The interruption or ablation of incompetent superficial veins has been shown to facilitate the healing of venous ulcers, as well as reduce ulcer recurrence.\textsuperscript{1,3,6} Recently, the ablation of incompetent perforator veins has also been shown to both facilitate ulcer healing and reduce ulcer recurrence;\textsuperscript{7} however, most studies of venous ulcer healing report absolute ulcer healing rates and do not use quantitative methods to evaluate the impact of various interventions on ulcer healing rates.\textsuperscript{5,6} Since venous ulcers present with a great range in size, the healing rate, rather than complete healing, is a more precise measure of the impact of therapy. In addition, there is little information about the impact of interruption of various incompetent superficial and perforator veins on venous ulcer healing. The sequence of specific vein interruptions and venous ulcer healing has particular relevance to the subset of patients who are unable to heal their ulcers with compression therapy alone. This study was conducted to explore the measurable change in healing rates that results from ablation of specific incompetent veins in patients who were unable to heal venous ulcers with compression alone.

METHODS

Patients with venous ulcers were evaluated in the Gonda Vascular and Wound Care Center at UCLA. Some patients had previously undergone wound care at an outside facility, but during the study period, all patients were treated at least weekly in our wound care center. Patients underwent a medical history and physical examination, as well as a complete vascular laboratory assessment by duplex ultrasound of the deep, superficial, perforator, and tributary veins.\textsuperscript{7} All veins were assessed for reflux and/or obstruction and classified using the CEAP reporting standards.\textsuperscript{8}

Ulcer management. All patients initially underwent noninterventional venous ulcer treatment in our dedicated wound care center for a minimum of 5 weeks. The treatment regimen has been previously outlined, but included wound culture, topical antibiotics, debridement when appropriate, topical wound healing agents, and routine three- or four-layer semirigid compression to the level of the knee.\textsuperscript{4} Any patient who failed to reduce the size of their ulcer by computer software measurements after a minimum of 5 weeks of compression underwent vein ablation of incompetent superficial and perforator veins. Patients who had superficial veins (great and small saphenous) with reflux $>1$ second, and a diameter $>3$ mm were treated by endovenous ablation. Additionally, perforator veins that showed reflux $>1$ second and diameters $>3$ mm were considered incompetent and treated with ablation. Con-
comitant microphlebectomy procedures were performed when there were large tributary veins with reflux >1 second and >3 mm in diameter that extended directly into the area of ulceration.

**Endovenous ablation technique.** The technique for radiofrequency ablation of both superficial and perforator veins has been reported by our center previously and in the instructions for use for the VNUS ClosureFAST and VNUS ClosureRFS devices (VNUS Technologies, San Jose, Calif). All patients underwent ablation of at least one incompetent vein during the study, and some had multiple vein ablations. Superficial veins were treated first if reflux was noted in both superficial and perforator veins. Additional ablation procedures were performed only if ulcer healing did not begin to occur within 4 weeks after initial vein ablation. Immediately following ablation, all patients continued with three- or four-layer semirigid compression bandages. A certified vascular technologist, not present during the procedure, assessed the limb for successful ablation postprocedure with duplex ultrasound.

**Ulcer imaging and tracking.** Dedicated wound care nurses were responsible for each patient’s wound care and took photographs of all ulcers weekly. A ruler was placed on both the x and y axis of the ulcer and photos were taken (Fig 1). Using a dedicated wound care software system (Wound Expert, Pittsburgh, Pa), a technique of box approximations was used to calculate the ulcer area during each weekly visit; the area of the ulcer was then plotted on a graph and the slope representing the rate of healing was calculated. Ulcer depth was also measured by wound care nurses and recorded with each visit. The date of complete ulcer healing was also recorded for each patient.

**Statistics.** Statistical analysis was performed with Prism 5.0 (Graph Pad Software Inc, La Jolla, Calif). The results for venous ulcer healing were analyzed with Kaplan-Meier life tables. A P value <.05 was considered significant. Not all ulcers were followed for the same amount of time, so treatment times were converted into percent of total treatment pre- and postablation as a standardization technique.

