CHAPTER 5

Unwanted Hair:
Evaluation and Treatment
With Lasers and Light Source Technology

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In all members of the animal kingdom, hair functions as a sensory organ, provides insulation against the elements, and serves a variety of social and sexual behavior purposes. Humans for the most part consider hair solely for its cosmetic significance. Patients seeking treatment of excess or, more commonly, unwanted hair have a variety of psychosocial complaints.

Lasers and light sources are now used to treat a variety of vascular and pigmented lesions with enormous success. More recently, there has been interest in the role of these technologies in the treatment of unwanted hair. This chapter looks at our current knowledge of the structure and growth of hair and diseases associated with and medical treatment of excess hair and describes the currently available lasers and light sources used for the treatment of unwanted hair. Finally, the review closes with a look at potential future technology in this new area of cutaneous laser surgery.

EMBRYOLOGY AND ANATOMY OF HAIR FOLLICLES

Hair follicles develop embryologically through a complex series of interactions between the epidermis and dermis. Hair follicles anatomically consist of three distinct units: hair bulb, isthmus, and infundibulum. The hair bulb, one of three pluripotent hair growth sites, is the region that extends from the base of the follicle to the insertion site of the arrector pili muscle. The isthmus and infundibulum
lum are not thought to play any role in hair growth. The other two sites of pluripotential hair cells are thought to be the "bulge" at the site of the arrector pili muscle insertion and dermal papilla.

The bulbar region of the hair follicle contains a pool of relatively undifferentiated epithelial cells termed matrix cells that give rise to the hair and its surrounding inner root sheath. During the growing phase (anagen) of the hair cycle, these matrix cells proliferate extremely rapidly with a doubling time of 18 to 24 hours. This proliferation appears to be tightly controlled. Not only does it depend on an adjacent population of specialized mesenchymal cells that form the dermal papilla, but it is also cyclic. After a period of active growth in anagen, matrix cells cease to divide and the lower part of the follicle regresses during catagen. When regression is completed, the follicle enters telogen, a resting phase that lasts for several months. The matrix cells then resume proliferation and produce a new hair bulb, thus re-entering anagen and completing the hair cycle. 3

It has generally been assumed that matrix cells, through interactions with the dermal papilla, play the pivotal role in follicular growth and differentiation. Given the important role attributed to the matrix, it is puzzling why a complete hair follicle can be regenerated after the matrix-containing hair bulb is surgically removed. Research evaluating the growth of new hair has revealed that the matrix is not the only growth center.

Although the dermal papilla is not technically part of the actual hair, it remains a very important site for future hair induction. The dermal papilla is also the major probable site of melanin production in terminal hairs. It is this melanin that absorbs the visible light and lasers used to remove unwanted pigmented hair.

In one series of experiments, nonhuman animal dermal papillae were implanted into small incisional wounds in the rat ear. Hair of much greater length and diameter than native local ear hair was observed emerging from wound sites 3 to 4 weeks later. Histologic observation of the wound site several days after implantation revealed interaction between dermal papilla cells and both sides of the incisional wound epithelium. This apparent interaction led to the formation of rudimentary follicular structures. Controls consisting of identical unfilled wounds or wounds simply implanted with cultured skin fibroblasts failed to elicit hair follicle formation. This experiment confirmed that implanted dermal papillary cells must have specific inductive characteristics to produce follicle formation. In other studies, nonpapillary dermal cells failed to induce hair formation. 4-6

Inconsistent with the view that hair follicle stem cells reside
solely within the hair bulb matrix and dermal papilla is the finding of pluripotential hair-forming cells in the bulge area of the mouse hair follicle. The bulge, a component of hair outer root sheath cells, is located in the midportion of the follicle at the arrector pili muscle attachment site. These cells can induce new hair formation.

The histologic appearance of the hair follicle varies with each stage of the hair growth cycle. The anagen, or growth phase, leads to the catagen, or regression phase. The telogen, or resting phase, follows just before resumption of the anagen phase. The anagen phase is variable in duration and can last up to 3 years depending on the site. The relatively constant catagen phase is generally of 3 weeks’ duration, whereas the telogen phase usually lasts approximately 3 months. At any given time, the majority of the hair follicles (80% to 85%) are in anagen and the remaining follicles are in either the catagen phase (2%) or the telogen phase (10% to 15%). However, anagen and telogen phases do vary from anatomical site to anatomical site. 10-12

Plexuses from both arterial and venous capillaries, as well as postcapillary venules, provide hair follicle blood supply. It has been assumed that increased localized blood supply leads to an increase in localized hair. Correspondingly, a decrease in localized blood supply may lead to a decrease in localized hair.

