tissue, or by moving the ball quickly around the site of the hemorrhage.

Dermatologic electrosurgery requires lower power settings than do gynecologic applications. The preprogrammed, nonvariable, higher power settings and product indications of the Utah Finesse II and the GyneTech Autolepe 2000 limit their use to gynecologic procedures. Other units may be limited by compatible electrode availability intended for dermatologic procedures, although many electrodes are interchangeable among manufacturers. Physicians may wish to purchase an electrosurgical unit capable of accommodating both gynecologic and dermatologic electrosurgery procedures.

Electrosurgery can be accomplished with any of the units evaluated, but those that include safety systems or that cut or fulgurate more effectively while producing minimal tissue injury may be preferred.

The findings and recommendations of this review were based on traditional electrical testing procedures and in vitro performance testing. Performance may differ slightly when the ESUs are used in the clinical setting. Realizing that unit cost may correlate with power specifications and unit design, the following electrosurgical units are recommended. For gynecologic electrosurgery, the Aspen Sabre 180 and Laserscope e[10] were rated best, followed closely by the Utah Finesse and Finesse II and the Gyne-Tech Autolepe 4000. Dermatologic electrosurgery may be accomplished with many of the generators included in the study, except as previously noted.

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