Electro-optical Synergy in Aesthetic Medicine: Novel Technology, Multiple Applications

Neil S. Sadick, MD, FACP, FAACS

This article reviews a newly developed nonablative technology known as *electro-optical synergy* (ELOS). This new technology encompasses a unique blend of optical and electrical radiofrequency (RF) energies simultaneously applied to tissue. The rationale behind combining electrical and optical energies is 2-fold: (1) a synergistic effect occurs between the 2 forms of energy and (2) lower levels of both energies can be used, facilitating treatment for individuals of all skin types and hair colors and potentially reducing the risk of side effects associated with either optical or RF energy alone. ELOS technology has been evaluated for a number of clinical applications, including hair removal and leg vein removal, as well as treatment of all aspects of aging, from pigmented and vascular lesions to skin texture improvement and wrinkle reduction. Study results suggest that this technology is safe and effective. However, direct trials comparing the efficacy of the combined-energy technology with that of other laser- and light-based systems are still needed at this time.

Laser therapy is one of the fastest growing technologies in cosmetic dermatology. According to recent estimates from the American Society for Aesthetic Plastic Surgery, the total number of cosmetic procedures performed in the United States has increased by 293% since 1997 to a total of 8.3 million surgical and nonsurgical procedures in 2003.[1] Nonsurgical procedures, which include the subcategory of noninvasive laser devices, have increased by an astounding 471%.[1] Currently, the number of options in noninvasive laser devices is overwhelming; cosmetic dermatologists can choose from more than 65 different laser systems for the treatment of a variety of cosmetic and medical skin conditions.

Dr. Sadick is Clinical Professor of Dermatology, Weill Medical College of Cornell University, New York, New York.

Dr. Sadick is a research consultant for Syneron Medical Ltd.

This article reviews electro-optical synergy (ELOS), a novel technology that encompasses a unique blend of optical and electrical radiofrequency (RF) energies simultaneously applied to tissue. Most cosmetic dermatologists are familiar with nonablative laser devices that use a single optical energy source to achieve selective photothermolysis.[2] However, directing optical energy to targets beneath the skin surface presents certain challenges. For example, light photons are scattered or absorbed by melanin on contact with the skin, and, as a result, only a variable proportion of photons actually reaches the target. Such variability necessitates providing higher energy for sufficient dermal heating thereby increasing the potential for epidermal complications (eg, crusting, dyschromia). The physician must consider a patient's skin type, treatment site, and the optical wavelengths and pulse dosimetry of the laser system before performing any laser procedure.

Electrical RF energy has become an increasingly popular method for nonablative cosmetic treatment. This type of energy interacts with tissue to produce heat. However, unlike optical energy, electrical RF energy produces heat from a current of ions rather than from absorption of photons. Thus, RF devices are dependent on the electrical conductivity of the target tissues to create selective thermal injury; RF energy is not scattered by tissue or absorbed by melanin, and RF devices have been reported to achieve dermal heating at a much greater depth of penetration than laser light devices.[3] In addition, RF devices can heat or denature collagen and stimulate fibroblasts to form new collagen over time.[4] Based on clinical experience, mild to severe pain (often requiring a topical anesthetic) has been a limiting factor of RF devices. Incidences of blistering, burns, and inflammatory nodules also have been observed in some patients.

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SYNERGISTIC MECHANISM

The optical and electrical RF energies of ELOS act synergistically in the following manner.[5] The light-based component converts optical energy to heat according to the principle of selective photothermolysis,[2] and the bipolar RF component generates heat through a current of ions based on the electrical conductivity of the target tissue.[5] It is well-known that electrical current will always follow the path of least resistance, a phenomenon known in physics as *impedance*.[6,7] Impedance is directly proportional to heat; the warmer a structure is, the more it will attract electrical current (ie, higher heat=greater conductivity). This same principle of conductivity works in reverse. An area where cold is applied results in reduced conductivity in that area. In ELOS applications, the optical component is most often used to heat the target first to lower its resistance (impedance), constructing a preferred pathway for the electrical RF energy to concentrate at the target site. The RF energy then adds to the selective thermal heating of the target. The final component of ELOS-controlled heating is integrated contact cooling delivered by the handpiece. Precooling of the skin increases the impedance of the skin surface, providing protection and comfort. When combined with the correct selection of energies, precooling provides greater control and enhances the ability to direct therapeutic electrical current to a greater depth of penetration than light-based systems alone.

