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REVIEW ARTICLE

Lasers for Becker's nevus

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Abstract
Becker's nevus is a common pigmented dermatosis, usually featured by ipsilateral pigmented patch with hypertrichosis. Becker's nevus is often treated with various types of lasers although other regimens are available. However, clinical outcomes appear inconsistent among studies. To summarize the clinical outcomes of Becker's nevus treated with lasers via literature review. A variety of lasers had been used alone or in combination to treat Becker's nevus. Laser wavelengths used for Becker's nevus ranged from 504 to 10,600 nm, while the number of treatment varied from 1 to 12 sessions. The clinical outcomes were mixed although combination of lasers with different wavelengths appeared to achieve a better efficacy. Adverse effects were usually mild to moderate erythema. While lasers are relatively safe, their efficacy for Becker's nevus is moderate. It seems that combination therapy could improve the outcome. However, trials in larger group of patients are required to validate the efficacy of each type of lasers for Becker's nevus.

Keywords Becker's nevus · Laser · Pigmentation · Hypertrichosis

Introduction

Becker's nevus is also known as Becker's melanosis, Becker's pigmentary hamartoma, nevoid melanosis, and pigmented hairy epidermal nevus. Its prevalence can be as high as 2–4% in young males in some regions [1, 2]. It can occur in both males and females either at birth or at adulthood [3–5]. Although Becker's nevus is commonly manifested by ipsilateral lesion, subject with bilateral lesions has also been documented [6]. Pigmented patch with or without hypertrichosis is the main clinical manifestation [7]. Although lesions are symptomatic, cosmetic concerns are bothersome. Lasers are the primary approach to treat Becher's nevus although other regimens, including oral antiandrogen and topical glycolic acid, are available [8, 9]. The clinical outcome varies greatly with studies. Laser wavelengths used for Becker's nevus range from 504 to 10,600 nm, which can be used separately or in combination (Table 1). Here, we summarize the efficacy and safety of various lasers for Backer's nevus.

Pulsed dye laser: wavelength 504 nm

Pulsed dye lasers use lamp to excite dyes to produce designed wavelength. Excitation of coumarin can produce a wavelength of 504 nm [32]. Wavelength at 504 nm can penetrate into the epidermis and the upper dermis and is absorbed by melanin [33]. Therefore, 504 nm pulsed dye laser can lighten Becher's nevus. Tan et al. [10] used a 504 nm coaxial Candela laser with a pulse duration of 300 nanoseconds (nsec) and a spot size of 3 mm diameter to treat two cases of Becker's nevus. Fluence levels were between 2 and 3.5 J/cm^2. Immediately following laser treatment, skin became purpura or whitening, which lasted 2–7 days. Two patients were treated for 2 and 6 sessions, respectively, at intervals of 6–12 weeks. Pigmentation completely cleared in both patients. But adverse events were not documented. It appears that 504-nm pulsed dye laser is effective for lightening Becher's nevus.

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Table 1 Summary of clinical observation of lasers and lights for Becker's nevus

