doi:10.36849/JDD.2021.5638

Intense Pulsed Light: A Methodical Approach to Understanding Clinical Endpoints

Michael B. Lipp DO, Kunal Angra MD, Douglas C. Wu MD PhD, Mitchel P. Goldman MD
Cosmetic Laser Dermatology: A West Dermatology Company, San Diego, CA

ABSTRACT

Background: Intense Pulsed Light (IPL) is a non-coherent polychromatic broadband filtered flashlamp that emits light in the spectrum of approximately 400–1200 nm. Its effects on photorejuvenation are well documented. The goal of this study is to help practitioners better conceptualize and fine tune IPL device settings in order to produce the most effective and safest clinical outcome.
Materials/Methods: This was a prospective study testing several filters (515 nm; 560 nm; 590 nm and 530–650; 900–1200 nm vascular filter), fluences, pulse durations, and pulse numbers (ie, multiple sequence pulsing or MSP) with a new IPL system.
Results: Post-procedure erythema response was more pronounced with increasing fluence, decreasing wavelength, fewer pulses and shorter pulse duration. The exception was the 515 nm filter with regard to pulse duration, which was observed to have a more pronounced response with longer pulse durations. The overall clinical outcome at the 4-week follow-up visit demonstrated greatest improvement in erythema and pigmentation using the 515 nm filter on a Fitzpatrick Skin Type III individual.
Conclusion: Greatest clinical endpoint response at 4-week follow-up was observed with more robust initial responses. This was most apparent at higher fluence levels and fewer pulse counts. However, when the IPL is pushed to aggressive parameters, there is risk of hypopigmentation and hair loss as seen in this case study. Skin type is an important consideration when using IPL and MSP adds to its safety profile.

J Drugs Dermatol. 2021;20(2):203-207. doi:10.36849/JDD.2020.5638

INTRODUCTION

Intense Pulsed Light (IPL) is a non-coherent polychromatic broadband filtered flashlamp that emits light in the spectrum of approximately 400–1200nm. Cut-off filters are placed over the window of an optical treatment head or embedded into a quartz or sapphire light guide to block wavelengths lower than the filter. Cut-off filters allow for preferential selection of various chromophores including melanin (400–755 nm), oxyhemoglobin (600–630 nm; peaks 418, 542, and 577 nm) and deoxyhemoglobin (600–750 nm). They can also be selected to adjust for both depth of penetration and different skin types.

Originally developed to treat leg telangiectasias,[1] IPLs soon found other applications including other types of vascular lesions, hair removal, destruction of benign pigmented lesions, and overall photorejuvenation.[2-10] One of the main advantages of the IPL is its ability to simultaneously treat both benign pigmented lesions such as solar lentigines and ephelides, as well as vascular lesions such as telangiectasia and erythema with minimal to no patient downtime. In addition, histologic analysis of the papillary and reticular dermis has shown that dermal heat produced from IPL treatments induce new collagen production.[11-14] This may account for the improved skin texture, fine wrinkles and pore size.[15] The combination of beneficial effects has been termed "photorejuvenation".[16,17]

IPLs typically feature integrated cooling via filtered cooling crystals.[14] A thin layer of chilled transparent water-based gel is applied to the skin for optical coupling with the crystal, allowing for optimal transmission of light by decreasing the refractive index of light to the skin. Cold-air cooling can also be applied during the treatment to enhance patient comfort. Studies have demonstrated increased thermal protection of the epidermis, allowing use of higher fluence parameters (15–30%) while reducing side effects.[18]

Numerous IPL devices exist in the current marketplace, and each has a unique set of parameters; thus, the efficacy and safety profile may not be reproducible between devices. In general Fitzpatrick skin types I–III can be safely treated with a 560 nm filter while skin types IV–V are often treated with longer wavelength filters. Correction of red vascular lesions and erythema where oxygenated hemoglobin predominates can be achieved by using 515–590 nm cut-off filters while blue vascular lesions or purpuric patches where deoxygenated hemoglobin predominates are better targeted with filters of 590 or higher.