Based on the mechanisms described, the optimal treatment method of ELOS is precooling of the epidermis followed by a near simultaneous application of the optical and bipolar RF energies. Treatment steps are as follows: (1) hydrate and cool the epidermis; (2) apply optical energy to selectively heat the target and bipolar RF energy to provide additional thermal energy to the heated target (the temperature of the epidermis should not exceed the target temperature); and (3) discontinue optical pulse and continue RF pulse for additional selective heating of the target.

ELOS-BASED SYSTEMS

Two ELOS-based systems, the Aurora™ and Polaris™, are available to treat a number of clinical applications (Table). The Aurora system uses intense pulsed light (IPL) (400–980 nm, 580–980 nm, and 680–980 nm) for optical energy, whereas the Polaris system uses a high-power diode laser (900 nm) as its optical source. Both systems are comprised of a bipolar RF generator and optical light (broadband pulsed light or laser) delivered through a contact sapphire light guide, with bipolar RF energy delivered through electrodes embedded in the system applicator and brought into contact with the skin surface.

The bipolar RF component of ELOS systems is designed so that the 2 electrodes are laterally affixed on opposite sides of the rectangular sapphire light guide. Electrical current is passed between 2 electrodes and is limited by the area between the electrodes. The penetration depth of electrical current can be calculated as half the distance between electrodes. Because the distance between the Aurora handpiece electrodes is 8 mm, the depth of penetration for this handpiece applicator would be 4 mm. Pulses of optical and RF energies are initiated at approximately the same time for both systems; however, in the Aurora system, the bipolar RF pulse is set at a longer duration than the optical pulse, enabling the optical component to preheat the target and increase RF selectivity.[5]

ELOS systems also include an active dermal monitoring system that measures changes in skin impedance. The user can adjust the system to provide an integrated safety mechanism (Impedance Safety Limit) that can prevent overheating of the dermis. The thermoelectric integrated contact cooling maintains a temperature of approximately 5°C before, during, and after energy delivery.

CLINICAL APPLICATIONS

There are multiple potential uses of ELOS, including hair removal, reversal of photoaging, treatment of vascular and pigmented lesions, skin texture improvement, and wrinkle reduction. As with all cosmetic procedures, the cosmetic dermatologist must determine which type of treatment will best serve each patient depending on

ELOS Technologies: Specifications of Aurora™ and Polaris™ Systems*

Parameter	Aurora	Polaris
Clinical applications	Acne Skin rejuvenation Hair removal	Wrinkle reduction Hair removal Leg vein/vascular lesion treatment
RF energy	5–25 J/cm^3	Up to 100 J/cm^3
Laser type	IPL	900-nm diode laser
Setting	480–980 nm (acne) 580–980 nm (skin rejuvenation) 680–980 nm (hair removal)	NA NA NA
Fluence	10–45 J/cm^2	Up to 50 J/cm^2 (wrinkle reduction) Up to 140 J/cm^2 (leg vein/vascular lesion treatment)
Cooling on skin surface	5°C–20°C	5°C
Spot size	12×25 mm	8×12 mm
Pulse repetition rate	0.7 pps	Up to 2 pps

*ELOS indicates electro-optical synergy; RF, radiofrequency; IPL, intense pulsed light; NA, not available; pps, pulse per second.

individual conditions, needs, and history. Patients should be counseled on pre- and postprocedural care, as well as realistic expectations of the treatment potential. With ELOS systems, patients usually require 3 to 6 treatments for hair removal or skin rejuvenation. As with laser light therapy, a level of patient commitment is required before effects are observed, and patients must be informed of potential side effects.

Skin Rejuvenation

Skin rejuvenation involves reducing the signs of aging and photodamage and toning, smoothing, and evening out skin imperfections of all varieties.[8] Nonablative photorejuvenation with laser light sources has become popular because it is minimally invasive, is associated with few complications, and requires little recovery time.[9] The goal of nonablative photorejuvenation is to induce subsurface remodeling without ablating the overlying epidermis.[10] Depending on the system specifications and selection of targets, some systems can be more effective than others. For example, the optical wavelengths that target melanin are most effective for treating pigmented lesions but at the same time may cause more complications in darker skin types. Although nonablative photorejuvenation is effective in reversing photodamage and treating fine lines and superficial defects, its efficacy in treating deeper wrinkles is limited.[3,11]