Lasers	Number of cases	Treatment methods	Outcome	Adverse events	Ref.
Pulsed dye (504 nm)					
	2	Fluence between 2.0 and 3.5 J/cm^2, pulse 300 nsec, average 4 treatments (2–6 treatments) at 6–12-week intervals	Pigment completely cleared in both patients	N/S	[10]
Q-switched Nd:YAG (532 nm)					
	1	Unspecified fluence and pulse (10–20 nsec), single treatment	43% clearance of pigment	Pain	[11]
	8	Fluence 1.1–4.4 J/cm^2, with a mean fluence of 2.9 J/cm^2. pulse 5–7 nsec, average 1.8 treatments at 3 month intervals	Fair in 2 patients; Poor in 6 patients.	Temporary hyperpigmentation	[12]
Intense pulsed light (550 nm)					
	2	For pigment: fluence 9–12 J/cm^2, pulse 5–10 msec; up to 5 treatments; For hair removal: fluence of 7–9 J/cm^2, pulse 5 msec; up to 4 treatments at intervals of 40 days	A progressive hair removal and a reduction in hyperpigmented area were achieved to the good satisfaction of the patient.	N/S	[13]
Intense pulsed light (615 nm)					
	3	Fluence 38 J/cm^2, pulse 5–10 msec, 4 treatments at 8-week intervals	Less than 50% clearance of pigment	Mild to moderate pain	[14]
Q-switched ruby laser (694 nm)					
	1	Fluence 8 J/cm^2, pulse 40 nsec.	Pigment was improved 2 weeks after treatment.	Hyperpigmentation 4 weeks after treatment	[15]
	4	Various fluence up to 8 J/cm^2, pulse 20 nsec, at 6–8-week intervals, number of treatment was not specified	Excellent results, but not quantitated.	Mild to moderate pain, edema	[16]
	1	Fluence of 8.4 J/cm^2, pulse 28 nsec, single treatment	63% clearance of pigment	Pain	[11]
	1	Fluence of 40 J/cm^2 for pigment and of 18 J/cm^2 for hair removal, pulse 3 msec, A second and third treatment at 19 and 22 J/cm^2, respectively, at 6–8-week intervals	Single treatment induced 50% and three treatments induced 90% reduction in hair density. Pigment was also improved	Tolerable pain, burning sensation, mild erythema that lasted 1–2 h	[17]
Long-pulsed alexandrite laser (755 nm)					
	11	Fluence 20–25 J/cm^2, pulse 3 msec, 2–12 treatments at 2–3 month intervals.	8/11 patients were satisfied with treatment outcome; Over 50% clearance in 7/11 patients.	Small hypertrophic scar in 1 patient; Mild hypopigmentation in some patients.	[18]
	1	Fluence 2.08 J/cm^2, pulse 550–750 psec, 4 treatments at unspecified intervals.	Both pigment and hair density improved	N/S	[19]
	1	Fluence 3.46 J/cm^2, unspecified pulse, 3 treatments at 4–6-week intervals.	Pigment was fairly improved (25–49% clearance)	No side effect	[20]
	2	Spot sizes from 2.5 to 6 mm, and energy densities ranged from 0.71 to 4.07 J/cm^2. Average 4.12 treatments.	Unspecified	N/S	[21]
808-nm and 810-nm diode lasers					
808-nm diode laser	4	Fluence 24 J/cm^2, pulse 6 msec	When hair clearance scored 0–5 (5, complete clearance). Scored 3.9 at 6 months, and 3.5 at 12 months.	Mild to moderate discomfort in 6 patients	[22]
810-nm diode laser	11	Fluence 10 J/cm^2, pulse 20 msec			

Table 1 (continued)