SES OF HIRSUTISM AND HYPERTRICHOSIS
The development of localized or diffuse unwanted excess hair may occur in association with many inherited syndromes, as well as the use of certain medications (especially androgens) or the presence of ovarian or adrenal tumors, or it may occur as a normal variant (Table 1). The use of proper terminology is confusing, yet important in describing excess hair growth. Hypertrichosis is the presence of increased hair in men and women at any body site. Hirsutism is defined as the presence of excess hair in women only at androgen-dependent sites. 13, 14

Hirsutism, or excess hair growth on a woman in androgen-dependent skin sites, is most commonly seen on the upper part of the chin, chest, inner aspect of the thighs, back, and abdomen. Hypertrichosis, on the other hand, which occurs in both men and women, may appear anywhere on the body. 15, is

Hirsutism is caused either by diseases of androgen excess or by exogenous medications. The most common causes are polycystic ovary syndrome (PCOS) and idiopathic hirsutism. The diseases of androgen excess are usually pituitary/adrenal or ovarian in
TABLE 1.
Causes of Hirsutism
and Hypertrichosis

Virilizing tumors
   Adrenal gland
   Ovary
Endocrine disorders
   Cushing’s disease
Medications
   Androgens
   Birth control pills
   Minoxidil
   Phenytin
   Penicillamine
   Diazoxide
   Cyclosporine
   Corticosteroids
   Phenothiazines
   Haloperidol
Syndrome Polycystic
   ovary
Malnutrition
Porphyria
Anorexia nervosa
Hypothyroidism
Dermatomyositis

source. Elevated adrenocorticotropic hormone levels, which increase
the adrenal secretion of cortisol, aldosterone, and androgens, are a rare
cause of hirsutism. Adrenal causes of hirsutism include virilizing
types of congenital adrenal hyperplasia and adrenal neoplasms.
However, PCOS (Stein-Leventhal syndrome) is the most common cause
of hirsutism. In the United States, 70% of patients with PCOS are
affected by hirsutism. The severity of the androgen effect ranges from
mild hirsutism to virilization. Hirsutism may also be caused by
androgen-producing ovarian neoplasms. Because insulin stimulates
ovarian androgen production, another ovarian cause of hirsutism is
insulin resistance with resultant hyperinsulinism.

Idiopathic hirsutism is a diagnosis of exclusion. Total testos-
terone levels in patients with idiopathic hirsutism may be normal,
although free testosterone levels are high. Of note, emotional stress may cause idiopathic hirsutism.

Anorexia nervosa and hypothyroidism may cause hypertrichosis. Fine, dark hair growth on the face, trunk, and arms, sometimes extensive, frequently develops in patients with anorexia nervosa. In hypothyroidism, the hair growth is of the long, fine, soft unpigmented (vellus) type.

Although multiple drugs may cause hypertrichosis, the pathophysiology of drug-induced hypertrichosis is unknown.

All races have similar androgen and estrogen levels despite striking differences in the amount of body hair. Whites have more hair than do blacks, Asians, and Native Americans. The number of hair follicles per unit of skin varies among ethnic groups (Mediterranean > Nordic > Asian). Asians rarely have facial hair or body hair outside the pubic and axillary regions. White women of Mediterranean background have heavier hair growth and a higher incidence of excess facial hair than do those of Nordic ancestry (blond, fair skinned). Thus men and women have a wide range of normal hair growth that is largely based on racial and ethnic predisposition.

EVALUATION OF HIRSUTE WOMEN

Although the overwhelming majority of patients seeking laser and light source hair removal are perfectly healthy or have idiopathic hirsutism, a clinical history must be undertaken to rule out serious diseases that cause hirsutism. Historical data suggesting a potential serious underlying disease include an onset of hirsutism that is not peripubertal; abrupt onset and/or rapid progression of hair growth; or virilization with associated acne, male pattern baldness, deepening of the voice, increased muscle mass, decreased breast size, amenorrhea, clitorimegaly, or increased sexual drive. If such a history is provided, a full medical evaluation is mandatory.

A careful drug history is also very important. A simple change in drug regimens may be all that is necessary to reverse unwanted new-onset hair growth.

TREATMENT OF HIRSUTISM

Before the advent of laser and light source technology, treatment options for hair excess included the treatment of associated diseases, suppression or blocking of androgen production and effect, and a variety of frustrating and/or protracted cosmetic measures (Table 2).