The Aurora SR system is specifically indicated for skin rejuvenation. A clinical trial by Bitter and Mulholland[12] evaluated this system for skin rejuvenation in 100 subjects. Subjects with Fitzpatrick skin types II to IV received treatment on the face and upper neck. Each treatment consisted of 1 to 3 passes over the face using a pulsed light fluence of 28 to 34 J/cm^2 and an RF current of 20 J/cm^3. Improvements were observed in erythema and telangiectasias (70%) and in lentigines and other pigmentary dyschromias (78%). In addition, both physicians and patients observed notable improvements in mild to moderate perioral, periocular, and forehead wrinkles. Mean improvement in skin texture and fine lines was 60%. Based on their clinical experience, Bitter and Mulholland[12] noted that treatment for wrinkle reduction with the Aurora SR system appeared to provide greater efficacy than IPL alone. Moreover, subjects who had previously undergone treatment with IPL reported a preference for the combined optical and RF procedure because it resulted in a greater degree of skin improvement, more rapid onset of effect, and less discomfort. In most subjects, pigmented lesions crusted one day after treatment. Only a small percentage of subjects (2.8%) were dissatisfied with the level of skin texture improvement after treatment with the Aurora SR system.[12]

Hair Removal

Laser light devices have been used effectively for hair removal.[13-16] Based on the theory of selective photothermolysis, lasers and IPL sources with wavelengths in the visible to near-infrared region are the most effective for hair removal because they preferentially target melanin in the hair shaft.[17] Within certain restrictions, most laser and IPL systems provide a degree of effective removal of dark hair on light skin. However, individuals with darker skin (Fitzpatrick skin types IV–VI) or tanned skin have a higher risk of blistering and undesirable pigmentation changes after laser light treatment because of the high concentration of melanin chromophores in the epidermis.[18,19] Individuals with light-colored hair (ie, red, white, gray, or blond) are difficult to treat for hair removal because of low levels of melanin in the hair shaft, which fails to absorb enough optical energy to achieve selective thermal destruction of the follicle. ELOS systems may help to overcome these difficulties. The RF energy in ELOS systems is not dependent on melanin absorption and can be used with lower levels of optical energy, which enables their use in patients with dark skin or light-colored hair. The theory is that the light is first absorbed and heats the hair shaft, while the additional conducted RF energy selectively heats the hair follicle.

I have conducted 2 studies evaluating the efficacy of the Aurora DS system for hair removal. The first study was comprised of 40 adult subjects aged 18 to 46 years with Fitzpatrick skin types II to V and various hair colors.[20] The second study was comprised of 36 adult women aged 38 to 83 years with overall lighter skin phenotypes (Fitzpatrick skin types I–V) and blond or white facial hair.[21] In both studies, subjects received 3 to 4 treatments at 8- to 12-week intervals over a period of 9 to 12 months. Depending on skin and hair phenotypes, light energy ranged from 15 to 30 J/cm^2; higher optical energy was used in subjects with lighter skin phenotypes and hair color. The RF current ranged from 10 to 20 J/cm^3 depending on the treatment site; higher RF energy was used on facial regions than lower body regions. Results for both studies were monitored 18 months after the first treatment or 6 months after the last treatment.[20,21]

In both studies, maximum hair reduction occurred 6 to 8 weeks after the first treatment, and hair density decreased progressively after each subsequent treatment.[20,21] Hair removal was greater in subjects with dark hair (mean clearance, 80%–85%),[20,21] which is similar to results achieved using laser light sources.[22] In both studies, up to 60% hair clearance was reported in subjects with light hair phenotypes. Results from both studies showed no significant relationship between treatment response and skin color. Side effects, including mild erythema and hyperpigmentation, were minimal.[20,21] Because the Aurora DS system is not dependent on chromophore targeting, it is hypothesized that its mechanism of action for hair removal may be based more on the thermal damage induced by the RF than the optical component.

Leg Vein Treatment

Until recently, laser therapy for the treatment of leg veins was restricted to vessels smaller than 1.2 mm in diameter because of limited depth of penetration.[23] Laser light sources in the visible-light wavelengths are appropriate for treating superficial small-diameter leg telangiectasias.[24-26] Deeper penetrating infrared wavelengths have enabled effective clearance of veins up to 3 mm in diameter.[27,28] For effective leg vein removal, laser light energy levels must be high enough to enable absorption by intravascular hemoglobin. The resulting heat coagulates or clots the blood, and vein destruction occurs.

With ELOS technology, the 900-nm optical energy penetrates the dermis and is absorbed by intravascular hemoglobin. This energy is converted into heat, and blood vessel temperature subsequently rises, creating a preferential path of conductivity through the vessel. Blood has very high electrical conductivity, and increased conductivity correlates with higher temperatures. Thus, the RF energy in ELOS systems is preferentially absorbed by the target vessel because of the increased temperatures of the target tissue (produced by the laser), as well as the high electrical conductivity of the blood. Through the heat created by both the diode laser and RF current, the blood vessel is able to reach a sufficient temperature level to cause irreversible vessel shrinkage or destruction.