Lasers	Number of cases	Treatment methods	Outcome	Adverse events	Ref.
Q-switched Nd:YAG (1064 nm)					
	11	Fluence 10 J/cm^2, pulse 10 nsec, 3 treatments at 2 month intervals,	After 3 treatments, 51–99% clearance in 1 patient; 26–50% clearance in 5 patients, and 1–25% clearance in 3 patients. No improvement in 2 patients. Overall ≈ 20% clearance in pigment.	Discomfort, crust formation and erythema	[23]
	1	Fluence 10 J/cm^2, unspecified pulse, 1 treatment, 10% overlapping	Less than 25% improvement in pigments 6 months after treatment.	Erythema lasted 15 days	[24]
	3	Fluence 20–45 J/cm^2, pulse 30–40 msec, at 6–8-week intervals, 2–6 treatments.	Two patients with mild and one with excellent reduction in hair density	Mild erythema	[25]
Erbium-doped fiber laser (1550 nm)					
	2	Fluence 6–10 J/cm^2, 8–10 passes, 5 or 6 treatments at 4-week intervals	Pigment improved over 75%. No changes in hypertrichosis	Mild pain, moderate to severe erythema	[26]
Erbium:YAG (2940 nm)					
	11	Fluence 28 J/cm^2, one pass, single treatment	Two years after treatment, complete clearance in 6 patients, and > 50% clearance in 5 patients. Overall ≈ 70% clearance in pigment.	Erythema lasted 3 months	[23]
	7	Fluence 700 mJ/cm^2, 3–5 passes, single treatment	Good improvement in pigment in 5 patients and moderate improvement in 2 patients. No changes in hair density	Erythema	[27]
	1	Fluence 28 J/cm^2, 1 treatment, 50% overlapping	Over 75% improvement in pigment 6 months after single treatment	Erythema lasted 2 months	[24]
Ablative fractional laser (10,600 nm)					
	10	Fluence 10 mJ/microbeam, 4 passes, 3 sessions at 4–6-week intervals.	Global assessment scores of pigment at 3- and 6-month follow-up were 3.8 and 5, respectively.	Mild to moderate erythema and burning sensation	[28]
	8	Fluence 10 mJ/microbeam, 35–45% coverage, 4 passes per session, 3 sessions	Moderately effective in some patients	Dermal fibrosis in 4 patients	[29]
Q-switched Nd:YAG (1064 nm) and erbium:YAG (2940 nm)					
	1	Nd:YAG: Fluence 10 J/cm^2, unspecified pulse, 1 treatment, 10% overlapping; Er:YAG: Fluence 28 J/cm^2, 1 treatment, 50% overlapping	100% clearance of pigment	Erythema	[24]
Long-pulsed Nd:YAG (1064 nm) and alexandrite laser (755 nm)					
	1	Five sessions of Nd:YAG 1064 nm at fluence of 26–27 J/cm^2, pulse 10 msec, 6-week intervals followed by six sessions of alexandrite laser at fluence of 60–70 J/cm^2, 1.5 msec, at 3 month intervals	Markedly improvement in both pigment and hypertrichosis	minimal edema and mild blistering, temporary mild hypopigmentation	[30]
Q-switched alexandrite laser (755 nm) and erbium-doped laser (1550 nm)					
	1	First treated with Alexandrite 755 nm (3 mm, 7.5–8 J/cm^2, 50 nsec) for a total of three sessions at 4–6-week intervals. Subsequently treated with Erbium doped laser 1550 nm (15 mm, 30–70 mJ, 20–32% coverage, total 1.70–3.24 kJ, cold-air cooling 5–6, 8 passes) for a total of 10 sessions at 4–8-week intervals.	Over 75% clearance	Post-inflammatory hypopigmentation with Q-Switched alexandrite laser treatment.	[31]
Long-pulsed Nd:YAG and non-ablative fractional erbium-doped (1550 nm) + topical hydroquinone					

Table 1 (continued)

Lasers	Number of cases	Treatment methods	Outcome	Adverse events	Ref.
	2	Patient 1. Nd:YAG fluence 10 J/cm^2, 3–5 msec, 2 sessions at 8-week intervals to remove hair, followed by Erbium-doped fiber laser (1550 nm) 9–40 mJ, 8 passes, 8 sessions at 4–8-week intervals; Patient 2. Nd:YAG (14 J/cm^2, 20 msec, 40/40 dynamic cooling) for a total of three sessions at 4–8-week intervals. Erbium doped laser (15 mm, 30–45 mJ, 20% coverage, total 1.74–2.10 kJ, cold-air cooling 5, 8 passes) for a total of 5 sessions delivered at 4–8-week intervals.	Over 75% clearance in both patients;	Mild pain and erythema	[31]

N/S not stated

Q-switched neodymium:yttrium-aluminum-garnet (Nd:YAG) laser: wavelength 532 nm

Yttrium aluminum garnet (YAG, $Y_3Al_5O_{12}$) is a synthetic crystalline material of the garnet group. Pure YAG cannot be used as laser medium. But the neodymium ion provides the lasing activity in the crystal. Neodymium can be doped into YAG as active laser ions, yielding Nd:YAG. Nd:YAG lasers operate in both pulsed and continuous mode. Pulsed Nd:YAG lasers are typically operated in the Q-switched mode. In Q-switched mode, output powers of 250 MW and pulse durations of 10 to 25 nsec can be achieved. The high-intensity pulses may be efficiently frequency doubled to generate laser light at 532 nm. Although one study showed that single treatment with 532 nm Nd:YAG with a pulse duration of 10–20 nsec and a spot size of 3 mm diameter induced 43% reduction in pigmentation [11], other study on eight patients showed that an average of 1.8 treatments with a pulse duration of 7–8 nsec and a spot size of 3 mm diameter at a fluence level of 2.9 J/cm^2 minimally improved pigmentation (0–25%) in six cases and moderately improved (26–50%) in two cases [12]. All patients experienced post-inflammatory hyperpigmentation, which gradually faded over a few months. Thus, additional clinical trials are required to assess whether 532 nm Nd:YAG laser is suitable for Becker's nevus.