Healing rate graphs were created using mean ulcer sizes at each percent interval during treatment. Univariate analysis of factors related to ulcer healing was performed using $\chi^2$.

**RESULTS**

Between January 2007 and February 2011, 433 CEAP 6 patients presented to our vascular center; none had undergone previous endovenous ablations (Fig 2). Seventy-two (17%) patients (Table I) failed to reduce the size of 110 venous ulcers with compression therapy alone. The 110 venous ulcers were present in 88 limbs, and each patient had a mean of 1.5 ulcers, with locations and distributions seen in Fig 3. Patient demographics and variables are displayed in Table II. All of the ulcers were located at or below the calf region (“gaiter” zone). The mean reported ulcer age before intervention was 71 ± 6 months (range, 2-432 months), and the mean surface area was 23 ± 6 cm$^2$ at beginning of treatment. At the time of initial evaluation, some patients had previously undergone venous surgery in an attempt to correct their long-standing venous insufficiency; these procedures can be seen in Table III. Sixty-three patients had an ankle-brachial index (ABI) >0.9; the remaining patients (nine) had an ABI >0.8. None showed signs of arterial insufficiency.

Univariate analysis showed that a history of deep vein thrombosis (DVT), superficial thrombophlebitis, diabetes, and vasculitis were not statistically associated with failure to heal.

**Endovenous ablation results.** Of the 140 endovenous ablation procedures performed, 74 were performed on superficial (great saphenous [GSV] and/or small saphenous [SSV]) veins, and 66 were performed on perforator veins (PTPV; Table IV). Mean diameters of ablated incompetent veins were GSV = 7.4 ± .2 mm, SSV = 5.2 ± .1 mm, and PTPV = 3.5 ± .1 mm. Twenty-two patients (31%) underwent ablation of more than one vein. The overall technical closure success rate was 100% (74/74) for superficial veins and 81.8% (54/66) for perforator veins; some patients (16) underwent bilateral ablations, including both saphenous and perforator vein ablations. Four patients with 12 incompetent veins were lost to follow up, and two patients died from an unrelated disease. A minimum of 4 weeks was used to assess the response to ablation before repeat procedures were performed. Concomitant procedures occasionally performed with vein ablation were microphlebectomy, debridement, and tissue biopsy (Table III).

**Ulcer healing rates and recurrence.** After a minimum of 6 months of follow up, 76/110 (76.3%) of the ulcers healed. The mean healing time for all patients was 142 ± 14 days (Fig 4). Although the minimum patient follow up was 6 months, the mean was 12 ± 1.25 months. There was a significant change in healing rate from preablation to postablation ($P < .05$) (Table IV), whether it was a composite evaluation of all procedures or by specific vein procedure (Fig 5, A and B). A positive healing rate indicates the ulcer was increasing in size, a negative healing rate indicates the ulcer was decreasing in size. Complete healing was not achieved during the study for 23.6% (26/110) of ulcers in 12 patients. Six patients still actively healing had a larger initial ulcer size of 46 cm$^2$ in comparison to the 19 cm$^2$ area of those ulcers that had already healed, four patients have been lost to follow up, and two patients died from unrelated illnesses. Of the healed ulcers, four patients with six ulcers (7.1%) recurred; two have re healsed.

**DISCUSSION**

In agreement with previously reported studies, 83% of our patients that presented with a venous ulcer were able to heal their ulcer with compression therapy alone. Although compression therapy alone is sufficient for a majority of patients in healing their ulcers, there still exists a subgroup of venous ulcer patients who experience ulcer growth despite strict compression compliance. Many of these patients have significant superficial or perforator vein reflux, which contributes to treatment failure.
Fig 1. Each ulcer was electronically circumscribed and then area was calculated. A-C, The ulcer increased in size as compression therapy failed to promote ulcer healing. D-F, These ulcer decreased in size until completely healed after vein ablation of incompetent veins. G, The graph is of ulcer measurements throughout treatment before and after incompetent vein ablation for a single ulcer.
Virtually all studies looking at the success of different treatment modalities in healing venous ulcers have primarily focused on the presence or absence of a patient’s ulcer as a measure for healing success, but patients present with ulcers that have tremendous variation in their size. Wound characteristics of size and depth are critical in both monitoring and measuring the success of therapy. The direct results of incompetent vein ablation on ulcer healing can be quantitatively measured with the use of planimetry software to precisely trace the ulcer and obtain an accurate ulcer area. When the ulcer size is plotted to determine the rate of ulcer growth or healing, a more informed judgment can be made for future treatment. Healing rates can further be used to evaluate the effectiveness of specific vein ablation and allow for earlier decisions to be made regarding a patient’s treatment.

