Research and Historical Works - 2021

A 6-Year Experience of Laser Treatments for Burn Scars in a Regional Burn Center-Safety, Efficacy, and Quality Improvement

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A 6-Year Experience of Laser Treatments for Burn Scars in a Regional Burn Center—Safety, Efficacy, and Quality Improvement

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Laser treatments have long been used as a treatment method for burn scars. Since 2012, more than 1800 laser treatments were performed at Lehigh Valley Health Network Burn Center, far exceeding any previous cohort in studies exploring laser treatments for burn scars. Although previous research has looked at improving scar appearance and physiology with laser treatments, very few have focused on safety. The purpose of the study was to determine whether laser treatments are a safe treatment option for burn scars. Four hundred and fourteen patients who had undergone at least one laser treatment in the outpatient burn center since 2012 were analyzed. Electronic medical records (EPIC) were reviewed. The data were entered in REDCap and later exported to Microsoft Excel and R Studio for statistical analysis. Most of the complications found were related to the moderate sedation during the procedures and were mild, ie, nausea. The most common adverse effect was prolonged recovery time, which can affect practice flow. The overall postoperative complication rate for laser treatments with and without moderate sedation was minimal at 2.2% and 1.4%, respectively. Pain during and after the procedure averaged 3.9 and 1.7, respectively, on a 1 to 10 scale. The Vancouver Scar Scale showed modest improvement in scar appearance over time with an average improvement of 1.4. The high variability of the Vancouver Scar Scale observed in this series underlines its lack of sensitivity. The study results show that laser treatments for burn scars in the outpatient setting generally are safe for patients in need of burn scar intervention. Some practice flow adjustments need to be taken into consideration when offering these procedures in an outpatient setting.

Severe burns can have a long-lasting impact on the burn survivor, mostly, but not exclusively, because the resulting scars from mid-dermal partial-thickness and full-thickness burns cause significant distress and functional impairment, especially if the burn covers a large surface area of the body.

Since 1997, laser treatments have been added to the range of treatments for hypertrophic burn scars.[1–4] The histological evaluation of the laser-treated burn scar was published by Ozog et al in 2013.[5] Treatment with a fractional carbon dioxide laser improved the appearance of mature burn scars, reduced burn contractures, and resulted in a significant improvement in collagen architecture following treatment. Furthermore, in treated skin specimens, a collagen subtype profile (types I and III collagen) resembling that of nonwounded skin was found.

During the past 15 years, prospective and retrospective studies as well as case reports have documented the success of fractional laser treatments to improve the appearance of scars of multiple etiologies.[1,6–14] A large retrospective study published in April 2014 by Hultman et al[15] analyzed 147 patients' results after laser treatment of burn scars. Improvements were experienced in the signs and symptoms (erythema, pliability, and height) of hypertrophic burn scars. This group published the first prospective controlled study of fractional CO_2 laser treatment effects on burn scars in 2015, which documented subjective and objective improvements in burn scar physiology (thickness, elasticity, sensation, itching, pain, and appearance).[16] Most previous studies on laser treatments focused mainly on efficacy for the improved appearance of burn scars following laser treatments. Only a few smaller studies and case reports have focused on its safety and quality improvement issues. Since 2012, Lehigh Valley Hospital Network's (LVHN's) burn center outpatient clinic has performed more than 1800 laser treatments on adult as well as pediatric postburn patients. These laser treatments have been performed with and without moderate sedation anesthesia with positive outcomes, providing a very large sample size. The burn scar treatment algorithm at LVHN burn center includes early treatment with moisturizers and scar massage directly after wound healing, edema therapy, and compression, as well as stretching, occupational and physical therapy, and silicone sheeting and splinting. As early as 3 weeks after wound healing scars are assessed regarding their potential for hypertrophic scarring. If the potential for hypertrophy is assessed as high or early signs are visible, or the patient complains of severe pruritus not controlled with moisturizer or antihistamines, nonablative laser treatments or IPL treatments are considered. For more mature or minimally hyperemic hypertrophic scars, ablative fractional laser treatments are suggested. Ablative fractional

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Funding: This research was in part supported by an institutional grant from the Department of Surgery and the Ferdock Scar Research and Treatment Fund.

Conflict of interest statement. There are no conflicts of interest.

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doi:10.1093/jbcr/iraa118

laser treatments cannot be successfully applied in the extremely hyperemic phase of scarring (personal experience of the authors) because of extensive bleeding during treatment, which renders it ineffective: The pulse energy is absorbed by the blood (higher water content than tissue) as opposed to the subepidermal matrix.