Intense pulsed light: wavelengths 550 nm and 615 nm

Intense pulsed light is the use of intense pulses of non-coherent light over a range of wavelengths from 500 to 1200 nm. The light energy is converted to heat energy, causing damage to the specific target area. One study showed that Becker's nevus with hypertrichosis was first treated with 550 nm IPL for 5 msec at fluence levels of 7–9 J/cm^2 and for four sessions at intervals of 40 days to removal hair, followed by additional two sessions [13]. Both hypertrichosis and pigmentation were substantially improved. For Becker's nevus without hypertrichosis, 550 nm IPL at 9–12 J/cm^2 for 5–10 msec for up to five sessions effectively improved pigmentation [13]. No adverse events were reported. It appears that 550 nm IPL at low fluence can remove hair and at high fluence can lighten Becker's nevus. However, 615 nm IPL does not seem as effective as 550 nm IPL. Moreno Arias and Ferrando used 615 nm IPL at a fluence level of 38 J/cm^2 and a pulse of 4.5 msec to treat three patients with Becker's nevus for four treatment sessions at 8-week intervals [14]. Less than 50% improvement was achieved. Most patients complained of mild to moderate pain and burning sensation. During 2–16-month follow-up, no repigmentation occurred. Based on these two separate clinical trials, 550 nm IPL

appears better than 615 nm IPL for Becker's nevus in regard to both efficacy and safety.

Q-switched ruby laser: wavelength 694 nm

Q-switched lasers can produce light pulses with extremely high (gigawatt) peak power and longer pulse durations than those with continuous wave (constant output). Ruby laser, type of solid-state laser, uses a synthetic ruby crystal as its laser medium, which enables high output energy (100–200 MW) at extremely short pulse times (20–80 ns) at a wavelength of 694 nm [34]. Ruby laser is selectively absorbed by the melanin in the skin, with very low absorption by hemoglobin and therefore, minimal risk of bleeding. The high absorption by the melanin chromophore allows for effective treatment of both superficial and deep pigment. A number of trials have been performed to evaluate the benefits of Q-switched ruby laser for Becker's nevus [11, 15–17]. One study showed that skin lightening occurred in 2 weeks following treatments with Q-switched ruby laser at a fluence level of 8 J/cm^2 and pulse of 40 nsec. But reactive hyperpigmentation occurred 4 weeks later [15]. Tse et al. [11] reported that single treatment could achieve an over 60% reduction in pigment. One study showed that the clinical improvements in both hypertrichosis and hyperpigmentation remained at least 10 months after the final treatment [17]. Adverse reactions included temporary tolerable pain and burning sensation and mild erythema.

Long-pulsed alexandrite laser: wavelength 755 nm

Alexandrite laser, another solid-state laser, uses alexandrite (Cr^{3+}:$BeAl_2O_4$.) as laser medium. As light passes through alexandrite crystal, wavelength 755 nm light can be produced. Although this light is intended to be used for removal of pigment, it can also decrease hair density of Becher's nevus. A study in 11 Koreans with Becker's nevus showed that 75–100% clearance of pigment was observed in 2 patients, and 5 patients displayed 50–70% clearance [18]. Four patients showed 25–50% clearance of pigment. Following laser treatment, hair density on the lesional sites was comparable to the uninvolved skin. The benefits of *long-pulsed alexandrite laser for* Becher's nevus were confirmed by other independent studies [19, 20]. The fluence levels and pulses used in the treatments ranged from 2.08 to 25 J/cm^2 and 2.5–3.0 msec, respectively, depending on lesions [18–21]. Similarly, requirement of treatment sessions also depends on the lesions and body sited. It appeared that lesions on the nose and cheeks required more treatment sessions [18]. Moreover, melanocytes may remain survival following treatment with Q-switched *alexandrite laser* (*755 nm*) [35]. Adverse cutaneous reactions to *long-pulsed alexandrite laser* included transient erythema and mild hypopigmentation in some patients [19].