Although the patient’s cosmetic feelings about unwanted hair growth must be considered, the physician must always be alert to
TABLE 2.
Management Options for Patients
With Hirsutism

Treatment of any underlying disease found
Suppression of androgen overproduction
  Oral contraceptives
  Dexamethasone
Blocking the effect of androgens
  Spironolactone Flutamide
  Cyproterone
  Finasteride
Cosmetic measures
  Shaving
  Bleaching with hydrogen peroxide
  Chemical depilatories Plucking
  Waxing
  Electrolysis
  Weight loss

rule out medical causes of excess hair growth. Spironolactone is the most clinically effective antiandrogen available today and is the drug of choice when hirsutism is associated with obesity or hypertension, especially when the menses are normal. The most common side effect of spironolactone is abnormal menstrual bleeding, which occurs in 19% to 61% of women. Breast tenderness may also occur, as may hyperkalemia and hypotension because spironolactone is a potassium-sparing antihypertensive medication. Flutamide, an investigational medication, is a potent nonsteroidal, selective antiandrogen with no estrogenic, progestational, corticoid, or antigonadotropic activity. Considerable data suggest that flutamide is efficacious in hirsutism; some data indicate an efficacy similar or superior to that of spironolactone. Unfortunately, serious hepatocellular necrosis and cholestasis have developed in patients using flutamide, with five dying of progressive liver disease. It should be noted that most of the medications used to treat hirsutism are contraindicated in pregnant women, and some are contraceptives. In addition, pharmacologic treatment of hirsutism must continue longer than the growth cycle of the hair involved to
decide whether it is effective. Most treated women notice no change until 6 to 12 months.\textsuperscript{14}

A variety of cosmetic therapies have been developed for the removal of unwanted hair. Shaving, certainly a simple, safe way to remove unwanted hair, provides a short-lived effect. In fact, shaving may synchronize hair growth cycles and give the appearance of increased hair growth. Commercially available hair bleach with hydrogen peroxide is also an inexpensive method of making facial hair less pigmented, yet the hair is still noticeable. Chemical depilatories with calcium thioglycolate are effective but frequently cause skin irritation when applied to the face. Many women find the procedure to be messy and the smell of the chemical offensive.

Plucking can be useful when few hairs are present, such as hair around the eyebrows and, around the nipples. Tolerance of plucking, however, is unpredictable, and pain, folliculitis, postinflammatory pigmentation, ingrown hairs, and scarring develop in some patients. In addition, chronic plucking can lead to follicular distortion and make subsequent hair removal procedures more difficult. In waxing, melted wax is applied, allowed to cool, and then stripped off along with the hairs embedded in the wax. The results of waxing last longer (2 to 6 weeks) than the results of shaving and chemical depilatories because waxing removes the hair from beneath the skin surface.

Electrolysis and thermolysis have traditionally been the only effective methods of removing hair and permanently stopping subsequent growth in that hair follicle. The main drawbacks are cost, pain, crusting, postinflammatory pigmentation, and scarring.

**ELECTROLYSIS AND THERMOLYSIS**

Electrolysis results in tissue damage and the destruction of hair follicles by the creation of a chemical reaction through the use of electrodes. Thermolysis involves the use of high-frequency alternating current at low voltage and low current to thermally destroy or epilate hair follicles. Thermolysis is synonymous with the term *electroepilation*.

The heating of tissue in electrolysis and thermolysis leads to tissue dehydration with resultant shriveling of cells, local necrosis, and coagulation. To achieve maximum effect with a minimum of electrical current, the size of the treatment site must be kept relatively small. Epilation, or permanent hair removal, is performed today by both electrolysis and thermolysis.\textsuperscript{17-21}

Correct placement of the epilating needle remains very important. Although tedious to perform and impractical for treating large...
areas of excess hair growth, when performed correctly by appropriately trained individuals, both electrolysis and thermolysis can provide permanent hair removal. Both techniques are associated with significant discomfort, however, and a potential for scarring.

**PHOTOTHERMOLYSIS**

Long-term hair removal requires that a laser or light source react with one or more growth centers of hair. To do so, an appropriate target or chromophore must be identified. The major growth center has always been thought to be the hair matrix. However, as described earlier, new hairs may evolve from the dermal papilla, follicular matrix, or the "bulge." Although the pluripotential growth sites of the arrector pili-associated bulge are only 1 to 1.5 mm below the skin surface, the other growth sites are often as deep as 3 to 7 mm below the surface. Because of the skin depth of these sites, significant energies must be applied for effective hair removal. However, not only must each follicle be damaged, but the surrounding tissue, especially the epidermis, must also be protected from damage. By doing so, adverse sequelae such as scarring and permanent pigmentary changes may be lessened. Melanin, the only endogenous chromophore in the hair follicle of pigmented hair, can be effectively targeted by lasers and light sources throughout the visible light spectrum. Although shorter visible wavelengths as seen with green light lasers are well absorbed by melanin, they are ineffective in removing hair. The longer wavelengths used in the current lasers and light sources are preferred because of reduced scattering in the dermis and consequently greater depth of penetration. Alternatively, an exogenous chromophore such as carbon can be applied to the skin. This chromophore will then be irradiated with laser energy of a wavelength that matches its absorption peak. Both of the aforementioned approaches have been shown to remove hair.