Chess[29] investigated the use of the Polaris LV for the treatment of leg veins with vessel diameters ranging from 0.3 to 5.0 mm. The study enrolled 25 female subjects (Fitzpatrick skin types I–IV) with a total of 35 sites. Energy settings were determined based on skin type and were increased until a vessel reaction was observed. The initial optical energy (900-nm diode laser) used in this study ranged from 80 to 120 J/cm^2. Higher energy levels were used in subjects with lighter skin types. RF energy settings ranged from 80 to 100 J/cm^3. Subjects received up to 3 treatments at 4- to 10-week intervals. At follow-up visits 1 month and 6 months after the final treatment, approximately 77% of treatment sites exhibited 75% to

100% vessel clearance; 13% of treatment sites exhibited 50% to 74% vessel clearance; and 10% of treatment sites exhibited 25% to 49% vessel clearance. In this study, up to 140 J/cm^2 of laser energy and 100 J/cm^3 of conducted RF energy, with pulses in the range of 100 to 300 milliseconds, resulted in substantial clearance of both small and large vessels (0.3–5.0 mm in diameter). Side effects included discomfort at the treatment site, dysesthesia (at 1 site), and eschars (at 3 sites).[29]

In a recently completed study of 50 patients who received leg vein treatment (vessel diameter between 1 and 4 mm) with the Polaris LV, preliminary assessment of results showed that most patients had good to excellent improvement in leg vein reduction.[30]

COMMENT

I have treated more than 1000 patients for a variety of clinical applications, including skin rejuvenation, hair removal, and leg veins, using ELOS technology systems. Based on my experience, the ELOS systems are effective, safe, and user-friendly. Integration of electrical RF and optical energies indicates that the ELOS systems do not rely on a single form of energy to achieve sufficient heating of the target site. The rationale behind a combination system such as ELOS is that there is a synergistic interaction between the 2 forms of energy. The optical component selectively preheats the target through selective photothermolysis, and the RF energy is driven to the target site by the electrical conductivity of the target tissue, as well as the increased conductivity generated from the optical preheating. Importantly, RF energy is not scattered by tissue or absorbed by melanin. ELOS technology overcomes the primary limitation of purely light-based treatments because it can be used on all skin types. In addition, with current light-based systems, the cosmetic dermatologist must rely on clinical judgment to determine if the skin is overheating during the procedure, and, in many cases, the patient may show no discomfort or excessive erythema during treatment. The active dermal monitoring system on ELOS devices helps to safeguard against overheating of the skin. Also, the combination of energies allows lower levels of RF and optical energies to be used, potentially reducing the risk of side effects. Minimal pain is associated with ELOS treatment, and I have observed side effects such as blistering and erythema.

Two ELOS-based systems (Aurora and Polaris) are available worldwide. The Aurora system uses pulsed light energy (wavelengths include 400–980 nm for acne treatment, 580–980 nm for skin rejuvenation, and 680–980 nm for hair removal). The RF component has a frequency of 1 MHz for all systems and applications. The diode laser of the Polaris system is set at 900 nm, producing optical energy up to 140 J/cm^2 and RF energy up to 100 J/cm^3. The Polaris LV system can be used to treat vascular lesions and veins that are 0.3 to 4.0 mm in diameter. In contrast, the maximum RF energy of the Aurora system is 25 J/cm^3, with pulsed light maximum energy of 25 J/cm^2, restricting predictable therapeutic benefit to vascular lesions and veins smaller than 1.0 mm in diameter.

Further studies are under way to determine optimal treatment parameters and techniques for the ELOS systems. Comparative studies have been conducted to demonstrate the benefit and safety of combining RF and optical energy over either energy alone. However, these studies were not done in North America and have not been published. Studies are currently being conducted in North America and will be published when completed (oral communication, Shimon Eckhouse, October 2004).