IPLs emit pulse durations in the millisecond range, which is longer than the thermal relaxation time (TRT) of melanosomes (TRT is ~200–400 nanoseconds). However, reports have

demonstrated 50%–100% improvement in benign pigmented lesions (ie, solar lentigines and ephelides) after 1–3 treatment sessions. For a typical vessel 0.1–0.3 mm in diameter, the TRT is approximately 4–10 ms, respectively. The epidermis is approximately 0.1 mm thick with a TRT of approximately 4ms. Therefore, vessels greater than 0.3 mm in diameter cool more slowly than epidermal cells with a single pulse. Multiple sequential pulsing (MSP), a feature of the Stellar M22 Universal IPL (Lumenis, Yokneam, Israel), allows for successive heating of targeted chromophores with adequate cooling time delays for the epidermis and surrounding structures effectively treating larger targets safely. MSP should be spaced 10 ms or greater to allow for epidermal cooling. Generally, lighter skin types can be treated with a 10ms delay between pulses, while darker skin types and skin types with hyperreactive melanocytes (eg, Asian skin) can be treated with a 30–40 ms pulse delay.

Clinical endpoints when treating conditions such as rosacea, melasma, poikiloderma of Civatte and benign pigmented lesions (ie, lentigines and ephelides) is mild to moderate erythema with some mild graying of the pigmented lesions. Vasospasm or coagulation of the vessel is the endpoint when treating facial, truncal and leg telangiectasias. Performing a test spot and observing tissue response after a few minutes is advised before proceeding further with treatment. If unsure of the cutaneous response or when treating lesions with a dense amount of chromophore, a test spot starting at low fluence with double or triple pulsing may be performed with evaluation at 1–2 weeks.

In this clinical study, we report the safety, efficacy and tolerability of the newest generation (6th generation) of an IPL system with MSP (Stellar M22 Universal IPL, Lumenis, Yokneam, Israel), using several of its filters with a variety of parameters (ie, fluence, pulse duration, number of pulses).

MATERIALS AND METHODS

This was a prospective study testing several filters (515 nm; 560 nm; 590 nm and 530–650; 900–1200 nm vascular filter), fluences, pulse durations and pulse numbers (ie, multiple sequence pulsing or MSP) with the newest generation IPL system (Stellar M22 Universal IPL, Lumenis, Yokneam, Israel) on a single subject.

Test Device

The IPL system emits a spectrum of light (400–1200 nm) with 9 different filters. These include changeable filters for "Acne" (400–600 nm and 800–1200 nm) and "Vascular" (530–650 nm and 900–1200 nm) lesions, as well as 515 nm; 560 nm; 590 nm; 615 nm; 640 nm; 695 nm; 755 nm filters using a single handpiece. There are 3 available continuous contact cooling sapphire crystals (8x15 mm, 15x35 mm, and 6 mm round) capable of delivering a max fluences of 35 J/cm^2, 35 J/cm^2 and 56 J/cm^2, respectively. Multiple sequential pulsing (MSP) allows the fluence chosen to be delivered within 1–3 pulses and pulse durations ranging from 3–20 ms in total.

Treatment

The treatment area was cleansed with 4% chlorhexidine solution and then baseline standardized digital photography was captured (Canon Rebel SL2, Canon USA Inc., Melville NY). No topical numbing was used so as to not interfere with target chromophores (ie, melanin vs. hemoglobin). A 4x3 grid was marked out on a 65-year-old male, Fitzpatrick skin type III (Figure 1). Four (4) filters (515 nm, 560 nm, 590 nm, 530–650 nm, and 900–1200 nm vascular filter) were marked out in columns across the back and 3 pulse durations (4 ms, 6 ms and 10 ms) were marked out in rows inferiorly. The one exception was a 6.5 ms triple pulse in the most inferior micro row due to the max pulse duration of the MSP technology limitation of 20 ms in total. Each micro column increased in fluence across and each micro-row increased in number of pulses (ie, 1–3) inferiorly (Table 1). The IPL device was technically limited to lower fluence levels for single pulse mode at 4.0 ms pulse duration for all of the investigated filters. Similarly, it was limited to lower fluence levels for single pulse mode at 6.0 ms pulse duration for the vascular filter. Adverse events were monitored, and standardized digital photography was captured immediately after treatment, 4-hours post treatment, 24 hours post-treatment, 1-week post-treatment, 2-weeks post-treatment, and 4-weeks post-treatment.

RESULTS

Observational Analysis

Standardized digital photography was obtained at baseline (Figure 1A), immediately post-procedure, 4 hours post-procedure, 24 hours post-procedure, 1-week post-procedure, 2-weeks post-procedure, and 4-weeks post-procedure.