Both ablative and nonablative fractional laser treatments as well as other high-energy light-based therapies can be very painful. The optimal type of pain control for these treatments should be matched with optimal patient safety. Using a powerful laser on a small child, which is totally unpredictable when awake, could have severe complications like eye damage. All small children are therefore placed under moderate sedation when treated with lasers. Some children older than 5 years have been treated at their own request without sedation and were able to undergo the procedure safely. Teenagers and adults with small areas of scarring can be treated with topical anesthetic creams (4% Lidocaine) and cooling following the procedure. Most burn survivors have a needle phobia and local injectable anesthesia is therefore rejected. Most burn centers perform these types of scar treatments under some form of sedation, often in the operating room, especially when large surface areas are to be treated.

The main purpose of this study was to determine whether laser treatments with and without some form of anesthesia are a safe treatment method for burn scars, since efficacy has been demonstrated in multiple previous studies. However, efficacy was an additional endpoint, as measured by the Vancouver Scar Scale (VSS) improvement throughout the treatments. In addition, opportunities for improvement of the procedure workflow were to be examined. Approval from the LVHN Internal Review Board was obtained.

METHODS

This study was a retrospective chart review of patients who were seen at Lehigh Valley Health Network Outpatient Burn Center at least once for laser therapy for the diagnosis of a hypertrophic/burn scar between January 1, 2012 and May 1, 2018. The patient's information was retrieved from the electronic medical record by querying the ICD-9 and ICD-10 codes for the diagnosis of hypertrophic and atrophic conditions of the skin and scar conditions and fibrosis, codes 701 and 709/L91.0 and L90.5. From this pool of patients those undergoing laser treatment for scar revision, procedure codes 17999.A-C or 17106, 17107, or 17108 were included. A total of 414 patients who had undergone 1877 laser treatments were identified and included in this study. The data collected included demographics, burn characteristics, anesthesia form, laser treatment details, pain, complications, VSS, and Patient Observer Scar Assessment Scale (POSAS).[17,18] Patients are routinely followed up for 6 months after their last scar intervention at the LVHN burn center. Study data were collected and managed using REDCap (Research Electronic Data Capture) tools hosted at LVHN.[19] Data were entered de-identified. The data set was then analyzed using Microsoft Excel. In Excel, descriptive statistics were calculated. The data were further analyzed in R Studio. *T* tests and mixed-effects logistical regressions were applied to determine significance between variables.

RESULTS

Demographics

Of the 414 patients, 328 were Caucasian, 30 were African-American, 12 were Asian, 32 were Hispanic, and 12 chose not to report their race: 57.5% of patients were male; 25.6% of the patients were pediatric patients (younger than the age of 18); 58.7% of patients initially had a burn severe enough that it required a skin graft. A few patients underwent laser treatments for nonburn-related traumatic scars (7.8%). The average initial total burn surface area (TBSA) was 15.8% and the average size of the treated scar was 547 cm^2. Ablative and nonablative laser treatments are uncomfortable, producing a stinging/burning sensation, so that the vast majority of patients opted to use some form of anesthesia during their treatment (92.9%). Of those patients, 69.3% used deep to moderate sedation, by definition a level of unconsciousness that supports spontaneous breathing but requires airway protection, during the treatment, while 30.7% used topical anesthesia, consisting of topical application of 4% lidocaine cream half an hour before treatment in conjunction with air cooling before and after the treatment. Figure 1 shows the primary location of the laser treatments on the patients. The median number of days from injury to the first laser treatment was 138 days for adults and 181 days in pediatric patients.

Laser Treatment Details

The Mosaic™ fractional nonablative laser and CO_2 fractional ablative laser (eCO_2™ and MOSAIC™ technology; Lutronic®, San Jose, CA) were the two most commonly used lasers during treatment. CO_2 fractional lasers made up 59.5% of the treatments, while Mosaic™ lasers made up 34.8% of laser treatments. Most patients underwent fractional

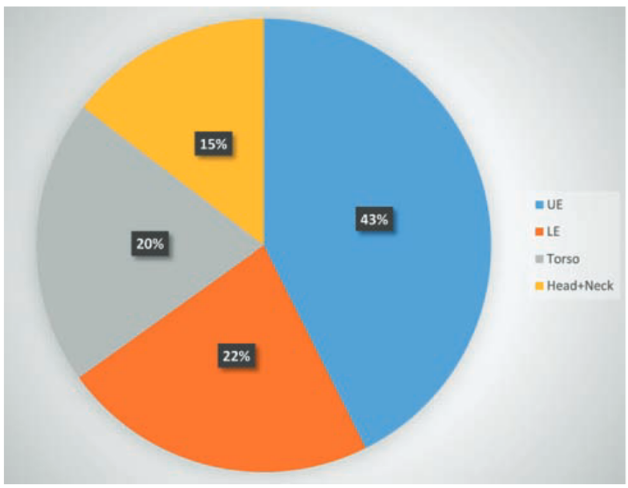

Figure 1. The location of the treatment area for patients with burn scars. If a patient had a large treatment area, the recorded area was the one that was treated the most. UE refers to upper extremities, which includes arm, forearm, and hand, and accounted for 42.6% of all injuries. LE refers to lower extremities, which includes legs and feet, and accounted for 22.5% of all injuries. The torso includes the abdomen, chest, and back, which accounted for 20.3% of injuries. The head and neck areas accounted for 14.6% of all injuries.

