Several investigators have shown the flow patterns and morphologic characteristics of perforator veins in healthy subjects and in patients with chronic venous disease (CVD). The complex nature of CVD, having many different factors associated with disease severity and deterioration, has made it difficult to elucidate the role of perforator vein incompetence. In this article, many of the important elements associated with perforator veins in CVD are analyzed.

ANATOMY AND NORMAL FUNCTION

There are approximately 150 perforator veins in each lower extremity. Using microinjection techniques, van Limborgh found approximately 60 perforator veins in the thigh, eight in the popliteal fossa, 55 in the leg, and 28 in the foot.1,2 Of these veins, about 30 become incompetent and are identified in clinical practice (Figure 1).3 Perforator veins connect superficial veins with deep veins by piercing the deep fascia, and that is why they are termed perforator veins (Figure 2).

Perforator veins should not be confused with communicating veins because the latter connect veins of the same system (ie, deep veins to deep veins). Most perforator veins have at least one subfascial bicuspid unidirectional valve that allows blood to flow from superficial veins to the deep veins (inward flow).4 In the foot, the flow in perforator veins is bidirectional, whereas in the calf, the flow is mostly inward (flow direction from superficial vein to the perforator), although bidirectional flow has been reported.4 Veins in the thigh area are much longer because they must cross a longer distance compared to those in the calf, ankle, and foot. The calf veins are often duplicated, with one limb connected to a muscular vein and the other into a deep axial vein.

In normal limbs, the outward flow (flow direction from the perforator vein to the superficial vein) is < 350 ms, and in the vast majority of them, it is even lower (< 200 ms).

Figure 1. The lower extremity with bony, muscular, and skin landmarks showing the most common locations where perforator veins become incompetent. The prevalence of reflux is more common in the medial aspect of the calf.
Outward flow of > 350 ms has been defined as reflux. Because this outward flow of 350 ms duration is short, as well as the fact that other veins have a cutoff value of > 0.5 s (with the exception of common femoral, femoral, and popliteal veins, which have a cutoff of > 1 s), most centers use a duration > 0.5 s as a cutoff for perforator reflux. Most normal perforator veins have a subfascial diameter of < 3 mm. The best cutoff diameter for reflux was identified to be 3.9 mm. Another study set this cutoff at 3.5 mm. Although the larger diameter indicates the presence of reflux with high certainty, one-third of refluxing perforator veins have a smaller diameter than these cutoff points. This is not unique and has been often observed in the saphenous veins as well.

CHARACTERISTICS AND FUNCTION OF PERFORATOR VEINS IN CVD PATIENTS

Incompetent perforator veins are often found in patients with CVD. The number and diameter of incompetent perforator veins increases with disease severity. It has also been shown that the diameter of a normal perforator vein increases with CVD deterioration. The diameter of a perforator vein is greater below the fascia because the lumen cannot expand as much at the collagenous deep fascia (Figure 4). In another study, in addition to increased diameters, perforator vein incompetence was characterized by significantly higher mean and peak flow velocities, volume flow, venous volume outward displacement, and a lower flow pulsatility. Reflux in perforator veins occurs only in the presence of superficial vein reflux that is in continuity with the affected perforator veins. In patients with deep vein incompetence, refluxing perforator veins sustain further hemodynamic impairment. Reflux in perforator veins is greater when there is triple-system incompetence compared to reflux confined to superficial veins and perforator veins. Reflux in all three systems—superficial, perforator, and deep—is more common in CVD patients with skin damage.

Reflux in perforator veins develops through the superficial veins, first in an ascending manner, because venous wall disease extends from superficial veins to perforator veins. Typical examples of this are perforator veins in the medial thigh connecting to the great saphenous vein (GSV) and posterolateral thigh perforator veins connecting to the local superficial vein plexus. Second, this development occurs in a
Reflux in perforator veins can develop in both manners but also in new locations where new reflux develops in superficial veins. Over time, the refluxing perforator veins affect the deep veins, which may become incompetent as well.\textsuperscript{4,9,11,12} The available information on perforator reflux development has been misinterpreted by multiple cross-sectional studies that have associated perforator veins as the cause for the superficial vein reflux.

In a prospective study, we identified the three patterns previously described by which once-competent perforator veins become incompetent (Figure 5). The ascending development of reflux into perforator veins from previously competent segments of superficial veins was more prevalent (47.4\%) but comparable to the reentry type. A smaller number of incompetent perforator veins were detected in new locations that previously did not have reflux in any system.\textsuperscript{9} Because there was no deep vein reflux in this location, and in the absence of other serial examinations, the reflux development in the new sites could have been either ascending or descending. Nevertheless, in all the types, perforator vein reflux always occurred with reflux in the superficial veins connected to them.

From the data in our study and the observations in other reports of patients with primary CVD, it would be safe to assume that reflux in perforator veins occurs only in the presence of incompetent superficial veins.\textsuperscript{9,13} As the local hemodynamic conditions change over time and as intravenous pressure increases, the perforator vein diameter increases, therefore rendering the perforator vein valve...
incompetent. This may or may not occur in combination with primary venous wall disease.

Our study also demonstrated that only a few incompetent perforator veins were seen in association with reflux in the deep vein connected to them. A very important observation was that in all cases, deep vein reflux was not present at the time of the first ultrasound study, when the perforator vein connected to them were still competent. Superficial vein reflux was present in all of these sites, suggesting that deep vein reflux is not required for development of perforator vein incompetence in primary CVD. Rather, deep vein reflux could develop as a result of increased flow from the incompetent superficial veins through the perforator vein, the diameter of which has increased.

**EFFECTS OF TREATMENT ON PERFORATOR VEIN FUNCTION**

As discussed, perforator veins are more involved with CVD deterioration. A multivariate regression analysis model indicated that perforator vein reflux was a significant factor for CVD severity, notwithstanding the conspicuous contributing effects of superficial vein and deep vein involvement. Perforator vein incompetence was significantly associated with aging, superficial vein reflux or deep vein reflux, or recurrence of superficial vein reflux, whereas the number of refluxing perforator veins depended on the presence of superficial or deep vein reflux regardless.13

**CONCLUSION**

Although the hemodynamic contribution of perforator veins seems important, clinical studies have failed to show that their treatment is necessary. It has been shown that in the absence of deep vein reflux, surgical correction of superficial vein reflux corrects perforator vein insufficiency in most limbs.14 More importantly, a prospective, randomized study of 200 ulcerated limbs in 170 patients did not show a benefit from perforator surgery.15 A very recent prospective, randomized trial showed that adding perforator vein treatment to superficial venous surgery was safe and effective in eliminating incompetent perforator veins in patients with a venous ulcer. However, this did not have any clinical benefit at 1 year.16

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