The pluripotential cells of the bulge, dermal papilla, and hair matrix must be treated in the anagen cycle for effective hair removal. If the damage is not permanent during this cycle, follicles will move into the telogen stage as they fall out. Thus all of the follicles may become synchronized after the first laser treatment. The hair follicles will then return to anagen according to the natural hair cycle. This cycle varies depending on the anatomical location. The cycle is shortest on the face and longer on the body, varying between several weeks and several months. Finally, early anagen, when the bulb is closest to the surface, would appear to be the best time for
selected wavelengths to destroy particular targets in the skin. In tandem with the principle of selective photothermolysis is the concept of thermal relaxation time (TRT). Thermal relaxation time is used to describe the limitation of thermal damage when a desired target absorbs a particular wavelength in an amount of time that is equal or less than that target’s TRT. With the right combination of wavelength, energy, and pulse duration, it is possible to precisely target the hair follicle without causing injury to the surrounding structures. One way to achieve greater injury to the hair follicle is by increasing the pulse duration of the laser exposure. The TRT for hair follicles that are 200 to 300 µm in diameter is approximately 40 to 100 msec. However, a pulse as long as 100 msec may not allow sufficient time for the heat to dissipate and lead to an undesirable temperature increase with thermal injury to nonfollicular structures and consequent scarring or irregularities in pigmentation. If pulse duration were the only factor, the ideal laser pulse duration should lie between the TRT for epidermis, which is approximately 3 to 10 msec, and the TRT for hair follicles. However, other factors must be considered. If a laser or light source delivers its energy through a large beam, an increase in skin penetration occurs. Greater depth of penetration provides a greater chance of reaching the hair growth centers.

In human skin, about 15% to 20% of the incident light at 700 nm penetrates to a depth of 3 mm. By using a large spot size, scattering of light in the dermis is lessened, and a greater depth of penetration is achieved. In addition, whenever a melanin-absorbing laser or light source is used for hair removal, competing epidermal melanin must be protected from damage, usually by cooling the skin surface. Finally, when the pulse duration used is longer than the TRT of melanosomes (1 µsec), the epidermis can be protected because the epidermal melanin is heated relatively slowly. This slow heating allows significant time for the heat to be conducted away into the surrounding cool epidermis. This approach of treating the target with a pulse shorter than its TRT but longer than the TRT of the competing chromophore has been called thermokinetic selectivity.

**LASER AND LIGHT SOURCES CURRENTLY CLEARED BY THE FOOD AND DRUG ADMINISTRATION**

Currently, three seemingly disparate methods are used to apply the concept of selective photothermolysis for the removal of hair. In the first two, either laser or nonlaser light is used to selectively target hair follicles. Here, the light is, absorbed by a normal component of the follicular apparatus such as melanin or possibly the vas-
culture that surrounds the hair follicle. In the third technique an exogenous chromophore applied to the hair is used to absorb laser energy. Table 3 lists the currently available lasers and light sources cleared by the Food and Drug Administration for hair removal.

**NORMAL-MODE RUBY LASER**

Normal-mode ruby lasers produce 694-nm red light. The first published study evaluated such a system with a pulse duration of 0.3 msec and a spot size of 6 mm. A cooling lens on the handpiece was used to protect the epidermis. Thirteen subjects with fair skin and pigmented hair had test sites treated on their back or thigh. All sites were treated with energy fluences of 30 to 60 J/cm². The study compared laser-treated sites with areas shaved or wax epilated. Quantitative hair counts in all treated subjects revealed a laser-induced growth delay lasting 3 to 6 months when compared with shaved or epilated, unirradiated control sites. At 6 months, hair growth was reduced an average of 15% to 20% in sites treated at 60 J/cm². After 2 years, some subjects continued to show 30% to 80% continued reduction in hair counts at laser-irradiated sites. Histologic evaluation of treated sites showed follicular disruption followed by a reduction in terminal hairs. A normal number of vellus hairs remained. Greater hair loss was noted at the laser-treated shaved sites as opposed to the laser-treated epilated sites, which suggests that light absorption by the pigmented hair shaft itself plays an important role. There was a tendency for greater hair loss at the higher energy fluences. Approximately half of the patients required local anesthesia. Transient hyperpigmentation developed in 1 patient and temporary hypopigmentation in another. No scarring was noted.