nonablative laser treatments in the earlier stages of the scarring process and then switched over to fractional ablative CO_2 laser treatments as scar maturation progressed. The other laser modalities used included intense pulsed light (IPL) purely for erythema and Q-switched laser for embedded pigmentation (M22™; Lumenis®, San Jose, CA): 5.6% of laser treatments were IPL and only 0.0016% were Q-switched and they were therefore eliminated from this analysis. All laser characteristics of the CO_2, Mosaic™, and IPL are shown below. The eCO_2™ and Mosaic™ lasers allow for static or "stamping" mode as well as dynamic or continuous modes of energy application. At maximum Joule setting, the penetration depth varies from 2 to 4 mm, depending on the density of the scar, its water content, and the irregularity of the surface area.

About 61.4% of all the eCO_2™ (ablative) laser treatments were applied in dynamic mode and the other 38.6% were applied in static mode. In dynamic mode, the average energy setting used was 170.3 mJ, with 240 mJ (maximum energy output) being the most frequently used. In static mode, 111.4 mJ was the average energy setting with 70 mJ being the most frequently used. In the static setting, lasers can be stacked two to four times, increasing the depth as well as the perimeter of the tissue damage in each spot, with 2 being the most common number of stacking used (540), followed by 1 (223), 3 (72), and 4 (3). CO_2 laser treatments used an average energy setting of 147.6 mJ, applied 4712.7 J of energy or 14.8 J/cm^2.

About 37.5% of all the Mosaic™ (nonablative) laser treatments were applied in the dynamic mode while 62.5% were applied in static mode. The average energy setting in dynamic mode was 49.4 mJ with 50 mJ being the most common setting. About 6.9% (17) of those procedures were carried out on the "half" setting while the other 93.1% (228) were carried out on the "normal" setting. The average energy setting in static mode was 48.6 mJ with 50 mJ being the most used setting. The average density was 290 spots/cm^2, with the vast majority on the setting of 300 (384) spots/cm^2, and a few on either 100 (17), 150 (1), 200 (5), or 250 (1) spots/cm^2. Two-hundred and twenty-six were stacked ×2 and eight were stacked ×3. Mosaic™ laser treatments averaged an energy setting of 48.9 mJ, had a total energy usage of 1929.7 J or 15.6 J/cm^2.

Fifty-six of the IPL treatments were meant for erythema, 1 was vascular, 40 were set to treat pigmentation, and 8 were for ingrown hair removal in hypertrophic scars with 590 nm being the most common filter size. The average number of shots was 26.7 and the average laser energy was 16.5 J. The average total energy usage was 441.5 J or 4.1 J/cm^2.

In summary, the nonablative fractional laser was used mostly early and in very hyperemic scars at settings that applied 15.6 J/cm^2. The ablative fractional laser was used in dynamic and static mode mostly in scars more than 3 months old, at settings that applied 14.8 J/cm^2 and the IPL laser was used for erythema, pruritus, and hair removal in areas of ingrown hair into scars, similar to pseudofolliculitis barbae. These constant irritations contribute to ongoing hypertrophic scar formation and laser hair removal can interrupt the disease process.

Efficacy and Safety of Laser Treatments

To measure the efficacy of laser treatments, the VSS[17] was used, a metric measured out of 15 points in four different categories to determine the severity of a burn scar. Higher values indicate more severe scars. The average VSS improvement for all patients was 1.43 (indicated by a decrease in VSS points). The box and whisker plot of the VSS improvement is shown in Figure 2. Since a lot of values were negative, a one-sample *t* test was conducted to determine whether the true mean of VSS improvement was above 0, which showed that the average was significantly greater than 0 ($P < .0001$). Next, all the individual aspects of the VSS were analyzed. The vascularity, pliability, and height aspects of the VSS improvement were all significantly greater than 0 ($P < .0001$). However, the pigmentation aspect of the VSS improvement was not significant ($P = .215$).