The immediate post-procedure erythema response was more pronounced with increasing fluence, decreasing wavelength, fewer pulses, and shorter pulse duration. The exception was the 515 nm filter with regard to pulse duration, which was observed to have a more pronounced response with longer pulse durations. The vascular filter had a relatively more robust erythema response compared to the 590 nm filter, which was comparable to the 560 nm filter. More robust erythema responses were observed with subtle darkening of lentigos (Figure 1B).

The 4-hour post-procedure photos demonstrated the same overall trend. However, the erythema response was overall more pronounced and deeper red in color. Darkening of the lentigos were also present in the treated squares with exuberant erythema response (Figure 1C).

TABLE 1.

Treatment Grid												
Pulse Number	**515 nm**			**560 nm**			**590 nm**			**Vascular (530-650 nm & 900-1200 nm)**		
I (4 ms)	10 J/cm²	13 J/cm²	15 J/cm²	10 J/cm²	12 J/cm²	14 J/cm²	10 J/cm²	11 J/cm²	12 J/cm²	10 J/cm²	11 J/cm²	13 J/cm²
II (4 ms)	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²
III (4 ms)	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²
Pulse Number	**515 nm**			**560 nm**			**590 nm**			**Vascular (530-650 nm & 900-1200 nm)**		
I (6 ms)	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	13 J/cm²	15 J/cm²	17 J/cm²
II (6 ms)	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²
III (6 ms)	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²
Pulse Number	**515 nm**			**560 nm**			**590 nm**			**Vascular (530-650 nm & 900-1200 nm)**		
I (10 ms)	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²
II (10 ms)	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²
III (6.5 ms)	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²	16 J/cm²	18 J/cm²	20 J/cm²

FIGURE 1A. Standardized digital photography at baseline with marked grid pattern.

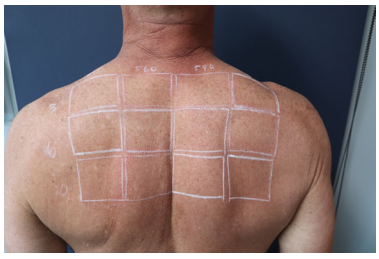


FIGURE 1B. Skin reactions immediately post-treatments. Greater tissue reaction seen with 515 filter, higher fluence, longer pulse

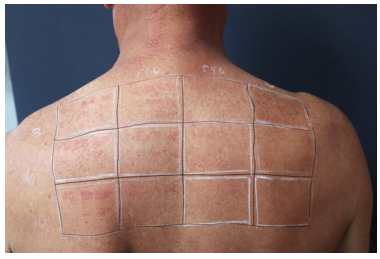


FIGURE 1C. Skin reactions at 4-hours post-treatment. More darkening of pigmented lesions.

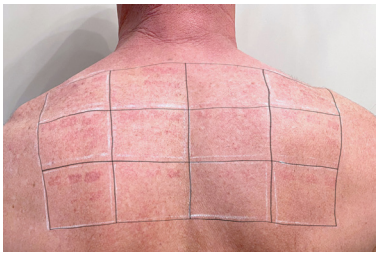


FIGURE 1D. Skin reactions at 24 hours. Improvement in erythema response.

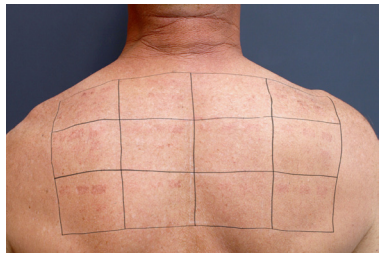


FIGURE 1E. Skin reactions at 1 week. Superficial crusting noted in some treatment areas.

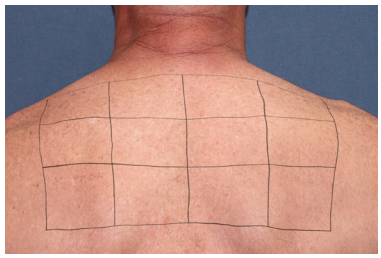


FIGURE 1F. Skin reactions at 2 weeks. Superficial crusting resolved. Hairless and hypopigmented areas present.