In a subsequent study of 100 dark-haired patients, temporary hair loss lasting 3 to 6 months was achieved with 20 to 30 J/cm², whereas more prolonged hair loss was noted with treatment fluences of 40 to 50 J/cm². In this study there did not appear to be a clinical difference between the use of a 0.3- or 3-msec pulse duration, single and double pulses, and a single treatment or two treatments 1 month apart. Eighty percent of patients were found to be responders, whereas 20% experienced prompt hair regrowth.25

We and others have been evaluating the effectiveness of up to six treatments performed at varying intervals on hair growth (presumed stage of early anagen). Preliminary results suggest that multiple treatments do lead to better results. Resistant hair appears to be thinner than originally treated hair, and terminal hairs are converted to vellus hairs (Figs 1 to 4). Because hair melanin is the laser-impacted chromophore, this technique is most practical for
TABLE 3.
Parameters of Light Sources Used for Hair Removal

<table>
<thead>
<tr>
<th>System Name</th>
<th>Source</th>
<th>Pulse Energy Wavelength (nm)</th>
<th>Pulse Energy Width (msec)</th>
<th>Pulse Energy Fluence (J/cm²)</th>
<th>Beam Repetition Diameter (mm)</th>
<th>Beam Repetition Fluence (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SoftLight (ThermoLase, Inc.)</td>
<td>QS Nd:YAG</td>
<td>1064</td>
<td>10-20</td>
<td>2-3</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>EpiLaser (Spectrum Ruby, normal mode Medical)</td>
<td>694</td>
<td>3</td>
<td>10-75</td>
<td>10-12</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>EpiTouch (Sharplan) Ruby, normal mode Medical</td>
<td>694</td>
<td>0.8</td>
<td>5-10</td>
<td>4-6</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Chromos 694 (Mehl Ruby, normal mode)</td>
<td>0.5</td>
<td>10-15</td>
<td>5 NA</td>
<td>Biophile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIPR (Cynosure) Alexandrite 755</td>
<td>20</td>
<td>10-20</td>
<td>7-10</td>
<td>1.0 EpiTouch (Sharplan) Alexandrite 755</td>
<td>2</td>
<td>40-50</td>
</tr>
</tbody>
</table>
FIGURE 1.
Hair before treatment with the EpiLaser normal-mode ruby laser.

FIGURE 2.
Clinical improvement after three treatment sessions with the EpiLaser normal-mode ruby laser.
FIGURE 3.
Hair before treatment with the EpiLaser normal-mode ruby laser

FIGURE 4.
Clinical improvement after four treatment sessions with the EpiLaser normal-mode ruby laser.
relatively fair-skinned individuals (skin types I, II, and III) with relatively dark hair (black or brown). Three companies are selling ruby lasers for hair removal: Palomar EpiLaser (694 nm, 3 msec, 7- to 10-mm spot, 0.5 Hz, 10 to 75 J/cm², cooling handpiece), Sharplan EpiTouch (694 nm, 0.8 msec, 3- to 6-mm spot, 1.2 Hz, 15 to 40 J/cm², cooling pad), and Mehl Biophile Chromos 694 (694 nm, 0.5 msec, 5-mm spot, 1 Hz, 10 to 15 J/cm², scanner).

**EpiLaser**

The EpiLaser (Palomar Medical) is a normal-mode (non-Qswitched), pulsed ruby laser recently developed by Rox Anderson at the Massachusetts General Hospital. The currently available system delivers a 3-msec pulse with fluences ranging between 10 and 75 J/cm² through either a 7- or 10-mm handpiece. A specially designed contact cooling handpiece consisting of an actively cooled glass sapphire prism/lens system is used to deliver a convergent beam with a 20-mm focal length to the skin. This cooling handpiece is held firmly against the surface before, during, and after each pulse of light to minimize thermal injury to the pigmented epidermis. This cooling also maximizes laser intensity in the deeper dermis. Finally, the cooling lessens patient discomfort.

The treatment technique consists of preoperative shaving of the treatment site. This practice reduces treatment-induced odor, prevents long pigmented hairs lying on the skin surface from conducting thermal energy to the adjacent epidermis, and promotes the transmission of laser energy down the hair follicle. In darkly pigmented or heavily tanned individuals, it may be beneficial to use hydroquinone, topical retinoic acid, and meticulous sunscreen protection for several weeks before treatment to reduce inadvertent injury to epidermal pigment. Postinflammatory pigmentary changes are still to be expected in more darkly complected individuals. Treatment is performed by delivering light in a continuous pattern at 0.5 Hz with a 7- to 10-mm spot size. Three-millisecond pulses are delivered adjacent to one another with the cooling handpiece held firmly in contact with the skin before each pulse. Overlapping of pulses does not appear to be harmful. The range of energy fluences used for effective treatment may range from 20 J/cm² for darkly pigmented individuals up to 50 J/cm² or higher for fair-skinned individuals. As a consequence, clinical experience and professional judgment must be used to determine the ideal treatment parameters for each patient. This individualized treatment can often best be determined by delivering several individual test pulses at an inconspicuous site, with equivalent pigmentation starting at an energy fluence of 20 J/cm² and slowly increasing the
energy. Undesirable epidermal changes such as whitening and blistering are to be avoided. The initial treatment appears to lead to induction of the telogen phase with a growth delay in most individuals. Repeated treatments lead to finer hair, conversion of dark to light hair, and prolonged intervals between required laser sessions. Occasionally no hair returns.