When adjusted for patients with the VSS measured across 10 or more laser treatments (ie, measured at their first and 10th laser treatment or greater), the average VSS improvement was 2.48 and the median was 3. A two-sample *t* test was conducted showing that patients with the VSS measured across 10 or more laser treatments had significantly better scores (VSS improvement) than those with the VSS measured over 2 or 3 laser treatments ($P = .015$; Table 1). VSS improvement was not significantly different between races or pediatric and adult patients but was between genders with males showing significantly more improvement than females ($P = .029$). Surprisingly, bigger burns had less improvement as documented by VSS than burns with less than or equal to 5% TBSA.

To measure safety, pain and complications were measured. Pain rating during and after treatment in cases using topical anesthesia is shown in Figure 3. The median of the pain during and after the visit was 3 and 1, respectively. Anesthesia complications in patients undergoing sedation during treatments are given in Table 2, while the overall

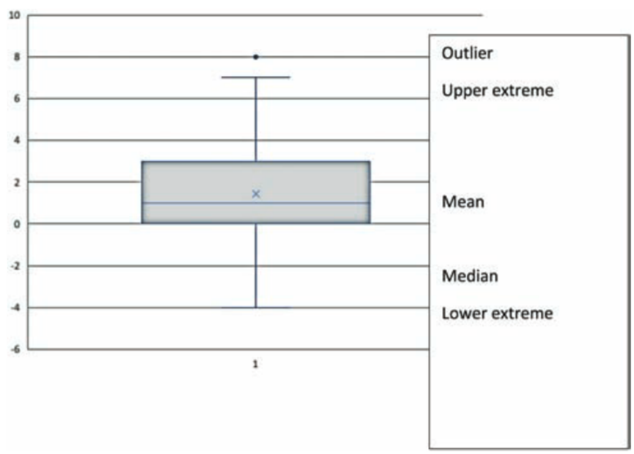

Figure 2. The Vancouver Scar Scale (VSS) improvement over the course of treatment. The improvement was calculated by taking the last VSS recorded and subtracting it from the first VSS recorded. If a patient only had one VSS, they were excluded from this analysis. The mean improvement was 1.41. The lower quartile, median, and upper quartile are 0, 1, and 3, respectively. The lower and upper extremes are –4 and 7, respectively; 8 is an outlier because it lies outside the outlier calculation for box and whisker plots: 1.5 × interquartile range.

Table 1. Vancouver scar scale (VSS) measurements over time

VSS Pretreatment, n = 167	VSS After 1–3 Treatments, n = 65	VSS After the Last Treatment, n = 150	*P*
10.32	9.04	8.71	.015

Measured across 1–3 and 10 or more laser treatments (ie, measured at their first and subsequent or 10th laser treatment or greater) the average VSS improvement was 2.48 and the median was 3. A two-sample *t* test was conducted showing that patients with the VSS measured across 10 or more laser treatments had significantly better scores (VSS improvement) than those with the VSS measured over 2 or 3 laser treatments ($P = .015$).

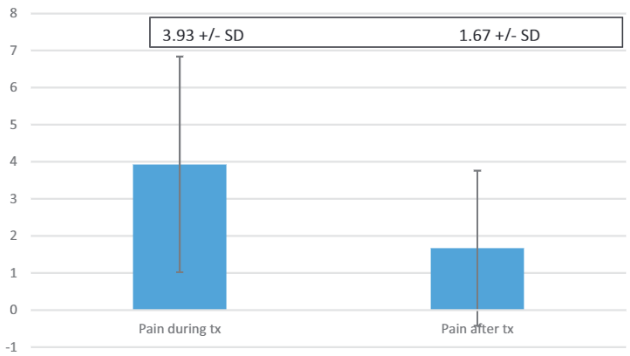

Figure 3. The average pain score from 0 to 10 during and 5 minutes after laser treatment with topical anesthesia. The error bars represent the standard deviations of the pain scores. The mean, standard deviation, and median for pain during the treatment were 3.93, 2.91, and 3, respectively. The mean, standard deviation, and median for pain after the treatment were 1.67, 2.09, and 1, respectively.

complications resulting from the laser treatments are shown in Figure 4.

Efficacy and safety by race were analyzed. Table 3 displays the results. Since the ratio of African-American patients experiencing anesthesia and postoperative complications was greater than that of Caucasians, a mixed-effects logistical regression was run between African-American and Caucasian patients between both anesthesia complications and postoperative complications. Both of those analyses were not significant (race in anesthesia complications: $P = .643$; race in postoperative complications: $P = .238$).

Pediatric and adult patients were separately analyzed for many variables. Four hundred and twenty pediatric procedures were performed under moderate sedation anesthesia, 31 had topical lidocaine applied, and 14 chose not to use anesthesia. Seven hundred and eighty-seven adult procedures were performed under moderate sedation anesthesia, 504 were done with topical lidocaine applied, and 120 chose not to use anesthesia. Pediatric patients had 11 anesthesia complications and 10 postoperative complications in total. Adult patients had 15 anesthesia complications and 16 postoperative complications.