Diode laser: wavelengths 808 and 810 nm

Diode laser, *also known as injection laser*, is a semiconductor laser, producing coherent radiation of wavelength 800–810 nm, which can penetrate into deep layer of skin and be absorbed by specific chromophores such as melanin. Because of its chromophore specificity, this laser can selectively target tissues such as hair and melanin. Lapidoth et al. [22] treated four patients with 808-nm diode laser at a fluence level of 24 J/cm^2 and pulse of 6.0 msec, and 11 patients with 810-nm diode laser at a fluence level of 10 J/cm^2 and pulse of 20.0 msec. Both patients' satisfaction and improvement scores were comparable between these two lasers. Average scores of hair clearance at 6 and 12 months were 3.9 and 3.5, respectively. Without the use of pretreatment anesthesia or skin cooling, six patients experienced mild to moderate discomfort during treatment. No other adverse events were noticed.

Q-switched Nd:YAG laser: wavelength 1064 nm

Nd:YAG laser is a solid-state laser, using Nd:YAG (neodymium-doped yttrium aluminum garnet) crystal as laser medium. The light energy travels at a wavelength of 1064 nm. The laser can produce a high intensity beam in extremely brief pulses in switched mode. Q-switched Nd:YAG can be used alone or in combination with other laser for Becher's nevus. Trelles et al. [23] treated 11 patients with Q-switched Nd:YAG at a fluence level of 10 J/cm^2 for 10 nsec, repetition rate of 10 Hz, and 10% overlapping, for a total of three sessions at 2-month intervals. After three sessions of treatment, one patient showed marked clearance (51–99%). Moderate (26–50%) and mild (1–25%) clearance were observed in 45.5% ($n = 5$) and 27.3% ($n = 3$) of the patients, respectively. But pigment reappeared progressively in scattered areas at 6, 9, 12, 15, 18, and 24 months after final treatment. In two patients, no clearance was observed after treatment. Hair regrowth was also noticed by all patients between 1.5 and 2 months after the last treatment. The quality of hair after treatment was the same as before treatment. Another study showed that single treatment with Q-switched Nd:YAG, using the same laser setting as Trelles's, induced < 25% clearance of lesion [24]. Koch et al. [25] treated three patients with Q-switched Nd:YAG at fluence levels of 20–45 J/cm^2, pulse 30–40 msec, for 2–6 treatments at 6–8 weeks intervals. Mild and excellent reductions in hair density were observed in two and one patients, respectively. Adverse effects included discomfort, crust

formation, and erythema [23]. Three patients developed skin textural changes and superficial fibrosis following the treatments [23]. These results suggest that Q-switched Nd:YAG likely may not exhibit long-term benefits for Becker's nevus.

Erbium-doped fiber laser: wavelength 1550 nm

An erbium-doped fiber uses an optical fiber doped with erbium ions $Er3^+$ as active gain medium. When laser diode beam is fed into an erbium-doped fiber, emission will be amplified, producing a wide range of wavelength, including 1550 nm [36]. Glaich et al. [26] treated two patients with erbium-doped fiber laser. One patient was given six treatments at fluence levels of 6–10 J/cm^2 at 4-week intervals, and the other was given five treatments at a fluence level of 10 J/cm^2. Both patients displayed over 75% improvements in pigment 1 month after the last treatment. No relapse was seen during 3- and 6-month follow-up. But no improvement in hair density was observed. During treatment, the patients experienced mild pain. Moderate to severe post-operation erythema and edema disappeared within 24 to 48 h.

Er:YAG laser: wavelength 2940 nm

An Er:YAG laser (erbium-doped yttrium aluminum garnet laser, erbium YAG laser) is a solid-state laser, using erbium-doped yttrium aluminum garnet (Er:$Y_3Al_5O_{12}$) as laser medium. Er:YAG lasers typically emit infrared light with a wavelength of 2940 nm, which is strongly absorbed by water. Although Erbium-YAG lasers have been used for skin resurfacing, it is also effective for Becker's nevus. A study of 11 patients showed that 2 years after treatment complete clearance (100%) was observed in 54% of the patients ($n = 6$), while over 50% clearance in 5 patients, following a single pass at a fluence level of 28 J/cm^2, 10 Hz repetition rate, and 50% overlapping [23]. However, hair regrowth occurred in some patients 2 months after treatment, and partial brown pigmentation in five patients. Hyperpigmentation was mild and no further treatment was requested by any of the patients. The same group treated another patient, using the same treatment protocol. Over 75% improvement in pigment was observed 6 months after treatment [24]. Another study in seven patients showed that five patients displayed 51–75%, and two patients showed 26–50% improvement in pigment, following a single session of treatment at a fluence level of 700 mJ/cm^2 and 3–5 passes [27]. Adverse events included crust formation and erythema. While in most cases crusts peeled off 1 week post-operation, erythema lasted up to 3 months [23]. Mild pain developed in the treated areas within first 24 h, which gradually decreased within 72 h to 1 week [27].