The benefit of ablation of specific incompetent veins has not been reported in prior studies on patients with venous ulcers. The Effect of Surgery and Compression on Healing and Recurrence (ESCHAR) trial was one of the first large studies that explored the potential benefit of compression plus surgery for ulcer healing, which concluded that there was no significant difference in healing
rate with the addition of surgery, compared with historic studies that advocated compression therapy alone in treating venous reflux. Recent trials comparing surgery plus compression with compression alone, although large in patient numbers, lack applicability to all CEAP 6 patients because most patients underwent only saphenous vein ablation despite the presence of perforator reflux. Elimination of perforator reflux combined with ablation of incompetent superficial veins, which was not included in the ESCHAR trial, has recently been reported to facilitate an increase in ulcer healing over ablation of incompetent superficial veins alone. The presence of venous superficial and perforator reflux in our subgroup of patients who failed compression therapy provides further evidence that continued reflux often results in an increase in ulcer size with failure of wound healing. In our study, the average patient whose ulcers healed required ablation of 1.3 incompetent veins to achieve healing. In our treatment algorithm, when a patient displayed progressive reduction in the ulcer area, no further ablation was required. However, if a patient did not exhibit a reduction in ulcer size in the 4 weeks following vein ablation, this suggested that additional refluxing veins were present and, if present, additional procedures were performed.

At our institution, the saphenous vein is routinely the first to be ablated for all patients who exhibit superficial reflux, even when perforator vein reflux is also present, due to our institution’s >98% successful saphenous ablation rate. While our reported success rate for perforator ablation of 79% is lower than that for superficial veins, it is accompanied by a low complication rate, allowing for repeat ablation, when the initial procedure is unsuccessful. In our series, the number of perforator vein ablations performed might have been higher, but was limited by each patient’s ability to gain approval for the procedure from insurance companies.

Ablation of all refluxing veins, whether superficial, perforator, or a combination of both, resulted in a significant change in ulcer healing rates. The number of ablation procedures performed on the GSV was higher than that of other superficial or perforator veins, because it resulted in the highest associated healing rate, so only this procedure was necessary. Ablation of incompetent veins in all patients who failed compression therapy led to the complete healing of 76% of ulcers. Even those patients who had not achieved healing of their wounds by the study completion had a significant reduction in wound size at a similar rate as those that had healed. Those patients who are still healing initially had ulcers more than twice as large as those that have already healed (46 cm² in contrast to 19 cm², respectively) indicating that a longer follow up should result in a similar healing rate, and complete healing.

### CONCLUSION

The subgroup of patients with chronic venous insufficiency that failed to decrease ulcer size, despite optimal compression therapy, benefits from the ablation of incompetent superficial and perforator veins. There is a measurable and significant change in ulcer healing rate prior to and following ablation. The use of planimetry software to document ulcer size on a weekly basis allows the surgeon to quantitatively track a patient’s healing progress throughout treatment, and forms a basis for planning future treatments.
Fig 4. Kaplan-Meier life table for healing venous ulcers.

Fig 5. A, The healing rate for venous ulcers that have completely healed. Ulcer size increased during compression treatment before ablation and decreased after vein ablation. B, The healing rate for venous ulcers that have not yet healed. These patients started with venous ulcers that were more than twice as large as those that completely healed during the study. As with the healed ulcers, the size increased before ablation with a similar healing trend seen postablation.
AUTHOR CONTRIBUTIONS

Conception and design: MH-L, PL, AA
Analysis and interpretation: MH-L, PL
Data collection: MH-L, PL
Writing the article: MH-L, PL
Critical revision of the article: MH-L, PL, DR, BD, JJ
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