Although required from every patient before the start of treatment, there were only a few POSAS[18] results reported in the electronic medical record (8), which were insufficient for analysis at this point.

DISCUSSION

The safety of laser treatments was determined by three main indicators: complications of laser treatments, anesthesia-related complications, and pain. Pain, either during the procedure in patients who received local anesthesia or after the procedure in patients who received sedation, is a very important variable that affects whether patients decide to endure laser treatments or not. Pain perception is highly subjective, but the average pain rating of 3.9 during the treatment was approaching moderate pain and may have caused some patients to be wary. Although not documented, only two patients discontinued treatments because of pain in this series, underlining the positive effects felt from the treatments. Also, the average result of 3.9 of 10 for procedural pain was skewed by some patients rating very high pain scores (10/10) and even so, returned for repeated treatments. This was verified when viewed from a statistical standpoint, where the median of pain during the treatment was 3, compared to the average of 3.9. A pain score of 3 is overall mild and tolerable, especially considering the benefits of laser treatments and the short duration of the pain. The pain score 5 minutes after the laser treatment averaged 1.7. Likewise, the median was lower at 1. A large proportion of the patients reported very mild pain shortly after the laser treatment, demonstrating that the pain was very short-lasting.

The complication rate that resulted from moderate sedation anesthesia was 2.1%: 97.9% of patients had no complications resulting from moderate sedation anesthesia. Of the 2.1% that did have complications, 67% had prolonged recovery time (more than 60 min). This should be taken into consideration from a workflow improvement perspective and alterations to the type of anesthetic drug combinations were made based on these results. The medication combination was changed to short-acting sedatives and opioids since these study results were analyzed. The other complications, which included nausea, drug reaction, Laryngeal Mask repositioning, and two others, were all minor and did not require further medical intervention. This demonstrates that anesthesia complications were minor and did not cause any significant harm to the patients.

The postoperative complication rate resulting from laser treatments was 1.4%. Again, no major complications were noted. Blisters (only in nonablative fractional laser treatments), some rashes, and some pustules were noted. While outbreaks of Herpes simplex and fungal infections have been documented in the literature after laser treatments,[20] no systemic antibiotic or antiviral or antifungal treatment was necessary in this patient cohort. Overall, these results showed that laser treatment was a safe treatment option for burn scars in this population.

The safety and efficacy results, after separating by race, also provided some interesting findings. Caucasian patients had the highest VSS improvement out of all the treatment groups. This may be attributed to the fact that lighter skin generally responds better to laser treatments. Even though the results of the race analyses of complications was insignificant, it is notable that African-American patients had a higher rate of postoperative complications compared to that of Caucasians. Patients with darker skin seemingly responded less favorable

Table 2. The complications resulting from undergoing anesthesia for laser treatment

	No Complications	Nausea	Prolonged Recovery	Adverse Drug Reaction (Anesthesia Drug)	Laryngeal Mask Position	Feeling Cold	Temporary Confusion	Sample Size
N	1181	5	17	1	1	1	1	1207
Percentage of patients	97.85	0.41	1.41	0.08	0.08	0.08	0.08	100

These were recorded if the patient exhibited any of the symptoms of the adverse effects after undergoing moderate sedation anesthesia. The blue area represents no complications and the dark blue area represents some type of minor complication, as shown in Figure 4. 97.85% of patients had no anesthesia complications and 2.15% of patients experienced a complication detailed in the table.

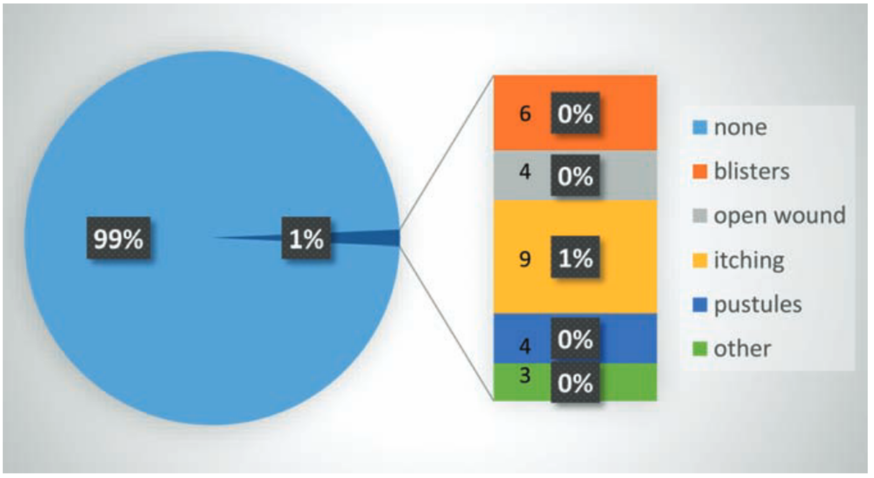

Figure 4. The postoperative complications that resulted after the laser treatment. These were recorded in two ways: if the patient complained about a side effect of the treatment right after the treatment in the office, or if he/she contacted Lehigh Valley Health Network's Burn Care Center in the month(s) following the treatment. The orange area represents some type of minor complications: 98.61% of patients had no postoperative complications and 1.39% of patients experienced a complication detailed to the bar out to the right of the pie chart.