**EpiTouch**

The EpiTouch (Sharplan) is a normal-mode ruby laser that can also be used in a Q-switched fashion for the treatment of tattoos and pigmented lesions. This laser removes hair in a manner much like that seen with the EpiLaser. This system uses a cooling transparent gel to minimize reflectance and scattering. The cooling lessens thermal injury to the epidermis. A patented template is used to allow precise treatment of all hairs in a particular area. The parameters for this system are 0.8-msec pulses at 1.2 Hz with a 4- to 6-mm beam diameter.²⁶

**Chromos 694**

The Chromos 694 (Mehl Biophile) is a normal-mode ruby laser that has been designed for the removal of unwanted or excess hair in a manner similar to that of the EpiLaser and EpiTouch. The parameters for this system are a 0.50-msec pulse and energy fluences of 10 to 15 J/cm². This machine comes with a scanner to allow treatment of larger areas.

Prolonged and permanent hair loss may occur after the use of all normal-mode ruby lasers; however, great variation in treatment results is often seen. Most patients with brown or black hair obtain a 2- to 6-month growth delay after a single treatment. Usually only mild discomfort is noted at the time of treatment. Pain may be diminished by the use of topical or injectable anesthetics.

Transient erythema and edema are also occasionally seen, and irregular pigmentation of 1 to 3 months’ duration has been described. No permanent skin change, depigmentation, or scarring has been reported.

**NORMAL-MODE ALEXANDRITE LASER**

The alexandrite laser with its 755-mm wavelength has a mechanism of action very similar to the ruby lasers. It is theoretically possible that the longer wavelength of the alexandrite leads to greater depth of penetration of the laser light. There may also be less risk of epidermal damage because of slightly lower melanin absorption.

**LIPR**

The LIPR (Cynosure) alexandrite laser produces a pulse duration of 20 msec. This pulse is consistent with the TRT of hair follicles.
It is postulated that this pulse duration spares the epidermis through a process called thermokinetic selectivity. This laser’s delivery system, unlike the situation with the normal-mode ruby laser’s articulated arm, is a 7- or 10-mm fiberoptic system. Such delivery systems are very user-friendly.

**EpiTouch Alexandrite**

The EpiTouch alexandrite laser (Sharplan), recently cleared by the Food and Drug Administration, is a 2-msec pulsed system delivered through a 5- or 7-mm fiberoptic system. This system delivers laser pulses up to 5 Hz, a very desirable speed when large body areas such as the back and legs are treated (Figs 5 and 6). We have recently begun to evaluate different alexandrite laser systems to determine whether there is an optimal pulse duration.

**INTENSE PULSED NONLASER LIGHT**

**SOURCE EpiLight/Photoderm**

Hair removal with an intense pulsed nonlaser light source involves the use of a broad-based visible light spectrum. All wavelengths between 550 and 1,100 nm are emitted from a flashlamp device. Particular wavelengths are included or excluded by the appropriate use of filters. Because of the diversity of wavelengths emitted by the machine, this technology may be used to treat a variety of

**FIGURE 5.**
Hair before treatment with the Sharplan alexandrite laser.
vascular and pigmented lesions as well. The operator can vary not only the wavelengths delivered but also whether the energy is delivered in two or more pulses; cooling time between delivered pulses can also be varied. When the proper parameter values are chosen, follicular temperature rises above its damage threshold while surrounding tissue temperature remains low enough to avoid skin damage. When hair is treated, the light emitted from the flashlamp is skewed toward the longer wavelengths for deeper penetration. Light is delivered to the skin through quartz light guides. The light guides are coupled to the skin with a transparent cooling gel to protect the epidermis from excessive heating. In one study, 50 patients received one treatment session with the EpiLight (ESC Medical Systems) and were monitored for 3 months. Facial areas showed hair loss of 45% to 60%. The trunk and extremities showed a loss of 40% to 50%. A second study evaluated the effectiveness of EpiLight in 37 predominantly female subjects. Eighty percent of the treated sites were on the neck and face. An approximately 60% hair loss in 12 weeks was shown after one treatment."

Our experience has shown that continued treatment leads to further improvement (Figs 7 and 8). Darker hair is removed more effectively than light or white hair—as would be expected with a system that delivers predominantly melanin-absorbing light. Of
FIGURE 7.
Hair before treatment with the EpiLight light source.