Ablative fractional laser: wavelength 10,600 nm

Ablative fractional laser is a CO_2 laser, producing light at wavelength 10,600 nm, which is absorbed by water in the tissue. When the laser energy heats up the tissue water until it reaches a boiling point, targeted tissue will evaporate. Because the ablative fractional laser only removes columns of the epidermis, the surrounding tissues will remain unaffected. Meeters et al. [28] treated 11 patients with ablative fractional laser at a fluence level of 10 mJ/microbeam, 4 passes/treatment session for a total of 3 sessions. The interval was 6 weeks between the first and the second session, 4 weeks between the second and the third session. Ten patients were followed up for 6 months. When the improvements in hyperpigmentation were scored according to a visual analog scale (VAS), VAS was 3.8 at 3 months and 5.0 at 6 months after the last treatment. Moreover, the epidermal melanin indices were comparable to that in normal skin following treatments. However, Wind et al. [29] reported that ablative fractional laser was only moderately effective in some patients, using the same treatment protocol as described by Meeters et al. [28]. Thus, the benefits of ablative fractional laser 10,600 nm for Becker's nevus remain to be confirmed. Adverse events of ablative fractional laser 10,600 nm included mild to moderate erythema, burning sensation, and dermal fibrosis [28, 29].

Combination of two lasers

Q-switched Nd:YAG (1064 nm) and erbium:YAG (2940 nm)

Trelles et al. [24] treated a patient first with a single session of Q-switched Nd:YAG 1064 nm at fluence level of 10 J/cm^2, spot size of 3 mm, repetition rate of 10 Hz, and a 10% overlapping, which produced < 25% improvement in pigment. Six months later, the patient was given a single session of Er:YAG 2940 nm at a fluence level of 28 J/cm^2, spot size of 3 mm with a collimated handpiece, 10 Hz repetition rate, and 50% overlapping. Two-year follow-up showed 100% clearance of pigment in the whole lesion and mild hypopigmentation. Thus, it appears that this combination regimen is effective for pigment.

Long-pulsed Nd:YAG (1064 nm) followed by alexandrite laser (755 nm)

Wulkan et al. [30] treated one patients with both hyperpigmentation and hypertrichosis, using Nd:YAG and Alexandrite laser sequentially, and obtained a satisfactory results. The patient was first given five treatments of Nd:YAG laser at fluence levels of 26–27 J/cm^2, 10 msec pulse, and a

spot size of 15 mm, at about 6-week intervals, followed by six treatments of Alexandrite 755-nm laser at fluence levels of 60–70 J/cm^2, pulse of 1.5 msec, 6 mm spot size, at about 3-month intervals. For treatment with Alexandrite 755-nm laser, Dynamic Cooling Device (DCD) was set to 20/20 msec. Adverse events of this treatment included minimal edema, mild blistering, and temporary mild hypopigmentation.

Q-switched alexandrite laser (755 nm) followed by erbium-doped laser (1550 nm)

In case of combination therapy, one laser could overcome adverse events induced by other laser. For example, Balaraman and Friedman treated a patient with atrichotic Becker's nevus with 755-nm Q-switched alexandrite laser at fluence levels of 7.5–8 J/cm^2, 50 nsec, for a total of three sessions at 4–6-week intervals. Following the treatment, post-inflammatory hypopigmentation developed. Then, this patient was subsequently treated with a non-ablative fractional laser, erbium doped laser 1550 nm at fluence levels of 30–70 mJ, 20–32% coverage, total 1.70–3.24 kJ, 8 passes/session, for a total of 10 sessions at 4- to 8-week intervals. An over 75% improvement was observed following the last treatment and sustained over the 18 months [31].