REFERENCES

1. 2003 Cosmetic Surgery Statistics. Available at: http: //www.cosmeticplasticsurgerystatistics.com/statistics.html. Accessed June 14, 2004.
2. Anderson RR, Parish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. *Science*. 1983;220:524-527.
3. Nelson JS, Majaron B, Kelly KM. What is nonablative photorejuvenation of human skin? *Semin Cutan Med Surg*. 2002;21: 238-250.
4. Hsu TS, Kaminer MS. The use of nonablative radiofrequency technology to tighten the lower face and neck. *Semin Cutan Med Surg*. 2003;22:115-123.
5. Sadick NS, Makino Y. Selective electro-thermolysis in aesthetic medicine: a review. *Lasers Surg Med*. 2004;34:91-97.
6. Duck FA. *Physical Properties of Tissue: A Comprehensive Reference Book*. 6th ed. New York, NY: Academic Press; 1990.
7. Gabriel S, Lau RW, Gabriel C. The dielectric properties of biological tissues, III: parametric models for the dielectric spectrum of tissues. *Phys Med Biol*. 1996;41:2271-2293.
8. Sadick NS. A structural approach to nonablative rejuvenation. *Cosmet Dermatol*. December 2002;15:39-43.
9. Herne KB, Zachary CB. New facial rejuvenation techniques. *Semin Cutan Med Surg*. 2000;19:221-231.
10. Weiss RA, McDaniel DH, Geronemus RG. Review of nonablative photorejuvenation: reversal of the aging effects of the sun and environmental damage using laser and light sources. *Semin Cutan Med Surg*. 2003;22:93-106.
11. Alster TS, Lupton JR. Are all infrared lasers equally effective in skin rejuvenation? *Semin Cutan Med Surg*. 2002;21:274-279.
12. Bitter P Jr, Mulholland RS. Report of a new technique for enhanced non-invasive skin rejuvenation using a dual mode pulsed light and radio-frequency energy source: selective radiothermolysis. *J Cosmet Dermatol*. 2002;1:142-143.
13. Lask G, Elman M, Slatkine M, et al. Laser-assisted hair removal by selective photothermolysis: preliminary results. *Dermatol Surg*. 1997;23:737-739.
14. Nanni CA, Alster TS. A practical review of laser-assisted hair removal using the Q-switched Nd:YAG, long-pulsed ruby, and long-pulsed alexandrite lasers. *Dermatol Surg*. 1998;24:1399-1405.

15. Ross EV, Laden Z, Kreindel M, et al. Theoretical considerations in laser hair removal. *Dermatol Clin.* 1999;17:333-355.

16. Sadick NS, Shea CR, Burchette JL, et al. High-intensity flashlamp photoepilation: a clinical, histological, and mechanistic study in human skin. *Arch Dermatol.* 1999;135:668-676.

17. Dierickx CC. Hair removal by lasers and intense pulsed light sources. *Semin Cutan Med Surg.* 2000;19:267-275.

18. Alster TS, Bryan H, Williams CM. Long-pulsed Nd:YAG laser-assisted hair removal in pigmented skin: a clinical and histological evaluation. *Arch Dermatol.* 2001;137:885-889.

19. Nanni CA, Alster TS. Laser-assisted hair removal: side effects of Q-switched Nd:YAG, long-pulsed ruby, and alexandrite lasers. *J Am Acad Dermatol.* 1999;41:165-171.

20. Sadick NS, Laughlin SA. Effective epilation of white and blond hair using combined radiofrequency and optical energy. *J Cosmet Laser Ther.* 2004;6:27-31.

21. Sadick NS, Shaoul J. Hair removal using a combination of conducted radiofrequency and optical energies—an 18-month follow-up. *J Cosmet Laser Ther.* 2004;6:21-26.

22. Orf RJ, Dierickx C. Laser hair removal. *Semin Cutan Med Surg.* 2002;21:129-144.

23. Kauvar AN. The role of lasers in the treatment of leg veins. *Semin Cutan Med Surg.* 2000;19:245-252.

24. Adrian RM. Treatment of leg telangiectasias using a long-pulse frequency-doubled neodymium:YAG laser at 532 nm. *Dermatol Surg.* 1998;24:19-23.

25. Massey RA, Katz BE. Successful treatment of spider leg veins with a high energy, long-pulse, frequency doubled neodymium:YAG laser (HELP-G). *Dermatol Surg.* 1999;25:677-680.

26. Quintana AT, Grossman MC, Kauvar ANB, et al. Removal of leg veins with Laserscope potassium titanyl phosphate 532 nm laser. *Lasers Surg Med.* 1998;23(suppl 10):41.

27. Sadick NS. Laser and intense pulsed light therapy for the esthetic treatment of lower extremity veins. *Am J Clin Dermatol.* 2003;4:545-554.

28. Weiss RA, Weiss MA. Early clinical results with a multiple synchronized pulse 1064 nm laser for leg telangiectasias and reticular veins. *Dermatol Surg.* 1999;25:399-402.

29. Chess C. Prospective study on combination diode laser and bipolar radiofrequency energies (ELOS) for the treatment of leg veins. *J Cosmet Laser Ther.* 2004;6:86-90.

30. Sadick NS, Trelles MA. A clinical, histological, and computer-based assessment of the Polaris LV, combination diode, and radiofrequency system, for leg vein treatment. *Lasers Surg Med.* In press.