Table 3. The efficacy and safety variables except pain shown in patients divided by their race

Race	Sample Size	VSS Improvement	Anesthesia Complications	Laser Complications
White	328	1.53	20 of 928 (2%)	17 of 1480 (1.1%)
African-American	30	1.27	3 of 98 (3%)	6 of 126 (4%)
Asian	12	1.17	0 of 44 (0)	1 of 61 (1.6%)
Hispanic	32	0.62	1 of 89 (1%)	1 of 136 (0.7%)
Missing	12	0.25	2 of 48 (4%)	1 of 73 (1.3%)

Mixed-effects logistical regression was run between African-American and Caucasian patients between both anesthesia complications and postoperative complications. Both of those analyses were not significant (race in anesthesia complications: $P = .643$; race in postoperative complications: $P = .238$). Pain was not included because of its inherent subjective nature.

to laser treatments. It is possible that they would require more treatments which may lead to more complications. It is probable that an insignificant value was returned after the mixed-effects logistical regression because the sample sizes of African-American patients were too small. It is broadly discussed in the dermatologic literature that laser treatments in darker skin types have significant challenges.[21] More research needs to be conducted to confirm these results in the African-American subgroup, since the sample size in this study is small. Anecdotal reports from patients treated in this patient group are favorable with regard to scar physiology improvement (height and tightness) and improvement of pruritus, however.

The VSS improvement results show that, on average, there is an improvement in burn scar physiology (thickness, elasticity, sensation, itching, pain, and appearance) after laser treatments, as the true mean of improvement lies above zero. The VSS improvement was shown to increase as the number of laser treatments increases, demonstrating the benefits of continuing laser treatments over a period of time. Although this study lacks a control group over time, two previous prospective studies have shown that laser treatments of hypertrophic burn scars improve scarring significantly more than time alone.[16,22] Also, the same patient on average returned for approximately five laser treatments, implicating that there was at least some improvement noted by all patients. Figures 5-11 show before and after laser treatment pictures of six different patients (Figures 8 and 9 are pictures of the same patient), treated with one or all laser modalities. This study affirms the results of many previous studies showing the efficacy of laser treatments. However, there was high variability of the VSS assessment throughout laser treatments, especially with the appearance of some negative VSS improvement values.

Figure 5. Burn scar hypertrophy—chin/face/neck, 16-year-old male after flame burn: (A) before laser treatments and (B) after nonablative laser treatment ×3.

Figure 6. Burn scar hypertrophy—right hand, 35-year-old male after contact burn: (A) before laser treatments and (B) after three ablative fractional laser treatments.

Figure 7. Burn scar hypertrophic retro-auricular and neck, 18-year-old male after 75% TBSA flame burns: (A) before laser treatments and (B) after both nonablative (3×) and ablative laser treatments (3×) over 1 year.

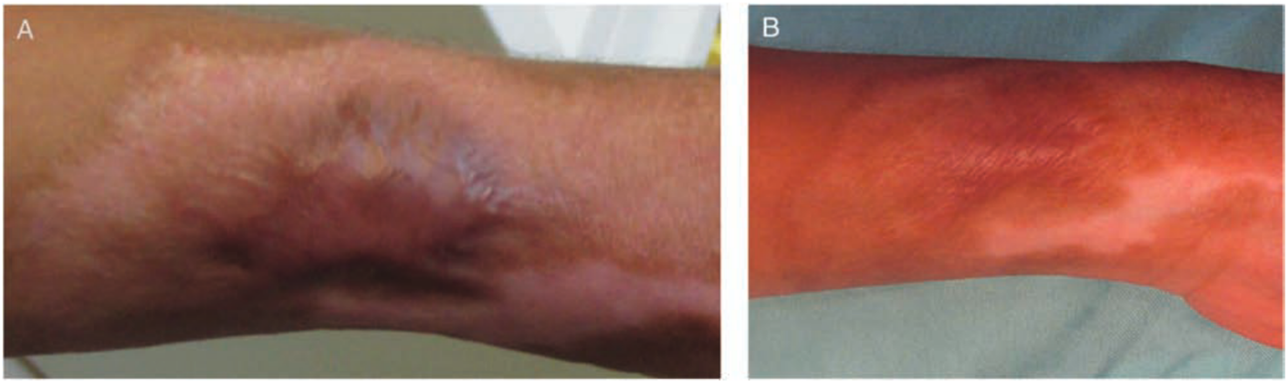

Figure 8. Burn scar hypertrophy—right forearm, 5-year-old male after flame burns: (A) before laser treatments and (B) after laser treatments.