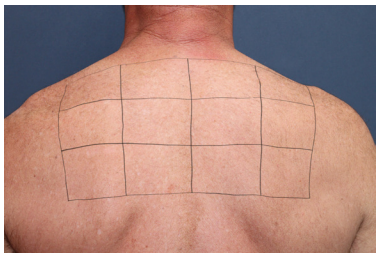
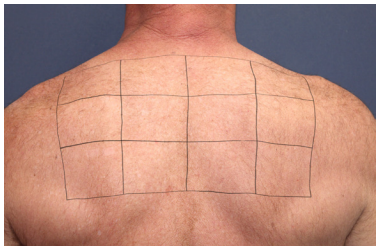


FIGURE 1G. Skin reaction at 4 weeks. Optimal results seen with 515 nm, 10 ms, 18-20 J/cm^2, single pulse.



The 24-hour follow-up photos followed the same overall trend, but there was an improvement in the erythema. Additionally, the erythema was characterized by more of a reddish-brown tone. Lentigines and pigmentation also lightened in color (Figure 1D).

The 1-week follow-up photos demonstrated further resolution of the erythema. Scant crusting was noted in 515 nm single pulse squares at all fluence ranges and pulse durations, as well as 560 nm single pulse squares at 20 J/cm^2 for all pulse durations. Degree of crusting was co-observed with immediate post-procedure erythema response (Figure 1E).

All crusting resolved by the 2-week follow-up visit. Although most of the original crust resolved without any sequela, some of the crusted areas (515 nm, single pulse, 10 ms pulse duration, 18 and 20 J/cm^2 fluence) was replaced by well-demarcated hairless hypopigmented square-shaped patches (Figure 1F). These same two patches were further demarcated at the 4-week follow-up.

The overall clinical outcome at the 4-week follow-up visit demonstrated greatest improvement in erythema and pigmentation using the 515nm filter. Clear demarcated areas of improvement were observed with the longer pulse duration (ie, 10 ms), single pulse, high fluences (ie, 18 and 20 J/cm^2).

DISCUSSION

The results of this case study conceptually align with our understanding of IPL therapy. Erythema response was inversely observed with filter wavelength (eg, the 515 nm filter had the strongest erythema response vs the 590 nm filter had the weakest erythema response). Given that IPL devices filter out wavelengths shorter than the selected filter wavelength, a 515 nm filter would allow for a greater spectrum of wavelengths to target the tissue chromophores at higher absorption coefficients. At 515nm, the IPL targets melanin at higher absorption due to the downward sloping nature of melanin's absorption curve. Additionally, A 515 nm filter targets oxyhemoglobin at all major (ie, 540 nm and 577 nm) and minor (ie, 920–940 nm) absorption peaks.[19] Lastly, it targets water in the infrared wavelength range. By targeting melanin, oxyhemoglobin/deoxyhemoglobin, and water, an IPL can treat pigmented lesions, vascular lesions, and stimulate collagen remodeling.[20] The 560 nm filter did not produce as strong of an erythema response likely because it did not target the 540 nm oxyhemoglobin absorption peak. The vascular filter had an erythema response comparable to the 560 nm filter likely because it targets the same oxyhemoglobin peaks. The 590 nm filter had the weakest erythema response likely because it did not capture both the 540 and 577 nm oxyhemoglobin peaks. Subtle darkening of lentigines was seen with more robust erythema responses, which can be explained by the fact that shorter wavelengths allows for improved targeting of melanin at a higher absorption coefficient.

Erythema response was also observed with higher fluence levels, as well as longer pulse duration. Conceivably, delivery of greater energy to interact with tissue chromophores will produce a stronger response. Additionally, longer pulse durations facilitates greater interaction time with targeted chromophores. This likely explains the extensive crusting, hair removal, and well-demarcated hypopigmentation noted with the following settings: 515 nm, single pulse, 10 ms pulse duration, 18–20 J/cm^2 fluence. In regard to pulsing, the fewer the number of pulses, the more exuberant the erythema response. Conversely, dividing a certain fluence over multiple pulses allowed the use of lower fluences for each stacked pulse, keeping the tissue response to a minimal. This allowed the surrounding tissue to cool while the target chromophores sequentially heat up. This is a safety benefit of MSP when treating darker and ethnic skin types.

Improved clinical response at the 4-week follow-up visit was observed where a greater erythema response was noted during the healing process. This finding was most apparent at the

higher fluence levels and fewer pulse counts. However, when the IPL is pushed to aggressive parameters, there is a risk of hypopigmentation and hair loss as seen in this case study. Skin type is another important consideration. The patient was a Fitzpatrick skin type III, which is more forgiving, and the outcomes may be an unacceptable outcome if treated on darker skin types. Treatment response and adverse effect profiles will vary greatly with skin type. We recommend that providers titrate their settings based on Fitzpatrick skin type and proceed cautiously in patients with skin types IV–V or history of recent tanning. Additionally, all IPL devices operate differently, and one IPL device may not have the same features (eg, MSP) as another.