FIGURE 8.
Clinical improvement 3 months after one session of EpiLight light source treatment.
note is the occasional response seen in nonpigmented hair. The mechanism of hair removal, presumed to be thermal, occurs by varying the pulse duration, interpulse rest period, and treatment fluences. Flashlamp technology requires a longer learning curve than does a laser. However, the potential for diversity in application is an advantage of such systems. EpiLight/PhotoDerm is computer software driven. As our understanding of hair removal continues, this machine can simply be upgraded rather than replaced with another machine.

**TOPICAL CARBON SUSPENSION-ASSISTED LASER HAIR REMOVAL SoftLight**

Unlike the previously mentioned laser and light source systems that produce millisecond pulses, the SoftLight (ThermoLase) technique involves the use of a nanosecond Q-switched Nd:YAG laser. These very short pulses produce a photoacoustic shock wave and subsequent photomechanical disruption of the topically applied carbon chromophore and the surrounding hair follicle.

The 1,064-nm infrared light from the Q-switched Nd:YAG laser is poorly absorbed by melanin. Thus an exogenous chromophore (carbon) is introduced into the hair follicle to potentiate the hair removal capacity of this laser. A topical mineral oil suspension containing a carbon-based material is applied to the skin surface and massaged into the areas to be treated. Prelaser wax epilation, once a requirement before this procedure, is no longer used.

The carbon material entering the follicle is then activated by the 1,064-nm laser light, such as in the treatment of tattoos and pigmented lesions. Minimal energy fluences are used to lessen procedural discomfort and the risk of complications. The carbon particles, after absorption of Q-switched Nd:YAG laser irradiation, undergo a rapid temperature increase. Light energy is converted into both thermal and kinetic energy. As the temperature of the carbon particles increases, a shock wave is produced that propels vacuolization to the depth of the hair follicles (Fig 9). This shock wave results in mechanical damage to various follicular cellular elements and thereby leads to a delay in hair regrowth.

The treatment technique is generally performed either without anesthesia or with topical anesthetic creams. After application, massaging, and removal of excess carbon, hairs are treated with a Q-switched Nd:YAG laser with an energy fluence of 2 to 3 J/cm², a 7-mm spot size, a pulse duration of 10 nsec, and a frequency of 10 Hz. The laser light is scanned over the entire treatment site until all visible carbon has been removed. Minimal immediate post-
operative edema may be present for 24 hours. Erythema is also seen transiently for 48 hours. With the infrequent exception of postoperative hyperpigmentation (<1%), which resolves completely in less than 6 months, complications are rare. The 7-mm spot size and 10-Hz repetition rate allow large areas to be treated in a relatively short period.

An initial pilot study of 60 subjects with varying skin types and hair color was performed, with most of the treated sites being on the face. A proprietary suspension of 10-µm carbon particles was applied to the skin and irradiated with 2 to 4 J/cm² of Q-switched Nd:YAG laser light (1,064 nm, 10 Hz, 10-nsec pulse duration, 7-mm spot size). Up to a 70% reduction in hair growth, as well as a reduction in hair coarseness and hair lightening, was noted 3 months after laser treatment. Local anesthesia was generally not necessary. No scarring or pigmentary changes were reported. A second study evaluated the effect of a single treatment on facial, neck, and axillary hair. The authors reported greater than 25% hair reduction in 70% of the subjects at 4 weeks and 69% reduction at 12 weeks. In a third study, women with unwanted axillary and "bikini-line" hair were treated with 2 to 3 J/cm² and a 7-mm spot size and received four treatments at monthly intervals.
The reduction in hair growth lasted longer than in the single treatment facial hair study (Figs 10 and 11).32

A subsequent study of 12 patients confirmed that one treatment has no long-term benefit. This study compared wax epilation and carbon suspension Q-switched Nd : YAG (2.6 J/cm², 7-mm spot size) laser irradiation with and without prior waxing. At 3 months' follow-up there was 70% to 86% hair regrowth at all sites except for sites treated by wax epilation alone, which had 100% regrowth. By 6 months there was 100% regrowth in all sites.33

The advantage of this laser approach relates to its speed, which is faster than all currently available techniques, and the ability to treat all hair colors with minimal risk of postinflammatory changes. However, long-term epilation has been an elusive goal of topical carbon suspension-assisted Q-switched Nd:YAG laser hair removal. One of the difficulties has been related to the size of the carbon particles. Because of their large size, they have never been able to enter the depths of treated hair follicles—the necessary prerequisite to have a significant impact on the hair's germinal centers. Recently, newly formulated, smaller, 10-nm carbon particles have been used. These particles have been shown, with histologic documentation, to be propelled to the depth of treated hair.

**FIGURE 10.**
Hair before treatment with the SoftLight topical carbon suspension-assisted Q-switched Nd:YAG laser system.
FIGURE 11.