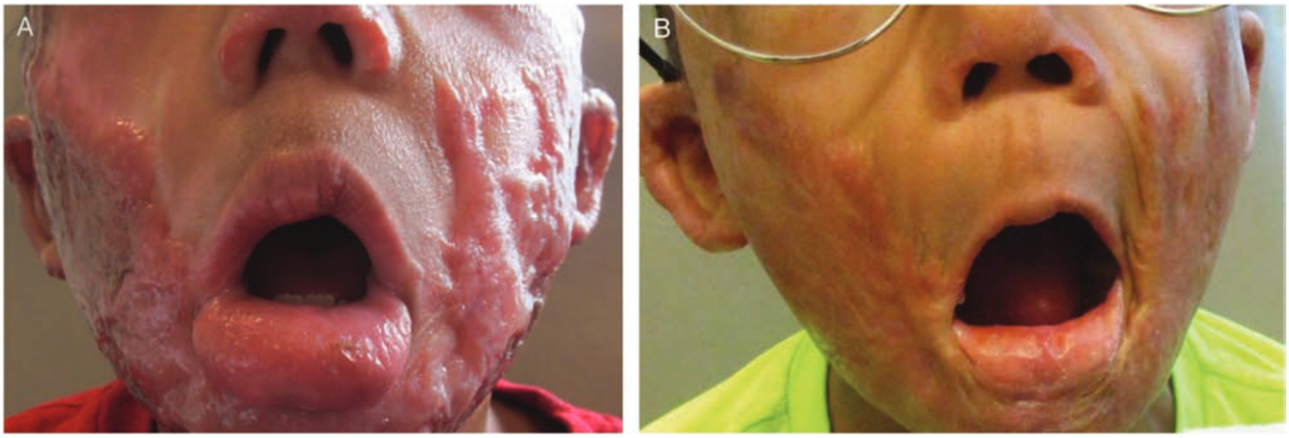

Figure 9. Burn scar hypertrophy and microstomia: (A) 5-year-old male after flame burns before laser treatments and (B) 5-year-old (here 7-year-old) male after flame burns after laser treatments and contracture release.

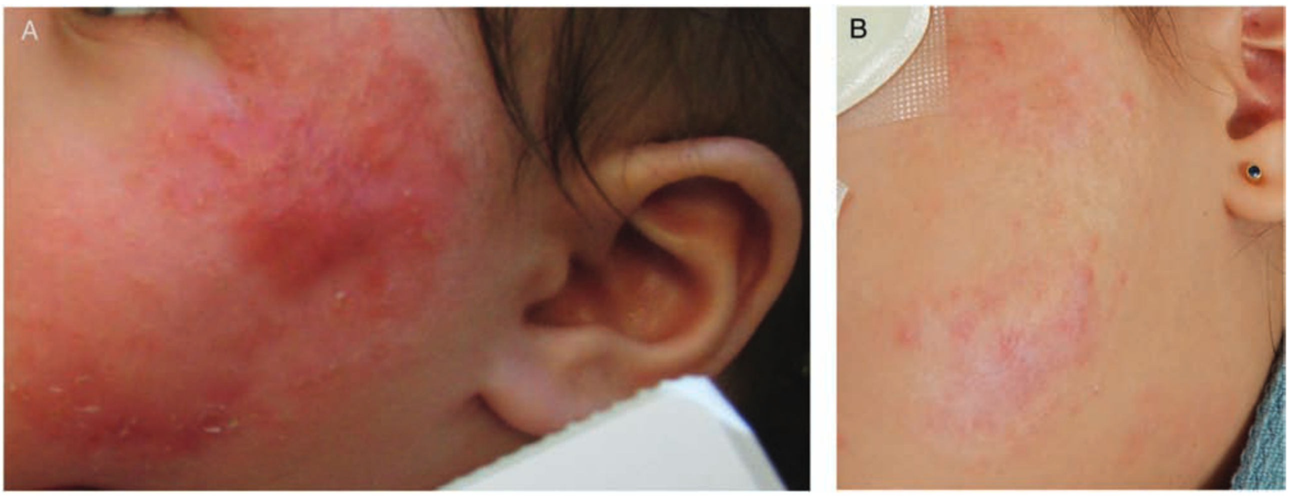

Figure 10. Burn scar hypertrophy—cheek: (A) 2-year-old female after scald burn before laser treatments and (B) 2-year-old (here 4-year-old) female after scald burn after laser treatments.