The IPL is a highly versatile energy device that can produce excellent clinical outcomes by targeting multiple different chromophores (melanin, oxyhemoglobin/deoxyhemoglobin, and water), improving pigmentation, redness, tone and texture. In addition, treatments are safe and well-tolerated. The goal of this study is to help practitioners better conceptualize and fine tune IPL device settings in order to produce the most effective and safest clinical outcome.

DISCLOSURES

Dr. Goldman conducts clinical studies and received the Stellar M22 on loan from Lumenis Ltd.

REFERENCES

1. Goldman MP, Eckhouse S. Photothermal sclerosis of leg veins. *Dermatol Surg.* 1996; (22):323-330.
2. Raulin C, C Schroeter, E Maushagen-Schnaas. Treatment possibilities with a high-energy pulsed light source (PhotoDerm VL)]. *Hautarzt.* 1997. 48(12):886-93.
3. Raulin C, et al. Treatment of adult port-wine stains using intense pulsed light therapy (PhotoDerm VL): brief initial clinical report. *Dermatol Surg.* 1997. 23(7):594-7.
4. Jay H, C Borek. Treatment of a venous-lake angioma with intense pulsed light. *Lancet.* 1998. 351(9096):112.
5. Weiss RA, et al., Hair removal with a non-coherent filtered flashlamp intense pulsed light source. *Lasers Surg Med.* 1999. 24(2):128-32.
6. Weiss RA, MP Goldman, MA Weiss, Treatment of poikiloderma of Civatte with an intense pulsed light source. *Dermatol Surg.* 2000. 26(9):823-7; discussion 828.
7. Wang CC, et al., Intense pulsed light for the treatment of refractory melasma in Asian persons. *Dermatol Surg.* 2004. 30(9):1196-200.
8. Kawada A, et al. Clinical improvement of solar lentigines and ephelides with an intense pulsed light source. *Dermatol Surg.* 2002. 28(6):504-8.
9. Wu DC, et al. Comparison of intense pulsed light with 1,927-nm fractionated thulium fiber laser for the rejuvenation of the chest. *Dermatol Surg.* 2014. 40(2):129-33.
10. Wat H, et al. Application of intense pulsed light in the treatment of dermatologic disease: a systematic review. *Dermatol Surg.* 2014. 40(4):359-77.
11. Alam M, et al. Nonablative laser and light treatments: histology and tissue effects--a review. *Lasers Surg Med.* 2003. 33(1):30-9.
12. Cho EB, et al. Effect of intense pulsed light on rat skin. *Dermatol Surg.* 2012. 38(3):430-6.
13. Goldberg DJ. New collagen formation after dermal remodeling with an intense pulsed light source. *J Cutan Laser Ther.* 2000. 2(2):59-61.
14. Negishi K, et al. Full-face photorejuvenation of photodamaged skin by intense pulsed light with integrated contact cooling: initial experiences in Asian patients. *Lasers Surg Med.* 2002. 30(4): 298-305.
15. Goldberg DJ, KB Cutler. Nonablative treatment of rhytids with intense pulsed light. *Lasers Surg Med.* 2000. 26(2):196-200.
16. Bitter PH. Noninvasive rejuvenation of photodamaged skin using serial, full-face intense pulsed light treatments. *Dermatol Surg.* 2000. 26(9):835-42; discussion 843.
17. Goldman MP, RA Weiss, MA Weiss, Intense pulsed light as a nonablative approach to photoaging. *Dermatol Surg.* 2005. 31(9 Pt 2):179-87; discussion 1187.
18. Raulin C, B Greve, S. Hammes. Cold air in laser therapy: first experiences with a new cooling system. *Lasers Surg Med.* 2000. 27(5):404-10.
19. Meesters AA, et al. Transcutaneous laser treatment of leg veins. *Lasers Med Sci.* 2014. 29(2):481-92.
20. Goldman MP. One laser for a cosmetic/dermatologic practice. *J Clin Aesthet Dermatol.* 2011. 4(5):18-21.

AUTHOR CORRESPONDENCE

Michael B. Lipp
E-mail:.....m.b.lipp@gmail.com