Clinical improvement 3 months after three sessions with the SoftLight laser system.

follicles. Studies are currently being undertaken to determine whether longer-term results can now be obtained with this technique.

INVESTIGATIVE APPROACHES

The Q-switched Nd: YAG and ruby lasers have been used with success to remove tattoos and pigmented lesions. They have also been evaluated for their roles in hair removal. Ten fair-completed, dark-haired subjects had trunk or leg hair irradiated with Q-switched ruby (694 nm, 40 nsec, 5-mm spot, 8 to 10 J/cm²) and Q-switched Nd:YAG (1,064 nm, 10 nsec, 3-mm spot, 3 to 5 J/cm²) lasers. A total of 3 monthly treatments were given. An 89% reduction in hair growth was seen after three Q-switched ruby laser treatments and a 58% reduction after three Q-switched Nd:YAG laser treatments. Five months after treatment, all hair regrew in the Nd: YAG lasertreated sites whereas only 50% of the ruby-treated hairs regrew. Hyperpigmentation at the ruby-treated sites occurred in three patients. No scarring was noted. 14

Although the Q-switched Nd:YAG laser is poorly absorbed by melanin as compared with the ruby and alexandrite wavelengths, there is still some absorption. However, the poor results when this
laser is used without adjuvant carbon may be related to the very short 10-nsec pulse durations. We are currently evaluating the effectiveness of millisecond Q-switched Nd: YAG laser hair removal.

Although the concept of using light to activate a topically administered photosensitizer to treat cutaneous malignancies and disorders has long been under active investigation, only recently have studies evaluated this approach for the destruction of unwanted hair. Topical aminolevulinic acid (ALA) is preferentially absorbed by hair follicles. The hair is first wax epilated followed by the subsequent application of an ALA-containing lotion. After several hours of follicular absorption, the treatment site is exposed to red light to activate the photosensitizer. Photosensitizer activation leads to cell membrane damage from the creation of singlet oxygen.

In a pilot study of 11 subjects, topical 10% or 20% ALA was applied to hair-bearing skin after wax epilation. The test sites were irradiated with 630-nm light from an argon-pumped tunable dye laser at 100 and 200 J/cm² 3 hours after ALA application. A dose dependent decrease in hair growth was noted and was still some what evident 6 months after treatment. No scarring was seen, but temporary hyperpigmentation developed in some patients.\(^3\)

This photodynamic approach is still only in its early stage of development. Much work remains before this approach can be considered a viable treatment approach.

**CONCLUSION**

The use of lasers has become commonplace in the cosmetic cutaneous arena. Dissatisfaction with currently available hair removal techniques has led to enormous interest in laser and light source treatment for hair removal. The principle of selective photothermolysis can be applied to hair much as it is applied to the treatment of a variety of pigmented and vascular lesions of the skin. Temporary hair removal is currently available with a variety of systems. Occasional permanent hair removal has been noted. With a greater understanding of hair biology and continued improvement in technology, the elusive goal of permanent hair removal with minimal risk is likely to be met in the near future.

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Editor’s Comment

It is fascinating how a structure with so little functional importance can garner so much attention. In the dermatologic cosmetic universe, hair certainly occupies a pivotal position. Few individuals comfortably feel that they have the right amount of hair in the right places. Hair restoration is probably the most prevalent aesthetic desire expressed by men, and hair removal is gaining speed as a major cosmetic interest of women. In his chapter, Dr. Goldberg provides a thorough discussion of hair biology, medical evaluation of excess hair, and treatment with various lasers and light sources. To date, options for hair removal have been less than satisfactory. Home remedies such as chemical depilatories, bleaching, and waxing provide variable degrees of temporary improvement with different levels of discomfort. The gold standard remains permanent epilation by electrolysis or thermolysis. Although the results may be outstanding, these procedures are very technique dependent, tedious, and often painful. Therefore, the door remains wide open for other options.

Lasers have gained popularity in dermatology because of their relative ease of use and selectivity. The concept of selective photothermolysis has been well put to use in the treatment of vascular and pigment disorders. The concept is to damage selective targets while sparing adjacent structures. The lack of a unique follicular target has made application of this principle to hair removal a bit tricky. Approaches have included targeting melanin, vasculature, or exogenously applied carbon-based chromophores. Minor problems have centered around postoperative hypopigmentation or hyperpigmentation. The larger issue is the temporary nature of hair removal and the requirement for periodic re-treatment to maintain the desired result. As Dr. Goldberg mentions, interest in this field is great and refinements are being made in an attempt to attain permanent laser epilation. If this goal can be achieved, the ability to treat large surface areas with a technique that can be easily standardized offers great appeal to both patient and practitioner.

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