This may be explained by various evaluators performing the assessment and also the questionable sensitivity of the VSS when comparing one scar to another or the same scar over time to itself. In addition, most burn scars are notoriously nonhomogeneous which makes any scar evaluation difficult.

The VSS data points were measured over a variable amount of laser treatments and when the scores measured more than 10 treatments were compared to those over 2 or 3, those more than 10 showed significantly more improvement with a VSS median improvement of 3. Within the VSS assessment, the subepidermal consistency improvement did not affect pigmentation. However, changing the collagen composition influenced the pliability, height (thickness), and erythema of the scar. More research is needed during 5 to 10 years of follow-up to assess the impact on pigmentation.

There are other limitations to this study. First, Lehigh Valley Health Network used EPIC starting in 2015. Before 2015, Citrix, another patient database, was used. Despite efforts to

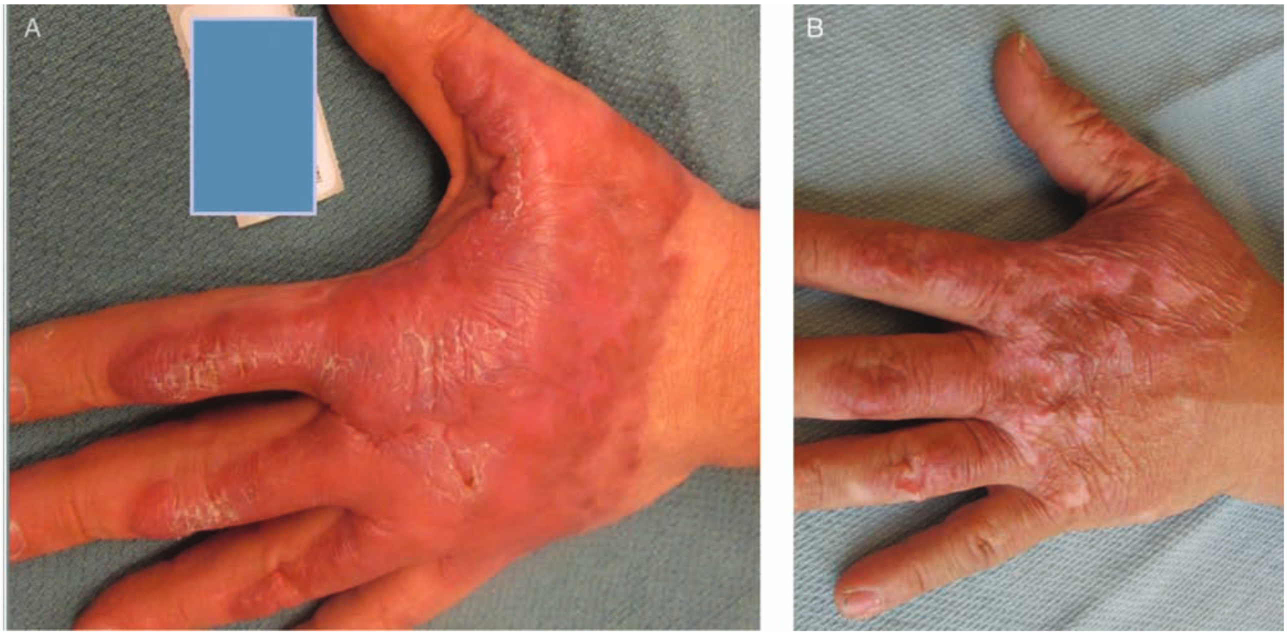

Figure 11. Burn scar hypertrophy—hand, 37-year-old male after electrical flash burn: (A) before laser treatments and (B) after laser treatments.

transfer all the information to EPIC during 2015, some of the information was lost, which led to some missing data. This effected especially VSS and POSAS data. The efficacy evaluation was further hampered by the lack of a control group. The choice of anesthesia drugs was dependent on the respective anesthesiology team during each procedure, which was not standardized.

In the future, an expansion of the database at Lehigh Valley Health Network is planned prospectively. In particular, more emphasis will be placed on the skin type of the patients and documentation of outcome data (VSS and POSAS) in a retrievable part of the electronic medical record. Special attention will also be paid to pigmentation changes over a longer follow-up period.

CONCLUSIONS

Laser treatments for burn scars were safe and effective with minimal complications or adverse effects in this patient cohort, which included 414 adult and pediatric burn survivors. A workflow improvement opportunity regarding drug choice for procedural sedation was identified.

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