Long pulsed Nd:YAG (1064 nm) followed by erbium-doped laser (1550 nm) and topical hydroquinone

In case of Becker's nevus with hypertrichosis, hair was first removed with the long pulsed Nd:YAG 1064 nm (18 mm spot, 10 J/cm^2, 3–5 msec pulse, and 30/20 dynamic cooling) for a total of two sessions at 8-week intervals. Then, erbium-doped laser 1550 nm was given following the treatment protocol (15 mm spot, 9–40 mJ, 14–20% coverage, cold-air cooling 5, 8 passes) for a total of 8 sessions at 4- to 8-week intervals. Sunscreen and topical 4% hydroquinone were also applied duration the treatment. Again, an over 75% improvement was observed and sustained at 10 months after the last treatment with erbium-doped laser 1550 nm. A similar result was also achieved in another patient treated with a slightly modified treatment protocol [31]. Adverse events of these combination therapies were erythema and mild pain during treatment. The erythema usually disappeared within 48 h.

Because increased basal layer pigmentation with variable hypertrichosis is the major histological feature of Becker's nevus, an ideal laser would be the one that can remove both pigment and hair. However, each laser has different wavelength, which determines the penetration depth of laser energy. Moreover, each wavelength is preferentially absorbed by specific substance or tissue. As seen in Table 2 [37–43], lasers or lights at wavelengths, ranging from 615 to 1064 nm, could benefit both pigment and hypertrichosis for Becker's nevus. In

Table 2 Characteristics of each laser pertinent to Becker's nevus

Lasers	Depth of penetration	Mainly absorbed by	Target tissues/cells	Benefits for Becker's nevus
Pulsed dye 504 nm	Epidermis	Melanin	Melanin-containing cells	Epidermal pigment [10, 12]
Q-switched Nd:YAG 532 nm	Epidermis	Melanin		
Intense pulsed light 550 nm	Epidermis	Melanin	Melanin-containing cells	Epidermal pigment [37, 38]
Intense pulsed light 615 nm	Upper dermis	Melanin		Epidermal pigment [38], Hair removal [39]
Q-switched ruby laser 694 nm	Upper dermis	Melanin	Melanin-containing cells	Epidermal pigment and hair removal [40]
Long-pulsed alexandrite laser 755 nm		Melanin and other dark pigments such as hemoglobin.	Melanin-containing cells and hair follicles	Epidermal and upper dermal pigment [19], hair removal [41]
808-nm diode laser	Middle and lower dermis	Melanin	Melanin-containing cells and hair follicles	Epidermal and dermal pigment, and hair removal [22, 42]
810-nm diode laser				
Q-switched Nd:YAG 1064 nm	Lower dermis	Melanin and water	Melanin-containing cells and hair follicles	Epidermal and dermal pigment, and hair removal [23–25]
Erbium-doped fiber laser 1550 nm	Middle and lower dermis	Water, collagen	Nonspecific damage of skin	Epidermal and dermal pigment [43]
Erbium:YAG 2940 nm	Upper epidermis	Water, collagen	Nonspecific damage of skin	Epidermal pigment [27]
Ablative fractional laser 10,600 nm	Lower dermis	Water, collagen	Nonspecific damage of skin	Epidermal and dermal pigment [28]

consideration of potential damage to surrounding uninvolved tissues by excessive heat, Nd:YAG laser 1064 nm may not be the appropriate choice. Instead, 808- and 810-nm diode lasers could be optional because of its specific absorption by melanin and deeper penetration. But which laser(s) to be utilized should be based on characteristics of each laser (Table 2) and individual's skin type and phenotype of skin lesions (with or without hypertrichosis).

In summary, clinical outcomes are controversial although a variety of lasers are available for Becker's nevus. Skin type and nevus with or without hypertrichosis can affect the efficacy of each type of lasers. It appears that clinical efficacy of the Er:YAG 2940 nm is better than Q-switched Nd:YAG 1064 nm for pigment although the Nd:YAG laser 1064 nm may be better for treating darker skinned individuals [44]. Trials in larger group of patients are still required to validate the efficacy of each type of lasers for Becker's nevus.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

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